SUMMARY REPORT

OF THE

GEOLOGICAL SURVEY

DEPARTMENT OF MINES

FOR THE CALENDAR YEAR

1913

PRINTED BY ORDER OF PARLIAMENT

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OTTAWA
PRINTED BY J. DE L. TACHÉ, PRINTER TO THE KING'S MOST
EXCELLENT MAJESTY
1914

To Field Marshal, His Royal Highness Prince Arthur William Patrick Albert, Duke of Connaught and of Strathearn, K.G., K.T., K.P., etc., etc., etc., Governor General and Commander in Chief of the Dominion of Canada.

MAY IT PLEASE YOUR ROYAL HIGHNESS,—

The undersigned has the honour to lay before Your Royal Highness—in compliance with 6-7 Edward VII, chapter 29, section 18—the Summary Report of the operations of the Geological Survey during the calendar year 1913.

(Signed) LOUIS CODERRE,
Minister of Mines.

To the Hon. LOUIS CODERRE, M.P.,
Minister of Mines,
Ottawa.

SIR,—I have the honour to transmit, herewith, my summary report of the operations of the Geological Survey for the calendar year 1913, which includes the reports of the various officials on the work accomplished by them.

I have the honour to be, sir,
Your obedient servant,

(Signed) R. W. BROCK,
Deputy Minister, Department of Mines.

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OF THE

GEOLOGICAL SURVEY

DEPARTMENT OF MINES

FOR THE CALENDAR YEAR 1913.

CHANGES IN PERSONNEL.

The Survey sustained a severe loss in the death of W. W. Leach, geologist. Mr. Leach was for many years engaged in work for the department in British Columbia and Alberta, particularly in reference to coal.

The following additions have been made to the staff during the past year *Geological Division:* C. W. Drysdale, J. J. O'Neill, junior geologists; L. D. Burling, palæontologist; E. Poitevin, assistant mineralogist; G. F. Sternberg, preparator and collector, vertebrate palæontology; E. J. Whittaker, preparator and collector, invertebrate palæontology. *Topographical Division:* B. R. MacKay, F. S. Falconer, A. G. Haultain, D. A. Nichols, junior topographers. *Biological Division:* Zoology, R. M. Anderson, mammalogist; Clyde Patch, preparator and collector. *Anthropological Division:* Ethnology, F. W. Waugh, preparator and collector; Archæology, Wm. J. Wintemberg, preparator and collector. *Draughting and Illustrating Division:* Alex. Braidwood, draughtsman. *Photographic Division:* Dry Plate Subdivision, Lillian A. Salt. *Stenographers:* Minnie B. Holcomb, Eva M. Liddle, Clara A. McConnell, Martha McKenna, Gladys L. Robertson.

ORGANIZATION.

The organization of the Geological Survey is at present as follows:—

Director.

Administration:

General: Secretary; 5 stenographers.

Distribution: Chief; publication clerk; distribution clerk.

Stationery: 1 clerk.

Cabinet-maker: 1.

Messengers: 1 mail clerk; 4 messengers.

Geological Division:

1 geologist in charge of field work; 1 geologist in charge of office work; 11 geologists; 10 junior geologists; 4 palæontologists; 2 preparators; 1 clerk; 1 stenographer; 1 mineralogist; 1 assistant; 1 collector; 1 stenographer.

Topographical Division:

Chief topographer; 1 triangulator; 7 junior topographers; 1 modeller; 1 custodian of instruments.

Biological Division:

Botany: 1 botanist; 1 assistant botanist; 1 stenographer.
Zoology: 2 zoologists; 3 preparators and collectors; 1 stenographer.

Anthropological Division:

1 chief; 1 junior ethnologist; 1 preparator and collector; 1 stenographer; 1 archæologist; 1 preparator and collector; 1 stenographer.

Draughting and Illustrating Division:

1 chief draughtsman and geographer; 11 draughtsmen; 1 clerk.

Photographic Division:

1 chief photographer; 1 assistant.

Library:

1 assistant librarian; 1 cataloguer; 1 stenographer.

In addition, a number of temporary officials, labourers, etc., are employed.

INTERNATIONAL GEOLOGICAL CONGRESS.

The Twelfth International Geological Congress met in Canada during the past summer, at the invitation of the Dominion Government. The Ontario Government, the Royal Society of Canada, and the Canadian Mining Institute joined in the invitation. The session was held at the University of Toronto, Toronto, from August 7 to August 14, under the presidency of Dr. F. D. Adams, Dean of the Faculty of Applied Science, McGill University. Practically all countries were officially represented, as were the leading universities, geological and mining societies of the world. Nearly 500 delegates and members were in attendance, and the total membership numbered nearly one thousand.

The executive committee of the Congress consisted of: President, F. D. Adams, McGill University, Montreal; General Secretary and Treasurer, R. W. Brock, Geological Survey, Ottawa; A. E. Barlow, Montreal; A. P. Coleman, University of Toronto, Toronto; T. C. Denis, Mines Branch, Quebec; O. E. LeRoy, Geological Survey, Ottawa; G. G. S. Lindsey, Toronto; W. A. Parks, University of Toronto, Toronto; J. B. Tyrrell, Toronto.

The main feature of the Congress was, however, not the session but the excursions, on which members became personally acquainted with the country from Sydney, N.S., to Victoria, B.C., and from the International Boundary north to Mount St. Elias and Dawson, Y.T. In all, there were over 25,000 miles of officially-guided excursions, which began on July 13 and ended on October 5. While the Business Secretary of the Congress, Mr. W. S. Lecky, the Chairman of the Finance Committee and of the Coal Resources Committee, Mr. G. G. S. Lindsey, the President of the Congress, the Executive Committee, the interested college professors, provincial mining officials, and the officers and members of the Canadian Mining Institute were unsparing in their assistance, without which this vast undertaking could not have been successfully carried out, and while Dr. W. G. Miller and his assistants of the Ontario Department of Mines edited and published two of the guide books and directed the major excursions in Ontario, the heaviest part of the work in connexion with the Congress naturally fell upon the staff of the Geological Survey. From the Director, who was General Secretary of the Congress, down, almost every member of the staff performed important duties writing guide books, editing publications, planning and supervising the details of excursions and acting as guides and leaders, attending to the manifold duties connected with the meetings, etc. Credit cannot be given to each individually for his share in the success of the undertaking, but special mention might perhaps be made of Mr. O. E. LeRoy, in connexion with the excursions; of Mr. G. A. Young, in connexion with the Maritime Provinces guide books and excursion and the meeting in Toronto; of Mr. C. Camsell, in editing the guide books; of Mr. A. Dickison, in preparing the special maps; of Mr. W. McInnes and his associates, Mr. D. B. Dowling and Mr. W. W. Leach, in editing the Coal Resources of the World, and of Mr. W. H. Collins, in editing the papers for the Transactions. The Coal Resources of the World consists of three quarto volumes and a large atlas; the Transactions will occupy about 1,200 pages. The guide books consist of thirteen well-illustrated volumes, of which two were issued by the Ontario Department of Mines, and eleven by the Geological Survey. For these the Draughting Division of the Survey, under Mr. C. O. Senecal and Mr. Dickison, prepared about one hundred and fifty special maps. The Department of Public Printing, Ottawa, deserve the highest credit not only for the excellent printing but also for filling, in the short time at their disposal, a rush order of this magnitude.

While for the past two years the Congress has been a heavy tax upon the resources of the Survey, it has been well worth the effort. It was perhaps the most successful international gathering yet convened. The most distinguished geologists, geographers, and mining engineers of the world were present. The views and suggestions of these experts regarding Canadian problems will prove helpful and stimulating. The geology and resources of Canada were unknown to most of them. They are now interested in them and will closely follow their development. Specimens of rocks and ores were collected and will now be found in all the important museums. The photographs and notes taken throughout the country will be used in lectures, papers, and text books, bringing such Canadian material for the first time into the authoritative literature of the world. The geological work done and publications issued for the Congress have long been needed for general use in Canada, and this want is now supplied.

FIELD WORK.

GEOLOGICAL DIVISION.

Although the majority of the officers were employed as leaders and guides on the Congress excursions, a fair amount of important work was accomplished in the field.

Mr. D. D. Cairnes conducted a geological reconnaissance along the Alaskan-Yukon boundary line in the Upper White River district, where native copper occurs in economic importance at one point. During the season the Chisana placer gold district in the adjoining portion of Alaska attracted attention; as the conditions are similar on both sides of the line, it is hoped that placers may be located on the Canadian side. On his way to the Yukon, Mr. Cairnes spent a few days on Quadra island, where a number of copper claims have been taken up. Mr. Cairnes is of the opinion that this mineralized belt is worthy of extensive exploration.

Mr. L. D. Burling was engaged in palæontological field work along the Yukon-Alaska boundary north of the Yukon river in the immediate vicinity of the Tutonduk. He also visited some localities in British Columbia.

Mr. R. G. McConnell examined the Rainy Hollow mineral area in the northwest angle of British Columbia. He reports several promising surface showings of copper and lead ores. He also examined the Granby mine at Anyox, Observatory inlet, and the Britannia mine at Howe sound.

Mr. J. D. MacKenzie investigated the coal fields of Graham island, Queen Charlotte group.

Mr. C. H. Clapp and Mr. H. C. Cooke geologically mapped a portion of the Duncan map-area, south of Ladysmith, Vancouver island. Copper deposits occur within this district. Mr. Cooke also made a special examination of the East Sooke peninsula.

Mr. Chas. Camsell made a geological reconnaissance of the Similkameen district, British Columbia.

Mr. Chas. W. Drysdale completed the detailed investigation of the geology and ore deposits of Rossland, commenced some years ago by R. W. Brock and G. A. Young.

Mr. S. J. Schofield completed his reconnaissance of East Kootenay. He was fortunate enough to discover a fossiliferous horizon that definitely establishes the age of the rocks as Middle Cambrian. This is of prime importance in the elucidation of the geology of this region.

Mr. D. B. Dowling visited the Flathead coal area in southeastern British Columbia, where several commercial seams occur, and also the North Saskatchewan coal areas, Alberta, which a branch line of the Canadian Northern railway is opening up. He also made a reconnaissance of the Sheep River area, near Calgary, which has attracted some attention as a possible gas and oil field. A well at Black Diamond, located on a small anticline, encountered a good flow of gas, rich in gasoline, and a little deeper some "white oil," also very rich in gasoline.

Mr. J. S. Stewart commenced the areal mapping and structural investigation of the coal measures and associated formation of the Racehorse area, Crowsnest pass, Alberta.

Mr. J. A. Allan spent his field season largely in work in the Rockies required in connexion with the Congress excursions, but also in connexion with a popular geological guide to the national parks.

Mr. C. H. Sternberg, assisted by Messrs. George and Charles Sternberg, collected vertebrate fossils from the rich bone beds of the Red Deer river, Alberta, securing specimens of almost priceless value.

Mr. Bruce Rose made a general geological examination of the coal-bearing rocks in southern Saskatchewan, south of the main line of the Canadian Pacific railway, and east of the third meridian. His work shows this region to be abundantly supplied with lignite and clays of economic importance.

Mr. E. M. Kindle examined important geological sections along the Hudson Bay railway east of Le Pas in northern Manitoba.

Messrs. A. H. MacLean and R. C. Wallace were engaged in central Manitoba, making a special study of the gypsum and salt horizons.

Mr. W. A. Johnston spent the field season studying and mapping the superficial deposits between Rainy lake and Lake of the Woods. These calcareous drift deposits are of exceptional value for agricultural purposes, and this study, while of great scientific interest, is also the cheapest and most reliable method of delimiting these available new and rich farming lands.

Mr. W. L. Uglow was engaged for a short time during the season in field work on the Canadian Northern railway west of Port Arthur, in preparation for the Congress excursion.

Mr. W. H. Collins completed the geological mapping of the Onaping map-area to the north of Sudbury, Ont., and began a revision of the Sudbury sheet. A practically continuous line of exploration has now been made between the Cobalt and Sudbury districts, an event of considerable importance in the study of the geology of these great mining districts.

Mr. M. Y. Williams' field work was in southwestern Ontario, making a detailed study of the Niagara escarpment to correlate and determine the areal extent of the various divisions of the Silurian rocks, many of which are of economic interest.

Mr. A. E. Barlow spent a few weeks in the vicinity of Craigmont, securing the information necesssary to complete his memoir on the corundum deposits of central Ontario.

Mr. L. Reinecke was engaged for a few weeks in a survey of a mica mine at Moose lake, Quebec, and for the balance of the season until the middle of November upon an examination of materials available for roadmaking in Ontario, furnishing a report on this subject to the Ontario Highway Commission.

Mr. M. E. Wilson began a geological investigation of a region north of the Ottawa river in Ottawa county, Que., important from the occurrence therein of deposits of graphite, mica, apatite, and other minerals, and also in connexion with problems of Pre-Cambrian rocks which cover over one-half of the Dominion.

Mr. J. Stansfield spent a portion of the field season in an investigation of the superficial deposits of the island of Montreal, to furnish information regarding sources of material for local clay industries, and also regarding conditions affecting building operations in the city of Montreal and environs.

Mr. Robert Harvie completed his reconnaissance of the serpentine (asbestos-bearing) belt of southern Quebec, and continued his detailed examinations of a geological section crossing the Sutton anticline. This section is hoped to elucidate many problems concerning the general economic geology of the Eastern Townships.

Mr. A. Mailhiot commenced a study of the granite areas of the Eastern Townships, in which are situated important stone quarries.

Mr. J. Keele investigated the clay and shale deposits between Montreal and Quebec, to determine their industrial value.

Mr. P. E. Raymond continued for a short time his study of the stratigraphy in the neighbourhood of Quebec city.

Mr. W. J. Wright was occupied during the greater part of the season in geologically surveying the Moncton map-area, New Brunswick, in which occur important gypsum and oil-shale deposits and an oil and gas field. His investigations indicate a large body of oil-shales at Albert mines that would seem to be capable of being worked by open quarry. He also spent a few weeks in the study of ore deposits of Clyburn valley, Cape Breton, where a vein of auriferous pyrite has been somewhat extensively prospected.

Mr. A. O. Hayes commenced the geological mapping of the St. John City map-area, New Brunswick. His work has developed a number of problems the solution of which will be of prime importance in the general interpretation of the geology of New Brunswick.

Mr. W. A. Bell commenced the areal mapping and a structural and palæontological investigation of the Windsor and Horton series of rocks, within the Windsor special map-area, Nova Scotia. Of the total area, 240 square miles, one-quarter was covered this season, and the whole can be completed in one more season.

Mr. J. E. Hyde spent a portion of the field season examining the Carboniferous section along the north shore of the Strait of Canso, between Port Hastings and Port Hawkesbury.

Mr. J. W. Goldthwait commenced a study of the surficial geology of Nova Scotia in order to prepare a memoir presenting in simple language a description of the scenery and an explanation of the surface features of the province. This proposed memoir should be of interest to students and general readers as well as to scientists.

Mr. E. R. Faribault continued his investigation of the gold-bearing rocks of Nova Scotia and his mapping in the southern portion of Queens and Lunenburg counties.

In addition to the above, geological field work is being conducted, along with other scientific investigations, by officers of the Survey who accompanied the Canadian Arctic Expedition, which is referred to at the close of this summary of regular field work undertaken by the various divisions of the Survey.

TOPOGRAPHICAL DIVISION.

Mr. W. E. Lawson topographically mapped the White River district, Yukon Territory.

Mr. E. E. Freeland completed the Bridge River map-area, Lillooet district, British Columbia.

Mr. F. S. Falconer mapped the East Sooke peninsula, Vancouver island, and the Flathead coal basin, British Columbia.

Mr. A. G. Haultain completed the Windermere map-area, British Columbia.

Mr. A. C. T. Sheppard was in charge of the topographical mapping of the Crowsnest map-area, British Columbia and Alberta.

Mr. D. A. Nichols began the topographical mapping of the Thetford-Black Lake district, Quebec.

Mr. B. R. MacKay had charge of the work in the New Glasgow area, Nova Scotia.

Mr. S. C. McLean was engaged in triangulation for control of the New Glasgow and Thetford-Black Lake areas and in triangulation in the Similkameen district, British Columbia.

In addition, two geographers are serving on the Canadian Arctic Expedition.

ANTHROPOLOGICAL DIVISION.

Ethnology and Linguistics.

Mr. E. Sapir continued his field work with the Nootka Indians of Vancouver island.

Mr. J. A. Mason undertook a preliminary reconnaissance of some of the Indians of the Upper Mackenzie River valley.

Mr. P. Radin continued his studies among the Ojibwa of southwestern Ontario, visiting also Minnesota and Wisconsin and northwestern Ontario for comparative studies.

Mr. F. W. Waugh spent some time with the Iroquois of the Six Nations reserve, Ontario.

Mr. A. A. Goldenweiser continued his investigations among the same Iroquois.

Mr. W. H. Mechling prosecuted his work among the Malecites and Micmacs of New Brunswick.

Archæology.

Mr. H. I. Smith was engaged in archæological reconnaissance near Banff, Alberta, and in New Brunswick and Nova Scotia, to determine the most promising localities for intensive work.

Mr. W. B. Nickerson spent his field season in intensive exploration of mounds and other archæological remains in the vicinity of Sourisford, southwestern Manitoba.

Mr. W. J. Wintemberg conducted a reconnaissance in New Brunswick, Nova Scotia, and Prince Edward Island, and did intensive exploration at Mahone Bay, N.S.

BIOLOGICAL DIVISION.

Botany.

Mr. John Macoun continued collecting the flora of southeastern Vancouver island.

Mr. James Macoun collected in the vicinity of Ottawa, to complete the information for a flora of this region.

Zoology.

Mr. Taverner with Mr. Patch and Mr. Young, were engaged in field work in southwestern Ontario, to secure material for a museum group to represent the peculiar southern flora and fauna of this district. One geologist is serving on the Canadian Arctic Expedition.

CANADIAN ARCTIC EXPEDITION.

Last spring the National Geographical Society and the American Museum of Natural History commissioned Mr. V. Stefansson to explore the Beaufort sea north of Herschel island and west of Prince Patrick Land, for the large island or continent which the tidal observations of the United States Coast and Geodetic Survey had indicated to be there. The Canadian Geological Survey was invited to co-operate in the expedition as it had done in the previous Stefansson expedition to the Coppermine river and Victoria Land, and from which it had secured valuable results. The Canadian Government decided that the expedition having for its main object the discovery of new land to the north of known Canadian territory, should preferably be wholly under Canadian control. The National Geographical Society and the American Museum generously transferred their interests in the expedition, which was placed under the general direction of the Department of Naval Affairs. Scientific work within the scope of the Geological Survey was placed under the jurisdiction of the Survey. The expedition was divided into two parties, the northern exploration party under Mr. V. Stefansson, the leader of the expedition, and a southern scientific party under Dr. R. M. Anderson of the Geological Survey, whose field of operations was to be in the neighbourhood of Coronation gulf, Coppermine river, and Victoria Land. Mr. George Malloch of the Survey was detailed to the northern party as geologist and geographer. On the southern party are the following officials of the Survey: R. M. Anderson, in charge, zoologist; J. J. O'Neill, geologist; K. G. Chipman, geographer; J. R. Cox, assistant geographer; D. Jenness, ethnologist; H. Beuchat, ethnologist. The scientific equipment for this regular work and salaries, together with expenses in joining the expedition, are borne by the Survey. Expenses in the field and instruments required for special services are being furnished by the Expedition. The officers of the Survey are working under the direction of and reporting to the Geological Survey. Owing to the unusually unfavourable ice conditions last summer, no boats were able to get as far as Herschel island. The *Mary Sachs* and the *Alaska,* with the southern party, reached Collinson point, Alaska, a short distance west of Demarkation point. The *Karluk,* with the northern party and Messrs. Jenness and Beuchat of the southern party, was caught in the ice not far from the same place, apparently frozen in for the winter. Mr. V. Stefansson, with Mr. Jenness and two other men, left for a trip ashore, when a storm arose, preventing their return to the ship and setting the *Karluk* either free or drifting, and no word has been received from her since. As she is under the capable command of Capt. Robert Bartlett, has men, both white and Eskimo, accustomed to ice conditions, and is well equipped with skin boats, sleds, dogs, winter clothing, and several years' provisions, they are, so far as is humanly possible, well able to look after themselves.[1]

The last mail received from the southern party showed all to be well with them. They were wintering comfortably, and had been able to secure some valuable scientific results. As soon as daylight permitted, Messrs. Chipman and Cox were going to survey

[1] Since the above was written word has been received from Capt. Bartlett, from St. Michaels, Alaska, that the *Karluk* was crushed and sunk near Herald island, Arctic ocean, and that the crew are safe, most of them on Wrangell island.

the Arctic coast from Demarkation point to Herschell island and the mouth of the Mackenzie, tying in this section with the determined position of Demarkation point, while Mr. O'Neill intended to make a geological reconnaissance extending inland, from the Alaskan boundary to the Mackenzie. Thus, though unable this year to carry out their original plans, the time of the southern party is not lost, as they are securing important information and filling a gap in the geographical and geological map of Canada.

PROGRESS OF DIVISIONS.

Publication Division.—The Distribution Division sent out to libraries and institutions on the exchange list, 17,300 publications, and in response to written or verbal requests, 33,812; making a total distribution of 51,112 copies of publications.

Geological Division.—This division has been strengthened by the addition of six officers.

The memoirs are unduly delayed in printing, keeping back from the public information that is of great value if promptly issued but that loses much of its value if delayed. These reports are not like ordinary Government blue-books—of value merely as records—but are essentially tools required by one of the country's foremost industries. Nothing should prevent their speedy publication. A new arrangement to this end is being effected by the Department of Public Printing.

Topographical Division.—This division has been strengthened by the appointment of four junior topographers and now consists of one chief topographer, one triangulator and computer, and seven junior topographers.

Although the division has been completing maps at a rapid rate, little progress has been made in having them reproduced. The same argument used in connexion with the memoirs holds with regard to the publication of these maps. The situation is becoming desperate, and some more effective arrangement with regard to publication must be made.

Photographic Division.—This division has been strengthened by the appointment of an assistant photographer. Its usefulness has been lessened by the failure to complete the necessary equipment, the responsibility for which lies outside this department.

The following work has been done during the past year:—

Contact prints (Vandyke and black and white), size 4×5 to 36×48.	13,719
Bromide enlargements, size 5×7 to 40×72	894
Films and plates developed, size $3\frac{1}{4}\times4\frac{1}{4}$ to $6\frac{1}{2}\times8\frac{1}{2}$	3,492
Dry plate negatives, size 4×5 to 11×14	976
Wet plate negatives, size 8×10 to 11×14	122
Photostat copies, size 7×11 to 11×14	956
Lantern slides, size $3\frac{1}{4}\times4\frac{1}{4}$	309
Photographs and titles mounted	1,690

Museum.—Considerable progress has been made with the museum, both in securing important acquisitions and in the preparation of exhibits for the public halls. The staff now includes skilled preparators in each division of the museum, and the exhibits now being prepared will be unexcelled by those of the same kind in any of the great museums of the world. The department having been supplied with cases for the Anthropological Hall, ethnological and archæological collections, representing the native races of Canada, have been installed. Unfortunately, lack of space prevents a complete exhibit of the now rich collections belonging to our National Museum. The herbarium, which is unusually full and complete, has been completely classified. Practically everything known in Canadian flora is represented in this collection. Large additions have been made to the zoological collections. Good progress was made on the group exhibit representing Atlantic coast life, and upon the group representing the southern flora and fauna of the southwestern peninsula of Ontario.

The most notable additions have, however, been made in vertebrate palæontology. Mr. C. H. Sternberg, assisted by his sons, has succeeded in recovering from the Edmonton and Belly River beds of Red Deer river a priceless collection of the extinct monsters that formerly inhabited this region. This material is rich, not only in new species but in new genera, and many of the specimens are, therefore, type specimens. Several striking mounts of these animals have been prepared and are on exhibition, and good progress has been made on others which will prove of exceptional interest and value.

In addition to the regular staff, the advice and assistance of specialists in other departments of the Government service, and in private life, are being secured by appointing them honorary curators. Mr. J. H. Fleming, Toronto, has been appointed Honorary Curator of Ornithology, and several other appointments are pending.

The museum work is severely handicapped by the delay in providing the department with the necessary equipment of exhibition cases, storage cases, workrooms, and accommodation. Collections that cannot be replaced are deteriorating and may be lost if these wants are not supplied, and much interesting material that is of value for exhibition or scientific purposes is for this reason at present inaccessible to public or student. It is most discouraging to zealous officials to be unable to perform their necessary duties on account of the lack of the essential tools and facilities.

GEOLOGICAL DIVISION.

UPPER WHITE RIVER DISTRICT, YUKON.

(*D. D. Cairnes.*)

Introduction.

After completing the examination of the mineral properties distributed throughout the lime belt of Quadra island, British Columbia,[1] during the early part of the summer of 1913, the writer proceeded to Upper White River district, Yukon, and arrived at the mouth of Beaver creek on July 3. The probable occurrence of native copper along the upper portion of White river has long been surmised, and as early as 1891 when this district is believed to have been first penetrated by an exploring party of white men, fabulous accounts of the enormous quantities of native copper found in Upper White River district were told to members of the expedition. From 1898 onward, prospectors in search of gold and copper have kept going into the region, induced so to do, partly or entirely as a result of Indian stories which had invested the Upper White River belt of both Yukon and Alaska with mineral wealth proportionate to its remoteness and inaccessibility.

Greatly exaggerated as were these early accounts concerning the mineral wealth of Upper White River district, they nevertheless contained some truth. Native copper occurs at different points, individual masses of which have been found, weighing several hundred pounds each, and one large slab was seen by the writer that is estimated to weigh approximately three tons. Quartz veins also occur in several localities, some of which contain encouraging amounts of gold, and recently placer gold has been discovered in economically important amounts on several of the streams draining into Upper White river and its tributaries.

This district lying along the landward edge of the St. Elias range, and including a portion of the Nutzotin mountains, has been known for some years to be geologically and topographically favourably situated for the occurrence of mineral deposits, and would have been mapped and investigated by the Canadian Geological Survey at least two or three years ago, except for a series of unavoidable delays. The writer was, however, last spring (1913) instructed to geologically map and explore this area, and reached there several weeks before the stampede commenced to the neighbouring Chisana gold fields,[2] across the International Boundary line, 30 miles to the west. Geological formations and conditions similar to those in Chisana district occur in Upper White River district, Yukon, and this winter (1913-14) several hundred men are prospecting the gravels of this district, and gold is reported to have already been found in paying quantities on several of the streams within the area.

Mr. F. J. Barlow acted as the writer's geological assistant in Upper White River district. Mr. Barlow reached the mouth of Beaver creek about three weeks before the writer arrived, and continued the field work until September 4. On August 8 the

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[1] For descriptions of these properties see pages 58-75 of this Summary Report.

[2] On account of the similarity, geologically, between the Chisana gold fields and portions of Upper White River district, Yukon, a brief description of the general geology and gold-bearing gravels of the portion of Chisana district that has been found to contain valuable deposits of placer gold, is included in the writer's memoir on Upper White River district, which is expected to be published shortly.

writer had to start for Vancouver to act as guide on C8 and C9 excursions of the International Geological Congress, leaving Mr. Barlow to proceed with the geological

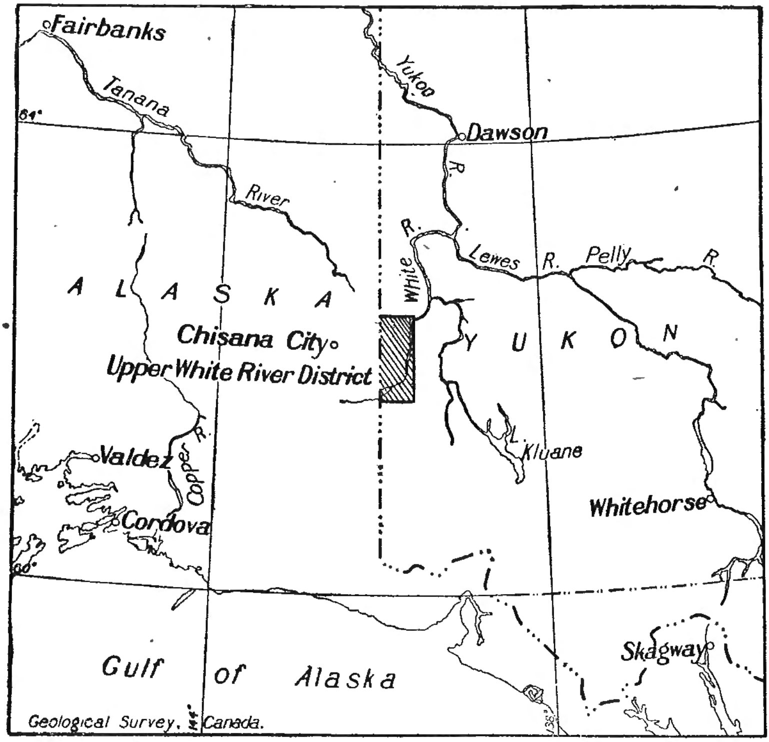

Fig. 1. Index showing location of upper White River district.

work. Thus the writer was unable to devote more than about one month to the actual field work in Upper White River district. Mr. Barlow performed all the duties assigned to him in a very willing and painstaking manner.

Location and Area.

The portion of Yukon Territory, along White river, which was mapped and investigated during the past summer (1913), and which is here designated as Upper White River district, is about 55 miles long, from north to south, and from 12 to 23 miles wide. This area lies to the east of and adjoins the 141st meridian, the Yukon-Alaska international boundary; extends to the north to about latitude 62° 30′, so as to include the mouth of Beaver creek; reaches to the south to about latitude 61° 42′, or to about 3 miles south of the crossing of White river by the boundary line; and stretches to the east to include White river (Fig. 1).

This particular area was selected for mapping and investigation as it was considered to be, geologically, one of the most promising sections of this part of Yukon for the occurrence of mineral deposits and because a number of discoveries of ore material had been reported from this vicinity. The mapping was extended so as to include, in the one season, as much as possible of the better mineralized portions of the district.

Routes.

Upper White River district has, in the past, been considered to be one of the more difficultly accessible portions of Yukon, and very little authentic information has been available concerning the routes and methods of travel thereto. It was generally understood that White river was practically unnavigable for steam craft, and in fact for all ordinary types of power boats, although it was known that small, specially built gasoline launches could, with considerable difficulty, and during favourable stages of water, get a few miles up this stream. It was thus only possible to economically get freight and outfits into the district by sledding such in over the ice and snow during the winter months. The only alternative plan was to pole up White river during the summer, which required considerable time and was very expensive; and further, for this work, thoroughly experienced polers and river men were necessary, and were not always available.

Since the discovery of placer gold in Chisana district, Alaska, within 30 miles of Upper White River district, the routes to this locality have become much better known. The Yukon Government has also built good pack trails to the district, and White river has become much better understood than formerly. In fact, last autumn, all manner of river craft including canoes, row-boats, poling boats, gasoline launches, and steamboats were to be seen working their way upstream at various points on the river. Some light-draught steamers reached the mouth of Donjek river, and others managed to get within a few miles of this point. One small specially designed gasoline boat, however, managed to get to the mouth of Beaver creek, and is reported to have accomplished the journey from the mouth of White river to the Beaver in four days. This winter (1913-14) a number of steam and gasoline boats are being built for use on White river next season (1914), and will take freight and passengers to Beaver creek, so that undoubtedly freight will next summer be taken to White River district by boat for a fraction of what it has formerly cost to take it over the ice or snow in the winter. Thus, from now on, it will be possible to reach White River district, or Chisana, with comparative ease and safety.

The majority of persons who have gone into Upper White River district, have followed one of three main routes which pass through Yukon, and may thus be considered as Yukon or Canadian routes. These three principal lines of travel may be designated as the White River, Coffee Creek Trail, and Kluane routes. Three more or less important Alaskan routes have also been followed to a considerable extent, mainly by persons going only to Chisana, but may also be used to reach Upper White River district. These may be termed the Tanana River, Russell Glacier (Skolai pass), and Nizina-Chisana Glacier routes: of these the glacier routes are very dangerous and the Tanana River route is only available to persons commencing their journey from Fairbanks or some nearby point in central Alaska. In addition to these more important routes, others less available or convenient, or possibly less well known, have been followed by a few persons. Three of the most travelled of these less-favoured routes may be termed the Chitina-Copper River, the Valdez-Copper River, and the Boundary routes.

In any case, irrespective as to which of these routes[1] is intended to be followed, persons travelling to Upper White River or Chisana districts direct, from practically all points not actually within Yukon, Alaska, or adjoining districts, go via either Skagway or Cordova, or possibly via Valdez, three ports situated on the southern coast of Alaska. Commodious steamers make regular and frequent trips from Vancouver or Seattle to these points, Skagway being distant about 870 and 1,000 miles from Vancouver and Seattle, respectively, and Cordova and Valdez being about

[1] Detailed descriptions of all these routes are included in the writer's memoir on Upper White River district, which is also accompanied by a map showing the Canadian routes to Upper White River district, Yukon, and to Chisana district, Alaska.

1,615 and 1,705 miles respectively from Seattle, measured along the inland Coast passage followed by the regular steamers. From Skagway and Cordova, short railway lines proceed toward the interior.

All the Canadian routes proceed from tidewater at Skagway over the White Pass and Yukon railway to Whitehorse, a distance of 110 miles. From Whitehorse, which is situated at the head of navigation on the Yukon and its principal tributary, Lewes river, the various Canadian routes diverge.

Climate.

The climate of Upper White River district is that of southern Yukon, as modified by the altitude and mountainous nature of the area. Being situated north of the 61st parallel of latitude, the district, as is to be expected, is during the winter months subjected to somewhat low temperatures; and separated as it is from the Pacific by a broad belt of mountains, the region does not come within the immediate influence of the ocean, with its tendency to increase precipitation and minimize the variations in temperature. Nevertheless, the climate of southern Yukon in general has been, and by many still is thought to be, much more severe than it really is.

The summer months in most parts of southern Yukon are particularly delightful, as, on account of the somewhat northern latitude there is almost continuous daylight during June and July, and for four months, typical warm, summer weather is generally experienced. The winters, although cold, are not so extreme as might be supposed. For instance, horses winter out safely in Upper White River district, without artificial shelter and without being fed, provided they are in fairly good condition when turned out in the autumn, and provided also that they are placed on bars along White river or elsewhere where food is plentiful. For several years past, numbers of horses have so wintered in different parts of the district, and in most cases have been found in good condition in the spring.

The amount of precipitation in southern Yukon varies considerably with the altitude and proximity to mountain ranges or groups. In Upper White River district, during most years, the amount of rain is moderate, and the snowfall is very light, snow rarely accumulating to a thickness of more than 12 inches on the level along the river flats or in other lower portions of the district. Good sledding also rarely commences, except on the river or lake ice, before December 1.

Ice commences to run thickly on the White about September 30, and the river freezes over, during most years, between November 10 and 15. The White generally opens in the spring below Beaver creek between May 25 and June 5, and above Beaver creek to Canyon City, opens about June 12.

As concerns mining operations, due to the almost continuous daylight during part of the summer, work can be conducted by night almost as well as by day, without the aid of artificial light. Also at least five months in each year are suitable for surface working and for the necessary outside operations contingent upon mining and similar industries. The ground is perpetually frozen to varying depths, but this does not interfere with mining operations, except while being conducted at or near the surface, and is of great value and assistance in placer mining in places, as the gravels, where deep, can be worked by drifting without having to timber, on account of their firm frozen condition. Hydraulicking, sluicing, and all washing operations connected with placer mining can be commenced some time in May and conducted until well on in September.

Vegetation.

Upper White River district, as a whole, is only sparsely forested, and nowhere do the dense growths of timber occur such as characterize portions of British Columbia and other localities to the south and southeast. Trees nevertheless grow on mostly all the valley floors up to an elevation ranging from 3,500 to 4,000 feet above sea-level, and on the mountain sides to practically the same height. Timber-line is, however, characteristically lower at the lower ends of the valleys than at the upper ends, and in places does not reach above 3,000 feet.

Four principal forest members occur that attain the dimensions of trees, and a number of varieties of shrubs were noted. The four main varieties of trees are white spruce (*Picea alba*), aspen poplar (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), and northern canoe birch (*Betula resini fera* or *B. alaskana*); and the more important shrubs include juniper, several species of willow (*Salix*), alder, dwarf birch (*Betula glandulosa*), wild rose (*Rosa acicularis* Lindl.), and " Seapollali " (*Shepherdia canadensis* Nutt).

Several varieties of wild fruits were also noted in this district. Of these, crow or heather berries (*Empetrum nigrum*), blueberries (bog bilberry, *Vaccinium uliginosum* L.), high-bush cranberries (*Viburnum pauciflorum* Pylaie), and northern cranberry or foxberry (*Vaccinium Vitis-Idaea* L.), were quite plentiful; and black currants (*Ribes Hudsonianum* Rich.), red currants (*Ribes rubrum* L.), gooseberries, strawberries, and raspberries occur in places.

Grass for horses is available in favourable localities throughout the entire year, and commencing in the latter part of May or early in June, becomes quite plentiful. From June until October, pack-horses, if well cared for and not worked too hard will, in most parts of the area, subsist on what natural fodder is available. As mentioned previously, in describing the climate of White River district, horses will winter out safely in this district if they are strong and in good condition when winter sets in, and if they are left in suitable localities.

Game.

Game is plentiful throughout most parts of Upper White River district, sheep, moose, and caribou being particularly numerous. In fact, were this locality only slightly more accessible and somewhat better known, few places on the continent would be more attractive to the sport-loving hunter.

The sheep are the white Alaskan variety (*Ovis Dalli*): these feed during the winter months in the main valleys, but with the approach of summer they work farther and farther back into the higher mountains, and choose especially the lofty, rugged, craggy summits, and are frequently found in the vicinity of glaciers. They rarely return to the valleys during the summer, except in crossing from one mountain to another. The writer, one day in July of last season, counted over 400 sheep, all of which were plainly in sight at one time on the hills to the southwest of Rabbit mountain.

The moose are the large giant moose (*Alces gigas*). These magnificent animals range the lowlands in considerable numbers and are particularly plentiful in the flats bordering White river. Caribou are also somewhat numerous, and are frequently seen on the low open hills in different parts of the district. They are, when seen, the least difficult of any game to procure, as their curiosity is greater than their fear, and they will follow a horse or watch a man until scent gives them warning. Black and grizzly bear are sufficiently numerous to make it unsafe to leave a cache unprotected for more than a day or two, and they have been known to disturb provisions in the presence of the owner. Rabbits also abound throughout the district. Lynx, mink, martin, wolverine, and red foxes are fairly numerous, and cross, silver, and black foxes are occasionally found.

The chief game birds noted are rock ptarmigan (*Lagopus rupestris rupestris*, Gmelin), willow ptarmigan (*Lagopus lagopus*), Alaska spruce partridge (*Canachites canadensis osgoodi*, Bishop), fool hens or Franklin grouse (*Canachites franklinii*), willow grouse or Oregon ruffed grouse (*Bonasa umbellus sabini*), and several varieties of ducks and geese. The rock ptarmigan are found above timber line, and during the summer months live mainly on the highest, often snow-capped summits; the willow ptarmigan live during the summer season at above timber line. Both varieties are very plentiful in White River district as well as in adjoining portions of Yukon and Alaska. These birds are very easily obtained, and can often be secured with sticks or stones. Consequently, many a stampeder to Chisana last autumn depended on them partly or entirely for subsistence, and in some cases lived entirely on ptarmigan for days or even weeks at a time after his other provisions became exhausted. The spruce partridge, fool hens, and ruffed grouse are much less plentiful than the ptarmigan, but still are quite frequently seen.

The streams and small lakes are generally well supplied with fish, chiefly grayling (*Thymallus signifier*).

Topography.

Yukon Territory may be, for the greater part, divided into three broad physiographic provinces which persist to the southeast through British Columbia and to the westward through Alaska. Named in order from southwest to northeast these provinces are, the Coastal system, the Interior system, and the Rocky Mountain system. These terranes constitute the cordillera of northwestern North America, and follow in a general way the peculiar concave contour of the Pacific coast line. In Yukon and Alaska, the Interior system is comprised entirely of the most northerly of its larger divisions, the Yukon plateau, and in the vicinity of the 141st meridian—the Yukon-Alaska International Boundary—the Coastal system is composed of the St. Elias range and the Nutzotin mountains, of which the latter are the more northerly and adjoin the Yukon plateau on the south, the St. Elias range extending from the Nutzotin mountains to the Pacific ocean.

Upper White River district includes a north-south section across the eastern or southeastern end of the Nutzotin mountains, and extends to the south part way across the broad valley separating these mountains from the Skolai-Natazhat group, a northern fork of the St. Elias range. To the north this district reaches slightly into the Yukon plateau region, but does not continue sufficiently far to embrace any of the typical plateau remnants which characterize this physiographic province.

Upper White River district is thus composed for the greater part of an eastern portion of the Nutzotin mountains whose higher summits within the district rise to elevations of from 6,500 to 7,200 feet above sea-level. This mountain belt is bounded on the north by a broad easterly trending flat some 30 miles or more in width, which really constitutes a southerly portion of the Yukon plateau, and throughout which occasional knobs, hills, and mountain masses rise, in places, rather abruptly. To the south of the Nutzotin mountains, and separated from them by White River valley, the lofty snow-capped mountains of the Skolai-Natazhat group constitute in that direction an apparently impassable alpine barrier.

All the more prominent uplands within Upper White River district thus constitute portions of the Nutzotin mountains, although occasional smaller mountain masses are included in the wide depression to the north. The Nutzotin mountains within the district, themselves enbrace two genetically distinct types—those resulting from differential erosion, and those produced dominantly by accumulation. The mountains of erosion belong to that class of the earth's features which are the result of differential erosion in regions of deformation and uplift. They embrace all the uplands to the north and northeast of Lake Tchawsahmon valley, and also include the eastern and northern portions of the group to the west and southwest of this depression. Farther west, however, the older rocks and former topography have become deeply buried under accumulations of lava and accompanying fragmental rocks which now compose all the higher, more prominent portions of this mountain group to the west of Lake Tchawsahmon valley.

The typical Nutzotin mountains of erosion are notably irregular in form, being composed of geological formations which lack in most places any prominent members or structures which might control and give a more marked or regular expression to the topographic features. The mountains of accumulation to the west and southwest are composed of lavas and accompanying fragmental rocks which have piled up as a series of superimposed sheets lying nearly horizontal in most places, the entire volcanic accumulation having the aspect of even, stratified beds.

This group of mountains to the west of Lake Tchawsahmon valley thus constitutes a decided transition from the typical Nutzotin mountains of erosion to the Wrangell mountains of accumulation to the west and southwest where floods of lava are claimed to have obliterated an ancient topography whose relief exceeded 3,000 feet.

Upper White River district is drained by White river and its tributaries, of which the Generc is much the largest member, being comparable in size to the White above their confluence. A great part of the area is, however, drained by Beaver creek, a much smaller tributary than the Generc.

White River valley from the source of this stream in the northern lobe of Russell glacier, to Yukon river, has a length of about 180 miles, and throughout its course this river is a turbid, swift flowing, shallow stream, with numerous channels traversing its wide flood-plain which is studded with constantly shifting bars and islands. Like all glacial streams, White river also varies greatly as to the amount of water it carries, rising and falling rapidly, not only with daily and seasonal variation, but also under the influence of irregularities of precipitation, moisture, and temperature.

A great part of the lowlands, which comprise about one-half of the entire district, are very imperfectly drained, and are dotted with small, often entirely unconnected lakes or ponds. In fact, these lowlands or flats throughout Upper White River district are dominantly very wet, and, with the exception of the flood-plains of the master streams, are characterized by muskegs and "niggerheads."

A number of important changes in drainage have occurred in this district and adjoining areas, as is evidenced by several old broad valleys whose former relationship is not now understood, and also by the rock-walled canyons along White river. A great amount of study will still be necessary, however, before the drainage changes in the district are understood, and this former stream system is established.

General Geology.

GENERAL STATEMENT.

The geological formations of Upper White River district embrace both igneous and sedimentary members, and include rocks ranging in age from Carboniferous to Recent. What appear to be the oldest rocks exposed in the district consist of a series of limestones, cherts, and shales which contain Carboniferous fossils. Apparently more recent than these rocks, but also of Carboniferous age, is a thick series of shales, sandstones, conglomerates, and limestones which contain Pennsylvanian or Gschelian fossils. Overlying, conformably, the Carboniferous beds is a thick series of shales, greywackes, sandstones, and conglomerates, which contain Mesozoic fossils. These Carboniferous and Mesozoic beds are extensively invaded and intimately associated with a group of volcanic rocks consisting mainly of andesites, diabases, basalts, and related pyroclastics. These volcanics appear to be the result of intermittent volcanism extending from Carboniferous to at least Cretaceous time. In late Jurassic or Cretaceous time the older rocks were invaded by a group of intrusive plutonic rocks of granitic habit, which range in character from granites to gabbros, or even in places to hornblendites. Overlying all these rocks, there occur in a few places, some loosely consolidated, lignite-bearing conglomerates, sandstones, shales, and clays which are believed to be, dominantly at least, of Eocene age. Commencing about Eocene time, also, volcanism again became active and in the Wrangell mountains to the west and southwest, has persisted to the present time. Basalts, diabases, andesites, and related rocks pierced the older formations, and lavas poured over the surface accompanied by showers of ashes and fragmental materials. These volcanic materials accumulated in places to a thickness of several thousand feet. In late Tertiary or early Pleistocene time, the district was also invaded by a group of latites, rhyolites, and related rocks which cut the older formations and in places flowed out over the surface. Overlying all these rocks are the unconsolidated Pleistocene and Recent accumulations which constitute a mantle of greatly varying thickness, obscuring the underlying bedrock throughout a great part of the district. These materials consist mainly of gravels, sands, silts, boulder clays, soils, peat, ground-ice, and volcanic ash, vast quantities of which have not only spread over the valley floors and have accumulated in the various depressions throughout the district, but extend as well over a great portion of the uplands.

Table of Formations.

Quaternary	Recent and Pleistocene	*Superficial deposits.*—Gravels, sands, boulder clays, silts, volcanic ash, peat, soil, and ground-ice. Dominantly glacial and glacio-fluvial deposits which are still accumulating.
		Rhyolites, latites, and related volcanics.
	Post-Eocene	*Newer Volcanics.*—Mainly augite andesites and basalts, dominantly amygdaloidal or pumiceous, with related pyroclastic rocks. Not perceptibly disturbed.
Tertiary	Eocene, possibly in part, Oligocene.	Conglomerates, sandstones, and shales, loosely consolidated in most places. Contains seams of lignite.
	Cretaceous or Jurassic	Intrusive plutonic rocks, ranging in character from granites to gabbros or even hornblendites. Apparently represent outlying portions of the Coast Range batholith.
Mesozoic	Cretaceous, possibly in part, older.	Shales, sandstones, conglomerates, and related sediments, considerably deformed and indurated. Only Cretaceous fossils were found, but Jurassic or even Triassic members may be present.
	Cretaceous, possibly in part, older.	*Older Volcanics.*—Andesites, diabases, basalts, and related rocks with their accompanying tufaceous types. These are intimately associated with the Mesozoic and Carboniferous sediments and are, in part, contemporaneous with them.
Palæozoic	Carboniferous	*Pennsylvanian.*—Shales, sandstones, conglomerates, and occasional beds of limestone, considerably deformed, indurated, and, in places, metamorphosed.
		Massive limestone with some associated cherts, considerably metamorphosed.

DESCRIPTIONS OF FORMATIONS.

Carboniferous Sediments.

What appear to be the oldest rocks exposed in Upper White River district, comprise a series of sediments consisting mainly of limestones, but including also some cherts and shales, which are here for convenience in description referred to as the limestone-chert series. The limestones are dominantly grey in colour, massive and crystalline in structure, and have a thickness of at least 500 feet. Underlying these limestones are some irregular, much altered, mashed and distorted, dark cherts and shales, which have an aggregate thickness of 100 feet or more. These limestone-chert beds were identified at only a few points, and in each case the exposures are small. They are overlain, wherever noted, by volcanic rocks, and nowhere were the lowermost beds of the series observed. Fossils collected from the limestone members at different points prove to be of Carboniferous and probably of Gschelian or Pennsylvanian age.

In addition to these rocks, a series comprised mainly of shales, sandstones, conglomerates, and limestones, containing Upper Carboniferous fossils, is also extensively developed throughout the district. For various reasons, these beds are believed to be more recent than the limestone-chert sediments and for the purpose of distinction are here designated as members of the shale-limestone series. These shale-limestone beds have an aggregate thickness of at least 1,500 feet and probably are nearer twice this thickness. However, due to the fact that they are in places much folded and distorted, and owing also to the fact that nowhere were the lowermost beds of the series observed, the total thickness of these sediments remains rather uncertain.

At a few points, also, some more or less schistose rocks are exposed, which are considered by Mr. Barlow, who examined them, to be the locally metamorphosed equivalents of certain of the arenaceous and argillaceous members of the Carboniferous series.

The attitude of these rocks is extremely variable, but still, in a general way, they strike in a northwesterly direction parallel to the trend of the main Nutzotin range, and dip prevailingly to the north. The structure is dominantly characterized by closed folds, the deformation being somewhat typically Appalachian. In places, these rocks are extremely and intricately folded, several closed or even reversed synclines and anticlines being often seen within a distance of 100 feet or even less.

Fossils were collected from both of these series at a number of points, and have been examined by Dr. George H. Girty of the United States Geological Survey, who refers them all to the Carboniferous. Dr. Girty, however, divides these remains provisionally into an upper and a lower group, both of which he considers belong to the Upper Carboniferous or Pennsylvanian. These fossil remains are found to correspond with Russian rather than with American facies, and should thus probably be referred to the Artinskian and Gschelian or entirely to the Gschelian. The grouping of the fossils does not entirely correspond to the stratigraphic divisions as indicated in this report, but agrees in a general way, the apparent discrepancies being probably due to the uncertain and indefinite character of the invertebrate remains.

The shale-limestone series of Upper White River district resembles very closely, stratigraphically, lithologically, and palæontologically, the Nation River series along Yukon river,[1] and thus, evidently either entirely corresponds to this formation or is included by it. The limestone-chert beds may also be included in the Nation River series, but would appear rather to represent a horizon just below it, and corresponding to the lower Pennsylvanian.

Similar Carboniferous sediments have been described by other writers in districts neighbouring Upper White River district. Brooks includes these beds in his Nutzotin series[2] which, however, embraces Mesozoic beds as well. Moffit and Knopf have also described similar rocks in the nearby Nabesna-White River district, under the general term "Carboniferous rocks."[3]

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[1] Brooks, A. H., and Kindle, E. M., "Palæozoic and associated rocks of the Upper Yukon, Alaska"; Bull. Geol. Soc. Amer., vol. 19, 1908, pp. 291-304.

[2] Brooks, A. H., "A reconnaissance from Pyramid harbour to Eagle City, Alaska"; U.S. Geol. Surv., 21st Ann. Rept., pt. 2, 1899-1900, pp. 359-360.

[3] Moffit, F. H., and Knopf, Adolph, Op. cit., pp 17-27.

Mesozoic Sediments.

The Mesozoic sediments have a somewhat extensive development in Upper White River district, and with the Carboniferous beds compose the great part of the main Nutzotin range. They are also lithologically very similar to certain of the arenaceous and argillaceous members of the Carboniferous shale-limestone series, and it was not always possible to distinguish these two formations; however, the Mesozoic beds were identified at numerous points not only throughout the Nutzotin mountains to the north of Lake Tchawsahmon valley, but also along the northern and northeastern portions of the mountain group immediately to the south of Tchawsahmon ridge and Lake Tchawsahmon valley.

The Mesozoic sediments consist dominantly of shales, greywackes, sandstones, and conglomerates, and have an aggregate thickness of apparently about 1,000 feet. However, neither the uppermost nor lowest beds of this formation have been identified.

Fossils were collected from these beds at a number of points, but in each case only a single species was obtained. These remains have been examined by Dr. T. W. Stanton of the United States Geological Survey, who considers them to indicate that the beds from which they came are of Lower Cretaceous age.

Similar appearing Mesozoic beds occurring in the Nabesna-White River district, Alaska, a few miles to the west of Upper White River district, Yukon, have been described by Moffit and Knopf.[1] From these rocks, fossils have been collected representing both the Jurassic and Triassic periods, and some remains were found which are thought to be possibly of Cretaceous age. Therefore, as these rocks resemble lithologically the Mesozoic beds in Upper White River district, and occur constituting in both areas a correspondingly prominent part of the Nutzotin mountains, and since in Upper White River district these beds overlie Upper Carboniferous sediments, it would seem altogether probable that in Upper White River district, these Mesozoic beds include not only Cretaceous but also Jurassic and even possibly Triassic members, but that unfortunately fossil remains were obtained from only the Cretaceous horizons.

These Mesozoic beds in Upper White River district, also appear to correspond very closely with the Laberge series[2] of other portions of southern Yukon and of northern British Columbia, which have been considered to be of Jura-Cretaceous age.

Older Volcanics.

Associated with the Carboniferous and Mesozoic sediments of Upper White River district is an extensively developed group of basic or semi-basic volcanic rocks which for convenience in description are in this report designated as the "older volcanics." These include mainly augite andesites, hornblende andesites, mica andesites, augite diorite porphyrites, basalts and diabases, as well as their accompanying and related tuffs and breccias. These rocks vary considerably in general appearance due to their possessing a somewhat wide range of colour, texture, structure, and mineralogical composition. They are dominantly fresh appearing rocks, but in places are considerably distorted, fractured, and veined with calcite and quartz. At a few points, also, these volcanics have become locally metamorphosed and given a laminated or even a schistose structure.

They are characteristically of dull subdued colours, of which dark shades of green prevail, but browns and even reds also occur. In texture, these volcanics range from

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[1] Moffit, F. H., and Knopf, Adolph, Op. cit., pp. 27-32.

[2] Cairnes, D. D., "Preliminary memoir on the Lewes and Nordenskiöld Rivers Coal district, Yukon Territory"; Geol. Surv., Can., Memoir No. 5, 1910, pp. 30-35.

"Wheaton district, Yukon Territory"; Geol. Sur., Can., Memoir No. 31, 1912, pp. 53-57.

"Portions of Atlin Mining district, British Columbia, with special reference to lode mining"; Geol. Surv., Can., Memoir No. 37, 1913, pp. 59-63.

homogeneous appearing rocks in which none of the component minerals are discernible with the naked eye, to much more coarsely grained rocks containing large, well defined phenocrysts embedded in a groundmass which, in some cases, may also be seen to be crystalline without the aid of a lens. The phenocrysts are dominantly plagioclase, hornblende, and pyroxene, of which the hornblende and pyroxene are black or nearly so, and the plagioclase ranges from light grey to pale greenish in colour. In places, also, these rocks are notably amygdaloidal; the amygdules range in size from microscopic to an inch or more, but are dominantly, however, less than one-quarter inch in diameter. These amygdaloidal cavities which, during the time the lavas were cooling, were occupied by gases or vapours, are now for the greater part filled with secondary minerals, mainly zeolites, calcite, chlorite, epidote, and chalcedonic quartz, the zeolites and calcite predominating in most places. It is in certain of these reddish amygdaloidal flows that the native copper of White River district of both Yukon and Alaska occurs. Native copper has only been found in these rocks in Upper White River district, in the vicinity of the Upper canyon on White river, but similar, reddish, amygdaloidal volcanics are typically and somewhat extensively developed on Cottonwood mountain, Miles ridge, and elsewhere throughout the area.

Thus many of these rocks have quite a mottled appearance, due either to large, light-coloured feldspar phenocrysts distributed throughout a finely textured, dark groundmass, or owing to the white zeolites, calcite, or quartz amygdule fillings being scattered throughout an otherwise dark greenish, reddish, or brownish rock. Such types are thus quite contrasted in appearance with other dull, dark, dense rocks in which none of the mineral constituents are discernible without artificial means.

The tuffs and breccias that occur occasionally associated with these various volcanic types, range from dense, finely-textured ash rocks to massive, coarse, breccias having somewhat the appearance of conglomerates. These breccias differ from conglomerates, however, in that they are composed mainly or entirely of igneous material, and the cemented rock fragments in addition exhibit little if any eroding action.

These older volcanics in Upper White River district at least, are dominantly of local origin. In the main Nutzotin range to the north and northeast of Lake Tchawsahmon valley, they are extensively developed, but are prevailingly intrusive into the surrounding rocks and occur in them in the form of dykes and irregular masses in the position in which they originally cooled below the former land surface. Along the eastern edge of the mountain group to the southwest of Lake Tchawsahmon, and in places on the hills on the northeastern side of this broad depression, these volcanics, however, occur in the form of flows associated with occasional tuffs and breccias, the flow structure being in places still quite apparent. These lavas appear to have come to the surface along certain fractures in the older rocks, and to have poured out over them from these long, incision-like vents.

The only direct available evidence concerning the age of these volcanics, is that obtained by a study of the relation of these rocks to sediments of known age. In Upper White River district wherever these volcanics were observed in contact with the Cretaceous-Carboniferous sediments, they cut or everlie them. It is thus evident that some of these volcanics are more recent than the Cretaceous beds, and in the short time available in the field, it was not possible to subdivide them into age groups, even if some of these rocks are older than Cretaceous.

However, in the Nabesna-White River district, Alaska, to the west, considerable evidence has been obtained indicating that the copper bearing volcanics there, which appear to be the same as those in Upper White River district, are of Upper Carboniferous age. Thus either these volcanics on the Yukon side of the boundary line include rocks of both Carboniferous and Mesozoic age, or these volcanics are of different age from those described in Alaska, or the Alaskan geologists have come to wrong conclusions concerning the volcanics in the Nabesna-White River district. From the evidence cited by Moffit and Knopf,[1] it would hardly seem possible that they could be mistaken. Furthermore, the writer investigated these volcanics on both sides of the line and they appear to be almost undoubtedly the same. It would thus seem probable that in Upper White River district, these older volcanics include members ranging in age from Pennsylvanian to Cretaceous, and thus represent a long intermittent period of volcanism similar to that giving rise to the Wrangell lavas, which commenced about Eocene time and is still in progress.

Granitic Intrusives.

At a number of points in Upper White River district, intrusive plutonic rocks occur which have characteristically a granitic habit, and are here for convenience in description, designated as granitic intrusives. These rocks constitute a number of isolated, irregularly-shaped bodies that occur as stocks or batholithic masses of no great size.

These intrusives vary in composition from that of an acid granite to a basic gabbro or even a hornblendite, and in general are some shade of grey, but possess quite a wide range of colour. The more acid varieties are almost white or light grey, but with increasing basicity, the colour becomes darker, the hornblendites being quite black. The granites and granodiorites have in places a pink or reddish hue, due to the colour of the prevailing alkali feldspar they contain; while greenish tints characterize some of the more basic rocks due to the development of chlorite, epidote, or related minerals. These intrusives are also remarkably uniform in texture, being dominantly coarse grained rocks. Medium textured facies, however, are developed and in places these intrusives are decidedly porphyritic. They are characterized nearly everywhere by a typical granitic appearance, and are thus commonly spoken of as granites, which term, however, is, strictly speaking, applicable to only a small percentage of these rocks.

Certain of the early Mesozoic conglomerates of this district contain granitic pebbles apparently derived from these intrusives, and at the same time the granitic rocks cut the early Mesozoic sediments at different points. This evidence corresponds exactly with that found to obtain for the Coast Range intrusives in southern Yukon and northern British Columbia,[2] where the early Jura-Cretaceous beds contain granitic pebbles and boulders evidently derived from these intrusives, but the intrusives themselves cut these same beds which are in part derived from them. Thus, it is seen that these Coast Range intrusives represent a long intermittent period of igneous activity extending possibly from early Jurassic well into Cretaceous time. After portions of the granitic batholith had cooled and been eroded, giving rise to various sediments, igneous activity continued or again broke forth, and granitic intrusives lithologically almost identical with the earlier members, invaded the sediments produced from them. The granitic intrusives in Upper White River district correspond lithologically with these Coast Range intrusives and appear to be undoubtedly closely connected, genetically, with the great Coast Range batholith, and possibly represent outlying portions of this vast geological terrane.

Tertiary Sediments.

Tertiary sediments have a relatively slight areal development in Upper White River district and comprise, mainly, loosely or only partly consolidated sandstones, shales, and clays. The sandstones are prevailingly greyish to yellowish and brown in colour, and the shales and clays are dominantly some light shade of grey, green, or

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[1] Moffit, F. H., and Knopf, Adolph. Op. cit., pp. 17-27.
[2] Cairnes, D. D., "Portions of Atlin district, British Columbia, with special reference to lode mining"; Geol. Surv., Can., Memoir No. 37, 1913, pp. 57-59.

blue, but some quite black strata also occur. All the beds are soft and decrepitate readily to form sand and clay beds. Some thin seams of lignite and a considerable amount of fossil wood were also found associated with these sediments in places.

These rocks are prevailingly nearly flat lying, and in most places have been only slightly disturbed by earth movements. They have, however, been extensively invaded by more recent volcanics, including members of both the rhyolite-latite group and the newer volcanics, which pierce or overlie the beds wherever they are exposed.

These Tertiary beds appear to correspond to the members of the Kenai series[1] which includes the oldest known Tertiary sediments in Yukon and Alaska, and which is generally referred to upper Eocene. Since, however, Kenai beds in places rest conformably upon the Upper Cretaceous, and form with it a continuous series without any perceptible stratigraphical break, it is possible that the Kenai series includes some lower Eocene. Since, also, the Kenai beds contain seams of lignite, it is customary to include in that formation all Tertiary beds contaning coal. It would thus seem possible that rocks more recent than Eocene have been in places included in the Kenai, just as has happened at times in connexion with certain lignite-bearing Cretaceous beds.

These beds in Upper White River district are thought to correspond to the members of the Kenai series because they lithologically closely resemble the rocks of this formation seen in other localities, and because of the fossil wood and lignite which they contain, the wood being somewhat indefinite but indicating at least a Tertiary period of deposition.

Newer Volcanics.

An important group of volcanic rocks which are dominantly at least of post-Eocene age and are extensively developed in Upper White River district are here for convenience designated as the "newer volcanics." These are confined practically entirely to the southwestern corner of the area, and are exposed mainly along the higher or southwestern portion of the mountain group which lies to the west and southwest of Lake Tchawsahmon valley.

These newer volcanics present, characteristically, a bright, fresh appearance and are contrasted in this respect with the dominantly dull-appearing, older volcanics of the district. Black and grey tones predominate, but lavender, and dark bluish slate colours occur, as well as various shades of pink and red which are very striking, the reds ranging from a dull brick colour to a bright vermilion hue. The tuffs and breccias are prevailingly lighter in appearance than the lavas with which they are interbedded, being generally ash coloured or some shade of grey, or yellow. These lavas and accompanying fragmental rocks have a maximum thickness in Upper White River district of about 3,000 feet, and are piled up as a series of superimposed sheets lying in most places nearly horizontal. They, however, dip gently away from the extrusive vents, and the lower beds and flows naturally conform to the topographic features over which they have accumulated. Particularly where considerable sections of these rocks are exposed, the entire volcanic group or series has a general stratified aspect, and the alternating grey, green, black, yellow, and red shades present a bright, vari-coloured appearance which constitutes one of the most striking pictorial features of the district. The lavas have also a characteristically well-marked columnar structure and the tuffs and breccias weather in many places to form tall, irregular, craggy pillars or "hoodoos" which are as much as 50 feet in height, corresponding to the thickness of the beds from which they were derived.

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[1] Collier, A. J., "The coal resources of the Yukon, Alaska": U.S. Geol. Surv., Bull. No. 218, 1903, pp. 17-19.

Brooks, A. H., "The geography and geology of Alaska": U.S. Geol. Surv., Prof. paper, No. 45, 1906, pp. 237-244.

Cairnes, D. D., "The Yukon coal fields": Trans. Can. Min. Inst., vol. xv, 1912, pp. 365-367.

These extrusive lavas are for the greater part porphyritic rocks of medium coarseness, containing phenocrysts of the intermediate feldspars, basaltic hornblende, pyroxene, biotite, or olivine. The feldspars are generally present and in many specimens, two or three of the bisilicates occur together. These volcanics are mainly augite andesites, diabase, or basalts, although there appears to be a practically complete series of transitional forms from fairly acidic andesites to olivine basalts. In texture, these rocks range from glassy to holocrystalline, and from extremely pumiceous to quite dense. They are, in addition, dominantly amygdaloidal, the amygdules being in most cases empty, although in some of the older members, they are partly or entirely filled mainly with calcite, zeolites, epidote, or chlorite. These newer volcanics thus differ from the amygdaloids of the older volcanic group, in which the amygdules are prevailingly occupied by secondary minerals.

In addition to these extrusive facies, dykes and other intrusive forms pierce not only the rocks older than the lavas themselves, but in addition cut the earlier members of this group. These intrusives are dominantly dense, dark, greyish green to nearly black rocks having a marked basaltic habit.

These lavas in Upper White River district, cut and overlie the Tertiary sediments and are thus at least post-Eocene in age. No evidence was obtained, however, indicating that any of these rocks have been extruded in recent times, as in the Wrangell mountains. These lavas, also, as mentioned before, correspond with similar volcanics to the west and southwest where they have been studied in detail by Mendenhall, who named them the Wrangell lavas, and who considers them to range in age from about Eocene time to the present. He states: "These flows, therefore, instead of preceding the deformation of the early Tertiary plain are later than the dissection which followed its uplift, and are to be regarded as very recent indeed."[1]

Rhyolite-Latite Volcanics.

Certain rhyolites, latites, and related rocks which occur in Upper White River district, are here for convenience in description, designated as the rhyolite-latite volcanics. These rocks are restricted in their occurrence practically entirely to the mountainous area lying north of White river and southwest of Lake Tchawsahmon valley, and even there, they have only a relatively slight areal development. Throughout this area, narrow dykes of these rocks are somewhat plentifully distributed, and at a few points, surface flows or larger intrusive bodies occur.

The members of this rhyolite-latite group consist of certain light-coloured porphyritic rocks ranging from nearly white, light grey, or yellowish, to pale lavender or darker greenish grey shades. The groundmass is invariably cryptocrystalline or too finely textured for the component minerals to be discernible with the unaided eye, and the phenocrysts include mainly feldspars, hornblende, and biotite.

These rocks are in places pumiceous or amygdaloidal, and are all notably rough to the touch, the lighter coloured varieties in particular having often somewhat the appearance of brick on a fresh fracture.

These volcanics cut the newer volcanics wherever members of the two groups come in contact, showing that the rhyolite-latite volcanics are at least of late Tertiary and possibly early Pleistocene age. They have in places also flowed over the present land surface since it has become uplifted and eroded to nearly its present form, only glacial action and recent erosion having since altered the topographic features.

Superficial Deposits.

The superficial deposits of Upper White River district include mainly gravels, sands, silts, boulder clays, muck, soil, ground-ice, and volcanic ash, some of which are

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[1] Mendenhall, W. C., Op. cit., p. 57.

of glacial origin, some are the result of volcanism, and other members again have been produced by ordinary subaërial destructive agencies. The great mass of all these Quaternary accumulations are, however, due either directly or indirectly, to ice action, but ordinary eroding and disintegrating processes have produced a certain minor amount of recent detrital materials which constitute a thin mantle covering the land surface nearly everywhere. The volcanic ash is a very notable feature of the district, but was only noted to the south of White river. The ground-ice, as in most parts of this northern region, remains in most places throughout the entire year, and occurs just below the surface vegetation.

Mineral Resources.

Upper White River district constitutes a portion of a well-mineralized region, and possesses itself a considerable degree of mineralization. The more promising of the mineral deposits that have been discovered, are those containing copper and gold, both of which metals either in this district or in adjoining portions of Yukon, are found not only in their bedrock sources, but occur as well in the form of placer deposits. The district as a whole, however, has been only slightly explored, and although promising prospects have been located, it has not yet been demonstrated, except possibly in the case of the gold-bearing gravels, that a single mineral deposit can be profitably exploited.

A considerable portion of this district is not only mountainous, but is somewhat rugged in character, and can be more easily prospected than many portions of western Canada, due to the relative abundance of bedrock exposures and also owing to the fact that little or no timber occurs in most places, the country being prevailingly quite open. Extensive valley or lowland tracts, however, also occur, throughout which superficial detrital accumulations, dominantly of glacial origin, have deeply buried whatever minerals the underlying bedrock includes.

The placer gold deposits had been only slightly prospected until during the past winter, when as a result of the Chisana discovery, a considerable number of men are reported to have been investigating the gravels of this district. As yet, however, the writer has been unable to obtain any definite and reliable information concerning these recent developments, other than to the effect that placer gold in encouraging amounts has been discovered on several creeks. Since the general geological conditions in portions of this area are very similar to those in Chisana district, Alaska, it is hoped that valuable deposits of placer gold will yet also be found across the line in Upper White River district.

Vein quartz is somewhat extensively developed in portions of this area and in places contains gold and even occasionally copper as well. The individual quartz veins and masses that have been discovered, although in places quite large and persistent, are nevertheless only very sparsely mineralized. It is quite possible, however, that deposits of similar extent and size may yet be discovered containing gold either alone or associated with other minerals in sufficient amount to allow of their being worked at a profit.

Native copper has long been known to occur in the White River basin, and it was the greatly exaggerated reports concerning the abundance of this metal that originally drew prospectors into this region. This metal, however, so far as is known, has been found in Upper White River district in economically important quantities on only one property, which is known as Discovery copper grant.

Discovery copper grant is located on the right or southeast side of the White about 1½ miles upstream from Canyon City, the workings on this property being mostly situated on the steep valley wall from 100 to 200 feet above the river. Copper is believed to have been first discovered here by Solomon Albert, in May, 1905, when three copper grants were staked by the discoverer and his two partners, Joseph P.

Slaggard and M. C. Harris, who still hold this ground. Practically all the development work has been performed on the first-located grant which is known as "Discovery" and on which the greater part of all the copper occurs that has as yet been found in this vicinity.

The geological formation on this property, where exposed, consists dominantly of greenish to reddish andesitic volcanics similar to those which are so extensively exposed to the west in Alaska, and with which are there associated most of the copper deposits of the White-Nabesna district. At Discovery, the copper occurs mainly in a finely-textured, massive, reddish amygdaloid, the amygdules of which are filled with a dark green secondary mineral apparently epidote. Bedrock is here, however, for the greater part covered with superficial deposits which add much to the difficulties and uncertainties of prospecting. The geological conditions are consequently somewhat obscure, and no definite flows could be detected to the west where in many places extensive sections of the copper-containing lavas are exposed.

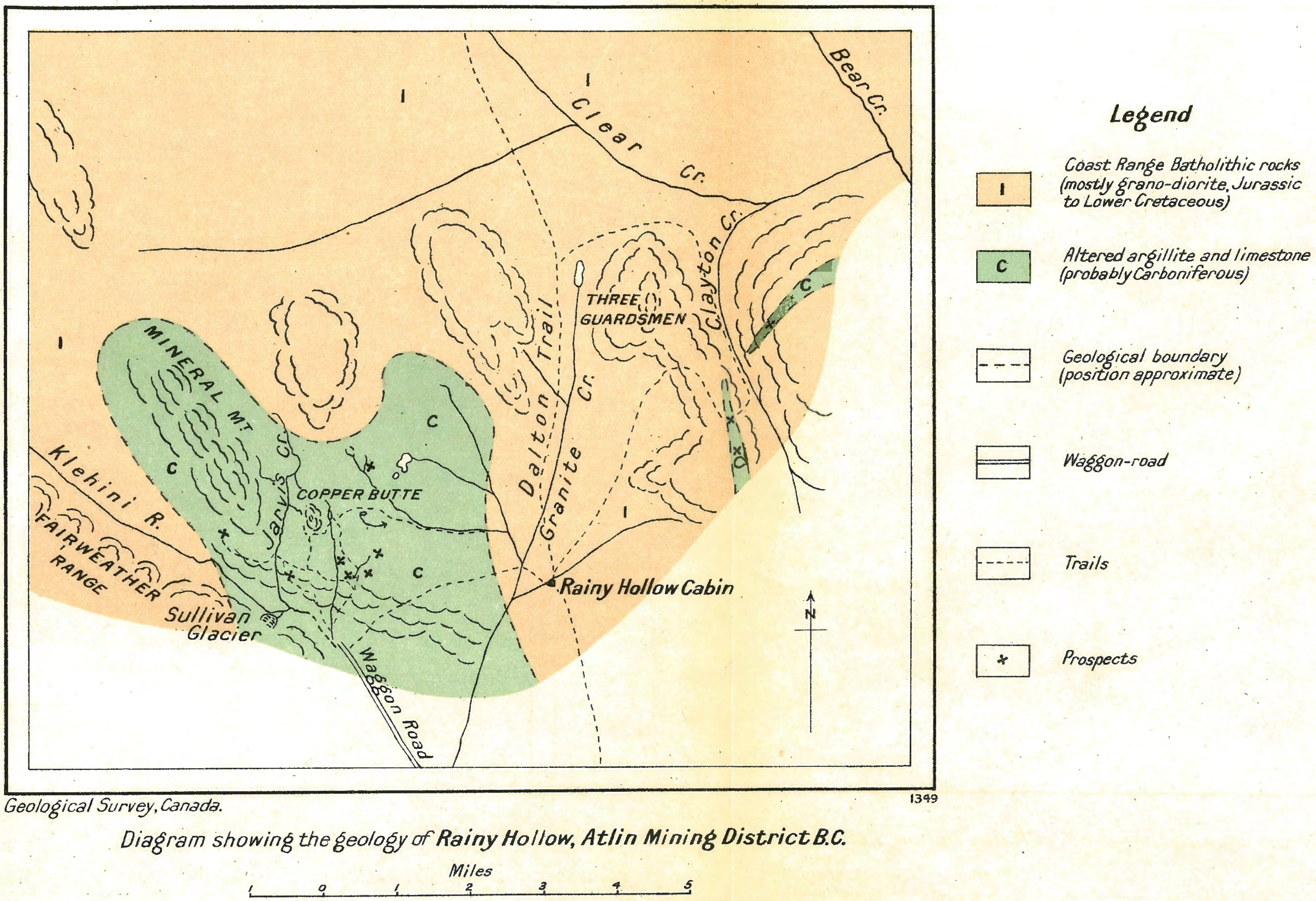
On Discovery property three adits have been driven distances respectively of 30, 20, and 20 feet; in addition, a certain amount of surface work has been performed mainly in the shape of open-cuts and trenches. This development has shown that the volcanic country rock is traversed by numerous irregular fractures, some of which exhibit pronounced slickensiding. These seams in places contain native copper, a number of slabs of which have either weathered out or have been dug up, which weigh as much as several hundred pounds each, and one particularly large tabular mass which was measured by the writer is about 8 feet long, 3 feet 6 inches wide, and 4½ inches thick, and is estimated to weigh about 6,000 pounds.

Narrow calcite veins containing chalcocite (copper glance) as well as stringers of cuprite and disseminated native copper also traverse these rocks in places. In addition, in one of the adits the dark green volcanic country rock contains occasional veinlets of chalcocite, which mineral is also disseminated through the rock in places. In the bottom of the cuts, chalcocite also begins to appear, and in places specimens were obtained showing the chalcocite partly oxidized to the native state. It is thus perfectly evident that the native copper is a surface oxidation product and is derived directly from the chalcocite. Further, as occasional particles of chalcopyrite (copper pyrites) occur in places disseminated through the amygdaloids, it would seem probable that with greater depth this will prove to be the primary copper mineral.

The native copper cannot, therefore, be expected to continue more than a few feet below the surface, except possibly along well-defined fissures where there is a ready circulation. Thus, although there appears to be a considerable aggregate amount of copper in this vicinity, it is problematical whether or not, except very near the surface, it is anywhere sufficiently concentrated to constitute workable ore bodies. Such will have to be determined by future mining operations. There is, however, enough copper in sight to warrant further development, and as bedrock is in most places covered with superficial deposits, there is no reason to suppose that the best deposits have first been discovered. On the other hand it is quite possible that underlying this mantle of detitral material, copper deposits much more valuable than those so far uncovered, may yet be found in this vicinity. However, unless the primary sulphides themselves, when reached, are sufficiently concentrated to pay for exploitation, the marketable ore will comprise for the greater part at least, only the occasional bunches, slabs, and masses of native copper at the surface, which would not seem to be sufficient in amount to afford more than limited and very uncertain output. In any case, until a railway is constructed into the district the shipping facilities will not permit of the mining of copper properties in this vicinity.

In addition to the bedrock source of copper in this district, placer copper occurs a few miles to the south of White river, associated with the gravels of Kletsan creek, a small stream which heads in Natazhat glacier and flows northward into the White. These Kletsan Creek nuggets constituted the native copper in which the Indians carried on quite a traffic until quite recently. In fact Kletsan creek is thought to be the original source of the native copper which has been popularly known to occur somewhere in White River basin for the past twenty-five years at least. The placer copper appears to occur only near the head of the creek, and the nuggets which have been found range in weight from a few ounces to 5 or 10 pounds. In 1902, Mr. James Lindsay investigated these deposits for the purpose of determining their copper possibilities. It is believed, however, that due to ice and snow in the high ranges near the head of the creek, and other adverse conditions, that he arrived at unfavourable conclusions.

Considering, however, all the different finds that have been made, as well as the general mineralization of the district, further prospecting and development are recommended, in the hopes not only of finding other deposits of economic minerals, but also of determining the importance of those already discovered, very little being as yet really known concerning the mineral possibilities of this district. Important finds and developments are, therefore, expected to result from the discovery of gold at Chisana, as hundreds of keen prospectors have since been scouring Upper White River district and adjoining areas as never before. It is thus quite possible or even probable that this prospecting, which is really an outcome of the Chisana discovery, will result in finds being made in other nearby portions of Yukon and Alaska which will greatly exceed in importance the placer deposits of the original Chisana area.



Geological Survey, Canada.

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Diagram showing the geology of **Rainy Hollow, Atlin Mining District B.C.**

To accompany Summary Report by R. G. McConnell, 1913.

RAINY HOLLOW MINERAL AREA, B.C.

(*R. G. McConnell.*)

Situation.

The Rainy Hollow mineral area is situated in the mountainous coast belt on the headwaters of the Klehina river, a branch of the Chilcat. It is connected with Haines, Alaska, on Lynn canal, by a wagon road about 55 miles in length. The wagon road from Haines to the crossing of Jarvis creek, a distance of 45 miles, is in Alaskan territory, and was built by the United States Government. The 10-mile stretch from Jarvis creek at the Internatitonal Boundary to the camp, was built by the British Columbia Government. The road follows the valleys of the Chilcat and Klehina rivers and is in fair condition except that the bridge over Jarvis creek has been carried away and the one over the Klehina river is unsafe.

Topography.

The upper Klehina river, with its spreading eastern branches, may be considered as separating the Fairweather or southeastern portion of St. Elias range from the Coast range. The region southwest of the Klehina is exceedingly rugged and difficult of access. The mountains are high, are largely snow-covered throughout the year, and glaciers stream down all the principal valleys. Mount Fairweather near the coast is the culminating point of the range. Northeast of the Klehina a broken upland dominated by Mineral mountain, a long iron-stained ridge about 5,700 feet high, and Copper butte, a low rounded dome, extends northeastward to Granite creek, a distance of 7 miles. The elevation of the plateau ranges from 3,000 to 3,500 feet. Beyond Granite creek is a group of granite mountains similar in character to the Coast range, but separated from that range by the wide valley of Bear creek, a branch of the Chilcat. Three prominent peaks in this group are known as the Three Guardsmen. They overlook to the northwest a desolate irregular granite plain, representing a wide pre-Glacial valley of erosion. The old Dalton trail ascended Granite creek and followed this plain to the head of Bear creek.

A prominent feature of the topography southwest of the Klehina are the number of large glaciers which descend from the Fairweather range. One of these, called locally the Sullivan glacier, terminating in the Klehina river, advanced in the summer of 1910 for a distance of fully half a mile. Since then, according to the statements of local observers, there has been a slight retreat. Sudden advances of glaciers after remaining stationary or slowly retreating for years have been frequently noted throughout the St. Elias range, and are generally attributed to earthquake shocks. The mountains bordering the glaciers are usually wholly or partially covered with snow and ice fields and with steeply hanging tributary glaciers. These are broken up by the shocks and showered down on the main ice stream, increasing its volume and necessarily accelerating its rate of flow. Abnormal local precipitation in the region from which the glacier draws its supplies, may also be a factor.

Geology.

The rocks of the Rainy Hollow district consist of granodiorites and a group of altered sedimentary rocks bordering them on the southwest.

The granodiorites occur as an irregular spur to the southwest from the main Coast range batholithic mass. They are greyish, medium-grained, granitic rocks made up of a plagioclase feldspar usually andesine, quartz, some orthoclase and biotite. They show a gneissic structure in most of the sections examined, the direction of schistosity usually trending to the northwest. Inclusions of the sedimentaries occur in places.

The granodiorites intrude dark argillites, alternating in places with bands of limestones, from a few feet to 300 feet in width. The limestones are greyish in colour and usually rather coarsely crystalline, especially near the intrusive. They occur as a rule in short bands or lenses seldom traceable for more than a few hundred yards. No fossils were found in them, but a less altered variety occurring on Porcupine creek southwest of the International Boundary and evidently belonging to the same series, has yielded specimens of a Carboniferous fauna.[1]

The argillites like the limestones, show considerable alteration. Ordinarily, they are dark, rather coarsely bedded rocks seldom strongly cleaved. In some areas considerable mica is developed and they pass into schists. Striped, greyish quartzitic bands resembling gneisses in hand specimens, alternate in places with the dark variety. These rocks apparently represent highly silicified argillites probably originally somewhat calcareous. In places, they consist mainly of mica, quartz, and garnet in thin alternating layers. Bands of greenish chloritic schists occur occasionally with the argillites.

The structure of the sedimentary series has not been worked out. In Mineral mountain the argillites and associated beds occur in a flat syncline interrupted by a number of subordinate folds. In other parts of the area they are inclined at steep, in places, almost vertical attitudes.

The sedimentaries are cut by occasional dark basic dykes and by a younger set of porphyritic dykes.

Economic Geology.

The Rainy Hollow mineral deposits occur in two areas, one in the vicinity of Mineral mountain and Copper butte, and the other 6 miles to the east on the eastern slope of the Three Guardsmen range.

The rocks in the Mineral Mountain area consist mainly of argillites with some limestones occupying an embayment about 4 miles wide projecting into the granodiorites of the Coast Range batholith. The deposits occur mainly as replacements in limestone, and are referred to the contact metamorphic group, but possess some peculiarities. They occur in places near the batholithic granodiorite contact but also at some distance from it, and the most persistent bodies have the linear shape of veins and have formed between limestone and altered argillite. The principal metallic minerals in the deposits are bornite, chalcopyrite, galena, sphalerite, pyrrhotite, and pyrite. The accompanying non-metallic secondary minerals include garnet, epidote, diopside, calcite, and quartz.

DESCRIPTION OF PROPERTIES.

Maid of Erin.—The showing on the Maid of Erin is the most important so far discovered in the camp. The claim is situated on a high bench between the Klehina river and the southern end of Mineral mountain at a distance of about 2½ miles in a straight line from the end of the wagon road. The elevation is approximately 3,400 feet above sea-level.

The rocks here consist of a band of light-coloured coarse crystalline limestone intruded on the west by granodiorites and overlain on the east by altered argillites.

[1] Bulletin 236, U.S. Geol. Surv.

The limestones are mineralized along an irregular zone about 450 feet in length and nearly 100 feet wide at one point. The mineralized area, as is usually the case in contact metamorphic deposits, is irregular in outline and in degree of mineralization. The main bodies of commercial ore occur in two lenticular areas, the largest of which has a length of 175 feet and a maximum exposed width of 80 feet. The smaller area has a width of about 50 feet. Bornite is the principal, practically the only, copper mineral present. It occurs in grains, small bunches, and stringers scattered irregularly through the crystalline limestone. Copper carbonates due to surface alteration, are conspicuous in places but occur only in thin films.

The workings consist of trenches, shallow pits, and shafts, none more than a few feet in depth. These serve to outline the surface extent of the deposit, but so far no attempt has been made to explore it in depth.

The percentage of bornite present is high in some areas and low in others. No definite estimate was made of the average copper tenor. A shipment of 37 tons of selected ore made some years ago, is stated to have yielded 55·67 ounces of silver per ton and 32·83 per cent of copper.

The Maid of Erin surface showing is an unusually good one and the deposit is well worth a considerable expenditure for further exploration in depth.

Elise.—The Elise claim is situated immediately east of the Maid of Erin. A band of altered rocks enters it from the latter and crosses it in an easterly direction. Some bornite occurs in this at a number of points, but so far no large body has been found.

Hibernian.—The Hibernian is situated south of the Maid of Erin, close to the valley of the Klehina river. The showing consists of a mineralized band of limestones, bordered by altered argillites. It has been opened up by two parallel trenches 50 feet apart. The lower trench shows mineralization for a width of 60 feet. The limestones in this zone have been almost completely replaced by metallic and non-metallic secondary minerals, mostly pyrrhotite, chalcopyrite, sphalerite, and galena in a gangue of garnet, actinolite, quartz, and calcite. In the upper trench the mineralized zone has an exposed width of 20 feet.

The percentage of chalcopyrite and galena, the two minerals of possible economic value, is small in the sections exposed along the trenches.

Victoria.—The Victoria is situated near the edge of the plateau rising up towards Mineral mountain at an elevation of 2,600 feet above the sea. The main showing is exposed in two cross trenches about 60 feet apart and consists of a lens-shaped mass of secondary minerals, 22 feet wide at one point. This is made up of sphalerite, galena, and occasional grains of chalcopyrite enclosed in a gangue of garnet, tremolite, quartz, and calcite. A short tunnel driven from the sloping hillside toward the lens has not been carried far enough to prove the downward extension of the ore body. An assay of the ore furnished by the owners shows 19 per cent lead, 37 per cent zinc, and 4·8 ounces silver per ton. This represents selected ore.

Fairfield and Montana.—These claims are staked on a rounded knob known as Copper butte. The southern portion of the butte is built of crystalline limestone and the northern portion of altered argillites. Small bornite ore bodies have formed in places in the limestone at or near its contact with the argillites. Tunnels have been driven along the contact for considerable distances on both claims, but the development work failed to open up any ore bodies of workable size. The croppings on the hillside looked very promising, but the lenses lacked persistence.

Majestic.—The cropping on this claim is exposed in the steep eastern bank of a creek heading near Copper butte and consists of a lens of pyrrhotite about 8 feet wide. The lens occurs in a band of limestone and is cut by a diorite porphyry dyke. Grains of chalcopyrite occur scattered through the pyrrhotite.

Wonderful.—The Wonderful is situated on the southern slope of the Mineral Mountain plateau a short distance south of the Majestic. A band of crystalline limestone about 300 feet wide, bordered on both sides by altered argillites, occurs at this point. The showing consists of a pyrrhotite lens trending to the northeast along the western limestone-argillite contact. A tunnel has been driven along the contact for a distance of 135 feet. This pierced solid pyrrhotite for some distance then passed through lightly mineralized country to the face. The pyrrhotite carries some chalcopyrite but not enough to constitute copper ore.

Custer.—The limestone band which crosses the Wonderful extends in a northeasterly direction into the adjoining claim, the Custer, and through it into the Adams. On the Custer it is mineralized in places along both contacts with the enclosing altered argillites. An oxidized zone on the western contact about 15 feet wide, has been opened up by a small cut. Pyrrhotite, carrying a small percentage of chalcopyrite, is the principal mineral present. On the eastern contact the limestone is irregularly mineralized at one point for a width of 50 feet. The mineralized zone is cut by a dioritic dyke about 15 feet wide and contains numerous unreplaced cores of limestone. A short tunnel driven into it, shows at the face a 4-foot band made up mostly of sphalerite with some galena and chalcopyrite.

Adams.—On the Adams claim the limestone band has a width of about 300 feet. On the southeastern side it is bordered by an important mineralized zone traceable on the surface for over 400 feet. No work has been done on this except to trench across it at several points. Two hundred and fifty feet from the boundary line, the zone has an exposed width of 28 feet and, 150 feet farther on, of 19 feet. The principal metallic minerals present are sphalerite and galena. A general sample from the 19-foot cut, collected by the writer and assayed in the laboratory of the Mines Branch, yielded 11·57 per cent zinc and 7·57 per cent lead. It contained no gold or silver. A sample from the 28-foot cut would probably give about the same result.

The Adams mineralized zone is well worth some development work. At present even its surface extent is unknown and it may continue northeastward for a considerable distance beyond the portion opened up by the cross trenches.

A number of claims, including the Arizona, Chilcat, Crackerjack, etc., have been staked northeast from the Adams. The showings on those examined consisted mostly of pyrrhotite lenses carrying small quantities of chalcopyrite.

Guardsmen Group.—The Guardsmen group of claims is situated about 5 miles east of those in the vicinity of Copper butte. The principal rocks here are granite gneisses, holding a long narrow inclusion of limestone and altered argillite. The inclusion widens to the south and in its northern extension bends to the northeast, crosses the deep valley of Clayton creek, and continues across the mountains separating Clayton creek from Bear creek. It is exposed in the upper slopes of the valley, but not in the lower, and probably terminates in depth before the level of the valley floor is reached.

The inclusion shows some mineralization near its contact with the granite gneisses along the greater part of its course. Twelve claims have been staked on it, some on both sides of Clayton Creek valley. Very little work has been done on any of the claims, not enough to demonstrate workable values. Small veinlets of chalcocite have been found on the Canadian Verdi situated near the southern end of the tier of claims. The Mildred, north of the Canadian Verdi, has been explored by a short tunnel. Bunches of chalcopyrite occur near the end of the tunnel. The mineralized zone is wide at this point, but the average tenor in copper has not been ascertained. Some surface work has also been done on the Lucy and Eagle, north of Clayton creek. A wide zone, irregularly mineralized with iron and copper sulphides, crosses both claims. The sulphides exposed at the surface are all more or less oxidized, and average values can only be determined by long tunnels or bore-holes.

CONCLUSIONS.

The net result of the exploration so far done in the Rainy Hollow mineral district has been to disclose two very promising surface showings, the Maid of Erin and the Adams, and to prove the presence of copper and lead minerals in some quantity on a number of other claims. Development at present is practically at a standstill except for necessary assessment work, and has been for some years. The claim holders are hoping for a railway, but until more work is done and some of the ore bodies proved to persist, there is little inducement to build one. At present, supplies and machinery can be brought in over the wagon road, at a reasonable expense, and the cost of development work ought not to be unduly high.

SOUTH-CENTRAL GRAHAM ISLAND, B.C.

(*J. D. MacKenzie.*)

Introduction.

GENERAL STATEMENT AND ACKNOWLEDGMENTS.

During the field season of 1913 the writer was engaged in the detailed topographic and geologic mapping of a portion of south-central Graham island. Owing to the increasing demand for coal and coke on the Pacific coast, the known deposits of coal on Graham island are being actively prospected by several companies, and a particular object of the investigation now reported on, was to ascertain the extent, structure, and economic value of such coal basins as were already known to exist, or that might be discovered during the progress of the examination.

Field work was carried on for three months, from June 22 to September 20. The various openings on the coal seams were carefully examined, and the district from Skidegate inlet to Camp Wilson supposed to be underlain by Cretaceous rocks was mapped in detail. A short reconnaissance was made north of Yakoun lake and west of the Yakoun river.

Assistance and information has been afforded the writer by the Graham Island Collieries Co., the Graham Island Coal and Timber Syndicate, the British Pacific Coal Co., the B.C. Oil Fields, Ltd., and by many individuals resident on or interested in Graham island. Particular acknowledgments are due to Mr. W. Fleet Robertson, Provincial Mineralogist, and to Mr. J. H. Dawson, Surveyor General of British Columbia; to Mr. E. M. Sandilands, Government Agent at Queen Charlotte city, and to Mr. Milnor Roberts, Dean of the College of Mines, University of Washington.

As no reliable maps of the district to be investigated were at our disposal, all trails and the larger creeks were traversed with the telemeter and aneroid, tied in and checked by the township posts of the Provincial Land Surveys. The Admiralty chart of Skidegate inlet, No. 48, served excellently for the coast line of that portion of the area. Pace and compass surveys were made of all streams showing exposures of rocks, and the rare outcrops occurring outside of the streams were located either by telemeter or by pace and compass traverses. All traverses were plotted as they were completed, and an outcrop map was continually kept up to date.

The writer was very ably assisted by Messrs. S. E. Slipper and C. E. Cairnes.

LOCATION AND AREA.

Graham island, the largest of the Queen Charlotte group, is about 2,500 square miles in area, and, with the exception of North island, it is the northernmost of the group. The area covered by this season's work consists of a strip of varying width up to 11 miles, extending north from Skidegate inlet about 15 miles to a short distance beyond Camp Wilson, and containing about 100 square miles. The portions of this area underlain by coal measures were examined in detail, and outside of the coal basins sufficient work was done to determine the structure of the underlying rocks and the absence of coal measures with as much certainty as the outcrops would permit. Traverses were made up Hidden creek for about 5 miles from its junction with the Yakoun river, and up Spirit river (west branch Yakoun river) for about 6 miles from its mouth. In addition to the above work on Graham island, the numerous small islands in Skidegate inlet, and the north shore of Moresby island, from the Deena river to a mile east of Alliford bay, were also studied in detail.

Communication with Graham island may be had by direct weekly steamer from Victoria and Vancouver, or by weekly steamer from Prince Rupert.

From Queen Charlotte city a good horse trail leads west about 2½ miles to the mouth of the Honna river, from here a trail, passable for horses after long continued dry weather, runs up the Honna for 4 miles to the so-called Fourmile camp near the junction of Sadie creek (west branch Honna river). Here the trail forks, one branch going northwest over a very rough country, following a quite unnecessarily hilly route, for 5 miles, to Camp Robertson. The other branch runs almost due north for 5 miles to the Junction, where it is met by a trail coming northwest some 3 miles from Camp Robertson. The trail then continues north and northwesterly about 9 miles to Camp Wilson. From Camp Wilson a trail follows down Wilson creek about three-fourths of a mile to the Yakoun river. Another trail runs northeasterly about 2 miles to where it meets the skid road of the Graham Island Coal and Timber Syndicate, which follows a roundabout route, said to be about 30 miles long, to Queenstown, on Massett inlet. Shorter trails than this, however, are available for reaching Queenstown.

From Camp Robertson a trail leads west about 3 miles to Yakoun lake. Canoes on this lake serve for transportation to the opposite side, whence a trail leads to Rennel sound; and to the north end, from where a trail runs about 2 miles due north to Hidden creek, and continues due north from there about 2 miles to the edge of the valley of Ghost river, where it turns east for some 600 yards to the Yakoun river. There is also a trail for several miles up Hidden creek to some survey camps. Except the trail from the mouth of the Honna to Camp Robertson, none of them are passable for pack animals, and virtually continuous corduroying will be necessary to make them so.

Owing to the thick wet moss and dead vegetation covering the soil, these trails are seldom in good condition. Underbrush and weeds spring up rapidly, and the pathway is soon obscured. The soft and insecure footing, the roots, snags, and bogholes make rapid travelling an impossibility. The distance from Camp Wilson to the mouth of the Honna, for instance, about 18 miles by the trail, is seldom made under seven hours without packs, and packers carrying 40 to 50 pounds require two days to make the trip. These conditions make surveying or prospecting slow and costly.

The Yakoun river is navigable at most stages of water for canoes and light-draught boats, to a short distance below Camp Wilson. About a mile below Wilson creek a log jam obstructs the river, and about 2 miles above Wilson creek are two other large jams. Above here, however, the river is almost free from logs, and could readily be made navigable for poling boats in times of high water. There are no serious rapids between Yakoun lake and Masset inlet.

PREVIOUS WORK.

Previous work in parts of the district examined has been summarized by C. H. Clapp, in the Summary Report of the Geological Survey for 1912. Dr. Clapp's investigation, there reported on, was of a reconnaissance nature, and the information he gathered during his brief stay was of great value to the present writer.

Summary and Conclusions.

GENERAL GEOLOGY.

The oldest formations exposed on Graham island are a series of metamorphic, volcanic, and sedimentary rocks, which have been considerably deformed in general, and are often extremely contorted in detail. These rocks, which are of Jurassic and perhaps Triassic age, have been intruded by stocks of diorite and granodiorite, in areas not investigated by the present writer. Fossils are abundant in the metamorphosed sediments, and the rocks are correlated with the Vancouver group. The intrusive rocks probably are satellites of the great Coast Range batholith, supposed to be of upper Jurassic age.

On the rough, denuded surface of these older metamorphic and igneous rocks, a series of conglomerates, sandstones, and shales were laid down unconformably. These sediments are called the Queen Charlotte series, and in their lower portion contain a coal-bearing horizon. The date of their deposition is placed in the Upper Cretaceous. The surface on which they were deposited was hilly, and often very uneven in detail. The general topographic conditions surrounding the basin probably resembled to some extent those found in the vicinity of Skidegate inlet to-day.

After, and perhaps to some extent during, the deposition of the Queen Charlotte series, they were intruded by dykes and sills of volcanic rocks. These dykes and sills are up to 50 feet in thickness and occur abundantly in many localities. After the deformation and partial erosion of the Cretaceous rocks, extensive flows of volcanic rocks, probably coincident with the later phases of dyke and sill intrusion, covered part of the area now reported on. With these volcanics, which are presumably of Tertiary age, are intercalated sediments, seen only at one locality, the southeast slope of Mount Kahgan. Tertiary sediments occur in the northeastern part of Graham island, in places carrying lignite. The Tertiary volcanics have been removed from the larger portion of the area examined this year, and in fact it is uncertain as yet just how far they ever extended over it. Erosion and denudation have greatly affected the slightly resistant rocks of the Queen Charlotte series, which now lie in several basins separated by ridges of the pre-Cretaceous metamorphic and volcanic rocks.

During the Glacial period, the Queen Charlotte range was occupied by an ice-cap, from which valley glaciers flowed, scouring out the present fiords which are so characteristic a feature of the Queen Charlotte group. The large amount of glacial till in south-central Graham island indicates that piedmont glaciers at one time occupied this area, while the occasional deposits of well stratified sands, gravels, and clays show that there was considerable deposition in lakes or estuaries of glacial origin.

ECONOMIC GEOLOGY.

Coal.

Coal is the principal mineral resource of the area examined, but deposits of gold, clay, building stone, and, possibly, oil also occur. Coal occurs at one fairly well-defined horizon in the lowest member of the Queen Charlotte series, of Cretaceous age. This Cretaceous coal is found in two separate and well-defined basins, which may be termed the Honna basin and the Yakoun basin, each named from rivers that drain the area underlain by them.

The Honna basin in the southern part of the area, contains the exposures at Cowgitz, and Slate Chuck creek on Skidegate inlet; Camps Robertson and Anthracite in the interior; and Camp Trilby and another small opening near Yakoun lake. These are all different exposures of what is with little doubt the same horizon, repeated by folding. The exposures of the coal at Cowgitz, Slate Chuck, and Yakoun lake show it to have been locally metamorphosed into a substance in appearance like a high grade of anthracite. At Camps Robertson and Anthracite the seam is about 7 feet in thickness, but contains many shale and bone partings, so that the total coal does not exceed 4 feet. It is a bituminous coal, high in ash.

The Yakoun basin fringes the north side of the highlands between Camps Robertson and Wilson, which consist of pre-Cretaceous rocks, with at least one small basin of Lower Cretaceous measures. The extent of the Yakoun basin northward toward Masset inlet is at present unknown. Camp Wilson in section 25, township 7, is the only locality where coal has been found in the Yakoun basin. At this place three openings show a seam ranging from 4 to 18 feet in thickness, and containing up to 16 feet of coal. This coal is of bituminous quality, and samples carefully taken by the writer show it to be higher in ash than has heretofore been supposed. It is free-burning, the ash is very light, and it makes excellent coke.

Gold.

Gold is found on the Southeasterly claim, northeast of Skidegate Indian village. The deposit is a quartz vein averaging 9 feet thick, and is apparently a quartz replacement of a shear zone in breccias of the Yakoun volcanics. The metallic minerals with which the gold is associated are sulphides, and are irregularly distributed in masses through the quartz gangue.

Oil.

In some of the pre-Cretaceous rocks, oil showings, consisting of coatings of black sticky tar on joint seams, are found, and some oil lands have been taken up on the strength of these appearances.

General Character of District.

TOPOGRAPHY.

Regional.

The Queen Charlotte islands form a part of one of the outer, largely submerged ranges of the northwestern Cordillera, and are generally considered to be the northern continuation of the Vancouver range. The group is separated from the main land by Hecate strait, 30 miles wide at its northern end, and widening to 80 miles at the south. The islands form a slightly curved triangle, with its apex at the south, its length in a northwesterly direction being about 190 miles, and the width of its base, the northern coast of Graham island, being about 60 miles. The eastern side of Graham island is low and comparatively straight, but the southern islands of the group are high and rugged, with an irregular deeply indented fiord coast line. The southern islands are wholly in the Queen Charlotte range. They are separated from Graham island by Skidegate channel, a narrow fiord running east and west, widening in its eastern portion into Skidegate inlet.

Local.

Graham island may be divided into three topographic provinces, each well defined, but gradational into the adjoining ones. The Queen Charlotte range, forming the western mountainous portion of the island, may be taken as the first of these provinces. It consists of a series of rugged, often serrate peaks and ridges, with steep, sometimes glaciated slopes. A distinctive feature of the range is the cuesta-shaped peaks, especially prominent in the northern portion, and probably caused by gently northwestward dipping sheets of Tertiary volcanic rocks. The Queen Charlotte range is partly cut across by several of the west coast fiords, and also by the valleys of Yakoun lake, Canyon river, Hidden creek, and Spirit river. The northern portion of the range is lower, probably not exceeding 2,000 feet, and apparently nowhere on Graham island is the elevation greater than 4,000 feet.

The second division, termed the plateau province, adjoins the Queen Charlotte range on the east and northeast, and has a rather sharply gradational contact with it. This boundary runs from the mouth of Slate Chuck creek in an irregular, though generally northerly direction, through Stanley and Yakoun lakes to the southern expansion of Masset inlet. Its position north of here is at present unknown to the writer. The eastern boundary of the plateau province runs from Lawn hill, north of the entrance to Skidegate inlet, in a direction west of north, to Masset inlet, probably at the point where the inlet widens into the southern expansion. Eastward of this line, the country is low and flat, forming the third province, which may be termed the northeastern lowland. This plain has not been visited by the writer, but is described by Clapp[1] as being underlain by flat lying unconsolidated sediments, recently uplifted 100 to 200 feet above sea-level, and surmounted by a few, conspicuous flat topped mesas, composed of the younger volcanic rocks.

Most of the field work done during the past season lay in the plateau province. The name is given because this part of the island—in brief, the south central part—is characterized by a number of hills with a general accordance of summit level from 1,000 to 1,500 feet, some of them flat-topped ridges, others plateau-like. These higher lands are composed of the pre-Cretaceous rocks, or the more resistant of the Cretaceous rocks, while the valleys are underlain by the softer Cretaceous sediments. The Honna river flows due south in a rather narrow trench from 50 to 150 feet deep, in a much wider, shallow valley. Sadie creek, the western branch of the Honna, flows eastward from Lake Stanley, a small nearly filled glacial lake which, like Yakoun lake, lies on the boundary between the mountain and the plateau province. Skowkona creek, a large eastern branch of the Honna, cuts across the eastern highlands of the plateau province The headwaters of the main Honna are rather sluggish creeks which are separated from Yakoun River drainage by a rather low divide. The eastern boundary of the Honna valley is a ridge of pre-Cretaceous volcanic rocks, extending north from Skidegate inlet, where they form the 1,200-foot hills behind Queen Charlotte city, and which gradually rise, until east of Camp Wilson the hills are about 1,800 feet high. This ridge, about 9 miles from the inlet, widens towards the west, and forms the marked highlands extending to the Yakoun river, and separating the Honna coal basin from the Yakoun coal basin. In the vicinity of Camp Robertson, hills to 1,000 feet high are formed of massive sandstones of the upper Haida member of the Queen Charlotte series, and south of here Conglomerate peak, about 2,000 feet high, is capped by Cretaceous conglomerate. From Camp Robertson the hills rapidly drop away westward into the valleys of Etheline creek, Baddeck river, and Yakoun lake, and north and eastward into the wide valley of Survey creek.

Between the Honna geologic and topographic basin, and the lowland underlain by the Cretaceous rocks of the Yakoun basin (this lowland extending to Masset inlet, and merging into the great northeastern lowland) is a distinct highland of pre-Cretaceous rocks. These highlands begin north of Survey creek, and extend from here northeastward around Sue lake, which has an elevation of 500 feet, thence swinging east and south, joining the highlands east of the Honna. The highlands extend northward and northwestward to the valley of Wilson creek, which in its upper part flows steeply from their northwestern slopes. The monadnock east of Camp Wilson, referred to by Clapp,[2] is the culmination of these highlands which have here been shown to form a virtually continuous range from Skidegate inlet to this vicinity.

[1] Clapp, C. H. Sum. Rept. Geol. Surv., Can., 1912, p. 17.

[2] Clapp, C. H. Sum. Rept. Geol. Surv., Can., 1912, p. 17.

The Yakoun river, draining Yakoun lake and flowing into Masset inlet, maintains a direct northerly course for 7 or 8 miles from the lake, where it swings northeasterly, and has not been surveyed by us beyond this point. It flows in a deep valley of varying width, and its upper reaches, in the vicinity of Yakoun lake, have been modified by glacial action. The river has cut its valley across several low ridges of Cretaceous sandstone and older rocks, and on it are occasional small gorges with banks in one case up to 50 feet high.

CLIMATE.

The climate of Graham island is on the whole rather constant, in that extremes of heat and cold are seldom or never experienced. Like many localities on the north Pacific coast, places only a few miles apart may vary considerably in the amounts of sunshine and rain that they receive. The south-central part of the island has a cool summer season with considerable rain, but abundant fine weather as well. The climate of the northeast lowland is said on good authority to be warmer and with a higher percentage of fine clear weather than in the interior, while the climate of the west coast is said to be not so agreeable. The winters are reported to be mild, and several residents of Queen Charlotte city stated that overcoats were seldom worn.

VEGETATION.

Graham island, except for the higher and more rugged peaks, is covered with a heavy growth of timber. The equable and moist climate is conducive to a rapid growth of vegetation, and many of the lower areas are choked with huckleberry, salmonberry, devils club, and other rank growths. Salal does not grow abundantly except up the east coast, and on some parts of the west coast. The underbrush, though unquestionably difficult to traverse, is not the "impenetrable jungle" that it has been described. On the uplands, the woods are often remarkably free from thickets of underbrush, the usual growth being the high-bush huckleberry. What does cause difficulty and delay in travelling, even on the trails, is the thick covering of decayed moss, and the very uneven, hummocky nature of the ground, due to the growth, fall, and decay in situ of many generations of trees. Forest fires of any magnitude are unknown, and the whole surface is covered, even on steep slopes, with a thick mat of moss and decayed vegetation.

The principal forest tree is hemlock, followed by cedar (yellow and red), spruce, alder, yew, mountain hemlock, and jack pine, the latter two growing on the higher hills.

COMMERCIAL POSSIBILITIES.

Coal, at the present time, is the chief asset of Graham island. Timber is of value, but probably can not yet enter the market except with the aid and development that an operating coal mine would bring. Large quantities of clays exist suitable for the lower grades of clay products, such as bricks, drain tile, and earthenware, and it is possible that clays of higher grade may be discovered. Oil is as yet an unproven resource.

In regard to agriculture, much has been written, unfortunately not always of a responsible nature. Graham island, in common with much of the Canadian west, has suffered at the hands of unscrupulous real estate boomers, whose misrepresentations have a tendency to bring the island into disrepute as a farming centre. There are, in the northeastern portion of the island, large areas of level or gently sloping land which are underlain by partially consolidated sands and gravels of Pleistocene or Tertiary age. Parts of this area support a dense forest growth, and the rest is covered with a surface deposit of decayed vegetation soaked with water, termed muskeg. There seems no good reason why, once this area is cleared and drained, it should not support agriculture on a considerable scale. It may be that local conditions will have to be carefully studied and crops suited to the environment selected, but the facts remain, that the land and the climate are there ready to be utilized. It is not probable that agriculture will flourish in the plateau and mountain regions for some time to come.

General Geology.

Table of Formations.

Pleistocene and Recent	Superficial deposits.
Upper Miocene or Pliocene and probably Eocene	Etheline volcanics (with intercalated sediments).
Cretaceous	Queen Charlotte series.
	Skidegate sandstones and shales.
	Honna conglomerate and sandstone.
	Haida sandstones and shales.
Upper Jurassic (?)	Batholithic (?) intrusives.
Jurassic-Triassic	Vancouver group.
	Yakoun volcanics (Middle Jurassic).
	Maude argillites (Lower Jurassic-Triassic [?]).

DESCRIPTION OF FORMATIONS.

Vancouver Group.

The Vancouver group consists of a series of metamorphic sedimentary and altered volcanic rocks of Jurassic and perhaps Triassic age.[1] Fossils from these rocks on Graham island have been studied by Dr. T. W. Stanton, and their age is stated on the basis of his determinations.

Maude Argillites.—Forming the lower member of the Vancouver group on Graham island, and in the vicinity of Skidegate inlet, are fine-grained, remarkably well-stratified and banded rocks named the Maude argillites, from their typical occurrence on the south shore of Maude island, in Skidegate inlet. These rocks are similar to, but less metamorphosed than, some members of the Sicker series[2] of Vancouver island.

Beside the type locality on Maude island, outcrops of the argillites are occasionally found over a strip of country several miles wide, running northwest from Skidegate inlet.

The lowest of the Maude argillites exposed are dark coloured, very fine-grained rocks, remarkable for their excellent ribbon-like banding. These rocks are often carbonaceous, and in places they split in paper-thin sheets, these thin layers often being characterized by abundant flattened ammonites. Most of the layers give off a foetid odour when struck or rubbed, and it is not uncommon to find films of tar on the joints and bedding planes. As one approaches the top of the formation, the rocks become coarser and thicker bedded, and calcareous layers are not uncommon. These coarser sandstones and quartzites gradually and unmistakably pass into the tufaceous sandstones of the lower Yakoun volcanics.

[1] Dawson, G. M. Rept. Geol. Surv., Can., 1886, p. 10 B.
Clapp, C. H. Memoir No. 13, Geol Surv., Can., p. 44.

[2] Clapp, C. H. Memoir Geol. Surv., Can., No. 13, 1912, p. 71.

The Maude argillites, originally a well-laminated series of argillaceous feldspathic shales and sandstones, have been strongly regionally metamorphosed, so that they now present a series of refractory slaty argillites and quartzites. In places, and usually over rather narrow areas which seem to have been the loci of relief of stress, they are highly mashed, folded, contorted, and faulted, while in other places they are apparently only slightly disturbed. They are strongly jointed, and often seamed with ramifying lenticular veins of calcite, and, more rarely, quartz.

It has been stated above that these rocks grade into the overlying Yakoun volcanics. This relationship is well seen on the south shore of Maude island, and also in Moresby island, west of Alliford bay. In both these places the conformable change from argillaceous through arenaceous (and in part calcareous) to tufaceous sediments is distinct as far as structural relations show. Fossil evidence agrees with this conclusion.

Yakoun Volcanics.—The upper member of the Vancouver group is a series of metamorphosed, largely pyroclastic rocks, called the Yakoun volcanics, taking the name from Yakoun lake.

The Yakoun volcanics are well exposed in many localities around Skidegate inlet, and form the larger part of the highlands east of the Honna, and between Camp Robertson and Camp Wilson. They are also typically exposed in the vicinity of Yakoun lake.

These rocks are dominantly tuffs and agglomerates, with a few intercalated flows or sills, and probably some dykes. Conglomerates are also found interbedded with the more angular types of sediment. Many of the beds, especially in the lower portion, are well sorted and stratified, others are very heterogeneous breccias with angular fragments of all shapes and sizes up to several feet in an uneven-grained matrix. The rocks are usually dark coloured, purplish or greenish, and the texture is sometimes not at once apparent owing to the similarity between the matrix and the fragments. The magmas from which the pyroclastics were derived were evidently basic, basalts, or andesites. Secondary minerals as chlorite, serpentine, calcite, epidote, etc., are common. Pyrite is universally present in small amounts, and some of the shear zones have been more extensively mineralized, as is the case at the Southeasterly claim, northeast of Skidegate Indian village. The Yakoun volcanics are metamorphosed and indurated, and are broken by innumerable joint planes and shear zones. They lie gradationally conformably on the Maude argillites, and are unconformably overlain by the Queen Charlotte series.

The structure of the Vancouver group as a whole is that of a broad anticline, doubtless complicated by minor folds. The axis of the anticline strikes about N. 30° W. from Skidegate inlet, passing east of Yakoun lake.

The fossils collected from the rocks of the Vancouver group, as determined by Dr. T. W. Stanton, are as follows:—

Yakoun Volcanics.

Brachiopods.—

Rhynchonella? sp.
Terebratula skidegatensis Whiteaves?

Pelecypods.—

Pecten? sp.
Nemodon? sp.
Thracia? sp.
Pholodomya? sp.

Avicula? sp.
Ostrea? sp.
Lima, sp. cf. *L. gigantea* (Sowerby).
Trigonia sp. cf. *T. dawsoni* Whiteaves.
Pleuromya lævigtata Whiteaves.
Pleuromya carlottensis Whiteaves.
Thracia semiplanata Whiteaves.

Cephalopods.—

Stephanoceras sp. a.
Stephanoceras sp. b.

Maude Argillites.

Brachiopods.—

Rhynchonella maudensis Whiteaves?
Rhynchonella? sp.
Discina semipolita Whiteaves.

Pelecypods.—

Pecten carlottensis Whiteaves.
Avicula, sp. cf. *A. Whiteavesi* Stanton.
Cardium tumidulum Whiteaves.
Ostrea? sp.

Gastropods.—

Several genera, undetermined.

Cephalopods.—

Schloenbachia propinqua Whiteaves?
Arniotites? sp.
Liparoceras? sp.
Harpoceras? sp.

Batholithic (?) Intrusives.

At several localities along South bay, on the north shore of Moresby island, and on South island, is found a greenish to greyish medium even-grained rock, considerably altered, which the microscope shows to be a coarse diabase. This diabase is intrusive into the Maude argillites and perhaps is to be correlated with some facies of the Coast Range batholith, generally supposed to be of upper Jurassic age. North-east of the area examined are said to be considerable areas of granodiorite, probably also intrusive into the Vancouver group.

Queen Charlotte Series.

The Queen Charlotte series consists of unmetamorphosed sediments lying unconformably on the rocks of the Vancouver group. The lowest member of the series contains coal, at what is thought to be a single horizon. Since the time of Dawson's[1] examination of Skidegate inlet, there has been some confusion of the relative ages of the pre-Cretaceous and Cretaceous rocks; due probably, as Dowling[2] suggested,

[1] Dawson, G. M. Rept. of Progress: Geol. Surv., Can., 1878-79.
[2] Dowling, D. B. Bull. Geol. Soc. America, No. 17, 1906, pp. 298-299.

to the fact that the fossils on which the determinations are based are from both of these formations. Clapp[1] gives a more detailed account of the difficulty, so it need not be gone into here.

The Queen Charlotte series has been subdivided on lithologic grounds into three members, as given in the table of formations. Clapp[2] considered that there was a fourth, the Image basal conglomerate, but more detailed work has shown that what he supposed was basal Cretaceous is more probably conglomerate members of the Yakoun volcanics.

Haida Formation.—The Haida formation is the lowest member of the Queen Charlotte series, and contains the coal horizon. It is also the thickest, and most extensive areally of the Cretaceous sediments. The Haida formation outcrops on most of the islands of Skidegate inlet, and extends along the shore of Bearskin bay from Haida point to the Narrows. It also occurs on the western limb of the syncline into which the Queen Charlotte series is folded, at Shoal bay, and other points in the western part of Skidegate inlet. Inland, the Haida formation underlies the Honna valley, and most of the country between the headwaters of the Honna on the east, Yakoun lake on the west, and from the hills south of Camp Robertson to the highlands north of Cascade creek. This formation also occurs in several smaller synclines between the Honna and the Yakoun basins. The Yakoun basin, containing the coal seam at Camp Wilson, is a narrow area in the valley of Wilson creek lying between highlands of pre-Cretaceous rocks, and widening to the north and northeast. Its extent in this direction is unknown, but it may underlie the country as far as Masset inlet.

Lithologically the Haida formation is largely composed of sandstones and shales, the proportion varying in different districts. In general, the rocks are coarser near the base, angular grits and arkoses predominating. In the vicinity of Skidegate inlet, the formation as a whole is fine-grained, well laminated, and highly fossiliferous. Sandy shales are the characteristic rock here, of a distinctly green colour, though yellowish and greyish rocks are found. Concretions, and calcareous and siliceous bands are common. On Maude and Lina islands, there are very thick massive beds of fine green sandstone in the upper two-thirds of the formation. About Camp Robertson the rocks are on the whole coarser, and here are divisible into two well-marked members, a division which is not so distinct around Skidegate inlet. The lower member is variable in its character, consisting of rapidly alternating bands of sandstones, shales, and coarse, angular greenish grits. The upper portion of this lower member is finer, characterized by grey shales, and it is here, about 2,500 feet above the base, that the coal seam at Camp Robertson is found. The upper Haida is almost wholly composed of fine, even-grained, strikingly homogeneous, thinly-laminated, grey and greenish grey sandstones, with occasional thin interbeds of shales or grits. In the vicinity of Camp Wilson the beds are coarser and characterized near the base by arkosic tufaceous rocks, greatly resembling, and difficult to separate from, the underlying Yakoun volcanics.

In thickness, the Haida formation varies. At Skidegate inlet, it is from 2,000 to 3,500 or 4,000 feet, while near Camp Robertson it is not far short of 5,500 feet. Here, the lower member is from 2,500 to 3,000 feet thick, and the upper massive sandstones are about 2,300 feet. The coal seam here occurs about 200 feet below the base of the upper massive sandstones.

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[1]Clapp, C. H. Sum. Rept. Geol. Surv., Can., 1912, pp. 20-25.
[2]Clapp, C. H. Sum. Rept. Geol. Surv., Can., 1912, p. 21.

Honna Formation.—The Honna formation, largely composed of conglomerate, is conformable on the Haida formation, and outcrops on Maude island, Nose point, and many of the islets in Waterfowl bay. It also is exposed in a horseshoe-shaped ridge, the eastern leg of which runs north from the Narrows, parallel to the Honna river and west of it, and, swinging westward north of Sadie creek, caps the high hills east of Mount Etheline and south of Camp Robertson. The western outcrop of the horseshoe-shaped syncline is largely covered by Tertiary volcanics, but is exposed on the shore from the mouth of the Slate Chuck to Steep point.

The Honna formation consists of two bands of conglomerate, one at the base, the other at the top, separated by coarse, cross-bedded sandstones and some grey shales. The conglomerates are well bedded, the pebbles are excellently rounded, and form 30 to 60 per cent of the rock. They range in size up to 3 feet in diameter at the base, but average much less, and many beds do not contain a pebble over 1 inch in diameter. The materials of the pebbles are various, consisting of diorites, granodiorite and other plutonic rocks, quartzites, argillites and slates, cherts, quartz, and rarely pebbles of the Yakoun volcanics. The Honna conglomerate has a sharply gradational contact with the underlying Haida sandstones where exposed at the Narrows, and the contact with the overlying Skidegate sandstones is also rather abrupt. The thickness of the Honna conglomerate is about 2,000 feet.

Skidegate Formation.—Conformable on the Honna conglomerate, is the Skidegate formation, almost altogether made up of shales and sandstones. The Skidegate formation is exposed along the north shore of Skidegate inlet; also on Nose point. Northward these rocks underlie the district between Skidegate inlet and the conglomerate hills south of Camp Robertson, and are partly concealed by the overlying Tertiary volcanics.

The rocks are very largely fine grey to black slightly carbonaceous shales, with thin interbeds of sandstone, and siliceous, ferruginous, and calcareous concretions. These concretionary beds weather to a light buff colour, and stand out in relief above the softer shales. Fossils are occasionally found in the Skidegate beds. The top of the formation is not exposed, but the visible thickness is about 2,000 feet.

Structure of the Queen Charlotte Series.—Under preceding headings it has been brought out that the sediments of the Queen Charlotte series occur as separated synclinal basins over a large area in south-central Graham island. It seems reasonable to suppose that these now separate basins were formerly part of a small geosyncline of Cretaceous sediments, occupying the area in central Graham island between Skidegate and Masset inlets, and perhaps having an even wider extension.

The surface on which the Queen Charlotte series was deposited, as evidenced by the variable thickness of the Haida member, was one of considerable relief, and it is possible that some of the present highlands of pre-Cretaceous rocks remained out of water during the depositional period, as suggested by Clapp.[1] However, owing to the frequency with which small basins of Cretaceous rocks dot the pre-Cretaceous hills, and on account of the large amount of erosion which has taken place, it seems more probable to the writer that the area was wholly submerged during the later period of deposition at least. Post-Cretaceous folding has elevated this area and denudation has stripped much of the sedimentary veneer from the pre-Cretaceous basement, leaving the Queen Charlotte series in the now localized basins. The structure of these basins can best be discussed individually.

The structure of the smaller basins may here be dismissed by saying that they are of no great thickness, none of them probably containing the coal horizon, and they are of a general synclinal form.

[1] Clapp, C. H. Summ. Rept., Geol. Surv., Can., 1912, p. 24.

The Honna-Skidegate Inlet basin is the largest and most complicated of the synclines. It is roughly pear-shaped, with a north-south axis of 12 to 13 miles, and an east-west axis at Skidegate inlet of about 10 miles, narrowing at Camp Robertson to about 5 miles. This syncline is complicated by numerous minor folds, such as those southeast of Yakoun lake, and at Camp Robertson. Many minor twists and contortions occur, as is to be expected in the somewhat severe folding of softer sediments between ridges of resistant rocks.

Faulting is not pronounced. The largest fault detected is one which runs from the mouth of Long arm, a little north of east, through Anchor cove to the Narrows. A smaller fault runs nearly north and south through the channel between Nose point and Maude and South islands, while the Haida formation is brought sharply against the Maude argillites on the southeast end of South island by another nearly east-west fault. Minor overthrust faults are not uncommon, and one of these repeats the coal seam in the tunnel at Camp Robertson. The coal seams at Cowgitz are also doubtless affected by faulting.

The Yakoun basin has a general synclinal form, pitching and widening to the north and probably to the east. It lies in the depression between the highlands east and southwest of Camp Wilson, and the basal beds fringe these hills. It is complicated by minor folds, and the coal seam at Camp Wilson is broken by several small slips, only one of which deserves to be termed a fault.

Intrusive into the Queen Charlotte series, especially into the lower Haida member, are numerous dykes and sills doubtless largely of Tertiary age. These bodies range up to 50 feet in thickness, and cut the sediments in all directions. Some of them have been faulted, and the intrusive period probably covered a long interval.

Correlation of the Queen Charlotte Series.—It has been already mentioned that there has been some doubt regarding the age and relationship of the Queen Charlotte series, owing to the uncertainty in respect to some of the fossils previously collected from this vicinity. Full collections were made during the work now reported on, and have been examined by Dr. T. W. Stanton. He states that there are a few very imperfectly-preserved specimens or single species that may be Jurassic, but most of the fossils are certainly Cretaceous and, judging from European standards, not older than Gault. The single species said to be probably of Jurassic age was not found in place, though in an area underlain by sediments of the lower Haida formation. The occurence of the Inoceramus, closely resembling if not identical with *I. labiatus* Schlotheim, is said by Doctor Stanton to suggest a higher horizon, represented by the Benton shale of the Rocky mountains and the Turonian of Europe.

It is perhaps worth while to indicate the relation between the various formations of Skidegate inlet as now determined on structural and fossil evidence, and as Dawson determined them.

Present subdivision.		Dawson's subdivision.[1]	
Skidegate formation. Honna " Haida "	Upper Cretaceous.	Cretaceous.	A. Upper shales and sandstones. B. Coarse conglomerates. C. Lower shales. D. Agglomerates. E. Lower sandstones.
Unconformity.			
Yakoun volcanics.	Middle Jurassic.		
Maude argillites.	Lower Jurassic.		

[1]Dawson, G.M. Rept. of Progress, Geol. Surv., Can., 1878-79, pp. 63 B-64 B.

The fossils of the Queen Charlotte series, determined by Dr. T. W. Stanton, follow:—

Skidegate Formation.

Pelecypods.—

Inoceramus sp. cf. *I. labiatus* Schlotheim.
(From the uppermost beds exposed.)

Honna Formation.

Pelecypods.—

Inoceramus sp. cf. *I. labiatus* Schlotheim.

Haida Formation.

Plants.—

Fern pinnule.

Echinoids.—

Spines with imprint of fragment of test.

Brachiopods.—

Rhynchonella? sp.

Pelecypods.—

Trigonia diversicostata Whiteaves?
Trigonia maudensis Whiteaves?
Cytherea subtrigona Whiteaves.
Thetis affinis Whiteaves.
Inoceramus sulcatus Parkinson.
Inoceramus moresbyensis Whiteaves.
Inoceramus sp. cf. *I. quatsinoensis* Whiteaves.
Inoceramus sp. cf. *labiatus* Schlotheim.
Anomia linensis Whiteaves.
Pecten (Entolium) lenticularis Whiteaves?
Tellina skidegatensis Whiteaves.
Nucula (Acila) turncata Gabb?
Thracia? sp.
Nemodon sp.
Pecten sp.
Cucullœa sp.
Nucula sp.
Trigonia sp.
Cyprina sp.
Teredo? sp.
Corbula? sp.
Astarte? sp.
Pleuromya? sp.
Cytherea? sp.
Undetermined pelecypods.

Gastropods.—

Amauropsis tenuistriata Whiteaves.
Undetermined gastropod.

Cephalopods.—

Desmoceras (*Puzozia*) *planulatum?* Sowerby, as identified by Whiteaves.
Desmoceras (*Puzozia*) *perezianum* Whiteaves.
Lytoceras (*Tetragonites*) *timotheanum* (Mayer).
Lytoceras sacya (Forbes).
Perislhinctes skidegatensis Whiteaves?
Desmoceras sp.
Belemnites sp.
Undetermined ammonites, one possibly *Prionatropis.*

Etheline Volcanics.

The Etheline volcanics consist of dykes, sills, and flows, the two former intrusive into, and the latter unconformably overlying all the formations hertofore described. In the area studied this year, the flows are found on the summit of Mounts Etheline and Genevieve. and forming an extensive volcanic cap in the area occupied by the Slate Chuck range, extending from the vicinity of Skidegate inlet to Yakoun lake. They were also found about 4 miles up Hidden creek, again overlying the Cretaceous rocks.

The volcanics of the flow type are usually dark bluish or greenish grey, dense to finely crystalline, fresh looking rocks. Columnar structures, flow breccias, flow lines, and amygdaloids are frequently found, and most of the formation consists of effusive types. Under the microscope the flows are seen to be basalts. Accompanying these effusive types are many dykes and sills, in some instances basalt, but usually dacite or andesite porphyrite. These dykes acted in part at least, as feeders for the effusive volcanics.

Interbedded with the volcanics have been found some beds of bright red argillaceous sediments, well stratified, and perhaps representing local lake beds. These do not appear to be of very great extent.

The Etheline volcanics were intruded and erupted during a considerable interval, probably beginning during the deformation of the Queen Charlotte series. Clapp[1] considers some of the basalts of northern Graham island to be virtually contemporaneous with the Tertiary sediments, and hence late Miocene or Pliocene or younger.

Superficial Deposits.

Pleistocene.—Deposits of the Glacial period are frequently exposed in the area examined, and are probably widely distributed over Graham island. Two types have been distinguished, the till, and the stratified clays, sands, and gravels. No attempt was made to map the relative distribution of these deposits.

Recent.—Virtually the whole surface of the south-central part of the island is covered with a layer of decayed moss and other vegetation. In poorly-drained areas, as on some of the plateaus and flat-topped ridges, this decayed organic matter becomes saturated with water and accumulates to form the open meadows or muskegs, so characteristic of the country. These water-soaked muskegs are frequently found on slopes as high as 10 degrees.

Economic Geology.

Coal is the principal economic resource of the district examined. Besides coal, gold, clay, building stone, and limestone occur, and possibly oil.

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[1] Clapp, C. H. Summ. Rept., Geol. Surv., Can., 1912, p. 25.

COAL.

Coal is found at a single horizon in the Haida formation of the Queen Charlotte series, of Lower Cretaceous age. The coal-bearing horizon is at a variable distance up to 2,500 feet above the base of the formation. In the vicinity of Camp Robertson, a good horizon marker is the base of a massive band of sandstone composing the upper Haida, about 200 feet below which the coal seam occurs. At Cowgitz the coal apparently rests on the Yakoun volcanics, but here it is almost certainly faulted, and at Slate Chuck creek, a short distance northeast, a considerable thickness of shales intervenes between the coal and the underlying volcanic rocks. The coal has been exposed at several localities, and the seams show considerable variation, due probably to original differences of deposition as well as to later changes.

The openings examined this year are at Cowgitz, Slate Chuck creek, Camp Robertson, Camp Anthracite, southeast of Yakoun lake, and at Camp Wilson. Of these, all, excepting probably the last, are different outcroppings of the same seam or of different seams at the same horizon. So far as the surface exposures give evidence, there is on Graham island just one horizon in the Cretaceous at which favourable conditions for coal formation occurred, although it is not impossible that others may be found.

Cowgitz and Vicinity.—Coal was discovered at Cowgitz, near the headwaters of Hooper creek, in 1859, and in 1865 a company was formed in Victoria to exploit the deposit. A description of the workings has been given by Richardson[1] and Dawson[2]. The workings are at present wholly caved and covered up by undergrowth, so that little is to be learned at this locality. It is evident, however, that the coal is near the underlying volcanics, and this is probably due to faulting, as nowhere else has the coal been found near the base of the measures. The seams at this place are said to be vertical, and the rocks disturbed. The coal is lenticular in its occurrence, and Dawson concludes that only one seam exists, repeated by folding or faulting. The more extensive field work of the present season supports this conclusion. The greatest thickness observed was 6 feet, and this seam contained "two veins of pure coal, averaging 3 feet, and 1 foot 3 inches in thickness respectively, but separated by a shaly midrib of about 6 inches."

Specimens seen on the old dumps give the appearance of a bright semi-anthracite, and are apparently quite unaffected by their forty years' exposure to the atmosphere.

On King creek, about a quarter of a mile northeast of the openings on Hooper creek, a coal seam was found this summer. The seam is at least 5 feet thick, though not wholly exposed, and is fairly clean. The coal is anthracitic in appearance, quite like that at the other workings, and there is little doubt that it is the continuation of the same seam. The dip is high, and the apparent roof is a black shale. This outcrop is directly on the line of strike between Cowgitz and the openings on Slate Chuck creek. Outcrops of black shale farther up the creek show that the seam here is at least 500 feet above the base of the measures, and on Coal creek, farther north, the distance is still greater.

Slate Chuck Creek.—In the Slate Chuck valley, two exposures of the coal horizon have been prospected. On Coal creek, a small tributary of Slate Chuck creek from the west, the coal is exposed in the stream bed about half a mile above the junction of the creeks. Here an adit across the measures has been driven for a distance of 757 feet by the British Pacific Coal Company. This adit cuts three coal seams which, according to Clapp[3] are involved in several small folds. This adit was not

[1] Richardson, James. Rept. of Progress, Geol. Surv., Can., 1878-79, pp. 57-60.

[2] Dawson, G. M. Rept. of Progress, Geol. Surv., Can., 1878-79, pp. 71 B-77 B.

[3] Clapp, C. H. Summ. Rept., Geol. Surv., Can., 1912, p. 30.

entered by the present writer on account of its gassy condition. Descriptions and analyses of the coal are given in Clapp's report.[1] About three-quarters of a mile northwest of this locality the coal is again exposed in a small prospect adit on the right bank of Slate Chuck creek. Here a seam, said to be 6 feet thick, was found. The coal on the dump is similar in appearance to that at the adit on Coal creek.

Specimens on the dump at Coal creek show the coal to be a brilliant, hard, rather heavy substance, greatly resembling high grade anthracite in appearance. It occurs in streaks and lenticles in a soft black carbonaceous shale. Analyses of the material resemble those of a semi-anthracite, high in ash and water. The cause for its anthracitic nature is thought to be due in part at least to some metamorphosing action of the Etheline volcanics, dykes and sills of which are found cutting the coal seams, and thick flows are at no great distance even at the present time.

Analyses of Coal from Cowgitz and Slate Chuck Valley.

—	1	2	3	4	5	6	7	8	9	10	11
Water	1·60	1·89	3·61(*a*)	6·68	6·85	6·69	6·60	6·45	6·75	6·77	2·3
Volatile matter	5·02	4·77	8·14	6·2[illegible]	5·43	6·59	3·95	4·15	4·25	4·23	3·8
Fixed carbon	83 09	85·76	74·09	68·49	66·32	57 23	68·17	63 60	65·50	35·48	90·8
Ash	8·76	6·69	14·16	18·55	21·40	29·49	21·28	25 80	23·50	3·52	3·1
Sulphur	1·53	0·89	......	......	0·20	0·30	0·43	0·45	0·34	0·42	......
	100·00	100·00	100·00	100·00	100·20	100·30	100·43	100·45	100·34	100·42	100·0
Coke	Noncoherent		88·25	87·04	87·72	86·72					

(*a*) Loss at 105°C.

1. Six-foot seam at Cowitz.
2. Two-foot five-inch seam at Cowgitz. Collector, J. Richardson; analyst, B. J. Harrington, Geol. Surv., Can., Rept. of Progress, 1872-73, p. 81.
3. Five-foot seam on King creek. Collector, J. D. MacKenzie; analyst, F. G. Wait, Mines Branch.

4, 5, and 6. Tunnel, British Pacific Coal Co., Coal creek. Collector, C. H. Clapp; analyst, F. G. Wait, Geol. Surv., Can., Summ. Rept, 1912, p. 31.

4. Coal from A seam.
5. " " B "
6. " " C "

7, 8, 9, and 10. Different benches from B seam, tunnel of British Pacific Coal Co. Collector, Alexander Faulds; analyst, Noble E. Perrie, Geol. Surv., Can., Summ. Rept., 1912, p. 31.

11. Picked sample, best clean bright coal, British Pacific Coal Co., tunnel. Collector, J. D. MacKenzie; analyst, Edgar Stansfield, Mines Branch.

Yakoun Lake.—Two openings on coal seams have been made near Yakoun lake, one less than a quarter of a mile from the southeast corner of the lake, the other, Camp Trilby, nearly 2 miles southeast of this. The first is on the southwest limb of a narrow syncline striking about N. 25° W., and the second is on the northeast limb. Both seams dip at high angles. At the locality nearer the lake, an adit has been driven S. 60° E. for 50 feet across the measures. Exposed in this opening are several thin seams of coaly material, none seen over 3 inches thick. Appearances here resemble the exposures at Slate Chuck, but the coal is coked, rather than changed to anthracitic material. It is very light, and often shows columnar structures, the individual columns being arranged perpendicular to the bedding, and often no larger than the lead in a pencil. Mr. Slipper, who visited Camp Trilby, states that the occurrence there is similar to that just described.

[1] Loc. cit.

There appears little doubt that these Yakoun Lake exposures are a continuation of the horizon found near Skidegate inlet, and that in both cases later volcanic rocks have changed the character of the seams.

Camp Robertson.—A large amount of prospecting work has been done at Camp Robertson since 1892, when these outcrops first attracted attention, and a number of shafts and other openings have been made. Through the co-operation of Dean Milnor Roberts, who was examining the property here and at Camp Wilson, at the time of the writer's visit, opportunity was given to make a thorough study of the various exposures of the coal.

Robertson creek, on which the coal was discovered and opened, flows along the axis of a small anticlinal fold. Minor wrinkles and small faults further complicate the locality, so it has generally been supposed that there are two coal seams at this camp. This is not the case. There is one seam, but it is folded and faulted, so that previous investigators have been misled.

The outcrop of this seam has been traced along the eastern limb of the anticline for a distance of about 1,500 feet south from the most northerly opening. At this most southerly exposure, the so-called Nutter mine, it is not certain that the same seam as farther north has been encountered, as only thin coaly streaks are found in place, though a large amount of blossom occurs. East of Camp Robertson, the rocks are folded in a narrow canoe-shaped syncline, with a north-south axis probably about a mile in length, the width probably not exceeding 300 yards east and west. Westward, however, the coal seam, though not certainly exposed in this immediate vicinity, underlies a large extent of country, between Camps Robertson, Anthracite, Mount Etheline, and the Baddeck river, and judging from surface exposures, is lying rather flat or is gently rolling. In much of this area, the depth of the seam probably does not exceed 1,500 feet, and a considerable portion of it is not deeper than 1,000 feet.

The coal seam itself at Camp Robertson has a maximum thickness of 8 feet 9¾ inches, and the greatest amount of coal found is 3 feet 10½ inches. This occurs in several different bands up to 25 inches thick, varying somewhat in their character, and separated by thin bands of shale and bone. The coal resembles the bituminous variety, and is hard, dense, and rather heavy. This seam was carefully sampled and the results of the analyses follow, as well as other available analyses:—

Analyses of Coals from Camp Robertson.

—	1	2	3	4	5	6	7	8	9	10	11	12
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)			
Water...........	1·28	0·30	2·12	0·64	1·76	0·42	1·61	0·47	1·09	0·80	1·33	1·20
Volatile matter....	25·99	27·73	24·60	26·27	29·66	27·29	24·19	25·81	13·92	23·27	35·25	29·13
Fixed carbon......	52·58	52·18	38·56	44·44	41·12	46·09	43·85	45·53	41·83	51·39	42·57	47·52
Ash	20·15	19·82	34·72	28·65	27·46	26·20	30·35	28·29	43·16	24·54	20·85	22·15
Sulphur..........	......	0·88	......	0·92	....	0·50	....	0·54	0·54	......	......	....
	100·00	100·91	100·00	100·92	100·00	100·50	100·00	100·64	100·54	100·00	100·00	100·00
Coke	72·73 coherent but tender	......	73·28 firm	......	68·58 coherent	......	74·20 coherent					

(a) Loss at 105°C. *(b)* Air dried.

1. Lowermost 7½ inches from drift from No. 1 shaft. Collector, J. D. MacKenzie; analyst, F. G. Wait, Mines Branch.
2. Same as No. 1, duplicate sample. Collector, Milnor Roberts; analyst, C. R. Corey, University of Washington.
3. Thirty-three inches of upper bench, slope at end of tunnel, northwest wall, 14 feet from face of slope. Collector, J. D. MacKenzie; analyst, F. G. Wait, Mines Branch.

4. Same as No. 3, duplicate sample. Collector, Milnor Roberts; analyst, C. R. Corey, University of Washington.
5. Same location as 3 and 4, sample of 25 inches beginning 12 inches below roof. Collector, J. D. MacKenzie; analyst, F. G. Wait, Mines Branch.
6. Same as No. 5, duplicate sample. Collector, Milnor Roberts; analyst, C. R. Corey, University of Washington.
7. Lowermost 8 inches best coal on southeast wall, 5 feet in from turn of tunnel. Collector, J. D. MacKenzie; analyst, F. G. Wait, Mines Branch.
8. Same as No. 7, duplicate sample. Collector, Milnor Roberts; analyst, C. R. Corey, University of Washington.
9. Eight-inch seam. Nutter opening, lower tunnel. Collector, Milnor Roberts; analyst, C. R. Corey, University of Washington.
10. Collector, W. A. Robertson; analyst, G. C. Hoffman, Geol. Surv., Can., Ann. Rept., vol. VI, 1895, p. 12 R.
11. Collector, R. W. Ells; analyst, J. T. Donald, Geol. Surv., Can., Ann. Rept., vol. XVI, 1906, p. 43 B.
12. Collector, R. W. Ells; analyst, M. F. Connor, Geol. Surv., Can., Ann. Rept., vol. XVI, 1906, p. 44 B.

The writer is indebted to Dean Milnor Roberts for permission to publish analyses 2, 4, 6, 8, and 9.

Camp Anthracite.—The coal from this opening, which is clearly on the so-called Robertson seam, has been called anthracite probably on the strength of the analyses 2 and 3 quoted below. It does not, however, resemble anthracite in any way, and has a great likeness to the Robertson seam. This similarity is all the more striking when the variable character of the measures is recalled, and it strengthens the probability that the Robertson seam is of considerable extent.

The coal, exposed in an adit across the seam, from which a drift runs along it for 30 feet, is 9 feet thick where measured, containing 4 feet 5 inches of rather slaty, crushed coal in several bands separated by shale and bone. The seam is doubtless thickened by minor faults and slips. The thickness and general appearance of the seam resembles the occurrences at Camp Robertson.

Where opened, the seam strikes N. 32° W. and dips 85° S.W., but this high altitude is only local, as up Anthracite creek, on which the opening is located, the massive overlying sandstone is rather flat and regular.

Analyses of the coal are quoted below:—

Analyses of Coal from Camp Anthracite.

—	1	2	3
Water	5·69	1·52	2·85
Volatile matter	7·83	8·69	7·59
Fixed carbon	42·10	80·07	68·25
Ash	44·38	9·72	21·31
	100·00	100·00	100·00
Coke	86·48 Noncoherent.		

1. Tunnel, 20 feet in from mouth. Collector, J. D. MacKenzie; analyst, F. G. Wait, Mines Branch.
2. and 3. Collector, W. A. Robertson; analyst, G. C. Hoffmann, Geol. Surv., Can., Vol. VI, 1895, p. 13 R.

Camp Wilson.—Camp Wilson is located in the N.W. ¼ section 25, township 7. At this place three openings have been made on a single coal seam, varying from 4 to 18 feet thick, and containing up to 16 feet of coal.

The coal seam occupies the central portion of a narrow synclinal basin, which is complicated by other folds, but which has a general pitch to the north and northeast.

It is possible that the extent of this syncline northward and northeastward may be considerable, and if the pitch is sufficient, a considerable body of coal may underlie this area.

The measures of this syncline, the so-called Yakoun basin, differ from the rocks in the Honna basin in being much coarser and less sorted, and there is a noticeable lack of the dykes and sills so prevalent farther south. The Wilson seam is nearer the base of the Haida than is the coal at Camp Robertson. It is probable that the seam is less than 1,000 feet from the base.

The opening showing the largest body of coal is on the right bank of Wilson creek, about half a mile from the Yakoun river, and consists of an adit on the seam, from which a winze gives access to a drift at a lower level. The seam at this place strikes from north-south to N. 23° W., and dips from 60° N.E. to vertical. In the face of the adit, 50 feet from the portal, the seam is cut off by a vertical strike fault, which brings the floor and roof of the seam together. From the drift, 11 feet 10 inches below the adit, a narrow cross-cut has been driven through the seam, showing it to have a thickness of 18 feet 1½ inches. The seam is divided by 5 inches of whitish grey sandstone into two benches, the upper about 12 feet, and the lower about 5 feet thick. There are a few other thin partings in the seam, but on the whole it is clean, and much more so than the coal at Camp Robertson. Not all the coal, however, is of the same quality, and the upper 3 feet or so of the upper bench is distinctly inferior. In appearance the coal is bright and clean, and much broken by fractures in several directions, although it may well become more solid at depth. Contrasting with the coal at Camp Robertson, the Wilson coal is light in weight. The seam is broken by several smaller faults, in addition to the one appearing in the upper level.

Analyses of Coal from Camp Wilson.

—	1	2(*c*)	3	4	5	6	7	8	9	10	11	12	13
		(*b*)	(*a*)	(*b*)	(*b*)	(*a*)	(*b*)	(*a*)					
Water.	1·8	1·22	2·2	1·82	2·02	1·6	1·33	2·3	2·44	2·65	1·06	2·47	1·91
Volatile matter.	35·2	36·20	30·1	30·81	39·21	29·9	30·40	6·1	35·96	38·19	43·48	35·25	35·24
Fixed carbon...	46·4	46·48	38·3	40·84	50·51	31·8	31·17	74·1	48·64	53·73	46·01	59·36	59·39
Ash......	16·6	16·10	29·4	26·53	8·26	36·7	37·10	17·5	12·96	5·43	9·45	2·92	3·46
Sulphur........	....	1·00	.....	0·50	.....	.....	1·20	.....	0·80	....	......	.....	.....
	100·0	101·00	100·0	100·50	100·00	100·0	101·20	100·0	100·80	100·00	100·00	100·00	100·00
Coke	barely cokes.	Firm coherent	barely cokes.	......	.....	barely cokes.	......	......	61·60 Firm coherent	Firm.	.....	Coherent	Non-friable

(*a*) Total moisture. (*b*) Air dried. (*c*) B.T.U. 11,235.

1. Upper bench, No. 1 opening. Collector, J. D. MacKenzie; analyst, Edgar Stansfield.
2. Same as No. 1. Collector, Milnor Roberts; analyst, C. R. Corey, University of Washington.
3. Lower bench, No. 1 opening. Collector, J. D. MacKenzie; analyst, Edgar Stansfield.
4. Same as No. 3. Collector, Milnor Roberts; analyst, C. R. Corey, University of Washington.
5. Same as No. 2, specimen sample. Collector, Milnor Roberts; analyst, C. R. Corey, University of Washington.
6. Sample of 18-inch coal, beginning 27 inches below roof, No. 1 opening. Collector, J. D. MacKenzie; analyst, F. G. Wait.
7. Same as No. 6. Collector, Milnor Roberts; analyst, C. R. Corey, University of Washington.
8. Coke, upper bench, No. 1 opening. Collector, J. D. MacKenzie; analyst, Edgar Stansfield.
9. Collector, C. H. Clapp; analyst, F. G. Wait, Geol. Surv., Can., Summ. Rept., 1912, p. 36.
10. G. C. Hoffmann, analyst, Geol. Surv., Can., Ann. Rept., vol. III, 1887-8, p. 17 T.
11. Collector, W. A. Robertson; analyst, G. C. Hoffmann, Geol. Surv., Can., Ann. Rept, vol. VI, 1892-3, p. 12 R.
12. Collector, R. W. Ells; analyst, J. T. Donald, Geol. Surv., Can., Ann. Rept., vol. XVI, 1904, p. 40 B.
13. Collector, R. W. Ells; analyst, M. F. Connor, Geol. Surv., Can., vol. VI, 1904, p. 44 B.

The coking qualities are excellent. Tests of a pound or so of the coal as it came from the seam, without selecting the best parts, crushed and coked in a tin by means of a slow coal fire, gave bright, shiny, hard coke.

A shaft and drift at 310 feet in a direct line southeast up Wilson creek, on the left bank, shows the seam to have a thickness of 9 feet 5 inches, containing 6 feet 2 inches of coal, in appearance like that already described. It is here evidently faulted to some extent.

About 75 feet northeast of the first opening, the seam is cut by an adit. When first encountered it is lying rather flat, suggesting, as do other facts, that the measures are involved in a minor anticline. Farther in, the seam steepens rapidly, and in the end of the workings, which follow the seam, it is dipping 45° N.E. The greatest thickness of coal exposed in this opening is 3 feet 6 inches, but it is not certain that the whole seam is exposed here. In appearance the coal is like that at the other openings.

From the foregoing descriptions it will be seen that the seam where at present exposed is of a distinctly lenticular nature, and this fact, together with the known variable character of the sediments, forces one to the conclusion that the seam is apt to be uneven in its thickness. The great mass of coal in the first opening described, although somewhat faulted, and doubtless slightly thickened by this agency, is on the whole well bedded, and the unusual thickness is probably due to original deposition. Until the seam is exposed at several other localities, little can be said regarding its probable character from the miner's point of view. The fact that there is known to be a rather widespread coal-bearing horizon at about this place in the measures, together with the occurrence of a distinct seam of good coal of workable size, points to the conclusion that there is every probability of finding workable coal north of Camp Wilson. The extent and value of this coal can only be determined by careful prospecting directed by a competent geologist. Haphazard boring operations are of little value, and even if a coal seam is encountered by them, a drill core tells very little about the structure, and virtually nothing about the extent of a seam.

GOLD.

Gold is found on the Southeast and Beaconsfield mining claims, situated about a mile northeast of Skidegate Indian village. Through the courtesy of John MacClellan, Esq., part owner, the writer had the opportunity of visiting the property, and the following information was largely obtained from Mr. MacClellan:—

The deposit consists of a vein averaging 9 feet thick, striking N. 40° W. and with a vertical dip. The vein is slightly irregular, and apparently faulted off at the southeast end. The vein material is almost wholly milky quartz, occurring as a replacement of a brecciated zone in the Yakoun volcanics. Irregularly distributed through the vein are bunches of sulphides, containing galena, sphalerite, pyrite, and chalcopyrite. The gold occurs in the galena, which carries up to 30 ounces in silver, and also with an unknown yellow mineral encrusting some of the specimens in thin films. Occasionally, free gold may be seen with the naked eye, but usually it cannot be thus made out. Specimens of galena gave assays as high as $2,600 to the ton, but the bunchy nature of the ore necessitates thorough prospecting before the value of the property can be definitely established.

CLAY.

But few outcrops of clay were seen, although a large part of the upper Honna valley, and the Yakoun valley below Camp Wilson are underlain by stratified clays and sands. Most of the clay seen was a bluish grey, fine-grained highly plastic variety, often with a thin film of fine sand on the bedding planes. It would doubtless make common brick and perhaps the lower grades of earthenware, and its consistency was such as to render its flowage through a die probable.

BUILDING STONE.

Should a demand for building stone arise in this section it is probable that quarries in the massive Haida sandstone on Maude island would repay working.

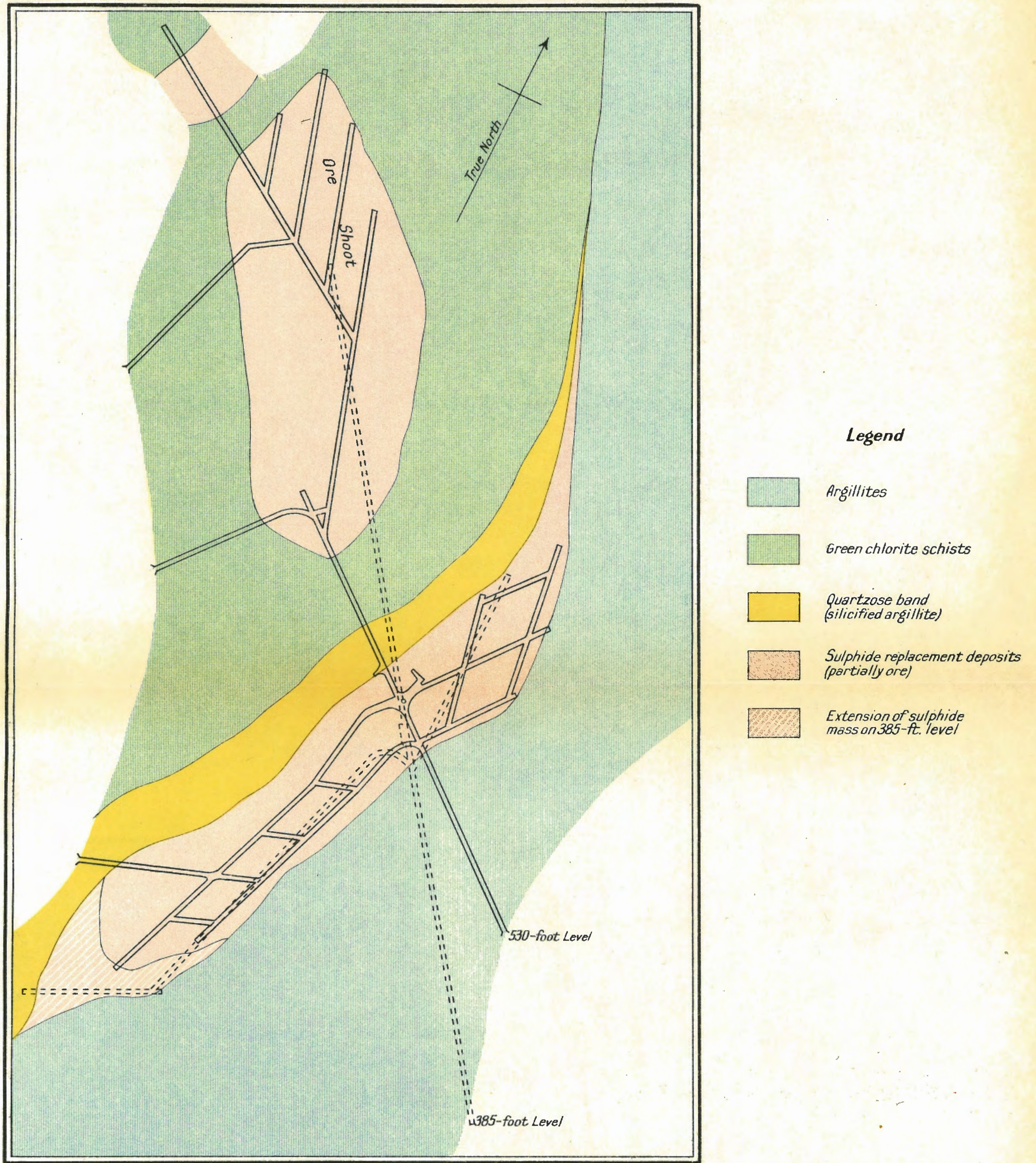
LIMESTONE.

On the southeast end of South island is a large body of what is apparently rather pure, partly crystalline, bituminous limestone, capable of furnishing lime for plaster or cement.

OIL.

The Maude argillites, wherever they occur, are strongly bituminous, and films of black, sticky tar are often found on joint and bedding planes. On Hidden creek, about a mile up from the Yakoun river the tar accumulations are especially plentiful, here occurring in veins of calcite that cut the argillites as well as on joint and bedding planes.

In view of the severe folding which the argillites have undergone, and their greatly fractured condition, prospectors should proceed with caution and not undertake extensive boring operations until advised to do so by a competent authority.



Geological Survey, Canada. 1365

Plan of 530-foot Level, Hidden Creek Mine, Granby Bay, British Columbia

(From surveys by Management)

Scale of feet

100 0 100 200 300 400

To accompany Summary Report by R. G. McConnell, 1913.

RECENT DEVELOPMENT AT THE HIDDEN CREEK MINE, OBSERVATORY INLET, B.C.

(R. G. McConnell.)

The Hidden Creek mine, Granby bay, Observatory inlet, was examined by the writer in 1911, and described in the Summary Report for that year. Since then development work has been prosecuted energetically and continuously both by drifting and drilling, and much additional information is available. The drifts now aggregate a total length of 17,000 feet, and the bore-holes about 30,000.

A few days were spent at the mine during the past summer in preparation for the visit of Excursion C8 of the International Congress of Geologists.

The extensive development has resulted in the partial outlining of two large sulphide masses and the discovery of a third one near the northern end of the 530-foot workings.

The ores are replacement deposits in argillites and greenstones and consist of pyrite and pyrrhotite with subordinate quantities of chalcopyrite and occasionally some blende in a gangue usually consisting of the silicified and altered country rocks. In a few places calcite replaces the silica. In limited portions of the ore bodies, the replacement of the original rocks by sulphides and silica is practically complete but, as a rule, even where mineralization has been most intense, cores of the original rocks still remain.

The deposits occur near the centre of a large inclusion of argillites and greenstones in the Coast Range granodiorite batholith and doubtless owe their origin to liquid or gaseous emanations from the latter carrying the various sulphides in solution. Genetically, they belong, therefore, to the contact metamorphic group, but differ from the ordinary deposits of this group in the scarcity or absence of the common contact metamorphic minerals such as garnet, epidote, and the iron oxides. Garnet, the commonest of these, has not been identified even in thin sections. Actinolite is present and at one point occurs in well formed columnar crystals embedded in the sulphides. Chlorite is abundant and muscovite and biotite are well represented. Quartz occurs in all parts of the deposits, while calcite is only found occasionally.

No. 1 ore body, so-called, consists of an elongated mass of sulphides, only a portion of which carries copper in commercial quantities. It has formed entirely in altered argillites near their contact with greenstones. Along the northern border is a quartz schist zone up to 80 feet in width, consisting of strongly silicified argillites, lean in sulphides. On the 530-foot level, this sulphide mass has been opened up for a distance of 1,600 feet, with an average width of 160 feet. It pitches to the southwest along the strike and extends in that direction in depth as shown by bore-holes, beyond its limits in the upper workings. Chalcopyrite is present practically everywhere, but the quantity varies, and the copper tenor of a considerable portion of the mass is too low for profitable extraction. Three large areas of commercial ore, that is ore carrying over 2 per cent in copper, have been blocked out.

No. 2 ore body, or second sulphide mass, is separated from No. 1 ore body on the 530-foot level by the quartz schist zone and a barren area 160 feet across. Unlike No. 1, which has developed in dark argillites, the country rock is a greenish chloritic schist, probably of sedimentary origin, but the original characters have been entirely obscured by the repeated metamorphism of the region. It is made up mostly of chlorite and other micaceous minerals, with quartz, a little feldspar, and sulphides. Tremolite and actinolite are also occasionally present. It is strongly schistose as a rule in and near the ore body, and only slightly a short distance away.

The following partial analyses of cores from the two ore bodies, furnished by the mine management, show considerable differences in chemical composition. The mineralized rocks of the first ore body carry less silica, alumina, and magnesia than those of the second ore body, and more iron, lime, and sulphur.

	First ore body. Formed in argillites.	Second ore body. Formed in chloritic schists.
Silica	24·8	33·3
Iron	26·7	24·3
Lime	5·2	3·3
Sulphur	28·1	16·0
Alumina	6·4	11·4
Magnesia	1·7	4·4

Analyses of Altered Argillies and Green Schists Outside the Mineralized Area.

	Argillites. Near first ore body.	Green chloritic schists. Near second ore body.
Silica	69·2	48·4
Iron	5·5	9·0
Lime	3·6	4·9
Sulphur	2·9	0·5
Alumina	9·8	18·1
Magnesia	2·9	9·7

These analyses show the rocks to be fairly typical examples of their respective classes. In the mineralized rocks the iron and sulphur content is greatly increased and the relative amount of silica present is necessarily much smaller.

The second sulphide mass, as developed on the 350-foot level, is elliptical in shape, the long diameter having a length of 880 feet, and the short one of about 240 feet. The strike is to the northwest and the pitch of the ore body is in the same direction or nearly at right angles to that of the first ore body. The sulphides in the south-eastern portion of the mass are lean in copper, but toward the northwestern end they become richer, and a large area of commercial ore measuring about 400 feet in length and 200 feet in width has been outlined. This ore mass extends to the surface, a distance of about 400 feet, and is opened up on several levels above the 530-foot. It has also been proved by bore-holes to descend for a considerable distance. A long tunnel to intercept it at the 385-foot level was nearly completed at the time of my visit. This is intended to be the main working level of the mine.

In addition to the two large sulphide masses described, a third area, about 120 feet across, has been pierced in the extension of the workings on the 530-foot level west of the second ore body. Development work to ascertain its size and quality is now in progress.

The total tonnage of commercial ore practically in sight at the mine, is now reported at nearly 9,000,000 tons. A large portion of this is actually blocked out and ready for mining.

A smelter with a capacity of 2,000 tons per day, is under construction and will be completed early in the present year, and ample supplies of ore are ensured from the Hidden Creek mine alone to keep it running for many years. Other buildings in course of construction by the company include substantial office buildings, a large hotel, a hospital, and workmen's cottages and boarding-houses, both at the beach and the mine.

BONANZA MINE.

Pyritized areas, bearing a general surface resemblance to the Hidden Creek area, occur at a number of points in the same inclusion in the Coast Range batholith. An occurrence on Bonanza creek, a small stream emptying into Granby bay, has been held under bond for some time by the Granby Company, and a number of bore-holes have been put down. The conditions found proved somewhat peculiar. The country rocks are green chloritic schists cut by pegmatite dykes and a later set of dark dykes mostly diabasic in character. The former are older and the latter younger than the mineralization of the region. The schists are mineralized at the surface with iron sulphides, associated with chalcopyrite in places, over an area about 400 feet wide, extending from Bonanza creek southward up the slope of the valley for a distance of nearly 500 feet. The extensive croppings apparently indicated a great deposit, rivalling that at Hidden creek in size, but bore-holes put down at various points have shown that the mineralization is confined to a zone in the schists from 20 to 50 feet thick only. The zone dips with the schists toward the creek at an angle of 15 degrees, and this happens to coincide with the slope of the lower part of the valley. The croppings, therefore, represent not a section across the pyritized mass, but a section along it. Bore-holes put down up the southern slope of Bonanza Creek valley south of the point at which the pyritized zone disappears under the schist covering, proves its continuation for some distance at least in that direction. Its northern extension along its dip north of Bonanza creek has not been investigated.

The pyritized zone as a whole is lean in copper, but certain areas contain sufficient chalcopyrite to constitute ore. A considerable tonnage has been determined by the diamond drill examination.

THE LIME BELT, QUADRA (SOUTH VALDES) ISLAND, B.C.

(*D. D. Cairnes.*)

Introduction.

GENERAL STATEMENT AND ACKNOWLEDGMENT.

A few days in May (1913) were spent in examining and sampling the ore deposits of Quadra island, British Columbia. It was reported that nickel in economically important amounts had been found to occur associated with the copper ores of this area, thus the examination was considered somewhat urgent, and the writer was accordingly instructed to visit this locality before proceeding to Yukon to commence his regular field work for the season. In connexion with this work on Quadra island the writer wishes to express his appreciation of the numerous courtesies extended, and of the assistance and hearty co-operation afforded him, by the various claim owners in the district, particular thanks being due Mr. James Deans and also Messrs. William Stramberg, C. E. Lynn, Thomas Holeman, Robert Sharp, T. Bachus, P. W. Hall, Fox Bros., and others.

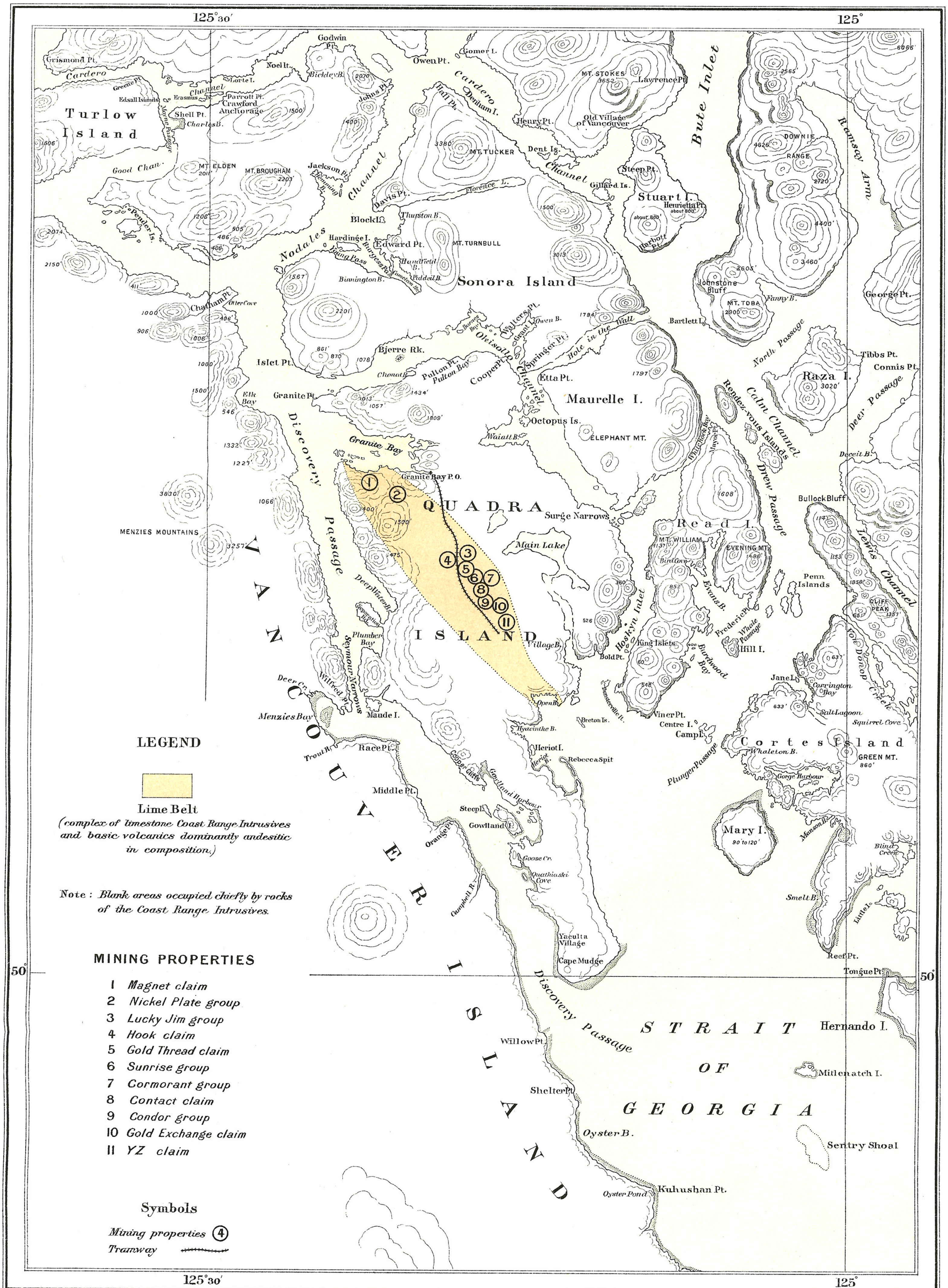
LOCATION AND ACCESSIBILITY.

The name Valdes was for many years applied to what was supposed to be one island situated on the west coast of British Columbia between Vancouver island and the mainland, and separated from Vancouver island by Discovery passage. The island was first chartered by Captain George Vancouver, in 1792, but more recent explorations and surveys have shown that the supposedly single island is really a group of three main islands which are separated by narrow intricate salt-water passages through which the high tides rush with great violence. The southernmost of these three islands has been named Quadra island, and Granite bay, which is at the western end of the lime belt of this island, is about 135 miles from Vancouver, measured along the steamer route. The lime belt itself is so called because limestone outcrops conspicuously within this area, and is of rare occurrence, not only in the remaining portions of the island, but also on the other islands and along the coast of the mainland, at least between the Strait of Georgia and Queen Charlotte sound. This lime belt extends in a northwesterly direction from Open bay on the eastern side of the island, toward Granite bay, and reaches to within about a mile of Discovery passage, on the western side of the island, a distance of approximately 10 miles, and throughout its length, the belt has an average width of from 1 to 2 miles.

The lime belt may be most conveniently reached by means of one of the regular steamers which run several times a week from Vancouver to Granite bay where there is a post-office, store, school-house, and a few other buildings—the post-office being named Granite Bay. From this point the Hastings Sawmill Company has constructed a logging railway about 6 miles in length for bringing logs from the interior of the island to tidewater; and it fortunately happens that the railway follows the lime belt practically throughout its length, the lime belt being marked topographically by a heavily timbered, irregular depression, or more or less connected series of depressions. Thus the mineral claims are nearly all readily accessible either directly from the shore of the island or from the railway, which runs to the beach.

Canada
Department of Mines
HON. L. CODERRE, MINISTER; R. W. BROCK, DEPUTY MINISTER.
GEOLOGICAL SURVEY

OUTLINE MAP



C.-O. Senécal, Geographer and Chief Draughtsman. 1351

MAP 120 A
(Issued 1914)

QUADRA ISLAND BRITISH COLUMBIA

Scale of miles
1 ½ 0 5 10 15

To accompany Summary Report, by D. D. Cairnes, 1913.

PREVIOUS WORK.

In 1885, Dr. Dawson made a systematic examination of part of the coast of British Columbia, including the shores of Quadra island[1], and described the general geology of this portion of the coast of British Columbia. Practically the only known published reports concerning the ore deposits of the lime belt, however, are included in a memoir written by Dr. Bancroft[2] for this department, and in two reports of the Provincial Assayer of British Columbia[3] made on behalf of the provincial Bureau of Mines.

Summary and Conclusions.

The consolidated geological formations exposed in the vicinity of the ore deposits in the lime belt belong, dominantly at least, to three rock groups, viz., the Marble Bay (?) formation, the Valdes formation, and the Coast Range intrusives. The Marble Bay (?) formation consists entirely of limestone beds which are thought to be of Jurassic or Triassic age. These beds have been invaded and overlain by the members of the Valdes formation which consists mainly of andesites, volcanic breccias, and tuffs. The members of both of these formations have been intruded and intensely invaded by the intrusives of the Coast Range batholith, and now occur throughout the lime belt mainly as remnants of what once, apparently, constituted portions of the roof of this batholith which is considered to be, for the greater part at least, of Jurassic age.

The ore deposits developed within the lime belt are all included within the contact aureole of the Coast Range batholith, and dominantly belong to the contact metamorphic type of deposit. Occasional veins also occur, however, and in places various transitional forms are also developed, ranging in character from ordinary fissure veins to typical contact metamorphic deposits.

The contact metamorphic deposits are extensively developed throughout the lime belt of Quadra island, and consist mainly of pyrrhotite, magnetite, chalcopyrite, pyrite, arsenopyrite, molybdenite, quartz, calcite, epidote, garnets, amphibole and other complex silicates. These deposits occur everywhere either in or near the limestones in the proximity of the granitic intrusives. They may thus occur along the contact between the granites and limestones, or along the contacts between any two of the three main groups of rocks developed in this area, or they may follow fault planes, or shear zones, traversing these rocks. The ore deposits of this type range from a few inches or less up to 10 or 12 feet in thickness, but in most places do not exceed 6 feet in this dimension. Certain members can be traced for several hundred feet along the surface, but in most instances the individual deposits do not appear to persist so far. The only minerals of economic importance discovered in these ores are gold and minerals containing gold or copper. The copper content of the deposits as shown by the samples taken by the writer, varies from 0·07 per cent to 4·13 per cent, the greater number of the samples containing less than 1 per cent. The only average samples that contained more than traces of gold were obtained from the Lucky Jim property, these samples containing from 0·16 to 0·24 ounces per ton.

In addition to the typical contact metamorphic deposits, there are also developed within the lime belt, certain veins or vein-like deposits which are intimately associated with the metamorphic deposits, but which have the general appearance of gold-copper veins. These consist mainly of quartz, calcite, chalcopyrite, pyrite, and pyrrhotite, of

[1] Dawson, G. M. "Report on a geological examination of the northern part of Vancouver island and adjacent coasts": Geol. and Nat. Hist., Surv. of Can., Ann. Rept., vol. ii, 1886, pt. B.

[2] Bancroft, J. A. "Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, British Columbia": Geol. Surv., Can., Memoir No. 23, pp. 133-135.

[3] Ann. Rept., Minister of Mines, British Columbia, 1908, pp. 148-149: 1910, pp. 158-160.

which the metallic minerals may occur as only scattered particles distributed through the quartz and calcite, or may exceed these gangue minerals in amount.

At a few points, also, gold-tellurium veins occur. These are composed dominantly of quartz with some associated calcite, through which gangue minerals there are distributed occasional particles of native gold, tellurides, and perhaps also of pyrite, pyrrhotite, and chalcopyrite. These deposits have been only slightly explored, and are not known to possess any actual economic value. With further development, however, they may prove to be of considerable importance.

The outcrops of a few of the deposits in the lime belt are considerably oxidized and somewhat porous, showing that a certain amount of leaching action has occurred. It is quite possible that in such cases an enrichment in copper is to be expected at the permanent ground-water level.

Therefore, though none of the properties within the lime belt of Quadra island have been proved to contain any considerable amount of ore, i.e., material that can under existing conditions be mined and treated at a profit, nevertheless the entire belt shows great general mineralization, and on one property at least, the ore material contains gold and copper in sufficient amounts to warrant further exploration. It would appear, therefore, as quite possible that other deposits of greater economic value than those already found, may yet be discovered within this area, and that, with further development, richer places or chutes may be found within the deposits already known. When the somewhat rugged character of the district is considered, and when it is remembered that the consolidated rock formations throughout the greater part of the belt are covered with superficial deposits in which is rooted a dense vegetation, it is somewhat surprising that so much mineral has already been discovered, and there is no reason to suppose that the best has been first found. Great credit is thus due the few men who have, up to the present, devoted so much of their time and energy to the exploration of this area which is readily accessible and is still well worthy the attention of the miner and prospector.

General Character of the District.[1]

Quadra island forms the most southerly of three islands which were formerly supposed to constitute an insular unit known as Valdes island; and the three members of this group are all quite typical of the islands of the fiord-indented, island-strewn coast of British Columbia. These islands are all topographically mountainous, and Sonora island, the most northerly of the three, is very rugged and rises in places to over 3,000 feet above the surrounding salt water. Quadra island is the least rugged of the group, and contains in the interior, several lakes lying in low, irregular, rocky basins. Nevertheless, even this island rises to elevations of approximately 2,000 feet above the sea. The shore-lines are characteristically bold, and in some places are so steep as to be inaccessible.

From Granite bay, quite a broad, somewhat low-lying, inhabitable, depression or succession of more or less connected depressions, extends in a southeasterly direction to Open bay, this belt being bordered on the south, in parallel fashion, by a rugged range of hills. This low-lying tract marks approximately, the axis of the lime belt. Thus, the greater number of the ore deposits within this belt are conveniently situated in comparatively accessible portions of the island. Nearly everywhere, however, the surface is deeply covered with superficial detrital deposits which support a luxuriant growth of vegetation, and it so happens that some of the best and most accessible

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[1] Since this report is primarily concerned with the ore deposits of the lime belt, no detailed descriptions, topographic or otherwise, are here given concerning this area, except where such have a direct relation to the economic geology. For a description of the general characteristics of Quadra island and adjoining portions of the coast of British Columbia, see Bancroft's report, to which reference has been made, pp. 11-60.

timber on Quadra island is or was contained within the lime belt. Consequently, a logging railway has been constructed from Granite bay for a distance of about 6 miles, through this belt, and the fallen trunks, tops, and branches left by the loggers make it now difficult to travel for some distance on either side of the railway. In addition, fires have swept portions of the belt, and have burned only sufficiently in many places to kill the trees, so that in such localities the surface is thickly and deeply strewn with charred and fallen timber which entirely obscures the surface in many places and makes walking in such places almost impossible. Thus, considering the fact that the district is somewhat rugged, that so much of the surface is covered with thick detrital deposits which support a heavy and often dense vegetation, and that, in addition, fires and loggers have littered the surface with fallen timber and brush, effective prospecting for mineral deposits has been attended with many difficulties, and the discoveries that have been made, have been largely more or less accidental.

General Geology.

GENERAL STATEMENT.

The consolidated geological formations within the lime belt appear to be all of Mesozoic age and include rocks of both sedimentary and igneous origin. The oldest rocks comprise the Marble Bay (?) formation which consists of limestones that are thought to be of Jurassic or Triassic age. These are in places overlain by the members of the Open Bay group which includes argillites, tuffs, cherty beds, schists, and intercalated sheets of diabase. These older formations have been invaded and overlain by the members of the Valdes formation which consists mainly of andesites, volcanic breccias, and tuffs. All these formations have been intruded and intensely invaded by the intrusives of the Coast Range batholith, and now occur throughout the Lime Belt mainly as remnants of what once, apparently, constituted portions of the roof of this batholith. All the consolidated rock formations are overlain by a mantle of detrital deposits which obscure the bedrock in most places.

In the portions of the lime belt examined by the writer, which include only those areas in which the principal ore deposits have been discovered, representatives of only three of the consolidated rock formations just mentioned, were noted. These are the Marble Bay (?) formation, the Valdes formation, and the Cosat Range intrusives, all three of which occur intimately associated and irregularly distributed, and comprise really a sedimentary-igneous rock complex. The limestones have been invaded and intruded and overlain by the members of the Valdes formation, and complex masses of the two rock groups occur as isolated bodies surrounded and intersected by the Coast Range intrusives. These isolated bodies appear to be really roof pendants of the Coast Range batholith and thus constitute portions of what was formerly in all probability a continuous roof over this great igneous mass.

Table of Formations.

Recent and Pleistocene	Superficial deposits	Chiefly sands, gravels, clays, and soil.
Cretaceous or Jurassic	Coast Range intrusives	Igneous rocks of granitic habit ranging in composition from acid granites to gabbros.
	Valdes formation	Andesites, vclcanic breccias, and tuffs.
	Open Bay group	Argillites, quartzites, cherts, tuffs, schists, intercalated sheets of diabase.
Probably Jurassic or Triassic (?)	Marble Bay formation (?)	Limestones.

DESCRIPTIONS OF FORMATIONS.

Marble Bay (?) Formation.

The Marble Bay (?) formation of Quadra island is practically limited in its occurrence to the lime belt; in fact but few other developments of these beds or similar limestones are known to occur on the islands of the coast of British Columbia or along the mainland, at least between the Straits of Georgia and Queen Charlotte sound. Throughout the lime belt these limestone beds occur in the form of more or less connected, irregularly-shaped masses, ranging in size from only a few inches or less to a mile or possibly more in length. This formation consists entirely of limestones which occur in beds usually from 1 to 6 feet in thickness; these rocks are typically finely-textured, compact, and bluish grey in colour, but in many places have become so altered as to have become crystalline or semi-crystalline in structure, and occasionally have been changed into marble.

No fossils have been found in these limestones on Quadra island, but Bancroft, upon lithological evidence, has correlated them with the Marble Bay formation[1] of Texada island, which has, in the past, been thought to be of Carboniferous or Devonian age. However, a few imperfect fossil remains were collected from these beds on Texada island by Mr. Walter Harvey some years ago, and were sent to the Geological Survey for identification. Dr. Kindle has quite recently examined these forms and reports them to be of Jurassic or Triassic age.

The members of the Open Bay group, according to Bancroft, occur in certain portions of the lime belt and are typically developed along Open bay. The writer, however, made no attempt to study the general geology of this belt except in the immediate vicinity of the ore deposits examined, and as a consequence did not encounter any of the recognizable members of this group. The rocks according to Bancroft's descriptions consist mainly of argillites, quartzites, cherty beds, tuffs, schists, and intercalated sheets of diabase.

Valdes Formation.

The Valdes formation extends over the greater part of Quadra island to the south of the lime belt, and throughout the lime belt itself is irregularly and extensively developed. This formation occurs nearly everywhere intimately associated with the Marble Bay (?) limestones, the two formations constituting irregularly-shaped rock masses which have been extensively intruded, invaded, and metamorphosed by the Coast Range intrusives.

The Valdes group includes, mainly, a series of volcanic rocks, but in places, according to Bancroft, also embraces a few intercalated beds of limestone. The volcanic rocks include mainly andesites, volcanic breccias and tuffs, which have extensively invaded, intruded, and overlain the members of the Marble Bay (?) formation; thus the two formations have become very intimately associated, and within the lime belt, it would be difficult to map them separately.

Coast Range Intrusives.

The Coast Range intrusives which occur on Quadra island, constitute a peripheral portion of the Great Coast Range batholith which is the master geological feature of the coastal belt of British Columbia. This huge batholith extends in a northwesterly direction from southern British Columbia to Lake Kluane, in Yukon, a distance of over

[1] Le Roy, O. E. "Preliminary report on a portion of the main coast of British Columbia and adjacent islands included in New Westminster and Nanaimo districts": Geol. Surv., Can., 1908, p. 16.

1,000 miles, throughout which distance the batholith is from 30 to 100 miles broad. The Coast Range intrusives are conspicuous throughout the lime belt, and are extensively developed on Quadra island to the north of this area.

These intrusives vary in composition from that of an acid granite to a basic gabbro or even a hornblendite, and have dominantly a typical granitic habit. In general, they are some shade of grey, but still possess quite a wide range of colour. The more acid varieties are almost white, but with increasing basicity the colour becomes darker, the hornblendites being quite black. The granites and granodiorites have in places a pink or reddish hue, due to the colour of the prevailing alkali feldspar they contain, while greenish tints characterize some of the more basic rocks due to the development of chlorite, epidote, or related minerals. These intrusives ore remarkably uniform in texture, being dominantly coarsely textured. Medium-textured facies, however, are developed, and in places these rocks are decidedly porphyritic. On account of their characteristic granitic appearance, these intrusives are commonly spoken of as granites, which term, however, is, strictly speaking, applicable to only a small portion of the rocks of this terrane.

The intrusives have invaded, intruded, and greatly metamorphosed the older rocks with which they have come in contact, and within the lime belt the masses of older formations exposed appear to constitute isolated roof pendants, distributed over this portion of the batholith. Accordingly, all settling or other movements in the batholith, due to readjustment during or after cooling, as a result of shrinkage from crystallization and other causes, have caused fissures to occur and shear zones to be produced in the older overlying rocks; and it is in and adjoining these fissures and fracture zones in the older rocks, as well as in similar spaces in the adjacent portions of the batholith itself, that the ore deposits prevailingly occur, the fault planes and fracture zones having afforded a ready passage for the escape of the mineralizing gases and vapours from the heated granitic mass. Some of the ore deposits, however, have been formed along the contact between the granitic intrusives and the older overlying formations.

Superficial Deposits.

Overlying all the older consolidated rock formations, there occurs a mantle of Recent and Pleistocene deposits which obscure in most places the bedrock structures beneath. These overlying deposits embrace all the Glacial and post-Glacial debris, and thus include all sands, gravels, silts, clays, peat, muck, and soil, some of which are nearly everywhere in evidence.

Economic Geology.

General Statement.

From the standpoint of economic geology, the lime belt of Quadra island is of interest mainly or entirely for its ore deposits, which are somewhat extensively developed throughout the area. A considerable number of mineral claims have been located covering these deposits, and on some of these quite an amount of development work has been performed. The greater number of these claims which are still in force were located within the past five years. The Lucky Jim, however, was staked about eight years ago, thus being one of the first locations in the lime belt.

No attempt was made by the writer to examine every claim located within this area, but all those claims were visited on which any promising ore deposits were reported to occur, as well as all claims on which any work other than the regulation assessment duties had been performed. In describing these properties they are here considered in order, beginning at the northwest and proceeding toward the southeast.

On the map accompanying this report, the different claims or groups of claims which were examined are indicated. No great accuracy, however, is claimed for the positions of these properties as shown, such having been estimated from points along the railway, the distance of which from the beach was known.

CHARACTERISTICS OF THE ORE DEPOSITS.

Types.

The ore deposits of the lime belt all occur within the contact aureole of the Coast Range batholith, and dominantly belong to the contact metamorphic type of deposit. At a few points, however, typical veins also occur, and in places deposits are developed that are transitional in character between veins and deposits of contact metamorphic origin.

The contact metamorphic deposits are characterized mainly by the presence of the oxides and sulphides of iron, chalcopyrite, garnet, amphibole, epidote, and related complex silicates. The decided veins, however, are dominantly composed of quartz and calcite, associated with which gangue minerals there occur in most places, only occasional particles of native gold and tellurides, with perhaps also some pyrite, pyrrhotite, and chalcopyrite. These are thus typical gold-tellurium veins. At other points, vein-like deposits occur which contain mainly quartz, calcite, chalcopyrite, pyrrhotite, and pyrite, there being every transition from a deposit or portion of a deposit composed practically entirely of quartz and calcite, to one comprised almost wholly of the three just-mentioned metallic sulphides. Since these deposits contain more or less gold they might thus, in part at least, be appropriately termed gold-copper veins. Associated with these veins or vein-like deposits, there occur locally some of the garnet-amphibole-epidote minerals, and with the gradual increase of these silicates, and the introduction in places of magnetite, the deposits become less tabular and regular in form, and may within a few feet assume all the diagnostic features of a contact metamorphic deposit. Most of the ore deposits within the lime belt, however, belong decidedly to the contact metamorphic type, and it is these deposits that have been found to be of most economic importance.

DISTRIBUTION.

The lime belt is a highly mineralized area, throughout which deposits containing ore minerals are plentifully distributed. Typical contact metamorphic deposits characterize the entire belt, and veins of different types also occur at a few points. The principal ore bodies that have been discovered on the Magnet claim, the Nickel group, the Lucky Jim group, the Sunrise group, the Cormorant group, and the Contact claim, are typical contact metamorphic deposits. Gold tellurium veins or masses of vein quartz, were noted mainly on the Geiler and the Gold Thread claims, but small representatives of this class of veins also occur on the Hook claim, on the Lucky Jim group, and elsewhere. On the YZ, the Hook, and the Gold Exchange claims, veins are developed which though closely related to contact metamorphic deposits in origin, nevertheless much more resemble copper-gold veins in character. On the Lucky Jim group and elsewhere, deposits were noted which in part resemble quartz veins and are in part of contact metamorphic origin, showing how closely related, genetically, are these two types of deposits.

ASSOCIATED GEOLOGICAL FORMATIONS.

The term contact metamorphic as applied to ore deposits is to a certain extent a misnomer, as deposits of this type do not necessarily follow contacts between different rock formations. The contact metamorphic deposits in the lime belt, however, invariably occur in close proximity to the limestone, and are developed dominantly along certain fracture zones which are very numerous, and which trend in various directions, no particular strike or strikes having been found to pertain throughout the area. These ore deposits may thus occur either in the limestones, in the volcanics, or in the granitic intrusives, or they may be developed along the contact between the members of any two of these formations. Individual deposits occur which follow a line or zone of fissuring trending across a contact between the members of two of these rock groups. Such deposits are partly in one formation and partly in the other, and for a certain distance follow the contact between the two rock groups.

The only gold-tellurium veins which were examined by the writer occur entirely within the andesitic volcanics, but it is to be expected that similar veins may be found in the granitic intrusives or even in the limestone. The gold-copper veins which occur within the lime belt are very closely related to the contact metamorphic deposits and, like them, may be developed either in any of the three groups of rocks, or may even occur along the contacts between these different formations. Like the gold-tellurium veins, however, they appear to dominantly occur in the andesitic volcanics.

MINERALOGY.

The contact metamorphic ore deposits consist mainly of pyrrhotite, chalcopyrite, magnetite, pyrite, arsenopyrite, azurite, malachite, molybdenite, quartz, calcite, hornblende, epidote, and garnets. In places, these deposits consist almost entirely of pyrrhotite with more or less chalcopyrite; in other places, magnetite with a small percentage of chalcopyrite comprise the deposits. Molybdenite was noted on only one property, and occurs there in the form of occasional flakes. In some portions of the lime belt the deposits contain little or none of the metallic minerals, and consist entirely of the siliceous minerals with some calcite, the garnets, epidote, and hornblende being generally conspicuous; in fact, throughout the belt, wherever the epidote-garnet-hornblende minerals are at all extensively developed, the copper as well, generally, as the iron minerals, fails. The amount of quartz in these metamorphic deposits varies greatly, there being apparently every gradation from a quartz vein containing practically no metallic constituents, to a deposit composed entirely of the metallic oxides and sulphides with their oxidation products.

The gold-tellurium veins consist dominantly of quartz, with which is associated more or less calcite. Throughout these gangue minerals, occasional particles of pyrite, native gold, and sylvanite occur.

SHAPES AND DIMENSIONS.

Contact metamorphic ore deposits comprise a type of deposit that is extensively developed in many parts of the world, and particularly along the western portion of this continent; and these deposits include a great number of important ore producers. Nevertheless, as is to be expected from their form of origin, these ore bodies are characteristically irregular in shape, and thus differ fundamentally from the comparatively uniform tabular vein deposits which are so well known, and consequently their successful development requires much greater skill and experience.

Within the lime belt of Quadra island, the contact metamorphic deposits are, as elsewhere, very irregular in contour, and occur as lenses, masses, impregnations, and various ramifying forms. They, however, appear to dominantly follow along certain contact, fracture, or other definite lines, and dominantly occur *en échelon,* as a series of more or less connected smaller individual masses, rather than as single more persistent bodies. They may thus terminate very abruptly, either along their strikes or dips, and in their development it is never safe to postulate far past their actual exposures. It can never be inferred, for instance, as is commonly done in the case of fissure veins, because ore has been found at a number of points more or less in alignment on the surface, that ore persists between these exposures.

The members of these contact metamorphic deposits, which are conspicuous on account of the iron and copper minerals which they contain, and which are thus to be regarded as constituting the ore deposits of the area, range from a few inches or less up to 10 or 12 feet in thickness, but in most places do not exceed 6 feet in this dimension. They can in places, also, be traced for several hundred feet along the surface, but in most cases the individual deposit does not appear to persist so far.

The gold-copper veins and others of the more tabular vein-like deposits may be expected to be more regular than the typical contact metamorphic deposits, both along their dip and strike. These veins range from a few inches or less up to about 5 feet in thickness, but were, wherever seen, exposed for only a few feet, the remaining portions of their outcrops being hidden from view by superficial deposits. It is thus not known how far these deposits persist.

The gold-tellurium veins are dominantly stringers only a few inches, at most, in thickness. On the Geiler claim, however, vein quartz in addition to occurring as veinlets, is also distributed throughout a much-fractured zone, 20 to 30 feet in width, and with the broken and comminuted andesitic rock fragments, really constitutes a brecciated vein deposit.

ASSAY VALUES.

Average samples were taken from all the more promising deposits examined, and these have been tested and assayed in the laboratories of the Department of Mines, Ottawa; and although nickel had been reported to occur in these ores, no trace of this metal was found in any of the samples obtained, although all were tested by the most refined known methods. The only metals of present economic importance discovered in these ores are copper and gold. The copper content of the ores as shown by these samples, runs from 0·07 per cent to 4·13 per cent, the greater number of the samples containing less than 1 per cent. The only average samples which contained more than traces of gold were obtained from the Lucky Jim property, these samples containing from 0·16 to 0·24 ounces per ton. It is quite possible, however, that other deposits actually contain gold in appreciable amounts, but as only a limited number of samples were taken, its presence was not detected.

OXIDATION, LEACHING, AND ENRICHMENT.

Some of the ore deposits within the lime belt have been considerably oxidized on the surface, the iron-ore minerals having been altered to limonite, giving the ores a reddish appearance. The chalcopyrite has been more affected even than the iron-ore minerals, and has been oxidized, and more or less entirely leached out of the upper portions of the ore deposits. It is to be expected that the copper which was thus removed by solution, has been partly, at least, redeposited lower down in the ore bodies, particularly where these are situated on comparatively flat or gently undulating ground, such as characterizes much of the lime belt. In such places the surface drainage is not so perfect and rapid as to carry off these copper-bearing solutions and thus prevent their descending along or through the deposits themselves.

Most of the ore deposits within the lime belt are, however, comparatively slightly oxidized, and show little evidence of leaching. This is probably due to the fact that the land surface has been heavily and deeply eroded during the Glacial period, and consequently any upper oxidized portions of these deposits which then existed, have been removed, and sufficient time has not since lapsed for the eroded surfaces of these deposits to become greatly oxidized. On a few properties, however, as on the Lucky

Jim, the surface ores are in places conspicuously oxidized and exhibit the results of leaching action. On such properties, therefore, where the surface ores are oxidized and porous, an enrichment in copper is to be expected at the permanent water level. The amount of this enrichment will be governed by a number of factors, but will be proportional to the amount of leaching the surface ores have suffered, and will, of course, be entirely controlled by the amounts of copper present in the unleached primary ore.

GENESIS AND AGE.

In studying the genesis of the contact metamorphic deposits, a number of striking and definite points have been noted. In the first place, the minerals constituting the ore-bodies are chiefly, pyrrhotite, chalcopyrite, magnetite, pyrite, arsenopyrite, molybdenite, garnets, epidote, hornblende and other complex silicates, as well as quartz and calcite. This combination of magnetite with sulphides is very characteristic of contact metamorphic deposits, and is practically unknown in fissure veins. Further, when these iron sulphides and this iron oxide occur with garnets and related silicates, an association is produced which is diagnostic of contact metamorphism. In addition, these ore-minerals occur only along or in the vicinity of the contact between the granitic intrusives and the limestones. There thus appears to be little or no doubt, but that these ore deposits owe their origin to the granitic intrusives, and that the materials comprising them were derived from the parent magma of these granitic rocks, as neither these nor the limestones appear to contain the necessary iron, copper, and sulphur for their production.

As to the cause of contact metamorphism,[1] geologists who have made a special study of this subject agree that this phenomenon is due to the heat of the molten magma combined with the action of water which it contains. In many cases, no perceptible accessions of substance from the magma have taken place, while in perhaps as many others, important additions have been received. The amount of material that is derived from the intrusive body appears to be due mainly to two circumstances, the amount of water-gas in the molten igneous body, and the susceptibility of the invaded rock. In many intrusives, there may be present only a very small amount of water-gas, and thus the accession of material to the invaded formation may be slight, and the contact phenomena mostly due to the heat of the rock; if, however, the water vapour is abundant, the amount of material given off may be very great. Magmatic waters also vary widely; some contain large amounts of boron, fluorine, chlorine, etc., while others hold none of these, and possess chiefly sulphur, copper, iron, and related minerals. Thus, a wonderful variety of contact metamorphic deposits are found.

The contact metamorphic ore materials in the lime belt are, therefore, in all probability due to magmatic vapours rich in iron, copper, and sulphur, which were derived from the granitic intrusives. If this is true, the ore deposits were formed during the cooling period of the granitic batholith, which is thought to have occurred in Jurassic and probably late Jurassic time.

These deposits would appear to be closely related to the gold-copper veins and also to the gold-tellurium veins; these veins, however, have been apparently formed either somewhat later than the metamorphic deposits or were deposited higher up or farther from the seat of the igneous heat, but in either case apparently resulted from cool solutions rather than heated vapours and gases, the mineral ingredients, as in the

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[1] Lindgren, Waldemar, "The character and genesis of certain contact deposits"; T.A.I.M.E., vol. xxxi, 1901, pp. 226-244.

Lindgren, Waldemar, "Contact deposits": Min. Sci. Press, vol. CIII, Nov. 25, 1911, pp. 678-681.

Barrell, Joseph, "Physical effects of contact-metamorphism": Amer. Jour. of Sci., 4th series, vol. XIII, 1902, pp. 279-296.

case of the contact metamorphic deposits, being, however, derived from the granitic intrusive body.

DESCRIPTIONS OF MINERAL PROPERTIES.

Magnet Claim.

The Magnet claim is owned by Mrs. Polly Fox and Mr. Arthur Prichard. On this property two main deposits of ore minerals have been discovered, which, although within close proximity to each other, do not appear to be connected; the one is dominantly a pyrrhotite deposit and the other a deposit of magnetite. Limestones, andesitic volcanics, and granitic intrusives are all exposed on this claim in the vicinity of the ore bodies.

The pyrrhotite deposit strikes approximately N. 75° W.,[1] and where crosscut, is about 6 feet in thickness. The dip of this deposit is peculiar in that the ore material extends over the surface, blanket fashion, for 50 feet or more and then suddenly inclines downward almost vertically. This deposit occurs in a greyish to dark greenish volcanic rock of andesitic appearance, near its contact with the granitic intrusives. A crosscut tunnel 130 feet long has been driven, which cuts this ore material at a distance from the surface of approximately 100 feet. There the deposit has a thickness of 6 feet and consists dominantly of pyrrhotite, with some disseminated chalcopyrite, and also includes small amounts of quartz and some garnet, epidote, hornblende, and associated silicates, as well as numerous small included masses and particles of more or less replaced andesitic rock. This tunnel, with a number of small pits, cuts, and trenches constitutes the development work on this pyrrhotite body.

Two samples were taken from this deposit. No. 1 is an average sample from across the ore material in the tunnel, and No. 2 is a sample taken of the exposed material on the dump at the mouth of the tunnel. These samples were assayed[2] and proved to contain:—

	Gold.	Silver.	Copper.
			Per cent.
No. 1	Trace	None	0·61
No. 2	Trace	None	0·47

The magnetite deposit is only slightly exposed, but appears to have a thickness of from 1 to 6 feet. This deposit is composed mainly of magnetite with which is associated considerable epidote and related silicates, as well as some quartz and calcite. In places, included particles of andesite were noted which were almost entirely replaced by these minerals.

Nickel Plate Group.

The Nickel Plate group consists of three claims, the Nickel Plate, the Last Chance, and the Stemwinder, which are owned by Messrs. B. S. Bachus and T. Bachus.

On the Nickel Plate claim, several open-cuts, small pits, and trenches have been dug which constitute the development work on this property, and have exposed at a

[1] All directions given in this report, unless otherwise mentioned, are magnetic, the magnetic declination being approximately 25° O′ E.

[2] All the samples taken by the writer from the lime belt were assayed in the laboratory of the Mines Branch, Department of Mines, Ottawa.

number of points a typical contact metamorphic zone. In places, this metamorphic zone is composed mainly of garnet, epidote, hornblende, and related silicates, but at certain points includes more or less pyrrhotite with some chalcopyrite and pyrite. At the main showing on this claim an open-cut has been run, which crosscuts a metamorphic zone over 20 feet in width, on both sides of which the rock formation is a greenish, dense, finely-textured andesite. Limestone also outcrops at a distance of about 50 feet, and the andesite at the entrance to the cut is intruded by a narrow band of granitic rock.

Most of the rock exposed in the open-cut is very hard and dense, is either greenish or reddish in colour, and consists mainly of garnet, epidote, chlorite, amphibole, and related silicates. Ore minerals have, however, a considerable development throughout a portion of this metamorphic material exposed in the open-cut. These are chiefly limited to a band about 6 feet in width, and include mainly pyrrhotite with also some chalcopyrite and pyrite. This ore material occurs irregularly distributed throughout the metamorphic zone and occurs in particles, lenses, and masses, which follow in a general way certain fracture lines, the ore material being somewhat wider or more extensive at the surface than at the bottom of the cut, 10 feet lower down.

An average sample was taken across 6 feet of this zone exposed in the open-cut, in which the ore minerals are most abundantly developed. This sample was assayed and proved to contain: gold, a trace; silver, none; copper, 0·07 per cent.

At other points on this claim, extending in a general direction having a trend of about N. 50° W., similar metamorphic deposits are developed, and in most places pyrrhotite is conspicuous and generally contains some chalcopyrite. At one point some magnetite also occurs.

On the Last Chance claim, a heavy contact metamorphic zone is exposed at several points, but where noted is composed dominantly of the garnet-epidote-amphibole minerals, no point being noted where ore minerals were developed in any considerable amount.

On the Stemwinder claim, a band of ore material occurs at one point between limestone and a finely textured andesite, the ore material with associated metamorphic silicates being domed or arched over an underlying small core of limestone, and overlain by the andesite. About 12 inches of this contact material consists dominantly of pyrrhotite, overlying which is a layer or band of 18 to 24 inches in thickness, which is composed mainly of the metamorphic silicates with some quartz and calcite, and also includes some of the ore minerals. This contact ore material is only exposed for a distance of 10 to 15 feet along the surface.

On this group of claims, as elsewhere in the vicinity, the bedrock is nearly everywhere covered with superficial geological accumulations, in which is rooted a dense vegetation, thus rendering prospecting in this locality very difficult and arduous. Therefore, although the ore material so far found on these claims does not appear to be of economic importance, the area is evidently highly mineralized and one in which valuable ore deposits may occur. Further prospecting is thus warranted, and it is quite possible that valuable deposits of ore may yet be discovered in the vicinity.

Lucky Jim Group.[1]

The Lucky Jim group consists of three claims, the Rising Sun, the Saxon, and the Lucky Jim, which are reported to be owned by Mr. Alexander McNair of Vancouver. The main workings on this property are situated close to the Hastings Sawmill Company's railway tracks, about 3 miles from Granite bay.

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[1] Notes by Provincial Assayer: Report of the Minister of Mines, British Columbia, 1908, p. 148; 1910, pp. 158-159.
Bancroft, J. A., Op. cit., pp. 134-135.

The rock formation on these claims consists mainly of limestone and volcanic rocks, the volcanics including mainly greyish to dark greenish andesites, and some related finely-textured tuffs and breccias, which are more recent than the limestone. The limestone beds are less extensively developed than the andesitic rocks, and occur mainly as more or less connected lenses or small irregular masses included in or surrounded by the volcanics.

Deposits of ore material are exposed at a number of points on these claims, nearly all of which deposits are included in an area not exceeding a few hundred feet in diameter. This ore material occurs either along the contacts between the limestone and volcanics, or follows fracture lines or shear zones traversing these formations. The ore deposits are characteristically very irregular in form, and only one of these deposits has been actually traced for more than a few yards. This particular deposit, considered the main deposit on the Lucky Lim group, has been definitely followed for approximately 200 feet.

Considerable money has been expended in developing these claims and, consequently, quite an amount of work has been performed. A shaft, 115 feet deep, has been sunk, from which drifts have been driven. In addition, a tunnel reported to be 150 feet in length has also been driven. A number of trenches, pits, and open-cuts were also noted. A number of cabins have been built, and a commodious sheet-metal engine house has been constructed. The machinery equipment includes a small boiler and hoist, a larger boiler and eight-drill Rand compressor and pumps, all being installed in a very substantial manner.

On the Rising Sun claim a trench and open-cut, at the edge of a small lake or pond, have exposed a deposit which strikes N. 15° E., and is composed mainly of pyrrhotite and accompanying metamorphic silicates. This deposit has a width of 5 to 6 feet, and follows a well-defined fracture zone in greenish finely-textured andesitic rocks. Associated with the pyrrhotite are certain minor amounts of pyrite and chalcopyrite, the accompanying silicates being mainly epidote, garnet, and amphibole. This metamorphic deposit is notably irregular in form, and the ore minerals are very unevenly distributed. A band or zone about 12 inches in thickness, is, however, exposed for a few feet, which is composed almost entirely of pyrrhotite with more or less included chalcopyrite and pyrite, this band being considerably the best mineralized portion of this deposit.

An average sample taken across the 12-inch pyrrhotite band was assayed and proved to contain: gold, 0·16 ounces per ton; silver, none; copper, 0·86 per cent.

The main, or at least what appears to be the most important ore deposit on the Lucky Jim group, outcrops near the engine house, and on this deposit the 115-foot shaft has been sunk. This deposit has a varying strike of from N. 52° W., to N. 69° W., and dips to the southwest at an average angle of about 80 degrees. The ore material, for the greater part of the distance throughout which it has been traced, follows a prominent line of faulting which traverses the andesitic rocks, but near the shaft the ore material lies along the contact between the andesitic rocks and limestone. As in the case of all the ore deposits on this property, this deposit is everywhere in the close vicinity of limestone.

This ore material, where exposed near the top of the shaft, consists almost entirely of pyrrhotite with some chalcopyrite and pyrite. At other points along its strike, this deposit includes more quartz, epidote, garnet, and other silicates; and to the southeast of the shaft a mass of magnetite is exposed which is, at least approximately, on the strike of this deposit. Where composed dominantly of pyrrhotite, this ore material on the surface has much the appearance of very rusty pig iron. The writer was unable to get down the shaft on account of water, but on the surface near the shaft this ore material lies blanket fashion with an almost flat dip for 15 feet or more, and then suddenly pitches downward at an angle of about 80 degrees. This deposit, here, has a thickness of 18 to 36 inches and is composed almost entirely of the metallic ore minerals.

An average surface sample was taken across this ore deposit at a point where it was 20 inches thick, and proved to contain: gold, 0·24 ounces per ton; silver, none; copper, 4·13 per cent.

In places in this deposit, particles of native gold as well as of black lustrous telluride have also been found.

The Provincial Assayer of British Columbia, in reporting on this property in 1910, states:[1] "The management stated that there was good ore for the entire depth of the shaft, and that 184 tons, taken from about 75 feet down, gave $22 in gold, 8 per cent copper, and 3½ ounces of silver per ton, and at the bottom of the shaft the ore was even of a higher grade; an examination of the ore on the dump would seem to confirm the above statement."

Along the short spur of the railway running to the shaft, and midway to the shaft, a deposit occurs which is interesting as exhibiting the close relationship which exists between the ore materials and the limestone. There, the ore minerals encase on two sides, at least, a mass of limestones, the ore turning at an angle of about 90 degrees in conforming to the shape of the central limestone mass. From 6 to 8 inches of this ore material is composed almost entirely of pyrrhotite which has the appearance of a metal shell partly enclosing the limestone. Adjoining the pyrrhotite is a layer of quartz 2 to 3 feet in thickness which is very sparsely mineralized, the quartz and pyrrhotite being overlain by andesite.

To the northwest of the shaft, and some 200 to 300 feet distant, a very irregular deposit occurs which where exposed is anticlinal in form, overlying a core of some much altered and replaced rock. This deposit has an average thickness of about 3 feet, strikes approximately N. 15° E., and is composed mainly of pyrrhotite with which is associated varying amounts of chalcopyrite, pyrite, quartz, epidote, and garnet. An average surface sample taken across this deposit was assayed and proved to contain: gold, 0·20 ounces per ton; silver, none; copper, 1·52 per cent.

The samples taken by the writer from this group of claims, upon being assayed, showed the presence of more gold and copper than in the case of any other property in the lime belt, and on the whole these claims show possibly greater mineralization than any other property examined by the writer in this area. The management also claim to have obtained considerably higher assay returns than those given in this report, particularly encouraging assays being reported from the ore in the shaft. It would thus seem that further prospecting and exploration were quite warranted in this vicinity.

Hook Claim.

The Hook claim is owned by Mr. Edward Hamilton, and is located along the south side of the railway track, about 3½ miles from the beach. A pit about 8 feet deep has been sunk on this property, in which quartz and calcite, carrying more or less disseminated pyrrhotite and chalcopyrite, occur irregularly distributed in limestone bordering, but not closely following, granitic intrusives. The ore materials occur as bunches, lenses, or vein-like masses, as much as 2 to 3 feet in thickness. A sample was taken across the ore material in the bottom of the shaft, which has there a total width of about 4 feet. This was submitted to assay and proved to contain: gold, a trace; silver, none; copper, 0·13 per cent.

On the surface within a few feet of the shaft, a mass of ore material about 3 feet wide was also noted which consists dominantly of pyrrhotite.

Numerous quartz stringers also occur on this claim in places, which are as much as 3 or 4 inches in thickness and are reported to contain occasional particles of native gold.

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[1] Report of the Minister of Mines, British Columbia, 1910, p. 158

Gold Thread Claim.

The Gold Thread mineral claim is owned by William S. Morrin and Andrew Law. On this property there occurs a quartz vein in a fissure in andesite, which strikes N. 25° W., and dips to the northeast at an angle of 70 degrees. This vein forks or branches in places, and has an average width for the 8 or 10 feet throughout which it is exposed, of from 1 to 8 inches. This vein also consists dominantly of quartz which is very sparsely mineralized, but exhibits occasional particles of chalcopyrite, pyrrhotite, pyrite, native gold, and a black lustrous telluride which has been carefully examined by Mr. R. A. A. Johnston, of this Department, and found to be sylvanite.

Sunrise Group.[1]

The Sunrise group is situated along the railway track about 3 miles from the beach, and consists of the Geiler, the White Swan, the Mystic Cave, and the Sunrise claims, which are owned by Messrs. W. Stramberg and W. L. Cameron.

On the Geiler claim the geological formation consists of a complex of the Coast Range intrusives, andesitic rocks, and limestone. The andesitic rocks range from greyish to light green, decidedly porphyritic members exhibiting large, well-defined feldspar phenocrysts, to dark green, dense volcanics exhibiting either no phenocrysts which are visible to the naked eye, or containing only phenocrysts of the ferro-magnesian minerals.

On this property, contact metamorphic deposits are typically developed, and in addition, mineralized vein quartz also occurs and is exposed both in the form of veins or stringers, and as a breccia cement distributed throughout a well-defined brecciated zone.

Two shallow pits, about 100 feet apart, have been dug on this claim, in which are shown masses of ore material from 6 to 10 feet in width, consisting dominantly of pyrrhotite with some disseminated chalcopyrite. The strike of the ore material in each of these pits appears to be the same, about N. 75° E., which would indicate that possibly these two exposures constitute portions of a single deposit, persisting between the two pits. Further development work will, however, quickly decide this question.

An average sample was taken across this ore material in one of the pits where it was about 6 feet in width. This sample was assayed and proved to contain: gold, a trace; silver, none; copper, 0·12 per cent.

Two shafts, known as No. 1 and No. 2 shafts, which are 30 and 18 feet deep, respectively, have also been sunk on this claim. No. 1 shaft was sunk along the volcanic-limestone contact, and shows a contact metamorphic zone composed mainly of garnets, amphibole, epidote, quartz, and calcite, throughout which are sparsely disseminated some pyrite, arsenopyrite, and chalcopyrite. Occasional particles of native gold also occur. No. 2 shaft was sunk on a fractured zone in volcanics and exposed a somewhat irregular vein-like deposit of quartz and calcite ranging, where visible, from 1 to 18 inches in thickness, although it is claimed to be as much as 3 feet thick lower down. The quartz and calcite are sparsely mineralized with disseminated chalcopyrite, pyrrhotite, and pyrite.

At one point on top of the hill above the shafts on this claim, some chloritic schist is exposed, which appears to be an altered phase of the volcanics. This schistose rock is in places heavily impregnated with pyrite, arsenopyrite, and pyrrhotite, with which is also associated some disseminated chalcopyrite.

In addition to these somewhat typical contact metamorphic deposits, there is also exposed at one point on this claim, in the vicinity of the pyrrhotite deposits, a quartz stringer about 6 inches in thickness, which is highly mineralized with chalcopyrite.

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[1] Notes by Provincial Assayer; Report of the Minister of Mines, British Columbia, 1910, pp. 159, 160.
Bancroft, J. A., op. cit., p. 134.

There also occurs a well-defined brecciated zone traversing the andesitic volcanics which is at least 20 to 30 feet wide, and is traceable for a distance of over 500 feet to where the rock surface becomes obscured by superficial deposits. Throughout this zone the volcanics are extremely broken and shattered, and the rock fragments have become cemented mainly by quartz which, in addition to playing this rôle of binder, also occurs as veinlets and stringers prevailingly from 1 to 6 inches in thickness, cutting the volcanic rocks. To so great an extent has this secondary quartz been introduced into this association with the volcanics along this fracture zone, that it appears in places to constitute as much as one-half of the bulk of the entire rock mass. The quartz is but sparsely mineralized, and shows only occasional particles of pyrite, native gold, and a dark lustrous telluride which has been carefully examined by Mr. R. A. A. Johnston, of this Department, and found to be sylvanite.

This quartz has been only slightly prospected, due to the fact that it is so sparsely mineralized, and was not, until recently, known to contain native gold and sylvanite, and because also the rock surface is in most places covered with superficial deposits. It would appear, however, as quite possible that, with further exploration and development, this and similar veins or mineralized fractured zones in the lime belt, may prove to be of importance as a source of gold ore.

On the White Swan claim, more development work has been performed than on most of the other properties within the lime belt. An 11 by 8½-foot shaft has been sunk for 50 feet, and from the bottom of the shaft 100 feet or more of drifts have been driven. In addition, considerable surface work in the shape of pits, trenches, and open-cuts, has been performed.

A large pit about 14 feet deep has exposed three parallel mineralized fracture zones which strike about N. 72° E., all of which are included within a width of 18 feet. The larger central zone is about 4 feet thick, and the smaller deposits on either side range from 2 to 18 inches in thickness. These mineralized zones or deposits are composed mainly of pyrrhotite, chalcopyrite, arsenopyrite, pyrite, quartz, garnets, and epidote, the better ore material consisting mainly of quartz, pyrrhotite, and chalcopyrite. An average sample was taken across the central deposit, 4 feet from the surface. This was assayed and proved to contain: gold, a trace; silver, none; copper, 0·62 per cent.

The shaft on the White Swan claim was filled with water to within 12 feet of the surface, so nothing was seen by the writer below this depth. Furthermore, timbering obscured the walls of the shaft to near the water level, and the surface of the bed-rock is all covered in the vicinity of the top of the shaft. Thus no evidence could be obtained as concerns dip, strike, and general characteristics of this deposit. However, just below the timbering in the shaft, a mass of pyrrhotite ore is slightly exposed which appears to be about 12 feet thick. An average sample was taken across this 12 feet, which was assayed and proved to contain: gold, a trace; silver, none; copper, 0·70 per cent.

A number of other smaller deposits of this typical pyrrhotitic ore occur on this property.

Cormorant Group.

The Cormorant group is owned by Messrs. C. E. Lynn, Robert Sharp, Thomas Holman, and Alexander McNair. The main showing on this group is on the Pelican claim, where an ore deposit is exposed practically continuously for about 600 feet. This deposit follows a well-defined fault zone which strikes N. 55° W., and is included, dominantly at least, in finely-textured, greenish, andesitic rocks. Irregular bunches and lenses of limestone occur, however, in the vicinity of the ore material. The ore deposit consists prevailingly of pyrrhotite, but contains also some chalcopyrite, quartz, calcite, epidote, garnet, and amphibole. Fine particles of native gold are also reported to have been found associated with these minerals. The more northerly exposed 300 feet of this deposit has an average width of only a few inches, but throughout the more southerly 300 feet the deposit is from 1 to 6 feet in width, or may in places be even still wider.

Three samples were taken from this deposit. No. 1 is an average across the deposit at a point near its most southerly exposure, where the ore material is about 3 feet in thickness. No. 2 is an average across 12 inches of practically solid pyrrhotite with some disseminated chalcopyrite, occurring midway between the extreme northern and southern exposures of this deposit. No. 3 is an average across the deposit at practically its most northerly exposure where the ore material is about 18 inches in width. These samples were assayed and proved to contain:—

	Gold.	Silver.	Copper.
			Per cent.
No. 1	Trace	None	1·78
No. 2	Trace	None	0·50
No. 3	Trace	None	0·51

Contact Claim.

The Contact claim is also owned by Messrs. C. E. Lynn, Robert Sharp, Thomas Holman, and Alexander McNair, and adjoins the Pelican claim on the south. On this claim, the granitic intrusives and limestones are both extensively developed, the contact between these formations being well defined for 1,000 feet or more, throughout which it has a general strike of N. 35° W. Along this contact and in its vicinity, ore minerals are developed at a number of points, and the ore masses or bodies including these, resemble very closely the deposit on the Pelican claim which is described in this report. On the Contact claim, however, garnet, epidote, hornblende, and related silicates have a greater development than on the Pelican. The ore material on the Contact claim, consisting as it does, dominantly of pyrrhotite with some quartz and chalcopyrite, was nowhere observed to exceed 3 feet in thickness, and in most places ranges from 1 to 3 feet. At one point, four typical narrow parallel mineralized bands or zones were noted, all of which occur within a thickness of 15 feet. Three of these bands average each about 6 inches in thickness, and the other is about 12 inches thick.

Condor Group.

The Condor group consists of seven claims and a fraction, all of which are owned by Messrs. Alexander McNair, Thomas Holman, Robert Sharp, and C. E. Lynn. This group lies to the south or southeast of and adjoins the Contact claim.

On the Sea Gull claim which is at the northern end of this group, an irregular mass of quartz, apparently several feet in width, is developed along the contact between the granitic intrusive and limestone. This quartz contains some disseminated pyrrhotite and chalcopyrite, and also includes occasional flakes of molybdenite.

On the Anaconda claim, a fractured mineralized zone, 15 to 20 feet in width, occurs approximately along the contact between limestone and finely textured, greenish andesitic rocks, the contact having a general strike of about N. 55° W. Throughout this zone, the volcanic rocks are much altered and iron-stained, and include in places some disseminated pyrrhotite, chalcopyrite, garnet, epidote, and other silicates. Quartz also occurs in places within this zone, either irregularly distributed or in the form of narrow veinlets up to 6 or 8 inches in thickness, the quartz of the veinlets being characterized by long, interlacing, interlocking crystals. The owners of this group claim to have obtained very high gold assays from this fracture zone.

At a number of other points on the Condor group, small deposits of pyrrhotite and related minerals occur, and quartz stringers, prevailingly very sparsely mineralized, are plentiful in different places.

Gold Exchange Claim.

The Gold Exchange is owned by Messrs. B. S. and T. Bachus. Three prospect pits, 8 to 12 feet deep, have been sunk on this claim, at points along the contact between granitic intrusives and limestone. This contact strikes N. 55° W., and is more or less mineralized where exposed, there being in the vicinity of the shafts from 1 to 18 inches of quartz which is sparsely mineralized with pyrrhotite, pyrite, and chalcopyrite.

Near these shafts, and at the back of an open-cut, there is also developed a vein-like deposit in a fissure in limestone in the close vicinity of both andesitic volcanics and granitic intrusives. This deposit is about 4 feet in width, strikes N. 5° W., and dips at high angles to the east. About 1 foot of this deposit lying next the foot-wall, is composed dominantly of pyrrhotite, pyrite, and chalcopyrite, with which is associated some quartz. The overlying 3 feet, however, is composed mainly of quartz which is only sparsely mineralized, principally with the three metal minerals just mentioned.

YZ Claim.

The YZ claim is owned by Mr. P. W. Hall, and on this property a somewhat irregular, but generally tabular vein-like deposit is exposed in two prospect pits which are only a few feet apart, and each of which is about 20 feet deep. This deposit follows a well-defined fracture zone which strikes N. 23° W., and dips at about 60 degrees to the southeast. This zone of fracturing traverses both limestone and andesitic volcanics, and thus the ore deposit may be entirely in limestone or entirely in the volcanics, and for a few feet follows the contact between these formations.

The deposit ranges from 1 to 5 feet in thickness, and consists mainly of quartz, chalcopyrite, pyrrhotite, and pyrite. The metallic minerals are irregularly distributed throughout the quartz and appear to compose from 20 per cent to 30 per cent by volume of the total mass of the deposit.

An average sample was taken across this deposit at a point where it is about 3 feet in thickness. This sample was assayed and proved to contain: gold, a trace; silver, none; copper, 2·09 per cent.

BRITANNIA MINE, HOWE SOUND, B.C.

(R. G. McConnell.)

Situation.

The group of mineral claims owned by the Britannia Mining and Smelting Company, and known as the Britannia mine, is situated in the Coast range, east of Howe sound, about 20 miles directly north of Vancouver and 28 miles following the steamer route along the coast. Howe sound is an irregular fiord, cutting well back into the Coast range, and is bordered along its whole length by rugged mountains and high ridges. The claims now being worked are situated on a steep ridge, about 4,300 feet in height, separating Britannia creek from Furry creek. The principal workings are in the north slope of the ridge at a distance of 3¼ miles from the coast and at an elevation of 3,275 feet to 3,775 feet above sea-level.

Rocks.

The Coast range is built predominantly of granitoid rocks, mostly coarse quartz diorites or granodiorites, but contains at various points a number of inclusions of the older rocks invaded by the granitic magma. These vary in size from small angular fragments, a few feet across, to wide bands extending along the range for miles. The mineralized zone at the Britannia mine occurs in an inclusion or undestroyed area of the intruded rocks, from 1 to 2 miles in width and running southeasterly from Howe sound for a distance of over 7 miles.

The rocks in the inclusion consist largely of slate, alternating with a dark basic eruptive usually crushed and altered into greenish chloritic schists.

The slaty rocks, when unaltered, are dark in colour and contain considerable carbonaceous matter. They are seldom regularly cleaved, except for short distances, and in places pass into fine-grained quartz biotite schists. A hard quartzitic variety due to silicification is common and alteration into greyish and silvery white quartz sericite schists occurs at a number of points.

The crushed eruptive is economically the most important rock in the group. It forms the country at the Britannia mine and is also heavily mineralized at other points. It alternates with the slates and their altered equivalents the sericite schists, in bands and lenticular areas, ranging from a few feet to over 1,000 feet in width. Like the slates, it exhibits varying degrees of alteration, often passing in a short distance from a hard, irregularly-jointed rock to a soft, greenish, well-foliated, micaceous schist.

The massive varieties show considerable alteration in thin sections. They consist mostly of clouded phenocrysts of plagioclase in a groundmass of decomposition products and small feldspar laths and might be classed either as porphyrites or andesites. The original ferro-magnesian minerals have entirely disappeared. Amygdules filled with chlorite or calcite or a mixture of both occur in some of the sections.

A light green variety of the crushed eruptive, blotched conspicuously with dark green chloritic films and irregular plates, often half an inch or more in length, forms the principal country along the mineralized zone of the Britannia mine. The origin of the dark green areas has not been definitely determined. The fact that the porphyrite is vesicular in places, makes it probable that they represent crushed chlorite-filled amygdules rather than altered ferro-magnesian phenocrysts or fragments of included slate. The close connexion between the spotted schists and the ore may have a genetic basis if this assumption is correct, as the vesicular bands would furnish the easiest channels for the ascending sulphide-bearing solutions.

Dykes genetically connected with the surrounding Coast Range batholithic rocks, usually abundant in inclusions, are rare in the Britannia area, except near the contact.

An excellent section of the alternating slates and crushed intrusives is afforded by a tunnel driven from Britannia creek at an elevation of 2,100 feet above sea-level, southwards across the strike of the rocks, for a distance of 4,200 feet.

Mineralization.

Mineralization at the Britannia mine is on an extensive scale. The deposits are of the replacement type and formed along wide, irregularly-fissured zones, enclosed in and striking with the greenstone schists. The most conspicuous croppings occur in the Jane and adjoining claim to the east, and consist of two high-stained bluffs, about 1,000 feet apart, facing each other across the drift-covered bottom of Jane Creek valley. The mineralized zone exposed in the two bluffs consists of silicified schists impregnated with iron, copper, and zinc sulphides, and has a width in the eastern or Mammoth bluff, of fully 200 feet. It undoubtedly extends across the concealed interval separating the two bluffs and may be considered to have a proved minimum length of 2,000 feet.

East of the Bluff mineral zone a number of disconnected croppings occur in the steep mountain slope covered by the Fairview claim. A tunnel driven under these from the Mammoth Bluff at a depth of about 1,000 feet below the crest of the ridge resulted in the opening up of a second important mineral zone, practically a continuation of Bluff zone, but separated from it by a short lean stretch. The strike is also more to the south. Development work on the second, or Fairview zone, is still in progress and its full dimensions have not been ascertained. The work done up to the present, has shown it to have a minimum width of fully 500 feet, made up of bands of commercial ore, separated by barren, or nearly barren, schists. Drifts have been carried along the zone for a distance of 1,200 feet.

MINERALS.

The metallic minerals in the Britannia ore bodies consist of pyrite, chalcopyrite, considerable zinc blend in certain areas, and rarely some galena. Small quantities of black oxide of copper and bornite occur as alteration products, but are nowhere abundant. The gangue is principally the greenstone schists forming the country, more or less silicified. Small quartz veins, generally following closely the direction of the schistosity, but frequently cutting directly across it, are numerous. Calcite in very small quantities is occasionally present and some fluorspar has been found.

ORES AND ORE BODIES.

The wide Bluff mineral zone originally worked, is practically a low grade copper deposit throughout its whole extent. Pyrite in masses and disseminated in grains and veinlets through the silicified country gangue, is the most abundant mineral present. Chalcopyrite in small lenses, veinlets, and scattered grains occurs with the pyrite, but in much smaller quantities and in places a notable percentage of blende is present. No mining is at present being done on this zone. A considerable tonnage was mined and concentrated before the discovery of the Fairview zone, but the venture was not commercially successful. Since then transportation has been improved, better methods of treatment, largely increasing the recovery, have been adopted, and the ores could probably now be mined and treated at a fair profit. The average tenor in copper is about 1½ per cent and, in addition, the ores carry one-half to one ounce in silver and in the western portion of the zone, 40 cents in gold per ton.

The character and distribution of the ores in the Fairview zone differ markedly from that in the Bluff zone. The chalcopyrite, the principal valuable mineral present, in place of being disseminated more or less irregularly through the whole width of the zone, is concentrated along certain lines in fairly definite ore bodies, ranging in width from a few feet to 30 feet or more, which have proved very persistent. The ore bodies are not confined between walls and are marked only by a cessation of the mineralization, both metallic and non-metallic. They are approximately parallel, but occasionally diverge or unite at a low angle. The dip is to the west, at an angle of about 70 degrees, and is conformable or nearly so, to that of the enclosing schists. Six ore chutes have been encountered in the present workings and followed for varying distances up to 1,000 feet. The vertical range has been proved for 500 feet.

The chalcopyrite in the ore bodies occurs characteristically in fairly large nearly pure aggregates, usually as short lenses occasionally a foot or more across, in stringers interleaved with or cutting the schists at a low angle and in reticulating veinlets, penetrating the silicified schists in all directions. Only a small percentage occurs in disseminated grains. The quantity present varies in the different ore bodies and along the dip and strike of the same ore body. The general average tenor in copper of the whole system of leads is given at 2½ per cent. The silver contents are small, amounting only to about four-tenths of an ounce per ton, and gold occurs only in traces.

The proportion of pyrite present is much smaller than in the Bluff zone, and zinc blende, prominent in the latter, is absent.

The production in 1912, according to published statement, amounted to 193,000 tons, yielding 14,300,000 pounds of copper and 76,500 ounces of silver. The present production is approximately 600 tons per day, the full capacity of the transportation facilities from the mine to the beach.

DEVELOPMENT.

The Fairview mineral zone has been opened up by five levels, at elevations of 1,050, 850, 700, 600, and 500 feet below the summit of the ridge into which they are driven. The levels, with numerous crosscuts and upraises following the ore bodies, serve to explore the zone for a distance of 1,200 feet along the strike and 500 feet along the dip. A long tunnel at a depth of 1,200 feet below the present lowest level, starting from Britannia creek, is now completed to a point beneath, and a short distance west of, the ore bodies worked. This will be connected in the near future with the upper workings by a large, three-compartment shaft and an ore chute. The extension downwards of the ore bodies, below the 1,050-foot level, can be reached from the shaft by short drifts.

GENERAL TREATMENT OF ORE.

The chalcopyrite in the Fairview ore bodies occurs, as a rule, in fairly large aggregates, usually separated by considerable waste, and the material mined is concentrated before shipment. The ore is crushed at the mine and transported to the concentrating mill at the beach by an aërial tram built in two sections, with a daily capacity of about 600 tons. At the mill, it is first washed in a 4 by 8-foot trommel with 1½-inch perforations. The oversize discharges on to a sorting belt, and about 50 tons of 12 per cent ore and 150 tons of waste are picked out daily from the 600 tons received. The milling ore, except the undersize, from the washing trommel, passes from the conveyor to a Blake crusher, and then through several sets of Gaetz spring rolls, which reduce it gradually to the size required, about 2in., for treatment in Hancock jigs. The greater part of the sulphides are separated in these machines. The tailings and the undersize, from 1½in. trommels, are ground in Hardinge pebble mills to a 40-mesh, or smaller size, and subjected to the mineral separation flotation process, the details of which are still kept secret. The Hancock jigs used are of the Anaconda type, and the separation of the sulphides by them, followed by the use of the minerals separation process on the finer material, has given excellent results, only a very small percentage of the sulphides escaping. The concentration is in the ratio of 4 to 1.

EQUIPMENT.

The present equipment is inadequate to the needs of the mine, and extensive improvements and enlargements are under way. A new concentrating mill with a daily capacity of 2,000 tons is contemplated, and work is in progress on a system of transportation of the ores from the mine to the coast, which involves the construction of a double-track gravity tram line, a mile in length, with an average grade of 15 per cent; a switch-back track, 5 miles in length, on a 3 per cent grade, on which gasoline locomotives will be used: a 9 by 13-foot tunnel, 3,600 feet in length, at an elevation of 2,100 feet, and a 1,200-foot vertical chute, connecting the tunnel with the present workings.

Water-power furnished by Britannia creek is largely used to operate the mill, compressors, and other portions of the extensive plant; 1,800 horse-power has been developed, and this, with a 650 horse-power obtained from steam, is ample for present requirements.

SHARP POINT HOT SPRING, VANCOUVER ISLAND, B.C.

(C. H. Clapp.)

On the west side of Sharp point, a narrow headland of the "west coast" of Vancouver island, between Sidney inlet to the east and Refuge cove to the west, is a hot spring issuing from a sheared diorite, and containing predominant sodium chloride and silica. This spring has been known for a long time, and it is reported that for several years sailors have bathed in its waters. In 1898, Mr. W. M. Brewer, a well-known mining engineer of Victoria, controlled the water rights of the spring and sent a sample to the Geological Survey for analysis. On learning from the analysis, made by Mr. F. G. Wait and published by Dr. Hoffmann in the Annual Report of the Geological Survey of Canada for 1899, vol. xii, pp. 55 R-56 R, that the spring water apparently had no medicinal or therapeutic properties, Mr. Brewer allowed his claim to lapse, but recently another application for the water rights has been made by Mr. Wallace Rhodes. The writer first learned of the occurrence of the hot spring on his trip to Kyuquot sound and visited it on his return. A small sample was collected, insufficient for a complete analysis, but sufficiently large so that a comparison of the present character of the water can be made with the character of the water in 1898 when Mr. Brewer collected his sample. As the spring is the best known of the very few hot springs known to occur on Vancouver island (the writer has heard of the occurrence of only one other hot spring on the island, a mile from the head of Fair harbour, Kyuquot sound), a description of the general features of the spring and a repetition of the analysis seem advisable.

The spring is situated 150 feet from the west shore of Sharp point, about 1,000 feet from the outer end, and about 60 feet above high tide level. In calm weather a landing can be made from a small boat at the spring, and at all times the spring may be reached by a trail, somewhat over a mile in length from the first protected bay indenting the east shore of Refuge cove.

Sharp point is a rather rough, narrow headland over 2 miles long and from 1,000 to 4,000 feet in width. It is composed of granitic rocks which form large, glacially-rounded ledges, which attain an elevation of 200 to 400 feet above sea-level. As the rainfall of the region is heavy, about 120 inches a year, the headland, like the rest of the region, is covered by a heavy forest growth and thick underbrush. The outer end of the headland is composed of a medium-grained, somewhat gneissic diorite composed essentially of andesine feldspar and hornblende with accessory magnetite and apatite. The rock is moderately altered to uralite, chlorite, a little epidote, sericite, and kaolin. The diorite is evidently a marginal facies of the granodiorite, which forms the middle and inner portions of the headland. The granodiorite is typical of the principal granodiorite of Vancouver island, the Saanich type, and is a light grey, medium-grained rock of subhedral texture, composed of well-formed grains of andesine-oligoclase feldspar, which has a pronounced zonal growth and ranges from ca. Ab. 65 An. 35 to ca. Ab. 85 An. 15, and hornblende, with interstitial quartz and orthoclase, flakes of biotite, and accessory magnetite. The rock is only slightly altered to kaolin, sericite, uralite, and chlorite. The granodiorite is the younger rock and is intrusive into the diorite, which is similar lithologically to and is correlated with the Beale diorite.[1]

[1] *See* Memoir No. 13, Geol. Surv., Can., 1912. pp. 99-101.

The water issues from a shear zone 6 inches wide, striking about N. 70° W. in the diorite. The writer estimated the flow to be about 100 gallons per minute and the temperature at the orifice to be about 125° F. (52° C.). Mr. Brewer, presumably from measurement, reports the rate of flow in 1898 to have been 100,000 gallons per day (70 gallons per minute) and the temperature 124° F. (51° C.).

The analysis of the 1898 sample made by F. G. Wait, recalculated to the ionic form of statement recommended by Clarke,[1] is given below with a statement of the amounts of the hypothetical salts present as calculated by Hoffmann.[2]

			Parts per million.
Potassium (K)	0·4	KCl	3
Sodium (Na)	28·4	NaCl	348
Calcium (Ca)	4·1	$CaCl_2$	2
Magnesium (Mg)	0·2	$MgCl_2$	5
Chloride (Cl)	44·9	$CaSO_4$	66
Sulphate (SO_4)	9·8		
Silica (SiO_2)	12·2	SiO_2	59
Organic matter	trace	Organic matter	trace.
	100·0		483
Salinity parts per million	480		
Specific gravity at 15·5°C	1,000·5		

Hoffmann states that the 1898 sample contained a very trifling amount of white, flocculent matter in suspension, which was removed by filtration, and that the filtered water was colourless, odourless, and devoid of any marked taste, and that the reaction was neutral. The white flocculent matter apparently separates from the water after cooling, and has been deposited on the banks of the small stream issuing from the spring and on the rocks and fragments of wood in the stream. The flocculent matter was not particularly examined by the writer, but was thought to be sulphur, and at the spring the water has a fairly strong odour of hydrogen sulphide, although no hydrogen sulphide was detected by the chemist, Mr. H. A. Leverin, in the sample collected by the writer after it had reached Ottawa. At the spring the water had a rather disagreeable taste, due largely to the sodium chloride and the hydrogen sulphide.

A comparison of the 1898 sample with that collected by the writer has been made by Mr. H. A. Leverin of the Mines Branch, and is given below:—

	1898 Sample.	1913 Sample.
Specific gravity at 15.5 C.	1,000.5	1,000.5
SO_4, parts per million	47	35
Salinity, parts per million	480	504

As shown by the analysis, the water of the Sharp Point spring is classed, according to the classification proposed by Lindgren,[3] with the warm, ascending sodium chloride and silica waters occurring in igneous rocks. As Lindgren states,[4] there is strong reason to suspect that such waters are in part of juvenile origin, that is, that the water is being given off from a cooling magma, and that it is reaching the earth's surface for the first time. However, as Lindgren also points out, the criteria for the distinction between juvenile and meteoric waters are not definite, and the distinction in the case of the Sharp Point waters is doubly difficult because of the situation of the spring, within a few feet of the ocean, for, as is well known,[5] wells and springs along

[1] Data of Geochemistry Bull. 491, U.S. Geol. Surv., 1911, p. 57.

[2] Geol. Surv., Canada, Ann. Rept., xii, 1899, p. 56 R.

[3] Waldemar Lindgren, Mineral Deposits, 1913, pp. 41-64.

[4] Op. cit., pp. 90-91.

[5] Waldemar Lindgren, op. cit., p. 46.

sea coasts usually contain a higher percentage of sodium chloride than those farther inland, presumably caused either by infiltration of sea waters into the rocks or by winds carrying finely divided salt from the spray of the ocean. That the Sharp Point water comes from considerable depths is amply testified by its high temperature, copious flow, which is much greater than could be accounted for by the shallow circulation of meteoric waters through the dense crystalline rocks forming the narrow headland, and by its comparative constancy in amount of flow, temperature, and salinity, as shown by the two analyses and observations by Mr. Brewer and by the writer. The granitic rocks from which the spring issues are of upper Jurassic age, and they have doubtless lost, even to very great depths, the greater part of their initial heat. No recent volcanic or other igneous rocks are known in the vicinity, although the discovery of evidence of comparatively recent volcanism would not be surprising. It is probable that the granitic rocks have been heated by comparatively late shearing, during which the shear zone from which the spring issues may possibly have been formed. The water may be entirely meteoric and in part derived from the ocean, or may be in part magmatic. In this instance it is interesting to compare the water in the manner suggested by Palmer[1] with the average analysis of sea-water, as calculated by Dittmar and recalculated by Palmer, and with an analysis by W. Skey, quoted by Clarke[2], of the water from the pink terrace, Rotorua geysers, New Zealand, that more closely approaches the analysis of the Sharp Point water than any other cited by Clarke.

	Sharp Point hot spring.	Ocean water.	Pink terrace, Rotorua geysers.
Base analyses.	Parts per million.	Parts per million.	Parts per million.
Radicles—			
Sodium (Na)	137	10,710	662
Potassium (K)	2	390	10
Calcium (Ca)	20	420	71
Magnesium (Mg)	1	1,300	5
Sulphate (SO_4)	47	2,700	136
Chloride (Cl)	217	19,350	1,026
Carbonate (CO_3)	...	70	...
Bromide (Br)	...	60	...
Colloids—			
Silica (SiO_2)	59	...	815
Alumina (Al_2O_3)	...	...	10
Ferric oxide (Fe_2O_3)	...	...	trace.
Total dissolved solids	483	35,000	2,735

Reacting values.	Formula.	Mg per litre.	Formula.	Mg per litre.	Formula.	Mg per litre.
Radicles—						
r Na	42·00	5·960	38·49	466·021	42·94	27·03
r K	0·36	0·051	0·82	10·015	0·41	0·26
r Ca	7·04	0·998	1·77	21·203	5·62	3·54
r Mg	0·58	0·082	8·92	107·268	0·65	0·41
r SO_4	6·89	0·978	4·62	56·099	4·49	2·83
r Cl	43·13	6·125	45·15	545·583	45·89	28·95
r NO_3	...	...	0·07	0·739	...	...
r CO_3	...	...	0·16	2·086	...	...
Concentration value	100·0	14·194	100.0	1,209·014	100·0	63·02

[1] Chase Palmer, Geochemical Interpretation of Water Analyses. Bull. 479, U.S. Geol. Surv., 1911.

[2] F. W. Clarke. Data of Geochemistry. Bull. 491 U.S. Geol. Surv., 1911, p. 185.

Groups.	Per cent.	Mg per litre.	Per cent.	Mg per litre.	Per cent.	Mg per litre.
Alkalies	42·36	6·011	39·31	476·036	43·35	27·29
Earths	7·62	1·080	10·69	128·471	6·27	3·95
Hydrogen	0·0	0·0	0·0	0·0	0·0	0·0
Strong acids	50·02	7·103	49·84	602·421	50·38	31·78
Weak acids	0·0	0·0	0·16	2·086	0·0	0·0
Concentrative value	100·0	14·194	100·0	1,209·014	100·0	63·02

Properties.			
Primary salinity	84·7	78·6	86·7
Secondary salinity	15·3	21·1	12·5
Tertiary salinity (acidity)	0·0	0·0	0·8
Primary alkalinity	0·0	0·0	0·0
Secondary alkalinity	0·0	0·3	0.0
	100·0	100·0	100·0

It is seen from the above table that the Sharp Point water is similar to sea-water in regard to the proportion of sodium chloride present, but differs radically from sea-water in that the relative proportions of magnesium and calcium are reversed, and in the presence of silica. It is also similar to sea-water in that it is neutral, having no alkalinity such as surface, lake, and river waters usually possess, and no acidity as is common in the case of mine waters and of waters of volcanic origins.[1] However, the presence of hydrogen sulphide in the water at the spring indicates that as it issues from the rock the water is slightly acid. On the other hand, except for its much smaller amount of total dissolved solids and somewhat smaller percentage amount of silica, the Sharp Point water is very similar to the Rotorua geyser water, which issues from Tertiary and recent volcanic rocks, and which is probably in part of juvenile origin. If the spring were not situated so near the ocean, its comparative constancy of flow, temperature, salinity, composition of the water, which although traversing granitic rocks is rich in sodium chlorite and lacking in carbonates, similarity of the water to that of the Rotorua geysers, and the geological occurrence of the spring would all indicate that the water was at least in part juvenile. Under the circumstances, however, it is possible that the sodium chloride is derived from sea-water which is able to penetrate the sheared diorite to such depths that it becomes relatively hot, and that the hot water on its journey to the surface gathers its load of silica and calcium; but the presence of a larger percentage of sulphate than occurs in sea-water and of hydrogen sulphide is of very difficult explanation according to this hypothesis of the origin of the waters.

The prospective value of hot mineral waters appears to be as speculative as the location of a popular pleasure resort. The Sharp Point water is apparently lacking, or nearly so, in most of those minor constituents like bromine, iodine, sulphur, lithium, barium, strontium, and iron, to which the therapeutic value of mineral waters is commonly ascribed;[2] but, as mentioned, the water is similar in its percentage composition to the Rotorua geyser waters, which are supposed to have great healing qualities. Except for the wet climate, the Sharp Point spring is apparently favourably located for a summer resort, which would certainly be cool and afford a variety of ocean and mountain scenery and an abundance of out-of-door activities.

[1] Chase Palmer. Geochemical Interpretation of Water Analyses. Bull. 479, U.S. Geol. Surv., 1911, p. 14.

[2] F. W. Clarke, Data of Geochemistry, Bull. 491 U.S. Geol. Surv., 1911, p. 173.

GEOLOGY OF A PORTION OF THE DUNCAN MAP-AREA, VANCOUVER ISLAND, B.C.

(C. H. Clapp and H. C. Cooke.)

Introduction.

The greater part of the field season of 1913 was spent by the writers and their assistants in a geological examination of the central and southern portions of the Duncan map-area of southern Vancouver island. The geology was plotted on the Duncan topographical map, prepared in 1910 under the direction of R. H. Chapman. This map consists of a thirty-minute sheet, mapped on a scale of 1:96,000 (1 inch = 8,000 feet) for publication at about 2 miles to 1 inch, with topography shown by contours at an interval of 100 feet. The total land area on Vancouver island and adjacent islands represented by the map is about 600 square miles. This includes that portion of Vancouver island between the forty-ninth parallel, which passes through the northern part of the town of Ladysmith, and the 48° 30′ parallel, which crosses Vancouver island near the pronounced valley occupied by the Leech and Jordan rivers and their tributaries, and between longitudes 123° 30′ and 124 degrees; also several small islands off the east coast of Vancouver island, and portions of Saltspring and Galiano islands. The geological mapping of the Duncan map-area and the Sooke map-area, the adjoining map-area to the south, was commenced in 1912,[1] and the entire Sooke map-area, except the East Sooke peninsula and the southern portion of the Rocky Point peninsula, and the greater part of a strip of 5 to 10 miles wide, extending across the southern part of the Duncan map-area, was completed. During 1913 the geological mapping of the rest of the Duncan map-area, about 550 square miles, was finished, as well as the uncompleted portions of the Sooke map-area, about 16 square miles.

The field work, although under the supervision of C. H. Clapp, was largely under the immediate direction of H. C. Cooke. The assistants were those employed during 1912, Victor Dolmage and Angus McLeod, and to their effective co-operation is due the successful prosecution of the summer's work.

Previous Work.

In 1908, 1909, and 1910, C. H. Clapp made reconnaissances over the southern part of Vancouver island, including the entire area mapped during the field season of 1913, and more detailed work was done in the vicinity of Mount Sicker in 1908 by C. H. Clapp, and in the vicinity of Mount Richards, Maple bay, and Southern Saltspring island in 1909 by J. A. Allan. The results of Clapp and Allan's work are presented in considerable detail by Clapp in Memoir No. 13, Geological Survey, Canada, 1912, with a reconnaissance geological map of southern Vancouver island. Previous to the work done under Mr. Clapp's direction, the only work that had been done was that of James Richardson, during the seventies, on the Cretaceous coal measures of the northeastern part of the map-area, and that of the Provincial Department of Mines and a few mining engineers on the mining districts of the area, especially that of Mount Sicker. As is true of much of Vancouver island, considerable private but unpublished work had been done by the late Mr. W. J. Sutton.

[1] C. H. Clapp. Geology of portions of the Sooke and Duncan map-areas, Vancouver island, British Columbia. Sum. Rep., 1912, Geol. Surv., Can., p. 41.

Since the area is treated rather fully in Memoir No. 13, as well as in the Summary Reports for 1908, 1909, and 1912, many of the subjects will be treated only briefly in this report, especial emphasis, however, being laid on those results obtained during 1913, which confute or support Clapp's previous conclusions.

Summary and Conclusions.

GENERAL GEOLOGY.

The oldest rocks of the Duncan map-area are a series of greatly deformed and partly schistose sedimentary and volcanic rocks, the Leech River formation and the Malahat volcanics. They are more metamorphosed and, therefore, apparently older than the rocks of the Vancouver group, and are assigned provisionally to the Carboniferous.

The lower Mesozoic rocks, constituting the Vancouver group, consist of the Vancouver volcanics and the Sutton formation and the Sicker series. The Vancouver volcanics are chiefly meta-andesites and intercalated in them; but also occurring as isolated lentils in the intrusive granitic rocks, are the contemporaneous crystalline limestones of the Sutton formation. The Sicker series consists of closely folded and greatly metamorphosed, chiefly schistose sedimentary, although probably tufaceous, rocks and volcanic rocks, almost exclusively porphyritic andesites. The relations of the Sicker rocks with the Vancouver volcanics are indefinite.

Intrusive into the rocks of the Vancouver group are batholiths and stocks of granitic rocks, and injected into the Sicker series are sills, dykes, and larger irregular masses of acid and basic porphyrites. The granitic rocks and also the porphyrites were irrupted during one general period of intrusion, during and following the deformation of the older rocks, probably in upper Jurassic time, and they are, therefore, correlated with the Coast Range batholith of British Columbia. Considered in detail, the granitic rocks are subdivided into three types, which were irrupted in a definite sequence as follows: Wark gabbro-diorite gneiss, Colquitz quartz diorite gneiss, and Saanich granodiorite. The first two types form virtually a single batholith and have been dynamo-metamorphosed, but their gneissic structure is considered to be a primary feature. Before the irruption of the Saanich granodiorite the Sicker series were injected first by sills and masses of the Tyee quartz-feldspar porphyrites, and later by sills, dykes, and larger irregular masses of the Sicker gabbro-diorite porphyrite. During and following the injection of the porphyrites the Sicker series and intruded porphyrites were closely folded, converting all the less competent formations into schists. Later all the rocks were intruded by the Saanich granodiorite.

A long period of erosion followed the irruption of the granitic rocks and porphyrites unroofing them and cutting deep broad valleys in the "stratified" or surface-formed rocks, those traversing the deformed Sicker series apparently having been developed along anticlines. However, the metamorphic and granitic rocks were not peneplaned but retained a relief of one or two thousand feet when submergence began and the deposition of the Nanaimo series, conglomerates, sandstones, and shales was initiated in Upper Cretaceous time. As is shown by its fauna the Nanaimo series is partly of marine origin, probably estuarine since it was deposited on a surface of considerable relief, and as the character of its sediments indicates a very rapid accumulation and deposition in relatively small basins. As the series also contains land plants and some coal, most probably of fresh-water accumulation, terrestial conditions must have alternated with marine conditions. It seems as if the sediments were first deposited in a marine basin between Vancouver island and the mainland. During the deposition the sedimentation progressed inland, at first filling the valleys in the pre-Upper Cretaceous erosion surface, and then, since remnants of the Nanaimo series have been found on mountain sides at elevations of 2,500 feet, possibly covering even the higher residual elevations. The maximum thickness of the Nanaimo series was, towards the close of its deposition, at least 10,000 feet.

The Nanaimo series was moderately deformed, presumably in post-Eocene time, since upper Eocene sediments and volcanics to the south were similarly deformed. In the northeastern part of the map-area the series, which there forms a part of the Nanaimo basin, was deformed into broad open folds, the axes of folding having a general northwest-southeast strike, and the prevailing dip being to the northeast. In the central part of the map-area the series, which there forms the Cowichan basin, has been deformed into closed folds, striking about N. 70° W., and slightly overturned to the southwest, so that most of the rocks dip steeply to the north.

Mantling the hard rocks are superficial deposits of various kinds, which, although deposited by river, lake, marine, and glacial agencies, are composed largely of glacial detritus. They were deposited during the Admiralty and the Vashon glaciation and during the Puyallup interglacial epoch. Since the last glacial epoch, the deposits have been uplifted, terraced along the larger valleys, in places covered by recent alluvium, and retrograded along the shore.

ECONOMIC GEOLOGY.

Gold occurs in the gravels of the streams which have cut into the Leech River formation, having been derived from small and very low grade quartz veins. The gravels, while of a fair grade, occur only in small amounts and, within the map-area examined during 1913, only in the extreme western part, in the vicinity of San Juan river and Meadow and Floodwood creeks.

Copper occurs in contact deposits; impregnated and replaced shear zones with accompanying quartz veins; in quartz veins; and in a lens-like body in a syncline of the Sicker schists, called the Tyee type. The Tyee ore body has been productive in the past but is now largely worked out. Development work is being done on the King Solomon claim, the mineral body of which is a modification of the contact and the impregnated and replaced shear zone types. Few of the other deposits are apparently of any commercial value, although some of the impregnated and replaced shear zones, especially within the Sicker series, may be of prospective interest.

Iron claims have been taken up on certain magnetite bearing schists of the Sicker sediments, but the known deposits are apparently too small to warrant mining.

Coal and oil have been sought for in the Nanaimo series, but no persistent coal seams are known, and since the deformation of the series is considerable, the geological conditions for the occurrence of commercial coal are not favourable. Whereas the structural conditions for the accumulation of oil are favourable there are no rich bituminous beds in the Nanaimo series, nor have any important seepages of oil ever been found in the Nanaimo series, either at outcrops or during the extensive boring for coal.

The crystalline limestones of the Sutton formation furnish excellent material for the manufacture of lime and Portland cement and for fluxing. Lime has been manufactured on the west shore of Saanich inlet and at present the limestone at this locality is being used for the manufacture of Portland cement on a fairly large scale. The "shale" which is mixed with the limestone in the manufacture of the cement is obtained from one of the slaty tuffs of the Malahat volcanics from the west shore of Finlayson arm.

The clays of the superficial deposits are suitable for common brick and drain tile but are used at present only at Somenos for the manufacture of common brick. Some of the shales of the Nanaimo series are possible sources of shale clay which could be used for the manufacture of brick and various kinds of semi-porous ware and stoneware. These shales are similar to those being used in the vicinity of Nanaimo and on North Pender island, but are not at present being utilized within the Duncan map-area.

Sand and gravel are obtained from the superficial deposits for use in concrete construction and for road ballast.

The sandstones of the Nanaimo series have been quarried for building stone on Saltspring island and northwest of Cowichan, and furnish a material of fair grade, but of rather dull colour. They have not been quarried for several years.

General Character of the District.

TOPOGRAPHY.

The greater part of the area represented by the northern portion of the Duncan sheet is a part of the mountainous, plateau-like region of southern Vancouver island, composed of resistant metamorphic and crystalline rocks, which have apparently been reduced to a nearly smooth surface, surmounted, however, by a few hills of especially resistant rocks, then uplifted, considerably dissected, and later glaciated. The even sky-line of the dissected plateau, or upland plain, broken only by the few rounded hills which surmount the general level of the plateau, and by deep and, in places, very steep walled valleys, is the most characteristic feature of the topography. The elevation of this upland plain is almost 1,800 feet in the extreme southeastern part of the Duncan map-area, but increases to the northwest to 2,500 feet, and in the western part of the map-area to over 3,000 feet. The upland attains a maximum elevation in the northwestern part of the area of 3,500 to nearly 4,000 feet, although in this region the plain was apparently never well developed, but the region retained before uplift, considerable relief. The conspicuous rounded hills, which surmount the upland, resemble low cones with rounded apexes, and are from 200 to 600 feet higher than the upland.

They range in elevation from 1,977 feet (Mount Wood on Malahat ridge) and 2,400 feet (Mount Bruce on Saltspring island), in the eastern part of the map-area, to 3,140 feet (Mount Tod) and 3,427 feet (Waterloo mountain), in the western part of the area, attaining a maximum elevation of 3,931 feet (Mount Brenton) and 4,268 feet (Mount Hall and Coronation mountain) in the northwestern part of the map-area, where, as mentioned, the region probably retained considerable relief before uplift.

The upland is separated into a northern and southern portion by a wide, deep valley, having a general S. 70° E. trend, which crosses the map-area near its middle. It is from 2 to 6 miles wide, and attains a maximum elevation of 500 feet in its western part, while the eastern end is submerged below sea-level. It is called the Cowichan valley, since it is occupied by the Cowichan river, which drains Cowichan lake, a large lake in a glacially over-deepened portion of the valley, west of the map-area, and flows southeastward, emptying into Cowichan bay, formed by the submerged eastern end of the valley. For the greater part of its 20-mile course, the river meanders in the flat floor of the valley between cut banks of sand and gravel 10 to 200 feet high. It seems, therefore, as if the river had been revived by a recent uplift, which has affected Vancouver island, and had been entrenched in its own food-plain. The uplift was not sufficient, however, to revive the submerged eastern end, where during the present cycle the Cowichan river is building an extensive delta.

The other valleys which dissect the upland are rather irregularly patterned, although a great number of the larger valleys have a general north-south trend, corresponding with the general movement of the glaciers which overrode Vancouver island. These glaciers scoured out the pre-Glacial valleys, notably the north-south valleys and the Cowichan valley, widening them, steepening their sides, but within the map-area, apparently not deepening them greatly. A few small lakes occur in some of the valleys, but most of these have been formed by dams of glacial drift. The easternmost north-south valley has, however, been severely glaciated. It is now below sea-level, and forms a fiord-like passage, called Sansum narrows, separating the southern, upland portion of Saltspring island from the upland of Vancouver island north of the Cowichan valley. The southward continuation of this submerged, glaciated, north-south valley is the wide Saanich inlet, the southern portion of which, called Finlayson arm, is, however, narrow and fiord-like.

The northeastern portion of the map-area is a part of the east coast lowland of Vancouver island that has been formed by the rapid erosion of the less resistant sedimentary rocks, fringing the east coast and lying on the more resistant metamorphic and crystalline rocks which form the upland axis of the island. Since the sedimentary rocks underlying the lowland are varyingly resistant, as well as moderately disturbed, their strike being northwest and their dip northeast, the lowland has considerable relief, extensive valleys having been developed in belts of soft rocks between ridges composed of more resistant beds. The hard rock ridges are of the cuesta type, with very steep, in places nearly vertical, front slopes, and gentle dip or back slopes. It appears as if most of the lowland portion of the Duncan map-area had been depressed sufficiently to drown the valleys, forming the long, wide channels, passes, and harbours of the region, while the hard rock ridges remained above sea-level as long points and islands, which are characteristically long and occur in chains.

CLIMATE AND VEGETATION.

Near sea-level the temperature of the region is uniform and temperate throughout the year, the average being near 40° F. in winter, and from 55° to 60° F. in summer. On the upland the differences in temperature are, of course, much greater. The amount of rainfall varies considerably in different parts of the area. On the lowland of the eastern part, in the lea of the upland, the rainfall is about 35 inches a year, while on the upland the rainfall varies from 60 inches, in the eastern part of the map-area, to about 90 inches in the western part. The greater part of the rain falls during the winter months, while the summer is usually dry.

With the exception of the cleared land, virtually the entire area is heavily forested. The principal forest trees are Douglas fir, red cedar, hemlock, and spruce, with some yellow cedar, balsam, and pine. Where the forest is thick, the underbrush is usually not very abundant, but in the outer and more open areas it is extremely thick, and is a great hindrance to travel. It consists of dense shrubs, such as salal, salmon and huckleberry, and varieties of maple and alder. In the poorly drained glaciated valleys, high, broad-leafed ferns and devil's club abound.

Considerable land has been cleared for cultivation in the drift-covered Cowichan valley and in the lowland and island region of the northeastern portion of the map-area, but the upland, except where logged and burnt, is still mantled with its original forest growth. The chief agricultural products are garden vegetables, fruit, and grain.

MEANS OF ACCESS.

The lower, eastern portions of the map-area and the Cowichan valley are readily accessible, but the upland regions are traversed by only a few trails, which, with one or two exceptions, are not suitable for pack animals. The upland is, therefore, reached and examined only by packing trips of several days duration. The eastern portion of the map-area and the Cowichan valley are traversed by excellent trunk roads and numerous branch roads. The Esquimalt and Nanaimo railway crosses the eastern part and follows fairly closely the east shore of Vancouver island. A branch line extends from Duncan, near the east end of the Cowichan valley, westward along the northern side of the valley to Cowichan lake. The grade of the Vancouver Island line of the Canadian Northern system crosses the southern part of the area a few miles to the west of the Esquimalt and Nanaimo railway, following a narrow glaciated valley leading into Cowichan valley and then following the southern side of Cowichan valley to Cowichan lake.

General Geology.

Table of Formations.

Quaternary	Recent	Beach, valley, and swamp alluvium.
	Glacial	Colwood sands and gravels. Stage of glacial retreat. Vashon drift. Stage of glacial occupation. Puyallup clays, sands, and gravels. Interglacial deposits. Admiralty till. Earlier glacial epoch.
Mesozoic	Upper Cretaceous	Nanaimo series.
	Upper Jurassic (and possibly Lower Cretaceous.)	Batholithic and minor intrusives. Saanich granodiorite. Sicker gabbro-diorite porphyrite. Tyee quartz-feldspar porphyrite. Colquitz quartz diorite gneiss. Wark gabbro-diorite gneiss.
	Jurassic and Triassic	Vancouver group. Sicker series. Relative age doubtful. Cherts, states, and schists; prophyritic andesites. Sutton formation. Lower Jurassic and may include Triassic. Lentils of crystalline limestone. Vancouver volcanics. Lower Jurassic and probably Triassic. Chiefly massive and porphyritic andesites.
Palæozoic	Carboniferous (?)	Malahat volcanics. Massive and schistose meta-dacites and meta-andesites, tuffs, and fine-grained cherty rocks. Leech River formation. Slates, slaty and quartzose schists, micaceous quartzites, amphibolites, and chloritic schists.

GENERAL DESCRIPTION OF FORMATIONS.

Leech River Formation.

Apparently the oldest rocks, not only of the Duncan map-area, but of southern Vancouver island as well, are a series of metamorphic, fine-grained sedimentary rocks, with some fragmental volcanics that have been called the Leech River formation.[1] Only the western part of the belt of these rocks which extends across the southwestern portion of the Duncan map-area, was examined during 1913. The lithology and structure of the formation in this part are virtually the same as to the east, so that the description given for the eastern portion is applicable to the western, and the following is taken from the Summary Report for 1912, page 46:—

"The metamorphic sediments consist chiefly of carbonaceous, slaty schists, with some true slates and micaceous and quartzose schists, and even micaceous quartzites. There are in places, especially along the northern boundary of the belt, some metamorphic volcanic rocks, now converted to amphibolite and chlorite schists. Some of the quartz-biotite schists are probably of volcanic origin. The rocks are greatly deformed and have a general strike parallel to the trend of the belt which the formation underlies. The dips are steep, ranging chiefly from 60 degrees to 90 degrees, the prevailing dip being to the north. Sheared and slickensided rocks are common, and doubtless many faults occur. Non-persistent veins and lenses of quartz are exceedingly numerous, and carry small values in gold. Along the northern boundary of the belt the metamorphic sediments of the Leech River formation are transitional into the metamorphic Malahat volcanics. The two formations are conformable, but their contact is fairly definite."

[1] *See* Memoir No. 13, Geol. Surv., Can., 1912, pp. 35-44; and Sum. Rep., Geol. Surv., Can., 1912, p. 46.

In the extreme western part of the map-area, north of Meadow creek and San Juan river, the Leech River rocks are separated from the younger Vancouver volcanics to the north by a profound fault, that appears to extend some 30 miles to the west, following the San Juan valley to the west coast. The age of the Leech River formation is doubtful, but has been considered provisionally to be Carboniferous.[1]

Malahat Volcanics.

To the north of the Leech River formation, and conformable with it, is a series of schistose and chiefly fragmental volcanics, largely of the composition of a dacite, that has been called the Málahat volcanics.[2] Only the western portion of the belt of these rocks, which lies to the north of the Leech River formation, was examined during 1913. The rocks of the western portion are similar to those of the east, and the description of the eastern portion from the Summary Report for 1912, page 46, will suffice here:—

"The rocks consist chiefly of dacite tuffs, varying from fine-grained carbonaceous and argillaceous tuffs to coarse-grained, sandy tuffs and breccia. There are also some flow rocks, both dacites and andesites. The rocks are prevailingly schistose, and many of the fine-grained tuffs are cherty. The rocks have been greatly deformed, having an altitude conformable with the Leech River sediments. They are sheared and slickensided, and cut by small veins and lenses of quartz."

The southern boundary of the Malahat volcanics is irregular, and is formed by the Vancouver volcanics and the intrusive Wark gabbro-diorite gneisss. In the extreme western part the boundary between the Malahat and the younger and less deformed Vancouver volcanics is the eastward extension of the fault separating the Leech River formation and the Vancouver volcanics. The greater part of the contact between the Malahat and the Vancouver volcanics is, however, concealed, and its nature is not known. Since the Malahat volcanics are conformable with the Leech River sediments, they are considered to be of the same age, that is, provisionally Carboniferous.

VANCOUVER GROUP.

The Vancouver group consists of the pre-batholithic rocks of Vancouver island, which are either known or are thought to be lower Mesozoic, Jurassic, and Triassic, in age; and they comprise the larger part of Vancouver island. Those rocks of the Duncan map-area that are assigned to the Vancouver group are the Vancouver meta-volcanics, the intimately associated and contemporaneous Sutton limestones, and the Sicker series.

Vancouver Volcanics and Sutton Limestones.

The Vancouver volcanics consist of metamorphic, basic volcanic rocks, principally meta-andesites, with both flow and fragmental types, the flow types predominating. They occur along the southern part of the area surveyed during 1913, south of Cowichan valley, underlying a belt 2 to 13 miles wide, that widens to the west, and extends from the Saanich inlet across the entire map-area. Associated with the Vancouver volcanics are beds of chert-like tuffs, similar to those associated with the Metchosin volcanics[3] and with the Sicker series. These are in places interbedded with flow rocks where fragmental material appears to be absent, and may be chemical precipitates.

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[1] Memoir No. 13, Geol. Surv., Can., 1912, pp. 43-44.
[2] Sum. Rep., Geol. Surv., Can., 1912, p. 46.
[3] Sum. Rep., Geol. Surv., Can., 1912, p. 48.

The Sutton limestones occur chiefly as lentils of dark-coloured, fine-grained, crystalline limestones, or light-coloured marbles, intercalated with the meta-volcanics. Several of these lentils, up to nearly a mile in length and 1,000 feet in width, occur with the Vancouver volcanics. The Vancouver volcanics and Sutton limestones are in general contemporaneous and conformable, the limestones probably having been built by marine organisms that lived on the shores of the volcanic islands formed during the eruption of the Vancouver volcanics. However, the actual contact between the two formations is intrusive, the volcanics cutting the limestones. At one place, 2 miles south of Cowichan valley, near the western border of the map-area, is a complex or breccia of chert and limestone, whose origin is obscure. On the north bank of Koksilah river, at the crossing of the Canadian Northern railway grade, is a breccia consisting of angular fragments of what appear to be Vancouver meta-volcanics in a matrix of fossiliferous limestone. This breccia has apparently been formed by fragments of the volcanics, which had been blown into the air by an eruption, falling into the beds of marine organisms, chiefly corals or crinoids, that were lying on the shores of what was possibly an island volcano. The age of some of the Vancouver volcanics and Sutton limestones is lowermost Jurassic, but they doubtless include some Triassic rocks.[1]

The Vancouver volcanics and Sutton limestones are deformed, although not nearly to such an extent as are the Malahat volcanics, or even as much as the Sicker series is in places. The prevailing strike is about N. 60° W., and the dip averages about 30 degrees to 45 degrees, and is chiefly to the south. They are also intruded by the batholithic rocks, along the southern boundary of the belt by the Wark and Colquitz gneisses, and along the northern boundary of the belt, by the Saanich granodiorite. Small isolated stocks of these intrusive rocks are also found at some distance from the main contacts. South of Cowichan valley in the western portion of the belt, and on Waterloo mountain, the Vancouver volcanics are cut by dykes of augite-hornblende porphyry resembling that of the Sicker series.

Sicker Series.

The Sicker series, consisting of a series of interbedded metamorphic volcanic and sedimentary rocks, underlies the northern third of the Duncan map-area. The series was first met with in 1908, and in Clapp's first long report on southern Vancouver island,[2] the series was described and mapped as including the intrusive porphyrites, since enough detailed work was not done to map the intrusive porphyrites separately. In 1909, J. A. Allan described a portion of the Sicker series as the Sansum formation.[3] This formation embraced the less metamorphosed rocks of the Sicker series, chiefly the fragmental rocks lying to the south of the more schistose members, chiefly volcanic and intrusive, and apparently included some unmetamorphosed sediments, chiefly shales, which have since been proved to be of Upper Cretaceous age, and members of the Nanaimo series. For this reason, and because the identity of the less metamorphosed rocks with the more metamorphosed rocks of the Sicker series was proved, the Sansum formation was not described nor mapped separately in Memoir No. 13. In 1910, Clapp mapped the Sicker series of a portion of southern Saltspring island and of Portland and Moresby islands in the northern part of the Saanich map-area, in considerable detail (for publication on a scale 1:62,500);[4] and subdivided them into the Sicker volcanics and the Sicker schists—also recognizing and mapping separately the porphyrites intrusive

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[1] Memoir No. 13, Geol. Surv., Can., 1912, pp. 68-71.

[2] Memoir No. 13, Geol. Surv., Can., 1912.

[3] Sum. Rep., 1909, Geol. Surv., Can., 1910, p. 99.

[4] See Geology of Saanich and Victoria map-areas, Memoir No. 36, Geol. Surv., Can., 1914.

into the Sicker series, describing them as granodiorite porphyrites and Sicker gabbro-diorite porphyrites. The term "Sicker series" was, however, limited to the "stratified" or surface-formed rocks, the Sicker volcanics and schists, the intrusive porphyrites being described and in general correlated with the batholithic and minor intrusive rocks of probably upper Jurassic age, which are correlated with the Coast Range batholith. It did not seem to Clapp, nor does it to the present writers after their work of last summer, that the Sansum formation is a distinct unit, and hence the term was not employed in Memoir No. 36, nor is it employed in the present report, and its further use is discouraged. The two subdivisions of the Sicker series, as determined in the Saanich map-area, were found during 1913 by the writers (Cooke had charge of virtually all the field work in connexion with the mapping of the Sicker series) to be distinguishable throughout the Duncan map-area, the Sicker series being subdivided into the Sicker volcanics and the Sicker sediments, the latter term being preferable to Sicker schists. The intrusive porphyrites were, of course, also recognized, and were mapped, and are described under the batholithic and minor intrusives as the Sicker gabbro-diorite porphyrites and the Tyee quartz-feldspar porphyrites.

Sicker volcanics: Porphyritic andesites.—As the basement on which the Sicker series was laid down is not exposed in the area studied, it is impossible at this time to state with certainty whether the basal members of the series are the volcanics, which are porphyritic andesites, or the sediments. The nearest approach to a basal stratum discovered is a great flow of hornblende porphyry in the northern part of the map-area. This flow is intruded by a large batholith of granodiorite, and dips gently southward away from it. Upon the amygdaloidal surface of this flow, or series of flows, the sediments lie with apparent conformity. This flow differs somewhat from the ordinary porphyritic andesite of the Sicker series in that it is fresher and less deformed, probably because its folding was not extreme as in the case of the other types; its porphyritic texture is more strongly developed, and hornblende phenocrysts locally attain diameters of half an inch or more over areas of several square rods; breccias and amygdaloidal phases are very common, and the nodular phase of the ordinary lava, presently to be described, is entirely absent. However, in the opinion of the writers, the two are of similar age and origin, as their composition is virtually identical, and their relations to the sediments similar.

The ordinary porphyritic andesites of the series, typically developed on Mount Richards, Mount Maple, Saltspring island, and in Coronation canyon, are clearly interbedded with the sediments. They are lavas of an olive green colour, the groundmass fine-grained, and containing in the more massive forms numerous phenocrysts of hornblende, up to 3 or 4 mm. in diameter. Where not too greatly altered, as in Coronation canyon, amygdaloidal upper surfaces may be observed. Fragmental varieties are rare, and only one doubtful occurrence was observed. The massive porphyritic phases grade into finer-grained forms, usually much more schistose, in which phenocrysts are entirely absent, or almost so. As this change goes on, another in the reverse direction accompanies it. Nodules and strings of greenish material, seen under the microscope to be mainly epidote (pistacite), with about 35 per cent of quartz, appear, and increase in size and number as the rock becomes finer grained and less porphyritic. They are of all sizes to 3 and 4 inches in diameter. The nodules may contain phenocrysts of hornblende where the rock in which they occur is porphyritic; but the phenocrysts in such cases appear to be fewer and smaller in the nodules than in the surrounding lava.

Sicker sediments.—The sediments with which the porphyries are interbedded are an interesting set of rocks grading from green, white, red, or black cherty rocks to black slates. Between these extremes lie a number of varieties whose exact petrographic nature has yet to be determined. Macroscopically, they are greenish, tuff-like rocks, of about the hardness of slates.

Bedding in these sediments is rarely seen except in the hard cherts, which have not been rendered schistose by deformation. In these, the bedding is indicated principally by colour differences; the beds are one-half to 4 inches in thickness, very uniform, and may be traced for considerable distances. Evidently they have been laid down in quiet water. The softer sediments have all been converted to true slates and schists; in them the bedding can only be seen when the beds differ notably in colour. The strike of the bedding varies from N. 45° to 65° W. in the majority of the cases; that of the schistosity is usually about N. 55° W., or approximately parallel to the axes of folding.

STRUCTURAL RELATIONS.—As already mentioned, the Sicker series has been intruded by the Tyee quartz-feldspar porphyrites and by the Sicker gabbro-diorite porphyrites. The quartz-feldspar porphyrites form large sills and irregular masses, and were apparently intruded before the deformation of the Sicker series, since, as described in the following paragraph, they have been greatly deformed, and in places converted into schists. The Sicker gabbro-diorite porphyrites form sills, dykes, and large irregular masses, and were also intruded to some extent before the deformation of the Sicker series, since they have been somewhat deformed. The Sicker series is also intruded by stocks and batholiths of the Saanich granodiorite.

The Sicker series and the intrusive quartz-feldspar porphyrites have been closely folded and the crests of the anticlines removed by erosion. The remaining synclines outcrop in a series of parallel belts, of which there are three in the map area; the belts are separated by pre-Cretaceous valleys, now filled with Nanaimo sediments. The axes of the synclines strike about N. 65° W., and plunge toward the west at low angles, generally from 10 degrees to 15 degrees.

The areal relations illustrate this well: the belts comparatively narrow toward the east, widen gradually toward the west. The strikes of the rocks are in all cases approximately parallel to the strike of the axes of the folding, varying from N. 45° to 65° W. The dips are nearly all steep, rarely lower than 50 degrees, although in one case on the east slope of Mount Brenton, dips as low as 20 degrees were observed. Minor folds can rarely be noted, except where hard, thin-bedded cherts are found. In the other thin-bedded, less-competent formations, the bedding has, in most cases, been entirely obliterated by subsequent deformation, which has converted them into schists. During this folding the harder beds of cherts, and the intrusive gabbro-diorite porphyrites, acted as competent units and suffered very little, except for zones a few feet in width at their edge. The more incompetent layers, however, which included the softer tufaceous beds, the porphyritic andesites, and the thinner sills of intrusive quartz-feldspar porphyrite, were greatly deformed, and in places were converted into slates, chlorite schists, and sericite schists, respectively.

AGE AND CORRELATION.—The Sicker series has been considered by Clapp to be one of the members of the Vancouver group, which includes all the pre-batholithic rocks of Vancouver island, which are known to be or probably are of lower Mesozoic, Triassic, or Jurassic age, and to be in general conformable with the Vancouver volcanics.[1] It was suggested by him that the Sicker series occurred near the upper part of the Vancouver group and overlay the Vancouver volcanics, although certain objections to this conclusion were advanced.[2] No definite evidence as to the relation of the Sicker series with the Vancouver volcanics was obtained last year. Only at two places were the rocks of the Sicker series found in contact with those of the Vancouver volcanics. (1) On Mount Waterloo, dykes of augite porphyry were noted cutting the andesites. These dykes, on account of their petrographic resemblance to the Sicker

[1] Memoir No. 13, Geol. Surv., Can., 1912, pp. 83-85.
Memoir No. 36, Geol. Surv., Can., 1914, p. 28.

[2] Memoir No. 13, Geol. Surv., Can., 1912, p. 83.

porphyritic andesites, were tentatively correlated with them. If the microscopic study of the two rocks confirms the field determination, it will suggest the conclusion that the Sicker series is younger than the Vancouver volcanics. Such evidence at best, however, is of only moderate value. (2) Cherts, slates, and hornblende porphyry of the Sicker series were found on the south side of the Cowichan valley, in the bed of a small creek near the western boundary of the map-area. These are well bedded, and dip to the southwest toward the Vancouver volcanics. This structure might seem to indicate that the Sicker series passes beneath the Vancouver volcanics, and hence is probably the older. Unfortunately, intrusions of the Tyee quartz-feldspar porphyrite and the Sicker gabbro-diorite porphyrite have been injected between the older series, so that it is now impossible to draw with certainty any conclusion as to their relations. However, since the external structural relations of the Sicker series are the same as those of the rest of the rocks of the Vancouver group, the Sicker series are considered as members of the Vancouver group, and in general conformable with the Vancouver volcanics.

BATHOLITHIC AND MINOR INTRUSIVES.

Intrusive into all the formations described above are batholiths and stocks of plutonic (granitic) rocks and smaller masses of injected rocks. The plutonic or batholithic rocks were irrupted during one general period of intrusion, during and following the deformation of the older rocks, probably in upper Jurassic time, and are, therefore, correlated with the Coast Range batholith of British Columbia.[1] Considered in more detail, however, the granite rocks may be divided into three types, which were irrupted in a definite sequence as follows: Wark gabbro-diorite gneiss, Colquitz quartz diorite gneiss, and Saanich granodiorite. The smaller masses of injected rocks were probably irrupted during the same general period and consist of acid and basic porphyrites, which are classified as quartz-feldspar porphyrites and gabbro-diorite porphyrites, these last being injected into the Sicker series only, having been called the Sicker gabbro-diorite porphyrites.[2] Within the limits of the Duncan map-area the quartz-feldspar porphyrites are also virtually confined to the Sicker series, and have been given the distinctive name of Tyee quartz-feldspar porphyrites.

Wark and Colquitz Gneisses.—No new material concerning the Wark and Colquitz gneisses was obtained during 1913, and the following description is condensed from the Summary Report for 1912. The Wark gabbro-diorite gneiss and the Colquitz quartz diorite gneiss are very intimately related, and form virtually a single batholith that extends almost entirely across the southern part of the Duncan map-area. The older type, the Wark gabbro-diorite gneiss, is a fairly typical fine to coarse-grained gabbro-diorite, composed chiefly of plagioclase feldspar and hornblende, with more or less biotite. Although large masses of the typical gabbro-diorite occur, it is nearly everywhere cut by numerous apophyses of quartz diorite and quartz-feldspar gneisses, and frequently a complex of the gabbro-diorite and the quartz diorite gneisses has been formed, in which the two types cannot be mapped separately. The Colquitz quartz diorite gneiss forms also large lenticular masses, which are intrusive into the gabbro-diorite gneiss. The Wark and Colquitz gneisses have been dynamo-metamorphosed by movements after their intrusion, but most of their gneissic, and in some places, banded structure, appears to be primarily due to movements during their intrusion, or before they became completely crystallized. They are also considerably altered and fractured.

[1] Memoir No 13, Geol. Surv., Can., 1912, pp. 112-113.
[2] Memoir No. 36, Surv., Can., 1914, p. 80.

Saanich Granodiorite.—The youngest batholithic rock, the Saanich granodorite, forms several small batholiths and much smaller stocks that are intrusive into the Vancouver volcanics and the Sicker series, including the Tyee quartz-feldspar porphyrites and possibly the Sicker gabbro-diorite porphyrites, which are both intrusive into the Sicker series. However, as stated below, the granodiorite masses intrusive into both the Sicker series and its associated porphyrites may be younger than the typical Saanich granodiorite. Those intrusive into the Vancouver volcanics occur in the southern part of the area surveyed in 1913, and consist of two batholiths, 6 or 7 miles in diameter, one in the eastern part of the map-area bordering Saanich inlet, and the other south of the middle portion of Cowichan valley. Besides these there are several small stocks, which are apparently protuberances of a much larger batholith, which may underlie the Vancouver volcanics at no great depth. Evidence of this is given by the occurrence of granodiorite in the stream bottoms, notably along the lower portions of the Koksilah river, while the upland on either side is capped with the Vancouver volcanics. With one exception, the batholiths and stocks intrusive into the Sicker series are rather small, and elongate in the general direction of the foliation of the Sicker series, that is about N. 65° W. The larger masses occur on Saltspring island, Maple mountain, Mount Brenton, and on the ridge north of the Cowichan valley near the western boundary of the map-area. The largest batholith of the map-area, intrusive into the Sicker series, is in the northwestern part of the map-area, west of Ladysmith. It is 7 miles long and at least 4 miles in width.

The Saanich granodiorite is a light-coloured, fine to rather coarse-grained, granodiorite, typical of the batholith of the coast region of British Columbia. It consists essentially of feldspar, orthoclase and andesite, quartz, accessory hornblende, and usually biotite. It contains also numerous small rounded segregations, darker coloured than the normal rock, and consisting chiefly of plagioclase and hornblende. The granodiorite, although less metamorphosed than the Wark and Colquitz gneisses, is considerably altered, greatly fractured, and in places, especially south of Cowichan valley and west of Ladysmith, somewhat gneissic. At the contacts with the intruded rocks, contact shatter breccias have been developed and apophyses of a lighter coloured and more felsic (salic) rock cut not only the intruded rock but the normal granodiorite.

Most of the masses intrusive into the Sicker series are composed of a granodiorite which differs from the typical Saanich granodiorite in that it is less altered and contains more of the potash feldspar, and a more sodic plagioclase, and more biotite. This type has been previously considered by Clapp[1] to be a phase (the Ladysmith phase) of the Saanich granodiorite, but it is possible that it is a younger rock, intruded separately after the irruption of the typical Saanich granodiorite.

Tyee Quartz-feldspar Porphyrite.—The Tyee quartz-feldspar porphyrite forms sills and irregular masses that are intrusive into the Sicker series, and is given the distinctive geographic name, Tyee, since the copper deposits of the region, of which the Tyee is the best known, are found closely related to the porphyrite. The rock varies greatly in composition from alaskitic or felsic porphyrite, with numerous phenocrysts of quartz, up to 4 or 5 mm. in diameter, to a much more basic rock in which phenocrysts of quartz are absent or nearly so, and their place taken by numerous phenocrysts of white feldspar. Further description of the petrography of this formation is deferred until the microscopic work has been completed. The feldspar porphyrite is economically the most important formation of the district, since in it are found the copper deposits, described briefly below.

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[1] Geology of the Nanaimo map-area. Memoir No. 51, Geol. Surv., Canada, 1914.

The quartz-feldspar porphyrite has been intruded by the Saanich granodiorite, and has suffered greatly from the effects of metamorphism during the deformation of the Sicker series, and with the exception of the thick mass on Saltspring island, it has been converted to schists. These are sericitic schists of varying degrees of acidity, corresponding to the degree of acidity of the porphyrite from which they were formed. Such schists are difficult to distinguish in the field from the sericitic schists which have resulted from the alteration of some of the softer cherty sediments of the Sicker series, but the distinction can usually be made by examining the weathered surface for phenocrysts of quartz or feldspar, many of which resist the deformation even when it is extreme, and through the easier weathering of the surrounding sericitic groundmass, stand out on the weathered surface.

Sicker Gabbro-diorite Porphyrites.—The Sicker gabbro-diorite porphyrites form large irregular masses, dykes, and sills, which are intrusive only into the Sicker series. They vary from rocks of the composition of a diorite to those of a basic gabbro. They are characterized in the more typical forms by a porphyritic texture, with phenocrysts of white feldspar. Rarely these phenocrysts are arranged in a star-shaped form, giving rise to the rosette texture described by Clapp.[1]

The relations of the Sicker gabbro-diorite porphyrite and the Saanich granodiorite are rather indefinite, since no contacts of the two rocks were found exposed. At the only points where the two rocks must be in contact, namely, on the summit of Mount Brenton, and to the north of Coronation canyon, the outcrops are heavily covered with drifts, and no contacts were seen. The granodiorite, which at these places is the Ladysmith phase, is, however, considered younger than the gabbro-diorite porphyrite for three reasons: (1) three inclusions were found at as many places in the granodiorite, of rock petrographically similar to the gabbro-diorite porphyrite. One of these inclusions, which was small, contained phenocrysts of feldspar with a sub-radial arrangement, "rosette tendency." (2) The granodiorite is not deformed, even where it is in contact with hard, competent cherts, as greatly as the gabbro-diorite porphyrite, which, although also competent, is in places converted into schists at its edges. (3) The mass of granodiorite on the summit of Mount Brenton appears to cut directly across the strike of the intruded rocks, and to break through both the gabbro-diorite porphyrite and an intercalated band of cherts. The areal relations of this mass would seem to show decisively that the granodiorite came into place after the intrusion of the gabbro-diorite porphyrite into the cherts.

NANAIMO SERIES.

The unmetamorphosed sedimentary rocks of southern Vancouver island, supposed to be of Mesozoic (largely Upper Cretaceous, Nanaimo) age and possibly of lower Cenozoic (Eocene) age, were previously grouped together by Clapp and called the Cowichan group,[2] since the sediments could not be definitely subdivided and were supposed to consist of two or more unconformable formations. It was found, however, during the detailed work of 1910 and 1911 in the Saanich and Nanaimo map-areas that all the sediments of the so-called Cowichan group were conformable, and largely, if not entirely, of Upper Cretaceous age and members of the Nanaimo series or formation, so named and described by Richardson,[3] Whiteaves,[4] and Dawson.[5] Since the probability of there being any Eocene members in the conformable series of sediments

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[1] Memoir No. 13, Geol. Surv., Can., 1912, p. 80.

[2] Memoir No. 13, Geol. Surv., Can., 1912, p. 124 and pp. 134-136.

[3] James Richardson. Report on the Coal Fields of Nanaimo, Comox, Cowichan, Burrard inlet, and Sooke, British Columbia, Geol. Surv., Can., Rep. of Progress, 1876-77, pp. 160-192.

[4] J. F. Whiteaves Mesozoic Fossils, vol. 1, part II, Geol. Surv., Can., 1879, pp. 93-96.

[5] G. M. Dawson. The Nanaimo Group. Am. Jour. Sci., vol. xxxix, 1890, pp. 180-183.

is very slight, the name Nanaimo was extended to embrace the entire conformable series, which in the Nanaimo map-area has been definitely subdivided into various members or formations. It was found during 1913 by Cooke that the transition supposed by Clapp[1] to occur along the Chemainus river between the unmetamorphosed rocks of the Cowichan group and the metamorphic rocks of the Sicker series does not exist, but that the supposed transition is in reality a transition between somewhat metamorphosed conglomerates and sandstones and conformably overlying unmetamorphosed sandstones and shales, and that the metamorphosed conglomerates rest unconformably upon the schistose Tyee quartz-feldspar porphyrites (sericitic schists), intrusive into the Sicker series. The proofs of unconformity found by Cooke are as follows: (1) the conglomerate and the Tyee quartz-feldspar porphyrite schists have similar strikes and are of somewhat similar colour, but the conglomerate dips about 60° S., while the Tyee schists dip about 65° N. (2) There is no gradation but a definite contact between conglomerate and the schists at the base of the former. (3) The conglomerate contains pebbles which clearly have been derived from the underlying Sicker series and the intrusive Tyee porphyrites, slates, cherts, and sericitic schists, some of which have a porphyritic texture. (4) The sericitic schists, which, as mentioned, have resulted from the metamorphism of the Tyee quartz-feldspar porphyrites intrusive into the Sicker series, are cut by two quartz veins, each about 5 inches in width and striking almost north and south, and these veins are cut off squarely against the base of the overlying conglomerates. It was also supposed by Clapp that the steply-dipping sandstones and shales exposed along the Chemainus river and forming the base of Mount Prevost were unconformably overlain by the gently dipping conglomerates forming the top of Mount Prevost.[2] The discordance of dip is now explained more satisfactorily in some other way than by an unconformity, since farther west the lower shales are conformably overlain by sandstones and finally by conglomerates, a sequence which is also exposed along the Chemainus river south of Mount Sicker, and since there is no suggestion elsewhere of an unconformity in the sedimentary series. The discordance may be due to the crumpling and nearly isoclinal folding, during the deformation of the sedimentary series, of the weak shales beneath the more competent conglomerates, which were deformed only into broad open folds. It is also possible that some thrust faulting has occurred along the contact of the shales and conglomerates. It is thus fairly certain that all of the sediments previously mapped as the Cowichan group are conformable and, since they contain in places fossils of Nanaimo age, are all members of the Nanaimo series. The term Cowichan group will, therefore be used no longer by the present writers and its further use by anyone is discouraged.

The rocks of the Nanaimo series occur in two principal areas or basins, one in the northeastern part of the map-area, being a portion of the southeastward extension of the Nanaimo basin, and the other extending across the central portion of the map-area called the Cowichan basin. The portion of the Nanaimo basin within the Duncan map-area fringes the east coast of Vancouver island from Ladysmith to Crofton, and its rocks form the northern part of Saltspring island and all the smaller islands of the northeastern part of the map-area. The Cowichan basin is separated from the Nanaimo basin by a narrow axis of the crystalline rocks of the Sicker series and their intrusive porphyrites, occurring to the south of Crofton, and extends from the east coast of Vancouver island entirely across the map-area. It has a maximum width of nearly 10 miles, but in its eastern portion it is broken by a narrow

[1] Memoir No. 13, Geol. Surv., Can., 1912, pp. 84-85.
[2] Memoir No. 13, Geol. Surv., Can., 1912, pp. 131-132.

axis of crystalline rocks of the Sicker series and in its western part it is divided into three elongate basins, which apparently fill anticlinal valleys in the Sicker series. The southern and largest of the three basins, between the Sicker series on the north and the Vancouver volcanics on the south, forms the Cowichan valley. A very small outlier of the Nanaimo series occurs near the first forks of the Koksilah river.

The rocks of the Nanaimo series consist of conglomerates, sandstones, and shales, with, in places, thin coaly streaks and lenses associated with carbonaceous shales. The conglomerates usually consist of rather small, fairly well rounded pebbles, chiefly of quartz and quartzose rocks, although the basal conglomerates contain much larger fragments of the underlying schists, meta-volcanics, and granitic rocks. The sandstones are commonly medium to coarse grained, yellowish or brownish grey to greenish grey in colour, although some in the northwestern part of the map-area are greyish white. They are composed chiefly of angular to sub-rounded grains of quartz, with fairly numerous grains of feldspar and of rock fragments, in an argillaceous matrix and cemented with calcite. They are commonly concretionary and some of them cross-bedded, but sun cracks, ripple marks, or other surface markings are rarely seen. The shales are virtually all sandy and many are carbonaceous, varying from olive grey to dark grey or black in colour. They are composed chiefly of small angular quartz grains in an argillaceous and carbonaceous matrix. Calcite is frequently present although rarely in large amounts. The shales are usually rather massive and weather concentrically.

The thickness of the Nanaimo series within the Duncan map-area is rather indefinite, but in the northeastern portion of the map-area is at least 10,000 feet in places, and may be more. The thickness of the sediments in the Cowichan basin is presumably at least 5,000 feet. As mentioned, within the Nanaimo map-area the series were subdivided on a lithological and stratigraphical basis into eleven formations,[1] and it was hoped that these formations could be recognized within the Duncan map-area and the series thus subdivided and correlated with the type section at Nanaimo. It was found, however, owing to the change in lithological character of the sediments, more especially to their rapid vertical and lateral gradation, to the absence of horizon markers, to their deformed character, and to the poor and scattered outcrops, in places, as in the northeastern part of the map-area, the greatly deformed rocks being separated by wide stretches of water, that the recognition of all the Nanaimo formations was impossible, and it may be found, after a more careful study of all the data available, that the Nanaimo series within the Duncan map-area cannot be definitely subdivided.

The rocks of the Nanaimo basin may, however, be provisionally subdivided into various formations. At the base is a formation composed largely of shales, which in places is separated from the underlying crystallines by a basal conglomerate and a thin horizon of sandstones. It is of varying thickness, but with a maximum thickness of at least 1,500 feet; it may be correlated with considerable certainty with the Haslam formation. Above this is a series of thick-bedded conglomerates and sandstones, but with some thin-bedded sandstones and shales, with a thickness of 500 to 1,000 feet. This may possibly be correlated with the Extension formation. In places, as on Saltspring island, apparently this formation rests directly upon the underlying crystalline rocks, the conglomerates being coarse basal conglomerates. Above this is a series, 2,000 to 3,000 feet in thickness, which is composed largely of shales with numerous thin sandstone interbeds. In places the sandstones attain a considerable thickness and on the shore at Ladysmith and on some of the Shoal islands between

[1] Sum. Rep. for 1911, Geol. Surv., Can., 1912, pp. 95-101.

Chemainus and Crofton the thick sandstones closely resemble the white weathering sandstones of the Protection formation. It is probable that this series, which cannot be further definitely subdivided, should be correlated with the Cranberry, Newcastle, Protection, and Cedar District formations. Overlying this is a formation 1,000 to 1,600 feet thick, composed chiefly of thick-bedded, in places concretionary and cross-bedded, sandstones, and even fine conglomerates, with some thin-bedded sandstones and sandy shales. This is rather definitely correlated with the De Courcy formation. Overlying it is the Northumberland formation, 1,200 to 1,600 feet thick, composed of sandstones virtually identical with the De Courcy sandstones, but these are associated with coarse conglomerates and thick interbeds of sandy shales. These two formations compose the larger portion of northern Saltspring island and the other small islands of the map-area with the exception of the previously mentioned Shoal islands and the northeasternmost island of the map area, Galiano island. Galiano island is composed of the highest formation of the series, the Gabriola formation, which in the Duncan map-area is composed almost entirely of thin to thick-bedded, rather coarse-grained sandstones.

Although the rocks of the Nanaimo basin may be presumably fairly definitely subdivided, this has not been found to be possible of the rocks of the Cowichan basin. They may, however, be roughly subdivided into three formations, which may correspond with the three lowest subdivisions of the rocks of the Nanaimo basin. In places, as south of Mount Sicker, the lowest rocks of the basin are apparently sandy shales and sandstones, separated from the underlying crystallines by a thin basal conglomerate and a thin horizon of sandstones, and these shales and sandstones may be correlated with the Haslam formation. Above them is a series of conglomerates and sandstones which form the top of Mount Prevost and two other hills to the west, and in places along the south side of the Cowichan valley and on Mount Tzuhalem apparently this formation rests directly upon the crystalline rocks. It seems probable that this formation corresponds with the formation of the Nanaimo basin provisionally correlated with the Extension formation. The conglomerates and sandstone of the middle formation grade upward into a series of alternating sandstones and shales, the sandstones predominating near the coast and the shales in the interior, and in the upper portion of the formation.

The structure of the rocks in the two basins is quite distinct and will, therefore, be described separately. The rocks of the Nanaimo basin have a general northwest-southeast strike and a prevailing dip to the northeast. They are, however, involved in a few large open folds and several minor ones. The southwesternmost large fold is the southeastward continuation of the Kulleet syncline,[1] and its axis extends across the map-area to the southwest of Kuper and Thetis islands and crosses Saltspring island near the southern end of St. Mary lake. The corresponding anticline crosses Thetis and Kuper islands and follows the northeastern shore of Saltspring island. Another syncline and anticline cross the northeastern corner of the map-area between Norway, Secretary, and Wallace islands to the southwest, and Reid, Hall, and Galiano islands to the northeast. The anticline is the southeastward continuation of the Trincomali anticline.[2] Only the De Courcy and Northumberland formations are involved at the surface in these folds. The limbs of the folds dip at angles varying from 5 degrees to 60 degrees, averaging about 20 degrees. To the southeast of the folds the rocks, except for minor wrinkles in the weaker rocks, dip uniformly to the northeast at angles varying from 15 degrees to 90 degrees, averaging about 35 degrees. Minor faults, seldom more than sharp rolls, are common, but so far as known there are no larger faults in the Nanaimo basin.

[1] See Geology, the Nanaimo map-area, Memoir No. 51, Surv., Can., 1914.

[2] Loc. cit.

The structure of the Cowichan basin has already been described in considerable detail.[1] The rocks as a whole have a general N. 60° to 70° W. strike and steep dips of 30 degrees to 80 degrees to the north. Apparently the eastern portion of the basin has been folded into two closely folded synclines, slightly overturned to the southwest, and the northern limb of each syncline has been broken by a fault, which brings the underlying crystalline rocks against the rocks of the Nanaimo series. The southern syncline extends across the map-area and is followed by the Cowichan valley, and apparently preserves its structure, since a similar faulted syncline is observed west of the map-area at Cowichan lake. Whether the fault extends across the map-area is problematical, but owing to the lack of outcrops, its existence cannot be proved or disproved. That it extends west beyond Quamichan lake is proved by a small outcrop of the Sicker schists southwest of the lake. No other outcrop of the Sicker series occurs for 7 miles farther west, but throughout the whole width of the valley are scattered outcrops of the Nanaimo sediments, chiefly shale. That the two rather closely-folded and overturned synclines are preserved is, however, very probable, and since there is no repetition of the conglomerates of the middle formation in what would be the north side of the southern syncline, it is possible that the fault does extend across the map-area, with, however, insufficient throw to bring the underlying Sicker series and their intrusive porphyrites to the surface. The conglomerates of the northern syncline are apparently those capping Mount Prevost, the lower shales, as mentioned, apparently being squeezed into a closed isoclinal fold beneath the more gently warped conglomerates. The fault, which at Maple bay separates the upper shales from the Sicker series to the north, apparently dies out to the west, for along the Chemainus river, as already described, the lower shales grade downward into a rather metamorphic sandstone and schistose basal conglomerate, which rests directly upon the Tyee quartz-feldspar porphyrite schist.

In the western part of the Cowichan basin the rocks occur, as already described, in three basins between wide axes of the Sicker series and their intrusive porphyrites. The southern and larger basin, that forming Cowichan valley, is probably, as already described, a closely folded syncline, overturned so that the rocks all dip to the north, and possibly broken by a fault along the northern boundary of the basin. The other two basins are apparently rather closely folded synclines also, the southern of the two, which is followed by Chemainus river, striking about N. 65° W., and the northern, which crosses the south slope of Coronation mountain, striking about N. 55° W. It is doubtful whether any of the contacts of these two basins with the underlying rocks are persistent faults, but considerable minor faulting has taken place along the contacts.

Besides the larger folds there are rather numerous smaller, more open folds, and doubtless there are also many smaller faults.

As in other parts of Vancouver island, the Nanaimo series rests upon an erosion surface of considerable relief, perhaps of 1,000 to 2,000 feet.[2] That this is true in the Duncan map-area is indicated by small irregularities directly observed in exposed unconformities, by the over-lapping of the conglomerates and sandstones of the middle formation so that they rest in places directly upon the underlying crystalline rocks, and by the restrictions of the narrow western basins of the Cowichan basin to narrow, apparently anticlinal valleys in the Sicker series.

Superficial Deposits.—A large part of the area is covered by superficial deposits of various kinds. These have been classified, as shown in the table of formations,

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[1]Memoir No. 13, Geol. Surv., Can., 1912, pp. 129-133.
[2]Memoir No. 13, Geol. Surv., Can., 1912, p. 133.
Memoir No. 51, Geol. Surv., Can., 1912.

but the various kinds were not mapped separately during 1914.[1] They were deposited by different agencies during the various stages of glacial occupation and retreat, the map-area having been twice over-ridden by glaciers. Little remains of the Admiralty till deposited by the earlier glaciers. On the retreat of the earlier glaciers the Puyallup interglacial deposits were formed in part below sea-level, but since the region has been recently uplifted they now occur below elevations of 300 to 400 feet. They consist of stratified clays, sands, and gravels, in general the clays occurring near the base of the deposits. The interglacial deposits were partially eroded during the later but less intense period of glaciation, the Vashon. During this period the Vashon drift was formed, largely by ice alone, but in part by water. The Vashon drift is ordinarily an unsorted till, but in places is rudely stratified. It forms a mantle a few feet thick covering the hard rocks and interglacial deposits, and is the most extensive of the superficial deposits. During the retreat of the Vashon glaciers, deposits of coarse sand and gravel, the Colwood sands and gravels, were deposited by the streams issuing from the larger retreating valley glaciers, filling the larger valleys to a depth of 100 to 300 feet with these deposits. Since the recent uplift of Vancouver island the revived larger rivers, such as the Cowichan and Koksilah rivers, have terraced the Colwood sands and gravels and have built an extensive delta at the head of Cowichan bay. Alluvium has been deposited also in the lakes and swamps which formed in the poorly drained hollows of the drift mantle and in dammed glaciated valleys.

Economic Geology.

The mineral resources of the area have already been fully described[2] and only need to be briefly summarized here, especially since little field work was done on them during 1913, and since, with the exception of the work done on the King Solomon claims, little development has been done since Clapp's previous examination.

GOLD.

Gold occurs in the gravels of the streams which drain the area underlain by the Leech River formation, having been derived from the very low grade quartz veins which traverse that formation. The gold-bearing gravels are usually a fair grade but occur only in small amounts. The gravels of Floodwood and Meadow creeks and of the San Juan river were worked during the late sixties after the deposits in the Leech and Jordan rivers were discovered and worked. Within the area examined during 1913 no recent attempts have been made to work these gravels.

Some of the quartz-feldspar veins which were formed during the intrusion of the granitic rocks have been prospected for gold entirely without success, and it is not probable that they contain gold in commercial quantities.

COPPER.

The copper deposits of the region may be subdivided into four types: contact deposits, impregnated and replaced shear zones with accompanying quartz veins, quartz veins, and the Tyee type. The contact deposits are developed chiefly in the metamorphosed Sutton limestones near the contact with the intrusive granitic rocks. No typical deposits of this type occur within the area examined during 1913, but on the Sterling

[1]For a complete description of the deposits see Geology of the Victoria and Saanich map-areas, Memoir No. 36, Geol. Surv., Can., 1914.
[2]Memoir No. 13, Geol. Surv., Can., 1912.

and Glen Apa claims on the upper Koksilah river and on the King Solomon and adjoining claims about 3½ miles southwest of Cowichan, the deposits partake partly of the nature of contact deposits and partly of the nature of impregnated and replaced shear zones. At both places the country rock is chiefly a dense silicified rock, closely associated, especially on the King Solomon claims, with the Vancouver meta-andesites. The silicified rock is apparently either original chert in the volcanics or the result of silicification of the volcanics during contact metamorphism. At both places, however, small lentils of Sutton limestone occur in the volcanics in the immediate vicinity and calcite or dolomite are gangue minerals; and to the east of the King Solomon claim the ore minerals occur disseminated through a garnet-diopside-quartz-calcite rock, which looks as if it were the result of the contact metamorphism of limestone. No granitic rocks outcrop within a half a mile of the deposit on the Glen Apa and Sterling claims, but several bosses of Wark gabbro-diorite occur within a mile, and the large batholith of Wark gabbro-diorite occurs a mile to the southeast. Although not in contact with the mineral deposit there are several small stocks of Saanich granodiorite in the vicinity of the King Solomon claims, and in contact with the ore body is a dyke-like mass of a quartz bearing, feldspathic gabbro which is apparently closely related to the Saanich granodiorite. It looks, therefore, as if in both deposits the granitic rocks underlay them at no great depth. The metallic minerals are chiefly pyrite and chalcopyrite, with some sphalerite, galena, and, in the King Solomon deposit, tetrahedrite. In one of the small deposits in the vicinity of the King Solomon arsenopyrite and native arsenic are reported to occur. The metallic minerals occur chiefly as impregnations and replacements of the sheared metamorphic rocks chiefly along well defined, although rather irregular, shear zones. On the King Solomon claim the ore minerals form at least one fairly distinct lens, which is the only metallic deposit in the region examined that is being developed at present, in a shear zone striking ca. N. 40° E. and dipping ca. 45 degrees to the southeast. The richer portion of the lens in contact with the quartz bearing feldspathic gabbro, which forms the hanging wall, is said to contain from 4 to 5 per cent of copper, and 303 tons of picked ore from the outcrop, shipped in the autumn of 1912, contained an average of over 5 per cent copper. The richer portion of the lens is about 20 to 30 feet wide with an outer and lower grade zone, 15 to 20 feet wide, averaging about 2 per cent copper, the foot-wall of the deposit being rather indefinite. The exposed length of the lens is about 200 feet, but its true length may be greater.

At several widely distributed places in the Vancouver volcanics, Sicker series, and closely associated schistose Tyee quartz-feldspar porphyrite, are schistose or sheared zones, more or less mineralized. Pyrite and chalcopyrite are the principal minerals, with, in places, pyrrhotite and magnetite, and more rarely, especially in the deposits occurring in the Tyee quartz-feldspar porphyrites, bornite and chalcocite. Associated with the mineralized shear zones are small veins and lenses of quartz, which frequently contain chalcopyrite and the other metallic minerals. Most of the deposits occur in the schistose rocks of the Sicker series, largely in the schistose Tyee porphyrite, the principal deposits occurring on Mount Richards, Mount Sicker, and Mount Brenton. Doubtless many of the deposits are closely related to the batholithic granitic rocks, although those occurring in the Sicker and Tyee schists are more closely associated with the intrusive Sicker gabbro-diorite porphyrite, which itself contains in places finely disseminated pyrite and chalcopyrite.

Small mineralized shear zones occur in the Saanich granodiorite also, although these are seldom or never extensive, and the metallic mineral is chiefly pyrite.

Traversing the Sicker gabbro-diorite porphyrite and the Saanich granodiorite are in places quartz veins from a few inches to 2 or 3 feet in width and from a few feet to 100 or 200 feet in length. Those associated with the gabbro-diorite porphyrite are also found cutting the Sicker series in the vicinity of the intrusive masses of porphyrite. Some of these quartz veins contain chalcopyrite, pyrite, and pyrrhotite, and in places, some bornite. A few prospects have been located on these veins, especially in the vicinity of Mount Brenton and Coronation mountain. There can be little question but that these veins are closely associated with the intrusion of the granodiorite and the gabbro-diorite porphyrite, and those occurring in the Saanich granodiorite, chiefly to the west of Ladysmith, are closely related to aplite veins.

The only known deposit of the Tyee type occurs at Mount Sicker and consists of a single lens of ore extending through three claims, from east to west, Richard III, Tyee, and Lenora. The lens occurs in a synclinal trough of the quartz sericite, quartz talc, and graphitic schists of the Sicker sediments and Tyee porphyrites, which in the vicinity of the lens are cut by a large dyke of Sicker gabbro-diorite porphyrite. The ore is chalcopyrite, associated with pyrite, sphalerite, and some galena, in a gangue consisting chiefly of barite with some quartz and calcite. The production from the deposit has been large, and during its activity from 1903 to 1907 the Tyee mine was the most important copper producer of the coast region of British Columbia. At present most of the ore has been worked out and the mines are shut down.

IRON.

Iron claims have been taken up on certain magnetite bearing jaspery schists of the Sicker sediments, near contacts with the intrusive gabbro-diorite porphyrite on the west slope of Mount Bruce, Saltspring island, one-half mile from the east shore of Sansum narrows, and on the northeast slope of Mount Brenton. The deposit on Saltspring island, although furnishing material which could be easily concentrated to a high grade product, is hardly large enough to warrant any attempts at mining. The deposit on the northeast slope of Mount Brenton has not been examined, little or no development work having been done on the deposit, which is probably not large. If fairly large deposits of this type are discovered, they will be of great prospective value.

FUEL: COAL AND OILS.

The Nanaimo series of the map-area has been considered as a possible source of coal, on account of the frequent indications of coal which have been found, and because the Nanaimo series in the vicinity of Nanaimo and Comox contain commercial coal seams. Although the rocks of the Nanaimo series within the map-area are fairly well exposed, no thick or extensive coal seams are known, although small lens-like seams are exposed in the northeastern part of the map-area and in the eastern part of the Cowichan basin. These lenses are rarely more than a foot thick, although beds of impure sandy and shaly coal occur from 3 to 6 feet thick. Although some of the formations of the Nanaimo series in the map-area are doubtless to be correlated with the coal bearing formations, the lithological character of the formations is entirely different, and no indications of persistent coal seams occur at those horizons at which coal occurs in the Nanaimo district. In the Nanaimo district the coal seams occur fairly near the base of the Nanaimo series (within 2,000 feet) and on account of the folding which has occurred within the Duncan map-area, these horizons, except near their outcrops, occur only at great depths. The folding and faulting of the district also increases the difficulty of prospecting, and in the Cowichan basin and in much of the Nanaimo basin it is so great as to almost preclude mining, unless especially thick and pure coal seams are found. Thus the geological conditions for the occurrence of commercial coal within the Duncan map-area are not favourable.

The Nanaimo series has been considered as a source of oil also. The structural conditions in the northeastern part of the map-area, where the series has been folded into rather broad, open fields of considerable length and breadth, are perhaps favourable to the accumulation of oil. However, there are no known bituminous beds in the Nanaimo series from which oil may have been derived in large quantities. In addition, no significant seepages of oil have ever been discovered in the Nanaimo series and no flow of oil has ever been obtained during the extensive boring carried on while prospecting for coal. It does not seem probable, therefore, that oil will be found in great quantities in the Nanaimo series.

LIME, CEMENT, AND FLUXES.

The Sutton limestones furnish excellent material for the manufacture of lime and Portland cement and for fluxing. They are, as a rule, pure, low in magnesia and soluble material, and virtually free from phosphorus. Sulphur in the form of pyrite is present in variable amounts, but in the less altered varieties is usually low. Limestones have been quarried for the manufacture of lime at three or four places in the southern part of the Duncan map-area, but within the area examined during 1913 only on the west shore of Saanich inlet about 5 miles south of Mill bay. At the present time in this locality the limestone is being utilized by the Associated Cement Co. of Canada for the manufacture of Portland cement. The "shale" which is mixed with the limestone is obtained from one of the slaty tuffs of the Malahat volcanics from the west shore of Finlayson arm. The cement plant has been in operation since March, 1913, and the capacity of the plant is about 25,000 barrels per day.

CLAYS.

The clays of the superficial deposits occurring in the Puyallup interglacial deposits and in the Colwood sands and gravels are suitable for the manufacture of common brick. The clays occur in beds up to 10 to 20 feet thick. They are chiefly sandy, and the interglacial clays contain numerous pebbles; however, they are of fair plasticity and of low air shrinkage. They burn hard and red at a low temperature and are of low fusibility. They are at present used for the manufacture of common brick only at Somenos.

Some of the shales of the Nanaimo series are sources of shale-clay which may be used for the manufacture of brick and various kinds of semi-porous ware and stoneware, either by the dry press or stiff-mud process; but most of the Nanaimo shales are too sandy and of too low plasticity to be of value. Even the best of the shale clays are of low plasticity and of low fusibility. Within the map-area the shale clays are not at present utilized although similar shale clays are being quarried, largely for the manufacture of brick, to the north of the map-area on Gabriola island and at East Wellington and to the southeast on Pender island.

SAND AND GRAVEL.

The sands and gravels of the superficial deposits, especially of the Colwood sands and gravels, are of fair quality and very abundant in the lowland portions of the map-area, that is, the Cowichan valley and the northeast lowland between Ladysmith and Crofton. At present they are quarried on the west shore of Saanich inlet for use in concrete construction, and locally and at several places within the Cowichan valley for road ballast.

STONE.

The fractured and sheared character of the rocks, with the exception of the less folded and fractured of the Nanaimo sandstones, renders them unfit for building purposes. The Nanaimo sandstones have been quarried on Saltspring island to the northwest and southeast of Vesuvius bay and about a mile northwest of Cowichan near the Esquimalt and Nanaimo railway. The sandstones are thick-bedded and not greatly or regularly jointed, so that fairly large blocks may be obtained. They are rather coarse-grained, yellowish or brownish grey, fairly strong, and although soft directly after quarrying, harden with seasoning. Their chief disadvantages are their dull colour, lack of regular jointing or decided grain or rift, and their steep dip, which makes the quarrying difficult, and causes great variation in the exposed stone. The sandstones of the map-area have not been quarried recently.

GEOLOGY OF THE SOOKE SPECIAL MAP AREA, VANCOUVER ISLAND, B.C.

(*H. C. Cooke.*)

Introduction.

The Sooke special map-area lies about 25 miles to the west of the city of Victoria, B.C., along the south coast of Vancouver island. It covers only the East Sooke peninsula, an area about 6 miles in length by 3 miles in width. Copper deposits discovered here some years ago were briefly studied by C. H. Clapp in 1912, and reported by him to be of prospective importance. Accordingly, a detailed examination of the district was considered desirable to secure more definite information as to its economic possibilities. It was mapped topographically in the early summer by F. S. Falconer, on a scale of 2,000 feet to 1 inch, with a 20-foot contour interval. Later in the season the writer and his assistants, V. Dolmage and A. McLeod, spent four weeks examining the geology.

Summary.

The Sooke gabbro, which underlies the greater part of the sheet, is an intrusive stock or laccolith of probably Oligocene age. It has undergone very great differentiation, partially in place, but mainly before intrusion. The result of this differentiation has been to produce an unusually large number of rock types, varying in composition from aplites to hornblendites. In general, the rocks are massive and unsheared. Some movement occurred before consolidation, locally producing original gneissic textures; but little after consolidation. Faulting has taken place to a small extent, but displacements have probably not been great. The faults are confined principally to large, previously formed veins of hornblendite, which were apparently less competent to resist stress than the normal unaltered gabbro; and through the fissures so produced moved the solutions which carried and deposited the ores.

General Character of the District.

The district is roughly dome-shaped, with two main domes, peaks of about 600 feet in height toward the east and west ends of the district respectively, from which the land slopes away fairly uniformly to the sea. Outcrops of rock are very numerous, owing to the recent glaciation, which has removed all the soil from the surface and left only patches of stony drift. As might be expected from this, the area is very dry, without permanent streams. Even from wells it is difficult in places to get a continuous supply of water all the year. Timber is not heavy, except in soil-filled gulches where the moisture is held, and near the coast. The salal bush, however, grows luxuriantly wherever there is soil, to a height of 3 to 6 feet, and is a great impediment to travel.

The peninsula is easily accessible from Victoria, either by launch or by road. Roads are unusually good except with regard to the matter of grade. Many steep hills might have been avoided had the builders paid only slight attention to the topography.

General Geology.

The principal formation of the peninsula is the Sooke gabbro. The nature of the mass, whether stock or laccolith, is unknown, since bedding is difficult to determine in the intruded basalt flows, and since erosion has removed all the basalt above sea-level, with the exception of a few small isolated patches along the shore. As it stands to-day, the gabbro mass resembles a shelled nut, with a few shreds of the basalt shell still adherent. It is overlain unconformably by the Sooke formation, a series of slightly consolidated sandstones and conglomerates, which are found underlying a small area along the southeast shore and filling isolated wave-built chasms. These sediments are of late Miocene age,[1] and the gabbro is, therefore, pre-upper Miocene. The intrusive cuts the Metchosin basalts of Eocene age,[2] and is, therefore, post-Eocene. A long period of erosion must have ensued, after the intrusion of the gabbro, before the deposition of the Sooke formation, since the cover of Metchosin basalt was entirely removed and the gabbro itself laid bare. Its age is, therefore, tentatively placed as Oligocene or early Miocene.

As already mentioned, the gabbro has differentiated into a wide variety of rock types, but the areal distribution of any one of these is so small that it was found impossible to map them separately. The work was thus limited to outlining the boundaries of the area of rock and drift, and to making as thorough a study as possible of the different rock types and their relations to one another. Description of these must necessarily be deferred until the microscopic examination of the specimens will have been completed.

Economic Geology.

Along certain zones, the gabbro has been converted into hornblendite. This alteration has taken place along joint fissures, by the action of solutions which replaced the original feldspar and hornblende with large crystals of long-bladed hornblende. The hornblendite zones may be of any width from one-fourth of an inch to 100 feet. They are plainly replacement veins; they have no definite wall, but grade out into the unaltered wall rock; the replacement is always more complete nearer the central fissure; the width of any one vein of hornblendite may vary from a few inches to several feet within a short distance along the strike. None of the hornblendite zones, when unaffected by later fracturing, contain pyrite, chalcopyrite, or other ore minerals. The larger of them appear, however, to have acted as planes of weakness in the gabbro stock, since stresses affecting the mass were relieved by faulting along these zones. Little or no movement appears to have taken place along any other belt, although the rock is very thoroughly broken by jointing. Movement along the fault planes has been horizontal as shown by the striæ on slickensided surfaces. Owing to the lack of good horizon markers, the amounts of the displacements cannot be determined, but they were not large, since the surrounding "shell" of Metchosin basalt was not faulted down into the mass.

Only where the hornblendite zones were broken by faulting are any ore deposits found. The ores characteristically fill small fissures in the hornblendite and are clearly of later date than the faulting, since they fill fissures with slickensided walls and, in rare cases, cut unbroken across a slickensided plane. The ore seems to have been deposited in bodies of somewhat irregular size and shape. At one point, it will form a rich shoot, 20 to 100 feet or more in width, while a few hundred feet along the strike of the vein the shoot will have become narrow and poor.

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[1] Clapp, C. H. Geol. Surv., Can., Memoir No. 13, p. 141, 1912.

[2] Clapp, C. H. Geol. Surv., Can., Sum. Rep., 1912, p. 48.

The writer can see no reason why the ore bodies should not continue to considerable depth. It is a fact well known to miners that there is a rough equality between the length of a fissure and its depth. The larger fault zones, here, through which the solutions evidently moved, are strong fissures several thousand feet in length. It seems reasonable to suppose, therefore, that they may be expected to continue to depths of at least 1,000 or 2,000 feet. It is also probable that ore will be found at depths in these fissures. Similar deposits in other localities have been shown to have been formed by the agency of upward-moving solutions, and a like origin for these may be postulated. If so, deposition of ore must have beeen more or less continuous, vertically, and the ore bodies probably extend downward to considerable depths.

Only two properties of prospective value were noted. The first and largest of these is situated near the centre of the peninsula; the second, about a mile to the northwest of Mount Maguire. A third claim on which consiedrable work has been done for iron, is on Iron mountain, near the southwest corner of the peninsula. No decisive statement can be made of the value of any of these, owing to the almost absolute lack of development, even of surface stripping.

The minerals of these deposits are principally pyrite with subordinate chalcopyrite. Where the ore is massive, the copper present will amount to 18 or 20 per cent, but in the average good body of ore the sulphides are disseminated through hornblendite and the percentage of copper sinks to 5 or 6 per cent, or less. Some magnetite and pyrrhotite are also present; the gangue minerals are hornblende, chlorite, feldspar, and quartz. Practically no gossan is present; weathering, except to a small extent along joint cracks, does not extend more than a foot in depth.

THE GEOLOGY OF THE ALUNITE AND PYROPHYLLITE ROCKS OF KYUQUOT SOUND, VANCOUVER ISLAND.

(*Charles H. Clapp.*)

Introduction.

In the southwestern part of Kyuquot sound, which is one of the large fiords indenting the west coast of Vancouver island, the metamorphic volcanic rocks, which comprise the greater part of Vancouver island, have been peculiarly altered to rocks containing large amounts of alunite and pyrophyllite. These deposits of alunite and pyrophyllite, which are the only deposits of their kind known in Canada, were "staked" in 1908, and during the last few years the pyrophyllite rock has been quarried by the British Columbia Pottery Company as a "fireclay," and by the San Juan Mining and Manufacturing Company as a base of a powdered "household cleanser." Of late years alunite has attracted considerable attention as a possible source of "potash," as well as a source of alum, so that the writer was directed to make an examination of the Kyuquot deposits during the summer of 1913. Accordingly, he spent four days during July examining the deposits and in making a reconnaissance in a launch of the neighbouring shores. He was accompanied throughout the examination by the late Mr. William J. Sutton, of Victoria, at the time geologist for the Canadian Collieries (Dunsmuir) Company, and one of the best-informed men concerning the natural resources of Vancouver island, by Mr. Wally, chemist of the San Juan Mining and Manufacturing Company, and J. L. Hangi of the British Columbia Pottery Company.

The principal alunite and pyrophyllite deposits are situated on a small peninsula in the northwestern part of Kyuquot sound between Kokshittle arm and a small inlet called Easy creek. The peninsula has a general northwest trend and is slightly over 2 miles in length and from 1,500 to 3,000 feet in width. The deposits occur in the outer northwestern portion within an area of somewhat more than 1 square mile. Kyuquot sound is reached by the C.P.R. steamer Princess Maquinna, which plies between Victoria and the ports of the west coast of Vancouver island. It touches at Kyuquot village at the entrance to Kyuquot sound twice a month, and if there is freight calls at the quarries of the British Columbia Pottery Company and of the San Juan Mining and Manufacturing Company in the pyrophyllite and alunite deposits. Other coasting vessels occasionally call at Kyuquot sound, and the deposits may be safely reached during the greater part of the year by launches from Alberni or Clayoquot sound.

PREVIOUS WORK.

No geological work had been done in the vicinity of the deposits previous to the writer's examination; nor have descriptions of the deposits been heretofore published. Dr. Dawson's work in 1885 on Vancouver island did not extend as far south as Kyuquot sound, and the writer's work on the island during 1908 to 1912 did not extend as far north. However, with the exception of the peculiar alteration of the metamorphic volcanics resulting in the formation of the pyrophyllite and alunite deposits, the geology is similar to that of the rest of Vancouver island. The general geology of the island is best summarized in the following publications:—

Report on a geological examination of the northern part of Vancouver island and adjacent coasts, by G. M. Dawson, Ann. Rep., 1886, Geol. Surv., Can., pp. 1 B-107 B.

Southern Vancouver island, by Charles H. Clapp, Memoir No. 13, Geol. Surv., Can., 1912.

Summary and Conclusions.

The rocks in the vicinity of the alunite and pyrophyllite deposits of Kyuquot sound are chiefly the Vancouver volcanics of Triassic and lower Jurassic age. They consist of amygdaloidal, porphyritic, and fragmental feldspathic andesites and dacites, which have a general east-west strike and southerly dip of 20 degrees to 40 degrees. They have been intruded by a feldspathic quartz diorite, which appears to be the peripheral phase of a large granodiorite batholith of the Saanich type and consequently of upper Jurassic age. They are cut also by a few dykes of quartz bearing diorite porphyrite which seems to be an apophysal phase of the quartz diorite, and by numerous dykes of andesite porphyrite, some of which are clearly later than the quartz diorite, but some of which appear to be injected equivalents of the effusive volcanics.

The volcanics, especially the fragmental varieties, have been metasomatically replaced by certain secondary minerals resulting in four different types of altered rocks: (1) quartz-sericite-chlorite rocks; (2) quartz-sericite rocks; (3) quartz-pyrophyllite rocks; and (4) quartz-alunite rocks. These occur in separate, well defined masses. All of the altered rocks contain more or less pyrite, but it appears as if the alunitization and pyrophyllitization and part of the silicification and sericitization of the original volcanics had taken place before the introduction of the pyrite.

From a consideration of the chemical and mineral changes and the geological relations it appears as if the alunitization nd pyrophyllitization were caused by hot sulphuric acid solutions of volcanic origin, which acted chiefly on the fragmental volcanics during their accumulation and before they were buried under the 4,500 feet or more of volcanic rocks which have been stripped away by erosion. The volcanic rocks were still further altered, pyritized, and silicified, under deep-seated conditions, during and following the intrusion of the granodiorite batholith with its marginal facies of feldspathic quartz diorite and accompanying minor intrusives. The pyrophyllite and alunite rocks have undergone still further alteration during the present erosion cycle, by descending meteoric waters; so that above ground-water level they are reddish to white rocks containing no pyrite but instead, limonite and kaolin, the oxidized alunite rocks containing also some sulphur. The rocks at or below ground-water level are commonly bluish grey, with a small percentage of pyrite.

Several claims have been taken up on the pyritized and altered rocks, which have been considered to be of value for gold and copper, for alunite or alum, and for pyrophyllite. Even the most highly mineralized deposits, the metallic mineral consisting almost entirely of chalcopyrite and pyrite, are too small and too low grade to be considered as possible sources of copper ore. Neither are the gold and silver values, ranging from $0.30 to $1.10 in gold and about 20 cents in silver, sufficient to encourage any considerable development.

The alunite in the Kyuquot Sound deposits is the sodic variety, natroalunite, and it occurs, mixed with quartz, diaspore, sericite, and other minerals, in masses of quartz-alunite rock, of which the alunite forms from 20 to 45 per cent. As yet the San Juan Mining and Manufacturing Company, who own the alunite deposits, have not used the alunite rock, although they have announced their intention of manufacturing alum. Alunite is at present considered to be of value not only for alum, which is now extracted from it, but also as a source of "potash salts" for fertilizers, and as a possible source of aluminium ore. Since the Kyuquot Sound deposits contain a large percentage of impurities, and since the alunite is of the sodic variety, they are not very promising as a source of alum or other potash salts. It is, however, to be hoped, considering the large quantities of alunite available, that some use for it may be found.

The compact variety of pyrophyllite is found in the Kyuquot Sound deposits mixed with 20 to 50 per cent of quartz and a little sericite. The quartz-pyrophyllite rock has been used successfully by the British Columbia Pottery Company as a "fire-clay" to mix with surface clays and Cretaceous shales to increase the refractiveness of the mixture, which is used to manufacture sewer-pipe and fireproofing. It has also been used by the San Juan Mining and Manufacturing Company, who have taken advantage of the extremely fine-grained character and slipperiness of the rock to manufacture a powdered "household cleanser," a metal polish, and a mechanic's soap. It is probable that the pyrophyllite rock might be employed as a substitute for powdered massive talc in other uses. It is to be hoped that an increasing use for the material may be found; and although the deposits are not large, they are doubtless large enough to meet any demand that is likely to be put upon them for a great many years.

General Character of the District.

TOPOGRAPHY.

Kyuquot sound is one of the six large inlets or fiords which indent the west or southwest coast of Vancouver island and afford access into the heart of the Vancouver range. It is situated in the northern part of the island, between the northernmost fiord, Quatsino sound, and Esperanza inlet. Kokshittle arm is the northwestern of the several straight, narrow, deep arms which lead into the open, islanded portion of Kyuquot sound. It trends about S. 15° E., and is about 9 miles in length, and from 200 yards to 2 miles in width. Entering Kokshittle arm from the west near its outer portion, is a small inlet called Easy creek, trending and opening to the northwest, about 2 miles long and from less than 1,000 feet to 2,000 feet in width. Between Easy creek and Kokshittle arm is a small peninsula, 1,500 to 3,000 feet wide, and, as already stated, it is on this peninsula, more especially in the outer northwestern portion, that the deposits of alunite and pyrophyllite rock occur.

The elevation of the plateau portion of the Vancouver range in the vicinity of Kyuquot sound varies from about 2,500 to 3,000 feet near the ocean to about 3,500 to 4,000 feet near the inner portion of the sound. Surmounting the general plateau surface are numerous rounded summits, many of them characteristicly cone-shaped, that attain elevations of 4,000 to 4,500 feet above sea-level. Only the higher mountains, more especially the Garibaldi peaks to the northeast of Kokshittle arm, have serrated summits. In the immediate vicinity of the sound the dissection of the plateau has been sufficient to entirely destroy it and to reduce the area to a large number of diversely arranged hills and ridges of unequal height, which have been smoothed and rounded by glaciation. Most of the larger hills are between 1,000 and 2,500 feet in height, but a few are over 3,000 feet. The four or five rounded hills and ridges which compose the small peninsula between Kokshittle arm and Easy creek are only from 250 to 500 feet in height and are arranged along the axis of the peninsula in such a manner that the northeast slope to Kokshittle arm is somewhat gentler than the slope to Easy creek.

The run-off is largely accomplished by numerous small, irregularly-patterned streams, most of which, on account of the abundant rainfall and the heavy vegetation of the region, flow continuously throughout the year. A few larger streams, that in several instances have their sources in glacial lakes, drain the larger glaciated valleys, which in their outer portions are fiords, small inlets, or bays.

CLIMATE AND VEGETATION.

In common with the rest of the west coast of Vancouver island, the rainfall is large, from 90 to 100 inches a year, although the summer months, especially July and August, are comparatively dry. The temperature is remarkably uniform and temperate throughout the year, averaging about 40° F. in winter and 55° F. in summer. At sea-level the snowfall is light and the snow remains on the ground only a few days at a time. Even at a thousand feet above sea-level the snowfall is much heavier and the snow remains much longer, virtually the entire winter, and in protected places above elevations of 4,000 feet, the snow remains most of the year, although the actual snow-line is about 5,000 feet above sea-level.

General Geology.

GENERAL STATEMENT.

The principal rocks of the area are a series of interbedded flow and fragmental volcanics which are similar to most of the other volcanic rocks of Vancouver island, hence they are doubtless of Triassic and lower Jurassic age and members of the Vancouver volcanics. These have been deformed and intruded by a feldspathic quartz diorite which is a peripheral phase of a large granodiorite batholith that is correlated with the Saanich granodiorite, and hence is considered to be of upper Jurassic age. The volcanics have been intruded also by two series of dykes—one set of quartz-bearing diorite porphyrite, which appears to be an apophysal phase of the quartz diorite; and another set of feldspathic andesite porphyrites, which appears to be in part injected phases of the effusive volcanics.

In places near the intrusive feldspathic quartz diorite the Vancouver volcanics have been metasomatically replaced by quartz, sericite, chlorite, pyrophyllite, alunite, and diaspore, giving rise to altered rocks of four different types, which are called: (1) quartz-sericite-chlorite rocks; (2) quartz-sericite rocks; (3) quartz-pyrophyllite rocks; (4) quartz-alunite rocks.

Table of Formations.

Upper Jurassic and possibly Lower Cretaceous.	Batholithic and minor intrusives:—	
	Feldspathic andesite porphyrite. (Position doubtful; may be in part injected phases of Vancouver volcanics).	Dykes.
	Quartz bearing diorite porphyrite.	Dykes.
	Feldspathic quartz diorite (Saanich type).	Peripheral facies of Saanich granodiorite batholith.
Lower Jurassic and Triassic.	Vancouver volcanics.	
	Altered or metasomatic rocks:— Quartz-alunite rocks; quartz-pyrophyllite rocks; quartz-sericite rocks; quartz-sericite-chlorite rocks.	
	Unaltered rocks:— Feldspathic andesites and dacites.	Flow and fragmental, effusive volcanic rocks and probably some dykes.

VANCOUVER VOLCANICS.

The unreplaced or comparatively slightly altered volcanics form the larger part of the peninsula between Kokshittle arm and Easy creek, on which the alunite and pyrophyllite rocks occur. The inner, southern portion of the peninsula is almost entirely composed of slightly-altered volcanics, and another area, 500 to 1,500 feet wide, extends across the northern portion of the peninsula and separates the altered rocks into two masses.

The Vancouver volcanics are feldspathic andesites and dacites, and include both flow and fragmental types, and the flow types are both amygdaloidal and porphyritic. However, in spite of their differences in composition and texture, all the volcanics have a very similar general appearance. They are most commonly dense, dark reddish rocks, although some are grey or greenish grey. The fragmental rocks range from dense rocks, resulting from the induration of very fine tuffs, to rather coarse breccias or agglomerates, with angular fragments up to 4 inches in diameter.

On microscopic examination the volcanics are seen to be essentially feldspathic, consisting largely of albite-oligoclase, ca. Ab. 85 An. 15. Doubtless they originally contained hornblende, but this has been completely altered to chlorite, epidote, and calcite. The rocks are, therefore, classed as feldspathic andesites although some varieties which contain essential quartz are, of course, classed as dacites. The mineral and chemical composition of a fragmental dacite, the chief volcanic rock to have been replaced by alunite and pyrophyllite, is given in the table on page 118.

ALTERED VOLCANICS.

The quartz-sericite-chlorite rocks are the most abundant of the altered types. They occur surrounding the other altered rocks, thus forming wide transition zones between the comparatively unaltered volcanics and those most completely replaced. On the peninsula between Kokshittle arm and Easy creek, the quartz-sericite-chlorite rocks form the larger part of the southern area of altered rocks, which extends from Monteith bay to the southwest side of the peninsula and is from 200 to nearly 1,000 feet in width. They also form most of the northern area of altered rocks which is a rudely triangular-shaped area over 2,000 feet long and 1,500 feet wide. The quartz-sericite-chlorite rocks also form smaller masses, replacing shear zones in the normal dacites and andesites.

The quartz-sericite-chlorite rocks are chiefly dense, light to dark greenish rocks which retain the porphyritic, amygdaloidal, or fragmental texture of the primary dacites and andesites. They consist of an irregular but extremely fine-grained (0·005 to 0·2 mm.) intergrowth of secondary minerals chiefly quartz, sericite, and chlorite, and almost invariably they contain finely granular pyrite and chalcopyrite.

The quartz-sericite rocks occur intimately associated with the quartz-pyrophyllite rocks of the Monteith claim and on the west side of the peninsula on the Deertrail claim; and occur also in fairly large masses composed almost entirely of the quartz-sericite rocks. One of these masses occurs on the east side of the peninsula and forms a part of the southern area of altered rocks.

The quartz-sericite rocks are dense and in places cherty, light bluish grey to flesh coloured, and, owing to the almost universal presence of pyrite, are stained with hydrous iron oxides on their weathered surfaces. Besides quartz and sericite the only other minerals present are pyrite, limonite, kaolin, and in some places probably alunite, and in other places possibly pyrophyllite. The rocks are of fine but irregular grain varying from 0·001 to 0·1 mm. The pyrite occurs in small regular crystals and is apparently replacing the quartz and sericite, and appears, therefore, to be of later formation.

A partial chemical analysis and the mineral composition of a typical quartz-sericite rock are given in the table on page 118.

The quartz-pyrophyllite rocks are more restricted in their occurrence than the altered types previously described, and except for a small area on the Sockeye claim on the south shore of Easy creek, about 1½ miles south of the end of the peninsula between Easy creek and Kokshittle arm, they are restricted to the peninsula. There they are found on the Deertrail claim on the west side of the peninsula, and on the Monteith claim on the east side of the peninsula, forming compact masses, composed almost entirely of the quartz-pyrophyllite rock, of 3 acres and 1 acre in extent, respectively. Small amounts of the pyrophyllite rock are found associated with the quartz-alunite rock, and some alunite is found in the masses of nearly pure quartz-pyrophyllite rock, but for the greater part the two rocks form separate and fairly pure masses.

The quartz-pyrophyllite rocks are all dense, and usually have a pronounced greasy or soapy feel. The rock is easily crushed to a very fine, smooth powder and its use as a clay and "household cleanser" is dependent upon this property. Much of the quartz-pyrophyllite rock contains disseminated small grains of pyrite or small masses of finely granular pyrite, and these varieties are invariably light grey to rather dark bluish-grey in colour. These rocks are not only stained yellowish or reddish brown on exposed surfaces, but pass into reddish, pinkish, or cream coloured rocks, which have apparently been leached of pyrite. Another variety, which is light greyish to cream coloured and weathers white, appears never to have contained any pyrite. The quartz-pyrophyllite rock has been more or less sheared, producing in places shear zones filled with a soft gouge, composed largely of quartz, pyrophyllite, and kaolin, and in other places resulting in a fault breccia, consisting of angular fragments of the quartz-pyrophyllite rock, cemented by a reddish matrix of quartz, pyrophyllite, kaolin, and iron oxides.

The minerals of the rocks are seen microscopically to be essentially quartz and pyrophyllite, with accessory sericite and small amounts of pyrite, limonite, and kaolin. Since the analysis shows the presence of almost as much soda as potash, it is probable that the rocks contain a small amount of unreplaced or secondary feldspar. Most of the rocks show that they have resulted from the metasomatic replacement, chiefly of fragmental, but in some instances of porphyritic and even amygdaloidal volcanics. The rocks are very fine-grained and some of the quartz is so fine-grained that it is microphanitic, that is, its crystalline character is doubtful; and it is possible that some of the secondary silica occurs in the form of opal.[1] The pyrophyllite occurs in small flakes, averaging about 0·01 mm. in diameter, that are rather irregular in outline and roughly equidimensional, and hence are easily distinguished from the flakes of sericite, which usually have a pronounced elongation. The pyrite usually occurs in small euhedral grains, which have apparently replaced the metasomatic rock. The pinkish and cream-coloured rocks contain no pyrite, but contain a little limonite, and also a dense, white, opaque substance, presumably kaolin. This supposed kaolin occurs in small, regularly shaped patches which are apparently pseudomorphs after pyrite, and in the greyish rocks the kaolin and pyrite occur together in such a manner that the kaolin appears to be replacing the pyrite.

The chemical and mineral composition of two typical quartz-pyrophyllite rocks are given in the table on page 118.

The quartz-alunite rocks form, at the extreme northwestern point of the peninsula between Kokshittle arm and Easy creek, on the Morris claim, a large mass, about 4½ acres in area, and another much smaller mass occurs along the shore to the east on the Snowstorm claim.

The alunite rocks are extremely fine-grained, dense, and in places porcelain-like rocks, possessing a hackly fracture and a harsh to a hard, finely gritty feel, and a few of the rocks are foliated. They vary in colour in much the same way as the quartz-pyrophyllite rocks from a light to dark bluish grey through reddish and pinkish colours to cream and white. The bluish grey rocks almost invariably contain more or less pyrite, either as minute disseminated grains, or in small, very finely granular masses. The red, pink, cream coloured, and white rocks are almost free from pyrite, although with the exception of some white, porcelain-like varieties, all the rocks are stained red, yellow, or brown on their weathered surfaces with iron oxides. The greyish-blue

[1] Cf. Alunite rocks in San Cristobal Quadrangle, Colorado. Larsen, E. S., Bull. U. S. Geol. Surv., No. 530-F, 1912, pp. 5-6.

rock is found chiefly near sea-level, that is, near or below ground-water level, while above the ground-water level, the rock is chiefly of the pink or cream coloured variety. These latter rocks frequently contain cores a few inches in thickness of the bluish grey rock. It thus appears that the reddish to pink and cream to white rocks have been formed during the present cycle by the partial to total leaching and oxidation of the pyrite (iron sulphide), by descending meteoric waters; and doubtless below the present ground-water level the greyish blue rock would predominate. The ability of these waters to leach the alunite rocks of iron is strikingly shown by the cementing of the beach detritus fringing the alunite deposit, with limonite, a process still in vigorous action.

The alunite rocks consist essentially of quartz and alunite, with, in places, accessory diaspore and sericite. Pyrite, as mentioned, is accessory in the bluish grey rocks. The only other minerals noted are kaolin, sulphur, and limonite, but these have probably been the result of recent surface alteration. Since the analyses of the quartz-alunite rocks show more than sufficient alkalis to combine with alumina to form alunite and sericite, it is probable that some undecomposed or secondary feldspar occurs in the rocks. The large percentage of water suggests the presence of hydrargillite also, but neither of these minerals was detected. The quartz-alunite rocks are clearly seen to have resulted from the metasomatic replacement of fragmental and occasionally porphyritic volcanics. They are fine-grained, the alunite varying from 0·005 to 0·3 mm. in diameter, and the quartz from 0·005 mm. to almost sub-microscopic in size. The alunite, which occurs in irregular, but roughly equidimensional grains, is readily distinguished by its moderate birefringence, basal cleavage, parallel extinction, and positive, uniaxial character. The diaspore occurs in well-defined lath-shaped to acicular grains, which are usually diversely arranged, but which in some rocks have either a sub-parallel or radial arrangement. As in the quartz-pyrophyllite rocks, pyrite occurs in small grains, many of which have regular crystal outlines and have apparently replaced the alunitized rock.

The chemical and approximate mineral composition of two typical rocks are given in the table on page 118. It is found that the alunite contains a large amount of soda, but alunite of this character is not uncommon and is properly called natroalunite.[1]

BATHOLITHIC AND MINOR INTRUSIVES.

The feldspathic quartz diorites are found only in the vicinty of the northern part of Kokshittle arm, 2 miles north of the alunite and pyrophyllite deposits. They are phanocrystalline, rather fine to medium-grained rocks, with a sub-porphyritic texture, and consist of rectangular reddish feldspars, oligoclase-andesine, ca. Ab. 50 An. 50 to Ab. 75 An. 25, in a fine-grained, rather dark greyish green groundmass. The groundmass consists largely of oligoclase-andesine, with hornblende, a little biotite, quartz, and orthoclase. Magnetite is virtually the only accessory. The rocks are moderately to considerably altered to uralite, chlorite, epidote, sericite, and calcite.

Cutting the Vancouver volcanics and the quartz-sericite-chlorite rocks, are a few rather large dykes which are apparently closely related to the feldspathic quartz diorite. The dyke rocks are dark, fine-grained rocks with a few medium sized, whitish weathering feldspar phenocrysts, shown microscopically to be oligoclase-andesine, Ab. 60 An. 40 to Ab. 75 An. 25. The groundmass consists of small laths of oligoclase-andesine feldspar with interstitial secondary ferromagnesian minerals, probably after both hornblende and augite, and quartz. Magnetite is the only accessory. The rocks are greatly altered to chlorite, serpentine, epidote, sericite, quartz, pyrite, and limonite.

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[1] Hillebrand, W. F. and Penfield, S. L. Some additions to the Alunite-Jarosite group of minerals in Bull. U.S. Geol. Surv., No. 262, 1905; pp. 37-41.

Cutting the normal Vancouver volcanics and some of the altered rocks are numerous small dykes of fine-grained and dense feldspathic andesite or diorite porphyrite. Similar dykes cut the feldspathic quartz diorite, and hence all the dykes may be later than the quartz diorite and related to it; but in their lithological characters, the dyke rocks are similar to the effusive andesites of the Vancouver volcanics. For this reason and in order to distinguish them from those coarse-grained, quartz bearing, diorite porphyrite dykes which are quite clearly related to the quartz diorites, the finer-grained dyke rocks are called andesite porphyrites. They are dark greenish grey, weathering to a lighter greyish green, very fine-grained to dense rocks, with numerous small, lath-shaped feldspar phenocrysts, seen microscopically to be oligoclase or oligoclase-albite, ca. Ab. 75 An. 25 to Ab. 90 An. 10. They are set in a groundmass consisting of smaller laths or microlites of oligoclase in a chloritic matrix formed by the replacement of primary interstitial hornblende. Magnetite is accessory. The rocks are greatly altered, and besides chlorite the secondary minerals are sericite, calcite, and quartz.

Structural Geology.

The Vancouver volcanics, although involved in several minor folds, have a general east-west strike and a southerly dip of 20 degrees to 40 degrees. They are broken by small normal faults and also by rather numerous shear zones. The shear zones are larger and more numerous near the various altered rocks derived by the metasomatism of the volcanics. The masses of altered rocks, with the exception of the quartz-sericite rock masses, are very greatly fractured and sheared, and have been brecciated in places by faulting. The volcanics are broken also by numerous irregular fractures and, in a few places, exhibit regular columnar jointing.

As noted, the altered rocks are confined to the neighbourhood of the feldspathic quartz diorite, and a zone of the pyritized quartz-sericite-chlorite rock, one-quarter to one mile wide, separates the relatively unaltered volcanics from the main mass of the feldspathic quartz diorite. The contact of the feldspathic quartz diorite and the quartz-sericite-chlorite rock is not actually exposed, but there is no doubt that the feldspathic quartz diorite is intrusive into the quartz-sericite-chlorite rock. In fact this rock appears to be partly the result of the contact metamorphism of the Vancouver volcanics. The intrusive character of the feldspathic quartz diorite is indicated also by the contact shatter breccia exposed along the shores of Kokshittle arm, consisting of numerous angular inclusions of dense, dark weathering rocks, presumably altered volcanics, in the feldspathic quartz diorite.

The dykes of quartz bearing diorite porphyrites are apparently related to the feldspathic quartz diorites and may be considered apophysal phases. Only a few of these dykes are known, and they occur cutting the normal andesites and dacites of the Vancouver volcanics and more characteristically cutting the quartz-sericite-chlorite rocks. The dykes of andesite porphyrite are numerous and cut all the volcanic rocks and their altered equivalents. Similar dykes, not examined microscopically, cut the feldspathic quartz diorite and the contact shatter breccia. Some of the dykes are so similar in character to the volcanics and are apparently so closely associated with them, occurring 7 miles from the feldspathic quartz diorite and even 5 miles from any of the altered rocks, that they are perhaps best correlated with the volcanics and considered injected equivalents of them. However, there are, of course, at least some of the dykes which are younger than the batholithic rocks.

As a rule, the various altered rocks form separate masses, especially the quartz-alunite rocks, but the quartz-pyrophyllite rocks are closely associated with quartz-sericite rocks. These latter occur, in the northwestern deposit on the Deertrail claim, as irregular streaks through the deposit and apparently follow shear zones. In the deposit on the Monteith claim a cherty phase of the quartz-sericite rock occurs interbedded with the quartz-pyrophyllite rock in such a manner that it appears as if some of the beds of the originally thin-bedded and southerly dipping volcanics had been replaced by quartz and sericite, and other beds by quartz and pyrophyllite. As noted, the quartz-sericite-chlorite rocks represent the less completely replaced volcanics, and they occur surrounding the other more completely replaced types. Shear zones in the quartz-sericite-chlorite rocks are frequently more highly altered, consisting almost entirely of quartz and metallic minerals, chiefly pyrite and chalcopyrite.

Alteration of the Volcanics.

Since the original textures of the volcanic rocks are preserved in the various altered rocks, it is clear that the Kyuquot Sound alunite and pyrophyllite deposits have been formed by the metasomatic replacement of the Vancouver volcanics, chiefly the fragmental varieties. As the altered rock masses show no evidence that either swelling or contraction took place during the replacement of the volcanics, it is supposed that the replacement took place without change in the total bulk of the original volcanics.[1] However, the altered rocks are slightly more porous than the volcanics indicating that a slight reduction in volume has taken place.[1] As shown by a comparison of the specific gravities and porosities of the altered rocks with the specific gravity and porosity of the original fragmental dacite, indicated in the following table, the increase in the porosity of the altered rocks is not sufficient to offset their increase of density; so that in all cases the fragmental dacite has not only gained slightly in weight, from 1·9 to 7·8 per cent, but, even considering equal bulk volumes of the fresh and altered rocks, there has been a slight addition of material, from 0·4 to 7·5 per cent.

The chemical and mineralogical changes undergone during the metasomatism of the fragmental dacite, resulting in the quartz-sericite, quartz-pyrophyllite, and quartz-alunite rocks, are shown by the accompanying table. It does not seem as if the chemical change resulting in the quartz-sericite-chlorite rocks with more or less undecomposed feldspar is very marked.

It is seen that the quartz-alunite rocks have increased in pyrite, sulphur, and sulphuric anhydride, and that all the rocks have increased in water, the quartz-sericite rocks to a much less extent than the other two types. All of the rocks have lost iron oxide, magnesia, and lime. It does not seem, however, as if relative loss of these constituents in the different rocks is significant. All of the rocks have lost soda, but in this case the relative loss is undoubtedly significant. The quartz-sericite rocks have lost the most and the quartz-alunite rocks the least, owing to the development of soda alunite. The other oxides, silica, alumina, and potash have increased in some rocks and decreased or remained nearly constant in others. It thus appears as if during alteration there was a rearrangement and slight transfer of these constituents, although they were not removed from the zone of alteration. The quartz-alunite rocks have lost some silica while the quartz-sericite rocks have gained a corresponding amount. In the quartz-pyrophyllite rocks silica has either remained constant or has increased slightly. As would be expected the quartz-pyrophyllite rocks have gained in alumina while the quartz-sericite rocks have lost. The rocks containing about 45 per cent of alunite have also gained in alumina, but those containing a smaller amount, about 20 per cent, may have lost some alumina. The change in potash is especially characteristic; as it has increased in the quartz-alunite rocks, decreased in the quartz-pyrophyllite rocks, and remained nearly constant in the quartz-sericite rocks.

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[1] Cf. Alunite rock formed by replacement of dacite. Ransome, F. L., Geology and ore deposits of Goldfield, Nevada. Prof. Paper, U S. Geol. Surv., No. 66, 1909, p. 180.

Table Showing Character of the Alteration of Dacite Tuff.

—	1	2	3	4	5	6
Silica (SiO_2)	73·22	87·80	81·94	71·88	48·82	62·70
Alumina (Al_2O_3)	13·46	9·08	15·29	23·56	19·08	12 68
Ferric oxide (Fe_2O_3)	2·33	0·40	0·11	0·14	0·07	1·40
Ferrous acid (FeO)	0·96	n.d.	n.d.	trace	n.d.	trace
Pyrite (FeS_2)	......	......	......	......	......	2·69
Magnesia (MgO)	0·42	n.d.	n.d.	0·21	n.d.	0·05
Lime (CaO)	1·50	n.d.	n d.	0·06	n.d.	0·20
Soda (Na_2O)	5·46	0·02	0·40	0·36	2·74	1·09
Potash (K_2O)	1·74	1·70	0·50	0·43	4·40	2·10
Water (H_2O)	0·62	1·04	2·40	3·24	7·00	7·15
Titanium oxide (TiO_2)	0·28	n.d.	n.d.	n.d.	n.d.	n.d.
Phosphoric acid (PO_5)	0·10	n.d.	n.d.	n.d.	n.d.	n.d.
Manganese oxide (MnO)	trace	n.d.	n.d.	n.d.	n.d.	n.d.
Sulphuric anhydride (SO_3)	trace	trace	trace	trace	17·32(*a*)	7·06(*a*)
Sulphur (S)	......	......	......	......	0·57(*a*)	2·88(*a*)
	100·09	100.04	100·64	99·88	100·00	100·00
Specific gavity of non-porous rock	2 70	2·75	2·76	2·91	2·75	2·84
Specific gravity of porous rock	2·68	2·70	2·73	2·88	2·69	2·79
Porosity, per cent	0·67	1·8	1·2	1·0	2·1	1·8
Number of grains of non-porous rock, derived from 100 gm. of non-porous fresh rock	......	101·9	102·2	107·8	101·9	105·2
Number of grains of porous altered rock, derived from 100 gm. of porous fresh rock	......	100·7	101·9	107·5	100·4	104·1
Mineral composition.						
Quartz	30	82	50	20	36	58
Feldspar	60	......	} 7·8	} 8	} 18·3	} 10·3
Sericite	2	14				
Kaolin	......	3	......	......		
Pyrophyllite	......	......	42	71	......	......
Alunite	......	......	......	......	45	20
Diaspore	......	......	......	......	......	4·5
Magnetite and ilmenite	2	......	......	......	......	......
Pyrite	......	......	......	......	......	2·7
Hematite and leucoxene	2	......	......	......	......	......
Limonite	......	1	0 2	0·2	0·1	1·6
Sulphur	......	......	......	......	0·6	2·9
Epidote and chlorite	2	......	......	......	......	......
Talc	......	......	......	0·7	......	......
Calcite	2	......	......	0·1	......	......
	100	100	100	100	100	100

(*a*) The sulphur and sulphuric anhydride were not determined directly. Both were estimated together as SO_3, and relative amounts of S and SO_3 arrived at by calculation.

No. 1—Dacite tuff, 1 mile southeast of Monteith bay.

No. 2—Cherty quartz-sericite rock, quarry of British Columbia Pottery Co., Monteith claim.

No. 3—Pink to white, quartz-pyrophyllite rock, quarry of British Columbia Pottery Co., Monteith claim.

No. 4—White to greyish, quartz-pyrophyllite rock, quarry of San Juan Min. and Mfg. Co., Deertrail claim.

No. 5—Pink to white, quartz-alunite rock, Morris claim.

No. 6—Bluish grey, quartz-alunite rock, Morris claim.

All rocks are from Kyuquot sound and analysed by N. L. Turner of Department of Mines, Mines Branch, Ottawa.

The original quartz in the dacite has not suffered any loss except in one doubtful case, the quartz-pyrophyllite rock containing 71 per cent of pyrophyllite. In this case the apparent loss may be partly accounted for by the conspicuous addition of material, chiefly alumina. It is probable that the original quartz has not been greatly affected by the alteration. On the other hand the original ferromagnesian or mafic minerals, now represented in the dacites by the secondary minerals, chlorite, epidote, hematite, and so forth, have been entirely decomposed and most of their constituents removed. It is clear that the alteration of the feldspar has resulted in the secondary quartz, sericite, pyrophyllite, alunite, diaspore, and kaolin, making up most of the altered rocks. Pyrite, with its alteration products, limonite, and sulphur, seems to have been introduced, as will be presently described, after the formation of most of the other minerals.

In addition to the facts given above the following are significant as indicating the nature of the alteration. The altered rocks are cut by dykes of quartz bearing diorite porphyrite, and of andesite porphyrite, which although similar in character to the original volcanics are not nearly so greatly altered as the volcanics, nor are they altered in the same manner. Hence it seems clear the alunitization and pyrophyllitization of the volcanics took place before the injection of the dykes. It appears from a microscopic examination of their texture that the altered rocks were impregnated and partially replaced by pyrite after the alunitization and pyrophyllitization. The alunite and pyrophyllite rocks are localized in their occurrence, for although similar and pyritized volcanics occur in great profusion over Vancouver island, many of them highly altered, no other alunite or pyrophyllite rocks are known. Not only are such rocks unknown in other portions of Vancouver island, but even at Kyuquot sound the deposits appear to be restricted to the vicinity of the intrusive feldspathic quartz-diorite. It is thus assured that the solutions causing the alunitization and pyrophyllitization were of local origin and were not descending oxidizing waters of meteoric origin.

On the other hand the difference between the surface rocks from those found near or below ground-water level indicates that descending oxidizing solutions have been effective in forming limonite, sulphur, and kaolin, which are to some extent clearly pseudomorphic after pyrite. Both the limonite and sulphur have apparently been derived by the breaking up and oxidation of the pyrite, although sulphur occurs only in the alunite rocks. The kaolin has probably formed by the action of sulphuric acid derived by the oxidation of the pyrite. In addition, it appears, from the analyses of the samples collected by the writer, as if the surface rocks contain more alunite than the rocks at a below ground-water level; and it is possible that the additional alunite was also the result of the action of sulphuric acid in the descending meteoric waters. However, Mr. Wally, chemist of the San Juan Mining and Manufacturing Company, states that his investigations indicate that the lower, bluish grey alunite rocks contain more alunite than the surface reddish to white rocks; and he believes that alunite as well as pyrite has been leached from the surface rocks.

The apparent restriction of the altered rocks to the vicinity of the intrusive feldspathic quartz diorite and the very great erosion that the volcanic rocks, associated with the alunite and pyrophyllite deposits, have suffered, at least 4,500 feet, suggests that the alteration was caused by hot, ascending, sulphuric acid solutions of deep-seated origin, which emanated from the intrusive batholith. However, in view of the fact that geologists do not generally admit the presence of such solutions,[1] the evidence in the Kyuquot Sound district is not strong enough to support the view that all the alteration took place in this manner; but there can be little question but that the rocks were somewhat altered following the intrusion of the feldspathic quartz diorite. The zone of quartz-sericite-chlorite rock in contact with the quartz diorite suggests that it and similar rocks were developed at that time. It is probable that at the same time the pyritization and possibly some of the silicification of the volcanics took place. However, as noted, the pyritization apparently followed the alunitization and pyrophyllitization. In addition it is certain that the alunitization and pyrophyllitization followed the injection of the dykes of quartz bearing diorite porphyrite, which is con-

[1] Larsen, E. S. Alunite in San Cristobal Quadrangle, Colo., Bull. U.S. Geol. Surv., No. 530-F, 1912, p. 7.

sidered to be an apophysal phase of the feldspathic quartz diorite, and of andesite porphyrite. As already mentioned, the origin and time of the injection of the andesite porphyrite dykes is doubtful, but apparently some of the dykes are related to the volcanics and may be considered as injected equivalents. If this is true, the alunitization and pyrophyllitization and part of the silicification and sericitization was accomplished by solfataric action during the eruption of the volcanics. Since alunite and pyrophyllite are probably developed only under moderate conditions of pressure and temperature, such as exist near the surface, although alunite may form through a vertical range of at least several hundred feet,[1] the alunitization and pyrophyllitization of the volcanics doubtless took place before the volcanics were buried by the 4,500 feet or more of volcanics, which have been stripped away by erosion, re-exposing the alunitized and pyrophyllitized volcanics. That the alunite and pyrophyllite were formed near the surface is indicated also by the extremely fine-grained and even microcryptocrystalline, opal-like character of the associated quartz, a feature which is characteristic of deposits formed near the surface.[2]

It is doubtful whether the sulphuric acid which was added to the volcanics was derived by oxidation, near the surface, of hydrogen sulphide, or was contained in the ascending hot waters. The deposits are not exposed through a great enough vertical range to indicate whether or not they change rapidly within a shallow vertical range. In either case the deposits were formed near the surface during the eruption of the volcanics, and it is doubtful if, during eruption, the volcanic rocks suffered any great amount of oxidation and weathering by descending, oxidizing, meteoric waters; at least no other possible occurrences of such rocks are known in the Vancouver volcanics. Neither are the altered rocks as porous as they probably would be if they had been altered by descending acid solutions. It is, therefore, assumed that the deposits were formed, as most alunite deposits in the United States are believed to have been formed, by hot ascending acid solutions of volcanic origin and that at least those solutions causing alunitization carried free sulphuric acid.

The occurrence in separate masses of the three different types of altered rocks, quartz-alunite, quartz-pyrophyllite, and quartz-sericite rocks, that are all believed to have been formed by hot, ascending, acid solutions may be explained in several ways, all of which may have been effective; by a variation in the character of the ascending solutions, during different stages of solfataric action, or perhaps caused by oxidation near the surface; by slight differences in either the chemical or physical character of the replaced volcanics; or by the loss of free sulphuric acid during the alunitization of a portion of the volcanics and the subsequent pyrophyllitization and sericitization of the volcanics somewhat farther away from the source of the solutions or from their main channels of circulation. However, as previously noted, there seems to have been a rather free interchange and transfer of materials throughout the altered zone. Since the three types of altered rocks are surrounded by quartz-sericite-chlorite rocks, it seems as if these were partly the result of the alteration of the volacnics at some distance from the channels of circulation by the somewhat cooler and less active solutions. However, as noted, the quartz-sericite-chlorite rocks are in part the result of alteration under deep-seated conditions following the intrusion of the granodiorite batholith and its attendant peripheral phases and minor intrusives. The occurrence of some of the quartz-sericite-chlorite rocks suggests that the deep-seated solutions which emanated from the intrusives followed the zones of previous alteration, as is indicated also by the more general pyritization of the altered rocks than of the comparatively fresh volcanics. As noted the altered rocks were still further altered by descending, oxidizing, meteoric solutions.

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[1] Butler, B. S. and Gale. H. S., Alunite, a newly-discovered deposit near Maryvale, Utah, Bull. U.S. Geol. Surv., No. 511, 1912, p. 37.

[2] Lindgren, Waldemar. Mineral Deposits, 1913, p. 434.

Economic Geology.

GENERAL STATEMENT.

Several claims have been taken up in the pyritized and altered volcanics. The deposits have been considered to be of value for gold and copper, for alunite or alum, and for pyrophyllite, which has been used as a fireclay and as the base of a powdered "household cleanser." Several claims have been staked for gold and copper at various times, but most of these claims have been allowed to lapse. Dr. F. W. Morris, of Victoria, claims to have accidentally discovered the alunite deposit on the Morris claim, in 1908, by throwing a piece of the quartz-alunite rock that had been roasted in his camp fire into a can of water and noticing that after two or three days' immersion the rock had been partially disintegrated. He evaporated the water and obtained almost a pound of alum. Dr. Morris also staked the adjoining deposit of pyrophyllite on the Deertrail claim. Shortly after the deposit of quartz-pyrophyllite rock on the Monteith claim was staked by Mr. J. L. Hangi for the British Columbia Pottery Company. Since that time, Mr. Hangi, who is in charge of the British Columbia Pottery Company's deposits and interests in the vicinity of Kyuquot sound, has staked the other claims now held by the British Columbia Pottery Company. The Morris, Snowstorm, and Deertrail claims are held by the San Juan Mining and Manufacturing Company, and the Monteith and Joseph Hunter claims and the J. D. Hunter and J. L. Hangi fractions are held by the British Columbia Pottery Company. The latter company controls also two claims on the southwest side of Easy creek, the Sockeye and Curtis, and the Gold Bug claims farther north, on the shore of Kokshittle arm.

GOLD AND COPPER.

The deposits that have been developed for gold and copper consist of the mineralized altered volcanics, especially the quartz-sericite-chlorite rocks. The metallic minerals are chiefly pyrite and chalcopyrite, and although they occur sparingly disseminated throughout the altered rocks, they are confined chiefly to shear zones of varying width in the altered rocks. Even in the shear zones the mineralization is not great and only small masses, a few inches or less in diameter, of finely granular sulphides, have been developed. These are, of course, of no value as sources of copper ore. The gold and silver values, even in the most highly-mineralized deposits, are low, from $0.30 to $1.70 in gold and about 20 cents in silver, and many of the mineralized rocks carry only a trace of these metals. Considering the small extent of the mineralization and the spotted occurrence of the values, these deposits are very doubtful sources of gold or silver.

ALUNITE.

General Relations and Size of Deposits.

Alunite is a hydrous sulphate of aluminum and potassium having the formula K_2O, $3Al_2O_3$, $4SO_3$, $6H_2O$. When pure it contains 11·4 per cent of potash (K_2O), 37·0 per cent of alumina, Al_2O_3, and 38·6 per cent of water. However, alunite is usually found in nature in an impure state, mixed with quartz, diaspore, sericite, and other minerals and containing more or less ferric oxide (Fe_2O_3) and soda (Na_2O). The sodic variety, which is the variety found in the Kyuquot Sound deposits, is properly called natroalunite.[1] Alunite occurs in a rather coarse-grained crystalline

[1] Hillebrand, W. F. and Penfield, S. L. Some additions to the Alunite-Jarosite group of minerals in Bull. U. S. Geol. Surv., No. 262, 1905, pp. 37-41.

form, but more commonly, as at Kyuquot sound, as a fine-grained to dense, massive variety.

A detailed description of the Kyuquot Sound alunite deposits and of the physical and chemical character of the alunite rocks has already been given. The alunite mixed with quartz and other minerals occurs in masses of quartz-alunite rocks, which have resulted from the metasomatic replacement of chiefly fragmental volcanic rocks, dacites, and feldspathic andesites. Only one large deposit is known; it occurs on the Morris claim, and is about 4½ acres in area. This deposit extends to and below sea-level and contains above sea-level about 600,000 tons. Another much smaller deposit occurs along the shore to the east on the Snowstorm claim. As presented under a previous section, it is believed that the alunite deposits have been formed by uprising thermal waters, so that it is probable that the deposits extend below sea-level for an indefinite distance, which, however, is probably not more than a few hundred feet.

Alunite forms from 20 to at least 45 per cent of the alunite rocks and is mixed chiefly with quartz varying from 40 to 50 per cent, sericite varying from virtually nothing to 14 per cent, a little diaspore, and usually pyrite. The pyritiferous alunite rocks are bluish grey in colour and are found chiefly near sea-level, at or below the present ground-water level, or as small cores in reddish to white rocks which occur above ground-water level and have been leached of their pyrite by descending rain waters. A part of the iron of the pyrite has been removed by the waters and has cemented the beach rubble fringing the alunite deposit, into a fairly firm rock. The remaining iron of the pyrite has been oxidized to limonite, which gives the surface rocks their reddish colour. Free sulphur has also resulted from the oxidation of the pyrite, and occurs mixed with the limonite and with kaolin. According to the analysis of the samples collected by the writer, it appears as if the reddish to white surface rocks contain more alunite than the bluish grey, unoxidized rocks; it thus appearing as if part of the alunite in the surface rocks were the result of the oxidation of sulphur in the pyrite and its reaction with the alumina and alkalies remaining from the original volcanics. However, Mr. Wally, chemist of the San Juan Mining and Manufacturing Company, who has tested the deposit carefully, claims that the bluish grey rocks contain on the whole more alunite than the reddish to white rocks, and he believes that alunite as well as pyrite has been leached from the latter rocks.

Development and Uses.

As yet the San Juan Mining and Manufacturing Company, who own the alunite deposits on the Morris and Snowstorm claims, have not used the alunite rock for any purpose, although they have announced their intention of manufacturing alum. However, they have stripped portions of the deposit and have opened up small quarries or prospect pits showing the continuity and extent of the deposit.

Future Possibilities.[1]

Alunite has been mined for alum and aluminium sulphates at several localities in other continents, chiefly at Tolfa, Italy, about 35 miles northwest of Rome, and near the village of Bulla Delah, New South Wales, Australia. At present no use has been made of the several deposits of alunite known in the United States, although they have lately attracted considerable interest on account of the increased demand for potash salts, which are used chiefly and very extensively in the manufacture of fertilizers. The United States Geological Survey has also

[1] The commercial availability of alunite, its occurrence in the United States and elsewhere, and the process employed in the manufacture of alum and aluminum sulphates from alunite are excellently and concisely summarized by B. S. Butler and H. S. Gale in Bull. U.S. Geol. Surv., No. 511, 1912, pp. 38-64, and the following material has been largely taken from this publication.

drawn attention to the possibility of using alunite not only as a source of alum and of other potash salts, but as a source of alumina. This suggestion is based on the results of the laboratory experiments on fairly pure alunite by W. T. Schaller, who has made the following observations:—

"Laboratory experiments showed that on igniting the powdered alunite all of the water and three-quarters of the sulphuric acid are volatilized. On leaching the residue with water the potassium sulphate is dissolved, leaving the insoluble aluminum oxide behind.

"The average amount of potassium sulphate leached from the ignited mineral powder is 17·9 per cent of the original material used. As the coarsely crystallized alunite was found to contain 19·4 per cent of potassium sulphate, 92 per cent of the total potash present was obtained by simple ignition and subsequent leaching.

"It is worth noting that, according to the laboratory experiments, 32·7 per cent of the ignited alunite consists of available potassium sulphate, which can be extracted by simple water leaching and evaporation. The remaining 67·3 per cent consists of nearly pure aluminum oxide."

It is suggested that in commercial practice the potassium in the alunite be utilized in the form of the simple sulphate instead of alum, thus leaving as a by-product the insoluble and nearly pure aluminum oxide, which might possibly be used as a substitute for the mineral bauxite in the manufacture of metallic aluminum.

Since the Kyuquot Sound deposits certainly do not contain on the average more than 45 per cent of alunite, and since the alunite is the sodic variety (natroalunite), the deposits, to judge from the fact that all the alunite rock in the Bulla Delah deposits carrying over 10 per cent of silica is discarded,[1] are not very promising as a commercial source of alum or other potash salts, unless the alunite rock might also be used as an ore for aluminum or for some other use. Whether or not the alunite rock might be used as an aluminum ore is questionable since as yet no attempt has been made to produce aluminum from alunite. Considering the relatively large quantities of alunite in the Kyuquot deposits, it is greatly to be hoped that some use for it may be found.

PYROPHYLLITE.

General Relations and Size of Deposits.

Pyrophyllite is a hydrous silicate of alumina, H_2O, Al_2O_3, $4SiO_2$, that occurs in two varieties, as a foliated and often radiated mineral, and as a compact massive mineral with a soapy feel, frequently called agalmatolite. This compact variety is the variety found in the Kyuquot Sound deposits, although, as already described, it occurs mixed with considerable quartz, from 20 to 50 per cent, and more or less sericite, from virtually nothing to 8 per cent. There are two deposits of the fairly pure quartz-pyrophyllite rock, one of about 3 acres in area on the Deertrail claim extending east to the Morris claim, and the other about 1 acre in area on the Monteith claim. The deposits, as shown by the quarries already opened up in them and by their outcrops, extend to sea-level, and the tonnage in each of the deposits above sea-level is about 400,000 tons in the Deertrail claim deposit and 100,000 tons in the Monteith claim deposit. It is believed, as indicated under the previous section on the alteration

[1] Loc. cit. p. 60. Quotation from Pitman, E.P. Alunite or alumstone in New South Wales, Rept. Geol. Surv., New South Wales, 1901, pp. 419-429.

of the volcanics, that the pyrophyllite deposits have been formed by uprising hot waters. Hence, it is probable that the pyrophyllite deposits extend for an indefinite, but probably not a very great distance below sea-level. It is also believed that the quartz-pyrophyllite rock was pyritized following the pyrophyllitization and that subsequent downward leaching by rain waters has resulted in the partial removal of the pyrite above sea-level and the formation of the pinkish and whitish rocks, free from pyrite, but containing some limonite and kaolin. It should also be noted, as described under structural geology, that mixed with the quartz-pyrophyllite rocks are rocks of the quartz-sericite type. On the Deertrail claim deposit these latter occur as irregular streaks and in the Monteith claim deposit they occur as thin interbeds, as if some beds of the originally thin-bedded and southerly dipping volcanics had been replaced by quartz and sericite, while other beds were replaced by quartz and pyrophyllite. These quartz-sericite rocks thus cut down the available tonnage of the pyrophyllite deposits.

Development and Uses.

So far as known to the writer, pyrophyllite is not used very extensively, and the only uses to which pyrophyllite has been put are, as listed in the various books on mineralogy, for slate pencils, French chalk, and as an easily carved ornamental stone, the Orientals using it to carve images and small ornaments. It is also used as a substitute for talc and is usually sold under that name. Pyrophyllite is, however, less valuable than true talc, although it is claimed that for bleaching cotton cloth, pyrophyllite is better than talc.[1] Thus the uses to which the Kyuquot pyrophyllite has been put, as a fireclay and as a "household cleanser" are rather unique. The British Columbia Pottery Company have been quarrying the deposit on the Monteith claim since 1910 to obtain a refractory material, virtually a fireclay, to mix with the surface clays dug near their plant in Victoria West, and with the Cretaceous shales from Comox, in order to increase the refractiveness of the mixture. The mixture has been used successfully for the manufacture of sewer-pipe and fireproofing. By itself, even the most highly weathered of the quartz-pyrophyllite rock, that rock containing the most kaolin, is of poor plasticity. Ries and Keele[2] give the following results of laboratory tests made on a sample taken from the stock pile at the British Columbia Pottery Company's factory:—

"It was worked up with 20 per cent of water and had an air shrinkage of 3 per cent, with a tensile strength of 84 pounds per square inch.

"The burning tests were carried out in some detail because of the refractory character of the material.

Cone.	Fire shrinkage.	Absorption.	Colour.
010 (1742°F)	Slightly swelled	15·50	Salmon.
03 (1994°F)	" "	14·22	Pink.
1 (2102°F)	" "	11·7	"
5 (2246°F)	0·6	9·23	Drab.
9 (2390°F)	−1·7	7·92	Grey.
13 (2534°F)	Not vitrified		
30 (3146°F)	Fused		

"It burns steel hard at come 1, and shows good refractiveness; in fact, there are few more refractory clays thus far known in the western provinces."

[1] Diller, J. S. Talc and Soapstone in Mineral Resources of the United States for 1912, part II, 1913; pp. 1139-1143.

[2] Ries, H. and Keele, J., Clay and shale deposits of the western provinces. Memoir No. 24, Geol. Surv., Can., 1912, pp. 148-150.

The San Juan Mining and Manufacturing Company has taken advantage of the fact that the quartz-pyrophyllite rock breaks up into an extremely fine powder, which, for the greater part, contains no grit coarse enough to feel between the fingers or the teeth, to use the powdered rock as a polishing powder and as a base for a "household cleanser," a metal polish, and a mechanic's soap. Since pyrophyllite has a hardness of only 1 to 2, it is of no value in itself as a polishing powder, but the Kyuquot pyrophyllite is, as described, mixed with 20 to 50 per cent of quartz, which occurs in very fine grains, averaging less than 0·001 mm. in diameter, and this quartz serves as the abrading substance. The pyrophyllite on account of its softness and slipperiness is, however, probably of value in the polishing powder, serving to keep the quartz from scratching. The softness and soapy feel of the pyrophyllite, like that of talc, makes the material of value as a base for soap, although for this use, except for the lower grades of soap, the quartz seems undesirable. The chief difficulty experienced in the manufacture of these products is in getting rid of the coarser grains of quartz; but if this is done satisfactorily the resulting products would seem to be of fairly good grade. As yet the San Juan Mining and Manufacturing Company have opened up only a small quarry in the Deertrail claim deposit and have been manufacturing their products spasmodically since 1911 in their factory in Esquimalt, west of Victoria.

Future Possibilities.

As described, the quartz-pyrophyllite rock fulfils the uses to which it has been put satisfactorily; and while the demand for the rock for these uses is somewhat limited, the demand will probably have a slow but fairly constant increase. As to the other uses to which the material may be put, it must be as a substitute for powdered massive talc, it being entirely unsuited to replace foliated talc, or on account of its fractured character, as soapstone. The uses to which powdered massive talc have been put are varied,[1] chiefly as a filler for paper, although for this use foliated talc is desired, in sizing and bleaching cotton cloth, as a heat and electric insulator, and a refractory material, for foundry facings in casting iron, for dressing skins and leather, and in the manufacture of rubber, shade-cloths and curtains, soaps, lubricators, toilet powders, and paints, particularly waterproof paints. Of these uses the quartz-pyrophyllite rocks of the Kyuquot deposits is only suitable for those purposes not requiring the purest material, and besides those uses to which it is now put, it might be used in sizing and bleaching cotton cloth, as a heat and electric insulator, and in the manufacture of soaps, lubricators, and cheap paints. Owing to the presence of even the finest quartz it is not suitable for toilet powders nor for pencils or French chalk. At present, so far as can be learned, pyrophyllite is mined in North America only in the eastern part of North Carolina in Alleghany and Moore counties, where in 1912, 1,969 tons of massive pyrophyllite were produced, valued at $12,851, and used for pencils, sizing and bleaching cotton cloth, and presumably for other uses.[2] Whereas the Kyuquot deposits are not large compared to other talc and pyrophyllite deposits, yet considering the annual production of pyrophyllite from North Carolina, and of talc from Canada, 8,270 tons in 1912 valued at $23,132,[3] they are large enough to meet any demand that is likely to be put upon them for a great many years. It is interesting to note here that Diller[4] states, that the uses of talc may be extended with advantage to both producer and consumer.

[1] See Uses of Talc, Diller, J. S., Mineral Resources of the U.S. for 1912, part II, 1913, pp. 1140-1142.

[2] Op. cit. p. 1142 and pp. 1153-1154.

[3] McLeish, John, Mineral Production of Canada during 1912, Mines Branch, Department of Mines, Ottawa, Publication No. 262, 1914, p. 279.

[4] Op. cit., p. 1140.

PROSPECTING FOR ALUNITE AND PYROPHYLLITE.

Little can be said to those desiring to prospect on Vancouver island for deposits similar to the Kyuquot alunite and pyrophyllite deposits. The writer has examined the Vancouver volcanics, in which the alunite and pyrophyllite deposits occur, over a large part of Vancouver island, and he has never seen any other deposits in the volcanics similar to those of Kyuquot sound. However, where the Vancouver volcanics are found to be altered in the ordinary manner, chiefly to rocks resembling the quartz-sericite-chlorite rocks previously described, it is well to examine the areas of altered rocks very carefully for light coloured, dense, porcelain-like rocks giving a test for sulphate, and for light-coloured soft rocks with a soapy feel. The change near the surface of bluish grey, pyrite bearing rocks to pinkish or white rocks without pyrite, but with cores of the bluish grey, pyrite bearing rocks, seems to be characteristic.

The following field test for alunite has been suggested by W. T. Schaller[1]:—

"Boil the powdered sample with water or with hydrochloric acid for several minutes; after allowing the powder to settle pour off the liquid and repeat the operation to insure the removal of all soluble sulphates. Dry the powder and heat to a dull red. Again boil in water and, after settling, pour off some of the clear liquid. To this add a small fragment or a solution of barium chloride. If the mineral is alunite, a heavy white precipitate will form. To be sure that the water used in this test does not contain sulphates in solution, it should be tested with barium chloride, and if it gives a marked precipitate, it cannot be used. For this test all that is required that is not included in a miner's or prospector's outfit is a little barium chloride, which can be carried in a small bottle or cartridge."

Since the Vancouver volcanics or the quartz-alunite rocks do not contain any soluble sulphates, the following test used by Mr. Wally while examining the Kyuquot deposits for the San Juan Mining and Manufacturing Company, may be used with less trouble and greater rapidity. Heat a fragment of the sample to a dull red, place in a vessel containing dilute hydrochloric (muriatic) acid, and after the residue is settled and the liquid clear, add a few drops of a solution of barium chloride. If the mineral is alunite, a heavy white precipitate will form.

[1] Butler, B. S. and Gale, H. S., Alunite, a newly-discovered deposit near Marysvale, Utah, Bull. U.S. Geol. Surv., No. 511, 1912, p. 63.

NOTES ON MINING DEVELOPMENTS IN SIMILKAMEEN DISTRICT, B.C., AND ON A REPORTED OCCURRENCE OF OIL AT KELOWNA, B.C.

(Charles Camsell.)

During 1913, the greater part of the season usually devoted to field work was spent on work in connexion with the Twelfth International Geological Congress. This work included the preparation of the guide books for the various excursions, attendance at the session in Toronto, and participation as guide on Excursion C2 to the Pacific coast and return.

In consequence of this, it was the middle of September before regular field work was begun in southwestern British Columbia, and only six weeks was devoted to it, including the time spent in travelling to and from the field. The work included the collecting of soils from Enderby, Kelowna, and Peachland, in Okanagan valley, for the Agrogeological Congress to be held in St. Petersburg, Russia, in the summer of 1914; the examination of a reported occurrence of oil at Kelowna, and a general reconnaissance of the Similkameen district to outline the area in which future topographic and geological work should be carried out, and to keep in touch with the progress of mining development there.

Kelowna.—The reported discovery of oil within the limits of the town of Kelowna proved to be of no consequence and, although about a dozen locations were made, they were all thrown up as soon as it was seen that the oil was merely a thin film of vegetable oil on the surface of a swamp.

Hedley.—At Hedley, little has been done during the past year on any mineral claims other than those owned by the Hedley Gold Mining Company. A group of claims, however, lying in the northwestern part of the camp, has been bonded by a syndicate composed of a few members of the Hedley Gold Mining Company, and two diamond drills were being used throughout the summer to test the beds of the Nickel Plate formation on the Red Mountain claim. The Nickel Plate formation is here covered by the Red Mountain formation, and where drilling was being done lies about 400 feet vertically below the surface. The slope of the mountain is here very steep and water had to be pumped over the top of Nickel Plate mountain and more than 1,000 feet down the western side, so that the difficulties of establishing a camp and carrying on the work were very great. On account of these difficulties, the work can only be carried on during the summer months.

On the property owned by the Hedley Gold Mining Company, all work has been discontinued on the three Sunnyside mines and all the ore mined is now being drawn from No. 3 and No. 4 tunnels of the Nickel Plate mine. On the exhaustion of the main ore body above the level of No. 3 tunnel—an event which is not far distant—the mine will be worked with No. 4 tunnel as the main entry. Two ore bodies are now being mined. The upper or original Nickel Plate ore body which lies on a footwall of porphyritic gabbro and has been shown to have a length of about 1,100 feet from the outcrop, has been stoped out for almost its entire length. The lower ore body lies directly underneath the gabbro footwall of the upper ore body and has been proven for about 600 feet. This ore body, known as the No. 5 ore body, dips about 30 degrees to the northwest. It extends below the level of No. 4 tunnel and is being mined by an incline from that tunnel. Other ore bodies have been proved by diamond drilling to lie below the No. 5 ore body and these are to be worked by a main incline from No. 4

tunnel. Diamond drilling has also proved the existence of a body of ore of unknown extent to the north of the main incline. Enough ore remains in the ore bodies now being worked to keep the reduction plant working to its capacity for some years, and the discoveries made within the last two years have extended the life of the mine several years beyond this period. Altogether there is good reason to expect a continuance of mining on this property for several years to come, and if prospecting is actively and intelligently prosecuted on this and adjoining property, there should be no fear of the exhaustion of the Hedley camp for many years to come.

The production from the Hedley camp has been entirely in gold and all of it has come from the mines owned by the Hedley Gold Mining Company. In the guide book prepared for the International Geological Congress (Guide Book No. 9, p. 115) it was stated that the total production to the end of 1912 was about $3,250,000. Although these figures were obtained from the Hedley Gold Mining Company in Hedley, by some chance a mistake was made and the corrected total, since given by the company, should have been $4,237,489.68.

Copper Mountain.—At Copper mountain, 12 miles south of Princeton, prospecting of the copper deposits is being actively carried on by the British Columbia Copper Company, with a staff of about 100 men and five diamond drills. The company has options on eleven mineral claims, but most of the work was being done during the summer on the Sunset, Helen H. Gardner, and Princess May mineral claims, where a considerable tonnage of low grade copper ore carrying a small amount of gold and silver, has been outlined.

Coalmont.—After meeting with a good deal of discouragement due to local crushing and disturbance of the coal seams, development in the Tulameen coal basin at Coalmont ceased early in 1913, and the property was sold to another company. The old company had attempted to mine the coal from a point on the north side of the basin where the outcrop approached nearest to the Tulameen river and the railway line. Unfortunately, the seams at this point have been disturbed by a strong strike fault which left them in a very much shattered condition and rendered the coal unfit for use. The new company proposes to mine the coal from the south side of the basin where the seams outcrop on the north fork of Granite creek. The seams here have proved to be more regular in dip and strike and have already been prospected by a number of adit tunnels, the longest of which is nearly 1,000 feet in length. This point, however, is nearly 3 miles in a direct line from the Great Northern Railway line in Tulameen valley and this distance will have to be overcome by a tramway.

ROSSLAND MINING CAMP, B.C.

(Chas. W. Drysdale.)

During the past field season (1913), the writer was engaged in a detailed investigation of the geology and ore deposits of Rossland, B.C. The time occupied was from May 22 until December 1, with the exception of one month spent on International Geological Congress business.

Able assistance in the field was rendered by Mr. E. L. Bruce from June until September, and Dr. B. Rose during October and November. The writer feels greatly indebted to the mine managers, superintendents, engineers, and others connected with Rossland for many courtesies rendered and for their hearty co-operation and interest in the work.

The Rossland ore consists mainly of pyrrhotite, pyrite, and chalcopyrite in a gangue of altered country rock containing some quartz and locally a little calcite. The values are largely gold with copper and a little silver. The main country rocks of the mines are augite-porphyrite, diorite porphyrite, granodiorite, and monzonite, and many of the largest and richest ore shoots occur on formational contacts.

All the ore is shipped to the Trail smelter for treatment. The total production from 1894 to 1913, inclusive, according to the Provincial Bureau of Mines, amounts to 4,358,098 tons, containing 2,154,666 ounces of gold, 3,493,536 ounces of silver, and 89,386,731 pounds of copper. The gross value is placed at $58,846,616. The chief mines at present being worked are the Le Roi, Centre Star, and Josie groups, the former two owned and operated by the Consolidated Mining and Smelting Company, and the latter by the Le Roi No. 2 Company.

The field work was the continuation of that previously carried on by Mr. R. W. Brock[1] and Dr. G. A. Young. The geological field data and the plans, structure sections, and illustrations necessary for the writing of the final report were completed before leaving the field. The areal work comprised an examination of the various geological units present, with particular reference to their age, their relationships to one another, and to the ore deposits. A short time was spent in the study of land forms and superficial deposits in and around the district, with the view of determining the recent geological or physiographic history of this section of the Cordillera. Most of the field season, however, was devoted to detailed geological work underground in the mines of the present operating companies as well as in the accessible workings of outside properties at present not in operation.

An endeavour was made to correlate the numerous veins, faults, dykes, and country rocks of the ore-producing belt in order to find out their structural relations to the ore bodies. Much time was spent in mapping the various rock formations present in the mines with the view of determining whether such a detailed study and separation of the different country rock formations might not throw some light on such economic problems as the localization of the ore shoots, control of fissuring systems, persistence of ore in depth, and distribution of gold and copper values within the veins. It is hoped that the inferences drawn from the underground data collected, may aid in future development work.

The results of the above investigation and conclusions derived from this and previous geological examinations of the Rossland district will appear in a memoir now in course of preparation.

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[1] Preliminary Report on the Rossland, B.C., Mining District. Geol. Surv., Can., No. 939, 1906.

RECONNAISSANCE IN EAST KOOTENAY, B.C.

(Stuart J. Schofield.)

Introduction.

The writer spent the greater part of the field season of 1913 in studying the stratigraphic relations of the Purcell series of the Purcell range, with those of the Rocky mountains to the east, and of the Selkirk series of the Purcell range on the west.

Messrs. T. L. Tanton, M. F. Bancroft, and G. Hanson rendered efficient assistance in the field work.

The rapidity of the work was greatly increased by the action of the province of British Columbia in causing the trunk trails to be cleared out across the Purcell range.

Summary and Conclusions.

The relationship of the Purcell series of the Purcell range to the Palæozoic series of the Rocky mountains to the east, was definitely determined. Middle Cambrian fossils, which were identified by Mr. Burling of the Geological Survey, were found in the Burton shales which rest upon the Roosville formation with an apparent conformity. Further collections of the Cambrian fossils were made by Mr. Burling, who will publish a more detailed report on the fauna at an early date. Following Walcott, this would place the whole of the Purcell and Galton series[1] in the Pre-Cambrian, since the Burton shale evidently corresponds to the Flathead sandstone. According to Daly, the Purcell series and Galton series may still be, in great part, Cambrian.

The Selkirk series which occur on the western slope of the Purcell range, are equivalent in part to the Purcell series, since the Selkirk series rest conformably upon the Creston formation of the Purcell series. In contrast to the Purcell, the Selkirk series have suffered very strong regional metamorphism with the development of schists which predominate in the lithology of the Selkirk series.

The study of the Pleistocene deposits occupying the Rocky Mountain trench, revealed the presence of Pleistocene lake beds which contain abundant plant remains. The name St. Eugene silts is proposed for these lake beds. These beds are overlain unconformably by till, called the Wycliffe drift, and underlain by stratified gravels which rest unconformably upon the bedrock series. The stratigraphy of the Pleistocene in this region suggests an interglacial origin for the St. Eugene silts, although the non-appearance of an older drift leaves it an open question.

The silver-lead deposits which occur in the Selkirk series were found to be associated with a very siliceous limestone which has a linear length within the region of about 15 miles.

General Geology.

The following table of formations is a composite one, including members of both the Galton and Purcell series, which, according to Daly,[2] are stratigraphically equivalent. The writer identified the Gateway formation in both series, and has used this as a horizon marker. Daly used the Gateway formation and the Purcell lava, the latter being the most valuable member for the purpose of correlation.

[1] Daly, R. A., Geol. Surv., Can., Memoir No. 38, p. 97.
[2] Daly, R. A., Geol. Surv., Can., Memoir No. 38, p. 119 and table viii.

Table of Formations.

Post Glacial		Stratified clays and sands.
Glacial.		Wycliffe drift.
	Unconformity.	
Interglacial?		St. Eugene silts.
	Unconformity.	
Jurassic?		Kootenay granite.
Mississippian		Wardner formation.
Devonian		Jefferson formation.
Ordovician and Silurian?		Elko formation.
Middle Cambrian		Burton formation.
	Unconformity.	
Beltian		Roosville formation. Phillips formation. Gateway formation. Purcell Lava and Purcell Sills. Siyeh formation. Kitchener formation. Creston formation. Aldridge formation.

A description of the Aldridge, Creston, Kitchener, Siyeh, Purcell Lava, Gateway, Phillips, and Roosville formation has been given in the Summary Report for 1912,[1]

Burton Formation.—The Burton formation, named after Burton creek, rests conformably on the underlying Roosville siliceous metargillites, and consists in great part of greenish black, calcareous shales. Separating the Burton formation from the underlying Roosville is a conglomerate 8 inches thick, the pebbles one-half inch in diameter, being composed of hematite with a matrix of hematite. A detailed section of the Burton formation at Elko is as follows:—

Elko limestone—
Burton formation.

	Feet.	Inches.
Greenish black shales with limestone interbands	60±	
Sandy limestone	10	
Greenish black shales	4	
Calcareous grit	3	
Hematite conglomerate	8	10

Roosville formation.

The Burton shales are marine in origin and have not suffered metamorphism to any extent. In contrast to this, the Roosville siliceous metargillites are considered to be a continental deposit exhibiting on the bedding planes abundant mud cracks. They have also suffered great metamorphism. The above facts point to a great change in the physical conditions in this region just before Middle Cambrian time.

Elko Formation.—The Elko formation, named after the town of Elko, rests conformably upon the Burton shale and consists of massive sandy limestone at the base, grading upwards into massive, heavy-bedded, sandy dolomite. The age of the Elko formation in which no diagnostic fossils were found, cannot be definitely determined, but as the Jefferson limestone rests conformably upon it, it is older than the Devonian and, since it rests on the Burton formation, it is younger than Middle Cambrian, hence the Elko formation may include Upper Cambrian, Ordovician, and Silurian horizons. The Elko formation possibly includes the quartzite described by Daly[2] as occurring beneath the Jefferson limestone at the International Boundary line.

[1] Schofield, S. J., Geol. Surv., Can., Sum., Rep., 1912, p. 224.
[2] Daly, R. A., Geol. Surv, Can., Memoir No. 38, p. 111.

Jefferson Limestone.—The Jefferson limestone rests conformably on the Elko formation. Dr. Kindle, of the Géological Survey of Canada, reports as follows on the small collection of fossils submitted:—

Lot 2. "The preceding numbers are represented only by fragments of corals in a black dolomite, too poorly preserved to permit determination. They appear, however, to resemble and are probably identical with one or two species which characterize the Jefferson limestone of Mantana."

Lot 3. "Contains the following species:—

Atrypa reticularis.
Atrypa cf. *missouriensis.*
Spirifer englemanni.
Strophostylus sp.

Lot 4. "Two species as represented in this list, viz:—

Stropheodonta demissa
Schizophoria n. sp.
Spirifer strialula.

"Lots 3 and 4 are of Middle or Upper Devonian age. The fauna of lot 3, though a small one for purposes of close correlation, is believed to represent the fauna of the Jefferson limestone of Montana. Lot 4 probably represents the same fauna."

Wardner Formation.—The Wardner formation rests conformably upon the Devonian limestone and consists essentially of limestone, in places somewhat siliceous, and shaly limestones. A list of fossils found in this formation, was given in the Summary Report of 1912.[1]

Kootenay Granite.—A description of this granite has been given in the Summary Report of 1912.[2]

Pleistocene Deposits.—The Pleistocene deposits in the neighbourhood of the Rocky Mountain trench (Kootenay River valley) can be classified under two main heads, viz., the Wycliffe drift, named from the town of Wycliffe, near where it is exposed, and the St. Eugene silts, named after the St. Eugene Mission, near where these silts are to be found. A detailed section measured on the east banks of the St. Mary river, about 3 miles east of Wycliffe, gave the following result:—

	Feet.	
Erosion surface.		
A. Stratified sand	15	
Unconformity.		
B. Till	30	Wycliffe drift.
C. Stratified silt	25	St. Eugene silts.
D. Stratified gravel	15	
E. Stratified silt	5	
F. Unstratified coarse gravel (till?)	25	
G. Stratified sandy clay	60	
Plant remains.		
H. Stratified gravels, lignite	60	
Base unexposed.		

Member A of the series consists of stratified, argillaceous sands which were deposited in quiet water which filled the depressions in the underlying glacial drift. The maximum thickness of this member is 15 feet.

[1] Schofield, S. J., Geol. Surv., Can., Sum. Rep., 1912, p. 226.
[2] Schofield, S. J., Geol. Surv., Can., Sum. Rep., 1912, p. 226.

Member B is true till and is unstratified. The most striking characteristic when a section is viewed at a distance, is its dark grey colour, which is in marked contrast to the underlying and overlying creamy white silts. The boulders in the till, composed of gabbro and quartzite, were as large as 2½ feet in diameter. Member B rested with an irregular surface contact of the stratified silts.

Member C consists of creamy white silts, very finely stratified, and, in general, entirely free from pebbles.

Member D is composed of boulders of quartzite and diorite and is plainly stratified, although very little sandy material is in evidence.

Member E very closely resembles member C, as it consists of finely stratified creamy white silts.

Member F, 25 feet thick, consists of unstratified, very coarse gravel, which strongly resembles till. The boulders, which are as large as 2½ feet in diameter, consist of gabbro and quartzite. The structure, character of the pebbles, and composition of the material, characterize it as true till, but on the examination of sections of the same Pleistocene material 1½ miles east of this locality, this member was absent in the series. Whether this member represents a regional deposit of till, can only be decided by further work in the Kootenay River valley, where the Pleistocene is well exposed in the river banks.

Member G consists mainly of finely-stratified silts and clay, with some gravel. The more clayey members near the base contain, between the laminæ, numerous well-preserved plant remains of the Pleistocene.

Member H consists mainly of stratified gravel chiefly composed of quartzite, but some pebbles of diorite occur. The exposed surface of the gravels has a rusty appearance and appears older than the gravels in the upper part of the section. Small seams of lignite and pieces of lignitized wood occur in the gravels. The lower part of these gravels was unexposed in this section, but 3½ miles west on St. Mary river, these gravels rest upon the eroded surface of the bedrock.

The possibility that the silts which underlie the Wycliffe drift are interglacial must be considered, but its final proof rests with the discovery of a lower till.

A Preliminary Report by Mr. Arthur Hollock of the New York Botanical Garden, upon the Plants from the Pleistocene Deposits.

The matrix in which the plant remains are contained is a light grey, friable, sandy clay, requiring considerable care in handling.

The specimens are, for the most part, comparatively well preserved, although a majority are fragmentary.

The species represented are few in number as compared with the number of specimens, even if the unidentifiable fragments are included as distinct species; and two genera, *Fagus* and *Platanus*, are so numerously represented that together they constitute about a third of the entire collection.

A systematic arrangement of the material identified is as follows:—

ANGIOSPERMAE.

Monocotyledonæ.

Fragment of a large leaf, with obscure parallel nervation. (43L.)

Fragment of a stem, with well-defined longitudinal striation. (43K.)

Both of these fragments are evidently monocotyledonous, but they are too indefinite for either generic or family identification. The leaf is somewhat suggestive of a palm or a *Yucca,* and the other fragment has some resemblance to the petiole of a palm, but the characters are too superficial to be of any diagnostic value.

Juglandaceae.

Hicoria n. sp. ? (43A, 43P in part.)

This is a leaf which is hardly to be distinguished from those of one or another of our living hickories, especially certain forms of *H. glabra* (Mill.) Britton. On general principles, however, we should probably be better justified in considering it as representing an extinct species.

Salicaceae.

Fragment of the lower part of a large leaf with well-defined lateral primaries, provisionally identified as belonging to the genus *Populus.* (43 O.)

Betulaceae.

Alnus n. sp. ? (43 G.)

This leaf is suggestive of the more orbicular leaf forms of *Alnus rugosa* (Du Roi) K. Koch.

Fagaceae.

Fagus n. sp. (43 F, 43 R.)

This species is represented in the collection by a number of specimens. The leaves are of large size and are well preserved.

Fagus n. sp. ? (43 P in part.)

A much smaller leaf than the latter and hardly distinguishable from the living *Fagus Americana* Sweet.

Artocarpaceae.

Ficus n. sp. (leaf). (43 E.)

Ficus n. sp. (fruit). (43 M.)

The latter specimen is the most interesting and remarkable in the entire collection. It consists of a long, slender branch, on which the sessile fruit is arranged in pairs and larger clusters. Their reference to the genus *Ficus* can hardly be questioned, and the probability is that the fruiting branch and the leaf belong to a single species, but as they are not associated together in the same piece of matrix it seems best to consider them as specifically different and, in the event of describing them, to give to each a distinct specific name.

Ulmaceae.

Ulmus n. sp. ? (43 Q.)

A single fragment of the base of a leaf, evidently an *Ulmus,* which might be more or less satisfactorily compared with leaf forms of certain living and fossil species, but not enough of the leaf is preserved for accurate comparison.

Menispermaceae.

Cebatha (Cocculus) n. sp. (43 B, 43 C, 43 D.)

These three specimens differ, between themselves, more or less, in outline and nervation, and it is possible that more than one species may be represented by them;

but, if the characteristic heterophylly of the genus be taken into consideration, they may well be regarded as all belonging to one and the same species.

Cissampelos ? (43 N.)

Fragment of a leaf, which presents some of the features characteristic of the genus, but only enough for provisional determination.

Platanaceae.

Platanus n. sp. (43 H, 43 J.)

This species is very extensively represented in the collection. Many of the specimens are very large, approximately 9 inches in width by 7 or more in length and, except for their size, are hardly to be distinguished from the deeply-lobed leaf forms of the living *Platanus occidentalis* L., or the extinct *P. aceroides* Goepp.

Vitaceae.

Vitis n. sp. ? (43 I.)

This leaf is hardly to be distinguished from certain leaf forms often seen on our living *Vitis labrusca* L., and *V. riparia* Michx.; but it is considerably larger than the normal size of the leaves in either of these species.

An analysis of these identifications indicates that at least a warm, temperate climate must have prevailed in the Kootenay valley at the time when this flora was living there. The presence of the genus *Ficus* alone is sufficient evidence on this point, inasmuch as this genus is tropical, for the most part, in its distribution, and only three species range as far north as the southern United States. The other genera are so widely distributed, north and south, that, regarded by themselves they would have but little significance as climatic indices. The prevailingly large size of the leaves, however, indicates a luxuriant growth such as would probably obtain only in a climate milder than that of the middle United States, and is corroborative of the evidence furnished by the genus *Ficus* in this respect.

The Selkirk Series.

The Selkirk Series was first outlined by Dawson[1] in a traverse across the Selkirk range in the vicinity of the main line of the Canadian Pacific railway. Although without fossil evidence, he placed the Selkirk series in the Cambrian, correlating them on lithological and structural bases with the fossiliferous Castle Mountain group of the Rocky Mountain system.

McConnell[2] identified the sedimentary rocks on the western slope of the Purcell range in the neighbourhood of LaFrance and Lockhart creeks as belonging to the Selkirk series and mapped them as such on the West Kootenay geological sheet.

A preliminary study of the series was made this year and it was found to consist almost entirely of sedimentary rocks, now for the most part altered to micaceous schists. In this series occur limestones, conglomerates, and quartzites, which serve as important horizon markers in the delineation of the structure and stratigraphy. As the study, this season, was purely preliminary, the series is not described in detail.

The structure of the Selkirk series, as it consists mainly of northerly-striking anticlines and synclines, shows that the region between Kootenay lake and Kootenay river belongs to one orogenic unit, since it has been shown[3] that the Purcell series which forms the eastern half of the Purcell range has a similar structure.

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[1] Dawson, G. M., Geol. Surv., Can., Ann. Rep., vol. iv, 1890, p. 29 B. Bull. Geol. Soc. Am., vol. II, 1891, p. 165.

[2] McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. x, 1897, p. 31 A.

[3] Schofield, S. J., Canada, Geol. Surv., Sum. Rept., 1912, p. 226.

RELATION OF THE SELKIRK SERIES TO THE PURCELL SERIES IN THE PURCELL RANGE.

The St. Mary valley in the vicinity of St. Mary lake cuts across a huge north-south striking anticline of Aldridge quartzites, the oldest known member of the Purcell series. On the western limb of this anticline, there is passed over to the west in ascending order, the sheared and metamorphosed upper parts of the Aldridge and Creston formations. The overlying Kitchener formation can hardly be recognized, while the series overlying the Kitchener conformably in this section, can not be identified with any of the Purcell series, due not only to shearing but also to a variation in lithology. It is this sheared series that has been identified as Selkirk series by Mr. McConnell. Therefore, the Selkirk series is in part equivalent to the Purcell series.

Shuswap Series.

In the neighbourhood of Crawford bay on the Kootenay lake is mapped an area of Shuswap rocks on the West Kootenay map sheet. This area of Shuswap was originally defined by Dawson[1] and this determination was followed by Brock and McConnell in their work of 1900.

These rocks consist of a series of crystalline limestones, schists, gneisses, and quartzites, intruded by numerous unmetamorphosed pegmatite dykes. This whole series dips on an average of 45 degrees to the west.

RELATION OF SHUSWAP SERIES TO THE SELKIRK SERIES IN THE PURCELL RANGE.

The stratigraphic relations of these two series were only studied in one section on Crawford creek. At this point, the Selkirk series appear to pass conformably underneath the Shuswap Series. If this be true, this area of so-called Shuswap rocks does not belong to the pre-Beltian but is a metamorphosed division of the Selkirk series. The abundant sills of pegmatite in the Shuswap series are unmetamorphosed, while the series itself consists entirely of highly metamorphosed rocks. These pegmatites, becoming more numerous as the batholith is approached, are provisionally placed as genetically related to the West Kootenay granite batholith of probable Jurassic age. The contact of the Shuswap and the Selkirk series has evidently been placed where the pegmatite sills cease to appear in the associated schists. From the above, it can be seen that these sills cannot be used in determining or delimiting the age or stratigraphic relationships of the Shuswap and Selkirk series.

Further work on these two series must be done before any definite statement can be made as to their relationships and stratigraphic position.

Economic Geology.

Burton Group.—The Burton group of claims is situated on the western slope of the Rocky Mountain system about 4 miles northwest of Elko. The country rocks in the neighbourhood consist of the upper members of the "Galton series" of Pre-Cambrian age and the lower Palæozic formation, all of which strike N. 40° W. with a dip of 45 degrees to the east.

For a detailed description of the formations, the reader is referred to a preceding paragraph.

The vein which is 2 to 4 feet wide, occurs in a fissure in the Roosville siliceous metargillites. There has been a vertical displacement along the fissure of 4 feet. The vein which strikes N. 50° E. and dips 85 degrees to the north, consists of pyrite and

[1] Dawson, G. M., Geol. Surv., Can., Ann. Rep., vol. iv, 1888-9, p. 29 B.

chalcopyrite in a gangue of quartz. The values sought after are copper and gold. A tunnel about 400 feet long has been driven along the strike of the vein to the

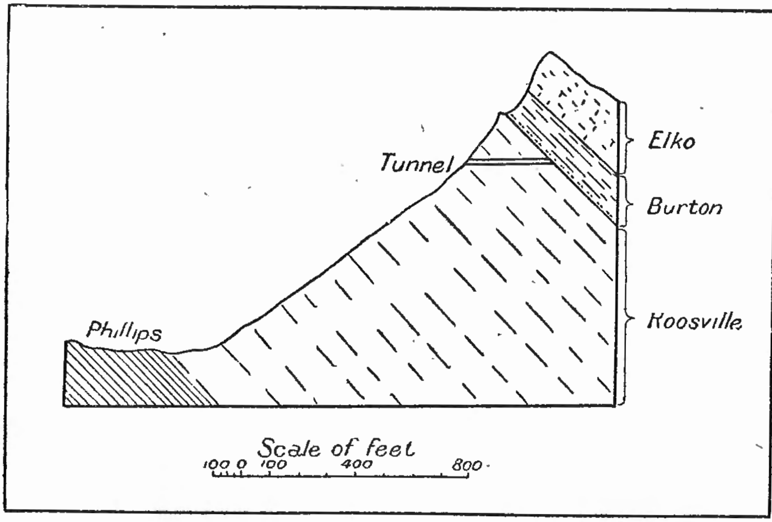

Fig. 2. Cross section of Burton mine.

contact of the Roosville and Burton formations. The possibility of this vein extending farther into the hill will depend upon the ability of the Burton shales to carry a well-defined fissure. It must be borne in mind that shales, as a rule, are not favourable for well-defined fissures.

Silver Hill.—The Silver Hill mine is situated on a branch of Crawford creek at an elevation of 5,800 feet above sea-level, or about 4,000 feet above Kootenay lake. The mine is connected with Crawford bay on Kootenay lake, by a wagon road 9 miles long on Crawford creek. From here, a trail about 3 miles long, reaches the mine. An aërial tram, now in a state of disrepair, built at a cost of $15,000, connects the road with the mine.

The country rocks belong to the Selkirk series which here strike N. 35° E., with varying dips from 0 degrees to 25 degrees to the northwest. The rocks in the immediate vicinity of the deposit consist of calcareous sericitic quartzites, calcareous sandstones, and dark sericitic quartz schists.

The veins which are three in number and which vary in thickness from 8 inches to 2 feet, are true veins formed between the beds of the enclosing sedimentary rocks, and since they approximate horizontality over a considerable portion of the deposit, they are locally known as blanket leads. The veins are separated from each other by about 50 feet of country rock.

The vein filling consists of quartz with varying amounts of coarse-grained galena, zinc blende, cupriferous pyrite, and argentiferous tetrahedrite.

The deposit is opened up by a number of short tunnels and open-cuts along the outcrops of the veins which are exposed over a linear distance of 2,800 feet.

LaFrance Creek Mining Company.—The claims of the LaFrance Creek Mining Company are situated at the head of LaFrance creek, 9 miles east of Kootenay lake, at an elevation of about 7,800 feet (barometric) above sea-level, or about 6,000 feet above Kootenay lake.

The country rocks in the neighbourhood consist of highly-contorted members of the Selkirk series, which consist of dark grey, sericitic argillites, siliceous limestones, argillaceous quartzites, and altered greenstones, the latter probably sheared diabase. The veins occur in a very siliceous, white limestone having a buff colour on the weathered surface. This limestone strikes about north and south with a dip of 35 degrees to the east. The veins are two in number, one striking 355 degrees with a dip of 85 degrees to the east, the other striking 320 degrees and dipping 80 degrees to the east. The ore mineral consists of argentiferous galena, zinc blende, with some chalcopyrite and cupriferous pyrite.

The deposit is opened by three tunnels, the upper one 130 feet long, with a winze 67·3 feet deep, 125 feet from the portal. The intermediate tunnel, 332 feet long with two cross-cuts, is driven 130 feet below the portal of the upper tunnel. The lower tunnel, 652 feet long, is about 240 feet below the intermediate tunnel. Prospecting is being pursued at present to open up stoping ground in the deposit.

Although mineralization in these siliceous limestones is quite extensive, and the limestones can be traced north and south of the LaFrance creek for several miles, the deposits as far as known are not very large. The claims located in the White Grouse mountain, in Harris basin, and on Hooper Creek summit, are all associated with bands of siliceous limestone which vary from 8 to 100 feet in width.

COAL AREAS IN FLATHEAD VALLEY, B.C.

(D. B. Dowling.)

The upper waters of the Flathead river drain from the southern part of the large coal area called the Crowsnest coal field. To the east and south, three small blocks of the coal-bearing rocks are found in the valley, apparently isolated within fault blocks consisting mainly of Devono-Carboniferous limestones. The first area is about due south of Corbin at the mouth of Squaw creek, and just west of North Kootenay pass. The Flathead here turns almost at right angles and seems to be following, in its upper course, a structural valley formed by an east and west fault with downthrow on the south side. The downtilted block is of Carboniferous limestone with reddish tinted upper beds that may be Permian and Triassic in the higher members. At the point of lowest depression near the fault line, a remnant of Cretaceous has been found. This contains several coal seams that may be of economic value. Considerable prospecting has been carried on and several seams exposed. The block near the fault line has been somewhat deformed so that the exposures give the impression that it is bent up in trough form near the fault. These exposures were examined by Mr. W. F. Robertson, provincial mineralogist, while freshly made, and the following notes were published in the Report of the Minister of Mines, British Columbia, for 1909, page 175:—

"The work done during 1909 consisted chiefly in proving the continuity of the coal seams by means of tunnels and incline shafts. There are four seams of bituminous coal on this property. No. 1 seam, 6 feet thick, has been opened by tunnels and incline shafts at six different points, one tunnel being run in on the coal for nearly 200 feet. Seam No. 2, 8 feet thick, has one tunnel run in on the coal for about 75 feet. Seam No. 3, 10 feet 3 inches thick, is the best seam on the property, the coal being exceptionally clean, with a high percentage of fixed carbon; one tunnel was run in on this seam for about 70 feet, at which point an incline shaft was sunk on the coal for 40 feet, where the coal is hard and firm; about 700 yards from this point an incline shaft was sunk on the same seam for a depth of 50 feet, showing the quality and thickness of the seam to be the same as in the original location. Seam No. 4, 16 feet thick, has been opened in several places with open cuts, and an incline run down on the coal for 50 feet, where the coal is hard and firm. The distance between each of the seams is about 300 feet; the coal seams trend east by north, west by south, and pitch north at an angle of 40 degrees."

The area is restricted to a narrow strip running westward from the North Kootenay pass; its western extremity has not been determined, but it is not far past Squaw creek.

Flathead river here turns southward and follows a probable line of fractures or sharp rolls. About 5 miles south of this bend on the west side of this valley, a block of Cretaceous rocks is found standing on edge, whether a fault block or a downward bend in the beds was not learned. In this, the exposed rocks consisted of a ridge of conglomerate striking about north and south. West of this, by trenching, several seams of coal have been found. The extent of the block is at least 2 miles along the strike of the rocks. At Donald Cate's location the coal seams, west of the conglomerate, probably occur in descending order, in a group about 250 feet from the conglomerate, and consist of two 6-foot seams and a 4-foot seam, then a large 40-foot seam and two others between 6 and 10 feet thick. The trenching had not been deep enough to penetrate the weathered coal so that it was all quite disintegrated and its character could not be judged.

Howell and Cabin Creek coal areas are of larger proportions and are farther down the Flathead, 8 and 6 miles respectively, north of the boundary line.

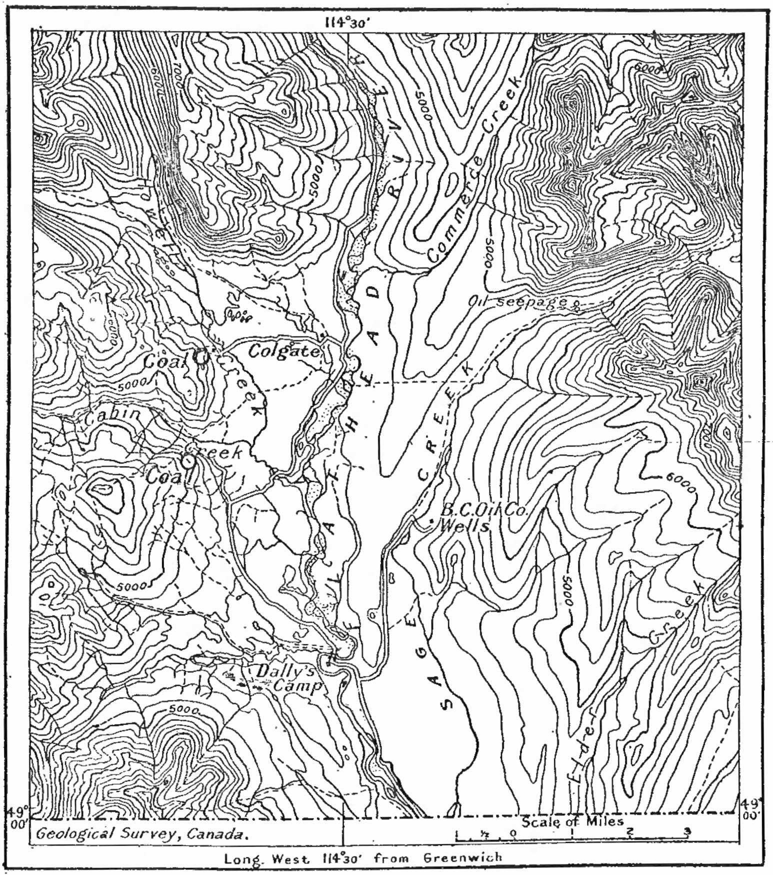

Fig. 3. Index showing the location of the Flathead coal outcrops.

The valley here is wide and floored with river and glacial debris, lying on the planed surface of late Tertiary beds with which the valley was partially filled. On the east, these deposits are lying against the flanks of Cambrian and Pre-Cambrian rocks. On the west, Devono-Carboniferous rocks protrude in bare ridges near the boundary line and again north of Howell creek. Between, there is an area occupied by wooded hills rising 1,000 feet above the river plain. These show along the eastern escarpment sandstones and other soft rocks of Cretaceous age. Coal seams have been found at two localities on the face of these hills in apparently advantageous places for mining. The one examined at our visit was near Howell creek, a western branch of the Flathead. The wooded hill which here forms the western edge of the valley, rises steeply for nearly 700 feet and, in a slight gully on its face, Mr. Butts, who was in charge of the prospecting, has constructed several short tunnels into the various seams exposed. The measures here strike nearly east and west and dip 25 degrees south. Six large seams have been exposed and some excavation done on each. No. 1 seam, near the top of the gully, is reported as being not far below the conglomerate and is 25 feet thick. No. 2 has 31 feet of solid clean-looking coal between the walls. This is probably the finest-appearing seam in the southern part of the mountains and should mine a large percentage of lump coal. No. 2 seam is 16 feet thick, No. 4, 10 feet, and No. 5, the big seam, is somewhere near 50 feet thick, but where opened appeared quite friable and easily crushed. This seam is near the bottom of the hill and probably easy of access, but seam No. 2 will probably be first mined, from its apparent good quality.

At the foot of the hill another seam was found, but from its position it was suspected that there had been a slide and that it was displaced. This one was about 11 feet in thickness.

The river flat appeared favourable for the construction of a railway, but to gain connexion with other Canadian lines a summit must be climbed.

GEOLOGICAL NOTES ON THE SHEEP RIVER GAS AND OIL FIELD, ALBERTA.

(D. B. Dowling.)

Introduction.

The western edge of the great syncline which runs north and south through Alberta and crosses obliquely the fifth initial meridian, is for a short distance bent over into anticlinal form. West of this, which is the region commonly called the foot-hill country, the rocks are faulted and folded, and exposures of the lower series of rocks are to be found on many of the streams. Where the above-mentioned anticline crosses Sheep river the rocks exposed by the erosion of the crest of the anticline are Upper Cretaceous shales. These, on the south branch of Sheep river, are well exposed beneath sandstones which appear to belong to the coal-bearing Edmonton series of northern Alberta or the St. Mary River beds of southern Alberta. In the middle of the anticline, sandstones and shales of the base of the Bearpaw or top of the Belly River formation appear, and in these, near the south branch of Sheep river, a leakage of strongly-smelling gas has been known for years at the apex of the anticline.

Recent boring operations in this vicinity disclosed the presence of gas in the upper beds of the Belly River formation and, at a depth of a little over 1,550 feet, a small amount of light oil (about 90 per cent gasoline) was found. This stimulated the belief that oil was to be found in commercial quantities in this region, and many companies were formed with the object of drilling for oil. Assuming that oil is to be found in the rocks of the Belly River, or those at a lower horizon, it would be essential to success that drilling should be started: (1) at a locality where oil and gas might be expected to accumulate; and (2) where it could be reached at reasonable depths.

The Sheep Creek anticline offers, as far as structure goes, an opportunity of piercing these rocks at a moderate depth. To the west, in the faulted zone of the foot-hills, these lower rocks are again brought to the surface, and there may be areas there where oil may have accumulated, but the broken nature of the country would argue against any very large reservoirs.

The most striking feature illustrated by the section here is the apparent great depth at which the Cretaceous rocks are buried at points to the east of the Sheep River anticline, and, therefore, all drilling in the Tertiary areas must depend for a possible supply of oil or gas on the rocks forming the Tertiary beds. Up to the present a small flow of gas has been obtained at several points, but this has been without much odour, and the only oil found in Alberta in beds near this horizon is to the north, near Edmonton, in surface showings which have a possible origin in drift material brought from the Athabaska.

Extended notes on the geology of the foot-hill area southwest of Calgary will be found in a report by Mr. D. D. Cairnes on Moose Mountain region, Geological Survey Publication No. 968. Information of a more general nature on the geology of the northwest provinces is contained in Memoir No. 29 by Wyatt Malcolm, entitled Oil and Gas Prospects of the Northwest Provinces of Canada. The following notes are intended to supplement the information therein given in regard to the possibilities of oil being found in the Cretaceous rocks. To the description of each formation is added a note regarding its oil-bearing character in the United States, especially in Wyoming and Colorado. The intervening state of Montana has not so far appeared to have an oil field.

The field work on which this report is based, was performed during a visit in October, 1913. The age of the shales in the section west of the Sheep River anticline requires careful investigation as the recognition of the several shale horizons is difficult and the position assigned in the sketch section first published is only provisional.

Summary and Conclusions.

The boring on Sheep river has demonstrated the presence of small quantities of oil in the Belly River rocks, and there is a trace of oil in the weathered face of these sandstones in outcrops on the stream nearer the mountains.

Gas has been obtained at a number of localities in the Belly River formation.

The Cardium sandstone, which seems to represent the top of the Niobrara, is exposed on Sheep river to the west of the Sheep River anticline, and paraffin and oil have been obtained from hand specimens by treatment with chloroform. This horizon is probably the source of much of the gas in the shallow wells at Medicine Hat.

The Dakota sandstone is in places, especially to the east where it is superposed on the Devonian, impregnated with bitumen and heavy oils.

The above three formations contain many sandstone beds which, where porous, may serve as reservoirs for the accumulation of oil or gas, but their accumulation in quantity depends partly on the structural form and mainly on the character of the surrounding shales. Traces of oil, it appears, can be found in many of the dark shales of the Cretaceous, and in the oil fields of the western states, such as Wyoming and Colorado, the finding of oil at the several horizons in the Cretaceous depends greatly on the presence of sandy, porous beds in which it can accumulate. The anticlinal form is, in the majority of cases, necessary for the concentration of the oil into pools, but in very dry beds such as in the Florence field, Colorado, the oil acts as the heavier liquids and collects in the bottom of the basins or synclines.

The Sheep River anticline would seem to be a favourable situation for the concentration of any oil or gas in the rocks beneath, and by deep drilling the horizons which present possibilities, namely, the Belly River, the Cardium sandstone, the Dakota, and the Lower Cretaceous sandstones beneath, may be reached. The anticline in the first fault block to the west, namely, the one passing near Lineham, affords a chance to reach the Dakota at a comparatively shallow depth.

General Description of Geology.

The Macleod branch of the Canadian Pacific railway skirts the eastern edge of a belt of hilly country which lies to the east of the foot-hills proper. The rocks in these hills are of early Tertiary age and consist of light-coloured sandstones and clays that are exposed in the vicinity of Calgary and westward, on the Bow river. In the district under discussion these beds are found in the hills west of Okotoks, and are there seen lying almost horizontally. To the west, up Sheep river, there are occasional exposures, and near the forks of the river the dip of the strata is to the east, thus showing the approach to the western edge of the syncline. The rocks beneath the heavy-bedded sandstones such as are occasionally seen cropping on the sides of the hills, are apparently varicoloured shales and sandstones dipping eastward and are in evidence on the banks of the stream north of the post-office at Black Diamond. From beneath these comes a thick series of sandstones which, a short distance farther west, are tilted at higher angles, and as coal seams are found with them they may be provisionally correlated with the Edmonton beds. As these latter sandstones are of a harder nature than the rocks above and below, their presence is indicated by a line of hills crossing the river valley, and through which the two branches of Sheep river have cut channels. This line of hills marks the eastern side of a long fold running parallel to the mountains, and, at a short distance west, a similar ridge seems to be formed by the westerly-dipping beds of the same series, thus indicating an anticline. The rocks exposed across this portion between the hills are dark coloured marine shales representing the Bearpaw or upper portion of the Pierre-Foxhill formations. The intercalated fresh and brackish water member, the Belly River series, comes very near the surface in the middle of the anticline. The presence of a sandstone with markings resembling plants indicates a change in condition of deposition, but, according to the record of drilling operations on this anticline, shales continued for nearly 300 feet before the sandstone series was reached. Westward of the sandstone rib on the west side of this anticline, a decided break or fault is indicated, and lower beds have been brought up. These, both in thickness and composition, resemble the Bearpaw shales. The axis of this anticline passes just to the west of Lineham ford. For some distance west, the shales continue with moderate westerly dips, but a broken zone is reached near the eastern boundary of section 33, in which there is considerable folding, and the thin sandstones included in this shale series are repeated several times. This sandstone is probably the series called by Mr. Cairnes the Cardium sandstone, and it is expected that in places some oil may be obtained from it. The outcrops in places are stained with paraffin which can be detected only by treatment with a solvent such as chloroform, and in this way a trace of a heavy oil can also be obtained. A band of steeply-inclined beds of Belly River sandstone is found just above the mouth of Macabee creek, and in these there are two horizons similarly stained with paraffin. One at about the centre is supposed to represent the beds from which some oil was obtained in the well being drilled on section 6, township 20, range ii. The shales to the east of this series of sandstones may possibly be the Claggett, but as their thickness is considerable and the sandstones at the base resemble the top of the Belly River series rather than the Cardium sandstones, they are provisionally called Bearpaw.

Description of Geological Formations.

The rocks exposed in the district, including also some of those found in the foothills to the west, are discussed in the general order of the following table:—

Table of Formations.

Tertiary.......	Paskapoo series of Northern Alberta, or Porcupine Hill beds of southern Alberta.
Cretaceous......	Edmonton series of northern Alberta or St. Mary River beds of southern Alberta.
	Bearpaw shales, the equivalent of the Pierre shales described east of the Alberta syncline.
	Belly River series.
	Claggett shales, the equivalent of the Lower Dark Shales of southern Alberta, or the lower part of the Pierre.
	Cardium sandstones.
	Niobrara-Benton shales.
	Dakota sandstones.
	Kootenay formation.
Jurassic........	Fernie shales.
Palæozoic.	

TERTIARY.

Paskapoo Series.—The rocks of this series as exposed in northern Alberta are thus described:[1] "The beds consist of more or less hard, light grey or yellowish, brownish-weathering sandstone, usually thick-bedded but often showing false bedding; also of light bluish-grey and olive sandy shales, often interstratified with bands of hard, lamellar, ferruginous sandstone, and sometimes with bands of concretionary blue limestone." The thickness in the outer edge of the foot-hills on Little Red Deer river was determined as being at least 5,700 feet.

J. B. Tyrrell, Geol. Surv., Can., Ann. Rep., vol. ii, 1886, p. 136 E.

In southern Alberta the sandstones are comparatively soft, with intercalated greyish and blackish shales, the lower beds (Willow Creek of Dawson) having a pronounced reddish or purplish tint.. The series is so far found to be entirely of fresh-water origin. A few coal seams in the lower part are found in the country between Calgary and Edmonton. No authentic records of oil having been found in rocks of this division are known, though there are unconfirmed rumours of oil being found in the country west of Red Deer. Small flows of gas have occasionally been found as instanced in the gas well at High river.

In the valley of Sheep river these sandstones are exposed in horizontal beds in Wilson coulee, near Sandstone station, and in the hills bordering the valley west of the forks. Near Black Diamond post-office a heavy bed of sandstone outcrops near the south branch in section 16, and west of this, exposures of the variegated shales and sands of the base of the formation are seen with an eastern dip. The thickness of the formation here has not yet been measured but seems to be very great. East of the hill country the beds that are at the surface should be those of the lower and more shaly part.

The late Tertiary rocks of Texas produce, in some of the domes, both gas and oil. Veins of gilsonite, a hardened bitumen, are found in Tertiary rocks of Middle Park, Colorado, and in the Green River formation in Utah. The great oil fields of California are mainly in late Tertiary rocks. The Tertiary rocks of Wyoming, the lower part of the Wasatch formation in Carbon county, contains sandstones that yield 8 per cent of oil with an asphaltic base.

CRETACEOUS.

Edmonton Series.—In the vicinity of Sheep river the series of sands and clays which form the base of the Paskapoo, merge into grey clays and sandstones in which one seam of coal is known, and these are succeeded by more sandy beds. The base of the formation is distinctly a sandstone which is exposed on each side of the anticline and, being more resistant to erosion, is marked in the topography by a series of long, narrow hills. The thickness of the sandstone rib is probably over 1,000 feet. In the foot-hills a second coal horizon is found near the base, though on Sheep river none was noted. The upper coal seam at Black Diamond and south near Tongue creek, is repeated on the west side of the anticline in the McDougall mine near Lineham post-office. Coal reported near the surface at the McDougall-Seger well may possibly have been from the lower coal horizon in the Edmonton.

Bituminous sands covered by boulder clay have been found at several places north of Edmonton. The origin of these sands is doubtful, and there is a possibility that in some parts of the series a small amount of oil has been formed which has been collected in sands beneath the somewhat dense boulder clay. The possibility, however, of masses of the tar sands having been transported from the Athabaska country by the Keewatin glacier, is not to be lost sight of. Drilling at these localities has been very expensive and has not proved the supposition that the oil found its way upward from the Dakota beds below. These pools of oil have, moreover, little value except when near enough the surface so that the containing bed can be removed by excavating. The localities so far reported are: near Egg lake, township 56, range xxv, west 4th; section 28, township 56, range ii, west 5th; at Legal in township 57, range xxv, west 4th; and north of the Athabaska on Freeman river, 12 miles above its mouth. Other localities whose positions are not definitely known, are reported near the east end of Lesser Slave lake.

Bearpaw Shales.—These marine shales occupy a position above the Belly River, and are the equivalents of the Pierre-Foxhill of the plains of Alberta. The latter formation, as now understood, embraces also shales below the Belly River formation, and hence individual names are required for the two divisions respectively above and below the Belly River.

In the foot-hill country near the mountains, the thickness is found to be 650 feet. In the Calgary borehole, shales amounting to 530 feet are taken as representing this formation. At Kipp, borings show a thickness of 615 feet of shale above the Belly River coal seam. On the Red Deer river, east of Calgary, the thickness is about 750 feet. East of Edmonton it is about 800 feet and on the north slope of the Cypress hills, McConnell found its thickness to be 900 feet. On Sheep river between the limbs of the anticline, there is, east of the apex, two apparently unbroken series of shales with ironstone nodules and thin, hardened streaks of sandy ironstone, separated by a very narrow band of shales with a discordant dip. This series each contains a section of shales, the eastern one nearly 1,200 feet and the western one 800 feet in thickness. At first view this would give a thickness of 2,000 feet, but as this does not seem warranted by the evident thickness elsewhere, the presumption that there is a repetition somewhere in this section is warranted. The crumpled beds between the above-mentioned blocks are taken to represent a line of weakness, and a possible normal fault is there assumed. Other faults may be present but were not detected, and as a preliminary it is assumed that there is a thickness of 1,200 feet of shales as shown in what appears to be one block.

In Alberta and, probably, also Montana, these upper shales do not seem to contain oil. In Texas, the beds representing the top of the Cretaceous contain oil in the Corsicana field and are supposed to have supplied the oil found in the Tertiary rocks at Beaumont.

Belly River Formation.—This is a brackish and fresh-water formation consisting of sandstones, shales, and a few coal seams. It very closely resembles the Edmonton formation and only by its position below the dark Bearpaw shales is its identity definitely known. According to Mr. Cairnes (Moose Mountain Report, No. 968, page 27) the maximum thickness in the vicinity of the mountains is 1,025 feet. On Sheep river above the mouth of the Macabee creek, where these beds are marked on the Moose Mountain map, there seems to be a greater thickness than the above. In these beds signs of paraffin were detected on the outcrops in two places and these may correspond to the horizons at which oil was found in the well on section 6, township 20, range ii, west of the 5th meridian. Gas has been obtained from this formation in several places in Alberta beside the above-mentioned well.

Claggett Shales.—The shales below the Belly River rocks are marine and, although very similar to the Benton, contain fossils that would place them higher in the series. They correspond in position to the Lower Dark Shales found by Dr. Dawson on Milk river, near Lake Pakowki. These latter are classed by Stanton as being of Pierre age and representing the lower part of the Pierre shales as found in South Dakota. These beds are not found in any very great thickness in the foot-hills (150 to 300 feet), and consist of dark shales with bands of ironstone similar to the shales above and below.

In Canada no reference has been made to the finding of oil or gas in these or in the lower Pierre shales, but in Wyoming some oil has been found in sandstones of the lower part of the Pierre, in the Powder River oil field, and also in the Salt Creek field in Natrona county. In Colorado, oil which is supposed to have come up from the Niobrara and Benton, is found in the lower part of the Pierre in the Boulder and Florence fields. This horizon may correspond to the Claggett of Alberta.

Cardium Sandstones.—This division, which seems to represent shore and possibly land deposits formed at about the period represented farther east by the calcareous shales of the Niobrara formation, consists of coarse sandstones and black shales which have a thickness of about 50 to 100 feet. These are described by Mr. Cairnes and correlated with part of the Eagle sandstone of Montana. They are exposed on Sheep river as a narrow crumpled band at several localities west of Lineham post-office. The interest in this connexion lies in the fact that several samples treated with chloroform imparted a decided brown-yellow colour to this liquid. One sample so treated in the office at Ottawa, on evaporation left dark brown, oily markings on the test tube and a large number of small needle-like particles, suggesting crystals of a white paraffin. This sandstone is a possible receptacle for oil that may come from the Benton shales beneath.

Niobrara-Benton Shales.—The upper part of this series may contain deposits of the same age as the Niobrara formation, but as these shales possess none of the Niobrara characteristics they are generally considered under the caption of Benton shales. This is also the case in Montana where the formation derives its name. At the town of Fort Benton there is no limestone corresponding to the Niobrara, and as there is no erosion interval or unconformity, the Niobrara is probably also represented by shales or sandstones, and in this particular the Benton shales of Montana and Alberta no doubt embrace more than the formation known by the same name in Nebraska.

In the eastern exposures of the Cretaceous in Manitoba and also at various places along the northern face of the Cretaceous plateau, calcareous shales are found beneath the Pierre which seem to be of Niobrara age, and at several localities these have a strong odour of petroleum and are often so impregnated that the shales will burn. Petroleum may be obtained from them by distillation.

These bituminous shales are exposed in the valley of the Pembina river south of Manitou in Manitoba, and on the face of the Pasquia hills in eastern Saskatchewan and, as before remarked, the Cardium sandstones which represent a contemporary deposit in the foot-hills seem to have contained petroleum in some of their exposures.

South of the International Boundary, the oil in the Salt Creek field of Wyoming is supposed to come from the Niobrara, but it is found in sandy beds at the base of the Pierre. In Colorado the oil of the Rangely oil district is procured from the central part of the Mancos shale, and as this formation includes Pierre and Niobrara-Benton, the horizon at which the oil is found may correspond to the Niobrara. In the Niobrara of the Florence field the rocks of the Apishapa and Timpas divisions contain in the pores and small joints much solid bitumen. None is found in the larger joints.

In Canada no mention is made of oil or bitumen as having been found in the Benton shales. In Manitoba they evidently contain much carbonaceous matter, but in the foot-hills the characteristic intense black colour is not so prominent and the shales are more rusty in appearance and may be described as dark grey, rusty shales with many thin bands of ironstone and rusty sandstone.

Oil is found in the Benton in Wyoming and Colorado. In the Wyoming fields of Unita county, oil is obtained in the Aspen formation northeast of Spring Valley, and in the Bear River formation near Spring Valley. Near Bonanza, oil is found in the Wall Creek sandstone near the base of the Benton. The upper part of the Benton in the Douglas field, Converse county, contains a very thick oil, while that from the lower part is much lighter in colour. In the Colorado oil fields, the Carlisle shale in the upper part of the Benton contains oil in the Florence field, while in the Boulder field it is thought that some oil obtained in higher measures has worked upward from the Benton.

Dakota.—The thickness of the Dakota in the foot-hills is from 900 to 1,700 feet. Rocks very similar to those of the Dakota formation and probably of the same age, are found in the foot-hills region and will, probably, be penetrated in some of the deeper borings. In the foot-hill exposures these rocks are sandstones of a general greenish tint. Dark shale beds are found in the lower part of the series, and the division between the Dakota and the Kootenay series below is not well marked and has been here assumed as a heavy conglomerate bed which serves as a horizon marker for the top of the coal-bearing rocks beneath. This series of sandstones is an important gas reservoir in the anticline which passes north through the plains region between Bow Island and Medicine Hat. The great pressure of the gas and its economic value has until lately satisfied the companies drilling so that the origin of the gas has not been determined. It is well known, however, that where these beds rest on the Devonian rocks of the Athabaska river they are impregnated with a heavy oil which on weathered outcrops is thickened to a bitumen. The origin has been ascribed to the Devonian beneath, and in this connexion it may be mentioned that these oils and tars are found over a large area in isolated exposures. The tar spring on Tar island, Peace river, and others in the country at the head of the Wabiskaw river, although found in rocks above the Dakota, probably derive their oil from the Dakota. The suggestion that this sand formation acts as a reservoir for oil extracted from Devonian rocks is quite probable, since in the basin drained by the Mackenzie, where a wide area of these rocks occurs, many instances of tar springs in the Devonian are known. Thus on Slave river, below Fort Smith, and at several points on the west shore of Great Slave lake, there are evidences of petroliferous shales and tar springs. Others are to be found on the banks of the Mackenzie near Fort Good Hope and below Fort Wrigley.

The sandstones of the formation discussed under the name Dakota no doubt underlie a great part of the area occupied by the Cretaceous plateau, and the question of its oil or gas-bearing qualities depends in great measure on whether the underlying strata are capable of producing oil or not. It is not expected that the Devonian is in immediate contact with the Dakota over the whole area now covered by the Cretaceous, since the contact is one of unconformity and in the exposures of the lower rocks in the mountains a great thickness of Carboniferous limestones and shales as well as later beds are there found between the Dakota and the Devonian. It may be that some of these intervening beds are themselves petroliferous or gas-producing, in which case the Dakota may have enriched zones which would in a general manner be aligned with the mountains and would also follow the structure lines or flexures on the plains.

The nearest of the foreign oil fields developed in this horizon is that of Wyoming. In several of the areas there prospected, the Dakota formation is credited with containing bitumen and heavy oil.

In the Powder River field some oil is found in sandstone doubtfully called Dakota, but which may be of earlier age. Dutton and Rattlesnake fields also credit some oil to the Dakota. In the Oil Mountain field there is one spring on Oil mountain in Benton shales, but the oil probably comes up through a fault from the Dakota. In several fields in Unita county, small amounts of oil are obtained from the lower part of the Benton or Dakota.

In Crook county a heavy lubricating oil is obtained from the Dakota. Some oil has been got from near the outcrop of the top of the Dakota in the Newcastle field of Weston county. In Converse county, oil that is found in the lower part of the Benton or top of the Dakota is lighter than that found in the upper Benton of the Douglas field. A very light oil has been found in the lower part of the Dakota in the Shoshone field of Fremont county.

In Colorado, solid bitumen is found in the Dakota, and in the states to the south the origin of oil in the Trinity sands (probably of this horizon) is generally ascribed to the underlying Palæozoic limestones and shales.

Kootenay.—This formation, which is generally very rich in coal deposits in the exposures in the Rocky mountains, thins out towards the east so that its presence beneath the Dakota can only be expected in the western and perhaps southwestern portion of the Cretaceous area. The rocks are brownish sandstone and shales with abundant plant remains, and coal seams may be expected in the foot-hills area. This formation is found in Montana, and thin deposits of about this horizon occur as far east as the Black hills. In the oil fields of Wyoming some oil is credited to sandstones at the base of the Cretaceous which may be of this age, such as in Fremont county and certain sandstones in the Douglas field of Converse county.

JURASSIC.

Fernie Shales.—In the foot-hills a thin series of black shales which vary in thickness from 100 to 250 feet is correlated with the Fernie shales of the mountain areas.

The formation has thinned so much to the east that very little of it may be expected even in boreholes in the outer foot-hills. As an oil-producing stratum it seems of rather small moment and oil, although found in rocks credited to this age in the Powder River field, Wyoming, and in the Florence field of Colorado, is found only in small quantities and is very heavy and black.

PALÆOZOIC.

It is quite certain that the floor on which the above-described Mesozoic deposits were laid down, consists of a series of limestones of which the western portion is formed of Carboniferous rocks with possibly some Triassic and Permian sediments lying here and there upon them. It is possible that these Triassic and Permian sediments and some of the Upper Carboniferous which is found to be oil-bearing in some of the Wyoming fields, may be oil-bearing in places beneath this mass of Cretaceous, and if so possibly may have enriched overlying beds that can be reached by the drilling from the surface. The eastern and northern part of the Cretaceous area is underlain by Devonian limestones and it is already demonstrated that the Devonian, in its northern portion at least, is fairly rich in bitumen and is there the source of the oil found in the Dakota sandstones.

Occurrences of Oil and Gas in General Region.

Gas.—In Alberta, small quantities of gas are to be found in the sandstones of the Paskapoo and Edmonton formations. As these formations contain abundant evidence of plant life both in the form of scattered material and in coal seams, the presence of gas may be expected, but as the beds are generally quite porous and are not capped by closer-grained beds than the occasional clay deposits, therefore the gas is probably to be obtained only in small amounts and at low pressure.

In the Belly River rocks which have a general resemblance to the Edmonton, the accumulation of gas is helped by the cover of close-grained Bearpaw shales which overlie them, and although no great accumulations have yet been found in the prairie country, a very fair flow of gas was obtained in drilling on the Sheep River anticline. The gas was strong smelling and was evidently associated with a volatile oil.

Gas has also been obtained from rocks at about the horizon of the Niobrara at Medicine Hat and in southern Manitoba.

The great flows of gas at Bow island and at Pelican rapids on the Athabaska are believed to come from rocks at the horizon of the Dakota.

Oil.—The Devonian rocks of the Mackenzie basin have long been known to contain bituminous shales and they are also supposed to have originally contained the oil found in the tar sand on the Athabaska. Small amounts of oil are known to exist in certain of the beds of the Niobrara as exposed in southern Manitoba and northern Saskatchewan. The percentage is low, however, and the oil could only be obtained by distillation. The value of these beds as sources of gas or oil depends mainly on the presence of porous material above it, at the base of the Pierre, to act as a retainer. As remarked above, small flows of gas from this formation have been found near Treherne, Man.

In the foot-hills a sandy deposit at about the horizon of the Niobrara has been found in outcrop samples to contain paraffin and some oil, and it is expected that oil may be found at this horizon in the Sheep River borings.

The presence of oil in the Belly River formation at the well on Sheep river is the first intimation that the formation might be a source of oil, but an examination of the outcrops near Macabee creek revealed the presence of small traces of oil in these rocks, so that the theory that this oil came up through faults or cracks at a recent date from below is not necessary.

NORTH SASKATCHEWAN RIVER COAL AREAS, ALBERTA.

(D. B. Dowling.)

A branch railway has just been put in operation by the Canadian Northern Railway Company and runs from Stettler westward to the mountains, crossing the North Saskatchewan river at Rocky Mountain House, and following the north bank to just west of the Brazeau hills. This is to be operated primarily for coal haulage, a mine being now opened on the Shunda Creek area. Notice of the discovery of this area was published in the Summary Report of this department for 1909, page 147. Coal seams were discovered in 1911 by private prospectors, and an area leased. Since then, the construction of the railway branch and the opening of the mine have been in progress. Other small mines for domestic coal may possibly also be opened in the vicinity of the Saskatchewan river, coal seams having been found in the Upper Cretaceous rocks exposed in the river banks.

From Rocky Mountain House westward to the Brazeau hills, the underlying rocks consist of the Cretaceous sandstones and shales of the Edmonton formation with probably some beds of the lower part of the Paskapoo, of Tertiary age. These form the western limb of the broad Alberta anticline and are here almost horizontal, a few bends showing the approach to the zone of disturbance in the foot-hills. At the Brazeau hills, the first of the regular fault block hills are met. The Devono-Carboniferous rocks are exposed to the west of the fault or broken overturned anticline which runs along their eastern face. These hills show the maximum uplift of the eastern edge of this block to be, at the Saskatchewan, decreasing to north and south. The limestones are exposed north of the Saskatchewan in three hills and to the south to probably past the gap of Ram creek. The rocks of the western surface of this uplifted block consist of Cretaceous sediments, and a great thickness has been removed by erosion. The coal-bearing lower series, the Kootenay, still remains and a large block is above the general surface and behind the Brazeau hills. These beds probably form a continuous trough along the western depressed edge of the block and abut against the front of the Bighorn hills. In the portion elevated above the general level, the largest portion of which lies between Shunda creek and the Saskatchewan river, several coal seams have been found, two of which will be mined at once. The measures remaining on this part are evidently the lower part of the Kootenay formation, the section secured by the excavations as given by the engineer's measurements, is as follows, in descending order:—

	Feet.	Inches.
Barren measures	60	0
Coal seam No. 5	7	2
Barren measures	120	0
Coal seam No. 4	2	6
Barren seam	106	0
Coal seam No. 3	15	11
Barren measures	123	0
Coal seam No. 2	7	9
Barren measures	85	0
Coal seam No. 1	4	2
Black shales and sandstones, about	100	0
	631	6

Five seams with an aggregate thickness of 37 feet 6 inches of coal in 631 feet 6 inches of measures.

Seam No. 1 (4 feet 2 inches) was not considered of sufficiently high grade coal to warrant its present exploitation.

Seam No. 2 (7 feet 9 inches), has a roof of shale in thick benches and is of satisfactory strength. In the tunnel, the coal is found to be very friable and as the surface burden is light for a long distance, the surface water is draining through the seam and the coal is very much damaged thereby. A higher grade coal may be obtained at a greater distance from the surface. At a distance of 135 feet from the mouth of the tunnel the coal was still friable and would produce a large percentage of small coal. An analysis by the Milton Hersey Company, of a sample taken across the full seam at 135 feet in the tunnel, gave:—

Moisture	0.44
Volatile combustible matter	17.01
Fixed carbon	69.12
Ash	13.43
	100.00

Coke dull but firm; heating value, 13,202 B.T.U.; sulphur, 0.49.

Seam No. 3 (15 feet 11 inches) is usually accompanied by a band of shale commonly found within a foot or so of the roof. It occasionally disappears and again is found with greater thickness. The lower part is the best coal, and may be separated from the upper shaly part. Of this, samples across a thickness of 13 feet 6 inches from the floor are as follows:—

	Upper 6 feet 6 inches which is below shale band.	Lower 7 feet 0 inches to floor of seam.
Moisture	0.63	0.45
Volatile combustible matter	17.97	17.63
Fixed carbon	66.00	69.92
Ash	15.40	12.00
	100.00	100.00
Sulphur	0.55	0.49
Calorific value	12,834 B.T.U.	13,426 B.T.U.
Coke	Dull but firm.	Dull but firm.

Seam No. 4 (2 feet 6 inches). This seam is considered too thin to be worked at present.

Seam No. 5 (7 feet 2 inches). The coal in this seam proved very high in ash, consequently very little excavation was made on it.

Mining is confined to seams Nos. 3 and 2, and as the railway has only recently reached the property, a temporary plant is installed.

Several coal seams in the Edmonton rocks are exposed in the vicinity of the railway betweeen Rocky Mountain House and the Brazeau hills and if mined will produce coal of a bituminous character suited to domestic use. The principal exposure is of a 10-foot seam, discovered in a small gully near the western edge of township 40, range xii, west of 5th meridian. This is brought up in a slight anticline in the beds and will probably be found over a considerable area. The discovery point was at a considerably lower elevation than the railway tracks and a mine there would require the installation of a hoisting plant. The seam may possibly be traced to a position more nearly on a level with the railway.

A few small seams were also found on the north bank of the Saskatchewan river near the mouth of Ram creek which enters from the south. The beds here for a short distance have a westerly dip and apparently the coal horizon shown in the anticline to the west again comes to the surface. Instead of a 10-foot seam, several thin ones are found quite close together, but they are only about 2½ feet thick and, therefore, hardly workable, the largest, which is mostly shale, is reported as being 8 feet between walls. During the construction of the railway, a steam shovel was supplied with coal from a 2-foot 6-inch seam which was mined only for this purpose. The coal is sub-bituminous of fair grade, giving on analysis:—

	Per cent.
Moisture	6.10
Volatile combustible matter	37.70
Fixed carbon	41.68
Ash	14.52

At Rocky Mountain House, small seams have been known for some time. As reported by Mr. J. B. Tyrrell in Annual Report, Geological Survey, Vol. II, 1886, page 101 E, the section exposed 2 miles below the mouth of Clearwater river was as follows:—

	Feet.	Inches.
Light-grey clay-shale containing obscure fragments of plants and numerous erect silicified stumps of trees, some of which, however, are turned into coal for a couple of inches around the outside	3	0
Coal	0	5
Grey clay-shale	0	8
Coal (at water's edge) reported about	2	0
	6	1

"This is undoubtedly the same seam as that seen in the cliff at the mouth of the Clearwater. Coal was formerly obtained from this place by the servants of the Hudson's Bay Company, and used by them at the forge at Rocky Mountain House. It is a coal very similar to that obtained at Lethbridge on the Belly river, and will keep for a length of time exposed to the air without crumbling, as large masses of it scattered along the banks of the river for many miles below its outcrop, and in some cases rounded off by the actio nof the water, retain all their firmness.'

"The following is Dr. Harrington's report on specimens brought from this seam by Dr. Selwyn in 1873:—

"A bright black coal, breaking with angular fracture and giving a brick-red ash. Two proximate analyses by slow and fast coking gave:—

	Slow coking.	Fast coking.
Water	7.82	7.82
Volatile combustible matter	31.35	38.00
Fixed carbon	54.97	42.25
Ash	5.86	5.93
	100.00	100.00

"Specimens from the same seam were collected by the writer (J. B. Tyrrell) in 1886, and analysed by Mr. Hoffmann, with the following results:—

Hygroscopic water	7.01
Volatile combustible matter	34.63
Fixed carbon	50.34
Ash	8.02
	100.00

WILLOWBUNCH COAL AREA, SASKATCHEWAN.

(*Bruce Rose.*)

Introduction.

General Statement.—The field season of 1913 was spent in a general geological examination of the coal-bearing rocks and associated formations in Saskatchewan, south of the main line of the Canadian Pacific railway and east of the third meridian. With the exception of a few side trips, work was confined to the area of the Willowbunch sheet of the Topographic Surveys Branch, Department of the Interior, and the sectional map on 3 miles to 1 inch scale, was used as a base map. Particular attention was given to the area included in townships 1 to 7, ranges xxi to xxx, west of the second meridian, of which the accompanying map of coal outcrops has been prepared.

A period of three months from June 23 to September 23 was occupied in field work. Mr. A. E. Cameron gave most efficient and satisfactory assistance throughout the season. Two weeks in August were occupied by a trip to Kamloops, B.C., in connexion with the excursions of the Twelfth International Geological Congress, during which time Mr. Cameron conducted the field operations.

On account of the extent of territory covered, work was necessarily of the reconnaissance type and consisted largely in the measurement and sampling of coal and clay outcrops, the location of these on the township plans, and the correlation of strata.

Previous Work.—A previous report on the geology of the area was made by Dr. G. M. Dawson, who was attached to the British North American Boundary Commission in 1873-74[1]. Dr. Robert Bell, of the Survey, made a trip from the Dirt hills to Wood mountain across the northwestern corner of this area in 1873, of which a brief account is given in his report for that year. These are the only previous reports bearing directly on the area, but reports on the surrounding areas are contained in the accounts of the early explorations of Sir James Hector and of H. Y. Hind in the northwest, in the reports of the Hayden survey of the territories, in various reports of both the United States Geological Survey and the North Dakota Geological Survey on areas to the south, and in reports of the Geological Survey of Canada on neighbouring areas. The latter are contained in the works of Selwyn, McConnell, Dowling, Tyrrell, Ries, and Keele.

Summary and Conclusions.

The investigation of this area shows that it is abundantly supplied with lignites and clays. The lignites occur in such quantity that they form a fuel and power reserve that is hard to estimate, in a region where there is practically no timber and where water-power is unattainable.

The clay supply is inexhaustible. Here again the scarcity of timber for building is offset by the ease with which bricks can be made from the clays. The tests of the clays show that there is not only an abundance suitable for common brick, but also there are more refractory clays suitable for sewer-pipe and fire-brick, etc., of which Canada imports annually a considerable quantity.

The close association of the lignite and clays is very fortunate. In cases where it might not be profitable to work either one singly, the combined working of clay and

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[1] Geology and Resources of the Forty-ninth parallel, 1875.

coal seams should be considered. In any case the working of the clays will be greatly facilitated by the ease with which a nearby cheap fuel supply may be had.

With the opening up of the Canadian west and the increasing demand for fuel and building material, along with the increasing facilities for railway transportation, it is to be expected that the working of the associated lignites and clays of southern Saskatchewan will soon form a considerable industry.

General Character of the District.

TOPOGRAPHY.

The Willowbunch area lies near the eastern border of the third prairie steppe just to the west of the Coteau du Missouri and to the east of the Wood Mountain area. It forms, with the Wood Mountain and surrounding areas, an elevated residual of nearly horizontal Tertiary strata on a base of flat-lying Cretaceous strata.

The topography is in general that of the Great Plains, or what is here more popularly called " the prairies." This consists of a plain developed on nearly flat-lying strata. where for great areas the level of the plain corresponds to the level of the strata, but which considered as a whole is seen to bevel the strata at small angles. The origin of this plain is then in part structural and in part erosional. It was formed in pre-Glacial time and its surface was somewhat modified by glacial scour and deposition.

In detail, two special phases of topography are exhibited. The southern part of the area is cut up by numerous small ramifying coulées, and where the vegetation is scanty, approaches bad land topography. The coulees are all tributary to the Missouri River system. The northern part of the area is a region of undulating prairie with numerous small depressions occupied by sloughs and lakes, and with an absence of any connected drainage system. The surface deposits are here morainic material or the outwash and lake deposits formed during the retreat of the last continental glacier. During this period the rise of the Coteau du Missouri doubtless formed a barrier at the front of the ice sheet and hence much morainic material was deposited here.

Although very irregularly distributed, there is a certain amount of parallelism of the morainic ridges in an east and west direction. Furthermore the morainic ridges occur in zones. A zone of hilly country several miles wide is followed by a depression of corresponding width. This suggests that there was a cyclic change of climate greater than that accompanying the seasonal retreat of the ice sheet, giving times of rapid retreat which are marked by the depressed areas with less morainic material. These depressions may, however, be valleys cut by Glacial or pre-Glacial streams, but no evidence of fluvial action remains. The railways and main roads follow these depressions.

Cutting across the area and roughly dividing the coulee country from the lake and slough country, is a large coulee known as Big Muddy valley. This valley is occupied at several points along its source by lakes and intermittent streams, and is tributary to the Missouri river although there is at present no through flowing stream. It is cut to an average depth of about 250 feet below the prairie level and has a width varying from 1 to 1½ miles. It was excavated when the climate was much more humid than at present. It probably represents the work of a large stream during the retreat of the continental glacier.

A line of terraces about 200 feet above the valley bottom marks a break between a mature upper valley and the main younger valley, so there were at least two stages in its development.

The present relief is then a function not only of Glacial but also of pre-Glacial topographic forms and has undergone small change since glaciation.

CLIMATE AND AGRICULTURE.

The climate is very similar to that of the open treeless prairie in general. It may be described as a typical steppe climate.

Winds and scarcity of moisture prevent the growth of trees except along stream courses or in the protected hollows of coulees. The vegetation is mostly of grasses, which grow abundantly during a wet spring season and cure to a natural hay during the late summer, thus making it a good grazing country.

The precipitation is about 14 inches per year, of which about 8 inches fall during the months of May, June, and July, when it is most beneficial to the growing crops.

The winters are cold and the summers hot. The range of temperature is large, from —40° F. in winter to 90° F. in summer, with an approximate average of 10° for the months from November to March and of 52° for the months from April to October.

The yield of grains is above the average for the prairie provinces, and although the area has been known and settled, particularly about the village of Willowbunch, for years, it is only since the coming of the railways into the northern part of the area within the last five years that there has been an inrush of settlers, and now practically all the best agricultural land is occupied.

The broken coulee areas which are too rough for grain growing are admirably suited for grazing. Numerous springs supply abundant good water.

TRANSPORTATION AND COMMERCIAL POSSIBILITIES.

On account of the open-plains nature of the topography, the Willowbunch area has always been easily accessible and has been connected by wagon road to Moosejaw and surrounding towns for many years, but it is only within the last five years that it has had railway connexion. The Weyburn-Lethbridge branch of the Canadian Pacific railway now cuts across the northern part of the area and the Radville branch of the Canadian Northern railway reaches as far as the town of Bengough. The coming of these railways has caused the area to fill with settlers, and grain growing has become general, but the area to the south along the International Boundary is still in need of railway connexion. It is, however, admirably suited for ranching, for which close railway accommodation is not so necessary as for grain growing.

The development of coal mining and the manufacture of clay products now only await the attracting of investors. Development up to date has been confined to the mining of coal for local use at various localities and to the establishment of a brick-yard at Claysite, in the Dirt hills. Some of the clays here are very refractory and it is the intention to manufacture a variety of products, from common brick to fire-brick.

Similar deposits of clays, shales, and coal beds are successfully worked in North Dakota and fire-brick are shipped into Canada.

One drawback to coal mining is that the lignites slack and crumble on exposure to air and so it is necessary to have mining just equal to the consumption. Experiments are being made on briquetting the lignites and if successful the difficulty of storing will be overcome. Mining can then progress at a steady rate and the briquettes can be stored until needed.

General Geology.

The only rocks exposed in the area examined, other than the surface deposits of Pleistocene and Recent accumulation, are the clays, shales, sands, and coal beds of the Fort Union formation. The geological maps published by the Canadian Geological Survey have not assigned to the Fort Union formation a separate colouring, but it has been included with the stratigraphically conformable formations from the top of the Pierre-Foxhill to the unconformity below the Oligocene, under the term "Laramie."

FORT UNION FORMATION.

The Fort Union is a fresh-water formation made up of a succession of almost horizontal strata of clays, clay shales, sands, and lignites with a small amount of sandstone. In general, it is quite uniform in appearance. The colours of the clays, shales, and sands range from yellowish-grey through drab and grey nearly to white. None of the members are greatly indurated except the sandstone and it forms a very small part of any section and is not continuous for any great distance.

Sandstone and clay-ironstone concretions are common in the beds. The clay-ironstone concretions are concentrated along certain strata and in places form an almost continuous band of from 1 to 3 inches thickness. Gypsum in the form of selenite often occurs as a parting between strata.

The succession of strata varies greatly from place to place and although a particular member may in places be traced for several miles the sections are so different at different points that no correlation can be made. The deposits really consist of a series of broad, thin, interfingering lenses of clays, sands, and lignites, and the variability in succession is due to the changing circumstances of deposition. The beds are a series of shallow-water lake deposits. This is evinced by the variability in character of the lens-shaped beds, the cross-bedding particularly in the sands, the general arenaceous character of the deposits, the gypsum between strata, the lignite beds, and a continental fossil flora and fauna.

The following section exposed on the south shore of Big Muddy lake in section 26, township 2, range xxii, west of the 2nd meridian, illustrates the character and variability of the strata:—

	Feet.	Inches.
Blue-grey clay with clay-ironstone band	11	0
Grey sand	5	0
Shaly blue clay	0	6
Lignite	0	9
Grey clay	5	6
Lignite	1	0
Grey clay	10	0
Dark grey shale	1	6
Blue-grey clay with clay-ironstone bands	21	0
Lignite—very small.		
Grey clay	3	0
Lignite	0	6
Grey clay	6	0
Lignite	1	0
Sandy grey clay	10	0
Shaly and woody clay	0	6
Sandy grey clay	24	0
Clay and lignite	0	9
Lignite	1	6
Woody clay with gypsum	0	6
Lignite	1	0
Yellow-grey sand	2	0
Lignite	2	0
Shaly grey-white clay	2	0
Lignite	2	0
Grey clay	10	6
Lignite (worked for local use by farmers)	6	6
Sandy grey clay with sandstone concretions	7	0
Yellow-grey shale with fossil leaves	1	0
Sandy yellow-grey clay	5	6
Lignite	2	0
Sandy grey clay	34	0
Lignite	0	4
Grey clay	2	0
Lignite	1	3
Grey clay	1	9
Lignite	1	0
Sandy grey clay	17	0
Lignite at waters edge.		
	203	4

A conspicuous feature is the presence of red beds and clinkers produced by the burning of lignite beds. The beds above the burned seam are the ones which show the most marked effects. These are commonly baked and changed in colour, some to cream and buff colours, but most conspicuous are those changed to pink and red. In one locality considerable slag of a red colour has been produced by the fusion of the overlying beds. The burned seam in this case is represented less than 1 mile away by an 18-foot seam of lignite.

SUPERFICIAL DEPOSITS.

Gravels, sands, and boulder clays mantle the surface except on the steep sides of coulées or stream courses. These are the morainic and outwash deposits from the continental glacier. They are thickest in the north part of the area close to the Coteau du Missouri. Large areas of level prairie such as that about Bengough, where the soil is uniformly fine, with occasional knolls and small ridges of gravel, represent outwash lake deposits. Similar fine soil on the broad, flat bottom of Big Muddy valley is thought to represent the aggradational material of the silting up of this valley during the last stages of the old stream which at one time occupied it. To this may be added the smaller amount of more recent silts brought in by the spring freshets from the side coulees.

The Recent deposits are so small as to be almost negligible. The deposits from spring freshets just mentioned, the filling in of sloughs with plant remains and blown material, and a slight rearrangement of surface material are all that is of importance.

Economic Geology.

COAL.

Lignite has been mined for local use only at a few localities. The mines or pits are in all cases located on the sides of coulées where coal outcrops occur, and no development work or prospecting has been done other than the actual mining. This has necessarily been confined to the southern coulee district, where outcrops are easily found, although coal has been reported from well borings at several localities in the northern drift-covered district.

The first mining is in most cases done by the open-pit method. This is commonly used by the farmers who go to the nearest coal outcrop, strip off the overlying strata and dig out the lignite. Mining by this method cannot extend far, for the sides of the coulees are usually so steep that after digging a few feet into the bank the thickness of the overburden becomes so great that the expense of removing it is greater than the value of the coal.

In a few localities underground mining is carried on. Timbering is used for a main tunnel and the coal is extracted by the room and pillar method. The scarcity of trees on the prairie and the consequent high cost of timber must be taken into account in the consideration of any mining operations.

The analysis of the coal shows it to be a true lignite. It is very black for lignite and when freshly dug is compact and breaks with a hackly fracture into massive lumps. On exposure to the air, however, a great deal of the moisture evaporates and it slacks almost to a powder. It is advisable then to mine the coal only as needed or to keep it sheltered in tightly-packed piles.

The following analyses, sections, and brief descriptions summarize the work on the lignite.

Analyses.

No.	West of the 2nd meridian.			Moisture.	Volatile matter.	Fixed carbon.	Ash.
	Section.	Township.	Range.				
1	17	3	21	9·1	41·2	32·7	17·0
2	2	4	23	8·1	38·2	42·3	11·4
3	3	5	23	8·8	39·6	38·8	12·8
4	28	1	24	8·1	36·9	39·8	15·2
5	30	2	25	8·1	40·8	39·1	12·0
6	32	3	26	8·5	39·5	35·4	16·6
7	35	5	26	7·4	34·6	34·3	23·7
8	27	7	27	8·2	40·6	35·6	15·6
9	11	3	19	7·3	38·4	36·2	18·1

These analyses show considerably smaller percentages of moisture and higher percentages of ash than most of the published analyses of the lignite of southern Saskatchewan. The small percentages of moisture are accounted for by thorough air drying. The samples stood for several months after collecting in a room heated to 60° F. or more.

The percentages of ash are thought to be representative. Care was taken in sampling to get average samples across the seams from freshly-opened workings, while it appears that many of the published analyses are from picked samples.

No. 1 is from a small mine operated by Mr. Richard Appleby, Roanmine, Sask., on the west side of Roan Mare coulee. Seven feet of workable lignite is overlain by 1 foot of bituminous clay shale which makes a good roof. Above this lies 3 feet of clean building sand and then a succession of clays, shales, and small lignite seams. The coulée sides are here quite grass-covered but the bed is thought to be of considerable extent. The mine is located well up a side coulee giving easy drainage and the seam is horizontal, so that mining is carried on at small cost. At the time of visiting only one tunnel had been driven.

No. 2 is from an open pit operated by Mr. W. H. Treleaven, Waniska, Sask. The pit is in a steep-walled coulee or amphitheatre on the east side of Bender's coulee, at the foot of a bold hill called Eagle butte. The strata is well exposed in the neighbourhood, and the following section was obtained:—

	Feet.	Inches.
Sandy clay, with concretions, grass-covered	40	0
Lignite	2	0
Grey clay	9	0
Shaly sandstone	9	0
Yellowish grey clay—sandy streaks	17	0
Lignite	4	6
Grey clay	7	0
Lignite	0	6
Sand	0	6
Blue clay	1	0
Lignite	1	0
Blue clay	4	0
Lignite	0	6
Blue clay	1	0
Sandy, yellow-grey clay	10	0
Lignite	0	4
Sand	3	0
Banded clay and lignite	11	6

	Feet.	Inches.
Selenite crystals.		
Sandy grey clay with concretions	15	6
Lignite with bands of clay and sand	6	0
Grey sanding grading to clay at bottom	25	0
Lignite	3	9
Compact, yellow-grey, limy sand contains bands of clay-ironstone and sandstone concretions	20	6
Lignite—upper part shaly	4	0
Limy sand with clay-ironstone concretions	15	0
Clay shale	2	0
Lignite—2-inch clay parting, 16 inches from the top. This is the seam which is mined and of which No. 2 is an analysis.	6	0
Clay shale	3	0
Lignite—reported from boring	5	0
From here to bottom of main coulee is clay with some lignite indications mostly grass-covered	50	0
	277	7

No. 3 is from an abandoned mine at Coal Mine lake, 6 miles southeast of Bengough. A 5-foot seam has been exposed by trenching for one-quarter mile along the east side of the lake and has been worked by tunnels at three points. But these had caved before the time of visiting, and it was impossible to go more than 50 feet into one of the tunnels, from where the sample analysed was collected.

No. 4 is from an open pit worked by the farmers of the district. A seam 4 to 5 feet thick is exposed on an open hill and is followed both above and below by clay. The slope of the hill is small and open-pit mining by stripping the clay overburden can be carried on for a number of years if the lignite is used only for local use.

No. 5 is from a mine operated by Mr. Olaf H. Person, Eddyside, Sask. There is an 11-foot seam of lignite with a clay parting at 3 feet from the bottom, and the upper 2 feet is banded with clay. Above is a bed of clay shale with fossil leaves, followed by fine yellow-grey sand.

The bottom 6 feet of lignite is worked by undercutting on the clay parting at 3 feet, picking down the upper 3 feet and then raising the lower 3 feet. The mine is well located on the side of a coulee where the coal can be dumped into wagons at the tunnel entrance. It is worked by the room and pillar system.

No. 6 is from a mine operated by Mr. C. H. Waldon, Hart, Sask. Seven feet of lignite from the bottom of an 18-foot seam is worked. The succession of strata here is the same as that at the mine operated by Mr. Person in section 30, township 2, range xxv (No. 5), and is thought to represent the same horizon. The clay parting is thicker and is located above the worked portion, so that there are really two seams of lignite. An old tunnel on the upper part was driven to 75 feet, while the tunnel on the lower part at present being worked was driven to 80 feet at the time of visiting the mine.

It was noted that the same succession of strata (lignite followed upwards by clay with fossil plants and then fine sand) occurs at various locations throughout the southwestern portion of the area, and that the thickness of lignite is in each case greater than the average for lignite seams in southern Saskatchewan. It is concluded that they are all contemporaneous deposits and, while there may not be a co-extensive seam, the various outcrops are at least at the same horizon. The only analyses from this seam are Nos. 5 and 6, but the following are a few of the localities where it outcrops:—

—	Section.	Township.	Range, west of 2nd meridian.	Thickness.
	12	2	23	9 feet.
	35	2	24	3½ "
No. 5.	30	2	25	11 "
	16	2	26	16 "
Well-boring.	28	3	26	22 "
	29	3	26	21 "
No. 6.	32	3	26	18 "
	32	1	28	11 "
	13	5	28	14 "
	4	1	29	8 "

Also south of the International Boundary, reported by Dr. G. M. Dawson,[1] thickness. .18 feet.

No. 7 is from a mine south of the town of Viceroy along Willowbunch lake. A tunnel is in more than 200 feet on a seam 5 to 6 feet thick. The quality of the coal is uniform throughout. It is overlain by a bed of clay or clay shale which is used as a roof. The seam outcrops at several points, but the sides of the coulee in which the lake lies are grass-covered, and no section was obtained.

No. 8 is from a mine operated by Mr. A. Caillet, Readlyn, Sask. The lignite is interbanded with clay as follows:—

Clay—	
Lignite	2 feet.
Clay with fossil plants	6 inches.
Lignite	1 foot.
Clay	6 inches.
Lignite	2 feet.

The thickness of the individual beds varies. The bands of clay are in places 1 foot thick or pinch to nearly nothing, and the coal is then correspondingly thicker.

Just across a coulee, to the north from this mine, are the caved workings of another mine. It is at a considerably lower level than the seam worked by Mr. Caillet.

No. 9 is from a mine operated by Eidsness Bros., Gladman, Sask. A 7-foot seam of lignite is overlain by clean building sand similar to that at Roanmine, Sask. (No. 1). The upper part of the seam is here also a bituminous clay; 4½ feet are worked, leaving a roof to support the sand. A 2-inch clay parting about 2 feet from the bottom is picked out in mining.

A second mine on the same seam, also in section 11, township 3, range ix, is operated by Mr. Bundgard. The room and pillar system is used in both mines and each is provided with an air shaft.

Lignite Occurrences Outside the Map-area.

At Brooking, Sask., lignite is reported to be common in well borings, in a coulee bottom which the Canadian Northern railway crosses near the station, 4 miles north of the village, where it is dug from the hill sides and in the hills to the south. The last occurrence includes the lignite at Gladmar (No. 9).

At Ceylon, lignite is reported from the Canadian Northern Railway well borings.

The following information about lignite in section 22, township 4, range xvi, west of the 2nd meridian, was given by Mr. Dowling of the Survey:—

Section:—	
Lignite	3 feet.
Clays, etc.	57 "
Upper seam—Lignite, clay parting	7 "
Yellow sand	5 "
Lower seam—Lignite	3 "
Clay	1 foot 4 inches.
Lignite	4 feet.

[1] Op. cit., pp. 97-100.

Analysis of the 7-foot seam by F. G. Wait, Mines Branch:—

	Per cent.
Water	24.10
Volatile matter	25.98
Fixed carbon	42.31
Ash	7.61

West of Avonlea, a 7-foot seam is reported from a well boring at a depth of 70 feet in section 24, township 12, range XXIV, west of 2nd meridian. Again in section 26, township 12, range XXIV, west of 2nd meridian, a seam 2 to 3 feet thick has been dug for local use. This is just at the escarpment of the Coteau du Missouri, where the Dirt hills face the level prairie to the east. Small seams of lignite are reported to be common in the disturbed strata of the escarpment. Farther west and well within the area of the Dirt hills in section 29, township 11, range XXV, west of 2nd meridian, a 3-foot seam outcrops in a small coulée.

Near Grace, Sask., in section 36, township 10, range XXVIII, west of 2nd meridian, the Consumers Coal Co. of Moosejaw, Sask., have carried on the largest mining operations of any place visited. Here a 7-foot seam outcrops in the coulee occupied by Lake of the Rivers. It rests on clay and is followed upwards by a series of clays and thin lignite seams. Several hundreds of tons were mined and used locally. Then a fault was encountered and mining ceased. Borings have since proved the seam on the other side of the fault. The faulted portion is only a block which has slidden into the coulee, and mining was carried on in the slumped portion.

A 10-ton lot of lignite from the Consumers Coal Company's mine was tested at the fuel testing plant of the Mines Branch, Department of Mines, Ottawa, and it was concluded that this lignite may be pronounced as an excellent fuel for the production of power when utilized in a producer gas power plant.[1] A proximate analysis of the coal is as follows:—

Moisture	32.42 per cent.
Volatile combustible matter	28.29 "
Fixed carbon	31.32 "
Ash	7.97 "

Other outcrops and reports of borings show that the area about the forks of the Lake of the Rivers contains a considerable quantity of lignite. This is associated with clays suitable for both common brick and for fire-brick. The location, only 40 miles from Moosejaw and close to railways, makes it a very attractive area for further investigation.

The lignite area described in this report is only a small part of a much larger field. That mining of the lignite is a profitable industry is shown by the production of the mines in the same formation in the Souris River coal-field and in North Dakota.

CLAY.

Samples of clay were collected from the most likely beds at various localities and sent to Mr. J. Keele of the Survey for physical tests. The results show that while some of the clays have serious defects, most of them are suitable for the manufacture of common brick, two are semi-refractory, and one which softened only at cone 27 (1670° C.) may be classed as a second-class fireclay.

Such a large proportion of the strata consists of clay that the few samples tested give a very restricted idea of their real importance. This is especially true for the refractory clays. Fireclays are known and worked in the same formation in North Dakota and in the Dirt Hills area where the Saskatchewan Clay Products Co., Ltd., have recently opened a plant.

[1] Summ. Rept., of the Mines Branch, Department of Mines, 1912, p. 37.

List of Clays Tested.

Laboratory number.	Field number.	Location.		
		Section.	Township.	Range, West of 2nd.
179 A.	1	3	5	XXIII
179	2	3	5	XXIII
179 B.	1 and 2	3	5	XXIII
170	5	30	6	XVIII
171	14	9	1	XXII
172	21	31	3	XXIV
176 B.	22	31	3	XXIV
176 A.	23	31	3	XXIV
173	26	12	6	XXX
174	27	6	6	XXIX
175	31	28	7	XXVII
176	33	5	7	XXVII
177	35	35	5	XXVI
178	38	14	11	XXVIII

The following descriptions are taken largely from Mr. Keele's report of the physical tests:—

Lab. No. 179A.—Grey shaly clay, in a 2-foot seam below the coal at Coal Mine lake. A highly plastic, stiff and sticky mass when wet, will probably crack on drying.

Burns to hard red body at cone 06, with a total shrinkage of 12 per cent, which is excessive. The burned body is badly scummed. This clay is of little value and is not recommended for brickmaking purposes.

Lab. No. 179.—Sandy clay underlying 179A, really a yellowish-coloured silt.

When tempered with 25 per cent of water, it forms a body of rather low plasticity, which is short in texture. The drying shrinkage is 6 per cent. It probably dries safely without cracking.

Burning tests: cone, 06; percentage fire shrinkage, 0; percentage absorption, 19:0; colour, light red.

It appears to be suitable for the manufacture of common brick. The drying qualities would have to be tested on a large scale.

Lab. No. 179B.—A mixture of equal parts of 179A and 179 was made up by the dry pressed process. This burned to a light red, very porous, and rather weak body at cone 06, but will give a better product at cone 03.

Lab. No. 170.—A 2-foot seam of greyish-white clay shale outcrops in a coulée at Brooking, Sask. It was thought that it might be a fireclay.

When tempered with 21 per cent of water, it forms a very plastic, good working body. Its drying shrinkage is 5 per cent and it will probably dry intact when made into full-sized wares.

This clay burns to a cream-coloured body at all temperatures up to cone 5 (1230° C.), and the body remains porous and open, behaving so far like a fireclay. The body is grey in colour and vitrified at cone 10 (1330° C.), but numerous dark fused spots appear on the surfaces. It fuses at cone 20 (1530° C.), so that it is not a fireclay [fireclay is required to stand up to cone 27 (1670° C.)].

Although this is not a refractory material it is nevertheless a valuable high grade clay. It can be used for a high-class face brick, and if mixed with good red-burning clay, for sewer-pipe and fireproofing.

Lab. No. 171.—Four feet of hard grey clay shale above a 3-foot seam near Big Muddy post-office. Requires 31 per cent of water for tempering, is very plastic, smooth, and sticky. Its drying shrinkage is 8 per cent. The small test pieces did not crack, but it is probable that full-sized bricks would check in drying.

It burns to a light red colour at cone 06, the fire shrinkage is 1 per cent, and the absorption is rather high. It fuses to a slag at cone 3.

The drying qualities of this clay should be tested on a large scale. If it dries intact it might be used for common brick, but the high shrinkage would have to be reduced by the addition of sand.

Lab. No. 172.—A grey-white gritty clay outcrops for several miles along Big Muddy valley, and is in places over 20 feet thick. It is easily recognized on account of being much lighter in colour than any other bed.

It requires 24 per cent of water for tempering and is very plastic, stiff, and pasty in the wet state. It dries slowly and exudes soluble salts. The test pieces did not crack in drying and the shrinkage was 7 per cent.

This clay burns to a pink colour at all temperatures up to cone 5 (1230° C.). The body is vitrified, develops fused iron spots, and becomes slightly vesicular at cone 10 (1330° C.). It fuses at cone 20, therefore it is not a fireclay, but like No. 170 may be classed as semi-refractory, a bastard fireclay, and is suitable for high-class face brick, sewer-pipe and fireproofing.

A sample dry pressed bricklet is light buff in colour at cone 03 and its absorption is 12 per cent. It ought to give good results for face brick if burned harder.

Lab. No. 176B.—A grey clay shale containing bands of clay-ironstone concretions in a 43-foot bed above No. 172. It makes a stiff sticky paste when tempered with 30 per cent of water. The test pieces cracked so badly in drying that they could not be tested further. The clay appears to be useless in the raw state, but the preheating treatment may render it workable if economic conditions ever allow the extra expense necessary for this purpose. The addition of sand will not cure the defects of this clay.

Lab. No. 176A.—A grey sandy clay in a 34-foot bed in section above Nos. 172 and 176B. When mixed with 30 per cent of water it becomes fairly plastic and rather sticky, but the small test pieces moulded from it cracked in drying and were not thoroughly dry in six days. It burns to a rather porous weak body at cone 06, and is useless for the manufacture of clay products.

Lab. No. 173.—A light yellow-grey silt clay in a 10-foot bed above a coal seam. It is one of the few clays in the region which has a noticeable lime content. It requires 25 per cent of water for tempering and is fairly plastic, but rather flabby owing to its silty character. It will stand fast drying with artificial heat. The drying shrinkage is 5·5 per cent. It burns to a porous, pale red or salmon colour at cone 06, and fuses to a slag at cone 5.

It is suitable for the manufacture of common building brick.

Lab. No. 174.—A dark grey clay shale above a coal seam. It requires the extraordinary amount of 44 per cent of water for tempering and forms a highly plastic, stiff, pasty mass which is very hard to work. Its drying shrinkage is 10 per cent, which is excessive. It burns to a red body, hard and dense at cone 06, with a fire shrinkage of 3 per cent.

This clay has several serious defects, such as excessive shrinkage, cracking in drying, and bad working qualities. It also contains a certain amount of carbonaceous matter which causes swelling in burning, except when fired very slowly. It is not recommended for the manufacture of clay products.

Lab. No. 175.—A grey clay shale overlying a coal seam. It is very similar to No. 174 in appearance and under treatment, so is not recommended.

Lab. No. 176.—A 15-foot bed of grey sandy clay shale along the Canadian Pacific railway, west of Verwood, Sask.

When tempered with 44 per cent of water this clay forms a highly plastic, stiff and sticky mass which is exceedingly hard to work. It is rather soapy to the touch and evidently contains considerable collodal matter.

It cracked so badly in drying that even the small test pieces could not be dried safely in the room-temperature of 65° F. It burns to a hard, red body at cone 06 and fuses at cone 5. It is useless for the manufacture of clay products.

Lab. No. 177.—A massive grey clay shale overlying the coal seam along Willowbunch lake, south of the town of Viceroy.

It requires 36 per cent of water for tempering and works into a very plastic, sticky mass. It will probably crack in drying when made up into large-sized wares, but the small test pieces did not crack. Its drying shrinkage is 9·5 per cent.

It burns to a steel-hard light red body at cone 06 with a fire shrinkage of 2 per cent; the absorption is 15 per cent.

The clay is vitrified at cone 3, but the shrinkage at this temperature is abnormal, being 10 per cent. This gives a total shrinkage of 19·5 per cent.

When made up by the dry pressed process this clay burns to a fair red colour and hard body at cone 06, and the shrinkage is within practical limits. If burned to cone 03 the dry pressed body is almost impervious, but the shrinkage is too great.

The shrinkage of this clay is too high, otherwise it is one of the best red-burning clays of the series.

Lab. No. 178.—A white sandy clay from the west arm of Lake of the Rivers, south of Expanse, Sask.

This is a soft clay consisting essentially of fine quartz grains in a matrix of white plastic clay. It requires 20 per cent of water for tempering, and its plasticity is good. Its drying shrinkage is 5 per cent and fast drying of full-sized wares can probably be accomplished with safety. It burns to an open, cream-coloured body at all temperatures up to cone 5 (1230° C.). When burned to cone 10 the body is grey in colour and contains small black specks. The fire shrinkage at this temperature is 2 per cent and the absorption is 6·4 per cent.

The clay softens at cone 27 (1670° C.), so that it falls slightly short of the requirements of a fireclay. It may, however, be classed as a second-class fireclay as it can be used for many purposes where refractoriness up to a certain point is essential.

GYPSUM AND SALT IN MANITOBA.

(A. MacLean and R. C. Wallace.)

STONEWALL SERIES AND UNDERLYING BEDS.

The season's work consisted of an examination of central Manitoba, with special reference to the gypsum and salt horizons.

West of the Red river and of Lake Winnipeg, an almost continuous section of the Palæozoic in Manitoba can now be obtained from the exposures due to quarrying operations, and from core drills. The lowest horizon examined during the summer was that shown by a core section taken from a depth of about 400 feet at well No. 4 of the city of Winnipeg, immediately north of the northwest limits of the city. The stone is a mottled limestone, resembling very closely the stone of the Tyndall quarries, but probably representing the Lower Mottled Limestone (Ordovician) of Dowling. From a depth of 200 feet to the surface, a fairly continuous section is obtained at well No. 24, 3 miles southeast of Stony Mountain station. These cores are valuable because they give a complete section of the beds between the Upper Mottled Limestone horizon and the base of the red shale of the Stony Mountain group—a section not heretofore obtained in the province. The Upper Mottled Limestone passes, through an impure reddish argillaceous limestone, into the red shales exposed at Stony mountain.

At Stony mountain the upper beds of the Ordovician appear. They fall into the following three groups, in ascending order: (1) a reddish shale interbedded with thin bands of limestone, 12 feet; (2) a fairly compact calcareous shale, 15 feet; (3) 14 to 16 feet of magnesian limestone, all of which, except the upper foot or two, is shown at the quarry face. The highest beds are seen at several exposures on the east arm of the hill.

Well-drillers in the Stonewall district recognize as Stony Mountain rock the beds which they reach after passing through the known Stonewall beds. The actual contact between Ordovician and Silurian is nowhere seen, but a freestone exposed at one of the quarries of the Winnipeg Supply Co. at Stonewall may probably be taken as the basal bed of the Silurian. The following continuous section (in ascending order) appears at the quarry: (1) grey to greenish freestone; (2) red shale; (3) harsh, porous dolomitic limestone; (4) thin bed of red shale; (5) fine-grained, well-bedded, white dolomite. The freestone, as it is locally named, is an unfossiliferous siliceous rock with a calcareous matrix. The total thickness is about 7 feet. Mud cracks and ripple markings on the surface of the beds seem to indicate that the beds were exposed, occasionally at least, above low-water level. For this reason the freestone may probably be taken to indicate, not only the beginning of the Stonewall period, but also the elevation marking the transition from Ordovician to Silurian times. The red shale is 8 to 9 feet thick, with a capping of a few inches of greenish shale. It is unfossiliferous, homogeneous, and very plastic when disintegrated. The harsh magnesian limestone which overlies the shale carries few fossils, and has everywhere a porous open texture. It is 6 feet thick. Separated from this by a few inches of shale are the quarry beds, 12 feet thick. These represent the top beds at Stonewall. They are compact, rather thin-bedded magnesian limestones, in fact, almost dolomites in composition, and are relatively unfossiliferous. What are probably rather higher beds of the Stonewall series are exposed at the quarries at Gunton, 12 miles north of

Stonewall. Some exposures farther north would seem to represent, on purely lithological grounds, horizons still higher than those of Gunton. These occur in townships 24 and 25, ranges I east and I west of the 1st meridian; and in township 23, range II west. In one locality an escarpment of limestone rises 70 feet above the level of the plain, though only the upper 20 feet are actually exposed. A very fine-grained, almost lithographic limestone, which has not been remarked at Stonewall or Gunton, is found in this horizon. One bed of this stone is well exposed, and is 5 to 6 feet thick.

These beds, from the freestone at Stonewall to the most northerly exposures referred to above, may be considered to constitute the Stonewall series as defined by Kindle, in so far as exposures in the southern part of the province are concerned. On this lies the gypsum horizon.

GYPSUM BEDS.

Gypsum of Silurian age appears at the surface, so far as yet known, only in the Gypsumville district, north and northwest of Lake St. Martin. Exposures are found in four townships, townships 32 and 33, ranges VIII and IX west. The aggregate area of outcrop is probably 5½ square miles. The beds on which this horizon rests are seemingly not exposed, but consist—from the evidence of a bore section—of reddish argillaceous limestone. At the quarry of the Manitoba Gypsum Co., the following section is exposed:—

Surface capping (gypsite and soil)................	1—3	feet.
Upper red gypsum..........................	29	"
Foliated gypsum..........................	75	"
British-grey anhydrite......................	25	"
Hard reddish gypseous rock..................	5	"

The beds dip sharply toward the north, and the contact between the anhydrite and the gypsum can be observed only for a short distance. While the upper beds of the anhydrite are gradually going over into gypsum, it is improbable that much of the gypsum has been formed in this way. The evidence points to a period of precipitation from inland basins, the character of the precipitate depending to some extent on the temperature of the solution. Vant's Hoff has shown that at temperatures above 30° C. anhydrite is deposited if the calcium sulphate solution is also practically saturated with sodium chloride. That the waters were rich in sodium salts is shown by the presence of glauberite ($CaSO_4$ Na_2SO_4), which was identified from one of the cores. There is some likelihood that if a complete core section were available, several of the more complex salts would be obtained. There is no direct evidence of sodium chloride, however, in the Gypsumville district.

Massive gypsum, selenite, fibrous gypsum and gypsite are all found in this locality; but only the massive variety occurs in quantity. It is so finely crystalline as to appear dull and amorphous. The colour is a dead white. Selenite is found in considerable masses at Elephant hill, 4 mles northeast of Gypsumville station. It appears to be underlaid and overlaid by massive gypsum. The crystals, which have developed at all angles to the bedding planes, are of considerable dimensions. Cleavage plates a foot square are not very uncommon.

In some ways the anhydrite is the most interesting mineral in the district. While the relationships at the quarry are as indicated, isolated areas of anhydrite are found elsewhere. Southeast of Gypsum lake, for instance, an uninterrupted section of anhydrite was obtained at one locality from the surface to a depth of 100 feet. The transformation from anhydrite to gypsum is clearly a very slow process.

A prominent feature of the topography of the Gypsumville district is the system of hills of gypsum, which are frequently elongated in a north and south direction, and between which are undrained or blind valleys, with occasionally a considerable depth of stagnant water. The surface has no doubt been affected by solution, but the linear character of ridge and valley suggests that the passage of the ice has left a permanent mark on the topography of the gypsum exposures. The ridges are pitted by circular depressions, frequently 15 to 20 feet deep, and partially filled with gypsite and soil. Boulders are sometimes found at the base of the depressions. While it is clear, from the sections at the quarry, that the depressions have been enlarged owing to the solvent action of surface water, they may have been originally formed as pot-holes during the passage of the ice over this district.

Of the other gypsum occurrences, those near Dominion City and near St. Pierre, both on the east side of the Red river, are probably of upper Silurian age. The gypsum occurs at depths of 325 to 450 feet, and 400 to 500 feet respectively, but not in continuous section. Anhydrite is not known to occur in association with the gypsum in either case. The records of boring are not yet, however, sufficiently conclusive with reference to the horizon of the beds in question.

Overlying the gypsum horizon occur the highest beds of the Silurian in Manitoba. They appear east of Gypsum lake in close association with the gypsum, at Davis point, between Davis point and Gypsumville, and at various places along the Canadian Northern Railway line between Ashern and Fairford. They are thin-bedded, rather reddish dolomites, which, in the vicinity of the gypsum outcrops at least, contain traces of sulphates. They are evidently partially due to chemical precipitation. Fossils occur sparingly, but on account of the comparatively numerous occurrences of the ostracod *Leperditia hisingeri,* the beds have been designated by Kindle the *Leperditia hisingeri* horizon. Some interesting igneous outcrops occur in close proximity to the dolomites of this horizon east of Gypsum lake. These are outliers of Pre-Cambrian age, and indicate that a ridge of considerable elevation above the Pre-Cambrian peneplain extends in a northwesterly direction from the narrows of Lake St. Martin. The rocks are a rather remarkable association of conglomerates and jasperized amygdaloids, to which no rocks yet found east of Lake Winnipeg bear any resemblance.

The salt springs reach the surface in argillaceous limestone of upper Devonian age. According to Kindle, the lowest Devonian beds in the neighbourhood of lake Manitoba and lake Winnipegosis—those at Elm point on lake Manitoba—are of middle Devonian age. They are almost pure limestones. On them lie the lower beds of the Winnipegosan dolomite, which is well exposed on the east side, and some of the islands, of Dawson bay. Succeeding these are the pure limestones of the Manitoba formation, which are seen at many points along lake Winnipegosis, and the highest beds of which are exposed at point Wilkins on Dawson bay, and on the Red Deer river. These limestones are characterized by an abundance of a large variety of *Atrypa reticularis*. At or near the base of the Atrypa zone the salt springs come to the surface.

SALT HORIZON.

Salt springs are found in greatest numbers along the west side of Dawson bay, but extend in a fairly continuous line southward along the west side of Lake Winnipegosis, the west side of Lake Manitoba, to the mouth of La Salle on the Red river. In addition, practically all the deep borings that have been made have penetrated horizons from which considerable flows of salt water have issued. A large number of springs were examined during the month of September, when, after an unusually dry season, the flow was considerably below normal, and much below the estimates made by Tyrrell twenty-four years ago. The springs on the west side of Lake Winnipegosis seem to issue from a limestone near the base of the Manitoba limestone. In many cases, however, the absence of good exposures renders the exact horizon uncertain. The flowing wells on the west side of Lake Manitoba, near the south end of the lake, are probably also associated with the upper Devonian. In fact, the fairly regular grouping of all the brine springs in the province on a line parallel to the long axes of the lakes would indicate that the horizon is the same throughout. However, the evidence already collected from borings shows that salt water occurs in at least two other horizons, e.g., the Winnipeg sandstone, which immediately overlies the Pre-Cambrian, and the Dakota sandstone, at the base of the Cretaceous.

The determination of the horizon in which the brines appear at the surface does not, of course, solve the problem of the origin of the salt. The average temperature of a series of brines on the west side of Lake Winnipegosis was found to be 44° F. The average annual temperature in this district is about 31·5° F. The temperature of a water which has ascended from a depth of 20 feet to the surface would be 32° or 33° F. It would thus appear that the brines rise from a depth of at least 600 feet, on the assumption of a temperature gradient of 1° F. per 60 feet. The percentage of potash salts in the brines is unusually high—a fact that would suggest that the brines represent the mother liquors left after long-continued precipitation of sulphates. It may be that the brines are genetically connected with the gypsum horizon of the Silurian, that precipitation of chlorides took place as a final stage of the evaporation, and that wherever the gypsum horizon is exposed to-day, all traces of such soluble salts have disappeared. Much more detailed investigation must be carried out on the underground waters of the province before definite conclusions can be reached.

Gypsum occurs in an upper Devonian horizon on the west side of Lake Manitoba. In the Leifur district, and in a northwesterly direction from that district, thin beds are found near the surface. The gypsum found in the bore at Vermilion river was considered by Tyrrell to be of Devonian age. The extent of this formation is not yet fully determined. There are no indications of it in the fairly complete exposure of the upper Devonian at Dawson bay, but the gypsum obtained in the bores at Neepawa and Rathwell is probably from this horizon.

SURFICIAL DEPOSITS.

The upper beds of the upper Devonian are the latest rocks of Palæozoic age in the district. The glacial deposits, which are widely distributed, and through which only occasional outcrops of rock appear, are of irregular thickness, but are deepest in the southern part of the province, where thicknesses of over 200 feet have been recorded. Work has not been done specifically on the glacial drift. On the ice till in the southern part of the province, lie the stratified clays which were deposited under Lake Agassiz. Wherever rivers emptied into the glacial lake, these clays are interbedded with layers of sand. In the ancient delta of the Assiniboine, in particular, the percentage of sand in the clays is high.

The character of the soil varies with that of the immediately underlying glacial material. Where it rests on till, it is similar to the soil in the southwestern peninsula of Ontario, being in each case formed from disintegrated Pre-Cambrian and Palæozoic rocks. When, however, it rests directly on the sediments deposited by Lake Agassiz, it is of a heavy, tenacious, waxy type, similar to the gumbo of Alberta and Saskatchewan. When it is considered that at the time of the sedimentation of Lake Agassiz, the rivers of the west, operating on the freshly-exposed Cretaceous shales, must have poured vast quantities of silt through the various gaps of the escarpment into the waters of the lake, it is to be expected that sediment of Cretaceous origin should be greatly in excess of that of Pre-Cambrian and Palæozoic. Hence the fertile soils of this part of Manitoba resemble those farther west which overlie the Cretaceous. The soils that overlie the delta deposits contain a greater proportion of sand.

GYPSUM.

The exposures in the Gypsumville district cover a total area of about 5½ square miles. Judged by the test pits distributed over the field, the average depth is at least 20 feet. If one-third of this volume be taken to be anhydrite, there is, on a conservative estimate, 130 million tons of gypsum in the Gypsumville district alone. The production is less than 100,000 tons per year. Even allowing, then, for a great expansion in the output as the western provinces develop, there is sufficient material—at the surface—in this district for several hundreds of years to come. Two companies—the Manitoba Gypsum Company and the Dominion Gypsum Company—are operating, but at present only one quarry—that of the Manitoba Gypsum Company—is being worked. The gypsum is very pure, and is utilized for plaster of Paris, dental plaster, several grades of wall plaster, plasterboard, and asbestos plaster; while unburnt gypsum is supplied to the cement mills of Manitoba and Alberta. The mills of both companies are located in West Winnipeg.

The extent of the beds which occur at considerable depths in the southern part of the province and west of Lake Manitoba, has not yet been definitely ascertained. They have been found near Dominion City, St. Pierre, Rathwell, Neepawa, Gladstone, Vermilion river, and near Leifur. They are consequently of widespread occurrence. Owing to the large amount of gypsum available at the surface, these beds are of no great economic importance at the present time.

The anhydrite which occurs at the "anhydrite quarry" southeast of Gypsum lake is a hard variety of the mineral, and takes on a good polish. The colour is bluish grey, with irregular streaks of brownish red. The polished rock has a very pleasing appearance, and may yet find a use as an inside decorative stone.

SALT.

Sufficient data have not yet been collected to arrive at an estimate of the total amount of salt which is carried to the surface by the brine springs each year. It is, however, very large—so large as to suggest that it is derived from beds of rock-salt. Such beds have not been found; but the use of the churn drill instead of the core drill—for instance, at Neepawa—precludes the possibility of obtaining information which would be very valuable in this connexion. As a rule the brines are weak, and are weaker in the southern part of the province than around Dawson bay; the total solid matter varies from 5 per cent to 9 per cent. At Neepawa, however, at a depth of 1,180 feet, a very strong solution is obtained. It is quite probable that this brine will be found to be associated with salt beds. During the greater part of last century, salt was manufactured from several springs on the west side of Lake Winnipegosis and Dawson bay. Under present conditions the majority of the springs are probably too weak to be worked profitably for salt alone. The percentage of potash in the total solids is, however, unusually high—much higher than in most of the waters which have been investigated for potash on this continent. The fact that a powerful monopoly has been established in the potash industry renders it difficult to forecast the success of a venture in this field; but there are at least possibilities, so far as the stronger brines are concerned, that a salt and potash industry might be successfully combined.

At Winnipeg the salt water obtained from the Winnipeg sandstone, at a depth of 550 feet, is utilized for medicinal purposes at the Elmwood sanitarium.

LIMESTONE.

The limestones of the Ordovician, Silurian, and Devonian formations in the province contain, as a rule, considerable percentages of magnesia. They are utilized as dimension stone (at Tyndall), as building material such as rubble, foundation stone, etc. (at Hecla island, Lake Winnipeg, at Stony Mountain, Stonewall, and Gunton), and for the manufacture of lime. Certain fine-grained limestones may be utilized for interior decorative purposes. Non-magnesian limestones are found in the Devonian at Steeprock point, east of Mooseborn, at Winnipegosis, Snake island, and, in fact, at many points on the west side of Lake Winnipegosis and Dawson bay. Some of these limestones will be utilized in the near future for purposes of Portland cement.

The freestone at the base of the Stonewall series may be utilized in the future as an easily-worked building stone.

THE CALCAREOUS DRIFT AND LACUSTRINE DEPOSITS IN RAINY RIVER DISTRICT, ONTARIO

(W. A. Johnston.)

Introduction.

During the past field season the writer spent nearly two months making an investigation of the Pleistocene drift deposits of Rainy River district, Ontario. The remainder of the field season was occupied by the meetings and excursions of the Twelfth International Geological Congress. Assistance in the field work was well rendered by J. K. Knox and J. T. K. Crossfield who also carried on the work during the writer's absence from the field. A few days in the latter part of July and again in September were also spent in company with Mr. Frank Leverett of the United States Geological Survey, in an examination of the features of the drift in Rainy River district and in northern Minnesota.

It has long been known that a considerable part of the Rainy River district is covered by calcareous drift deposits, similar to those found in Manitoba and northern Minnesota, and that these deposits form soils which are of exceptional productiveness for agriculture. Lacustrine sediments, laid down in the waters of Lake Agassiz, which was formed in front of the retreating ice sheet at the close of the Glacial period, and covered a great portion of the area, are also of wide extent and add to the fertility of the soil.

The main object of the field work in the district was to determine the limits of the calcareous drift and to map its various phases from the standpoint of its economic value for agriculture. The character and origin of the calcareous drift and the extent of glacial Lake Agassiz in the district were also matters of interest and scientific importance.

Data for a map on the scale of 2 miles to 1 inch was secured for a considerable portion of the area.

Location and Area.

The area mapped lies between Rainy lake and Lake of the Woods and just north of Rainy river which connects the lakes and, throughout its course of 80 miles, forms a portion of the International Boundary between Canada and the United States. The northern border of the area is from 5 to 20 miles north of the river and the area includes about 1,000 square miles. The main line of the Canadian Northern railway traverses the southern part for 55 miles, from Fort Frances in the east to Rainy river in the west, where it crossses into Minnesota.

The results of previous work in the district may be briefly summarized as follows:—

J. J. Bigsby in three papers published in the Journal of the Geological Society, London, 1851-2 and 1854, gave results of an examination made of Rainy lake and Lake of the Woods in 1823-4.

H. Y. Hind in the "Report on the Exploration of the Country between Lake Superior and the Red River Settlement," 1858, devotes a chapter to a description of Rainy lake and river.

G. M. Dawson in his report on the "Geology and Resources of the 49th Parallel," gives an account of the southern portion of the Lake of the Woods and devotes considerable space to the geology of the superficial deposits of this portion of the region.

A. C. Lawson in his two reports on the "Geology of the Lake of the Woods Region and Rainy River Region," published by the Geological and Natural History Survey of Canada in 1885 and 1888, summarizes the Glacial geology of the district and more particularly describes the "alluvial plain or river country" bordering the Rainy river.

Accessibility.

At the time of Dr. Lawson's field work in the district, which was the last exploratory work done previous to the past year, the interior of the country lying to the north of Rainy river was, for the most part, inaccessible on account of its densely wooded and swampy or muskeg character and the general absence of lakes and navigable streams. Since that time the construction of the Canadian Northern railway, and the settlement of a considerable portion of the southern part of the district, have served to open up the country and provide better means of access and communication. During the past year, a number of highways were also constructed by the Provincial Government, which have furnished further means of travel, but a considerable portion of the northern part of the district is still nearly inaccessible, except in winter time or in exceptionally dry seasons.

Physiographic Features.

The general character of the surface of the greater part of the Rainy River district is that of a nearly flat, well-wooded plain; the materials of which are mainly of glacial and lacustrine origin. The plain extends from the southwest corner of Rainy lake to Lake of the Woods and forms the easterly limit of the extension of the wooded portion of the prairie plains of Manitoba and northern Minnesota into the province of Ontario. The topographical expression of the plain is varied, however, because of the fact that the superficial deposits overlie Pre-Cambrian crystalline rocks. In general, the glacial and lacustrine deposits are of sufficient thickness to conceal the irregularities of the surface of the underlying rocks, but frequently knobs or ridges of rock protrude through these deposits, or by their nearness to the surface give a gently undulating or rolling character to the topography. In some cases also, the rock ridges apparently formed nuclei for accumulations of boulders and till, but well-developed morainic ridges are generally absent over the greater portion of the district. Where till occupies the surface the relief is generally small and presents only a gently rolling appearance.

Well records show that the superficial deposits at some points in the district have a maximum thickness of about 150 feet and rocky knobs rise to a maximum altitude of about 100 feet above the general surface of the lacustrine plain. This amount of relief corresponds in general with that of the rock surface in adjacent areas where there is very little drift covering. The extension of this surface, which is essentially that of a plain, with many small but few large irregularities beneath the drift deposits, is a function of the present plain, as well as the deposition of the glacial and lacustrine sediments. Wave action during the lifetime of Lake Agassiz was also instrumental, to some extent, in producing the plain surface. The rock surface which underlies the sediments slopes gently toward the southwest and, in general, the rock exposures become fewer and the drift deposits thicker in that direction. Drainage of the area is effected mainly by Rainy river and its tributaries from the north. A considerable portion, however, drains toward the north. The divide, which is generally low and swampy in character, is highest in the central northeastern portion, where it attains a maximum altitude of nearly 100 feet above Rainy lake. Northwestward, toward Lake of the Woods, the level of which is 50 feet below that of Rainy lake, the divide is much lower and is occupied by extensive swamps and muskegs.

The most notable features in the character of the surface of the plain are the general absence of lakes, due mainly to the evenly aggraded surface of the lacustrine deposits, and the undrained character of much of the surface. The undrained areas, which are extensive and occupy over one-half of the whole district, consist of muck swamps, peat bogs, and muskegs or quaking bogs, and are due mainly to low-surface gradients, the impervious character of the subsoil, and the rank growth of vegetation which holds the rainfall like a great sponge, so that the run-off is for the most part by ground water and consequently extremely slow. In many cases, also, the undrained areas are shallow depressions partially enclosed by sand and gravel ridges which are numerous in the district and mark successive shore-lines of glacial marginal Lake Agassiz, the water of which at its maximum extension covered the whole district to a considerable extent.

General Geology.

THE SOLID ROCKS.

Although the solid rocks which underlie the district are, for the most part, concealed by a thick covering of drift deposits, sufficient exposures occur to make it fairly certain that Pre-Cambrian rocks underlie the greater portion of the area. The great abundance of upper Ordovician limestone in the drift deposits, the nearest known exposure of which in place is in Manitoba and is distant nearly 200 miles, suggests the possibility that outliers of the limestone may occur in the district, but no direct evidence was found that such is the case. The Pre-Cambrian rocks of the region need not be further referred to here as they have been described by Dr. A. C. Lawson in the above-mentioned report.

PLEISTOCENE AND RECENT.

Calcareous Drift.

Almost the entire thickness of superficial deposits of the district is made up of calcareous drift containing a large percentage of limestone similar to that which outcrops a few miles north of Winnipeg in Manitoba. North of the central portion of Lake of the Woods and of a line drawn thence southeastward to a point on Rainy lake near its outlet, the limestone drift is almost entirely absent. The calcareous deposits consist mainly of till and bedded sands and clays derived from the till or directly from the ice sheet and deposited in water. The till where it forms the surface, which it does only in small areas, is generally disposed in the form of ground moraine and has little relief. Drumlins, kames or eskers associated with this till sheet were not noted in the district. That the calcareous drift was brought in by ice sheets advancing from the northwest is shown by the southeastward and eastward bearing striæ which occur at several points around the southern portion of Lake of the Woods and also in the Rainy River district, at several places, as far eastward as the vicinity of Fort Frances. The calcareous till is known to extend southeastward into the neighbouring state of Minnesota a considerable distance, and southeastward bearing striæ have been found at many places in that state by Mr. Frank Leverett and others. These striæ in the southern part of the district were found, in some cases, to cross southwesterly bearing striæ, but were not observed to be themselves crossed by later striæ. The easterly bearing striæ were not seen outside the area in which the calcareous drift occurs. In the northern portion of the Lake of the Woods, southwesterly bearing striæ are crossed by others which bear more nearly south. In a few places near the northern border of the calcareous drift these latter striæ were observed to cross easterly bearing striæ. Along the line marking the northwestward extension of the calcareous or grey drift, there is a zone of varying width in which there is considerable mingling of the calcareous or grey drift and the red drift derived from the northeast. Near the central part of Lake of the Woods a remarkable deposit of boulders derived from Pre-Cambrian rocks, occurs. The deposit can be traced for a considerable distance along the shores of the islands, in a southeasterly direction, and appears to mark a marginal deposit of an ice lobe advancing from a direction a few degrees east of north. At some places in the northern portion of the Rainy River district the grey drift is overlain by large numbers of boulders derived from the crystalline rocks, and at one place near the centre of Carpenter township a section was seen which showed several feet of red drift overlying grey drift, the upper portion of which consists of a foot or so of limestone gravel. On adjacent rock surfaces which underlie the red drift, well marked striæ bear in a southwesterly direction.

Calcareous Till.

The calcareous till or boulder clay consists of two different portions, a yellowish somewhat oxidized till, which varies considerably in thickness, and a bluish-grey unoxidized till. The yellow till is well exposed in numerous sections along the lower portion of Rainy river, where it is seen to consist of yellowish compact unstratified clay containing numerous small fragments of limestone but comparatively few large boulders. Most of the large boulders are of crystalline rock, but at least 75 per cent of the smaller stones and pebbles are of the yellow limestone, from which fossils of upper Ordovician (Richmond) age have been obtained. The bluish till is best exposed in sections along the upper portion of Rainy river, where it is generally overlain by lacustrine deposits. In composition, it appears to be similar to the upper yellowish till, and on exposure to the atmosphere for some time assumes much the same colour.

Lacustrine and Fluviatile Sediments.

Lacustrine and fluviatile sediments occupy the surface of by far the greater portion of the district, and frequently have considerable thickness. They also consist of two dissimilar portions. In the vicinity of Lake of the Woods, horizontally bedded, finely laminated, yellowish-grey, silty clay occurs which in places occupies the surface up to a height of 15 or 20 feet above the lake and unconformably overlies yellow till or bluish laminated stony clay. In some sections it is seen to have a thickness of 8 or 10 feet. Fresh-water shells are numerous in the deposit. Similar clays interlaminated with sand and limestone gravel also occur along Rainy river at several places as far east as Fort Frances up to an altitude of 60 feet above Lake of the Woods.

The bulk of the lacustrine sediments, however, are of somewhat different character and origin. They appear to have been laid down in standing water in close proximity to an ice margin of one of the lobes of the continental glacier. They consist generally of horizontally-bedded, stony clays which are generally bluish-grey in colour. Bluish-black clays of similar character also occur in the upper part of some of the sections. Their stony character is the most striking feature of these clays. The stones are generally small and are sometimes glaciated. No shells were noted in these deposits. As stated above, the upper clays are seen in many sections to unconformably overlie till or bluish laminated stony clay. This unconformity is well shown in numerous sections exposed around the southern portion of Lake of the Woods.

A Fossil Shore-line.

Cliff recession of the present shore-line by wave action around the southern portion of Lake of the Woods, has exposed sections at a number of places showing a former wave-cut platform and beach, buried beneath lacustrine sediments. The wave-cut platform can be readily seen in section for several miles along the southern shore of the lake on Long point and again on Buffalo point on the west shore. At several places buried gravel beach ridges at the base of the wave-cut platform were also seen in section. A good exposure of one of these beach ridges occurs on the south side of Buffalo point, and behind the beach there is also a buried sand deposit containing water-worn chips and fragments of wood. Along the southern portion of the lake, the old wave-cut platform is seen to be cut in the stony laminated clays and in yellow calcareous till, and is overlain in most sections by 6 to 10 feet of lacustrine clays of the character as described above. Its height is from 2 to 4 feet, and that of the gravel beaches from 7 to 8 feet above the present high-water level of the lake. The plane of the old lake corresponded closely with that of the present lake in an east and west direction. In a northeasterly direction it is probable that it did not, judging from the fact that the beaches of Lake Agassiz in the district are known to rise differentially in that direction, but no trace of the fossil beach was found near the north end of the lake. At the southern portion of the lake, it is evident that the water of the lake stood at a height of 4 or 5 feet above the present high-water level. Then followed a rise of lake level, probably consequent upon an advance of the ice, which more effectually dammed on the north the ice marginal lake waters. The question arises whether the existence of this lake at near the present level of Lake of the Woods and the subsequent rise of the water were merely episodes in the general recession of the waters of Lake Agassiz, which at its maximum extension in the district stood at an altitude of some 300 feet above the present level of the lake, or whether its existence did not really mark the beginning of Lake Agassiz in the district. Sufficient field work has not been done to determine which was the case, but there are certain points which seem to suggest that the latter was more probable.

The lacustrine sediments which are seen to unconformably rest upon the wave-cut surface form a considerable proportion of the total thickness in the district of the lacustrine sediments as distinguished from the glacio-lacustrine deposits so far as seen.

The presence of shells in these deposits and in many of the beach ridges in the district up to an altitude of at least 140 feet above the lake suggests a correlation in time and that different conditions existed at the time of the deposition of the lacustrine clays than when the glacio-lacustrine deposits were laid down.

The fossil gravel beaches are much older in appearance than the higher but more recent beaches. They contain no shells and the gravel is sometimes partially cemented by deposition of carbonate of lime. The leaching of the till is very difficult to explain on the supposition that the till was laid down in the waters of Lake Agassiz, when it is considered that many of the beaches of the lake contain well-preserved fossil shells, so that very little leaching has taken place even in the loose gravel beaches. Very little leaching of the till could have taken place beneath the waters of the lake, and that it should have taken place since the disappearance of the lake seems equally impossible.

At any rate, it seems certain that the waters of glacial marginal Lake Agassiz in Rainy River and Lake of the Woods districts rose to a considerable height subsequently to the formation of the fossil shore-line, a few feet above the present level of lake of the Woods, and that these waters were connected with the main body of water in Red River valley, since the lacustrine clays occur at higher altitudes than the divide. Hence it is evident that the life history of Lake Agassiz was not so simple as has been generally supposed, and its records are complicated by the possibility that beaches were formed during the rise of the water as well as during the final recession. In this connexion it may be noted that several of the gravel ridges in the district were found to be partially eroded as if by wave action and in some cases covered with a foot or so of clay.

Records of Lake Agassiz.

Little has been known concerning the extent of glacial-marginal Lake Agassiz in the region beyond the fact that the sediments of the plain were long ago recognized as being lacustrine in character, and the altitude of beach ridges, etc., in adjoining regions showed that the greater part of the district must have been submerged. In his report on Glacial Lake Agassiz in Manitoba, Mr. Upham states (page 13 E): "The general level of the country adjoining Rainy lake and Lake of the Woods is 50 to 150 feet below the highest stage of Lake Agassiz; but the northern and eastern part of this district may have been still covered by the waning ice sheet when the lake stood at that height. On account of the impracticability of tracing the shores of Lake Agassiz through the wooded and uninhabited region, the northeastern limits of this glacial lake where the shore in its successive stages passed from the land surface to the barrier of the receding ice-sheet remain undetermined." Recent work by Mr. Frank Leverett in northern Minnesota has shown that the highest shore line of Lake Agassiz in that district has an elevation of about 1,350 feet. This would give, by extending the up-warped plane northward, an altitude of possibly 1,450 or 1,500 feet for the highest shore-line in the Rainy Lake district. No shore-lines have been found, however, in that district at or near this altitude, probably because little search has been made for them and partly because on account of the bare rocky character of much of the surface, conditions were unfavourable for the development of shore features; or it may be that the highest shore-lines were not developed in the district.

Following is a list of localities and elevations of abandoned beach ridges of Lake Agassiz found during the past season in Rainy River district and levelled with pocket spirit level and rod, the levels being based on the United States Geological Survey precise levelling done in northern Minnesota. The elevation of Lake of the Woods in July of the past season as determined from the United States Geological Survey bench-marks was 1,061, and that of Rainy lake, 1,109.

Three miles below Fort Frances near north bank of Rainy river, crest of gravel beach ridge	1,131
Eight miles below Fort Frances near Rainy river, crest of gravel beach ridge	1,141
Section 3 sp. Crozier, 6 miles southwest of Fort Frances, crest of gravel beach ridge	1,145
One-half mile north of Devlin station, 13 miles west of Fort Frances, crest of gravel beach ridge	1,200
One mile east of Emo station, 20 miles west of Fort Frances, crest of gravel beach ridge	1,140
One and a half miles northwest of Emo, 20 miles west of Fort Frances	1,141
One mile west of Barwick station, 27 miles west of Fort Frances	1,140
One and a half miles west of Stratton station, 35 miles west of Fort Frances	1,139 and 1,177
Section 33, Dilke township, near Pinewood, 42 miles west of Fort Frances	1,146 and 1,133
One and a half miles southwest of Sleeman station, 48 miles west of Fort Frances	1,116
Two and a half miles northwest of Rainy River station, 55 miles west of Fort Frances	1,117

The beaches are generally of considerable strength, and the intervals between beaches are marked and frequently show little trace of wave action, even in exposed positions and where the material was easily erodable.

The isobases appear to run in a direction a few degrees north of west. There is insufficient data to determine the rate of warping of the different beaches in the district.

From the work of Messrs. Upham and Leverett in Manitoba and northern Minnesota, it is known that the beaches in these districts rise differentially in a northeasterly direction and that the highest beaches have a higher rate of warping than the lower ones. It is probable that this holds true also for the Rainy River district.

It has been claimed by some geologists that this earth warping has continued into recent or historical time and that it has affected more particularly the northern part of the Great Lakes region and the area lying to the north. With this in mind a search for evidence was made around the shores of Lake of the Woods.

Recent Earth Warping.

Around Lake of the Woods there is little or no evidence of wave action up to a height of 15 or 20 feet above the present level of the lake, other than the fossil beach which generally shows only in section, and that associated with nearly the present level of the lake.

The lake has a maximum length in a north and south direction of about 70 miles and has its outlet at the north end. The outflow is over hard crystalline rocks, and as the water is almost entirely free of sediment it is probable that little erosion has taken place of the outlet in historical time. If differential upwarping has continued into recent time, resulting in the relative raising of the northern end or outlet of the lake, it follows that the water surface would have maintained the same relation to the land at the northern end of the lake but would have submerged and overflowed the shores of the southern portion. A comparison of the height of beach ridges near the two ends of the lake, coupled with the age of the beach ridges at the southern end, would form an approximate measure of the rate of warping. It was found that gravel beach ridges occur near the south end of the lake, which are well forested and have growing on them oak trees 14 or 15 inches in diameter and partially decayed stumps of trees of similar size, so that these beach ridges are at least 100 years old and are possibly much older. It was also found that their crests have very nearly the same altitude as the average altitude of those near the north end of the lake. In one case in the northern portion of the lake a well-forested beach was found which was nearly a foot higher, but the average was found to be about the same. In making these measurements a rod and level were used in determining the height above the surface of the lake, the elevation of which was obtained from daily gauge readings made at several points on the lake, the zeros of the gauge readings being correlated and referred to a bench-mark. Another line of evidence is that derived from measurements of the altitude of a high-water mark which exists on the rocks of the shores of the lake. It is stated to have been in existence over twenty-five years, and eighteen years ago was marked by a number of panels cut in the rock at the level of the mark at several places around the shores of the lake. Its altitude was determined in the same way at various points in the lake, and was not found to vary in altitude, otherwise than might be accounted for by the somewhat indefinite character of the mark. The height of the mark could generally be determined within a limit of one-tenth of a foot, and for a distance of 40 miles in a north and south direction no difference in altitude of the mark was detected, taking this into account. It, therefore, seems that if differential warping has gone on in the past 100 years it has been too small to be measured by such crude methods.

The Red Drift.

The term red drift has been used to designate the drift which was derived from Pre-Cambrian areas and brought in by ice-sheets advancing from the northeast. It sometimes overlies calcareous or grey drift in the northern part of the district, but not abundantly. Red drift is also seen in some sections to underlie the grey drift. Boulder clay ridges occasionally occur in the district, overlain by a few feet of calcareous till or lacustrine sediment, and considerable deposits of cross-bedded sands and gravels, in the form of kames, associated with an advance of the ice-sheet from the northeast are also seen at a few points in the district. Good sections, showing the character of these kame-like deposits, may be seen in the gravel pit about 3 miles west of Fort Frances. The lower portion shows horizontally—and cross-bedded sands and gravels wrapped around and built in the lee of a knob of crystalline rock heavily glaciated in a southwesterly direction. The sands and gravels contain no limestone, so far as could be seen. They are overlain by a few feet of bluish-grey laminated clays containing limestone pebbles, which are in turn overlain in some places by 6 or 8 feet of calcareous till. About 2 miles west of this locality, eastward-bearing striæ were found crossing other earlier striæ having a southwestward bearing.

In the northern portion of Lake of the Woods and eastward to Rainy lake the crystalline rocks which occupy the surface are, over wide areas, almost entirely free from drift covering, even boulders being scarce in some localities. The greater portion of the areas now occupied by the calcareous drift was, prior to its deposition, possibly almost as bare, which would account to some extent for the great preponderance of limestone in the drift brought in from the northwest, although the ice-sheet advanced for over a hundred miles across a region occupied almost exclusively by Pre-Cambrian rocks.

STRATIGRAPHY OF THE NIAGARA ESCARPMENT OF SOUTHWESTERN ONTARIO.

(M. Y. Williams.)

Introduction.

During the field season of 1913, the writer was engaged in a detailed study of the stratigraphy of the Niagara escarpment of southwestern Ontario. In order to correlate the formations of Ontario with those of New York state, the writer accompanied Dr. E. M. Kindle of this Survey on a six days' study of the sections exposed at Clinton, Rochester, Albion, Lockport, and Niagara Falls, N.Y. Following up this preliminary work, Dr. Kindle, Mr. H. V. Ellsworth, and the writer made a reconnaissance trip along the escarpment as far north as Collingwood, examining sections at Thorold, Grimsby, Stony Creek, Hamilton, Ancaster, Credit Forks, Guelph, and Collingwood. Then followed the detailed work of the season, during which twenty-three important sections were measured, and numerous partial sections were studied. Along with the stratigraphic studies a careful palæontological examination of the formations was made and much important material was collected for laboratory examination. Note was also made of materials that might be valuable for building stone, road metal, lime, and brick manufacture.

In order that the information gathered might be used in the future for geological mapping, the most important sections were carefully located in reference to fixed points, and in several cases local maps were made. For mapping and measuring sections the telemeter was used at a number of localities. At other places the hand level was found best suited for measuring sections, and the more northerly localities were mapped by compass and pacing.

From August 15 to 22, the writer accompanied Professor Charles Schuchert of Yale University on a trip over most of the sections previously visited between Limehouse, Ont., and Lockport, N.Y. At this time a number of special problems were carefully investigated and considerable new information was gained.

The writer was assisted in the field by Mr. H. V. Ellsworth, who rendered efficient service in the various phases of the work.

Field work was begun on June 6 and ended October 23. Mr. Ellsworth was occupied with business relating to the Twelfth International Congress of Geologists on July 18 and 19, and he and the writer were both engaged with Congress business from August 1 to 11, and attended the Congress meetings in Toronto, August 7 to 15. Mr. Ellsworth went on Congress Excursion C 5 and was consequently not engaged in field work from August 15 to 24. He left the field to resume college work on September 25, the writer continuing the work until October 23.

Location and Extent of Area.

The area studied in detail extends along the Niagara escarpment from Niagara Falls to the end of the Bruce peninsula, a distance of more than 230 miles. The whole Bruce peninsula furnishes good exposures and was studied in considerable detail; northern New York state and the region about Guelph were investigated for correlation purposes.

Previous Work

The older reports dealing with the Silurian stratigraphy of Ontario are those by Alexander Murray[1] and Sir William Logan.[2] A. W. Grabau has more recently dealt with the Silurian stratigraphy along the Niagara river[3] and has generalized on the geology farther north.[4] Various parts of the Niagara escarpment are described by W. A. Parks and others in the Guide Books[5] of the Twelfth International Congress of Geologists. Finally, the Niagara Folio, by E. M. Kindle and Frank B. Taylor, gives the report of recent field work done by them along the Niagara river.[6]

For the palæontology of the lower part of the Ontario Silurian the reader is referred to the works of James Hall,[7] E. Billings,[8] Henry Alleyne Nicholson,[9] and J. F. Whiteaves.[10]

Object and Progress of the Investigation.

As a result of the field work done during 1912 in preparation for the Geological Congress excursions, especially that by J. Stansfield and the writer, important questions of stratigraphy were raised that demanded, for settlement, a careful revision of the lower formations of the Silurian system of Ontario. The whole Medina-Clinton question raised by Charles Schuchert at the 1912 meeting of the Geological Society of America had to be investigated if the stratigraphy of Ontario was to be cleared of errors in correlation that had from early days been associated with it.

As a result of the field work of the past two seasons, a final report covering the stratigraphy and palæontology of the Niagara escarpment is now being prepared.

Summary and Conclusions.

The Silurian formations of Ontario are continuous with those of New York state, but vary with the distance from the sources of clastic deposits. Thus while the sequence of the well-known formations at Niagara Falls is Medina, Clinton, Niagara (including Rochester and Lockport), at Credit Forks, only 70 odd miles to the northwest, the deposits forming the Clinton and Rochester are entirely absent. Likewise at Credit Forks the upper firm, sandy portion of the Medina has disappeared, but the Cataract formation is well developed, including 20 feet of sandstone, 40 feet of limestone and calcareous shale, and more than 100 feet of grey and red shale. The conditions at Credit Forks extend with variations to the end of the Bruce peninsula. The most marked change is the disappearance of the Whirlpool sandstone from the base of the Cataract formation. This member, which is nearly 20 feet thick at Credit Forks, gradually thins northward and disappears south of Collingwood.

An interesting outcome of the season's work is the finding of an area of undoubted Guelph strata extending over the northwest corner of the Bruce peninsula from Stokes bay northeastward some distance beyond Tobermory.

From the date of the early settlement of the country, the Niagara escarpment has furnished building stone and material for the manufacture of quicklime and road metal. Formerly, in the Niagara peninsula, a bed of argillaceous limestone at the base of the Lockport dolomite was used extensively for the manufacture of rock

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[1] Report of Progress of the Geol. Surv. of Can. for 1843, 1847-8, and 1850-51.
[2] Report of Progress of the Geol. Surv. of Can. for 1843 and 1863.
[3] Bulletin of the New York State Museum, No. 45.
[4] Palæozoic Delta Deposits of North America, Bull. Geol. Soc. Am., vol. 24, No. 3, Sept,. 1913.
[5] See Guides to Excursions A12, B3, B4, and C5.
[6] U.S. Geol. Surv., Folio No. 190.
[7] Palæontology of New York, vol. ii, 1852.
[8] Canadian Fossils from the report of the Geol. Surv. of Can., 1857.
[9] Palæontology of the province of Ontario, Toronto, 1874.
[10] Palæozoic Fossils, Geol. Surv. of Can., 1884, vol. iii, parts i, ii, iv.

cement. However, with the advent of newer methods of cement manufacture the old workings have been abandoned. Building-stone and road-metal quarries are being actively developed along many parts of the peninsula, and limekilns are running at a number of localities. From Credit Forks south, where the overburden is not too great, the Whirlpool sandstone is quarried extensively and yields an excellent building stone. Lockport dolomite is generally serviceable for road metal and is easily obtained almost everywhere along the escarpment. It is also generally used for quicklime manufacture and, where not too massive, is serviceable for dimension stone.

General Character of Area.

The formations studied outcrop along a remarkable cliff front, known as the Niagara escarpment. This well-defined topographic feature crosses, at Niagara Falls, from northern New York state into Canada. It continues in a general westerly direction through the Niagara peninsula to Hamilton, and thence northward with numerous sinuosities to Collingwood. From this town westward, the escarpment is roughly parallel to the south shore of Georgian bay, but is at some places several miles inland. At Owen Sound, the escarpment consists of two distinct declivities and is close to the bay. Along the east side of Bruce peninsula, the escarpment is generally close to the shore, but is some distance inland on the larger promontories such as Cape Croker.

The Palæozoic formations of southwestern Ontario dip, in general, at low angles to the southwest and away from the Pre-Cambrian rocks upon which they rest. During the long cycles of erosion which have reduced the earth's surface to its present relief, the hard Lockport dolomite has suffered less than the underlying formations and, being modified chiefly by cliff recession, has assumed the form of a prominent ridge with steep declivities toward the east and north, and a gently-sloping surface toward the south and west. The escarpment is a fine example of the physiographic form known as a "cuesta."

Table of Formations.

—	—	Niagara peninsula.	Central Ontario.		Bruce peninsula.
			Southern part.	Northern part.	
Silurian	Niagara	Lockport: Dolomite. Gasport limestone. De Cew limestone.	Lockport dolomite.	Lockport dolomite.	Lockport dolomite.
		Rochester shale.	Rochester shale.		
	Clinton.	Irondequoit limestone. Williamson shales.	Irondequoit limestone.	(*Disconformity*)	(*Disconformity.*)
		Wolcott limestone. Sodus shale.	Wolcott limestone.		
		Thorold sandstone. Grimsby sandstone. Shale. (Cabot Head?)	Cabot Head shale.	Cabot Head shale	Cabot Head shale.
	Medina.	Manitoulin beds.	Manitoulin dolomite.	Manitoulin dolomite.	Manitoulin dolomite.
		Whirlpool sandstone.	Whirlpool sandstone.	(*Disconformity*)	(*Disconformity.*)
Ordovician		Queenston shale.	Queenston shale...	Queenston shale.	Queenston shale.

General Geology.

Everywhere on the mainland of Ontario, the Queenston shales underlie the formations of the Niagara escarpment. They are of an iron red colour and are generally soft and friable. At the top of the Queenston are 4 or 5 feet of shales of a green colour, the discoloration being apparently due to leaching and deoxidation by water which, coming from the strata above, seeps out through the upper part of the shale. Wherever examined, the top of the Queenston shale shows mud cracking, casts of the original spaces being well preserved in sandstone where the Whirlpool is the overlying member.

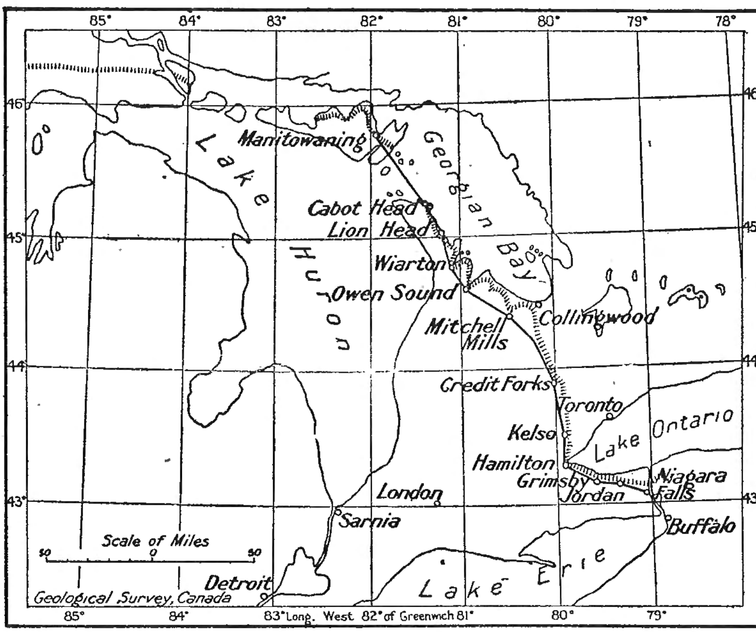

Fig. 4. Index showing Niagara escarpment and location of line of section.

In 1905, Grabau[1] suggested the probability of the Richmond age of the Queenston shales. Later, Grâbau and others have confirmed that conclusion and have placed the Ordovician-Silurian boundary at Niagara Falls at the top of the Queenston. Quite recently E. O. Ulrich has raised the question of the Ordovician-Silurian boundary, and advanced reasons for placing it at the base rather than at the summit of the Richmond.[2] The question is still under discussion.

As will be seen from the accompanying sections, the Whirlpool sandstone rests directly upon the Queenston shale in the southern part of the province, but from a short distance south of Collingwood, west and north, the Manitoulin dolomite rests on the shale. Thus a distinct overlap is indicated, since the dolomite rests on the sandstone wherever the latter is present.

The Silurian section as studied is incomplete at the top, the Guelph forming the highest beds observed. Pleistocene deposits along the escarpment are of much interest, but were not considered in the present investigation.

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[1] Science, New Series, vol. xxii, 1905, pp. 528-535.

[2] The Ordovician-Silurian Boundary. Advance Copy—Congrès Géologique International, Douzième session, Canada, 1913.

Description of Formations.

NOMENCLATURE.

In discussing the various divisions of the Silurian system of Ontario and New York, great difficulty is met in finding a suitable nomenclature. For several years

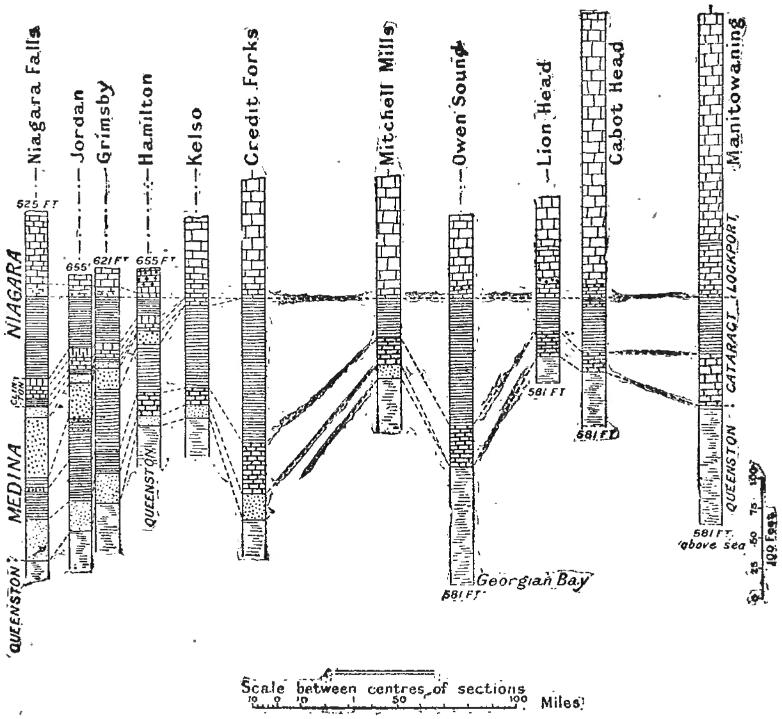

Fig. 5. Geological sections along the Niagara escarpment of southwestern Ontario.

back, almost every article on the subject appearing in print has either proposed new names for the whole or parts of formations, or else has redefined old terms. An attempt is here made to use as far as possible the names already best known; but in order to complete the subdivision of formations, already begun, it has been necessary to introduce some additional names. These will be dealt with in their appropriate places.

MEDINA FORMATION.

Medina is used in the sense in which Grabau[1] has redefined the term, that is to include the beds above the Queenston shale and below the Clinton formation. It is extended, however, laterally to include the Cataract formation as defined by Schuchert. At Niagara river it is the equivalent of the Albion sandstone of Kindle.[2]

The term *Cataract*[3] *formation* as proposed and defined by Schuchert at the 1912 meeting of the Geological Society of America, includes the Whirlpool sandstone, Manitoulin beds, and Cabot Head shale of the Medina formation.

[1] Science, New Series, vol. xxix, 1909, p. 356.

[2] U.S. Geol. Surv., Folio No. 190, p. 6. (Niagara Folio). This term has recently been abandoned by Kindle, Science, N.S., vol. 39, 1914.

[3] Ottawa Naturalist, vol. xxvii, June-July, 1913, pp. 37-38. Twelfth International Congress, Guide Book No. 5, p. 91. Williams, M. Y., Summ. Rept., Geol. Surv., Can., 1912.

Whirlpool Member.—The oldest member of the Medina formation is the Whirlpool sandstone. This is commonly almost white in colour (although some red beds occur) and is composed of medium-sized, white quartz grains. The beds are, as a rule, thicker near the base and generally show cross-bedding. At the top a single specimen of *Pleurotomaria* cf. *littorea* was found by Mr. Ellsworth in Niagara gorge. The sandstone, which is 25 feet thick at Niagara gorge, thins rather gradually to the northwest, being last observed at Glen Huron (about 12 miles south of Collingwood) where it is 4 feet thick. Here it is slightly micaceous. At Lockport, N.Y., the Whirlpool sandstone, as measured by the writer, is 17 feet thick, and is similar in character to the beds at Niagara gorge.

The Whirlpool sandstone rests on Queenston shale, the upper few feet of which are deoxidized to a light green colour. At the contact, mud-cracking appears to be universal and is preserved by consolidated sand casts projecting downwards from the sandstone beds. There is no indication of any transition. Upward, the sandstone generally grades into the overlying shale; but where dolomite overlies, the contact is generally sharp, or else a few inches of shale intervene between sandstone and dolomite.

Manitoulin Member.—The dolomite of the Manitoulin member is fine-grained, hard, and of a light blue-grey colour, weathering grey and buff. The beds are generally less than 10 inches thick, the thickness of the member varying from 50 feet on Manitoulin island and 40 feet at Credit Forks (with lesser thicknesses between), to 8 feet at Stony creek. Farther south, the dolomite is represented by calcareous shales, which measure 25 feet in thickness at Niagara gorge, and have a 3-foot bed of arenaceous limestone, or calcareous sandstone at the top. From Collingwood, west and north, the dolomite rests on Queenston shale with a sharp even contact. To the southwest, it rests on Whirlpool sandstone, with a sharp contact except at a few localities, where shale intervenes. Upwards the dolomite tends to become shaly and grades into the overlying shale.

For the fossils of the Manitoulin dolomite as far as the collections are worked up, reference should be made to the 1912 Summary Report of this Survey, and the Guide Books of the International Congress already referred to.

Fossils were collected this summer from the 3½-foot bed of arenaceous limestone which overlies 22 feet of grey shale at Niagara gorge, the shale and limestone being considered by the writer the equivalent in age of the Manitoulin dolomite. The fossils are: *Lingula cuneata, Whitfieldella oblata, W.* cf. *cylindrica, W. intermedia?, Bucania trilobata, Euconia? pervetusta,* and unidentified Lamellibranch and Orthoceratite.

Cabot Head Member.—For the shale above the Manitoulin beds the writer recently proposed the name Kagawong.[2] This name was preoccupied by A. F. Foerste[3] who applied it to an upper Richmond member. Cabot Head was proposed by Grabau[4] for the shale under discussion and it is here accepted. The writer, however, wishes to draw attention to the fact that the measurements and description of the section at Cabot Head which were taken from Logan[5] are seriously in error, due to the failure, on the part of former workers (and the writer also upon a previous occasion), to recognize a structural disturbance, which repeats much of the section. A section beautifully exposed along the shore about 2 miles west of Cabot Head includes 14 feet of Manitoulin dolomite resting upon Queenston shale at an elevation of about 40 feet above the level of Georgian bay; the dolomite is succeeded by 37 feet of grey shale, 8 feet of limestone, and 3 feet of grey shale. The last is overlain by 10 feet of platy

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[1] Ottawa *Naturalist*, ibid.
[2] Ottawa *Naturalist*, ibid.
[3] Ohio *Naturalist*, Dec. 1912, p. 46.
[4] Bull. Geol. Soc. Am., vol. 24, No. 3, Sept., 1913, p. 460.
[5] Geology of Canada, 1863, p. 319.

dolomite which, on lithological grounds, is included in the Lockport dolomite Slabs of red sandstone near Cabot Head, which contain remains of *Helopora fragilis,* would indicate the presence of a red horizon in the section there, which does not occur at the exposure farther west. From Owen Sound, east and south, red sandy beds occur in the upper half of the Cabot Head shale. These are dense and heavy, suggesting an iron ore. They usually contain bryozoa, one of the commonest species being *Helopora fragilis.* The grey portion of the member varies from firm shale to shale of a clay consistency. From Hamilton, south, the upper beds are sandy, sandstone and shale being commonly interbedded. At Niagara gorge about 4 feet of firm grey shales are referred to the Cabot Head member.

Upward, the Cabot Head shales, from Niagara gorge to Dundas, pass with lithological changes only into the overlying sandstones, which appear to be an inshore phase of the upper beds of the shales which accumulated farther north. From Waterdown to Limehouse the shales support the lower member of the Clinton formation, and farther north they lie directly beneath the Lockport.

Grimsby Member.—For the sake of completeness and convenience in description, it has seemed best to give a separate name to that part of the Medina formation which lies below the "Grey band" or Thorold sandstone, and above the Cabot Head shale, as it occurs in the Niagara peninsula. Because of the good exposures along the east side of the gorge at Grimsby, the name of that town is proposed for the sandstone in question. The section consists of 12 feet of thick-bedded, mottled (red and grey) sandstone and 6 feet of grey shale which lies immediately beneath the Thorold sandstone. The underlying strata are red Cabot Head shales. An excellent section is also exposed at Niagara gorge above Lewiston (on the New York Central and Hudson River railway), where red and grey sandstone and shale grade upward into hard red sandstone, the total thickness being over 50 feet.

Fossils are found in this section in a thin bed of red shale about 10 feet above the base of the member. They include: *Modiolopsis primigenia, Tellinomya machaeriformis? T. elliptica?* Higher up *Lingula cuneata* occurs.

The Grimsby sandstone is seen as far west as Dundas, where it is not easily differentiated from the lower shales but is about 14 feet thick. Southward it increases in thickness, being, as above stated, 50 feet at the American line. In Canada this member rests upon the Cabot Head shale, and is doubtless the inshore equivalent of the upper beds of that shale as seen north of Dundas. As far north as Stony creek the Grimsby sandstone is overlain by the Thorold quartzite. Whether the upper grey shales and sandstones at Hamilton are to be included with the Grimsby or the Thorold, is not easy to decide, but on the evidence of pillow structure which is not reported in the Thorold but is well known in the Grimsby, the lower beds are referred to the latter member. That the upper thin grey sandstones and shales are a facies of the Thorold is probable.

Thorold Member.[1]—The Thorold sandstone (quartzite) is the equivalent of the Medina grey band, which includes the upper grey sandstone beds of the Medina formation. The sandstone is light grey, thin to thick-bedded, and at Thorold is indurated, approaching quartzite. It is often cross-bedded and contains at some localities, *Daedalus archimedes* Ringueberg, and *Arthrophycus harlani* Hall.

At Niagara gorge the Thorold sandstone is 7 feet thick; it reaches a thickness of about 12 feet near De Cew falls, thins to 6 feet at Stony creek, and at Hamilton and northward is not differentiated, if present, from the Grimsby sandstone and shale. The lower contact of this member is marked by little more than a lithologic change from the Grimsby sandstone below. The upper contact is clearly defined, being at the top of a thick bed of sandstone. However, the succeeding Clinton beds are arenaceous at some places.

[1] Grabau, A. W. Bull. Geol. Soc. Am., vol. 24, No. 3, p. 460.

CLINTON FORMATION.

The Clinton formation, as it occurs in Ontario, includes four members, the generally accepted nomenclature being followed. They are the Sodus shale, the Wolcott limestone, the Williamson shale, and the Irondequoit limestone.

Sodus Member.—The colour of the Sodus shale is dark grey, weathering lighter, with blue or green shades. It is of fine, even grain, and is very thinly laminated.

At the Niagara gorge the Sodus shale is 4 feet thick. Westward, it is not seen again, unless about 1 foot of shale holding its horizon at De Cew falls and Grimsby may represent it. The shale is separated by sharp contacts from the members above and below it.

The following fossils occur in the Sodus shale at Niagara gorge: *Rhynchotreta cuneata* var. *americana, Pterinea emacerata,? Tellinomya elliptica,? Conularia* sp.

Wolcott Member.—The Wolcott is the lower limestone member of the Clinton formation. It is dark grey in colour, hard and compact, and is rather thin-bedded. A few characteristic fossils are contained in it. *Hyattella congesta* is found near the base at Niagara gorge, and *Pentamerus oblongus* is common in a bed about 1½ feet above the base of the limestone west and north of Niagara. At Niagara gorge the following occur: *Leptaena rhomboidalis, Rhynchotreta cuneata* var. *americana, Camarotoechia* sp., *Atrypa reticularis, A. nodostriata, Spirifer niagarensis, Homoeospira* sp., *Hyattella congesta, Whitfieldella nitida?* Pentamerus has not been reported except in a single instance from Niagara gorge, although it occurs to the east and west.

From 12 feet at Niagara river this member thickens to 14 feet at De Cew falls, and thins northward to 8 and finally 6 feet at Limehouse, where it is last recognized. The Wolcott rests, successively, from south to north, upon Sodus shale, Thorold sandstone, and Cabot Head shale. The contact is always sharp, but the basal limestone is arenaceous at some places where resting on sandstone.

Williamson Member.—At Niagara river and De Cew falls a few inches of shale separate the Wolcott from the overlying Irondequoit limestone. This shale holds the position and is suggestive of the Williamson shale of New York state. Northward to Waterdown, the Irondequoit limestone rests directly on the Wolcott, and at Kelso and Limehouse the Lockport is the overlying member.

Irondequoit Member.—The upper member of the Clinton, the Irondequoit limestone, is of crystalline texture and is generally massive. In colour it is light grey, here and there showing pink or other shades. This limestone is crinoidal and in shaly beds near the top contains many fossils, which are mostly of species common to the everlying Rochester shale. The following occur at Niagara gorge: *Rhynchotreta cuneata* var. *americana, Atrypa reticularis, Atrypa nodostriata, Spirifer niagarensis, Whitfieldella oblata?, Sirophonella? patenta?* Lenses of dense, amorphous rock occur at some localities in the Irondequoit limestone, and in places extend up into the Rochester shale. They may be a score of feet across and several feet in thickness, and appear to represent reefs composed mostly of bryozoa but including other marine forms.

The Irondequoit rests in general upon the Wolcott limestone, being separated from it between Niagara river and De Cew falls by a few inches of grey shale. Upward it passes from shaly limestone to the soft grey shale of the Rochester.

NIAGARA FORMATION.

The Niagara, according to the usage of the Geological Survey, includes the Rochester and Lockport.

Rochester Member.—The Rochester is essentially shale, although toward the top some of the beds appear calcareous. The shale is dark grey in colour, is soft and thinly laminated.

The fossils found at Niagara gorge include: *Enterolasma calicula, Lichenalia concentrica, Leptaena rhomboidalis, Plectambonites tranversalis, Dalmanella elegantula, Rhynchotreta cuneata* var. *americana, Schuchertella hydraulica, Atrypa reticularis, A. nodostriata, Spirifer radiatus, S. niagarensis, S. crispus?, Whitfieldella nitida.*

At Niagara river, the Rochester is somewhat more than 60 feet thick; it thins toward Thorold, thickens to nearly 70 feet at De Cew falls, and thins northward to 2½ feet at Waterdown, beyond which it has not been observed. Everywhere the Rochester rests conformably upon the Irondequoit limestone, the two disappearing together between Waterdown and Kelso. From Niagara river as far west as Hamilton, the Rochester is succeeded above by the amorphous De Cew limestone. From Hamilton, north, crystalline Lockport dolomite rests upon the Rochester shale. The character of the upper contact will be dealt with under the Lockport member.

Lockport Member.—According to generally accepted usage, the Lockport includes the calcareous deposits between the top of the Rochester shale and the base of the Guelph dolomite.

In general, the Lockport consists of thin to thick-bedded or massive dolomite, dark grey-blue on fresh fracture but weathering white. Fossils are not very plentiful in these dolomites, but compound corals are well distributed, and sponges, brachiopods, and other forms are plentiful at some localities. Especially along Georgian bay, crinoid columns are widely distributed. At Niagara river the Lockport-Guelph contact is not well defined. At Ancaster the Lockport as delimited is 105 feet thick, and at Cabot Head the thickness is at least 240 feet.

Included in the Lockport are several horizons of more or less local development. These will be described below.

De Cew Limestone.—In the Niagara peninsula, a fine-grained, dark grey, argillaceous limestone occurs at the base of the Lockport. It is especially well exposed at De Cew falls, and for it the name De Cew limestone is proposed. Formerly this rock was mined and manufactured on a considerable scale into natural cement.

At Niagara river the De Cew limestone is about 9 feet thick, and it retains a thickness of 8 feet as far north as Grimsby. From Grimsby north it thins out, being last recognized at Hamilton where it is about 2 feet thick.

The relationships of the De Cew limestone are of considerable importance, and the following characters bear upon the subject. The top and bottom contacts of the limestone are clearly defined, although lithologically the limestone is with difficulty separated from limy beds occurring in places at the top of the Rochester shale. The thickness of the member is almost constant to within a few miles of its northern limit. At some localities the De Cew limestone shows on weathered surfaces, cross-bedding, and remarkable, churned structure, some of the material showing evidence of having been worked over more than once; where these disturbed conditions exist the even-bedded Rochester shales below are channelled out parallel to the limestone cross-bedding, and the dolomite above rests on the uneven bedding or in small channels cut somewhat into the limestone. These channels are generally less than 1 foot deep and may be seen best along the New York Central and Hudson River railway in the Niagara gorge near Niagara University. Similar disturbances, but of less development, have been observed in the bedding of the Lockport dolomite a few feet above the De Cew limestone. Grabau has ascribed the above conditions to the result of diagenetic changes in the rocks.[1] To the writer the evidence points to disturbed water con-

[1] Bull. Geol. Soc. Am., vol. 24, No. 3, Sept., 1913, p. 471.

ditions during the deposition of the limestone. The material of the beds suggests reworked Rochester shales to which lime has been added. The effects of wave action at the bottom of a shallow sea which was already floored with mud, might give the required conditions. If the above explanations be accepted, no hiatus or unconformity, in the sense of an emergent, erosion interval need be postulated between Rochester and Lockport sedimentation. This is in accord with Grabau's conclusion. Changing conditions of sedimentation are, however, indicated.

Because the De Cew limestone has been previously included in the Lockport formation, and because it is even more distinctly separated by channelling, etc., from the Rochester than from the Lockport, it has seemed best to include it with the Lockport. If the conclusions of the writer be correct, it might be considered transitional.

Gasport Limestone.—The 9 to 20 feet of Lockport strata above the De Cew limestone, have been called, by Kindle,[1] the Gasport limestone.

This is a grey to white, semicrystalline, crinoidal limestone. At Lockport, N.Y., Kindle states it is nearly pure limestone, becoming more magnesian farther west. He assigns to the Gasport an average of 9 and a maximum thickness of 20 feet on the east side of the Niagara river, but only 7 feet on the Canadian side. In the opinion of the writer, 14 feet of strata on the Canadian side should be included in this horizon. Westward, the crinoidal beds vary in thickness from 20 to 28 feet, containing at Thorold, bryozoan reefs similar to those described by Kindle as occurring in the Niagara gorge. At De Cew falls, the typical Gasport characters appear to be lacking, but nearby, at the St. Catharines Power Company plant, nearly 23 feet of Gasport was identified. At Grimsby, the Gasport is probably 12 to 14 feet thick, but at Stony creek only about 7 feet of rock could be referred to this member, on the evidence of crinoids which were found at one horizon about 4 feet up. At Hamilton about 5 feet of strata may be included in the Gasport. At Ancaster, 15 feet of strata appear to have the characters of the Gasport, and at Dundas, 13 feet of similar beds occur. Beyond this point, the term Gasport does not seem applicable as crinoidal beds occur northward, throughout the member, the 70 feet of Lockport at Kelso appearing quite uniformly crinoidal.

The following fossils were collected from the reef horizon of the Gasport limestone near Thorold, Ont.: *Zaphrentis turbinata, Cyathophyllum hydraulicum, Diphyphyllum multicaule, D. caespitosum, Favosites gothlandicus?, F. hisingeri, F. parasiticus, Halysites catenulatus, Plasmopora follis?, Helinonites elegans, Leptaena rhomboidalis, Platystrophia biforata, Dalmanella elegantula, Bilobites bilobus, Rhipidomella hybrida, Rhipidomella circulus, Atrypa nodostriata, Spirifer crispus?, Spirifer radiatus, Spirifer eudora, Whitfieldella laevis, Diaphorostoma niagarensis, Eucalyptocrinus decorus, Ichthyocrinus laevis,* and various bryozoa.

Remaining Lockport Horizons.—Excluding the De Cew and Gasport limestones as described below, the Lockport member consists mainly of thin to thick-bedded dolomites, dark grey-blue on fresh fracture and weathering white or buff. There are a number of variations in the characters of the rocks of which the chert beds are a good example.

These beds consist of dense dolomite which contains nodules of chert generally less than 2 inches in diameter. These nodules frequently contain fossil sponges, portions of orthoceras, etc. At Niagara Falls, 30 feet of thin to massive dolomite separates the chert beds, which are only a few feet thick, from the Gasport limestone below. At Stony creek, Hamilton, and Ancaster, the chert beds rest directly upon Gasport limestone and at the last two localities are 15 feet thick. Thin beds of chert were observed at Owen Sound, 6 feet above the base of the Lockport; at Lion Head, they occur 12 feet above the base; and at Cabot Head, 8 feet above the base.

[1] Niagara Folio, U.S. Geol. Surv., Folio No. 190, p. 7.

Another series of beds consisting of thin- to thick-bedded dolomite, with interbedded shale (in part bituminous) is locally known in the vicinity of Hamilton as the "Barton beds." As measured at Ancaster ,they are about 10 feet thick, and rest directly upon the chert beds. At the top, the rock is thin-bedded and bituminous and appears to be equivalent to similar beds lying below the Guelph dolomites at Guelph, Ont. On the Bruce peninsula, beds of thin bituminous character underlie Guelph strata, and it seems probable that such beds are characteristic of the top of the Lockport member upon which the Guelph dolomites rest.

Pentamerus Beds.—At Owen Sound, *Pentamerus oblongus* occus in large numbers packed into a 5-foot bed of dense dolomite, the base being 1½ feet above the base of the Lockport. In the upper 1-foot of Pentamerus beds, Lockport corals occur, increasing in numbers upward. The same general conditions hold on Bruce peninsula, and on Manitoulin island. On the northern part of the peninsula, however, and on Manitoulin, several feet (8 to 10) of thin-bedded dolomites lie below the Pentamerus beds. A second Pentamerus zone occurs on Manitoulin about 180 feet above the base of the Lockport.

Pentamerus oblongus thus furnishes an example of a recurring species. Making its first appearance in the lower Clinton limestone of New York and southern Ontario, it is not known in the upper Clinton[1] or Rochester beds, but occurs at two horizons in the Lockport of the Georgian Bay region.

GUELPH FORMATION.

The typical fauna of the Guelph formation as long known in the vicinity of Guelph and Galt, was discovered this past summer at various places between Cape Hurd and Stokes bay. *Megalomus canadensis* occurs in abundance and gastropods and cephalopods, etc., of Guelph types, are numerous. At the "Zinc prospect," near Wiarton, described in the Summary Report for 1912, *Pycnostylus guelphensis,* and *P. eleganus* were found, showing that the strata are of Guelph age and are to be correlated with the Guelph rather than the Lockport horizon at Racine, Wis.

The dolomite is light coloured, porous, and is usually thick-bedded to massive, although thin beds occur.

Because of the difficulty of making vertical measurements on the wide extent of undulating but nearly flat-lying beds, the thickness of the Guelph formation was not determined.

The field work of the past summer dealt only incidentally with the Guelph formation and stopped short of its upper boundary. The problems of correlation and classification of the Guelph are, therefore, not dealt with in the present report.

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[1] One occurrence reported by Grabau, N.Y. Museum, Bull. No. 45, p. 191.

GEOLOGY OF A PORTION OF SUDBURY MAP-AREA, SOUTH OF WANAPITEI LAKE, ONTARIO.

(*W. H. Collins.*)

Outline of Field Work.

In the summer of 1913 the geological mapping of Onaping map-area (sheet No. 139, Ontario series), which has been under exploration since 1910, was completed and a revision was begun of the Sudbury sheet (No. 130, Ontario series), the present edition of which has been in print since 1891 and is now somewhat obsolete. Each of these sheets represents an area 72 miles long from east to west, and 48 miles wide. The town of Sudbury lies almost at the centre of the Sudbury map-area and the Onaping map-area is contiguous on the north, hence the positions of both can readily be determined.

The part of Onaping map-area left over from 1912 and finished in 1913 comprises about 400 square miles in the west end of the area. This part was found to be underlain by granite and gneiss with small included remnants of older schists and is not, therefore, of particular interest, so nothing further need be said about it here.

The work done in the Sudbury map-area covers the townships of Mackelcan, McCarthy, Kelly, Falconbridge, Street, Dryden, and parts of Scadding and MacLennan, all south or east of Wanapitei lake. This work is of more interest, for it substantiates one of the chief conclusions reached in 1912. In that year, after completing the eastern part of Onaping map-area, a less thorough exploration was extended southwestward by way of Wanapitei lake and Wanapitei river to the Sudbury district mapped by Professor Coleman.[1] This made a practically continuous exploration between Cobalt and Sudbury districts, and on the strength of it the geological succession given by Coleman for Sudbury district was correlated with that formulated for Cobalt and neighbouring districts by W. G. Miller.[2] A classification of the rocks of the region based on this correlation was stated in the Summary Report of this Department for 1912, pages 307-309. The work upon which this correlation was based was weakest in the country south of Wanapitei lake, for that locality is unusually swampy, soil-covered, and hard to explore geologically, and it had been examined only along the principal canoe route. So in 1913 this weak link of the exploratory chain connecting Cobalt and Sudbury was strengthened by examining it more thoroughly, more particularly in the area represented on the accompanying map. The present report is restricted to describing this mapped area.

The writer was in the field only from May 24 to June 1, and from September 11 to September 29. During that time the area shown on the accompanying map was investigated. In the interval between June 1 and September 11 he was engaged with International Geological Congress work, and the remainder of the work in Sudbury map-area, and all of that in Onaping map-area, was done by Messrs. J. R. Marshall, A. C. Hazen, and C. W. Robinson, under the direction of Mr. Marshall.

Geological Succession.

A tabular statement of the geological succession found in the area shown on the accompanying map is given below. The evidence upon which this classification is based and the descriptions of each rock-group follow.

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[1] The Nickel Industry, Publication No. 170, Mines Branch, Department of Mines, Canada.
[2] Ann. Rep. Bureau of Mines, Ontario, 1907; vol. xvi, part ii.

Quaternary	Pleistocene	Glacial.
Pre-Cambrian	Keweenawan	Dykes and sills of quartz-norite, olivine-diabase and nickel-bearing intrusive.
	Whitewater series	Chelmsford sandstone (not represented).
		Onwatin shale (not represented).
		Onaping tuff.
		Trout Lake conglomerate.
	Cobalt series	Quartzite.
		Greywacke and limestone.
		Conglomerate.
	Batholithic intrusives	Granite and gneiss and associated inclusions of older formations.
	Sudbury series	Copper Cliff arkose.
		McKim greywacke (not represented).
	Keewatin	Basic igneous complex.

KEEWATIN.

The oldest group of rocks in the area may be called Keewatin. It consists essentially of an igneous—chiefly volcanic—complex, which has been schistified and, along its contact with the younger granite and gneiss, rendered especially crystalline by contact metamorphism. There are two areas of these rocks, one in Falconbridge township, the other in Street.

The Falconbridge area is not accurately defined on the north, for the schists underlying it are so cut to pieces by apophyses of granite that a boundary between these rock-groups can be drawn only arbitrarily. There is no doubt, along this contact, of the intrusive relation of the granite. The Keewatin is made up of comparatively massive hornblende—and other basic schists probably of igneous derivation but now wholly recrystallized.

The area in Street contains a somewhat different assemblage of rocks, and their schistosity is notably strong and uniform compared with the chaotic structure of the Falconbridge area. Along the contact with the younger granite and gneiss to the south the Keewatin consists of coarsely crystalline, frequently garnetiferous hornblende-gneiss. This gneiss is very well foliated, its angle of dip is 70 degrees to 90 degrees, strike 70 degrees to 80 degrees, and it is invaded along the strike by bands of granite, pegmatite, and quartz, all derivatives of the batholithic granite mass. The exact contact line between Keewatin and granite-gneiss cannot be drawn. Half a mile north of the line representing it on the map the contact-metamorphic effects of the granite die out and the coarsely crystalline hornblende-gneiss gives place to a variety of finer-grained Keewatin rocks in which schistosity is less uniform and less pronounced. This part of the complex was examined hurriedly, but even casual inspection indicates that it is not entirely igneous. One highly schistose, light grey formation, that outcrops along the Canadian Northern Ontario railway in the northeast corner of Street, looks much like a well-stratified, feldspathic quartzite. This opinion, however, has not yet been supported by microsopic study. It is proposed to investigate this locality more thoroughly and, if sediments do occur in the complex, to ascertain what relation, if any, they bear to certain para-gneisses that are mingled with the batholithic granite gneiss.

SUDBURY SERIES.

The Sudbury series is represented in this area by the Copper Cliff arkose member only. The arkose is remarkably uniform in character over the whole area. Usually, as in Falconbridge, it is a nearly white, hard, feldspathic quartzite, the upturned beds of which are 1 to 6 feet thick, and show cross-bedding frequently and distinctly. Much less often it consists of layers of this arkose 6 to 12 inches thick, alternating with softer, more greywacke-like layers 2 to 6 inches thick, that weather into grooves, so that on exposed hillsides the stratification of the almost vertical formation is very conspicuous. This phase is well shown near Wanapitei village and at a portage on Wanapitei river on the eastern boundary of Dryden. The general strike of the Copper Cliff formation ranges from 20 degrees to 65 degrees, with angles of dips of 50 degrees to 90 degrees. The formation is 5 miles wide in places and it is evident in traversing it across the strike that its thickness is to be estimated in thousands of feet. There are, however, several lines of crush-breccia in it that were probably caused by faulting, and there is more indisputable evidence of faulting along its contact with the batholithic gneiss in Dryden; consequently the thickness cannot be calculated directly from its known width, dip, and strike, and must be estimated only approximately as thousands of feet.

The Copper Cliff arkose is intruded by the granite and is, therefore, older than it. But the arkose has not been found in immediate contact with the Keewatin, so its age relations to that complex cannot be positively stated. It seems, at least, to be distinct in age from the Keewatin, for throughout the map area it contains no eruptive matter except the much younger Keweenawan diabase; and it is unlikely that the change from varied, and probably intense, vulcanism to undisturbed sedimentation, or vice versa, took place suddenly. It is, therefore, distinctly older or distinctly younger than the Keewatin. And that the Keewatin is the older of the two is suggested by the general structure of the district. The arkose area that extends from southwest to northeast across the area is probably down-folded between the granite-gneiss areas on the northwest and southeast, and as the Keewatin occurs only along the periphery of the arkose the Keewatin must be beneath the arkose and, therefore, older than it.

The greater metamorphism of the Keewatin might also be advanced as an argument in favour of its greater age. It seems reasonable, at first sight, that the older of the two rocks in the same locality should endure a greater amount of the geological stress that causes metamorphism and should consequently be more altered or metamorphosed. But in the present instance even if the Copper Cliff arkose were older than the Keewatin, it might be much less metamorphosed, for it resists metamorphism much more effectually than the unstable basic rocks of the Keewatin complex. This is demonstrated along the contact with the granite batholith, where the Keewatin has a recrystallized contact zone half a mile wide, while the arkose is little changed a few yards away from the invading granite. The greater metamorphism of the Keewatin schists south of Wanapitei lake is extremely unreliable proof of their greater age than the Copper Cliff arkose.

BATHOLITHIC INTRUSIVES.

Two areas of granite and gneiss appear on the map, one in Falconbridge and MacLennan, the other in Awrey and Dryden. Both are small parts of great batholithic bodies that extend far to the north and south respectively. These great intrusive masses bear identical relations to the other rocks of the district, but the materials composing them are so unlike that they are described independently. Each batholithic mass is composed of intrusive granite and vestiges of other, older materials which were mingled with the granite and partly assimilated by it. The two composite masses differ mainly in the character of these older included materials.

The granite of the Falconbridge-MacLennan batholith is a pale grey variety, very poor in dark minerals. In lot 6, concession XI, MacLennan, stringers of this granite were found invading Copper Cliff arkose, without altering the arkose noticeably, and farther out in the granite there are a few included fragments of the arkose, as well as others of hornblende-schist or gneiss. In Falconbridge the granite penetrates the Keewatin rocks in the same manner and contains a great quantity of hornblende-rich inclusions derived from the Keewatin. These inclusions, especially the larger ones, are not so strikingly foliated as they are in the batholith to the southeast. This is true of the complex as a whole. The granite and included materials are also cut by dykes and small irregular masses of the younger diabase so that the whole is a chaotic mixture of granite and gneiss, Keewatin and Sudbury inclusions, and diabase intrusives, with granite and gneiss predominating.

The intrusive portion of the Awrey-Dryden batholithic mass is also a granite, but with more biotite and often with red feldspar. Associated with the granite, apparently as acid differentiates, are pegmatites, quartz veins, and gradations from one of these types to the other. These different phases can be seen very well just south of Wanapitei railway station, where they reticulate through an older garnetiferous gneiss. Mingled with this distinctly igneous portion of the complex are bands of highly foliated, hornblendic gneisses and other materials, which appear to be highly metamorphosed inclusions of Keewatin and other formations older than the granite. Unlike the inclusions in the Falconbridge-MacLennan batholith those in Awrey and Dryden are highly foliated and give the whole complex a notably gneissic structure. A large part of the included material is a glistening hornblende-gneiss like that found about the contacts between Keewatin and intrusive batholithic areas. The actual transition from continuous, undoubted Keewatin to a mixture of hornblende-gneiss and intrusive granite-gneiss is observed in the northeastern part of Street township, so there seems good reason to regard the hornblende-gneiss there and farther out in the batholith as derived from the basic volcanics of the Keewatin. But some other included materials may have had a different source. Professor Coleman has described a patch of crystalline limestone surrounded and intruded by the granite, in lot 12, concession I, Cleland township, 8 miles southwest of Wanapitei village. Quartzite intruded by granite occurs in the same locality. Feldspathic quartzite containing occasional highly micaceous layers that suggest the greywacke layers on the Copper Cliff arkose, intruded by pegmatitic granite, was found just south of Wanapitei station. A little east of the station the ordinary intrusive gneiss alternates with highly foliated garnet- and kyanite-bearing hornblende-biotite-gneiss. The limestone and quartzite are certainly sedimentary and some of the gneisses are probably of the same origin.

The source and age of these sedimentary vestiges are rather obscure. The Keewatin complex does not usually contain notable amounts of sediments and seems an unlikely source. The Sudbury series may have supplied the feldspathic quartzite inclusions, and perhaps even material for some of the hornblende-gneisses, but no limestone is known to occur in it. Professor Coleman has called attention to the similarity of these rocks to the Grenville series of southeastern Ontario and has applied that name to them, regarding them as of the same age as the Keewatin or older.

The relation of the granite to the Copper Cliff arkose in the area here described, is obscured by the covering of soil. Along the entire line of contact across Dryden, Awrey, and Street the two formations were found close to each other in very few places and the actual contact was seen at only one point. There the arkose, greatly schistified parallel to the contact but showing no contact-metamorphic recrystallization, is in immediate contact with a gneiss consisting of alternating light and dark hornblendic bands, the strike of which is inclined 10 degrees to 60 degrees to that of the arkose. From this exposure alone it cannot be satisfactorily decided whether the arkose lies upon an older gneiss surface, or whether it has been faulted against the gneiss, which might then be older or younger. The age relations are more definitely expressed, however, in lot 5, concession I, of the adjacent township of Neelon, where the Toronto branch of the Canadian Pacific railway crosses the contact. There thick apophyses of coarse, reddish, biotite-granite cut the vertical Copper Cliff arkose, and render it slightly micaceous and more crystalline. There seems no doubt that the granite is the younger. This being the case, the line of contact across Dryden, Awrey, and part of Street must be a fault line.

COBALT SERIES.

The Cobalt series has been traced continuously from Gowganda district into Falconbridge township and there can be little or no doubt that it corresponds to the sedimentary series in Cobalt district to which the name Cobalt series was first applied. In the present map-area, it has been eroded quite thin and only its basal conglomerate is left in most places; but there are a few places where the series has been more closely folded than usual, and there the succession is more complete. Thus in lot 5, concession II, Falconbridge, the basal conglomerate passes upward into greywacke. The greywacke contains a layer of impure, sandy limestone 10 to 15 feet thick and grades higher up, into a better stratified greywacke phase which, in its turn, grades into feldspathic quartzite. The quartzite appears as layers that are at first only a few inches thick, but these become thicker and more numerous and in a vertical range of 50 feet completely take the place of the greywacke. The series is so crumpled, however, that thicknesses cannot satisfactorily be determined. Another section is afforded on the Canadian Northern Ontario railway just west of Wanapitei river. There a conglomerate, whose base is not visible, grades upward into greywacke, and the greywacke into quartzite. The rocks dip about 45 degrees northwest and present a total thickness of perhaps 2,000 feet. The limestone band was not seen in this section, but it is exposed in the river, a quarter of a mile away. The greywacke in this section is not so finely stratified in its upper portion as in the first locality and merges imperceptibly into quartzite instead of showing alternating layers of those materials. The work in McCarthy, Kelly, and Mackelcan townships farther northeast also indicates the general upward succession of formations in the Cobalt series to be conglomerate, greywacke with finely banded phases, and quartzite; the limestone band in the greywacke may be present but have escaped observation as it weathers easily and is usually soil covered.

There is satisfactory evidence in the district that the Cobalt series is younger than the Sudbury series and rests unconformably upon it. Contacts between the basal conglomerate and the arkose may be seen on the Canadian Northern Ontario railway in lot 7, concession V, Street, and in many places along the Wanapitei Lake road in Dryden and Falconbridge. At all these the relations are the same. The conglomerate rests upon an irregular surface of Copper Cliff arkose and the line of separation is always conspicuous, and knife-sharp in most cases. The arkose dips at 70 degrees to 90 degrees, but the conglomerate, unfortunately, is not stratified; consequently the structural evidence of unconformity is not apparent in detail. But for the district as a whole structural unconformity is quite clear. If the two formations were conformable the conglomerate would necessarily appear as long narrow bands standing on edge like the arkose and striking in the same northeast-southwest direction. But, as may be seen by consulting the map, such is not the case. The actual areal arrangement shown on the map can result only from unconformity. The slight tendency of the conglomerate in southwestern Falconbridge to finger out in the direction of strike of the arkose, appears to be due not to any conformity between the two formations but to the fact that the arkose surface was eroded into ridges and troughs along the strike of its edgewise beds before the Cobalt series was laid down, and the troughs now protect from erosion vestiges of conglomerate that was deposited in them.

Two small patches of conglomerate occur in the granite area of MacLennan township. Mr. Marshall, who found them, did not observe their contacts with the granite, but found in them no evidence of contact metamorphism. They are almost certainly younger than the granite, and the fact that conglomerate overlies both granite and Sudbury series is a further structural indication of unconformity.

The conglomerate also contains pebbles of arkose and quartzite like that composing the Copper Cliff formation; also pebbles of hornblende-schist and other rocks that are found in the Keewatin along its metamorphosed contacts with the granite. As these metamorphic materials resulted from the granite intrusion, the Cobalt conglomerate would appear, from this evidence also, to be younger than both Sudbury series and batholithic intrusives.

Although arkose pebbles occur in the Cobalt conglomerate, they are surprisingly infrequent. The mineral compositions of the conglomerate and of the underlying arkose are also strikingly unlike. The latter is a white rock composed entirely of quartz and feldspar, while the cement of the conglomerate is dark grey or green and contains an abundance of dark, iron-bearing minerals. It is clear that a very small fraction of the conglomerate materials was derived from the arkose and that the greater part was transported from a considerable distance. One of the granite boulders in the conglomerate measured 63 inches in diameter on its exposed surface. These facts are no doubt significant of the mode of deposition of the conglomerate.

WHITEWATER SERIES.

Although this series of sediments and volcanic tuff occurs in the western part of MacLennan, it was not studied by the writer or his party, the information for its mapping as well as that of the nickel-eruptive being taken from Professor Coleman's map. A description of the series is given in "The Nickel Industry," Publication No. 170, Mines Branch, Ottawa, under the name Animikie.

KEWEENAWAN.

The various intrusives grouped in the Keweenawan were determined in the field to be quartz-norite or diabase, and are all very similar in appearance. They occur as dykes and larger bodies, probably sills, that intrude the granite, Copper Cliff arkose, Keewatin, and, in one or two observed instances, the Cobalt conglomerate. The last-mentioned relation can be seen on the Canadian Northern Ontario railway in lot 7, concession V, of Street, where a dyke of olivine-diabase cuts the conglomerate.

No attempt is made here to describe the nickel-bearing eruptive in Falconbridge and MacLennan, as an excellent account of it has already been given by Professor Coleman.

PLEISTOCENE.

Deposits of sand, gravel, and other Pleistocense deposits are abundant in this map-area. The most interesting exposures occur in the recent cuttings of the Canadian Northern Ontario railway and in the banks of Wanapitei river. One mile northeast of Wanapitei River crossing the railway has cut through a tough boulder clay carrying very large boulders. Near Boland bay, on Wanapitei lake, a rather steep-sided hill has also been partly removed for ballast, and in the face so exposed the whole hill can be seen to consist of strongly cross-bedded gravel and coarse sand, deposited presumably by a glacial stream. Coleman has also described a kettle lake 165 feet deep in Falconbridge township. There is present, therefore, a considerable amount of material deposited by the ice-sheet or by waters from the melting ice.

Associated with these are other deposits that appear to have been laid down in lakes or by Wanapitei river. The Canadian Northern Ontario railway has made cuttings through horizontal, stratified clay at several places near Wanapitei River crossing. That exposed half a mile east of the bridge is finely laminated and contains occasional boulders that must have dropped from blocks of ice floating on the water in which the clay was deposited. At least, no alternative explanation occurs to the writer. Two of these boulders, 6 and 15 inches in diameter, were noticed. This stratified clay rests on boulder clay about 850 to 875 feet above sea-level at the few places where its bottom could be seen. It appears to be part of a post-Glacial lake deposit of which little is yet known.

In lots 4, 5, and 6, concession V, of Street, the railway traverses a flat plain of fine gravel and sand about 840 feet above sea-level. The cuttings, which are not over 15 feet deep, show fine gravel and sand composed of well-sorted, rounded pebbles. The gravel and sand are well stratified and show comparatively little cross-bedding. A terrace of coarser gravel conceals the southeast corner of the nickel-eruptive in Falconbridge at an undetermined elevation. These lower-level stratified gravels and sand are at about the same level as similar lake deposits near Sudbury which are regarded by Coleman as representing a former level of the Great Lakes (Lake Algonquin).

The deep rock valley occupied by Wanapitei river contains stratified gravel and clay deposits at a number of different levels. A comparatively flat-topped terrace at about 830 feet above sea-level can be seen from the Canadian Northern Ontario Railway bridge. Near Wanapitei village, also, the river traverses a flat plain of small extent, at about 750 feet above the sea. Banks of stratified clay at higher elevations were observed farther up the river. These probably represent a time when the waters of the Great Lakes extended up this valley.

SOUTHEASTERN PORTION OF BUCKINGHAM MAP-AREA, QUEBEC.

(*M. E. Wilson.*)

General Statement and Acknowledgments.

During the past field season, the writer commenced the geological investigation of a region lying to the northeastward of the city of Ottawa, in Ottawa county, Quebec.

In connexion with this investigation, it is proposed that a regional map of a rectangular area (approximately 430 square miles) extending from the village of East Templeton northward to High Falls on the Lièvre river (24 miles) and from the Gatineau river eastward to a point 2 miles beyond the town of Buckingham (18 miles) be prepared. This map, which is to be known as the Buckingham sheet, will be published on the scale of 1 mile to 1 inch. It will include the whole of Portland township, the larger part of Templeton, Buckingham, and Derry townships and portions of Hull, Wakefield, and Denholm townships.

In addition to this areal map a number of small local maps of areas adjacent to some of the mineral deposits of the district, are being prepared for publication on scales ranging from 100 to 500 feet to 1 inch. On these maps, it will be possible to indicate the distribution of the mineral occurrences and the areal and structural relationships of the various rock types in much greater detail than could be attempted on the general sheet.

In the compilation of the Buckingham sheet, the following surveys and maps are being used, supplemented by surveys made by the writer and his assistants: township surveys by Crown Lands Department of Quebec; mining and topographical map of the Lièvre river and Templeton phosphate district; sheets 1 and 2 by James White, Geological Survey, 1891; Thurso sheet, Department of Militia, 1908.

Owing to my absence from the field from July 20, to September 7, on work in connexion with the meeting of the International Geological Congress, the time spent on the Buckingham map-area in 1913 was somewhat curtailed. The mapping of the southeastern part of the sheet (approximately the township of Buckingham), however, was completed and small detailed maps of areas in the vicinity of the following mines were prepared: Dominion graphite mine, Walker graphite mine, Emerald phosphate mine, Little Rapid mica-phosphate mine, Poupore mica mine.

The assistance rendered during the course of the work by those interested in the development of mining in the region was most hearty and general. The thanks of the survey are especially due to Mr. H. P. H. Brumell, to Mr. A. Geister, manager of the Quebec graphite mine, to Mr. C. Kendall, manager of the Bell graphite mine, to Mr. B. Winning, manager for O'Brien and Fowler, and Mr. E. Wallingford, manager of the Wallingford Mica and Mining company.

I was assisted in 1913 by Messrs. F. J. Alcock and S. Brunton, both of whom, during my absence on the work of the International Geological Congress, were engaged in preparing detailed maps, the former at the Little Rapid mine and the latter at the Dominion Graphite mine.

Previous Work.

The region included in the Buckingham sheet, because of its numerous occurrences of both rare and economic minerals and because of its peculiar and complex geology, has been of interest to the Geological Survey almost from the time of the Survey's inception, but the geological work carried on in the district has been for the most part either of a general character, or very local, having reference to particular mines. It is not proposed to review all the voluminous literature having reference to the district, but the most important geological work and the principal publications, in which the geology and economic resources of the district are described, may be mentioned.

Reference to the production of economic minerals from the area is to be found in the reports of the Mines Branch of the Department of Colonization, Mines, and Fisheries for Quebec, and in the statistical reports of the Geological Survey and the Mines Branch of the Department of Mines. A number of special bulletins and reports having reference to minerals occurring in the district have also been published from time to time by the Geological Survey and the Mines Branch of the Department of Mines. These include a report on the mineral resources of the province of Quebec by R. W. Ells, published by the Geological Survey in 1890; bulletin on graphite, apatite, and mica by R. W. Ells, published by the Geological Survey in 1904; reports on mica and graphite by Fritz Cirkel, published by the Mines Branch of the Department of Mines in 1905 and 1907, respectively; and a second edition of the report on mica by H. S. de Schmid, published by the Mines Branch of the Department of Mines in 1912.

The earliest geological work carried on within the area included in the Buckingham sheet, was an examination of the southeastern part of the district by Sir William Logan, in 1842, for, in that year, Logan studied the geology along the Ottawa river between Montreal and Ottawa (then known as Bytown). As a result of this investigation, Logan was able to separate the Palæozoic sediments from the Pre-Cambrian "metamorphic complex" in that region, the position of the contact between which he described briefly in the report of the Geological Survey of Canada for that year, and, more minutely, in his account of the geology along the Ottawa river, published in the Report of Progress of the Geological Survey for 1845-6, and, again, later, in the Geology of Canada, published in 1863.

In 1866, Mr. James Lowe visited several occurrences of iron and graphite in the southern part of Templeton, Buckingham, and Lochaber townships for the Geological Survey, also a graphite mill recently erected by the Lochaber Plumbago company near the Blanche river, on lot 28, range X, Lochaber. Lowe's description of these deposits and of the milling process in operation at the Plumbago mill is outlined by Sir William Logan in the Report of Progress of the Geological Survey for 1863-6.

In the autumn of 1873, Mr. H. G. Vennor spent a short time in making an examination of the graphite deposits of the district and described them in the Report of Progress of the Geological Survey for 1873-4.

In 1876, Vennor again spent part of a field season in the region and prepared a geological map of the southwestern part of Ottawa county, and a report on the apatite and plumbago deposits of the district, both of which were published in the Report of Progress of the Geological Survey for 1876-7.

In 1883, Mr. J. Fraser Torrance visited some of the principal apatite mines of the district, which he described in the Report of Progress of the Geological Survey for 1882-3-4.

In 1898, Mr. E. D. Ingall published a paper in the *Canadian Record of Science,* entitled "Some Preliminary Notes on the Limestones of the Laurentian System." This paper was based on observations made by Mr. Ingall in the course of surveys carried on in association with Mr. James White in 1887-8.

During the field season of 1892-3 and 4, Dr. R. W. Ells was engaged in geological work in the Buckingham district and vicinity, this work being carried on partly in the course of the preparation of the Grenville map (known as sheet number 121 in the series published by the Geological Survey on the scale of 4 miles to 1 inch) and partly in the course of the preparation of the map of the city of Ottawa and vicinity. The geology of the region included in these two sheets was discussed by Dr. Ells in reports published by the Geological Survey and in numerous papers contributed to magazines and to the transactions and bulletins of various scientific societies.

Subsequent to his earlier work, Dr. Ells visited the Buckingham region on two occasions (October, 1902, and April, 1908) to report on landslides occurring along the Lièvre river. The first of these—the Poupore landslide—was described by Dr. Ells in the Summary Report of the Geological Survey for 1902, and the second—the Salette landslide—in a report entitled "Landslide at Notre Dame de la Salette" published in 1908.

Dr. C. H. Gordon has published several papers with regard to the character and origin of the rocks occurring at the High Rock Phosphate mines on the Lièvre river, the most important of these was that on "Syenite Gneiss (leopard rock) from the Apatite Region of Ottawa County, Canada," presented at the meeting of the Geological Society of America in August, 1895.

In the autumn of 1897, Mr. A. A. Cole made a preliminary study of the graphite deposits of the Buckingham district and published his results in the mineral statistics section of the annual report of the Geological Survey for that year.

In 1899, Dr. O. Osann made a series of geological excursions extending over five weeks, into the region northeast of the city of Ottawa, during which he examined the geology in the vicinity of several of the most important graphite, apatite, and mica mines of the district. Dr. Osann's report entitled, "Notes on Certain Archæan Rocks of the Ottawa Valley" is contained in the annual report of the Geological Survey for 1899. With the exception of Dr. Gordon's investigation of the rocks occurring at the High Rock mine, this was the first petrographical study of the rocks of the area.

In the Summary Report of the Geological Survey for 1904, the geology of the northern sheet, or sheet number 2, of the map of the "Lièvre River and Templeton Phosphate District," prepared by Mr. James White, is described by Mr. J. F. E. Johnston who spent the field season of 1904 in examining the rocks of that area.

Mr. E. Haycock was also engaged in mapping the geology of the southern sheet of the map of Lièvre river and Templeton phosphate district in 1904, and continued the work during the summer of 1905 and 1906. Reports regarding this work are given by Mr. Haycock in the Summary Reports of the Survey for 1904 and 1905.

During the field season of 1911, Mr. J. Stansfield examined and mapped a number of local areas in the district including some of those reported on by Mr. Osann. The results of this work were published in the Summary Report of the Geological Survey for 1911, and in Guide Book Number 3, prepared by the Geological Survey in connexion with the excursions of the International Geological Congress in 1913.

A number of papers by Mr. H. P. H. Brumell have appeared, during recent years, in the *Journal of the Canadian Mining Institute,* in the *Canadian Mining Journal,* and in the *Engineering and Mining Journal,* in which the mode of occurrence of the graphite deposits of the Buckingham region and the milling methods employed in the district, are described. These publications embody the results of Mr. Brumell's observations in the course of several years' experience in graphite mining in the Buckingham district.

Topography.

The area included in the Buckingham sheet lies across the boundary between two physiographic provinces—the St. Lawrence lowlands and the Laurentian plateau—but for the purpose of local description it may be more conveniently divided into two somewhat different divisions, namely—the marine flats and terraces, and the Laurentian uplands. To the first of these divisions belong all those portions of the region underlain by post-Glacial stratified marine clay and sand. To the second division belong, on the other hand, all those portions of the region, which, because of their elevation, stood above the highest limit of marine deposition and consequently retain all the typical topographic features which characterize the Laurentian plateau.

In the upper part of the Lièvre River valley, the surface of the stratified marine clay and sand has an elevation of approximately 460 feet above sea-level, although in places cross-bedded sand and gravel (beach-deposits) occur at an elevation about 20 feet higher, or 480 feet above sea-level. From the Lièvre River flat southward to the Ottawa river, the marine clay and sand occurs in a succession of terraces having the following elevations.

	Above sea-level.
Lièvre River flat	460 feet.
Buckingham terrace	435 "
	375 "
	350 "
	300 "
Masson terrace	200 "
	150 "

Some of these have a very local extent. Others, however, such as the 300-foot terrace, are continuous for many miles.

With regard to the origin of these terraces, two possibilities suggest themselves. They might be (1) river terraces formed by the Ottawa river in cutting its way through the marine clay and sand to its present level; or (2) wave-cut terraces formed by the Pleistocene sea during periods of still-stand as it withdrew from the St. Lawrence embayment. The investigation of this problem has not yet been completed for the larger part of the Buckingham sheet, but such evidence as was obtained during the past field season, on the whole seemed to favour the second hypothesis, as regards at least the upper terraces.

General Geology.

The rocks occurring in Buckingham township when classified according to age and structure, all into four well defined groups:—

(1) The metamorphic complex or Laurentian of Logan, consisting of crystalline limestone, pyroxenite, banded gneisses, and pegmatite.

(2) Late Pre-Cambrian (or possibly early Cambrian) intrusions of diabase and lamprophyre.

(3) Potsdam sandstone and Beekmantown limestone.

(4) Unconsolidated glacial drift and stratified marine clay and sand.

Table of Formations.

The succession of formations arranged in descending order is as follows:—

Quaternary	Post-Glacial	Marine clay and sand.
	Glacial	Boulder clay, gravel, and sand.
Palæozoic	Beekmantown	Limestone.
	Potsdam	White, pebbly sandstone.
Late Pre-Cambrian ?		Lamprophyre.
		Diabase.
Early Pre-Cambrian	Basal complex	(7) Pegmatite.
		(6) Biotite granite gneiss.
		(5) Pyroxenite.
		(4) *Buckingham series*: pyroxene granite, pyroxene granite gneiss, biotite-pyroxene granite, biotite-pyroxene granite gneiss, pyroxene syenite, pyroxene syenite gneiss, biotite-pyroxene syenite, biotite-pyroxene syenite gneiss, gabbro, gabbro gneiss, biotite gabbro, biotite gabbro gneiss, peridotite and pyroxenite.
		(3) Sillimanite g gneiss.arnet
		(2) Quarcz rock.
		(1) Crystalline limestone.

BASAL COMPLEX.

General Statement.

The oldest of the four great groups into which the rocks of the Buckingham district have been divided—the basal complex—is composed of a heterogeneous assemblage of rock types, the larger part of which have been so greatly deformed and metamorphosed that their original character and relationships to one another are now a matter of conjecture. They thus present a striking contrast to the rocks that succeed them, in that the latter are only slightly metamorphosed and retain all the characteristic features which they originally possessed.

The most abundant of the rocks of the complex belong to a genetically related group of banded gneisses, the members of which constitute a gradational series ranging in composition, from a pyroxene granite to peridotite and pyroxenite. This group will be referred to as the Buckingham series.

Locally throughout the southern portion of the area examined, and throughout the northern portion generally, the rocks of the Buckingham series are interbanded with a sillimanite garnet mica gneiss and a highly quartzose rock. The last-mentioned rock has been generally called quartzite by previous workers in the district, but as this name implies a sedimentary origin—an assumption that might possibly be wrong— it will be referred to as "quartz rock."

All of the foregoing rocks, but more especially the rocks of the Buckingham series, contain numerous irregular included masses of crystalline limestone or dolomite. These masses are nowhere continuous areally for more than a few hundred feet, but are very numerous throughout wide zones, the zones having a more or less northeasterly-southwesterly trend.

In addition to the fine-grained dark pyroxenite which belongs to the Buckingham series, large masses of a coarsely crystallized light green pyroxenite occur here and there throughout the region. These masses are very similar to the masses of crystalline limestone in their mode of occurrence, and like the crystalline limestone, contain numerous inclusions of foreign rocks. It is with this pyroxenite that most of the most important deposits of mica in the region, are associated.

Throughout the northern ranges of Buckingham township the rocks of the Buckingham series, the garnet gneiss, the quartz rock, and the pyroxenite, are all intruded by numerous dykes of a biotite granite gneiss. This rock, although evidently considerably younger than the rocks which it intrudes, has suffered considerable metamorphism and for that reason is regarded as belonging essentially to the basal gneissic complex.

Very commonly the banded gneissic complex is intruded (generally transversely) by large irregular dykes of coarse pegmatite. These intrusions have been faulted in places along the planes of foliation of the gneisses and locally have been slightly mashed. On this account and because of their lithological similarity and possible genetic relationship to some of the basement rocks they have been placed in the basal complex.

Detailed Description.

Crystalline Limestone.—The crystalline limestone of the basal complex corresponds in its character and geological relations to the limestone which in other districts has been referred to the Grenville series. No chemical analyses of the rock occurring in the Buckingham district have been made, but analyses of the Grenville limestone found in adjoining regions have shown that it generally contains magnesia, and in some localities has the composition of a dolomite. It is probable, therefore, that the limestone in this region also contains considerable magnesia.

In the Buckingham district, the Grenville limestone occurs in small scattered irregular outcrops and contains numerous more or less rounded inclusions of rocks belonging to the Buckingham series. The matrix enclosing the included rock masses consists of a coarsely crystalline grey to white (presumably) magnesian, lime carbonate, and a number of other accessory minerals in variable proportions, such as, pyroxene (generally altered to serpentine), phlogopite, biotite, graphite, sphene, apatite, microcline, and orthoclase. The accessory minerals do not occur evenly disseminated through the limestone but concentrated along parallel lines so that the rock has a banded appearance. These bands are generally intensely folded and minutely crenulated, features which have evidently originated as the result of profound deformational movements.

Sillimanite Garnet Gneiss.—The Sillimanite garnet gneiss occurs chiefly in bands and lenticular masses interlaminated with quartz rock and the gneisses of the Buckingham series. Like the quartz rock, it is found much more extensively in the northern part of Buckingham township than in the south.

This gneiss is generally a moderately fine-grained rock, containing an abundance of garnet, quartz or feldspar, and pyrite in scattered grains. Owing to the occurrence of the common mineral constituents in aggregates, the rock generally presents a variegated appearance—the garnets being red, the biotite black, and the feldspar and quartz rusty yellow. Examined under the microscope the garnet gneiss is seen to consist of garnet, deep brown mica, sillimanite, feldspar—chiefly orthoclase—quartz, rutile, and pyrite. The relative proportions of these minerals in various occurrences of the rock are, however, very different. In some thin sections examined, the garnet was very abundant and the sillimanite entirely absent, while in others the sillimanite made up a large part of the rock and the garnet was absent. Similarly in some thin sections, the quartz composed a large part of the rock and the feldspar was lacking, or, on the other hand, the feldspar was a common constituent and the quartz was lacking. The texture of the rock is granular, the quartz, feldspar, and mica forming a mosaic in which sillimanite prisms are embedded.

Quartz Rock.—The quartz rock is very similar in its mode of occurrence and relationships, to the garnet gneiss, occurring as crumpled masses and bands associated with the garnet gneiss and the rocks of the Buckingham series. It has its greatest development in the northern part of Buckingham township where it occurs in numerous bands having a uniform strike and dip over wide areas.

On the freshly-broken surface, the quartz rock can be seen to consist of blue, granular semitranslucent quartz containing scattered aggregates of feldspar and ferromagnesian minerals. On the weathered surface, the rock is generally white in colour and presents a characteristic pitted appearance due to the weathering out of the included ferromagnesian aggregates. When examined in thin section under the microscope, it is seen that the quartz contains numerous dark, needle-like inclusions from 0·2 mm. to 2 mm. in length. These lie in every direction and are evidently not oriented parallel any of the crystallogarphic planes of the quartz, for they cut across the contacts of adjacent grains. The aggregates of feldspar and ferromagnesian minerals vary greatly in composition in different localities. In some thin sections examined they consisted entirely of biotite or of biotite and garnet and in others of pyroxene and feldspar or of biotite pyroxene and feldspar. The mineral constituents present in the aggregates are thus very similar to those of the garnet gneiss or the rocks of the Buckingham series. Very commonly the aggregates are strung out linearly and the quartz throughout the zone in which they occur is much finer grained than in other parts of the rock, a relationship which indicates they are distributed along zones of deformation.

Buckingham Series.

General Statement.—This group is composed of a series of rocks, which, although ranging in composition from a pyroxene granite to peridotite and pyroxenite, have so many features in common as to indicate that they are genetically related to one another. They are remarkably similar lithologically to the Charnockite series of India described by Holland[1] and the Cortlandt series of New York State, described by G. H. Williams.[2] In consideration of their wide extent, their peculiar mineralogical composition, their evident genetic relationship to one another, and their probable approximate contemporaneity in age, it has been deemed advisable to group them together and to refer to them under a local name—the Buckingham series.

Distribution.—The rocks of the Buckingham series are found in all parts of the district examined during the field season of 1913, but are most extensively developed in the southern part of the district, where they occur, for the most part, in large, irregular-shaped masses. The areal extent of these rocks outside the Buckingham district is not even approximately known. To the east of the Buckingham map-area, similar rocks have been described by Adams (pyroxene granulites) in the region north of Montreal[3] and by Osann[4] (hypersthene gabbro) at Côte St. Pierre. To the west of the Buckingham region, pyroxene rocks similar to those of the Buckingham series have been observed by the writer in the vicinity of the Gatineau river at Kirk Ferry and in the area of Pre-Cambrian rocks which occurs in the township of South March about 15 miles to the west of the city of Ottawa. The series is thus known to occur throughout a region extending over 100 miles from east to west and 50 miles from north to south, that is, throughout an area of at least 5,000 square miles. This is probably much less than their actual extent, however.

Lithological Character.—They are generally blue grey to black rocks of medium texture, and in most places, are much foliated, although in a few localities they are quite massive. The massive types are usually uniform in character throughout considerable areas, whereas the foliated types are banded, the banding being due either to the alternation of bands of entirely different rock types or to the alternation of bands of the same rock in which the proportion of minerals present is slightly different.

On the basis of their mineralogical composition as determined in thin section under the microscope, the rocks of the Buckingham series may be classified as follows:—

Class 1.—Rocks in which quartz and potash feldspar are the principal salic constituents.

- (1) Pyroxene granite.
- (2) Biotite pyroxene granite.
- (3) Granite pegmatite and aplite.

Class 2.—Rocks in which potash feldspar is the principal salic constituent. (Shonkinite type.)

- (1) Pyroxene variety.
- (2) Biotite pyroxene variety.
- (3) Pegmatite and aplitic varieties.

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[1] Memoirs, Geol. Surv., India, vol. 28, pp. 119-249, 1900.

[2] Amer. Jour. Sci., vol. 31, pp. 26-41, 1886; vol. 33, pp. 135-144, pp. 197-199, 1887; vol. 35, pp. 438-448, 1888; vol. 36, pp. 254-259, 1889.

[3] Annual Rept., Geol. Surv., Can., vol. VIII, part J, 1895.

[4] Annual Rept., Geol. Surv., Can., vol. XII, part O, 1899.

Class 3.—Rocks in which albite is the principal salic constituent.

(1) Pyroxene variety.
(2) Biotite pyroxene variety.
(3) Pegmatite and aplitic varieties.

Class 4.—Rocks in which oligoclase and andesine are the principal salic constituents.

(1) Pyroxene variety.
(2) Biotite pyroxene variety.

Class 5.—Rocks in which labradorite is the principal salic constituent.

(1) Pyroxene variety.
(2) Biotite pyroxene variety.

Class 6.—Rocks in which salic minerals are very subordinate or entircly absent. (Peridotites and pyroxenites.)

(1) Variety consisting essentially of pyroxene and olivine. (Harzburgite or wehrlite.)
(2) Variety consisting entirely of pyroxene (pyroxenite).

In addition to the principal mineral constituents—quartz, feldspar, pyroxene, biotite, and olivine, which were used as a basis for the foregoing classification, all of the various members of the series generally contain an abundance of apatite and considerable titanite and pyrite or pyrrhotite. In some localities graphite is also a common constituent, notably so in the vicinity of included masses of crystalline limestone.

The most noteworthy characteristics of the rocks of the Buckingham series, as seen under the microscope, are their granular texture, the needle-like acicular inclusions contained in the quartz and feldspars, and the microperthitic intergrowths of the feldspars with one another. The pyroxene contained in the rocks of the series is a pink to pale green variety which is commonly altered along its fracture planes or around its margin to a compact, olive green or brown uralite. It has been stated generally by those who have studied the rocks of the Buckingham series microscopically that they contained two pyroxenes, a pink or red pleocheoric rhombic type and a pale green monocline variety. In all the thin sections examined by the writer, however, the difference in colour appeared to be due either to the plane in which the individual mineral grains happened to be cut or to incipient uralitization, the first stage of this alteration being indicated by a loss of the pink colour. Moreover, the pink pyroxene had inclined extinction in sections showing prismatic cleavage and the birefringence was considerably higher than that of hypersthene (about 0·025). It seems evident, therefore, that if two variteies of pyroxene are present in these rocks they are both monocline.

Pyroxenite.—The rocks of this class are found chiefly as large irregular masses elongated in the direction of the strike of the quartz rock, garnet gneiss, syenite, and other rocks of the banded complex which encloses them. The principal masses of the rock observed during the past field season were those occurring in the southern part of lot 25, range XII, Buckingham township; in the vicinity of the Little Rapid mine; at the Poupore mine (lot 1, range I, Portland East township); at the Cameron mine (lot 5, range I, Derry township); and at the Daisy mine (lot 9, range I, Derry township).

As seen in these localities the pyroxenite is composed chiefly of a pale green, coarsely crystalline or granular pyroxene, and throughout the rock occur scattered irregular masses of rocks belonging to the Buckingham series and of pegmatite. A large number of minerals occur associated with the pyroxene, the most abundant of which are calcite, phlogopite, and apatite; the less common minerals observed were scapolite, pale green amphibole, tourmaline, fluorite, quartz, pyrite, and chalcopyrite. The apatite and phlogopite contained in the pyroxenite, occur partly in scattered crystals and aggregates and partly in very irregular veins generally accompanied in the case of the phlogopite, by an abundance of pink calcite. The scapolite is a massive, pale yellow variety and occurs around the margin of included masses of pyroxene syenite gneiss. All of the other less common minerals are found in the rock either along fracture planes as vein deposits or along the walls of cavities. Whether these cavities were originally geodal or were originally filled with calcite since dissolved away, has not yet been positively determined.

Biotite Granite Gneiss.—This rock was observed in places throughout the northern ranges of Buckingham township and in the adjacent portions of Portland East township. It occurs as narrow dykes varying in width from a fraction of a foot to 50 feet. These are, for the most part, roughly parallel the strike of the banded complex which they intrude, but here and there they cut across the bands of quartz rock and garnet gneiss, etc., obliquely. They are excedingly variable in width in the direction of the strike, swelling out into large lenticular masses in short intervals. Numerous examples of this feature may be seen in the area mapped in detail, in the vicinity of the Little Rapid mine.

Lithologically, the biotite granite gneiss is a fine-grained grey to pink foliated rock which under the microscope is seen to consist chiefly of fine, granular microcline and quartz. Throughout this material there are aggregates of a deep brown, partly chloritized biotite, and scattered grains of apatite, titanite, and iron oxide. The proportion of biotite in the rock is so small that it might possibly be better described as a foliated granite aplite, but further study of these dyke rocks is necessary before a definite conclusion can be reached with regard to their original character.

Pegmatite.—Throughout nearly every part of the Buckingham region the rocks of the basal complex previously described, are intruded by irregular masses and dykes of pegmatite. These are generally exceedingly variable in width from point to point and are usually not continuous for long distances. In many places they are broken by faults. They consist chiefly of coarse pink feldspar and quartz, but also contain crystals of muscovite and large crystal aggregates of tourmaline. In a few dykes, garnet was also present.

LATE PRE-CAMBRIAN INTRUSIVES.

The pegmatite intrusives described in the last section of the report constitute the youngest member of the basal (Archæan of the geologists of United States) complex of this portion of the Canadian Pre-Cambrian shield. There are some younger intrusive rocks in the district, however, which have been classed as late Pre-Cambrian. These are lithologically distinct from all the rocks of the complex and unlike the rocks of the complex have not been greatly deformed or otherwise metamorphosed. On the other hand, no rocks of similar composition have anywhere been observed to intrude the Palæozoic sediments which overlap the Pre-Cambrian complex at the south end of Buckingham township. They are, therefore, presumably not only younger than the basal complex but also older than the Potsdam or Upper Cambrian, and are, thus, probably late Pre-Cambrian or early Cambrian in age. They include two different varieties of rock: (1) diabase and (2) lamprophyre.

Diabase.—This rock occurs in numerous parallel dykes from 30 to 150 feet in width trending approximately in an east-west direction. Some of these dykes have been traced continuously for many miles. The diabase is a typical medium-grained variety which under the microscope is seen to consist of laths of labradorite, augite, and scattered grains of ilmenite. The texture of the rock is definitely ophitic, the augite filling the interspaces between the feldspar crystals.

Lamprophyre.—The rock of this class was observed to intrude the basal complex in the southern part of Buckingham township. It occurs partly as dykes but has its greatest development in an elliptical-shaped mass about three-quarters of a mile in width and 2 miles long, situated in ranges IV and V of Buckingham township, a short distance to the east of the town of Buckingham.

The lamprophyre, both in the dykes and throughout nearly the whole of the larger mass, is an exceedingly fine-grained, black, aphanitic rock with a well developed triangular jointage. When examined under the microscope, the finer-grained portions of the rock are seen to consist of small phenocrysts of plagioclase in a dusty crypto-crystalline groundmass. In its coarser phases, however, it is seen to consist of crystals of albite about 0·07 mm. in width and 0·4 mm. in length, enclosed in a matrix of blue hornblende (riebeckite), biotite, and quartz, with scattered grains and apatite, ilmenite, and pyrite. The rock thus has the composition of a riebeckite kersantite.

In the first paragraph of the description of the late Pre-Cambrian intrusives, it was stated that similar rocks were not known to intrude the Palæozoic sediments at the south end of Buckingham township. On the Island of Montreal and in the eastern townships of Quebec, however, the Palæozoic sediments are intruded by masses of alkalic rocks which stand up prominently about the St. Lawrence lowland forming what is known as the Monteregian hills. It might be possible that the mass of riebeckite kersantite to the east of Buckingham corresponds in age to these intrusives. The reasons for placing it in the Pre-Cambrian are the following:—

(1) The rocks composing the Monteregian hills are characteristically rich in potash, while the riebeckite kersantite from its mineralogical composition is probably a soda rich rock.

(2) The Monteregian hills all stand up as topographic prominences, whereas the riebeckite kersanite mass has been reduced to the same elevation as the pre-Palæozoic base level.

These reasons can scarcely be considered conclusive, however, and the classification of the riebeckite kersantite as Pre-Cambrian must for the present be regarded as provisional.

PALÆOZOIC SEDIMENTS.

The whole of the southern part of the Buckingham map-area is underlain by Palæozoic sediments which rest on the truncated surface of the Pre-Cambrian complex and have a regional dip toward the south so that the various formations outcrop in successsive eastwest trending bands. In Buckingham township, only the Potsdam or Upper Cambrian is exposed although the Beekmantown limestone is also probably present. The Potsdam occurs in numerous scattered outcrops, but is best exposed on the Lièvre river at Masson or Buckingham station. At this point, the crystalline limestone and pyroxene gneisses of the Buckingham series are overlapped by a bed of coarse conglomerate 3 feet in thickness which in its turn is overlain by cross-bedded, pebbly sandstone having a maximum vertical thickness of 20 feet.

QUATERNARY.

Glacial.—As elsewhere throughout the region covered by the Labradorian continental ice-sheet, the surface of the solid rock in this district is strewn with glacial debris, but thick deposits of these materials are uncommon. They consist largely of scattered boulders and a few local areas of boulder clay.

Marine Clay and Sand.—Throughout all the lower portions of the Buckingham district up to an elevation of 460 feet above sea-level, the glacial and older deposits are hidden beneath Pleistocene stratified clay and sand containing marine shells. The greatest vertical thickness of these deposits observed was 110 feet. They vary greatly in character from point to point, but in general the clay beds predominate at the bottom and the sand at the top. The clay occurs generally in thin uniform beds, whereas the sand commonly contains scattered pebbles and is cross-bedded and ripple marked. In the vicinity of the town of Buckingham, these marine sands in places have an undulating dune-like surface.

Economic Geology.

The mineral deposits of economic value in the Buckingham district, belong entirely to the non-metallic class, but are nevertheless important. The principal minerals of this class occurring in the district are mica, graphite, apatite, feldspar, and quartz. All of these with the exception of the feldspar were being mined in the area mapped during the past season.

MICA-APATITE.

The mica and apatite found in the Buckingham district are so generally associated and are so evidently genetically related that the deposits in which they occur must be regarded as forming a single class. Only a few deposits of these minerals were encountered during the field season of 1913, so that no final statement with regard to them can be made at this stage of the investigation, but of the deposits examined two definite types were observed: (1) irregular veins in the rocks of the Buckingham series; (2) scattered crystals and aggregates and irregular veins in pyroxenite.

The deposits of the first class consist chiefly of pyroxene, apatite, and calcite. They are most irregular, but generally trend across the foliation of the gneisses comprising the Buckingham series. The most typical examples of this type of deposit are the veins occurring at the Emerald mine. A description of the deposits of the second variety has already been given in the section of the report in which the pyroxenite member of the basal complex is described. They are exemplified by such occurrences of pyroxenite as those at the Little Rapid, the Poupore, and the Daisy mine.

In the district mapped in 1913 (Buckingham township, range I, Portland East, and range I, Derry township) mica and apatite were being mined by O'Brien and Fowler at the Little Rapid mine, by Mr. E. Wallingford at the Poupore mine, and by Mr. W. L. Parker at the Cameron mine.

GRAPHITE.

The graphite deposits of the Buckingham district are among the oldest known mineral deposits of Canada and have been mined at intervals in different localities for over fifty years. They occur chiefly in the south and eastern parts of Buckingham township, in an area underlain for the most part by the pyroxenic gneisses of the Buckingham series and crystalline limestone.

The deposits are of two types: (1) the disseminated and (2) the aggregated. The first are much the more important.

The graphite of the disseminated type of deposit occurs, for the most part, scattered through limestone or the pyroxene gneisses of the Buckingham series, less commonly, disseminated in garnet gneiss or pegmatite. The disseminated deposits of sufficient graphite content to be commercially valuable, are generally found along the contact of the pyroxene gneisses and limestone or at least in the vicinity of such a contact. The microscopic examination of the graphite ore from this type of deposit shows that it varies greatly in different localities. In some places, as at the Bell graphite mine, the ore appears to be a contact type between a pyroxene syenite and limestone consisting of carbonate, pyroxene, orthoclase, sphene, and graphite. At the Quebec mine, the ore at one point was a graphite pyroxene granite. At the North American mine (lot 28, Buckingham township) on the other hand, the ore consisted entirely of pyroxene and graphite. The graphite very commonly occurs along the contact of the mineral grains or along their clevage planes.

The aggregate types of graphite deposits are aggregates of graphite either in pegmatite or veins. The veins occur chiefly in the pyroxene gneisses or the limestone, but may also cut the pegmatite. They are generally not over a few inches in width, are very irregular or branching, and while affording good specimens of graphite, have nowhere been found to be of sufficient extent to be of economic importance.

During the past summer a Krupp milling plant was installed on the property of the Quebec Graphite Company, lot 5, range IV, Buckingham township, under the management of Mr. A. Geister, and was in operation at the time the writer left the field in October. This is the only property in the district where graphite is being mined at present.

THE DRIFT ON THE ISLAND OF MONTREAL.

(*John Stansfield.*)

During the broken field season of 1913 the writer has been engaged in the areal mapping of the drift of the Island of Montreal, and simultaneously, information has been gathered, where possible, as to the depth of bedrock from the surface within the cities of Montreal, Westmount, Outremont, and Maisonneuve, such information to form the nucleus for a more extended series of notes which will make possible the construction of a bedrock contour map.

The characters of the drift are well known and need not be discussed at any length here. The three main lithological types are: Saxicava sand; Leda clay; boulder clay.

The boulder clay occupies the greater part of the surface of the island, covering more especially the higher part of the island, which runs down its middle, with the exception of the actual vicinity of Mount Royal itself.

The Leda clay occupies the flat just above river level around the nose of the northern end of the island, extending from Bas au Sault, by way of Bout de l'Isle to Parc Lafontaine, to the south of which, within the city, it has only small exposures. Another area extends from the Blue Bonnets race track to Montreal West, having a maximum width of 1½ miles. Leda clay extends from Dorval west through Lakeside to beyond Beaconfield station, the maximum width from the shore of Lake St. Louis being 2½ miles. The uneven surface of boulder clay on which the Leda clay was deposited, is best illustrated to the north of Strathmore station. Leda clay extends from the St. Charles road along the St. Marie road to the western tip of the island at Senneville, the more westerly part being overlain by sand, which is true of another small area south and east of Baie d'Urfe station. There are a few other small areas of Leda clay along the bank of Rivière des Prairies between Senneville and St. Geneviève.

The Saxicava sands and gravels are practically confined to an area described by the following limits: Montreal West, Villeray, Maisonneuve, and Dorchester street. Outside of this, the two areas north and south of the Canadian Pacific and Grand Trunk railways in the vicinity of Baie d'Urfe, have been mentioned above. Other deposits of sand occur at the Dorval race track and just east of Dorval station, on the southeast side of the Lachine canal, and in Maisonneuve at the crossing of Pie IX and St. Catherine streets. The deposit at the latter locality is certainly river sand and it is probable that the others are also.

On the north side of the island, coarse river gravel extends along the bank of Rivière des Prairies from 1½ miles above Cartierville to 1½ miles below Bas au Sault. It can be seen unconformably overlying the Leda clay at several points. The upper surface of the Leda clay in these cases shows uneven erosion.

To the north of Mount Royal, the Saxicava sand is developed in a series of more or less sharply-defined and distinct beach levels, preserved only in certain parts of the city, and being thus separated from each other, were formed at different levels. On the southern slopes of Mount Royal and Westmount, however, this separation does not occur. The shell-bearing gravels can be followed with only one break from the highest point on Mount Royal (in the Roman Catholic cemetery), to the lowest point at Montreal Junction station, and again without a break from the highest beach on Westmount to Montreal Junction. There are several other separate beaches in Mount Royal park and the Protestant cemetery, some of which have recently been described and discussed by Goldthwait.[1] The beach described by Sir Charles Lyell[2] has been re-exposed during the last year in a cut made for road widening on Côte des Neiges road at the end of Westmount boulevard, and displays essentially the features as described by Lyell. Excluding the possibility that the material above the Saxicava gravel may be made ground—there is no evidence in favour of a made-ground explanation—any of the following explanations might be applied: (1) that the material is true boulder clay, and the gravel is interglacial, as supposed by Lyell; (2) that it represents talus and wash which has been swept down from the slope to the north; (3) that it is a deposit of drift ice along shore; (4) that the gravel was accumulated at the edge of a small cliff of boulder clay, which later collapsed and covered the gravel. Each of the three latter explanations carry equal weight with the writer, but he would be loth to subscribe to the first in the absence of a larger amount of similar evidence.

Determinations of the levels at which beaches have been formed at various points in the city and on the mountains, have been made by means of the hand level, using as reference points, either city bench-marks of Montreal, Westmount, Outremont, or Maisonneuve, such as have been recently determined, or railway elevations or bench-marks, and finally one or two elevations supplied by the Sewer Department of the city of Montreal. The determinations can, therefore, be taken as correct to the nearest foot. Some forty-seven of these determinations were made. They indicate that beach building has taken place at twenty-six distinct altitudes, and that of these twenty-five may be said to represent important general levels.

The discovery of a new upper limit of submergence on Mount Royal is a matter of considerable scientific interest and importance, as it bears directly upon the determination of the amount of warping or inequality of uplift which the region of the lower St. Lawrence has undergone in geologically recent times. The accepted highest beach of Goldthwait (loc. cit.), is given by him as 568 feet above sea-level. De Geer's highest beach (625 to 615 feet barometer elevation) appears not to have been accepted as such by Goldthwait. Critical examinations and re-examinations of this beach by the writer have led him to accept this as a true beach, though lacking some of the more obvious features of such deposits. The highest point of this beach as determined by the hand level is 585 feet above sea-level. The subsequent discovery of shell-bearing gravel running up to an even greater altitude in the Roman Catholic cemetery (617 feet) confirmed this acceptance.

Whilst the boulder clay and Leda clay have fairly constant characters, they show local variations which sometimes necessitate close attention in order that the varieties may be correctly referred to the one or other type. The most important of these variations is the development of quicksands. It is well known that the upper part of the Leda clay often passes gradually into the Saxicava sand. The lower part of the Leda clay is also locally sandy, the strata being composed of a mixture of very fine sand and clay. The mixture is capable of retaining moisture and when wet will run under the slightest pressure. It is incapable of standing by itself and in excavations made within it, the work done on one day will be completely counteracted overnight by the oozing in of the quicksand, even when the excavation is heavily timbered and only the smallest cracks are left between neighbouring planks. Leda clay of this nature has been met with on Côte St. Luc road, 1½ miles north of Montreal Junction station, and at the southwest corner of St. Catherine and Bishop streets.

The matrix of the boulder clay is usually a stiff clay without sandy admixture, but locally the matrix is a mixture of exceedingly fine sand with clay, and with the

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[1] XII International Geol. Cong., Guide Book 3, p. 122.
[2] Travels in North America, 1845, Vol. 2, p. 119.

loss of boulders this takes on the characters of a quicksand. Such a quicksand when dry is very hard, and would make an excellent foundation, if it could be kept dry. When wet, however, it runs easily under its own weight. Such a development of the boulder clay has been met with at the filtration plant in course of erection at Verdun and in the new trunk sewer at Montreal West, betwen the Canadian Pacific railway and the Upper Lachine road.

Deposits of marl and peat have long been known in the southwest part of the city of Montreal. The delimitation of the area in which these deposits occur has been partially completed, but will finally be completed only after excavations have made the necessary observations possible. Marl has been met with at the intersection of Lusignan and St. James streets, near that of Atwater and St. James streets, and has been followed as a broad area from Côte St. Paul to Montreal West. This is the largest of the drained lakes of the island and might be called the Turcot lake. Other small deposits of marl and peat occur along the aqueduct; a small drained lake occurs at Côte des Neiges village. Molson creek flows through a flat which is the filled-in and drained floor of a lake. Another is to be found north of the village of Côte St. Michel. In all of these, marl is found to be overlain by peat, and in some of them lake clays are found. The marl is composed of the shells of recent fresh-water gasteropods with occasional fresh-water lamellibranch shells.

The economic geology of the drift falls into two sharply-defined divisions: (1) the utilization of the Leda clay for structural products and cement; (2) the composition and depth of the drift within the city and its bearing on foundation construction.

The Leda clay is utilized for making bricks by the soft mud process at two points in the city of Montreal, viz., near Davidson and Iberville streets, at the edge of the Sherbrooke Street terrace. The Saxicava sand is locally fine enough for sanding the moulds and for mixing with the clay, and has been stripped off the clay for these purposes.

At Lakeside the Leda clay is utilized by the Terra Cotta Lumber Company of Montreal in the production of their hollow tiles for structural purposes. The output of the yard is considerable. This represents the most important usage of the Leda clay for structural materials on the island.

At Longue-Pointe the plants of the Canada Cement Company utilize the Leda clay which is found alongside the Trenton limestone to give the silicate admixture necessary in the manufacture of cement.

The advance in constructional engineering and the erection of large structures, along with the deterioration which has overtaken many buildings not sufficiently safeguarded in their foundations, have made it imperative to investigate the depth and character of the drift before making foundations for any structure of importance. In the lower part of the city, say below Sherbrooke street, bedrock may be from 20 to 75 or more feet from the surface. But a sufficiently safe foundation is afforded by the boulder clay, so long as it does not contain a development of quicksand. The Leda clay cannot be depended on for a foundation at all. If the boulder clay reaches the surface, e.g., at the corner of Dorchester and Metcalfe streets, an excellent foundation is obtainable at whatever depth it may be desired.

Where Leda clay or gravel overlies the boulder clay, it is necessary to drive wood or concrete piles at least into the boulder clay, or more preferably, as far as they can be driven. Another practice is the construction of concrete piles with spread footings.

When the boulder clay contains quicksand variations it becomes necessary to sink caissons using air at the pressure required to keep the quicksand from running into the caisson, until bedrock is reached. The foundation can then be placed directly upon it.

MARINE SUBMERGENCE AT MONTREAL, COVEY HILL, AND RIGAUD MOUNTAIN.

(J. W. Goldthwait.)

The preliminary examination of the route of Excursion A10 of the Congress afforded new information concerning the amount of post-Glacial elevation of the region around Montreal and Ottawa.

On Mount Royal, the reopening of a ditch near the park ranger's house furnished a large number of shells of *Saxicava rugosa* and a few specimens of *Tellina groenlandica.* This, which is Sir William Dawson's highest shell locality, stands 575 feet above sea-level. Water-washed gravels were seen farther up the slope, to a height of about 625 feet; but their marine origin was not regarded as demonstrated. The subsequent important discovery by Mr. Stansfield of marine shells at a height of 617 feet near this locality, as reported in his summary of field work in this volume, seems to justify raising the upper marine limit to 625 feet, or as far as the water-worn gravels extend beyond the well-formed beach ridges.

At Rigaud mountain, the famous "devil's garden" was visited and found to consist of a very deep deposit of wave-rolled boulders piled in parallel beach ridges over an area of many acres, largely without vegetation. The uppermost of the twenty-five or thirty beach ridges is not far from 600 feet above sea-level, agreeing roughly with the highest marine beach at Montreal. No shells have been found in the beaches on this mountain, although the gravels at the lower levels are sufficiently earthy in texture to give promise of their discovery. The boulder beaches above must have been utterly inhospitable to life. In size of boulders and in the extent and number of beach ridges the display at Rigaud is unequalled, so far as known, on this continent, surpassing even the well-known locality at Cobblestone Hill in New York.

A re-examination of the district near Covey Hill confirmed my opinion that the highest marine beach at that place is 525 feet above sea-level. Marine shells were found at several places between 250 and 300 feet; from which point wave-washed slopes extend up to 525 feet, culminating in a closely-set and very beautifully-built series of rocky beaches ranging from 450 to 525 feet. Above this mark, on the other hand, there appears to be no distinct nor continuous mark of wave work to an altitude of over 700 feet, although the slope and the structure of the ground are as favourable for such records above the 525-foot level as below it. At the 750-foot contour, extensive sandy deposits have been noted by previous workers. These seem to me to lack the sharpness characteristic of shore features in this district, and to be best interpreted not as marine shore-line deposits, but as ice-border deposits somewhat worked over by waves in a high level lake, previous to the opening of the Champlain valley to the sea, as Professor J. B. Woodworth has concluded in his report to the New York State Geological Survey.

GEOLOGY OF ORFORD MAP-AREA, AND THE SOUTHERN PART OF THE "SERPENTINE BELT," POTTON TOWNSHIP, QUEBEC.

(Robert Harvie.)

Introductory.

During the past season the field work of the mapping and geological examination of the serpentine belt of southern Quebec was completed with the examination of Potton township, Brome county. Work was commenced at Potton Springs on May 22 and completed at Sugar Loaf pond on August 27. The remainder of the season, until October 13, was spent in detailed structural work near West Brome, continuing an examination of the general structure across the Sutton anticline, begun in 1912. Mr. R. M. Asselstine proved a very capable assistant.

Location.

The serpentine belt lies in that part of the province of Quebec southeast of the River St. Lawrence, and runs in a northeasterly direction approximately parallel to that river from within Vermont to Gaspe. Potton township adjoins the state of Vermont immediately west of Lake Memphremagog.

General Statement.

The examination of the serpentine belt which, as stated, has been proceeding for several seasons, is being undertaken with a view to obtaining a general, modern interpretation of the petrography and mode of intrusion of this group of rocks, all leading up to a detailed study of the important asbestos-producing district of Thetford-Black Lake. Previous work had only dealt with the serpentine belt as one issue incidentally met with in areal mapping, and the petrographic details given are meagre, as the work was done before the great recent advances in microscopical examination.

General Geology.

The district lies just within the western border of the Appalachian folding and chiefly on the Sutton mountain or westernmost of the three principal anticlines which are the striking feature of the geological structure of this portion of the province. The axis of the anticline in this district is composed of Pre-Cambrian sediments and is flanked on either side by Cambrian, Ordovician, and Silurian. The serpentine belt comprises a series of intrusives occurring chiefly in the Ordovician slates along the eastern limb of the anticline.

Table of Formations.

Quaternary		Sand, gravel, and clay.
Palæozoic	Devonian	Igneous alkaline rocks of the Monteregian type; generally considered to be of Devonian age.
		Limestone.
	Middle Silurian	Shale and limestone.
	Ordovician	Intrusive serpentine, diabase, etc.
		Trenton graphitic slates.
	Cambrian	Schistose grey and white quartzites.
		Dolomitic quartzose marble.
		Extrusive porphyries and greenstones.
Pre-Cambrian	Sutton Mountain	Recrystallized arkoses and greywackes.

DESCRIPTION OF FORMATIONS.

Pre-Cambrian.

Structural work at present in progress shows the presence in this district of a very thick series of sedimentary crystalline schists of the general composition of arkoses and greywackes. The thickness of the series cannot be measured with any accuracy on account of the crumpling to which the rocks have been subjected, but it is estimated, however, that in Bolton pass there is a continuous succession of the order of 10,000 feet in thickness, without the base being seen. These rocks form in this district, the core of the Sutton anticline. The age of these rocks is established by the fact that they are intruded by igneous rocks of Cambrian age.

Cambrian.

The Cambrian consists chiefly of a series of volcanics—probably chiefly extrusives overlain in conformable succession by quartzite, limestone, and impure slate. The volcanics were probably originally of the diabase group, but are now altered to chlorite and epidote schists usually still showing abundant amygdules. They are intrusive into the Pre-Cambrian schists of the Sutton anticline, and extrusive and partly interbedded with the lower portion of the Cambrian quartzite member. Near the top the volcanics commonly contain an interbedded layer of quartzose dolomitic marble. This produces a strong, characteristic outcrop and has been mapped for many miles along its strike by Sir Wm. Logan and affords an extremely valuable key to the structure.

The quartzite is usually chloritic and highly schistose. The limestone and slate may be traced along the strike into the lower limestone and Georgia slates of Walcott's section at Georgia, Vermont. In Canada, heretofore, these slates have been considered to be of Trenton age on account of the presence of fossiliferous Trenton outcrops within the main area of slates. It is now recognized that the Trenton was brought into this relation by an overthrust fault with a measured throw of 11 miles.

Trenton.

The series of black slates occurring above the Cambrian quartzite east of the Sutton anticline, and beneath the middle Silurian, appear to be of about Trenton age. In most places the metamorphism has been sufficient to remove nearly all traces of bedding and it is only by the presence of occasional more sandy layers that it can be recognized that the slates are closely folded in all places across their breadth. The slates are somewhat infolded with the Cambrian quartzite, but that they are younger than Cambrian is shown by the discovery near their base of fossil forms referable to the Orthoceratites, a group of forms which is not known to occur as early as the Cambrian. The graptolites of Castle brook, on which the determination of the Trenton age is based, occur near the top of the slates, and since there are no signs of other divisions of the Ordovician such as the Chazy and Calciferous, the presumption is probably justified that this whole series is of Trenton age.

Silurian.

The Silurian is represented by two synclinal troughs, in one of which lies the northern portion of Lake Memphremagog, and in the other Sargent bay. The age of these rocks has been determined from fossils collected near Knowlton Landing as detailed in the Summary Report for 1911.

The western limb of the Sargent Bay syncline shows a thickness, above the conglomerate at the base, of 2,500 feet. The lower 1,500 feet is composed of a dark, buff-weathering, calcareous slate, while the upper 1,000 feet is chiefly a limestone, generally weathering blue, although in some portions, notably along the axis of the syncline, it is somewhat brownish in colour. A minute examination of the section showed no sufficient or even probable field evidence for the assumption of the presence of Devonian beds in this section. Further, the discovery in 1911 of fossiliferous beds yielding a much more abundant fauna than heretofore obtained, establishes the general age as middle Silurian. Therefore, in view of this weightier evidence, the previous determination as Devonian, based as it was, solely on the somewhat vague fossil, *Taonurus,* should be revised.

Underlying the calcareous slate is a definite belt of 15 to 20 feet of a light grey conglomerate composed chiefly of quartz pebbles. Search was made for diabase pebbles, but none could be found.

Underlying the quartz conglomerate is found what appears to be an agglomerate consisting of angular fragments of diabase, greywacke, and argillite in a matrix of smaller portions of the same materials and grading down to single grains of quartz and feldspar and argillaceous material. The fragments measure as much as 1 foot across. In most places this agglomerate appears to be a characteristic basal conglomerate and as such would establish an upward limit to the age of the diabase. In other places the diabase appears to intrude the agglomerate and until this doubt in the interpretation of the field relations has been cleared up, the evidence offered by the basal conglomerate cannot be safely used as a determination of the age of the diabase, even though it is confirmed by the following general evidence given by the quartz conglomerate.

In a number of places the quartz conglomerate is in contact with the diabase of the serpentine series, but nowhere is there any sign of the diabase intruding the conglomerate. The general mapping also shows numerous instances of the diabase occuring close to, but never within the limits of the base of the Silurian. The conclusion is, therefore, reached that in this vicinity all of the serpentine rocks are pre-middle Silurian. In view of this fact it is necessary to correct the numerous references in the literature to this locality as indicating the age of the serpentine belt intrusives to be post-Devonian. These intrusives are at least as early in age as pre-middle Silurian.

As already described by Marsters[1] numerous dykes of the camptonite group are foufnd cutting the middle Silurian rocks on the shore of Lake Memphremagog.

Devonian.

Close to the site of the old Mountain House on the Memphremagog Lake side of the base of Owl head, a triangular area of rocks consisting of limestone apparently lying on black graphitic shales, is found in faulted contact with the igneous rocks of the mountain. The igneous rock is sheared and somewhat metamorphosed near the contact, but there is no positive indication one way or the other of the relative ages of the two. From the relations of similar igneous rocks to the middle Silurian near Knowlton Landing, the presumption is that the igneous rock here also is older than the limestone, which is Devonian.

A collection of fossils from the limestone was examined by Mr. E. M. Kindle who reports as follows:—

[1] Marsters, V. F. Camptonites and other intrusives of Lake Memphremagog, Am. Geol., vol. xvi, 1895, p. 25.

"The collection includes the following species: Crinoid stems, *Favosites* cf. *basaltica*, *Favosites* sp., *Zaphrentis* sp., *Spirifer* cf., *arrectus*, *Actinopteria?*, *Panenca* . . . . ?, *Proetus*. . . .sp.

"The deformation and partial metamorphism of all of the material render any determinations beyond generic, highly problematic except in the case of one of the two species of *Favosites* which is either identical with or closely related to *F. basaltica*. The very poor state of preservation of the fauna prevents close comparison with other faunas and the most that can be said regarding its correlation is that it is highly probable but not entirely certain that the fauna is of middle or lower Devonian age."

The Serpentine Belt.

In this district the serpentine belt is represented almost solely by diabase or closely related rock types; serpentine is present only as a few dykes.

Diabase.—A quartz diabase is much the most abundant rock and composes the greater portion of the rugged hills so prominent locally. Commonly the diabase is very much decomposed so that its recognition is in many cases a matter of comparison with determinable fresher specimens. The diabase in these hills is usually fine grained, whilst the smaller dyke-like bodies frequently contain coarse-grained material. A very notable feature of all these hills, as well as of a number of the smaller bodies, is the widespread occurrence of pillow structure. So widespread and striking is this structure that it suggests the possibility of the diabase having been cooled under surface conditions; however, there is much evidence against this possibility and only this one fact in favour of it, so that this hypothesis need not be entertained at present. The rock showing pillow structure is much finer grained than typical diabase and ordinarily shows an abundance of amygdules just within the boundaries of the pillows. Whilst in itself not a true diabase, this rock grades into a normal diabase and cannot be separated in mapping.

In the section on the Silurian mention is made of the evidence as to the age of the diabase and it is shown that it is pre-middle Silurian.

Associated with the diabase are found deposits of copper of economic importance, amongst which may be mentioned the following mines and prospects: the Ives, Bolton, and Huntingdon near Eastman, the Parker-Cromwell, and Davis-Smith near South Bolton, and the Memphremagog near Knowlton Landing. All of these are situated on the west or foot-wall side of the diabase and, except the Memphremagog, they are associated with what is probably one long, nearly-continuous dyke.

Serpentine.—The serpentine is found in what appears to form one or more parallel dykes, with nearly continuous outcrops in the valley of the Missisquoi from Eastman southwards to the Vermont boundary, a distance of 21 miles. For about half of this distance the dyke is not over 100 feet wide, but it broadens in a few places to as much as 500 feet. It is in these wider portions that there are found the Pharoah asbestos prospect near Mansonville, a chrome prospect near South Bolton, and the Clark asbestos prospects near Trouserleg lake.

Alkaline Rocks.

A number of dykes of alkaline rocks related to the intrusions on the St. Lawrence plain, known as the Monteregian hills, are found within the district. A small area containing such varieties as camptonite, nordmarkite, and monzonite, is found in a cutting on the Canadian Pacific railway about 2 miles east of Eastman. At the Huntingdom mine two camptonite dykes are found cutting both the serpentine and the ore-bearing schistose diabase. In a cut on the railway three-quarters of a mile south of

Bolton Centre, a deeply weathered dyke of tinguaite cuts the Cambrian schists. On the east side of Georges pond outcrops of an augite camptonite are found within an area of diabase outcrops occurring in the Trenton slates. No rock contacts were found, but the presumption is that the camptonite intrudes the diabase. Numerous dykes of this class are found on the shores of Lake Memphremagog, some of them cutting the Silurian. Many of these have been described by Marsters. The alkaline rocks have not been found in contact with the Devonian, so that it can only be said that they are younger than middle-Silurian.

GRANITES OF THE EASTERN TOWNSHIPS OF QUEBEC.

(A. Mailhiot.)

General Statement and Acknowledgments.

Coincident with the recent great industrial development of Canada there has arisen a corresponding increased demand for building materials. Amongst other materials, granite building stone has shared this increase, the most important granite-producing district being found in Stanstead county in the southeastern portion of the province of Quebec. The stimulus to production is reflected by the figures for the value of the product, which have risen from $149,000 in 1909 to $482,000 in 1913.

A detailed study of the deposits was started by the writer during the past season and the months of June and September were devoted to field work in the Stanstead area. In this work the writer was assisted by Mr. C. B. Hamil, who rendered efficient and intelligent assistance. He wishes also to thank Mr. J. McIntosh, manager of the Stanstead Granite Company, for much valuable information on the exploitation of granite quarries, and Mr. A. Perron, of the Coaticook Marble and Granite Works, for many points of local information.

General Character of the District.

The district including the occurrences of granite is one of rounded hills of about 200 feet relief. The granite is found to occupy the hills, whereas the sediments have been deeply eroded to form the valleys, very few localities being met where the sedimentary rocks have been spared by this erosion.

General Geology.

The granites of the areas under consideration have been referred to in several previous reports of the Geological Survey. Logan mentioned them for the first time in his report of 1847-8. Later they were located and partly studied by R. W. Ells, who gave a summary description of them in his report of 1866.[1]

The granites are generally grey in colour. They consist mostly of quartz, orthoclase, and biotite and may be classed as biotite granite. In addition to these more important constituent minerals, others are frequently present in lesser and microscopic quantities, namely, zircon, apatite, muscovite, garnet, and a little pyrite, the latter being detected with the unaided eye by the occasional rusty spots and stains to which it gives rise on weathering. The intrusive character of the granite is clearly indicated by its metamorphic action on the sedimentary rocks with which it is in contact; also by the fact that numerous pegmatite dykes related to the granite penetrate the surrounding sedimentary rocks with ramifications in all directions. The sediments have been altered to andalusite staurolite, and chiastolite mica schists. The andalusite is sometimes completely altered to muscovite. In places where the contact action of the igneous rock has been less strong the schists are only "spotted." Upon the sandstone the metamorphism is hardly visible.

Pegmatite dykes cut through the granite and also penetrate the schists in the vicinity of the contact. The mineral constituents of these pegmatites are generally

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[1] Geology of a portion of the Eastern Townships—Annual report, Geol. Surv. of Can., 1866, part J.

coarse-grained quartz, feldspar, and mica. In the pegmatites which cut through the granite, the biotite is sometimes replaced by a mica approaching muscovite in composition and several other minerals make their appearance in small quantities, namely, garnet, beryl, and tourmaline. In the pegmatites which penetrate the schists the garnet and beryl are generally lacking, but on the other hand the tourmaline increases in quantity to such an extent as to become an essential mineral.

Economic Geology.

The granite is worked for building stone and the quality of the material produced in the neighbourhood of Graniteville is such as to allow it to compete with stones produced in the adjacent state of Vermont.

The three principal quarries at Graniteville are those of the Stanstead Granite Company, Samuel B. Norton, and James Brodie; other quarries of less importance are those of David Moore, George Somerville, M. Boulet, C. E. Haselton, W. Haselton, and Parmenter's.

At Stanhope, township of Barnston, the Coaticook Marble and Granite Works is working a quarry on the slope of a mountain one-quarter of a mile from the Grand Trunk railway.

The granite extracted from these quarries is shipped to all parts of Canada from St. John, N.B., to Calgary, Alberta, and some firms compete with the American granites in their own market.

THE SUCCESSION OF FAUNAS AT LEVIS, QUEBEC.

(*P. E. Raymond.*)

During each of the field seasons of 1911, 1912, and 1913, the writer has spent a few days in collecting fossils at Lévis, with the hope of getting some definite clue to the rather complicated stratigraphy. Fossils are not especially uncommon in the debris at the foot of the cliff, but until the last season, I was not able to get enough material in place to arrive at any definite results. The incomplete collections of the earlier visits did, in fact, lead to wrong correlations, which caused me to make certain erroneous statements in the Guide Book No. 1, of the International Geological Congress, which may now be corrected.

In spite of the fact that Point Lévis is the typical locality for the cosmopolitan and widely-known early Ordovician (Canadian) graptolites, the distribution of the species and the succession of faunas at that locality has remained entirely unknown. The description of the graptolites collected by James Richardson in 1854 and the two following years was entrusted by Sir William Logan to James Hall. Hall described the species, first without figures, in the Report of Progress of the Geological Survey of Canada for 1857 (1858), and later with very full and beautiful illustrations in a Decade of the Survey in 1865. Many of the species there described have since been found to have a world-wide distribution, and, thanks to the labours of distinguished British and Scandinavian palæontologists, very orderly successions of graptolite faunas have been worked out for Great Britain, Scandinavia, and Australia.

The best section at Lévis is in the bluff which faces up the river about one-half mile below the station at the point where the street car line climbs to the upper level. It is known locally as Begins hill. On this bluff about 300 feet of strata are exposed, all dipping steeply to the southwest. The following is the section, beginning at a layer of conglomerate exposed in the river at low tide.

Section at Begins Hill.

			Feet
1.	Massive conglomerate with large pebbles of limestone and sandstone. The matrix is largely limestone, but with abundant rounded sand grains. The whole mass weathers to a rusty yellow colour	12 feet	= 12
2.	Shale, mostly concealed by the river and railway tracks. About	100 "	=112
3.	Hard, dark grey to black shale, some bands of which weather to a rusty yellow	60 "	=172
4.	Thin-bedded rather blacker shales with fragments of graptolites all through. Good specimens of *Didymograptus nitidus* and others have been found 7 feet below the top	49 "	=221
5.	Thin-bedded limestone with shale partings. *Didymograptus similis* and minute trilobites and ostracods	11 "	=232
6.	Hard, dark green clay shale. No fossils seen	9 "	=241
7.	Banded green and grey shale with very numerous graptolites and brachiopods. The best layer is 17 feet above the top of No. 5. Lowest bed with *Didymograptus bifidus*	19 "	=260
8.	Hard grey shale band	6 "	=266
9.	Similar shale, weathering yellow. Contains graptolites, *Didymograptus bifidus* (90° variety) and *Phyllograptus anna* being most characteristic	3 "	=269
10.	Dark grey shale	9 "	=278
11.	Similar shale weathering yellow. Graptolites present. Top of range of *D. bifidus*	4 "	=282
12.	Alternating bands of shale which weathers grey or yellow. No fossils seen	51 "	=333
13.	Limestone conglomerate	4 inches	
14.	Dark shale above, and yellow weathering shale with *Tetragraptus serra* below	12 feet	=345
15.	Limestone conglomerate with 4 inches quartz sand at top	4 "	=349
16.	Dark grey shale	30 "	=379
17.	Thin-bedded blue limestone, without fossils	3 "	=382
18.	Dark grey shale	12 "	=394
19.	Thin-bedded limestone with a bed of conglomerate at top and bottom. Zone of *Shumardia granulosa* and *Diplograptus dentatus*	14 "	=408
20.	Dark shale, weathering yellow	14 "	=422
	Top of bluff.		

In the lower layers of the above section, below the street, no fossils have so far been found. Above the street, the lower strata, No. 4, are very thin bedded, break into small pieces, and though graptolites are present, as is shown by fragments, it has not so far been possible to collect them. The really fossiliferous part of the section begins, therefore, about 215 feet above the base. Throughout the next 57 feet fossils are fairly abundant, extremely so in zone No. 7. This entire thickness is characterized particularly by species of *Didymograptus,* the lower 24 feet by the "horizontal" types (*D. nitidus,* etc.), and the upper 33 feet by a "dependent" species (*D. bifidus*) as well as many of the larger "horizontal" species. Brachiopods are exceedingly abundant, and the originals of *Elkania desiderata* (Billings), *Acrothele levisensis* (Walcott), and *Lingulella irene* (Billings), undoubtedly came from this zone.

Above this zone the strata appear to be almost barren until the limestone at the top of the bluff is reached. This limestone is exceedingly fossiliferous, in certain layers, and about forty species have been identified, one-half of them graptolites, the remainder brachiopods and trilobites. The most diagnostic graptolite is *Diplograptus dentatus* (Brongniart), but the most abundant ones are species of *Dictyonema.* The striking trilobites are *Shumardia granulosa, Endymionia meeki* and *Holometopus angelini,* all of which were described by Billings from this locality and horizon. This layer was designated by the late T. C. Weston the "Shumardia limestone," a name which it well deserves.

About half-way between Begins hill and the railway station at Lévis there is a flight of steps by which one may ascend to the upper part of the town. At the base of these steps, at the right hand side of them as one faces the bluff, one may see thin-bedded, light grey limestone, and at the left hard green shale with thin black seams. The limestone contains *Shumardia granulosa* and the shale above it is full of *Diplograptus dentatus, Climacograptus,* etc., showing that these are the same strata as those at the top of the bluff at Begins hill, and not, as stated in the Guide Book referred to above, the equivalent of the thin-bedded limestone (No. 5) in the middle of the section. These strata can be traced in the face of the bluff into the well-known anticline on Davidson street, where one finds the following section, showing the strata above the top of the section on Begins hill:—

Section Above Anticline on Davidson Street. (Numbers and measurements continuous with the preceding.)

		Feet	
19.	Thin-bedded limestone, some conglomerate and shale partings. *Shumardia granulosa,* and other characteristic fossils present	30 feet	—
20.	Interstratified limestone and shale, the shale carrying graptolites; *Diplograptus dentatus* being abundant and characteristic	49 "	=457
21.	Hard black and grey shale	80 "	=537
22.	Concealed	20 "	=557
23.	Red and green shale	10 "	=567
24.	Limestone conglomerate with large limestone pebbles. "A" of Guide Book	10 "	=577
25.	Red shale	15 "	=592

From this point the section is concealed for a short distance, then follow dark grey shales in which the dip reverses, indicating the middle of the syncline.

These two sections combined include all the strata at Lévis which can at present be definitely placed. The heavy conglomerates west of the cemetery at St. Joseph de Lévis are now thought to belong lower in the section, but the structure is so obscure that it is not possible to be certain until an accurate topographic map is available for plotting the outcrops.

It will be noted that the lower part of the section at Begins hill is concealed by the river and the railway. It is possible, however, to trace the rusty conglomerate, which in this section is numbered 1 ("C" of Guide Book), for a half-mile north along the railway to a small cutting, which may easily be recognized as it is the only one in this vicinity in which there is shale on both sides of the track. The rusty conglomerate is not continuous through this half-mile, but is, as explained by the writer in Guide Book No. 1, of Excursion A1 of the Twelfth International Geological Congress, twice faulted and pushed to the south. That it is the same conglomerate seems, however, to be quite certain, as it has peculiar lithological characters not shared by the other conglomerates of the region.

In the small cutting above referred to, and about 20 feet above the rusty conglomerate, is a fine-grained black shale which contains many beautifully preserved specimens of a few species of graptolites. *Clonograptus flexilis* and *C. rigidus* are the most important species. About 30 feet higher in the section is a hard dark grey shale, in which the long form of *Phyllograptus typus* is particularly abundant (zone B). Only a few other species have been found in this zone.

In the guide book referred to above, the writer has stated that the lower of these graptolite zones is about 100 feet below the conglomerate, which in the section on Begins hill is No. 15. This is its actual field-position, but now that the measured section has been compiled, it becomes evident that the faulting has obscured the real relations. The cross faults above referred to have carried the rusty conglomerate farther than the conglomerates above, thus mashing it into the shales and greatly shortening the section. The true position of the zone with *Clonograptus rigidus,* which may be called A, is probably nearly 200 feet below the thin-bedded limestone which forms zone 5 of the Begins Hill section. Unfortunately this is the only outcrop of the *Clonograptus* beds now known, and its location with regard to the *D. bifidus* zone will have to remain a matter of estimate for the present. The *Clonograptus* zone is, however, considerably below that of *Didymograptus bifidus.*

The sections given above show that fossils are distributed through a thickness of nearly 500 feet of strata at Lévis, and that four faunas may be recognized, the lower two confined apparently to a very narrow vertical range, and the upper two range through a (relatively) considerable thickness of strata and are capable of division into faunules. The faunas may be designated A, B, C, D.

A is the lowest zone. The graptolites are in a black, very fine-grained shale, which is more or less faulted, and does not appear to be more than 3 to 5 feet thick. Graptolites are exceedingly abundant, but only a few species seem to be present, and whole slabs are covered by great numbers of one species. *Clonograptus flexilis, C. rigidus,* and *Tetragraptus quadribrachiatus,* are the most common species and a "horizontal" species of *Didymograptus* is present. Dr. Ami reported *Goniograptus thureaui* (McCoy) from this zone.

B is the next higher zone, and the strata are hard dark grey sandy shale about 30 feet above A. *Phyllograptus typus* is very abundant, and other species like *Tetragraptus quadribrachiatus* and *Dichograptus octobrachiatus* are rare and the specimens usually poorly preserved. These fossils have been found to range through only about 4 feet of shale.

C is the zone in which the various species of *Didymograptus* reach their greatest development. It includes the zones 5 to 11, and the upper part of 4, 57 feet in all. In the lower sub-zone C 1, most of the Didymograptids are of the "horizontal" type, though one delicate "dependent" form, *D. indentus,* is present. C 1, includes the upper part of zones 4, 5, and 6. C 2 is the sub-zone in which *D. bifidus* is very abundant, other common species being *Didymograptus extensus, D. pennulatus, Phyllograptus ilicifolius, Thamnograptus anna,* and the brachiopods, *Elkania desiderata, Linguelella irene,* and *Acrothele levisensis.* C 2 includes the zones 7 to 11. Within C 2 is another sub-faunule, in zone 9, characterized by *Phyllograptus anna* and that variety of *Didymograptus bifidus* in which the branches diverge at an angle of about 90 degrees.

D includes zones 19 and 20 and the fauna is large. The lower part, D 1, is principally limestone, but it contains twenty or more species of graptolites and a considerable number of species of trilobites and brachiopods. The trilobites are mostly small, and the brachiopods with few exceptions, inarticulates. Some of the more important species are: *Diplograptus dentatus, Dictyonema* of several species, *Trigonograptus ensiformis, Agnostus orion, A. sidenbladhi, Shumardia granulosa, S. pusilla, Endymionia meeki, Holometopus angelini, Symphysurus elongatus, Triarthrus,* and undescribed species of *Acrotreta, Lingulella,* and *Paterula.* An unexpected find was a cystid column of large dimensions. The zone is from 15 to 70 feet thick, varying rapidly from place to place.

D 2 contains both shale and limestone, but the fossils are all from the shale. The specimens are abundant, but usually rather poorly preserved. Common species are: *Diplograptus dentatus, Cryptograptus antennarius, Climacograptus pungens, Tetragraptus headi,* and small specimens of *Loganograptus logani.* The strata containing this fauna are about 50 feet thick.

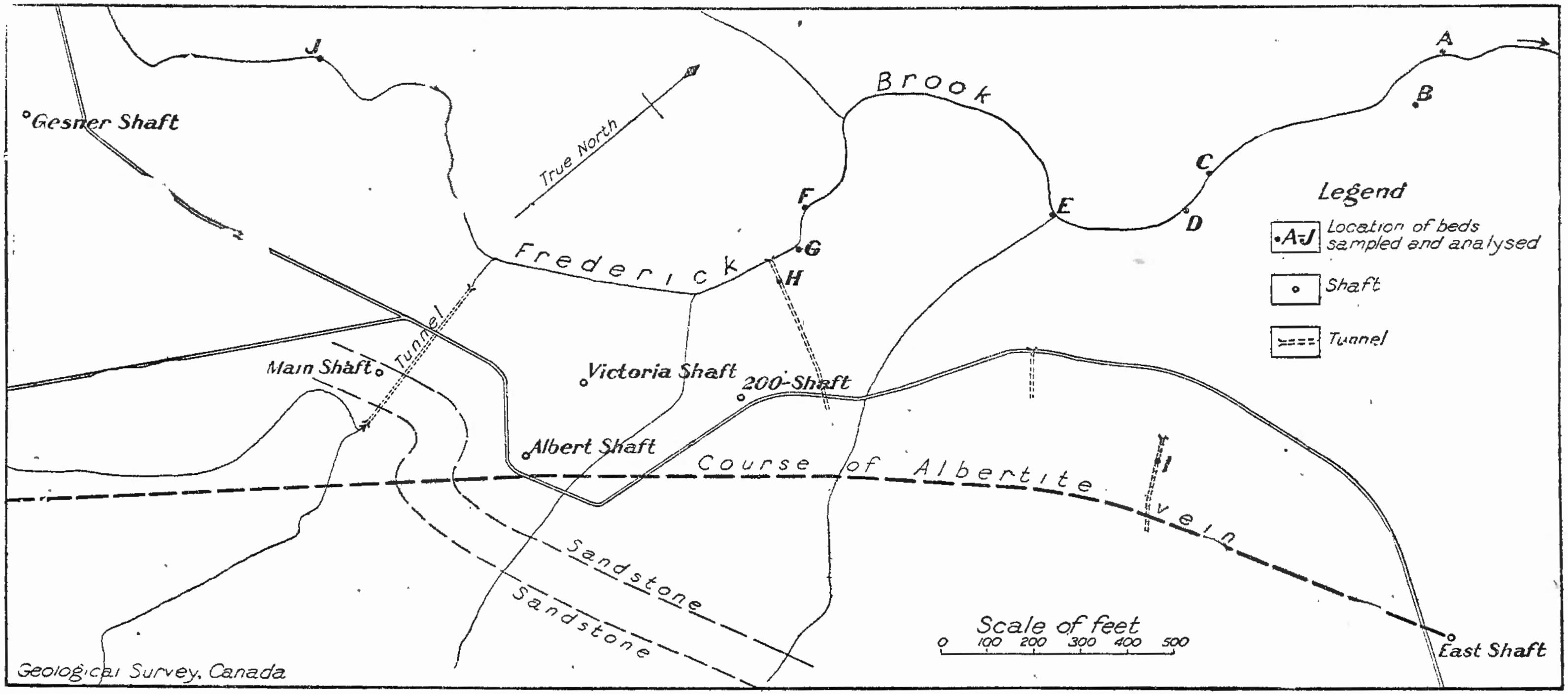

Fig. 6.—Diagram showing portion of Albert Mines oil-shale area, New Brunswick.

GEOLOGY OF THE MONCTON MAP-AREA, NEW BRUNSWICK.

(W. J. Wright.)

Location of Moncton Sheet.

The Moncton map-area includes about 300 square miles lying in the basin of the Petitcodiac river. The northern boundary passes just north of Moncton, while the southern passes about 5 miles south of Hillsborough. The eastern boundary lies 2 miles east of Hillsborough, and the western crosses the Petitcodiac river about 5 miles west of Moncton and through the head-waters of the west branch of Turtle creek in the south. The Petitcodiac river enters the northeast corner, 6 miles from the northern part of the sheet, runs diagonally across the sheet, and passes out at Big cape about 1 mile below Hillsborough.

Object and Extent of the Work.

Field instructions were to begin the areal mapping of the Moncton map-area giving special attention to the gypsum and manganese deposits, the oil shales, and petroleum-bearing rocks.

The work was confined to about 60 square miles in the southeast corner of the Moncton map-area, including the gypsum deposits in the vicinity of Hillsborough and Demoiselle creek, and the oil-shales at Albert Mines. In this area, the areal and structural geology were mapped on the recently-completed topographic sheet, on a scale of 4,000 feet to 1 inch. In view of the renewed interest in the oil-shales of Albert Mines, a telemeter survey was made of that area and the results plotted on a scale of 200 feet to 1 inch, showing the location and extent of the abandoned workings of the albertite vein and the structure of the rocks.

Conclusions.

(1) A preliminary subdivision was made of the Carboniferous rocks, but it seems advisable not to publish this until it is seen how it holds for the whole sheet. (2) The oil-shales at Albert Mines cover a relatively large area, but they are so contorted that it is impossible to predict their extent in depth from structure alone. However, judging from information obtained concerning the workings of the albertite, the shale over part of the area extends to a great depth, and a few bore-holes would prove the remainder of the area.

Acknowledgments.

The many kindly courtesies extended to the party by men interested in the development of the economic resources were greatly appreciated even though it was not possible to take advantage of all of them at the present stage of the work.

Previous Work.

It does not seem necessary at this stage of the work to go into details concerning the great amount of literature bearing on the area under consideration. Most of it has been published by the Geological Survey and the Mines Branch under the names of L. W. Bailey, R. W. Ells, Sir William Dawson, G. F. Matthew, L. H. Cole, W. J. Jennison, H. E. Kramm, and G. A. Young. In the discussion of Albert Mines, the references to Ells are from a report by R. W. Ells on bituminous shales, published jointly by the Mines Branch and the Geological Survey of Canada in 1910.

Oil-Shale, Albert Mines.

Interest in the Albert Mines was first aroused in 1849 by the discovery of a vein of solid hydrocarbon called albertite. After a great amount of legal dispute, the mining operations on the albertite vein settled down to an economic basis, and for almost thirty years the company continued to grow rich. At the end of that time the vein was mined to its limit, operations ceased, and the property was bought for the timber. In the last twenty-five years, interest has been aroused from time to time in the oil-shale, several men of note examined the property, extensive experiments were made on shale shipped to the Scottish retorts, showing the shale to be of good value, the property changed hands several times, but as yet no one attempted any development. The trouble seems to be that at best the oil-shale industry yields only a narrow margin of profit, and financial interests hesitate to invest the money necessary to build a retorting plant yielding products which in part have to compete with the products of other already well-organized industries. During the summer of 1913 interest was again aroused when the property was examined by engineers representing an English syndicate. They sent samples of the oil-shale to the Mines Branch, Ottawa, for analyses, and shipped 40 tons of oil-shales to Scotland for experimental purposes. But as yet no active operations have been started on the property.

QUALITY OF OIL-SHALE.

The following is a list of analyses made on oil-shale from the Albert Mines. The samples by Ells are copied from his report on the "Bituminous or Oil Shales" in 1910. The samples by Simpson and Burls were taken in 1913 by Messrs. Louis Simpson of Ottawa and H. F. Burls of Westminster, England. The analyses were made by H. A. Leverin in the laboratory of the Department of Mines, Ottawa:—

Variety of shale.	Sample by Ells.				Sample by Simpson and Burls.	
	Locality (See Fig.)	Crude oil, Imp. gallon, per long ton.	Sp. gr. of crude oil.	Ammonium sulphate, pounds per long ton.	Crude oil, Imp. gallon, per long ton.	Ammonium sulphate, pounds per long ton.
Massive	A.	....	....	....	41	89
Curly	B.	48·5	0·898	82·8	43	92
"	C.	38·9	0·892	60·3	52	73
Massive	D.	45·5	0·891	48·0	....	....
"	E.	43·5	0·896	56·8	....	....
"	F.	27·0	0·895	49·1	42	52
Paper	G.	....	....	....	32	38
"	H. } I.	40·8	0·892	41·0	34	38
"	I.				42	38
"	J.	....	....	....	47	45

Another set of three samples was sent in by Simpson and Burls to determine the amount of lime and magnesia in the spent shale.

Sample.	Volatile combustible matter.	Lime.	Magnesia.
Rock shale	38·35	11·60	3·57
Paper shale	33·10	9·92	1·84
Shale from dump at pump shaft	17·80	4·82	1·92

The general run of Scotch oil-shale yields from 20 to 35 gallons of oil and 12 to 35 pounds of sulphate of ammonia per ton (See "Oil Shales of the Lothians," published by the Geological Survey of Scotland, Edinburgh, 1912). Comparing these figures we see that, on the surface at least, the oil-shales of Albert Mines are much richer than the Scotch oil-shales. But it is not known whether the richness of the shale at Albert Mines will decrease with depth or not.

QUANTITY OF OIL-SHALE.

As yet no writer has committed himself as to the amount of shale in this locality. Ells says there are six well developed beds of massive and curly shale opened along Frederick brook, varying in thickness from 3 feet 6 inches to 7 feet, and an immense amount of paper shale.

Under favourable conditions the probable extent of the shale in depth would be largely a question of thickness of the beds and the structure of the rock. But in this area it is soon seen why a person should hesitate to predict the probable extent from a structural standpoint. In general, the distortion of the rocks is so complex that it is impossible to work out the general structure with any degree of accuracy, and the only way of predicting the extent in depth is by underground exploration.

Excellent evidence as to the underground extent of the shale could be obtained from a knowledge of the workings of the albertite vein, but, unfortunately, the records are lost, and knowledge of these workings is confined to the memory of men who worked in the mines. The following details are based chiefly on the observations of J. Robertson, who worked in the mine most of the time it was in operation, checked as far as possible by personal observations of the writer. To make the discussion clear reference may be made to figure 6.

In the area outlined (see Fig. 6) there is very little glacial drift and the shallow soil cover consists chiefly of fragments of the underlying rocks. In addition, there are almost continuous outcrops along the stream beds. As far as can be seen under these conditions, all the rocks north of the band of sandstone and barren shales are good grade oil-shale with occasional bands of iron stone up to 4 or 5 inches thick.

Coming up Frederick brook as far as the lower tunnel, are the curly and massive oil-shale mentioned by Ells, all dipping at low angles. South of the band of sandstone we find interbedded paper oil-shale, and barren shale, dipping regularly to the south at steep angles. Over the remainder of the area the strata are so highly contorted that it is impossible to make out the general structure, and the contortions shown in the solid rock of the tunnels are much greater than one would judge from surface outcrops.

Cutting through this contorted belt there is the gash from which the albertite was worked at an average depth of 1,300 feet, the main shaft of the Albert mines 1,400 feet deep, with a drift north from the 1,200-foot level for 500 feet, Victoria shaft and East shaft 1,000 feet deep respectively, and in addition, several shallower shafts and tunnels as shown on the plan. The tunnels are in good grade paper shale, highly contorted. All the other workings with the exception of the upper 60 feet of the main shaft and the upper 20 feet of East shaft, are said to be in good grade oil-shale, and the reports are substantiated by the fact that the material in the dumps is nearly all oil-shale of good grade. If these facts mean anything, they show here a unit body of oil-shale at least 1,000 yards by 350 yards, which have been partially proved to be of great depth. But it would be unfair to conclude that the depth of the oil-shale is as great over the whole area. The strata on the lower part of Frederick brook are dipping at low angles and may be shallow. But it would be relatively a simple matter to strip off the thin cover of soil and sink a few bore-holes and prove the whole area. If the results were favourable we at once see that in all probability here is sufficient oil-shale to last a good-sized retorting plant for upwards of 200 years.

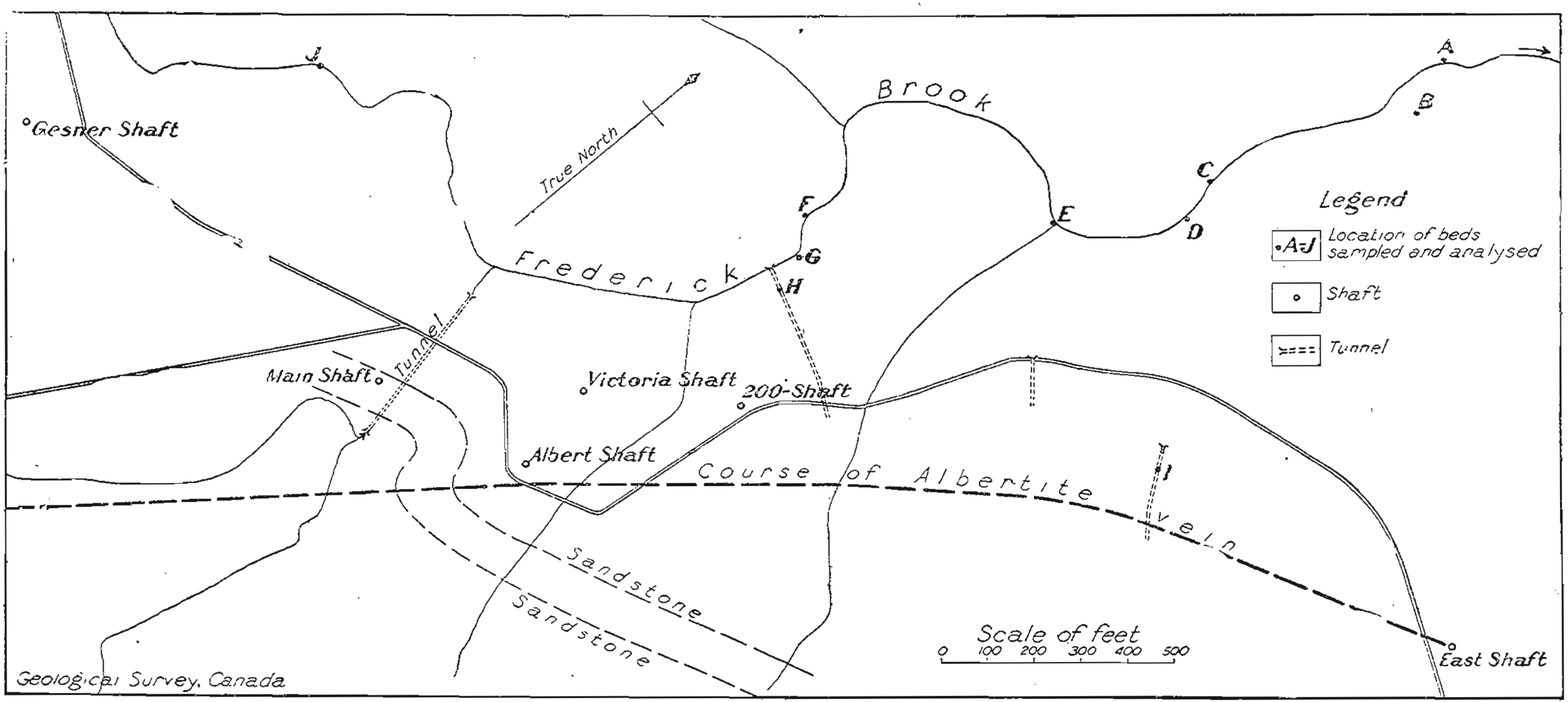

Fig. 6.—Diagram showing portion of Albert Mines oil-shale area, New Brunswick.

TRANSPORTATION.

There is one important problem which will have to be solved before starting operations on the shale, and that is the question of transportation. If transportation is entrusted to railways, the problem is simple, for the Salisbury and Albert railway, giving direct connexion with the Intercolonial, passes right by the property. But if the oil is piped to tank steamers, the nearest point which could be developed to a deep-water harbour is said to be Alma, located on the Bay of Fundy, about 25 miles south of Albert Mines.

GEOLOGY OF THE ST. JOHN MAP-AREA, NEW BRUNSWICK.

(Albert O. Hayes.)

Introduction.

The solution of some geological problems in the vicinity of St. John, N.B., will furnish a basis for correct interpretations over a much wider field. Many varieties of rocks, representing with few exceptions the geological column from Pre-Cambrian to Carboniferous, are met with in this district. All of these have been much disturbed by structural movements, and it has been only by long study and keen perception that their history has been read.

Fortunately, the sedimentary rocks from the Cambrian upwards contain many fossils. Eminent palæontologists have studied these records of life, and differing interpretations have led to more determined efforts to read their record correctly. Thus the work of G. F. Matthew on the St. John group has revealed the succession of the faunal horizons at St. John. A somewhat different interpretation of the range of certain faunas by C. D. Walcott, has led to wider study in other fields holding similar fossils. J. W. Dawson studied the flora of the Little River group, considering it to be Devonian. G. F. Matthew later thought it to be still older, while Dr. Robert Kidson, Dr. David White, Dr. Mary Stopes, and Mr. W. J. Wilson, to-day place it in the Middle Carboniferous.

The age of the Mispeck group is doubtful, that of the Red Head formation has been only roughly determined as Lower Carboniferous. The best stratigraphical interpretation in a country so shattered, can be made only with the help of a topographical map. Hence to aid in the solution of the geological problems in this area an accurate topographical map was prepared for the Survey in 1912-13 by Mr. A. C. T. Sheppard. The writer received instructions to commence mapping the areal geology during the summer of 1913. Mr. C. L. Cumming and Mr. F. H. McLearn were appointed assistants and carried on their work in an able and enthusiastic manner.

The season's work consisted chiefly in a delineation of the geological boundaries, and such preliminary study of the other geological features as could be accomplished. As this was the writer's first season in Maritime Province work, it has taken considerable time for him to become familiar with the district and, as yet, the larger relations outside this area have not been seen. Hence no definite conclusions may be reached which depend in any way on larger field relations than occur in the map-area.

In former classifications, names or numbers have been assigned to certain rock series and since, in a number of instances, geologists have differed in their interpretations of age relations, and occasionally in lithological identifications also, the writer, in order to avoid confusion, does not employ the designations previously used. A tentative classification will be given in which the intrusive rocks are grouped separately. While the various series are placed in order of their respective ages as far as possible, in many instances the age relations are very uncertain, and hence the numbers given are employed only for brevity and clearness in this summary report and not to indicate stratigraphical succession, or to be considered as a permanent classification. It is hoped that further work may make it possible for a more definite succession to be established.

On behalf of the Geological Survey, I take pleasure in thanking the citizens of St. John who aided in our work. Dr. G. F. Matthew walked over the St. John City

section of the Cambrian with the writer, and kindly pointed out many important features. Mr. Wm. McIntosh, curator of the Natural History Museum of St. John, placed the resources of the Museum at our disposal and gave unsparingly of his time on many occasions. To Mr. Wm. Murdock, city engineer, the writer is also indebted for many courtesies. The Citizens' Committee in preparing for the excursion of the International Geological Congress, and by their hearty personal co-operation, enabled the plans for that occasion to be carried out satisfactorily, and provided also a greatly appreciated and abundant hospitality.

Extent of Map-Area.

The St. John sheet covers a rectangular area of about 180 square miles. The city of St. John is in its central southern part. It is about 12 miles wide east and west, and 15 miles long north and south. The southern boundary reaches from Cape Spencer on the east coast of St. John harbour to Negro head on the west coast, and the northern limit extends along a line from a point about 1½ miles southeast from Quispamis, westward across Kennebecasis bay between Long island and Mather island to Long Reach, at a point about 1 mile north of Purdy lake. The southern part of Kennebecasis bay and the St. John river traverse the area, and the waters of the St. John harbour cover its southern portion.

The St. John sheet forms part of the geological map No. 1, southeast of southern New Brunswick, published in 1880, on a scale of 4 miles to 1 inch.

Previous Work.

Investigations in the vicinity of St. John, N.B., have been carried on almost continuously for seventy-five years by many geologists, and the literature pertaining to this field is voluminous and scattered. The earliest geological observations were made by Abraham Gesner and published in 1838-43. These were followed by the publications of James Robb, J. W. Dawson, C. F. Hartt, G. F. Matthew, and L. W. Bailey, up to 1871. In 1878, J. W. Dawson gave, in his third edition of Acadian Geology, the geological knowledge to this time, except for the observations of Bailey, Matthew, and Ells, puplished in a report of the Geological Survey, Canada, 1877-8. G. F. Matthew of St. John, N.B., has spent many years studying the geology and palæontology of this district and the results of his work are published by a number of scientific organizations, and for the most part in the Proceedings of the Royal Society of Canada, from vol. i, 1882-3, onward.

A complete review of the literature pertaining to the geology of New Brunswick, much of which deals in part at least with St. John and vicinity, is given in a report of the Geological Survey on the geology and mineral resources of New Brunswick, by R. W. Ells in 1907.

A description of the geology in the vicinity of St. John is given by G. A. Young in Guide Book No. 1, part II, of the Twelfth International Geological Congress, and various views held regarding the age of the formations are presented.

The other more important publications are:—

Bailey, L. B., Matthew, G. F., and Ells, R. W., Report of the Geol. Surv., Canada, on the Geology of Southern New Brunswick, 1877-78.

Robert Chalmers, "Report on Surface Geology of Southern New Brunswick," 1890, Geol. Surv., Canada.

Walcott, C. D., Wash. Acad. Sci., 1900, p. 301, "On Cambrian at St. John."

Walcott, C. D., Monograph LI, U. S. Geol. Surv.

Physiography.

The map-area lies within the New Brunswick highlands, which extend along the western shore of the Bay of Fundy. While this tract of rough hilly country attains elevations of from 1,000 to 1,200 feet, northeast of St. John, it does not rise above 600 feet in the map-area. West of the New Brunswick highlands, the greater portion of the southern half of New Brunswick is comparatively level, rising to elevations of from 200 to 300 feet. This is the Carboniferous lowland.

R. A. Daly[1] described Acadian land forms in terms of two topographic facets, each a nearly perfect plane of denudation, interrupted by incised valleys and surmounted by residual hills. The older peneplain is thought to have been completed at the close of the Cretaceous or during the early Tertiary, the younger in late Tertiary time.

The Cretaceous peneplain is thought to be represented in New Brunswick by the New Brunswick highlands, and the Tertiary peneplain by the Carboniferous lowland.

According to this view the St. John map-area may be considered as a much dissected portion of the New Brunswick highlands including small tracts of the Carboniferous lowland. The larger rivers have become deeply entrenched and their lower reaches are partially drowned.

Subsidence took place in post-Glacial time as shown by marine deposits of sands, clays, and gravels, at least 200 feet above the present sea-level. A final emergence has exposed these post-Glacial deposits.

Topography.

The district is everywhere broken by valleys of varying size and character, and the occurrence of marine tidal waters furnishes a long and varied coast line. About one-third of the area is covered by water. The deepest valleys are now flooded by the waters of Kennebecasis bay and the St. John river, while the highest elevation is attained by the hills between Milkish inlet and the St. John river to the westward. These summits rise to 580 feet above mean sea-level.

The larger groups of surface features conform to the general north-northeast trend exhibited throughout the Atlantic coast region.

On the Kingston peninsula, the hills east and west of the Milkish river are elongated in a north-south direction and the southern part of the Milkish valley holds this direction. This orientation is coincident with the general direction of elongated areas and dykes of diabase which intrude the Kingston series in this locality.

The broad neck of the peninsula of Milkish head and the northern part of Kennebecasis island are flat and low-lying compared to their adjacent southern extremities. This difference is apparently due to unequal degrees of erosion, since soft Carboniferous rocks floor the lower land and resistant granite forms the hills. Similar variations are found to the south of Kennebecasis bay. An interrupted, rough highland runs parallel to the shore of this bay northwards as far as Rothesay. This is composed in large measure of resistant plutonic rocks. To the southeast, the valley of Marsh creek and the lower land on which the city of St. John is built, are underlain by the softer slates of Cambro-Ordovician age. In the extreme southeastern part of the map-area, an upland country is found where much marshy land occurs and many small lakes abound. It maintains an elevation of about 300 feet, to within about 1 mile of Courtenay bay, where steep slopes seaward are found, ending in cliffs which frequently rise 100 feet above the water.

[1] Daly, R. A. "Physiography of Acadia"; Bull. Mus. Comp. Zool., vol. xxxviii, 1900-3, Geol. Series, vol. v.

The Mispeck river has entrenched itself deeply in these rocks and near its mouth a dam has been built forming a narrow lake about half a mile long, 80 feet above sea-level. From this reservoir, the water falls precipitously over cliffs of purple and green conglomerate and empties into a bay, the upper half-mile of which is left dry at low tide. Immediately west of the Mispeck river, the highest hill in the map-area, south of Kennebecasis bay, is found reaching an elevation of 450 feet.

In the northeastern part of the map-area, east of Rothesay, a rolling, drift-covered country stands at elevations of less than 300 feet. Southwest of Carleton, between South bay of the St. John river and the Bay of Fundy, a large tract of country is covered by marine sands and clays, the highest elevation reached being 200 feet. As suggested by Robert Chalmers,[1] the St. John river may have had an outlet by way of South bay and Mill cove east of Piasarinco and perhaps also by way of Fairville and Manawagonish cove. These lowlands were filled up in post-Glacial time with the marine sand and gravel now covering them.

The smoothing action of glacial ice has rounded the rock outcrops and roches moutonnées forms are frequently met with. The movement of the ice has been controlled by the topography, its general direction being southwards with local variations to the east and west.

General Geology.

A ridge of gneiss (No. 6 in table on next page), crystalline limestone, dolomite, and quartzite (7), together with plutonic rocks, ranging from gabbro to granite (1 and 2), form the central portion of the map-area and extend in a broken ridge about 3 miles in width, northeastwards along the southern shore of Kennebecasis bay.

The rocks have been called the Portland group, formerly placed in the Laurentian. This correlation is now questioned. The age of the plutonic intrusives (1 and 2), is uncertain, but is younger than the Pre-Cambrian series 7, and older than the Carboniferous, as represented by series 13.

In the northeast quarter of the area, north of Kennebecasis bay, is found series 8, forming a portion of the extensive Kingston group. The rocks extend in a north-easterly direction in a strip about 5 miles wide and about 70 miles long.[2] Their age is uncertain but they are considered to be pre-Silurian by Professor Bailey.[3]

Succeeding the crystalline rocks and gneisses to the south, series 9 (Coldbrook of Matthew) of volcanic and pyroclastic rocks is found. These were formerly thought to be of Huronian age, but in Cape Breton, rocks correlated with them by G. F. Matthew, occur with sediments holding fossils referred to the Lower Cambrian by G. F. Matthew,[4] and to the Middle Cambrian by C. D. Walcott.[5] No fossils have been found in these rocks in New Brunswick, and their age and correlation have not been established. They underlie series 10a (Etcheminian).

The rocks of series 10 (Etcheminian and St. John group) cover a relatively small area, but have furnished a large fauna and served as a basis for the division of the system into several horizons. No faunas have been discovered older than the Protolenus found on Long island. The highest measures are represented by the graptolite and dictyonema beds on Navy island and the graptolite beds near the Suspension bridge.

Series 11 is found south of St. John city, in faulted contact with the Cambrian.

A large number of genera and species of plants has been collected from these rocks at a locality on the coast west of Carleton, at Seaside park, called the Fern Ledges, and at Duck cove, about half a mile farther west, and these are the only

[1] Surface Geology of Southern New Brunswick, 1890, Geol. Surv., Canada.
[2] Matthew, W. D. N.Y.A. Sci., vol. xiv, 193.
[3] Trans. Roy. Soc., Can., 1889, sec. 4, p. 8.
[4] "Report on the Cambrian Rocks of Cape Breton"; Geol. Surv., Canada, 1903.
[5] Monograph LI, U.S. Geol. Surv.

Table of Formations.

BEDDED, SEDIMENTARY, VOLCANIC, AND METAMORPHIC ROCKS.

Series No.	Age.	Character of rocks.	Name previously given.
15	Recent...............	Alluvium, marsh deposits, gravel.	
14	Pleistocene.........	Stratified sand and clay, boulder clay and till.	
13	Carboniferous	Thick-bedded, coarse purple conglomerate composed largely of pebbles of white limestone, red and grey granite, etc.; coarse arkose holding drifted fragments of lepidodendron trees and other flora. Thinner beds of purple sandstone and sandy shale and green shale holding plants and *Estheria* cf. *dawsoni*.	Red Head.
12	....	Volcanic flows, coarse agglomerates, thin-bedded conglomerates composed mostly of quartz pebbles, green and purple sandstones, thin-bedded siliceous limestone, shale, and ash rocks all highly sheared across the bedding.	Mispeck.
11	....	Thin-bedded, fine-grained conglomerates composed largely of quartz pebbles with olive green and rusty red sandstones and sandy shales. Graphitic and sandy shales holding a large flora.	Bloomsbury and Little River.
10	Cambro-Ordovician .	(e) Thin-bedded, fissile, black carbonaceous shales. Graptolites, trilobites, brachiopods.	St. John Group Div. C 3.
	Cambrian...........	(d) Dark green shales with fine-grained quartzitic sandstone. Trails and lingula.	St. John Group Div. C 2.
	"	(c) Alternating beds of fine-grained, green and grey quartzitic sandstone and grey green shales. Protolenus and Paradoxides fauna.	St. John Group Div. C 1.
	"	(b) Coarse, white quartzitic sandstone. No fossils.	St. John Group Div. C 1.
	"	(a) Fine-grained, purple conglomerate and purple sandstone. No fossils.	Etcheminian.
9	Cambrian? May be Pre-Cambrian.	Amygdaloids, green and purple volcanics, with bedded green and purple pyroclastic breccias and ash rocks.	Coldbrook.
8	Called Pre-Silurian by Prof. Bailey. May be Pre-Cambrian.	Fine-grained, feldspathic pink and grey gneiss with pyroclastic breccias and amygdaloidal volcanics, all intruded by diabase in the form of dykes and larger masses	Kingston.
7	Pre-Cambrian	Interbedded limestone, dolomite, and quartzite...........	Portland.
6	Age uncertain, older than 13.	Coarse grey and reddish gneiss.........................	Portland.

IGNEOUS INTRUSIVE DYKES.

Series No.	Age.	Character of rocks.	Name previously given.
5	Intrudes 11.........	Massive and amygdaloidal diabase.	
4	Post-Cambrian, may be earlier in part.	Diabase, augite porphyrite.	
3	Age uncertain, older than 13.	Pink felsite and acid granite.	

PLUTONIC ROCKS.

Series No.	Age.	Character of rocks.	Name previously given.
2	Age uncertain, older than 13.	Grey and pink biotite and hornblende granite, quartz diorite and diorite.	Portland.
1	Age uncertain, older than 13.	Gabbro	Portland.

criteria of their age at present available. While considered of Devonian age by J. W. Dawson and of Silurian age by G. F. Matthew, Drs. White and Kidson have referred them to the Carboniferous, and Dr. Mary Stopes, in an unpublished report, correlates them with the Westphalian of Europe.

In the southeastern quarter of the area, series 12 (Mispeck) is found. These rocks have been considered to overlie 11 (the Bloomsbury and Little River series). The rocks have a much more altered appearance than those of series 13.

Series 13 (Red Head) covers considerable country along the shores and islands of Kennebecasis bay and outcrops also along the coast of Courtenay bay and at Red Head. These rocks are of Carboniferous age and contain a flora which is thought to be early Carboniferous. They overlie the rocks of series 1, 2, 6, and 7, unconformably. Some fossils found in this series on the south shore of Milkish head between Milkish river and Summerville have been reported on by Dr. Kindle as follows:—

"The specimens are all referable to a single species, *Estheria* cf. *dawsoni*. This fossil has been reported from the Horton series of Nova Scotia, and the Lower Carboniferous of Scotland. Its recorded range is confined to the Lower Carboniferous. Its occurrence near St. John, therefore, appears to indicate a Carboniferous horizon below the limits of the Coal Measures."

A great unconformity occurs between the Carboniferous and Pleistocene rocks (14). The Pleistocene stratified sands and gravels are found at elevations up to about 200 feet above sea-level.

The dyke rocks (3), appear to be genetically related to the granitic rocks, probably as the latest intrusions from the same magma. The diabase (4), is very generally distributed, cutting all but series 11, 12, 13, 14, and 15. Only a few dykes are found cutting rocks younger than the Cambrian. Those listed under 5 cut series 11.

Structural Geology.

Earth movements in this district are recorded by the rocks of every geological age. The Pre-Cambrian rocks suffered intense deformation before the close of that era and were subsequently folded and faulted during later periods of diastrophism until it is impossble to read the full record of their complicated history. The Cambrian beds are isoclinally folded, and exhibit intense pre-Glacial and slight post-Glacial overthrusts, due to compressional movements acting from the southeast towards the northwest. The rocks of series 11 and 12 are much indurated and have a cleavage at various angles to the bedding. The Carboniferous rocks of series 13 are much folded and many thrusts of considerable magnitude indicate that intense disruptions occurred between the time of their deposition and the Glacial epoch.

With very few exceptions, the contacts between the various rock formations are marked by faults or thrusts parallel to their extension in a general north-northeast direction. The contact between series 8 and the Carboniferous series 13 on the north shore of Kennebecasis bay, is a good example of this, the contact being marked by a scarp facing the bay to the southeast and extending across and beyond the map-area.

Breaks also occur along lines approximately at right angles to this direction, sometimes accompanied by horizontal movements of considerable dimensions. About 4 miles northeast of St. John, faulting in both these directions occurs, whereby the Cambrian measures are broken along their strike to the northeast and across their strike nearly at right angles.

Two principal types of movement appear to have taken place, one consisting of nearly vertical breaks along a north-northeast direction in which the northern block was frequently uplifted, relative to the southern. This is seen especially in sedimentary rocks. The plutonic rocks appear to have been usually uplifted as units forming horsts. The other type of movement has resulted in overthrusts from the southeast combined with cross faulting parallel with the direction of movement.

Post-Glacial movements have taken place in the form of many small overthrusts in the Upper Cambrian measures in St. John city along the south side of City road just west of the city hospital. City road follows a valley, the hillside to the south of which at this point reveals a glaciated surface with glacial striæ well preserved in the slaty shales and fine-grained quartzitic sandstones. The direction of the striæ is S. 5° W., at Rock street about halfway between City road and the top of the slope. The overthrusts are along planes approximately parallel to the bedding of the rocks which strike N. 65° E. and dip 50° S. The movements have caused the southerly beds to be raised relative to the adjacent northerly beds. In an exposed area measuring 30 feet across the strike, thirty overthrusts were counted with throws varying from one-quarter of an inch to 3 inches.

Dr. G. F. Matthew observed these and other post-Glacial movements in this vicinity in 1893, and the results of his detailed observations are given in the Bulletin of the Natural History Society of New Brunswick, volume iii, pages 34 to 42.

Description of Series.

Series 6, Gneiss.—Several varieties of gneiss are found, varying in colour from reddish grey to light and dark grey according to the varieties of feldspar and bisilicates contained. They consist mainly of quartz, feldspar, and usually mica with decomposition products. They occur intermittently in narrow belts, the widest of which is 4,000 feet, from south of Green head on the west side of St. John river to a point about 1 mile east of Rothesay, crossing the Intercolonial railway just south of Brookville station. In a number of instances, granitic rocks (3) have intruded them, but usually their contacts are faulted. Their origin is uncertain. They have been considered as highly metamorphosed sediments, and if true, conditions approaching the plutonic must have been reached to give them their present coarsely crystalline texture. Many of them resemble granitic rocks so closely in mineral content and texture, that only a rearrangement of the minerals would suffice to produce such.

Series 7, Limestone-quartzite Series.—This is a much more extensive series which occurs in two principal bands, one averaging about 100 yards wide reaching from the falls of the St. John river through Rockwood park north of the city. The other forms Green head and extends southwest beyond the map-area and northeast as far as Riverside. About 1 mile southwest of Drury cove this band has a width of 1½ miles. On Green head, the limestone is interbedded with a fine-grained dark coloured quartzite, in thin beds. Quartzite of varying character occurs frequently with the limestone generally having an attitude indicative of an interbedded series.

Dolomite also forms an integral part of the limestone series. It occurs in beds varying in thickness from a few inches to several feet and occasionally a band includes strata of dolomite 100 feet or more thick.

While the limestone is usually recrystallized it is occasionally only slightly altered. On the north side of Green head the so-called fossil Archæozoon Acadiense occurs in the limestone. Cross-bedding in the quartzite is frequently well preserved.

The colour of the limestone varies from blue to white, and is generally finely banded blue and white giving a greyish blue. The dolomite is usually yellowsh white weathering to a darker buff.

Peculiar dark-coloured areas are found with both the limestone and quartzite, the origin of which has proved puzzling. They are frequently pyritiferous and probably owe their origin to alterations caused by intrusive diabase.

Diabase dykes are everywhere to be found cutting these rocks.

Series 1, Gabbro.—Among the oldest of a series of plutonic rocks is a gabbro first described by W. D. Matthew[1] from a small exposure at Indiantown. It is more widely spread in two exposures, one about 1 mile and the other about 2 miles east of Riverside. The rock varies in texture from fine and even-grained to extremely coarse and porphyritic. W. D. Matthew[2] pointed out that some of the massive crystalline rocks previously considered as highly metamorphosed sedimentary gneisses, were really plutonic granitic rocks intrusive into the limestone series.

Series 2, Granite.—A pink granite is intrusive into the gabbro at Indiantown. Dykes of pegmatitic material probably from the granite magma, cut the gabbro near Riverside, and the gneiss in Rockwood park and elsewhere. Other acid plutonics and related dyke rocks (series 3) are frequently met with intruded into and faulted in with the gneiss and limestone quartzite series in the highly disturbed belt to the south of, and forming the islands and shores of Kennebecasis bay. These rocks vary greatly in character. A typical biotite granite occurs on Milkish head and Kennebecasis island, intruded by a more acid rock having the appearance of quartz porphyry (series 3). In a large area extending through Lovett point, Indiantown, Rockwood park, and farther northeastward, hornblende granite with porphyritic pink feldspar and diorite of varying appearance are found. A number of inclusions of limestone and quartzite suggests that the present surface is near the top of a plutonic intrusion, and while the overlying rocks have been removed, little of the granitic rock itself has disappeared. On the north side of Lovett point, where there is an unfaulted contact between the granite and limestone, a splendid development of garnets has formed in the limestone, while at the transition point a band of greenish yellow epidotic material about 2 inches thick has formed, due to contact metamorphism. In Rockwood park, a beautiful development of tremolite has grown along a similar contact, thus proving beyond doubt the intrusive nature of the granite.

Many diabase dykes (series 4), similar to those cutting the older rocks, have also invaded these plutonic intrusions.

Series 8, Volcanic and Pyroclastic Rocks (Kingston).—Series 8 consists of volcanic breccia, amygdaloids, gneissic, and schistose feldspathic material, all of which have been invaded by diabase in the form of dykes and elongated masses (series 4) oriented in a north-south direction. As stated above, the age of this group is uncertain, but is placed as pre-Silurian by Professor Bailey. No comparative petrographic study of the diabase dykes with those cutting series 1, 2, and 7, has yet been made, but macroscopically they appear very similar. It is probable that the local sources of these dykes are represented by the larger areas.

Series 9 (Coldbrook).—Series 9 consists also of volcanic breccia, amygdaloidal and fine-grained felsitic volcanics. These underlie the 10*a* measures and extend through the northern part of St. John city in a belt about 500 feet wide. About 3 miles northeast of St. John city the belt suddenly widens to 2 miles and continues to cover a considerable area farther east.

Considerable diabase, apparently intrusive, is found closely associated with the amygdaloidal, volcanic, and pyroclastic rocks; near the reformatory, and with the reddish and greenish sandstones of series 12 near the almshouse. Medium-grained

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[1] N. Y. A. S., xiii, p. 197.
[2] N. Y. A. C., xiii, 1894, p. 187.

non-amygdaloidal, diabase occurs also with the volcanic rocks in Carleton. It is probably of later age than the volcanic rocks and intrusive into them. Its relations to the sandstones of series 12 are not clear, but it is probable that the contacts are faulted.

Series 10a (Etcheminian).—Series 10*a* consists of purple conglomerates, sandstones, and sandy shale, and overlies series 9, north of the city of St. John. They form the Etcheminian of G. F. Matthew, who considers them to be Lower Cambrian, while C. D. Walcott places them in the Middle Cambrian age. They appear to consist of the worked-over material of series 9.

Series 10b, 10c, 10d, 10e (St. John Group).—St John group consists of fine-grained quartzitic sandstone and shales of varying light to dark green colour and coarse to fine texture. Divisions C1, C2, and C3 as worked out by G. F. Matthew are found overlying series 10*a* (the Etcheminian rocks) from Seeley street, southwards to Meadow street, St. John city, forming the northern limb of an isoclinally folded synclinal. Division C 1 does not appear to the south of Seeley street, but the higher beds are found overturned on Canterbury street and elsewhere on the peninsula. These rocks extend from Carleton northeastward in a band about 2 miles in width, until suddenly narrowed and possibly entirely cut off by the Coldbrook rocks, about 3 miles northeast of St. John city. The Cambrian rocks appear again farther east and are found in more open folds beyond the map-area. Rocks holding a fauna belonging to the middle of Matthew's division C 1, and also an agnostus horizon not yet identified, occur on the south shore of Long island. Other small outcrops of Cambrian beds are found on the north side of Milkish head, the north side of Kennebecasis island, at Sandy point, and in a small bay about one-half mile north of Drury cove. Fossils have been collected from some of these localities but have not yet been identified. In some places the Cambrian rocks are cut by diabase dykes which resemble those intrusive into the Pre-Cambrian.

Series 11 (Bloomsbury and Little River).—A series of reddish, purple, and light and dark green conglomerates, sandstones, and shales, succeeds the St. John group to the southeast. They are faulted against the black slates of the Cambrian on the shore of Courtenay bay south of the almshouse, and outcrop again along the coast south of Little river. They form the southern extremity of the peninsula of St. John city and appear again on the coast west of Carleton, from Seaside park to Duck cove. The rocks dip to the southwest at angles varying from 30 to 80 degrees. Intrusive diabase outcrops between these rocks and the Cambrian slates on the peninsula of St. John city and is intrusive into series 11 south of the almshouse and in Carleton.

The rocks are considerably indurated and many quartz veins occur along fault cracks.

Series 12 (Mispeck).—These rocks consist of a series of interbedded volcanic flows, purple and green conglomerates, agglomerates, sandy shales, sandstones, and siliceous limestones. The agglomerate and shale beds have the appearance of water-sorted pyroclastic rocks, consisting of breccia and volcanic ashes. They blanket the southeastern part of the map-area, and continue westward along the coast of Courtenay bay to within about 1 mile of Red Head. The rocks of this series outcrop northwards to the glacial drift which covers a strip about 1 mile wide between the Loch Lomond road and a branch road about 1 mile to the south. They are probably separated from the rocks of series 9 to the north of the Loch Lomond road by a narrow belt of Cambrian rocks hidden by glacial drift. To the westward they skirt the northern side of Red Head extending along the Black River road to within about 1 mile of Little river. The rocks dip northwestwards for the most part at varying angles usually 15 to 20 degrees. Anticlinal, synclinal, and monoclinal folds occur, and along the Black River road near the eastern edge of the map-area, the rocks are flat lying.

The rocks have been highly cleaved and many quartz veins fill fault cracks.

Volcanic flows with bedded ash rocks are found at Carleton and along the coast at Sheldon point, Manawagonish beach, at Pisarinco, on Manawagonish and Partridge islands, forming Shag Rocks west of Partridge island and covering about 1 square mile of country east of Red Head. While these last-named occurrences appear to have had a very similar origin to the rocks north of St. John city, they are composed of more ash and amygdaloid and less breccia. They are characterized by many quartz veinlets frequently carrying specular iron, and highly ferruginous felsitic beds also occur in them. These rocks are described by W. D. Matthew under the name Coastal,[1] as follows: "Overlying the Coldbrook is another series of rocks, more altered in its typical exposures than the lower group. Its lower part (as defined by Professor Bailey in the report for 1877-8) is made up of volcanic rocks entirely similar to those of the Coldbrook, from which the writer has not been able to distinguish it." They have been found by the present writer to be interbedded with the upper measures of series 12.

Series 13 (Red Head).—Series 13 consists of coarse purplish-red conglomerates, coarse arkose, sandstones with sandy shale, the last varying in colour from purplish red to olive green. South of St. John city this series is found at Red Head about 2 miles southeast of Little river. A similar series occurs much more extensively on the shores and islands of Kennebecasis bay. An area reaching from Boars head on the St. John river to the Sandy Point road is about 1 mile wide and 3 miles long. The greater part of Long island, the northern portions of Milkish head and Kennebecasis island, together form an interrupted area nearly 10 miles long by about 1 mile in width.

The Red Head occurrence is apparently faulted against a series of volcanic rocks to the southwest, while to the north it is drift covered. The measures here strike S. 37° W. to S. 55° W. and dip 30° to 40° N.W. The relatively large area of Kennebecasis bay is widely separated from series 11 and 12. The attitude of the small outlier at Red Head does not suggest conformity with any of the other formations. The conglomerate is made up mostly of pebbles of red and grey granites closely resembling the plutonic rocks north of St. John city, and greyish white crystalline limestone with a few pebbles of red limestone (some of which at a locality on the Courtenay Bay coast near Red Head, hold an unidentified fauna of brachiopods and trilobites), quartzitic sandstone, shales, etc. The series does not appear to be as greatly altered as any of those already described and lithologically appears younger.

Series 14.—An interval of erosion is represented by the absence of sedimentary rocks between those of the Carboniferous age and Glacial periods.

Glacial till is found in all parts of the map-area, and some splendidly-preserved moraines testify as to the manner of its deposition. Near the south shore of Milkish head, overlying the Carboniferous lowland, a series of terminal moraines indicate the final retreat of the ice northeastwards. The country east of Rothesay is so completely covered by drift that no rock outcrops were found within an area of about 10 square miles. Similar conditions occur south of Loch Lomond road in the vicinity of the lakes used for water supply by St. John city. Boulder clay is commonly found in the drift.

Over the mantle of drift is found a stratified series of gravels and sands interbedded with clay. These are found principally along the coast where they have accumulated at lower elevations and the waters of the bay have since exposed them to

[1] Trans. N.Y. Acad. Sci., xv, 1895, p. 193.

view. Examples may be found on Courtenay bay, southwest of Red Head, where a thickness of 60 feet is exposed having boulder clay in its lower part and stratified gravel and sand in its upper part. An area thickly covered by marine sediments occurs between Seaside park and Duck cove. Here, boulder clay is overlaid by marine clay followed by stratified sand and gravel. To the west of Carleton between South bay and Manawagonish beach, the surface is thickly covered by Glacial and post-Glacial material. West of Sheldon point a thickness of about 100 feet is exposed consisting of gravels in its lower part followed by stratified clay and covered by sand.

Economic Geology.

LIMESTONE QUARRIES.

The quarrying and burning of limestone and dolomite provides an important industry at St. John. All of the quarries are in the belt of Pre-Cambrian limestones and dolomites extending from Green head to Torryburn. The general strike of the series is north-northeast; and beds suitable for quarrying may occasionally be traced for several hundred yards. Six quarries in operation and three that were idle, were examined last summer. Representative samples were taken from the working face of each quarry, and analyses of these have been made by Mr. H. A. Leverin, chemist, of the Department of Mines. The results of these analyses are tabulated on page 241, *et seq.*, and these are referred to by number in the text descriptive of each quarry. Samples of different varieties of limestone and dolomite were also taken and the results of analyses of these throw some light on the question of origin of the dolomite.

The fine-grained, yellowish-white magnesian limestone weathering to a typical dirty yellow or buff, contains from 10 per cent to 40 per cent magnesian carbonate, and the blue limestone from 0·27 per cent to about 5 per cent, and has also been found to hold as high as 12 per cent magnesian carbonate in one instance. The yellow-white magnesian limestone is frequently found interbedded with blue limestone in an alternation of thin beds, and belts comprising a number of thick beds of dolomite sometimes occur in the series, and in these the dolomite quarries have been opened up.

Diabase dykes cutting the blue limestone are usually bordered by a fringe of white limestone presenting a striking example of alteration resulting from igneous intrusion. The altered zones accompanying thin dykes are usually much larger and more marked than those associated with thick dykes. Thus a dyke half an inch thick may have altered the blue limestone to white through about 2 inches, while a dyke of 6 inches up to 2 feet or more thick usually has a fringe of half an inch or less, and sometimes no distinct border of the metamorphosed material.

The fact that the dolomite has a white colour somewhat similar to this altered zone and also occurs intimately associated with the blue limestone suggests that the intrusive diabase may have aided in the dolomitization of the limestone. The results obtained from chemical analyses of the limestone altered by the diabase indicate, however, that no increase in magnesian content can be traced to this source.

Analysis 134 (page 241) is of the white metamorphosed limestone from a limestone quarry on the northwest coast of Green head. The content of 0·45 per cent MgO is less in this case than the average content of MgO in the unaltered limestone.

Randolph and Baker Quarries.—Three quarries are being worked on Green head, No. 1 in dolomite and Nos. 2 and 3 in limestone. A belt of dolomite is interbedded with limestone and crosses the south central highland part of the peninsula of Green head. It has thus been possible to open quarries of both limestone and dolomite at either end of this belt on a sloping surface. The two northeastern quarries lie close together and the dolomite quarry on the northwest side will be referred to as No. 1, and the limestone quarry 100 feet to the south will be referred to as No. 2.

About 50 feet of strata in the limestone and 80 feet in the dolomite have been opened up. The limestone varies in colour from dark blue to white. Two diabase dykes cut the limestone and some of the white colour appears to be due to contact metamorphism. Analysis 152 is from the unaltered limestone and analysis 149D from the white metamorphosed limestone, showing that while the unaltered rock holds 12·12 per cent $MgCO_3$, the white holds less, 9·45 per cent $MgCO_3$. The dolomite of quarry No. 1 is a fine-grained yellow-white rock, and very little diabase occurs with it. Analysis 132 is of an average sample from 80 feet of strata across the working face of quarry No. 1.

The quarries on the southwest side of the hill, about half a mile distant from the northeast quarries, have been taken from about the same stratigraphical horizon. The limestone and dolomite appear to be of equal purity to those of the northeast quarries, but more disturbed by faulting. While this has not had any detrimental effect on the limestone, the more brittle dolomite has been so shattered that it crumbles and chokes the kiln, rendering it unsuitable for burning.

Limestone quarry No. 3 at the southwest side of Green head was carefully sampled and analysis 144 represents the composition of the rock from the working face.

An alternation of blue limestone with yellow-white rock in bands up to about 1 foot in thickness occurs on the north side of quarry No. 3. No diabase occurs at this point, and the yellow-white and blue bands were sampled separately. Analysis 143DB is of the blue rock, showing 4·70 per cent $MgCO_3$, and 143DW the yellow-white rock, showing a higher content of 10·40 per cent $MgCO_3$.

Two kilns are operated by Randolph and Baker, one for lime, the other for magnesia.

Charles Miller Quarry.—This quarry is located on the north side of St. John river, opposite the southern part of Green head and about 1 mile above Indiantown. There are extensive old workings since the quarry has been operated for about thirty years. In the northern part of the quarry, the normal blue limestone has been quarried out from between masses of a yellow, apparently iron-stained limestone which is not burned for lime. A diabase dyke also cuts across this space. This part of the quarry is not being worked at present. Analysis 17A shows the composition of the yellow limestone. At the southern side, where quarrying is now being carried on, the limestone appears to be of excellent quality and free from diabase. Analysis 6 is of a representative sample from the working face. One kiln is supplied with material from this quarry.

Quarries Operated by Stetson and Cutler, and Purdy and Green.

These firms each operate a large quarry located about 1 mile north of Indiantown. The quarries join along the strike of the limestone so that the same stratigraphical horizon is being worked in each case. In the Purdy and Green quarry to the southwest, the beds strike N. 40° E. and dip 40° S.E., while 250 feet to the northeast in the Stetson and Cutler quarry the strike is more to the east, being N. 70° E., dip 40° S., with local variations. The limestone is coarsely crystalline and the colour varies from laminated blue and white, to white. Superior lime is obtained and there is ample room for expansion to the north in both quarries.

Purdy and Green Quarry.—One hundred and seventy feet of strata have been cut across, in two levels, and one kiln is supplied from each level. A diabase dyke extends the length of the quarry and has formed a natural division for working each level. The floor of the northerly half of the quarry workings stands at 30 feet above at floor of the southerly workings, thus providing a large reserve for quarrying each level farther northwards. Analysis 106 is of a representative sample from the lower level and 107B of a sample from the upper level where cut by a diabase dyke.

Stetson and Cutler Quarry.—Opened in 1900, more rock appears to have been removed from this quarry than from any other during this period of time. A diabase dyke cuts across the northwest portion of the quarry, but the east and northeast parts, where future work will be done, are free from this intrusive. Analyses 47, 51, and 55 are of representative samples from the working face.

Stetson and Cutler have also operated a dolomite quarry located about half a mile north of Indiantown, but this has been idle for some time. A greater demand for magnesia, however, might be a sufficient reason for reopening. A thickness of about 50 feet of strata has been cut across, which is free from diabase for about 200 feet along the strike. Analysis 116A is of an average sample from these beds. The dolomite is light yellow to white, and although considerably faulted does not appear to crumble. A number of diabase dykes occur in it, but a large portion is free from them and could be very easily quarried. Two kilns were supplied with material from this quarry.

Drury Cove Quarries.—Two limestone quarries, together with three kilns, were recently operated by Mr. L. Rokes, but have lately been sold and are not worked at present. One of the quarries is on the south side of the cove, the other on the north side. The south quarry, No. 2, is in blue limestone which rises steeply from the shore. A width varying from 100 feet at the opening to 25 feet at the face, has been taken out along the strike for a distance of about 300 feet. The rocks rise from 0 to 100 feet at the face. They strike N. 70° E. and dip 30° S. A zone of diabase dykes cuts across the strata at irregular intervals in the western 150 feet of the cut, and would necessitate a large amount of rock sorting in this part of the quarry. The eastern portion is free from dykes, but a much smaller amount of rock is available.

Analyses have been made of two sets of samples, one (analysis 179C), representative of the limestone where cut at intervals of about 10 feet by diabase dykes, each about 6 inches thick, the other (analysis 179E), from the portion of the quarry free from diabase, and from 25 to 50 feet distant from a dyke.

The content of MgO in the normal limestone away from the diabase dykes is 0·25 per cent (analysis 179E), while within the zone of the dyke the limestone holds only 0·13 per cent MgO. There is, therefore, no increase in magnesium due to the diabase intrusion. Similar results were obtained from analyses of the limestones of Green head, and the writer considers this confirmatory evidence from localities several miles apart to be conclusive.

Quarry No. 1, on the north side of Drury cove, is about 200 feet long by about 100 feet wide, and may be enlarged to the east, north, and west. The north face is about 30 feet high, while the east and west faces slope from the floor to 30 feet, averaging 15 feet.

The limestone is coarsely crystalline, usually finely laminated blue and white, with some interbedded pure white strata. Some diabase occurs in the east portion of the north face, but otherwise it is free from objectionable material. Analysis 164C is of a representative sample. Fuel for burning has to be hauled to the kilns. Drury cove is about 4 miles north of St. John, and about one-half mile west from the station of Brookville on the Intercolonial railway of Canada.

Fuel Supply for Kilns.—It is worthy of note that with the exception of the Drury Cove and the Purdy and Green kilns all of the above mentioned secure their fuel supply from the waste lumber of saw-mills near which the kilns are built.

Analyses.

Sample No.	Insoluble matter.	$Fe_2O_3 + Al_2O_3$.	$CaCO_3$.	$MgCO_3$.	CaO.	MgO.
6	2·56	0·31	93·75	3·34	52·50	1·60
17 A	15·46	2·00	78·93	4·11	44·20	1·97
47	2·00	0·40	95·89	1·25	53·70	0·66
51	2·04	0·40	94·46	1·75	52·90	0·84
55	0·96	0·26	96·78	1·17	54·20	0·56
106	0·44	0·16	98·75	0·96	55·30	0·46
107 B	0·20	0·14	98·21	1·32	55·00	0·63
116 A	2·88	1·26	56·43	40·00	31·60	19·14
132	0·62	0·50	57·59	40·96	32·25	19·60
134	0·84	0·50	97·14	0·94	54·40	0·45
143 C	11·16	2·86	78·93	6·60	44·20	3·16
143 DB	3·40	0·58	90·53	4·70	50·70	2·25
143 DW	3·52	0·30	82·32	10·40	46·10	4·98
144	3·20	0·24	90·44	4·36	50·65	2·09
149 D	6·16	0·26	83·50	9·46	46·80	4·53
152	3·32	0·30	84·10	12·12	47·10	5·70
164 C	2·20	0·24	96·60	0·98	54·10	0·47
179 C	2·00	0·24	97·68	0·27	54·70	0·13
179 E	1·86	0·28	96·69	0·52	54·15	0·25

References to Analyses.

Sample No.	Character.	Quarry obtained from.
6	Blue limestone.....................	Chas. Miller, St. John, N.B.
17A	Yellow limestone....................	" " " "
47	Blue limestone..........	Stetson & Cutler, St. John, N.B.
51	" "	" " " "
55	" " cut by diabase dyke..	" " " "
106	" "	Purdy & Green, St. John, N.B.
107B	" " cut by diabase.......	" " " "
116A	White dolomite....................	Stetson & Cutler, St. John, N.B.
132	" "	Randolph & Baker, No. 1, St. John, N.B.
134	White limestone altered by diabase...	Green Head.
143C	Yellow limestone..................	Randolph & Baker, No. 3, St. John, N.B.
143DB	Blue limestone...	" " " " "
143DW	White limestone near dyke	" " " " "
144	Blue limestone..........	" " " " "
149D	White limestone near dyke..........	" " No. 2 " "
152	Blue limestone........	" " " " "
164C	" "	Drury Cove, No. 1.
179C	" " near dyke............	" " " 2.
179E	" " away from dyke.....	" " " 2.

ROAD METAL.

At the east end of Rockland street in the northern part of the city of St. John, the volcanic rock of series 9 is being quarried for road metal. This appears to be largely a felsitic rock of the nature of trachyte. It is somewhat soft for heavy traffic, but has fair cementing qualities and is very conveniently obtained.

Trap rocks are much more satisfactory than felsitic rocks for nearly all grades of traffic. These occur quite plentifully in and about St. John. In nearly all the limestone quarries, diabase dykes occur. These are detrimental to the lime industry but make the very best of road metal. The diabase is left standing in the quarries in such attitudes that very cheap quarrying could be done, yet since it is dead work these walls of "whin rock" are left frequently covering up much good lime rock.

If this could be removed and used for road metal both the roadmaking and lime industries would benefit. Diabase or trap also occurs in fairly large areas in Carleton, East St. John, where it has been used in the construction of the new breakwater, and elsewhere.

GRAPHITE.

Graphite occurs on the northeast shore of the St. John river at the falls. It may be seen outcropping at intervals from the shore a few hundred feet north of the railway bridge, northerly for about 500 yards along a small valley, to a point east of Murray and Gregory's saw-mill. Near the saw-mill, an old dump of considerable size has been taken from a shaft, and other old workings are found in the valley. A section across the occurrence may be seen at its southern extremity near the river, where a small tunnel 20 feet long has been driven.

Here the graphite occurs in a vertical fault zone mixed with dark-coloured pyritiferous shales much reddened with iron oxide. The country rock to the east of the fault zone is dark blue limestone and in order from east to west, the following section was measured:—

2 feet graphitic shale with calcite.
3 " green shale somewhat graphitic.
6 " shaly graphite.
6 " green limestone.
8 " hard graphitic shale.
6 " green earthy rock which does not effervesce with acid.

No work has been done on this property for a number of years.

INFUSORIAL EARTH.

About 7 miles northeasterly from St. John city and 1 mile south of the Loch Lomond road, in a portion of a small depression covering about 50 acres and marking the site of a former glacial lake,, a deposit of infusorial earth occurs. An attempt has been made to market this material for use as a polish, but nothing is being done at present with the property. No detailed examination was made.

CLAY, SAND, AND GRAVEL.

There is an abundance of these raw building materials in the vicinity of St. John in the Pleistocene deposits. No detailed examination has yet been made by the writer, but sections exposed along both the east and west shores of St. John harbour give promise of supplying them in abundance. Clay suitable for brickmaking is also to be found in land basins up to elevations of about 200 feet above sea-level. Superior brick and tile are now manufactured from such clay deposits in East St. John, and by careful testing other localities will doubtless be discovered.

No attempt was made last season to make a general study of these deposits, but an examination of two samples taken from surface deposits has been made by Mr. J. Keele and his report will be given.

Sample 255A.—Taken from a point about three-quarters of a mile southwest of Milidgeville, 200 yards southeast of Mr. John Hannah's farmhouse, and about 50 yards east of the wagon road near a small westerly-flowing stream. Clay underlies an area of 50 acres or more lying at an elevation of about 75 feet. Its thickness was not measured. The sample was taken at a depth of 22 inches, and is reported on by Mr. Keele as follows:—

"*Sample 255A, Lab. No. 164A.*—A reddish, very gritty clay, probably a river silt. It required 35 per cent of water for tempering, works up to a flabby mass with low plasticity. The drying shrinkage is 6·5 per cent.

"It burns to a light red porous body at cone 010. The brick is very weak and useless for structural purposes when burned at this temperature. When burned to cone 03 (2,000° F.) a fairly good red-coloured brick is produced, but it is too porous.

"This material is not recommended for brick or tile making."

Sample 255E.—Taken from the surface of a shallow basin at the extreme westerly portion of the peninsula immediately east of Boars head, at an elevation of 125 feet. An area of 5 acres or more appears to be underlain by the clay. The sample was taken at a depth of 15 inches. Mr. Keele gives the following report:—

"*Sample 255E, Lab. No. 164B.*—This is a reddish non-calcareous clay, apparently the usual marine clay, which occurs at various localities in New Brunswick.

"It works up into a good plastic body with 23 per cent of water. The working and drying properties are good. The drying shrinkage is 5·5 per cent.

"It burns to a good hard light red body at cone 010, with an absorption of 18 per cent, and no fire shrinkage. Burned to cone 06, the body is denser and the colour better than at 010. It burns to a steel hard, dark red body, almost vitrified at cone 03, but the fire shrinkage of 7 per cent is high.

"This is a good material for the manufacture of building brick, either by the wire-cut or soft-mud process. It will also make good field drain tile.

"It is not suitable for the manufacture of vitrified wares as the shrinkage is too great, and the fusing point too low. A small portion of the silt (164*a*) might be mixed in with this clay in order to reduce the shrinkage and assist in faster drying."

OTHER MATERIALS.

Chalcocite and malachite occur in the limestone on the most southern of the islands near Millidgeville in Kennebecasis bay. These are found in quantities too small to be of economic value. A small specimen of bornite with malachite was found in the east dolomite quarry on Green head.

A small specimen of fluorite with calcite was found in the limestone quarry of Stetson and Cutler.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY OF NOVA SCOTIA.

(J. W. Goldthwait.)

Introduction.

During the summer of 1913 I spent approximately three months in the Maritime Provinces. Two months were devoted to a study of the surficial geology of Nova Scotia, particularly its glacial features. The rest of the time was used in preparing the route for Excursion A10 of the International Geological Congress (Marine submergence at Montreal, Covey Hill, and Ottawa), in participation in Excursion A1 (the Maritime Provinces), in guiding Excursion A10, and in attendance at the Toronto meetings.

The work in Nova Scotia, to which it has been planned to devote the greater part of two field seasons, consists in the investigation of the topography, drainage, shoreline, and other surface features of the province, the aim being to prepare a memoir on Nova Scotia which will present in simple language an explanation of the scenery and of smaller surficial features such as glacial deposits and groovings, that are of interest to the general reader as well as to the scientific man. While this first season was given up largely to reconnaissance, in seeing the relations of upland and lowland belts to geologic structure and physiographic history, and in discovering what small features of topography and drainage characterize the several physiographic provinces, attention was given primarily to the glacial phenomena of the peninsula and of neighbouring land areas such as Prince Edward Island, Cape Breton, and the Magdalens, inasmuch as previous workers in this field have disagreed fundamentally as regards its glacial history. The collecting of new observations of striæ, dispersal of drift boulders, drumlins, and other records of the Glacial period, at localities widely distributed over Nova Scotia and Cape Breton island during the past season goes far towards demonstrating the nature of the ice movement in this district, as well as on the neighbouring islands and shoals of the St. Lawrence; and when supplemented by similar observations next season will settle some, at least, of the problems which have been raised by the conflicting reports of earlier observers. Until a rational interpretation of the glacial history of Nova Scotia can be worked out, the larger task which has been undertaken would, of course, be incomplete.

In this work I was ably assisted, during the whole season, by Mr. Philip P. Baily.

Glaciation of Nova Scotia.

INTRODUCTION.

Three conflicting views are current in regard to the glaciation of the peninsula of Nova Scotia. Dr. Chalmers, of all glacialists the most familiar with the field, held positively the view that Nova Scotia had its own centre of glaciation during the climax of the last Glacial epoch, shedding ice both southeastward into the Atlantic and northwestward into the Bay of Fundy. He further insisted upon a local movement outwards from the Cobequid mountains over the isthmus of Chignecto. Professor L. W. Bailey, on the contrary, whose observations of glacial phenomena in southwestern Nova Scotia have been extensive and very reliable, holds the view that the great ice movement was a southeastward advance from New Brunswick across the Bay of

Fundy and the peninsula; although he also found reason to think that at the close of the last Glacial epoch there was a slight spreading of ice from a local centre over the interior of Nova Scotia. A view more recently advanced by Dr. J. H. Wilson, whose book on "The Glacial History of Nantucket and Cape Cod" aroused interest in the question of local centres of ice dispersion in this region, conceives of the peninsula of Nova Scotia as covered by ice which moved southwestward from Newfoundland to the banks and islands off southern New England.

Briefly, the evidence gathered last summer seems to show that the last and most clearly-recorded glaciation of Nova Scotia consisted in a southeasterly movement from New Brunswick, with a southward tendency near Yarmouth county and an eastward tendency in Cumberland and Pictou counties. Prince Edward Island, Cape Breton, and the Magdalen islands seem to have been glaciated by ice moving eastward and northeastward.

STRIÆ.

The observations of striæ in Nova Scotia recorded in the maps and reports of Mr. Faribault and Prof. Bailey form a great body of evidence in support of the view of a southeastward movement of the ice-sheet. A large part of this evidence was already published when Dr. Wilson presented his theory of a southwestward movement through this district, and was easily sufficient to disprove a movement from Newfoundland like that which he postulated. Nevertheless care was taken last summer to test the possibility of a southwestward movement, and the accuracy of the observation of the Canadian geologists, by securing new and independent measurements of striæ at scores of places, covering all parts of the province except Guysborough and Antigonish counties. In all places where a southeastward or a southward movement of the ice had been reported this was found to be correct; and in not a single locality was there found evidence of the southwestward movement to which Dr. Wilson attaches so much importance. Indeed, on Cape Breton island the striæ near Sydney and Louisburg indicate a movement from southwest to northeast, almost directly towards Newfoundland. It will be possible, after next season's work, to present a map of Nova Scotia and Cape Breton showing striæ in all parts of the province. This will make evident a main movement toward the southeast from New Brunswick, diverging toward the south over Yarmouth and Shelburne counties, and toward the east over Cumberland and Pictou counties, Prince Edward Island, and Cape Breton.

Attention was given particularly to reports of previous observers regarding small local centres of movement, from which the ice is supposed to have radiated at the close of the last Glacial epoch. The discordant striæ reported in such cases, wherever seen, were found to be erroneous, or of questionable value. For instance, striæ at Rawdon gold mines, reported by Mr. Faribault to run westward, were not seen; but on the ledges indicated on his map striæ were found which run southeastward. Search at localities in Cumberland and Pictou counties, where Dr. Chalmers reported two or three sets of striæ on the sandstone, revealed the fact that in most cases the striated surface was the face of a small boulder rather than bedrock. Many of the localities are explicitly given as furnishing striæ on "a boulder in situ." The acceptance of such uncertain evidence accounts in large measure for the difficulty which that observer experienced in working out a rational explanation of the ice movements on the isthmus of Chignecto. Out of the hundreds of observations of criss-cross striæ which he records on the sandstone lowland, there are some cases, however, of true exposures of bedrock. At Pugwash Junction, for instance, the sandstone bears grooves which indicate a northward movement followed by an eastward one; and at Hardwood hill, near Pictou, the ledges are distinctly grooved by movements successively in the directions of N. 15° E., due east, and S. 35° E. The exact bearing of these earlier movements on the question of local centres in Nova Scotia cannot be clearly seen until we secure more facts; but it is clear that whatever outward movements from these local centres there may have been, their records have been generally concealed and erased by the last great advance of ice from New Brunswick. I have seen no reason, as yet, to suppose, as others have done, that local movements occurred in Nova Scotia at the close of the last Glacial epoch.

DISPERSAL OF THE DRIFT.

In some respects the direction of movement of the ice-sheet can be more satisfactorily worked out by a study of the paths taken by the stones of the drift, in their journey from known outcrops to their final resting places, than by a study of the directions of striæ. While the grooves and scratches in most cases record the direction of movement at the very close of the active advance of the ice, this final scouring having removed all earlier marks, the erratic stones in the drift, shifted to right or left by varying currents in the ice-sheet during a long journey, afford the means of obtaining an average direction of glacial movement during the epoch which they represent. Indeed, since the drift of one Glacial epoch may be picked up and redistributed by a second ice advance, the dispersal of stones expresses in some measure the net direction of movement for the entire period of glaciation. Recognizing, therefore, that while in general a study of the lithological consitution of the drift would support the evidence of eastward or southeastward movement which the striæ record, I have been prepared to find more or less disagreement between the two sets of phenomena and to seek a definite explanation for them.

An interesting and hitherto unrecognized proof of the movement of ice from New Brunswick southeastward across the Bay of Fundy is found in the occurrence on North mountain and the western part of the Annapolis valley, of pebbles of red and green conglomerates foreign to Nova Scotia. Their foreign derivation, indeed, was the occasion of comment by Prof. Bailey; but their evident source in the "Redhead" formation of the St. John district was not made known by him. Boulders composed of identically the same material are large and numerous around St. John, appearing conspicuously on the beaches where till cliffs are being cut back by the waves. On the Nova Scotia side of the bay, particularly in the district around Digby, the conglomerate stones are small and constitute only 2 or 3 per cent of the total stony material of the drift; yet this percentage is remarkably constant. The rock is easily distinguished from those types of conglomerate which occur in Nova Scotia; and its derivation from New Brunswick can hardly be questioned. In the district, also, the drift contains 4 or 5 per cent of granites and syenites which presumably come from the crystalline areas of southern New Brunswick, rather than from the granite area of South mountain in Nova Scotia. A few felsites and pink quartzites seem likewise to have come southeastward into Nova Scotia.

Of the stones from sources in Nova Scotia, which have been widely distributed by ice movement, the most significant is the trap and amygdaloid of North mountain. The excellence of this rock as an index to the ice movement lies largely in these facts: (1) the limits of the exposure of the rock are known and well defined; (2) it outcrops in a high, steep-sided mountain trending across the direction of the ice advance, affording ample opportunity for the plucking of joint blocks by the glacier; (3) it is pre-eminently tough and hard, enduring the wear and tear of transportation better than any other rock, even granite; and (4) it is one of the youngest rocks of the province, and fragments of it have not found their way in earlier geological periods into fluviatile or marine conglomerates, to be subsequently released by weathering and incorporated into the drift at a point far from the original source. These trap boulders not only constitute the great bulk of the stone on the floor of the Annapolis valley, but form a considerable part of the drift on the rocky slopes of the "South

Mountain" granite upland. A few, in fact, appear to have travelled completely across the peninsula to the Atlantic coast, as Prof. Bailey has reported.

In the Annapolis valley, where the red sandstones and shales of the Triassic system occur beneath the drift, traps from North mountain form from 80 to 95 per cent of the stones by actual count. Along the southeast side of the valley, at certain points where Palæozoic quartzites outcrop between the Triassic and the granite interior, the local supply of quartzite reduces the percentage of traps to from 35 to 50 per cent. Farther southeast, on the granite area, one finds within 2 or 3 miles of its border a rapid decline in the percentage of traps as the plentiful supply of granite boulders appears, so that ordinarily at a distance of 10 miles over the granite the traps will be found to constitúte only 10 per cent and the granites 80, with a scattering of other types. For instance, near Vaughan, in Hants county, 26 miles from North mountain, traps form from 6 to 12 per cent; at Maitland in southern Annapolis county, 26 miles from North mountain, traps form 6 per cent; and at New Germany in Lunenburg county, 37 miles from North mountain, they constitute 4 per cent. When one sees how prolific the granite ledges must have been in furnishing fragments of all sizes and of good quality, it is indeed surprising that the North Mountain traps are not completely lost sight of after a mile or two of passage across the granite area. Possibly an explanation of their persistence in the drift of this district lies in the fact that since they were picked up by the ice where it crossed high ground, the trap fragments overrode the local drift during the ascent of the "South Mountain" hills, and thus in time were the last to be set down upon the ground. Three or four per cent of the stones in the drift at localities as far away as southern Yarmouth and Shelburne counties are of trap; and they occur sparingly at Chester and Halifax. While some of these must come from the trap dykes which are known to occur in some places east of the granite area, the amygdaloidal structure in others betrays their origin in the North Mountain trap sheet.

A map of Nova Scotia showing the occurrence of trap fragments in the drift would display a well-defined boundary on the northeast side of the trail, which, starting near Parrsboro, passes southeastward through Rawdon to the vicinity of Lawrencetown on the shore east of Halifax, nearly parallel to the prevailing direction of striæ. The occurrence of red boulder clay in the district around Halifax, in contrast to the ordinary grey, buff-weathering boulder clay of the rest of the southern shore of the peninsula, is in itself an indication that the main movement of the ice during the last Glacial epoch was southeastward; for near Halifax alone is there a gap in the exposure of the granite axis, over which the red drift of the Triassic area streamed without alteration of colour by the admixture of grey and buff rock debris.

Although the southeastward drift of debris in the ice-sheet is thus conspicuously shown both by the colour of the boulder clay and by the dispersal of trap and foreign boulders, there is, as others have reported, some indication that a slight transportation of material outward from the granite area of the interior took place during the Glacial period. The evidence referred to is the presence of granite boulders in considerable number at certain points in the Annapolis valley a little distance north of the area where granite outcrops. As already suggested, the 5 per cent of granite and syenite stones in the drift at Digby and Middleton is satisfactorily explained by the southeastward transportation of these rocks from the crystalline areas of New Brunswick, together with the boulders of red conglomerate. Locally, however, granite boulders are so numerous in the Annapolis valley as to attract attention, as, for instance, along the line of the Dominion Atlantic railway between Lawrencetown and Annapolis. In some cases, doubtless, these boulder belts are due to the existence of granite ledges beneath the surface; for it is known that here and there the granite descends to the floor of the valley. The porphyritic texture of the rock, and its composition leave no doubt that the boulders came from the South Mountain batholith.

One of the localities where a northward movement of the granite fragments seems surely to have occurred is Bridgetown. On the summit of the hills that constitute "South mountain," 3 miles south of this town, and 2 miles within the granite area, the drift contains granites 89 per cent, traps 10 per cent, and quartzites 1 per cent. Two miles farther north, but still presumably within the granite area and 200 feet above the floor of the Annapolis valley, the drift contains: granites 56 per cent, traps 43 per cent, and quartzites 1 per cent. A quarter of a mile beyond here, and probably outside of the granite area the proportion is: granites 21 per cent, traps 75 per cent, and quartzites and argillites 4 per cent. Granite boulders are rather plentiful on the surface of the ground as far north as the middle of the valley, and occur sparingly even on the slopes at the base of North mountain. Nearly 200 feet above the valley, on the south slope of North Mountain, the drift contains: 95 per cent traps, 2 per cent granites and syenites, and 3 per cent quartzites and felsites. The granite pebbles here seem most naturally to have come from New Brunswick; but the occurrence of so many granite boulders within the first mile north of the South mountain cannot be explained by the general southeastward drift which scattered the traps. The striæ in this district, so far as I have observed, register only the southeastward movement. The low relief of the hills of the granite upland seems utterly inadequate to account for a local persistence of ice during the melting away of the sheet from Nova Scotia, especially in view of the fact that even the highest mountains in northeastern North America, the White mountains of New Hampshire; did not possess significant snowfields or local glaciers during the disappearance of the continental ice-sheet from New England. The working hypothesis which seems to promise most in solving the problem is that a northward movement of granite fragments from South mountain took place before the last ice advance, either in the form of glacial transportation in an earlier epoch or of floating ice during a stage when the Annapolis valley was submerged. Once carried northward, these granite boulders might not all be picked up and carried back by the southeastward drift of the ice-sheet, but might be left mingled with the newly accumulated debris in the shelter of North mountain.

A somewhat similar condition of things is seen near Pictou, as Sir William Dawson has stated. Although the only granite area within 50 miles of Pictou is the Cobequid Mountain area on the south and southwest, granite and granodiorite boulders compose about 40 per cent of the stony part of the drift at that locality. According to the striæ preserved on Hardwood hill, as mentioned on an earlier page, the last movement was eastward and southward, in harmony with the drift on Prince Edward Island. The nearest source of granite boulders to the west, so far as is known, is in the hills of Albert county, New Brunswick, nearly 100 miles away; and there is no such profusion of granite boulders in the wide space between the source in question and Pictou as the theory would require. Unless there is a small and as yet unknown local source for the granites of this district, therefore, it seems necessary to believe that they came northward from the Cobequid range. It is interesting in this connexion to remember that the ledges on Hardwood hill bear distinct grooves of earlier date which run N. 15° E. Moreover, at the foot of the hill on its south side a shallow section shows a reddish-brown boulder clay covering a grey boulder clay, as if to record a movement northward from the granite area followed by a movement eastward and southeastward from the areas of red sandstone. Strangely enough, however, there does not seem to be any evidence of a similar northward transportation of rocks from the Cobequid farther west, at Springhill and Oxford Junction.

DRUMLINS AND DRUMLINOID HILLS.

In districts where shales and limestones are widely exposed, as near Windsor, the hills present long, smoothly-rounded forms very much like drumlins. Although very deceptive at first sight these are found to be less symmetrical than true drumlins, and to trend parallel to the strike of the rocks rather than to the direction of glaciation. In many of them the decayed shale or limestone has been exposed at no great depth below the surface by artificial sections. The ice-sheet seems to have moulded these non-resistant rocks into a semblance of drumlin form.

There is, however, at least one great area of true drumlins, in Queens and Lunenburg counties. The well-known lake district near Caledonia lies in the heart of it. From the top of a hill at Caledonia one can count as many as seventy-five drumlins which rise to accordant heights on every hand. Inasmuch as this drumlin district extends southward to Liverpool and Bridgewater, and seems to be limited only by the occurrence of slate as the prevailing rock, it is probable that it covers a few hundred square miles and contains several thousand drumlins. Groups of drumlins occur also at Chester, Halifax, and Yarmouth. Perhaps the most significant thing about the drumlins of the Caledonia district is the fact that they occur almost in the centre of the peninsula, where Dr. Chalmers supposed the centre of the ice-sheet to have been. Inasmuch as drumlins are now recognized as deposits formed not far back from the margin of the ice-sheet, their occurrence at this place supports the evidence of striæ and of drift dispersal that the ice moved across Nova Scotia from New Brunswick toward the southeast. The drumlins in this large area all trend parallel to the striæ, southeastward.

MORAINES.

Although terminal or recessional moraines would not occasion surprise, if found along the Atlantic coast beyond the drumlin area just described, I have not as yet seen examples of them. Mr. Faribault's maps indicate the occurrence of such moraines east of Halifax, at localities not yet visited. A gravelly ridge near Liverpool, mapped by him as a "lateral moraine," seems to me rather to be an esker or "hogback" like those described by Dr. Chalmers and other writers, which are somewhat common in Nova Scotia.

POST-GLACIAL SUBMERGENCE AND ELEVATION.

Around the Bay of Fundy the marks of wave action at levels now above the sea are strangely indistinct. Possibly this is due in large part to the effacement of strand lines by high tidal range. At any rate, the raised beaches here lack the sharp definition which they present in some localities on the shore of the "Champlain" sea. At St. John, stratified gravels carrying marine shells occur at the top of the sea cliffs near Negrotown point and extend inland on rising ground to some weakly-built gravel beaches near the Martello tower, at an altitude of approximately 190 feet. This seems, therefore, to be the upper limit of marine submergence at St. John. On the opposite shore, near Digby, the upper marine limit is perhaps marked by a certain ill-defined beach at Point Prim, 75 feet above the sea, and by the uppermost river terrace at the mouths of rivers like the Bear and the Sissiboo rivers, whose height is 65 to 75 feet. At Truro an extensive outwash deposit which appears to be an estuarine plain, at an altitude of 60 feet, is the only index to the amount of post-Glacial marine submergence and re-elevation.

Along the south coast of the peninsula, and on Cape Breton island, no signs of post-Glacial elevation whatever were found. If any movement has taken place here since the withdrawal of the ice, it appears to have been a subsidence. At Arisaig on the north shore, a brief visit in company with the members of Excursion A1 of the Congress did not convince me as to the wave-cut character of certain terraces which Dr. Twenhofel has described as raised beaches. While the lowest of these, which stands some 20 or 25 feet above the sea, has a veneer of waterworn sediments and finds extension up the mouths of creek valleys in old stream terraces, the higher terraces seem to have surfaces of glacial boulder clay, to lack uniformity of level, and to disappear entirely in the re-entrant places along the slope, where a fully-matured sea cliff would give way to an equally distinct beach ridge. As suggested by other members of the party, these upper terraces may prove on further study to be wave-cut terraces of an early date, overridden but not entirely obscured by the last ice advance. This hypothesis calls to mind certain high-level terraces found a few years ago on the Gaspe peninsula which seemed explicable only as records of marine submergence of an inter-glacial or pre-Glacial epoch. It is hoped that next season's work will shed light on the question.

Glaciation of the Magdalen Islands.

A brief visit to the northern peninsula of Cape Breton island disclosed the fact that it, like the northern part of the peninsula of Nova Scotia, had been glaciated by ice moving eastward. This led to the expectation that a study of the Magdalen islands, which lie not far to the north of Cape Breton, would show that the ice-sheet had covered them, also, particularly since the water which surrounds the Magdalens and separates them from the glaciated islands already mentioned is only about 30 fathoms deep, and thus quite insufficient to float an ice-sheet of moderate thickness. A hurried trip was, therefore, made to the Magdalens on the *Lady Sybil*, giving opportunity to go ashore at four of the islands. On Amherst island, the first one visited, a sheet of boulder clay containing foreign stones and striated till pebbles of local volcanic rock was found. It is not less than 12 feet thick, and lacks stratification. I do not think it likely that such a deposit marks simply the action of sea ice during a stage of submergence; but on the contrary am inclined to regard it as proof of the extension of the New Brunswick ice sheet across this part of the submerged plain of the Gulf of St. Lawrence. Striated stones were found also on Alright island; and stones from foreign sources on all the islands touched. Although the general covering of the islands is residual in character, as others have pointed out, the occurrence of these glacial materials seems to require that the Magdalens were glaciated. Detailed study will be required to show to what extent and during which of the Glacial epochs this took place. Hitherto the islands have been regarded as quite unglaciated.

GEOLOGY OF THE PORT MOUTON MAP-AREA, QUEENS COUNTY, NOVA SCOTIA.

(*E. R. Faribault.*)

Introduction.

The writer's field work in Nova Scotia during the season of 1913, was the continuation of the mapping of the western part of Queens county. It consisted in the topographical and geological survey of the Port Mouton map-area covered by sheet No. 92 and the revision of the geological structure of the western part of the New Germany map-area covered by sheet No. 95. This completes the field work necessary to finish these two sheets.

In the New Germany area are situated the gold-mining districts of Brookfield and of Pleasant River Barrens. A detailed survey of Pleasant River Barrens was made and a plan published on the scale of 500 feet to 1 inch, and an accompanying report is included in this volume. A plan of the Brookfield gold district was published in 1908 on the scale of 250 feet to 1 inch.

The writer was again assisted in the field by J. McG. Cruickshank and R. A. Tapley for the whole season, and by W. P. Crowe and J. C. Hanson for parts of the season. The long experience of Mr. Cruickshank in the Gold-bearing series was especially valuable in working out the detailed structure of the rocks, while Messrs. Tapley and Crowe proved most efficient in the topographical surveys. Field work commenced on May 21 and continued until the end of November.

Location and Physical Features.

The Port Mouton map-area, covered by the Nova Scotia serial sheet No. 92 and including the small land area comprised in sheet No. 91, lies on the Atlantic coast, at the southern extremity of Queens county. The southern limit of the map-area fronts on the Atlantic and extends from Liverpool bay westward to Port Hébert; the northern boundary lies just south of the town of Liverpool, while the western boundary passes 3 miles east of First lake, and crosses Broad river at the foot of Long Point stillwater.

The surface is drained for the most part by Broad and Five rivers and their tributaries, and also by a few smaller streams, flowing southerly to the Atlantic.

The whole surface of the area of the Gold-bearing series bordering the Atlantic has been subjected to extensive erosion, and all that remains of what was once a highly-elevated mountain system is a plateau reduced nearly to sea-level. The plateau has a general southerly slope toward the Atlantic, and its elevation seldom exceeds more than 200 or 300 feet above sea-level.

The hills and valleys have a general southeasterly trend, and in the immediate vicinity of the shore they are more marked than in the interior where the surface is generally level and occupied by large swamps, hay marshes, and peat bogs drained by a succession of sluggish streams and small lakes, with but few rapids or falls. Much of the lowland is made up of coarse sandy material and loose pieces of rock with clay alluvium deposits along the depressions, while the hills are largely composed of thick deposits of boulder-clay and rock debris carried from the north by glaciation.

Along the foot-hills and the edge of the flat intervals, the surface is often strewn with large angular blocks of weathered rocks detached from the thick beds of quartzite of the region.

In the interior, rock exposures are scarce, but the bedrock is generally well exposed along the sea-shore and along the rapid parts of Broad river and some of the other streams.

The greater part of the area has been burnt over repeatedly, and is either barren or covered with young growth. A few small patches of spruce and pine timber, partly culled, are still to be found in the northern part of the map-area. A certain amount of logs are driven down Broad river every year and cut at Leslie Brothers' saw-mill at the head of tidewater. The land affords very little good soil for agricultural purposes and the interior is altogether uninhabited and not even traversed by a public road. Good coarse hay grows naturally on many of the large marshes of the interior, and much is cut annually for cattle.

All the habitations are confined to the sea-shore where several small settlements are scattered along the head of harbours, coves, and bays. On some of the long convex hills of glacial drift a few farms and gardens are cultivated successfully by the use of an abundant supply of fish refuse and sea-weeds as fertilizers. Cranberry-vine is cultivated on a small scale on a marsh at Southwest Port Mouton. The most important settlements along the coast are Western Head, Hunt Point, Port Mouton, Port Joli, and Port Hébert.

Most of the inhabitants are engaged in fishing for cod, haddock, herring, mackerel, lobster, and eels. At the mouth of Port Joli lobsters are trapped in winter and exported to the Boston market at a good profit. Eels are exported alive in barrels. The recent introduction of motor boats for fishing and of cold-storage boats to collect and ship fresh fish, has done much to facilitate and promote the fishing industry along the Atlantic coast.

Port Mouton affords a good anchorage inside of Mouton island for the refuge of large and small vessels. Port Joli and Port Hébert are long, narrow inlets with shallow, muddy, and grassy bottoms, affording good feeding grounds for wild geese and ducks which flock here in large number during the winter months.

One of the remarkable features of the coast is the great number of beautiful white crescent-shaped sand beaches fringing the heads of coves and bays facing the broad Atlantic. The largest sand beaches are those of White point, Summerville, Southwest Port Mouton, Little Joli bay, Cadden bay, and Sandy cove. They generally consists of sand bars enclosing saltwater ponds and marshes, and on some of these the action of the wind has developed prominent sand dunes, those of Port Mouton being especially remarkable for their altitude and their glistening whiteness.

The line of the Halifax and South Western railway runs through the district along the sea-coast, and gives daily communication with Halifax and Yarmouth from Port Mouton, which is the most important centre. One highway also runs westward from Liverpool toward Yarmouth, touching the head of Port Mouton, Port Joli, and Port Hébert, with local branch roads to the settlements on the sea-shore, but no road runs north into the interior.

Geology.

The Port Mouton map-area is wholly underlaid by the Gold-bearing series, which occupies the whole of the southern half of the province along the Atlantic, from Canso to Yarmouth. The series consists of a great thickness of more or less metamorphosed quartzites and slates, estimated at 30,048 feet, together with intrusions of granite and dykes of diabase.

The sedimentary series is divided lithologically into two divisions: a lower one, called the Goldenville formation, consisting of thick beds of quartzites with intercalated layers of slate, estimated at 18,348 feet in thickness; and an upper division, called the Halifax formation, composed essentially of slates and estimated at 11,700 feet. After being deposited conformably as sand and clay beds on a sea-bottom, probably in late Pre-Cambrian time, these sediments were closely folded, mostly during the early Devonian, in long east-west anticlines, then intruded at the close of the Devonian by many large batholiths of granite and by dykes of diabase.

In the process of folding, the sand and clay beds were much cleaved and indurated, and later, during the granite intrusion, were more or less metamorphosed into quartzites or gneisses and slates or schists, or sometimes even probably completely absorbed into the granitic masses at the contacts. Extensive erosion, over a long period of time, has truncated the crest of the folds and gradually planed down the surface to its present level, exposing the up-tilted, once deeply-seated strata and the low granite masses that intruded them.

The age of the series cannot be determined by palæontology as it is practically barren of fossils. From lithological analogy, they have been regarded until recently as Lower Cambrian, but they are now believed to be late Pre-Cambrian in age.

DISTRIBUTION AND CHARACTER OF THE FORMATIONS.

With the exception of a narrow zone of the Halifax formation occurring along the deep trough of a sharp synclinal fold, all the sedimentary strata exposed in the map-area are the quartzites and slates of the Goldenville formation, or their metamorphic equivalents the gneisses and schists.

In the southern part of the map-area, along the seaboard, the sedimentaries are intruded by masses and dykes of granite and by dykes of diabase. The largest mass of granite is a batholith intrusion spreading east and west along the seashore for a distance of 13 miles between White point and Port Hébert and measuring 8 miles in width from Port Mouton railway station to Joli point.

To the south of the Port Mouton batholith, gneisses and schists reappear again on the peninsula between Port Joli and Port Hébert and at the southern extremity of Joli point, where they are penetrated by numerous lenses and dykes of granite and pegmatites, generally lying in the plane of schistosity which coincides with that of bedding. The sedimentaries of that area are so coarsely crystalline as to suggest their similarity to some varieties of the Laurentian complex, but they are undoubtedly only an extreme metamorphosed phase of the quartzites and slates of the Gold-bearing series. An examination of these rocks farther west, beyond the western extremity of the granite batholith where they join the main area, will no doubt settle this point conclusively.

On Liverpool bay, between Moose harbour and Scott point, a small mass of light pearl-grey muscovite granite, three-quarters of a mile in length, extends between the shore and the road; and a short distance inland from Scott bay, a smaller mass of the same granite is also exposed; while along the shore, from Scott bay to Western head, and farther west at Black point, numerous dykes and reticulated veins of granite penetrate the sedimentary rocks and metamorphose them into different varieties of gneisses and schists.

The large and persistent dyke of diabase, previously traced along the coast in a southwest direction for 25 miles from West Ironbound island to Cowie brook, just north of the town of Liverpool, was located across the Port Mouton map-area, where it crosses Five rivers at Jim brook and Broad river at Huphman landing, then follows the north side of the railway to and beyond Wilkins station. This dyke has thus been traced for a length of 42 miles, and its width varies from 200 to 600 feet with a few short spurs in places. The alteration due to the diabase intrusion does not extend more than a few feet from the line of contact. The altered zone is generally impregnated with magnetite weathering to red hematite, which gives the soil a characteristic colour indicating the presence of the dyke where it does not outcrop.

Another dyke of coarse greenish black diabase, 330 feet wide, outcrops conspicuously at Black point, on Liverpool bay, but does not appear to extend any distance west from the shore.

The sedimentary rocks show every gradation of metamorphism from slightly altered quartzites and slates in the northwestern part of the map-area far remote from granitic intrusion, to completely recrystallized coarse gneisses and schists along the seaboard where they are intruded by granitic masses and dykes. The metamorphism is sometimes so intense as to blend the two rocks with no perceptible line of contact.

The gneisses are dark grey and consist chiefly of quartz more or less coarsely crystalline, with some foliated mica. The schists are silvery light grey to dark grey, and mostly composed of foliated mica with more or less crystalline quartz. Near the granite contacts some layers of the more coarsely crystalline varieties of schists contain crystals of hornblende, staurolite, or garnet, as at Scott bay. Some hard siliceous layers are heavily charged with well-developed stout grey crystals of feather amphibolite showing in relief on weathered surface, as on the shore of Liverpool bay. At Huphman landing on Broad river, immediately north of the diabase dyke, in biotite schists of the Halifax formation, were observed lenticular aggregations of quartz, orthoclase, sillimanite, and damourite, the latter in plumose form. In Sandy cove on the west side of Port Joli, and at other places in that vicinity, pegmatite dykes show coarsely crystalline associations of quartz, orthoclase, microcline in plates, damourite in plumose forms, and garnets in small crystals.

Along the seashore the rocks are generally well exposed and offer a good field for the study of various kinds of granitic and diabase intrusions, igneous contacts, metamorphism, and mineral developments.

STRUCTURE OF THE SEDIMENTARY SERIES.

Much economic importance is attached to the location and structure of the anticlinal folds and domes, because practically all the gold and tungsten-bearing veins are found aggregated on domes of pitching anticlines.

In the eastern part of the province the folds have a general east and west direction, but in the western part they take a southwesterly direction. In the Port Mouton map-area, the quartzites and slates of the Gold-bearing series are closely folded into long parallel anticlines and synclines whose axes have a uniform northeast and southwest direction. The strata on the limbs of the olds dip at angles varying from 45 degrees to 90 degrees from the horizontal. Most of the folds pitch easterly at low angles. Two of the anticlines, however, pitch in opposite directions and form within the map-area two long and narrow domes, on one of which gold-bearing quartz deposits have been discovered, a short distance west of the map limits.

The structure of the folds is not affected by the igneous intrusions, the attitude of the strata remaining generally undisturbed right up to the lines of contact. No cross-country faults affect the region, but small local faults have been observed, and one important dislocation at right angles to the folding in the vicinity of Five river, has disturbed the strata for a few miles northward from the seashore.

The structure of the gneisses and schists of the small area lying south of the main granitic batholith on the peninsula between Port Joli and Port Hébert, does not, however, harmonize with that of the main area to the north, for the strata have a general north and south strike and dip nearly vertical. This would indicate between the two areas an important dislocation which might be established farther west at the western extremity of the granitic batholith.

The greatest width of the Gold-bearing series in the Port Mouton map-area, measured at right angles to the folding, is 11 miles from Western head to Clancy meadow in the northwestern corner of the map-sheet. A transverse section between these two points shows that the strata have been folded into three major anticlines and two intervening synclines, whose axes are nearly parallel and have a northeasterly and southwesterly direction.

The following list of major anticlines and synclines gives the order in which they occur from Western head to Clancy meadow, together with some notes on their location and structure:—

1° Anticline.—Begins 0·3 mile north of Black point on the western shore of Liverpool bay, where it has a decided pitch to the east; runs in a southwesterly direction, crossing Gull Island road 0·1 mile north of the farthest north house, where it pitches west at low angle; and ends at the mouth of Five river, where it is cut off by the White Point granite. Between Liverpool bay and Gull Island road the anticline forms a much elongated and narrow dome, the centre of which is probably not far distant from the latter road.

This dome may be mentioned as one of the most favourable places for the occurrence of gold-bearing veins. Rock exposures are scarce, and no quartz veins were observed on the dome; but west of the inlet of Five river and close to the granite contact and to the seashore, some interbedded quartz veins were located.

On this dome are exposed the lowest yet known strata of the Gold-bearing series. It is estimated that 18,348 feet of strata of the Gold-bearing formation are exposed in a continuous sequence between the apex of the dome and the base of the Halifax slate formation at Milton. This thickness is 2,348 feet greater than that previously recorded at Moose river, Halifax county, and added to the 11,700 feet of slates of the Halifax formation, as exposed in the eastern part of the field, will give a total known thickness of 30,048 feet for the Gold-bearing series. We may further assume that this enormous thickness of exposed strata forms only a part of the whole thickness of the series. It shows also the immense amount of erosion which has taken place over a very long period of time.

Several small subordinate folds were located on this major anticline. On the north limb, three-quarter mile north of its axis, one syncline and one anticline are developed, one-quarter mile apart, east of Five river, in the vicinity of the railway. This fold appears to terminate eastward before reaching the shore of Liverpool bay. On the south limb, the strata are folded into five subordinate small synclines and as many anticlines, within a distance of a little over 2 miles, between the major anticline and Western head. The folds were located on the shores of Liverpool and Gull bays, but could not be traced inland between the two bays, as the rocks are not exposed.

1° Syncline.—Crosses Liverpool river at Milton, halfway between the two upper bridges, and Five and Broad rivers, 2 miles north of the main shore road, and is cut off by the granite batholith, 3 miles west of Port Mouton station and 1 mile south of the railway.

This is the deepest synclinal trough of the district and the only one along which the Halifax slate formation lies, forming a zone 1½ miles in width. On the north limb, between Broad and Five rivers, a small subordinate fold was located, along which several large veins of quartz were observed crossing Bearhole brook and Five river and at a few other places. Above Huphman landing on Broad river and on the portage road, the slates are highly altered into coarse mica-schists with intercalated layers of staurolite schists and lenses of pegmatitic associations of orthoclase, quartz, sillimanite, damourite, and possibly other rare minerals.

2° Anticline.—The axis of the fold runs southwesterly across Trout pond on Five river where it pitches westward; passes a short distance south of the dam at the foot of Crooked stillwater on East Branch of Broad river; and crosses Broad river half a mile above Campbell mill pond, and the railway a little east of Mitchell brook, while a short distance further west it is cut off by granite. On account of the scarcity of the rock exposures, it is difficult to determine the structure of the fold.

2° *Syncline.*—Passes at the head of Shalnoes lake, where the fold forms a broad trough pitching east, and extending southwesterly it crosses the East Branch stream a little below Long Stillwater, and Broad river at the inlet of Indian-log brook.

3° *Anticline.*—Crosses the East Branch 0·4 mile north of Clancy's meadow, and Broad river at 0·15 mile north of the inlet of Little Lake brook, and runs southwesterly along the south shore of Little lake. North of Clancy's meadow the bedrock is well exposed and shows the strata to curve broadly on the eastern pitch of the fold, and dip from 45 degrees to 55 degrees on both limbs, while westward betwen the river and Little lake the few outcrops observed indicate a western pitch and the strata to dip N. 45° and S. 55° to 60°. The fold forms undoubtedly a much elongated dome between these two points, but on account of the scarcity of the rock exposures it is difficult to determine its structure.

This anticline is of special economic importance on account of the very rich float of gold quartz found on its axes, a short distance west of the western limit of the map-sheet, on the western side of the river, just north of Little Lake brook and east of the portage road. Loose blocks of white quartz also were observed along the anticline at a place situated 1½ miles east of Broad river and one-quarter mile south of Oak hill.

Economic Geology.

GOLD.

No gold deposits have been mined or prospected as yet within the map-area limits.

One prospect hole was opened for gold on an interbedded vein, in the Halifax slate formation, at the head of Bearhole brook, 2¼ miles up Beach Hill road; but it is said that it did not show any values. Several other interbedded veins occur here between Five and Broad rivers in the slate of the Halifax formation along a subordinate fold on the north limb of the first major syncline. The width of some of the veins runs up to 6 and 10 feet, but they do not appear to contain gold.

A considerable amount of prospecting for gold was done, however, 1 mile beyond the western map limit, 7 miles up Broad river, on the western side of Long Point stillwater, on a swampy island formed by two channels of the Little Lake brook. About the year 1888, Louis Labrador and Mitchell discovered here a large boulder of quartzite, from 3 to 4 tons in weight, split in two parts, and on one of the split faces was adhering a sheet of quartz, one inch in thickness, peppered with coarse gold. Since then several attempts have been made by James McGuire and others to find the vein, but the swampy nature and thickness (5 to 7 feet) of the surface covering hindered prospecting considerably. A few small veins are said to have been cut and more gold float found in the prospecting trenches and pits opened. At the time of the visit the veins were covered over. One of the veins is reported by Mr. McGuire to have a course bearing a little north of west and to intersect the strata obliquely, and is believed to be that from which the rich float was derived, although it shows only a little fine gold where it was cut. It is said to be irregular in width, swelling up to 4 inches in soft rock and tapering to nothing in hard rock. This gold discovery is situated on the western pitch of the dome already described on the third major anticline, quite close to the axis, where the geological structure and conditions are generally favourable to the development of gold-bearing quartz veins. The locality along the western pitch of this dome is considered well worth the attention of the prospector.

Gold float was also found by Labrador and Mitchell three-quarters of a mile north-west of James McGuire's prospect, on the road toward Payzant meadow; also 1½ miles north of the same prospect on the portage road to Flake woods. A few trenches and pits were opened at both places searching for the source of the gold, but apparently without success. In this locality the bedrock is wholly covered with drift, and judging from the structure of the rock farther east, there is no indication of an anti-clinal fold passing through these places. It is better, however, to reserve conclusion on this point until the investigations have been carried farther west.

It is said also that Labrador and Mitchell brought to the settlement some rich gold quartz from other parts of Broad river, the locations of which were never made known.

IRON.

A reference has already been made to the occurrence of magnetite in the sedimentary rocks along their contact with the large diabase dyke traversing the map-area. The amount of iron, however, is probably nowhere abundant enough to be of economic importance. A concentration of the decomposed magnetite in the form of bog-iron deposits in low places along the line of contact was observed also, but in too small quantities to receive attention.

Bog-iron deposits were observed also at a few places along the narrow zone of pyritous slate extending along the first syncline, and crossing Broad river at Iron Rock and Five river 2 miles above the Liverpool-Shelburn road; but the deposits appear to be of too little extent and depth to be of commercial value.

BUILDING STONE.

Granite has been obtained mostly from large boulders at White point and Hunt point, but only for local use such as foundations, walls, and wharfs at Liverpool, and for the abutments and piers of bridges on the Halifax and South Western railway. The White Point granite is mostly fine grained and of a light grey colour, and is taking a very durable, good polish and not subject to colour change.

ROAD METAL.

Diabase takes high rank among the natural road building materials because of its hardness, toughness, fineness of grain, homogeneity, and good binding power. So far not a single quarry has been opened in any of the diabase dykes which abound in the western part of Nova Scotia. The materials crushed to macadamize streets and roads in Nova Scotia are generally quartzite, slate, limestone, and granite, all of which are very deficient in qualities required for good road metal.

In the Port Mouton map-area, two large dykes of diabase are well situated with respect to roads and railway and shipping facilities. One of these crosses Liverpool river at the railway bridge above the town of Liverpool and traverses the map-area in a southwesterly direction toward Wilkin Siding. The other one outcrops at Black point, on Liverpool bay, where vessels could be loaded directly off the ledge of rock.

SAND.

Attention has already been drawn in last year's Summary Report, to a deposit of "Rock flour" or glacial quartz till observed at the dam of the mill pond on Meadow brook which runs through the town of Liverpool, at the northern limit of the map-area. The material is composed of fine crushed quartz, nearly free from impurities, and the particles are highly angular and unweathered. The physical qualities of this sand may render it particularly serviceable in the manufacture of wood filler, scouring soaps, polishers, and sand paper.

An unlimited supply of dune and beach sand is available along the many beaches fringing parts of the seashore. Most of the sand is fine grained, wind-and water-worn, and siliceous, and may be suitable for many uses. The dune sand at Southwest Port Mouton is white in colour, fine, and of uniform size, and highly siliceous, and it may have the necessary qualities for the manufacture of good glass. Some deposits of the coarser variety of sand and of gravel would be suitable for building purposes, although it is much water worn. It is said that some years ago quite a lot of sand, mostly of the coarse variety, was transported by vessels to Halifax for building.

OTHER DEPOSITS.

Dykes of pegmatite penetrating the granite, as well as the schists and gneisses in the vicinity of the granite, are quite numerous along the sea coast. They appear to be of the same nature and probably belong to the same phase of intrusion as that of New Ross, and like these they may contain useful minerals, such as that of tin, tungsten, molybdenum, bismuth, copper, lithium, thorium, etc. Orthoclase feldspar occurs often in large crystals, but they are too intimately associated with the other constituents to be worth considering as of commercial importance. No special examination has been made yet of the pegmatites and their associated minerals with the view of determining the presence of rare minerals. They are certainly worth being investigated.

The pegmatite dykes are best exposed along the seashore, and more especially along the western shore of Port Joli, on Cadden bay, Little Joli bay, and Western head.

GEOLOGY OF THE GOLD DISTRICT OF PLEASANT RIVER BARRENS, LUNENBURG COUNTY, N.S.

(*E. R. Faribault.*)

Location.

Pleasant River Barrens gold district is situated in the northwestern part of Lunenburg county, on the road between Bridgewater and Pleasant River, 15 miles north of the town of Bridgewater, 6 miles southeast of Pleasant River station, and 3 miles south of a siding on the Caledonia branch of the Halifax and South Western railway. It lies on the height of land between Lahave and Pleasant rivers, halfway between Rhyno and Lower Shingle lakes. It is drained by Bridge-meadow brook flowing westward into Lower Shingle lake, and by a part of Dexter brook flowing eastward into Rhyno lake.

The greater part of the district is quite level, and mostly covered by swamps and meadows separated by long parallel outcrops of thick beds of quartzite standing out in wave-like ridges. Toward the south and southeast the surface rises and forms Moose-pit and Stony hills which do not attain more than 100 feet above the lowest level of the area.

Geology.

The district lies on a dome of quartzite of the Goldenville formation of the Gold-bearing series, formed by the plunging of an anticline to the east and west; the anticline being the eleventh one crossing Lahave river to the north of West Iron-bound island on the Atlantic coast. The axis of the anticline runs eastward across Hirtle, Kaulback, Mader, Grant, and Church lakes, beyond which it is cut by granite. Westward, it passes at the outlet of Lower Shingle lake and crosses Pleasant river a short distance below the bridge on New Elm road, beyond which the anticline terminates by meeting a subordinate syncline that extends northeasterly for 3 miles, at the end of which another anticline begins and runs southwesterly through Brookfield gold district, where it forms another dome. The two anticlines may be considered as one and the same anticline effected by a transverse syncline, producing the two domes which are 6 miles distant from one another.

This dome approaches more the circular form than any other known in the Gold-bearing series. Thick massive beds of quartzite, dipping at low angles and over-lapping one another, outcrop nearly everywhere and stand out prominently in long curved and parallel ridges, 5 to 30 feet high. A few of these have been traced in the field, more or less continuously around the dome, and are indicated on the plan, showing well the general structure of one of the most beautiful elliptical-shaped domes.

Folding and subsequent erosion have been sufficient to expose the upper beds of the Goldenville formation in the form of an ellipse, 3 miles broad and 5 miles long, while more remote from the centre of the dome and overlying the quartzites are the slates of the Halifax formation. The dome has its centre on area 32, block 2. From the centre, the axis runs S. 83° E. (magnetic), plunging to the east at an angle increasing gradually from a very low angle near the centre to 30 degrees; and in the other direction, its course is S. 85° W., pitching westerly at an angle increasing gradually to 20 degrees. The dip of the strata to the north and south increases also gradually from the centre to 44 degrees on the north limb and 35 degrees on the south.

The horizon of the strata of the Goldenville formation exposed by erosion at the centre of the dome is 3,950 feet below the base of the Halifax formation.

Radiating from the centre of the dome toward the east, southeast, and northeast, are several subordinate gentle undulations, or flexures of the strata, on which fractures were formed favouring ore deposition. On the southwestern part of the dome originates one broad undulation which develops toward the southwest into an important anticline and syncline. It is worthy of note, that on the western and northwestern part of the dome, where the strata curve regularly in portions of perfect ellipses, without undulations, no quartz veins have been found.

The dome has suffered also some dislocations, along lines generally radiating from the centre of the dome toward the southeast and northeast. An important zone of dislocation runs from the centre in a southeasterly direction following swampy depressions. On the northeastern part of the dome, faults have been found in the western end of the workings on the Mill lead and in other explorations in that vicinity. There is possibly also a small fault following the anticline toward the west. The lines of faulting indicated on the plan are only approximatively located, and in most cases only inferred from structural evidence in the field.

The faults are local and confined to the dome, and, as has been proved in several other districts, they probably do not extend to much depth. They are younger than the folding and the veins, and are probably due to comparatively recent orogenic movements brought about after the dome had been relieved by erosion of the greater part of the superincumbent mass lying above the present surface.

Between Moose-pit hill and Stony hill the rock surface has been eroded by a local glacier. The magnetic directions of the glacial striæ observed are: lot 448, block 4, on the main road, 1,500 feet south of Awalt lead, S. 28° E. (magnetic); lot 407, block 5, on the road to Moose-pit hill, S. 48° E. (magnetic); lot 213, block 5, 375 feet south of Moose-pit Hill road, S. 32° E. (magnetic).

Character of the Deposits.

All the veins found in the district are comprised within an area measuring 1⅓ miles east and west, by 1⅓ miles north and south. They are not numerous, and do not occur in groups close to one another, as in some of the more important gold districts, but they are rather scattered around the broad dome, and extend as far as 5,000 feet east, 3,000 feet west, 3,000 feet north, and 4,000 feet south from the centre. The greater number, however, are found in a circular zone on the eastern portion of the dome, where the strata, after curving over the dome, begin to assume a more constant dip. All the most important are situated at but little distance on each side of the Bridgewater and Pleasant River roads.

The two types of auriferous quartz veins are represented, the interbedded and the cross veins. The latter veins are locally called "fissure" veins, to distinguish them from the stringers that do not contain gold outside of the main veins from which they branch off and are called "angulars," or "feeders."

The interbedded veins generally lie in layers of slate intercalated between thick beds of quartzite. They necessarily strike and curve with the strata, and dip away from the centre at the same angle. The quartz in these veins is generally banded and sometimes lies in distinct layers which are different in character, indicating intermittent fissuring and deposition.

The cross veins strike across the strata in more or less straight lines, dip at high angles, and generally are very irregular in width. In these veins the quartz is more coarsely crystalline and shows no banding as in the other type of veins.

In most of the veins the ore occurs in shoots formed at the junction of angulars, always entering on the footwall side. Some of the ore-shoots were found very rich at the outcrop, but they do not appear to have proved persistent in depth. On some of the veins, the ore bodies were lost probably because the developments were not conducted in the right direction and with due regard to structural conditions. This is especially the case with the early developments.

At the time the survey was made, no mining operation was in progress, and no underground workings were opened for examination; and only a few of the veins could be observed at their outcrops. The information obtained regarding the character of the ore bodies and the extent of the developments was from the recollection of local miners, and it was often incomplete and probably also more or less inaccurate.

The richest ore-shoot in the district was found on the Dunbrack lead at the junction of an angular entering on the footwall side and coming from the southwest. The Dunbrack lead occurs also here on an undulation of the strata radiating from the centre of the dome toward the east along the major anticline. The lead was thus formed under two peculiar structural conditions, which are generally favourable to the development of an ore-shoot. The ore-shoot pitches north 25 degrees, and was found to be very irregular in size and value.

Mr. W. H. Prest, who last worked the Dunbrack ore-shoot, gives the following information: "The vein causing the ore-shoot is a "fissure" vein striking southwest and dipping northwest 85 degrees. It is irregular in structure, some parts showing 12 inches of quartz, while other portions are made up of many seams of quartz and crushed slate mingling with and apparently passing into the vein matter of the ore-shoot on the interbedded vein. The ore-shoot though varying in depth will average about 20 feet in length, measured horizontally, the gold passing into the fissure. The fissure, however, appears to be barren, except at or near its junction with the interbedded vein. The latter vein is of very variable width, from 2 to 12 inches, and where seen south of its junction with the fissure is very narrow and completely barren. Its extension towards the north has not been found north of the ore-shoot, though an interbedded vein has been reported in that direction. The evidence seems to bear out the opinion that the Dunbrack lead was impregnated with gold only in the later stage of its formation. The more regular portions of the lead are barren, or almost so, and cut through by the fissure; while the most irregular and twisted portions that are closely connected with the fissure are the richest. Some portions of the barren parts of the lead within the ore-shoot show an additional thin layer of quartz well filled with gold and apparently connected with the fissure, while the rest of the lead was cut by the fissure, and was barren."

A small ore-shoot was found on the Joe Thompson lead at the junction of a 12-inch angular coming in from the northwest. The angular does not actually pass into the lead, but terminates in the slate underlying the lead, where it ramifies into small stringers impregnated with gold which constitute the ore-shoots. At the depth of 20 or 30 feet, however, the ore-shoot is said to pinch out.

No information could be obtained regarding the character of the ore-shoots on the Pine Tree and the Mill leads, which were both worked to the depth of 75 feet.

The ore deposits developed on the S. Ernst and the Deal fissure veins, and possibly also on the Brignell, occur apparently also in shoots at the intersection of interbedded veins or the junction of angulars entering on the footwall side. The ore is generally low grade, and the value of the gold is less than that of the interbedded veins. In some returns from the Brignell vein, the value of gold is said to have been as low as $16 per ounce, while in the interbedded veins it is nearer $20 an ounce. Although irregular in size, the cross veins are generally larger and more persistent than the bedded veins; they also dip at higher angles and can be worked at less cost than some of the interbedded veins dipping at low angles. On this flat dome, it is believed that the cross veins are more promising than the interbedded veins.

Float of rich gold-quartz has been found on both sides of the road, and much prospecting has been done searching for the veins. Unfortunately, owing to ignorance of the rock structure, much of the early trenching was in a direction parallel with the leads, and probably some of the richest leads in the district are not yet discovered.

Probably the richest float was found on areas 848 and 849, block 4, a short distance east of the road. An examination of the float shows that it comes from an interbedded vein, 10 inches wide, enriched by quartz stringers. The ore body may be found southwest of the Wilson shaft at the intersection of the Dunbrack angular with an interbedded vein occurring on the undulation running eastward along the major anticline. In tracing the float northward to its source, the direction of the glaciation, which is here about S. 35° E. (magnetic), should be followed.

Rich float, from two or more interbedded veins, has been found one-half mile farther south, on the eastern side of the road and the northern end of Stony hill. A great deal of prospecting has been done searching for the leads, but without success. The surface covering is deep and the float may have been carried some distance south from its source. The leads probably occur on the undulation radiating southeasterly from the centre of the dome and crossing the Mottled, Brignell, Blue, and Awalt veins.

Still farther south, on the east side of the road, in line with S. Ernst vein, on lot 145, block 4, loose pieces of 10-inch gold-quartz were found. Many prospecting trenches were opened in the thick drift covering, but without success. The float is believed by local miners to come from the eastern extension of S. Ernst vein.

We may conclude that the knowledge of the geological structure of the dome is necessary to the discovery and successful development of the ore bodies, and that the publication of the structural plan and sections of the district may lead to practical results.

History and General Development.

Gold was first discovered in the eighties, at a short distance north of the Mill lead, by a Cape Bretoner named McRay. Since then, a few veins have been developed, but no important operations have been carried on yet. The greatest developments on any veins do not attain more than 85 feet in depth and 180 feet in length. The depth of the shafts indicated on the plan were from the recollection of miners and are only approximate.

Proceeding from north to south along the road, the veins that have been worked come in the following order:—

The Pine Tree lead lies 450 feet north of the road in a slate layer intercalated between beds of quartzite, strikes S. 85° E. (magnetic), and dips N. 42°. It was traced at the surface some 400 feet in length. A shaft was sunk 75 feet, and a level driven westward 75 feet, above which the lead was stoped to the surface. The lead is 6 to 8 inches at the surface, and only 3 inches at the bottom of the shaft.

The Mill lead, also called McDonald lead, was worked on the Wade property, immediately east of the road, where the old Thompson stamp-mill still stands. It is about 8 inches, strikes S. 77° E. (magnetic), and dips north 30 degrees. Three shafts have been sunk, the one farthest east to a depth of 75 feet, the next one 50 feet, and the west one 30 feet. The block of ore stoped extends from the bottom of the three shafts to the surface and for a length of 180 feet.

The Dunbrack lead was worked on the Wilson property, 800 feet east of the road. An inclined shaft was sunk 125 feet on the ore-shoot pitching north 25 degrees. At the outcrop of the ore-shoot another shaft was sunk 63 feet on the dip of the lead at 32 degrees. Two levels were driven from the latter shaft, one at the depth of 30 feet for 20 feet southward, and the other at the depth of 50 feet for 70 feet northward. It is stated that some of the ore at the junction of the two veins yielded $3,000 per ton, and much gold was found in the gouge following the angular. The discovery of this rich shoot led to a short-lived boom. The Field of Gold Mining Company was organized with an enormous capitalization, the Thompson big mill on the Wade property was remodelled, and other buildings erected. Returns from the Dunbrack lead were very encouraging, work was started on the Pine Tree lead and explorations on other leads were stimulated for a while. Then the ore-shoot on the Dunbrack was lost and mining ceased. This was in the spring of 1891, and the Dunbrack was not worked until 1895, when it was bonded from the Field of Gold Mining Company and opened by J. W. Ferguson and Wm. McNeil. The ore-shoot was recovered and some good-looking ore was got out, but an attempt to sell the mine led to litigation and a cessation of mining operations.

On the Brignell property, one-quarter mile west of the road, three veins have been worked, the Brignell cross-vein and the Blue and Mottled leads. The Brignell vein is believed to be the continuation of the Deal fissure vein opened nearly one-quarter mile northeastward by two pits, each 15 feet deep. It strikes N. 33° E. (magnetic), and dips south 85 degrees. A shaft was sunk 85 feet and levels driven 35 feet southwesterly and 40 feet northeasterly, and some stoping was done on the former level. The vein is very irregular in size, the largest portions varying from 6 to 48 inches, with a gouge following the hanging wall. The Blue lead and the Mottled lead were both sunk only 20 feet in depth on a dip of 25 degrees and 28 degrees respectively. A five-stamp mill was erected in connexion with the shaft engine on the Brignell vein for testing the ore.

One-quarter of a mile southwest of the Brignell is the Joe Thompson lead, on which two shafts were opened from the same point, one 25 feet following the junction of the angular, and the other 48 feet on the dip of the lead. Some little ore was crushed at the Brignell mill.

Three-quarters of a mile south of the Wilson mine, on the west side of the road, is the Simeon Ernst mine on a fissure vein striking east and west (magnetic), and dipping north 53 degrees. It was opened in 1903 and prospected by Simeon Ernst, Aaron Crouse, and Baker for 1,200 feet along its outcrop. The explorations were much hindered by the heavy surface covering. A shaft was sunk 65 feet at the junction of a 6-inch angular entering the vein from the south and dipping westward 45 degrees. At the depth of 60 feet levels were driven eastward 40 feet and westward 30 feet, and above this 10 to 16 feet of stoping was done. The vein is 15 inches at the surface and 12 inches at the bottom of the shaft. Fifty feet east of the shaft the vein pinches to a 'hulk,' but it is said to have been cut farther east on both sides of the road by Baker and Crouse, where rich float has been found. Westward from the shaft it was traced by shallow pits for a length of 630 feet, and found to vary from 23 inches down to nothing. It is reported that 53 tons of ore crushed have yielded 22 ounces of gold.

Two stamp-mills only have been erected in the district, the Thompson 10-stamp mill situated on Wade property, and the Brignell 5-stamp mill on Brignell property. They have not been used for some years, and are at present out of repairs.

THE WINDSOR-PENNSYLVANIAN SECTION ON THE STRAIT OF CANSO, NOVA SCOTIA.

(Jesse E. Hyde.)

Owing to time consumed in preparation for the Twelfth International Congress of Geologists and to the writer's attendance on the meetings later in the summer, the field season of 1913 was shorter than usual, interrupted and insufficient for the completion of the work planned. The results may be briefly stated.

The most of the season available for research was devoted to the study of a very thick section of highly-inclined strata, the lower part of which is exposed along the north shore of the Strait of Canso between Port Hastings and Port Hawkesbury, the upper part very poorly shown from Port Hawkesbury inland to the northward. The section begins with a great thickness of indurated sandstones and shales referred heretofore to the Devonian. This is succeeded by the Windsor formation, with the contact structurally conformable, and the Windsor in turn is overlain by a great thickness of Pennsylvanian rocks.

Fletcher gave many detailed sections of these rocks from the shores around Port Hastings and Port Hawkesbury. These he combined with estimates of thicknesses of the yet higher rocks poorly exposed back from the shore and obtained a thickness of 21,960 feet of "Carboniferous."[1]

However, on the map of the region (sheet 22, published in 1884), the upper 10,200 feet of this is cut off as a duplication of the lower half of the section, the result of faulting. In the sections and in the text accompanying them, no attempt is made to subdivide the "Carboniferous," but on the map these rocks are subdivided into three members: (1) Lower Carboniferous metamorphic (or Carboniferous conglomerate), (2) Lower Carboniferous, and (3) Middle Carboniferous, the last including "Millstone Grit and Coal Measures." In note 2 on the margin of the map it is stated that the boundary between the Lower Carboniferous and the Middle Carboniferous "is a somewhat arbitrary line drawn about 2,000 feet above the *Leaia* bed." Reference is then made to the section on the shore between Emery pond and Plaster cove (between Port Hastings and Port Hawkesbury) to a particular *Leaia* bed described therein as 13 feet and 2 inches thick, and the only *Leaia* bed mentioned in the description of the section.

The writer finds that many hundreds of feet of the shales and sandstones following next above the truly marine Windsor limestones of the section are rich with the *Leaia-Anthracomya* fauna, the same species to all appearances, found in the Riversdale and Union series. If this fauna extends upward to Fletcher's bed (which was not recognized by the writer) as it very probably does, at least 1,500 or 1,600 feet of sediments carry this fauna. This is the minimum distance possible of Fletcher's *Leaia* bed above the Windsor strata, by his measurements. The actual distance is probably greater as there is a large covered interval between the lowest observed *Leaia* beds and the highest Windsor. Although the writer made no measurements, it appears certain the beds in which the *Leaia* fauna is abundant are at least 1,500 feet thick. This fauna appears to be confined to the lower part of the Pennsylvanian part of this section; if present in the upper part it is far less abundant.

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[1] Geol. and Nat. Hist. Surv., Canada, Rept. Progress for 1879-80, p. 86 F.

From this it is evident that at least 3,500 feet (by Fletcher's measurements) of the beds which are mapped as Lower Carboniferous (sub-Carboniferous) in this region are Pennsylvanian in age.

The season's work was insufficient to allow any determinations of thickness to be made, but it was sufficient to show that a few thick members can be designated, each of which is the result of certain peculiar conditions of deposition, and none of which can be recognized from Fletcher's very careful enumeration of individual beds of "sandstone," "shale," etc., with their measured thicknesses. Enough was done to show that at least one of the members of the shore section with a pronounced and apparently distinctive character in its abundant ripples changes considerably along the strike and within 4 miles loses almost all of its ripples, although it retains sufficient character to be recognizable.

Although the writer is inclined to regard the Leaia-rich beds of this section as more or less the equivalent of the Riversdale-Union series about the Basin of Minas, he is not prepared, as yet, to defend this position. The beds consist of alternating beds of indurated red and green shale, both abundantly mud-cracked, with occasional sandstone members, red, green, or grey in colour. The series suggests an interesting problem as to the conditions of deposition under which it accumulated. The abundant *Leaia* suggest a phase of marine deposition, accumulation must have been rapid, and the surface of the sediments, from the ever-present mud-cracks, would appear to have been constantly near the level of the body of water in which it accumulated; for the abundant fauna suggests that almost the whole of the series must have accumulated in water rather than subaërially.

The degree of oxidation of the iron in the successive beds is a part of this problem. At present it is generally held that red, mud-cracked shales indicate terrestrial accumulation, the red colour due to the fact that most of the iron is in the ferric state, the result of oxidation under subaërial conditions of deposition. The green shales which are not infrequent in a formation where red shales are abundant, have much of their iron in the ferrous state due to the deoxidizing conditions under which it accumulated, and it is concluded that the green shales are, in general, the result of subaquatic accumulation. There can be no doubt as to the value of the generalization, and it appears to be quite applicable to the formation under consideration. But it will not always account for the conditions observed in particular beds, a very common and perhaps natural failing in all generalizations. Analyses were made of the iron content from four of the shale beds of this formation in the hope that they might throw light on the problem or suggest other lines of investigation. The results are as follows, the figures indicating percentage of the whole content of the shale:—

	Ferric oxide.	Ferrous Fe.	Total Fe.
1. Green mud-cracked shale...............	1·57	4·37	5·94
2. Green non-mud-cracked shale	1·42	5·40	6·82
3. Red mud-cracked shale	3·50	3·53	7·03
4. Red non-mud-cracked shale	3·40	3·32	6·72

Numbers 2 and 3 are in agreement with the generalization, but number 1 and, to a lesser extent, number 4, appear to be anomalous, although shale beds of the same general type appear to be not infrequent in the formation. Thus number 1, from its mud-cracks, would appear to have become subaërial some time after accumulation and would presumably be subject to conditions favourable to oxidation. Again, number 4 does not show evidence of such drying, from which it may be inferred that it was buried under other sediments without being dried. Yet the iron is in the ferric state, which must indicate conditions favourable to oxidation. The last case may be explained, however, by assuming that the iron was oxidized while in transit in streams before being deposited. The whole series is remarkably free, so far as observed, of plant remains the decomposition of which would cause reduction to go on within such a bed of buried oxidized sediment. Then, again, there is the possibility that mud-cracks in a shale bed may not be preserved, a possibility which the writer believes has been over-accented.

The structures, fauna, conditions of oxidation, etc., obtaining in the lower part of the Pennsylvanian of this section, that is, in the portion in which the *Leaia-Anthracomya* fauna occurs abundantly, suggest that these beds are the result of some phase of deltal deposition very near the surface of the water body under fresh or modified marine conditions. The interpretation of conditions is, however, open to considerable modification and further qualifications as, for example, in order to account for the accumulation of so great a thickness of fairly uniform sediments, all of them mud-cracked. It is not yet known whether the *Leaia* fauna indicates fresh or brackish water conditions, but the evidence favours the former view. Certainly it was not a normal marine fauna.

Lest the writer should be prevented from continuing the work begun on this section, one fact discovered should be mentioned, the significance of which is not yet determined but may be considerable. The Windsor beds in this section are poorly exposed around Plaster cove at Port Hastings, and along the middle stream which enters the head of the cove. There is a basal limestone bed which is unmistakable; certainly one thick bed of gypsum, but at least two if there is no faulting; at least one marine dolomite, probably more; and a considerable thickness of red, grey, and green clay shales which are very much softer than those appearing higher in the section in what, for lack of a better name, have herein been called the *Leaia* beds of the Pennsylvanian. As a result, the beds furnish very poor outcrops. The rocks dip fairly uniformly to the southeast at a high angle. On the west side of Plaster cove is a great mass of gypsum, the bed just mentioned. Overlying it are rather soft, grey, slightly calcareous shales which weather into small fragments. In these shales and not more than 75 feet above the gypsum bed, a species of *Leaia* was obtained; apparently it is fairly abundant in certain layers. On the east side of Plaster cove appears another gypsum bed, and on the hill above a rotten, yellow dolomite with a meagre marine Windsor fauna. Unless there is a fault running down the cove the *Leaia* occur below this dolomite and in the Windsor. Faulting is not uncommon in the region, but a fairly close study of all available outcrops, and the finding of marine Windsor at other nearby points suggest relationships that leave this explanation unsatisfactory; from what has been seen it appears that *Leaia* probably occurs in the Windsor, but more work must be done before this can be affirmed. Should it prove to be thus, the supposed age of the Windsor may require reconsideration in the light of this new faunal element.

A fauna with *Leaia* and *Anthracomya* characterizes the Riversdale-Union formations of the early Pennsylvanian at several points on the south side of the Cobequid axis. Apparently the same species occur in the Point Edward formation which overlies the Windsor formations in the Sydney Harbour section, as shown during the field season of 1912, and again the same fauna overlies the Windsor beds in the thick section about Port Hastings and Port Hawkesbury on the Strait of Canso, as just noted. These occurrences of the *Leaia-Anthracomya* fauna all lie south or southeast of the Cobequid axis of old metamorphics and intrusives or the line of its projection from Cape George northeastward into Northumberland strait. In all cases the fauna occurs in the formation next succeeding the Windsor series (excepting as noted above the possible occurrence of *Leaia* in the Windsor at Port Hastings). From this it is suggested that these *Leaia*-bearing beds are approximately contemporaneous, although the writer is not as yet prepared to defend this position. Certainly the mere presence of *Leaia* alone in abundance is not sufficient ground for correlation, as is shown by the discovery during the past season in the Coal Measures at Sydney of a horizon with a *Leaia* probably distinct from those lower down. This *Leaia*-bearing horizon, midway between the Emery and Phalen coal seams of the Glace Bay tract, is some 4,000 feet above the top of the Point Edward formation, according to Fletcher's determination of the thickness of the intervening Millstone Grit at Sydney.

Although great caution must be observed in correlating those beds next younger than the Windsor which carry a more or less rich *Leaia* fauna, yet it is suggested from these occurrences that, succeeding the Windsor time, there was a more or less continuous basin south and southeast of the Cobequid axis extending from Sydney southwestward to the Basin of Minas at the head of the Bay of Fundy and thence down the present Bay of Fundy at least as far as St. John, N.B. (to include the Little River group). In this basin accumulated a thick series of detrital sediments under shallow water and subaërial conditions (mud-cracks are everywhere abundant) and the conditions were favourable for the continuous presence or repeated appearance of *Leaia-Anthracomya,* and associated species.

Bell in his detailed study of the Joggins section which lies north of the Cobequid axis has failed to find this fauna. This suggests that possibly different conditions existed in the basin lying north of the Cobequid axis at this stage and accordingly the Arisaig section was visited for several days with the search for the *Leaia* fauna as one of the objects. The Arisaig section lies at the northeastern end of the exposed part of this basin, whereas the Joggins section lies at the southwestern end.

M. Y. Williams has described the Arisaig-Antigonish section.[1] According to him the Windsor is represented by the Ardness formation, 2,045 feet thick. In the shore section there is only a single member that is certainly Windsor in age, the 20-foot bed of limestone appointed by Fletcher and adopted by Williams as the base of the formation. The Ardness formation is succeeded by the Listmore formation or the Millstone Grit of Fletcher, which is assigned to the Pennsylvanian with uncertainty, following Fletcher's usage; of this, 982 feet are shown. Although 2,045 feet of sediments are assigned to the Windsor, the single basal limestone is unique in the whole thickness, and there is no evidence seen by the writer or cited by Williams as to the age relationship of the remaining 2,025 feet. For several days this thickness of the Ardness and the lower part of the Listmore were searched for a fauna, on the chance that it might be the equivalent of the Riversdale-Union, but without result. The shales are for the most part red clay shales, which by their very appearance offer little inducement to search. Mud-cracks are present but only rarely seen, probably owing to the nature of the outcrop. Although the time devoted was too short for a conclusive detailed search, and the outcrops are not continuous, it is apparent that the conditions were somewhat different from those obtaining at the time the Riversdale-Union and its supposed equivalents were formed on the south side of the Cobequids. In so far as the section can be observed, it agrees with the Joggins section in that the *Leaia* fauna apparently fails to be represented. But whether the greater part of the Ardness is Pennsylvanian or Mississippian is not known. Indeed, the Listmore may be Mississippian so far as any evidence yet brought forward is concerned, and so far as any lithological grounds for separation from the Ardness is concerned. The Riversdale-Union horizon may be higher than the exposed parts of the section. The evidence, if such it can be called, is of negative value only. The facts so far obtained and the reason for seeking them are recorded that other workers may know that one has gone thus far by this path with little result.

ADDENDA.

Following is a brief description of the Windsor and lower part of the Pennsylvanian of the section at the Strait of Canso, based on field work carried out during 1914. The Windsor, best shown at Port Hastings, rests on a very thick series

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[1] Sum. Rep., Geol. Surv. Branch, Dept. of Mines, for 1910, see especially pp. 244, 245. Also Am. Journ. Sci., 4th ser., vol. 34, pp. 248-249.

of sandstones and shales of unknown age, but mapped as Devonian. From there down the northeast shore of the strait to the head of Hawkesbury harbour, steeply dipping, successively higher and higher beds are well shown. Inland from the latter point yet higher beds are found up to the old Richmond coal mine which is near the top of the series and beyond which, according to Fletcher's map, they are faulted against the Windsor. To this section Fletcher assigned a thickness of 11,684 feet. He has described the lower portion, which is much the better exposed, in great detail in six overlapping sections exposed along as many portions of the shore.[1]

But, although his successive beds are described and measured, his remarks do not indicate what, if any, may be the chief subdivisions of the series above the Windsor. The following summary of the beds shown between Port Hastings and the head of Hawkesbury harbour, the same portion he has described, has been drawn up to indicate these subdivisions, so far as they have been worked out. They are chiefly lithological, but the faunal subdivisions appear to agree. The thicknesses have been determined by calculation from dip and strike observations, often over long intervals. Since there is considerable variation in both, any attempt to determine the thickness from such averages is subject to error. For the upper portion to which a thickness of 7,180 feet is here assigned, Fletcher records 6,562 feet, a discrepancy of 618 feet. It is not apparent which is the more accurate.

Although from our present understanding of the faunas it appears that all of the beds above the Windsor are best assigned to the Pennsylvanian, no trace of a coal bed was observed in the described portion of the section, nor has any bed been observed which appears promising for the collection of fossil plants. Only occasionally were plant remains observed, stems that were probably floated to the place where they were buried and of little or no value for purposes of age determination. It further appears that Fletcher's use of the terms Millstone Grit and Coal Measures on the maps of the region is quite without significance in correlating with other Pennsylvanian basins in Nova Scotia.

The section is given in descending order.

9. Unrippled grey and red sandy shales and reddish, mud-cracked sandstones, with thin, fœtid, *Anthrocomya*- and *Naiadites*-bearing limestones in the lower part. Not measured. The base of this member forms Fletcher's numbers 62-66, page 85 F.

8. Finely laminated and abundantly ripple-marked, fine-grained, dark, slaty shales, almost black, the laminæ separated by yet thinner laminæ of yellowish, finely sandy shale. Current-marked sandstones of unimportant thickness are present. No fossils have been observed. This member can be traced inland at least 4 miles to the northward, within which distance it loses its ripples almost or quite entirely, but it continues lithologically easily distinguishable. The top is shown on the shore at the head of Hawkesbury harbour between the railway and wagon bridge. . . 946 feet.

7. Massive grey sandstone, hard and resistant, current marked and with prostrate *Lepidodendron* trunks; best shown and measured in the deep cut of the Intercolonial railway near Point Tupper station, but easily recognizable at other points. The easily determinable presence of this member at the head of Embree (Emery of Fletcher) pond makes possible the correlation of the Hawkesbury Harbour section and that shown from Embree pond to Port Hastings. . . . . 95 feet.

6. Alternating shales and sandstones. The shales are red, grey or greenish, fine-grained, but gritty, moderately hard, but not as hard and tough as in the underlying member. Mud-cracks have not certainly been recorded. The sandstones are grey,

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[1] Rept. Progress, Geol. Surv., Can., 1879-80, pp. 76 F—88 F.

red or greenish, current-marked; they may be resistant or shaly. No fossils have been observed. Red is the predominant colour throughout. Incipient slaty cleavage can be detected occasionally and rarely quartz-filled veins are present. . 3,896 feet.

5. Covered on shore of strait 1 mile below Port Hastings. The beds on either side of this interval are different in nature and the higher beds have a lower dip. It is not apparent of what significance these differences in lithology, fauna, and structure may be. Thickness of sediments involved, at least. . . . . . 200 feet.

4. Alternating shales and sandstones. The shales ar red, grey, or greenish, abundantly mud-cracked, harder and tougher than in the overlying member. Some are sandy, others are fine-grained. Beds of dark grey, sometimes almost black slaty shales with thin beds of limestone apparently higher in iron carbonate are common. These three types, the red shales, the greenish-grey shales, and the very dark grey shales with limestones form distinct members, often 200 or 400 feet thick, but with thin beds within them of the other types. The sandstones, grey or red, are of minor importance and are scattered throughout. The series shows little evidence of pronounced current action. *Leaia* and *Estheria* are abundant in certain beds but *Anthrocomya* are rare. The fauna is, so far as observed, practically confined to the greenish or light grey beds. It has not been observed in the dark grey limestone-bearing beds.

Incipient secondary cleavage is developed in the shales and the mud-cracks and fossils are uniformly elongate parallel to this direction. Veins of calcite and quartz are common. These features are much more marked than in the overlying member above the covered interval, but this is believed to be due not to an essential difference in age, but to proximity to the upfaulted mass of Cape Porcupine, of very old probably Pre-Cambrian rocks. This, for a small, upthrust block, seems to have altered the surrounding rocks to an unusual degree.

Certain outcrops on a small tributary from the eastward at the head of Plaster cove indicate that this member is at this point faulted against the underlying Windsor. The general basin structure of the whole region leaves no doubt, however, as to the stratigraphic superposition of this bed on the Windsor, although possibly some member is missing at this point in the section. . . . . 2,043 feet.

3. Covered in shore outcrops, thickness of rocks involved not determined. This is included in Fletcher's 754-foot covered interval, member No. 144, page 83 F.

2. Windsor series, consisting of gypsum, thin limestones, and dolomites, red and grey shales. Structures and succession not satisfactorily worked out. Basal bed structurally conformable on underlying sediments. Thickness, by rough estimate only, 650 feet.

1. Hard and resistant conglomerates, sandstones, and shales, mapped as Devonian, but of undetermined age; thickness very great.

GEOLOGY OF CLYBURN VALLEY, CAPE BRETON.

(W. J. Wright.)

Introduction

GENERAL STATEMENT AND ACKNOWLEDGMENTS.

Upwards of $50,000 have been spent during the last four years prospecting in the vicinity of the Clyburn valley, Cape Breton, but the work has been carried on in so quiet a way that no accounts of the operations have occurred in print. Most of the money has been spent on and around the Franey gold mine. In 1913, the owners of this mine asked the assistance of the Geological Survey in interpreting the geology of the deposit, and the following report is based on information obtained during the month of November, checked by hasty microscopic examination of the more characteristic rocks. The report deals chiefly with the classification and description of the so-called Pre-Cambrian rocks in which the deposits are found, a description of the Franey gold mine, and notes of economic interest about the country in general.

The writer wishes to thank the owners and employers of the Franey mine for their hearty co-operation in the work, and especially Messrs. J. H. Brown, O. Theriault, and J. C. Pryor, for without their aid it would have been impossible to collect the information in so short a time.

LOCATION AND CONNEXIONS.

Clyburn brook is in Victoria county, Cape Breton, and empties into the Atlantic ocean about 40 miles north of Sydney. South Bay, the nearest post-office, has a daily mail and telegraph connexions with North Sydney. Ingonish Beach, 4 miles from the Franey mine, is the nearest calling point of the north shore steamship boat carrying passengers and freight from Sydney and North Sydney. This boat makes a bi-weekly trip during open navigation, March to January, and affords the best connexion with the nearest railway at North Sydney. When navigation is closed, the only way to reach the mine is by a long drive over the mail route from North Sydney.

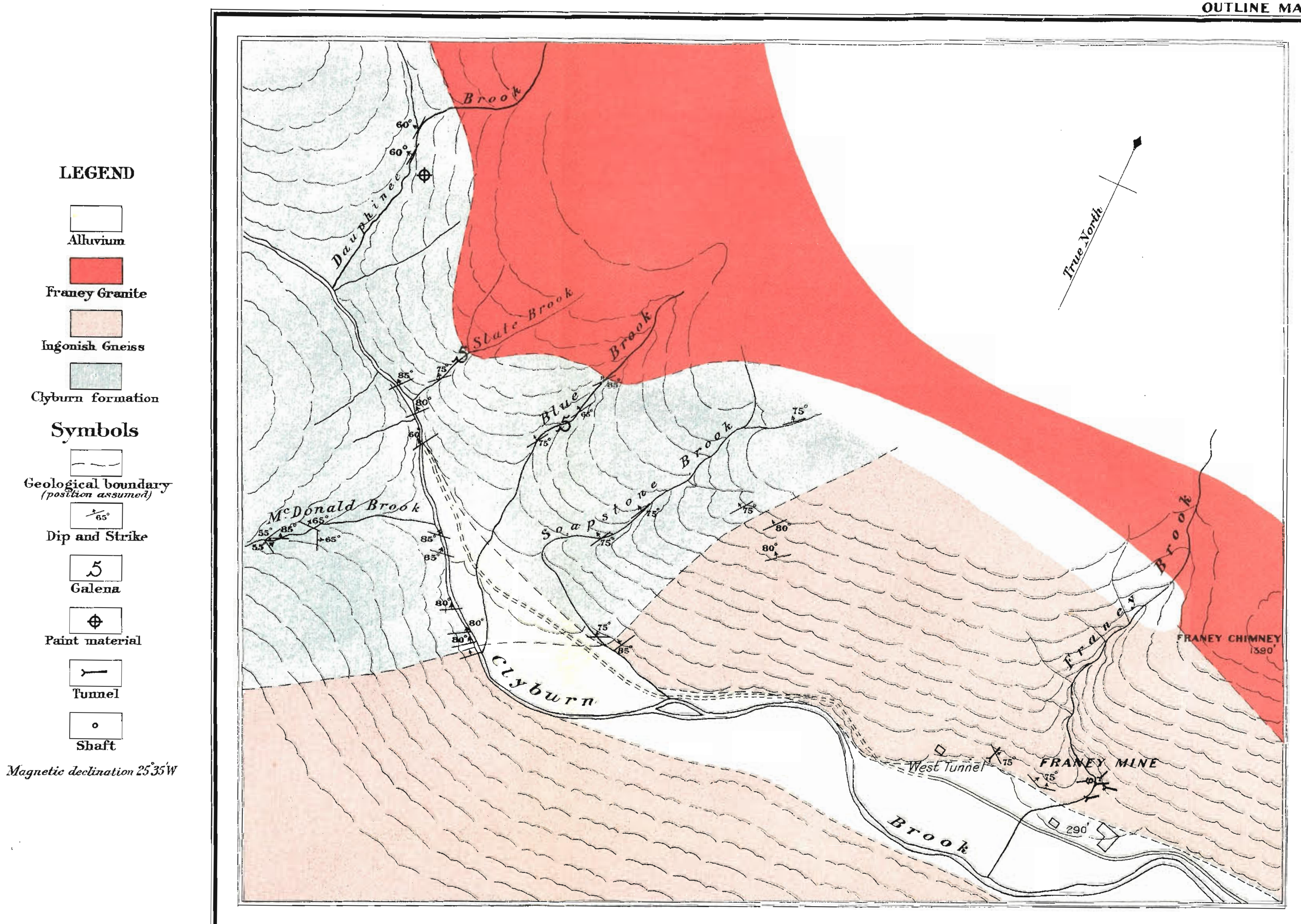
PREVIOUS WORK.

The geology of the district was mapped by the late Hugh Fletcher and described in the Summary Reports of the Geological Survey for 1882-4. Fletcher divided the rocks into three divisions:—

Lower Carboniferous	Conglomerate, shale, limestone, and gypsum.
Pre-Cambrian	George River Limestone Series. Syenites gneissoid, and other feldspathic rocks.

Fletcher's maps show that most of the area included in the sketch map accompanying this report is underlain by the lower group of the Pre-Cambrian, but a belt of the George River limestone about one-half mile wide, crosses Clyburn brook at the mouth of Dauphinee brook, extending to the north about 1 mile and to the south beyond the boundary of the area mapped. A narrow band of the Lower Carboniferous extends all along the valley of Clyburn brook up to within 1 mile of the mouth of Dauphinee brook.

OUTLINE MAP



C.O.Senécal, *Geographer and Chief Draughtsman*

1353

MAP 121A
(Issued 1914)

FRANEY MINE AND VICINITY, VICTORIA COUNTY, N.S.

Scale of feet

1000 0 1000 2000 3000 4000 5000

To accompany Summary Report by W.J. Wright, 1913

Base Map from plans of surveys of mining locations as filed at the Department of Public Works and Mines, *Halifax*

Nothing has been published about the mineral deposits. However, in 1913, private reports were made to the owners of the Franey mine by F. H. Sexton, principal of the Nova Scotia Technical College, Halifax, and Prof. Chas. E. Locke, of the Massachusetts Institute of Technology, Boston. These reports were made for the private information of the owners, but were open to the inspection of the writer, and references to them will be made later.

Conclusions.

The major conclusions drawn in the report are as follows: (1) The metalliferous deposits occur in rocks mapped as Pre-Cambrian. (2) The Pre-Cambrian rocks are made up of a bedded series of volcanics which has been intruded by (*a*) a batholith of quartz-diorite; (*b*) sills and dykes of basic material; (*c*) a batholith of granite; and the whole group deeply eroded before the deposition of the Lower Carboniferous. (3) To drop the term Pre-Cambrian as applied to this group and adopt the term Pre-Carboniferous. (4) The metalliferous deposits are of two types and ages: (*a*) auriferous pyrite associated in origin with the quartz-diorite; (*b*) argentiferous galena associated with the granite. (5) The Franey mine, on a lead of auriferous pyrite, promises to be of economic value, and the whole locality merits careful prospecting.

General Character of the District.

TOPOGRAPHY.

General Statement.

The surface of northern Cape Breton falls naturally into two divisions—highlands and lowlands. The highlands cover the greater part of the interior at an elevation of 1,000 to 1,200 feet. The surface is such that it forms an even skyline, the plane of which truncates all rock structure of the area. The lowlands form an irregular fringe along the shore and extend up the lower valleys of the main rivers.

On comparing our knowledge of the surface of the country with the geological map of Cape Breton, we see that the larger bays, the lowlands, and even many of the lower valleys of the larger streams are underlain by Carboniferous rocks, while the highland is floored by the harder pre-Carboniferous. Thus, in a general way, the relief is dependent upon the lithology. Furthermore, it appears that the present lowlands were lowlands during the early Carboniferous period, and that the present physiographic features are in part at least a revival of pre-Carboniferous topography.

R. A. Daly has pointed out the similarity between the land forms of Nova Scotia and those of the New England States, and calls the highland a remnant of an uplifted Cretaceous peneplain, and the lowlands partly developed Tertiary peneplains. No detail study was made of the physiography for this report, but one cannot but favour Daly's hypothesis, and think of the highland as a remnant of a base-levelled surface which was at one time developed over the whole island but which has since been elevated and preserved only over the hard rocks away from active streams, while the areas of softer rocks and the stream valleys have been cut down to their present level. But there is neither evidence to show the age of the base-levelling nor whether it was produced by marine or subaërial denudation.

In the vicinity of the Clyburn valley, the two features, highlands and lowlands, are sharply defined, and the slope between them is steep and often precipitous. As a result, the country has a very rugged appearance when viewed from the lowlands, while from the highlands, the surface appears to have very little detail relief. The change from the highland surface to the valley of the Clyburn is frequently so abrupt that a view of the country 200 feet from the rim of the valley shows nothing but the Clyburn brook flowing in a valley 1,000 feet deep and 2½ miles from rim to rim. The total relief is 1,392 feet.

Detailed Statement.

Highlands.—West of Ingonish the highland is unbroken. One may travel for days over a surface which rises and falls in broad gentle slopes with a relief of 100 to 200 feet, and occasionally reach places where there is an unobstructed view of 20 miles around half the horizon. Nearer the shore the valleys of the main rivers become deeper and broader, and the surface of the highland is preserved as long ridges between the rivers, dropping over a series of foothills and ending more or less abruptly at the sea.

LOWLANDS.

Lowlands.—A narrow fringe of lowlands extends along the shore and up the valley of Clyburn brook. Along the shore, the lowland is developed on Carboniferous rocks and shows the rolling surface accompanied by sink holes so commonly developed over limestone and gypsum. The lowland along the Clyburn brook is different from that along the shore.

The lower part of the Clyburn valley has a flat bottom, about one-quarter of a mile in width, built up of alluvial material. In summer, the river meanders through this flat, in places dividing to form two or more distributaries. In spring, the water rises and sometimes overflows the whole flat. The walls of the valley rise up as talus-covered slopes of about 35 degrees, and end abruptly at the level of the highland. The tributary streams tumble into the valley over a series of cataracts, in narrow gorges, which in places are impassable.

Above the mouth of Slate brook, the valley bottom is narrow, and in places the river flows in narrow canyons which are impassable in times of floods.

CLIMATE.

The climate is much the same as that of all the seaboard of the Maritime Provinces. Summer and autumn are delightful seasons and open weather continues until Christmas. Winters are changeable and subject to extremes, but the snowfall is not great. Early spring brings the drift ice and is the most disagreeable season of the year. On the highlands of the interior the climate is cooler, and generally snow comes in November and remains all winter.

AGRICULTURE.

Agricultural lands are confined to the lowlands. In general, the soil is rocky, but there are excellent farm lands along the alluvial flats of the Clyburn brook. Agriculture is in a backward state and is confined chiefly to domestic gardening and raising hay for small herds of cattle and sheep. In view of the facts that there are areas of good soil a good climate, and a ready market at Sydney with easy water transportation, it would seem that market gardening should be a profitable industry in several of the sheltered valleys along the coast.

FLORA AND FAUNA.

The type of vegetation varies with the condition of drainage. Large areas of the highlands called "barrens" are covered with moss and herbs, with fringes and patches of stunted spruce, fir, and shrubs along the drainage lines. The better-drained areas along the river valleys and the lowlands support a good mixed growth of hard and soft woods.

In addition to the domestic animals, cattle, horses, sheep, we find the small game usual in Nova Scotia. The moose has been exterminated from the island. and there are no deer; but the caribou roams in small herds over the highlands of the interior.

INHABITANTS.

The inhabitants are chiefly the descendants of Scotch and Irish who came to the country within the last 100 years and settled on lands abandoned by the Acadians in 1755. The chief occupation is fishing.

General Geology.

In the Clyburn valley there are numerous outcrops, showing that the pre-Carboniferous extends down the river to within 1 mile of the shore, where it is covered by a thin deposit of the Lower Carboniferous. The pre-Carboniferous of the valley is made up of at least four distinct varieties of rocks: (1) a bedded series of dark slates and schists which have the structure of sedimentary rocks; (2) a batholith of grey, gneissoid quartz-diorite, which has been intruded into the bedded series; (3) dark basic dykes cutting the bedded series and the quartz-diorite; (4) a batholith and dykes of pinkish, biotite muscovite granite intruded into all of the above-mentioned rocks and overlain unconformably by the Lower Carboniferous. The Lower Carboniferous consists of conglomerate, dolomitic limestone, gypsum, sandstones, and shales. The metalliferous deposits are all associated with the igneous rocks of the pre-Carboniferous.

A sketch map, accompanying this report, was made of 5 square miles, showing the general topography and areal geology in the vicinity of Franey mine. The southeast corner of this area is 2·4 miles from the public road along the shore. The map is based on the official surveys of the mining leases. The land forms are sketched from rough barometric readings, checked with the elevation given for Franey Chimney, and the geology located by pacing along the streams and claim lines.

The surveys for the plans of the workings at Franey mine were made with a Brunton pocket transit and steel tape.

Table of Formations.

Recent		Talus, stratified sand and gravel, boulder clay.
Lower Carboniferous		Limestone, gypsum, sandstone, shale, and conglomerate.
Pre-Carboniferous	Franey granite	Reddish biotite, muscovite granite.
	Ingonish gneiss	Grey gneissoid quartz diorite.
	Clyburn formation	Slates and schists with bedded structure; in part, volcanics.

CLYBURN FORMATION.

The Clyburn formation lies in the upper part of Clyburn brook. Under this head is grouped a series of slates and schists which have a bedded structure resembling sedimentary rocks. The prevailing colour is black or dark green, with occasional grey bands, and at least one band of sericitic quartz schist. The lithology and relation of the various beds of this group are unknown. A few sections examined under the microscope show that much of the material in these rocks is of volcanic origin.

The structure is readily interpreted. The beds, with few exceptions, have a general trend northeast and southwest, dipping to the northwest at about 75 degrees. Generally a schistose structure is evident, but the only place it is marked is in the quartz schist on Soapstone brook. The planes of schistosity are about parallel with the bedding. Jointing is very marked and so well developed that the rocks break readily into small rectangular blocks. Some of the black beds show cubes of pyrite. Occasionally there are irregular zones of pyritiferous white quartz in irregular lenses cutting the structure.

Dykes.—It is possible that some of the bands of this series are intruded sheets or dykes, but the only dykes noticed cutting the formation are pinkish dykes of Franey granite and dykes of a greenish basic rock. The dykes of Franey granite are common in all the rocks older than the granite itself, but the basic material mentioned was only observed cutting the Clyburn formation. Most of the basic material was seen on Blue brook, where it occurs in dykes, and one small boss about 100 feet across, distinctly cutting across the structure of the slates and cut by dykes of the Franey granite.

The rock has been considerably altered so that the section examined is made up chiefly of chlorite, epidote, calcite, and small amounts of a pale fibrous hornblende, probably actinolite. The rock is probably an altered diabase. It appears to be different from the basic dykes cutting the Ingonish gneiss, and it is probably older than the gneiss. But the relative ages are not known.

Contact of Clyburn Formation with Other Rocks.

The contact of the Clyburn formation with the igneous rocks of the area was seen at various places, but the detailed description will be more intelligible after reading the descriptions of the other rocks. However, we shall see that the Clyburn formation is cut by dykes of Franey granite and basic material and that the aspect of all the igneous rocks at the contact indicates that they have been intruded into the Clyburn formation.

Age of Clyburn Formation.

No information was obtained to show the geological age of the Clyburn formation. We know the rocks are the oldest in the locality, and they belong no doubt tc the feldspathic group of Fletcher. So it is probable that they are Pre-Cambrian.

INGONISH GNEISS.

The Ingonish gneiss floors the Clyburn valley from Blue brook to within 1 mile of the sea, and forms the ridge between Clyburn brook and Power brook to the south. The general appearance varies. The most common type is a grey, medium-grained, slightly gneissed quartz-diorite, made up of megascopic crystals of plagoclase (andesine-labradorite), brown biotite, green hornblende (hastingsite), and quartz. The microscope reveals the presence of the accessory minerals, magnetite, titanite, and apatite, and the secondary minerals chlorite, epidote, calcite, and sericite. The gneissoid structure is not very noticeable in some parts, but in others it is very pronounced, and grades into distinctly banded zones.

The banded structure is especially pronounced along the east side of Franey brook at the mine. It occurs in zones varying in width up to one or more hundred feet, which are persistent along the dip and strike, and often resemble finely-bedded argillites. The bands vary in width from a few inches down to microscopic lines and are due to differences in texture and composition. They vary from a dark green felsite, through fine-grained granitic material showing tiny phenocrysts of pink feldspar elongated parallel to the structure, into gneissic quartz-diorite.

The origin of the banded structure is not known. The resemblance of these zones to the Ingonish gneiss at the contact with the Clyburn formation, suggests that they may be due to the presence of blocks of the Clyburn formation which have dropped in the molten magma and been partly dissolved. But the microscope shows that the minerals are the same as in the normal gneiss, and it is more probable that the bands are due to the segregation of the darker minerals of the granite into zones before the solidification of the whole mass.

Lamprophyres.—The Ingonish gneiss is characterized by a great many dyke-shaped masses of greenish, basic material which follow the general trend of the gneissic structure. Some have the appearance of basic segregations, others are distinctly dense at the contact and coarser grained in the central part and are no doubt true dykes. Some of the dykes so closely resemble the dense, dark felsites of the banded zones in the gneiss that it is impossible to distinguish one from the other either in hand specimens or under the microscope. And it is only on examination of their mode of occurrence that the dyke nature becomes evident. A good example of the fine-grained basic dykes is the one cutting the ore body in Franey mine. This dyke, which is called slate by the miners, is distinctly finer grained at the contact and the smaller stringers cut across the quartz veins. The microscope shows that the original minerals were principally plagioclase, hornblende, biotite, and quartz, but the rock has been altered, so that the hornblende and biotite have largely changed to chlorite, epidote, and other secondary minerals.

The resemblance of the minerals of the dykes to those of the gneiss, and the lithological resemblance to some of the bands in the banded zones, suggest that they are closely related in origin to the gneiss, and they are probably lamprophyric in nature and derived from the same magma as the gneiss.

Banded Quartz Veins.—Quartz veins are numerous, but one distinctive variety appears to be confined to the Ingonish gneiss. This is the banded quartz veins. All of those seen follow the general trend of the Ingonish gneiss. They vary in width up to 3 or 4 feet. Some from regular ledges split up into plates one or more feet across and 2 or 3 inches thick, and often showing fine muscovite along the parting planes. Others are much shattered. Some are associated with pyrite and others are not.

Faulting.—Slickensided faces are common in the Clyburn formation and the Ingonish gneiss, but they are generally parallel to the structure and do not appear to be extensive. Thus far the only place where the displacement is known to be of any extent and importance is along Franey brook.

The Franey mine lead lying west of the brook ends abruptly at a brecciated zone in Franey brook and has not been found on the east. The brecciated zone was traced by intermittent exposures for 800 feet up the brook. Opposite the mine, the zone is about 20 feet wide and the footwall dips east 45 degrees. A shaft was sunk on this zone 42 feet, but so much water was encountered that the work had to be abandoned. The dykes of basic material and of Franey granite along the west side of the brook, end abruptly at the brecciated zone with slickensided faces, and are not in line east of the zone. A strongly-banded zone of Ingonish gneiss 40 feet wide, on the east side of the brook, at the lower tunnel, does not appear on the west side. The structure of the granite is about parallel on each side of the brook. These facts all point to the presence of a fault along the lower part of Franey brook.

Along Franey brook the dykes of basic material and Franey granite are cut off at the brecciated zone and one dyke of Franey granite shows distinct slickensides against the fault zone. Thus displacement has taken place after the intrusion of the dykes of Franey granite. At the same time, a small pit on the fault zone about 50 feet above the mine, shows a small stringer of pegmatite from Franey granite which appears to have been intruded after the brecciation. Thus it would seem that the faulting occurred during the intrusion of the Franey granite. To support this evidence, the area at the head of Franey brook should be examined to see if the boundary between the Franey granite has been faulted. However, the basic dykes are older than the Franey granite and are older than the fault, but they are younger than the ore deposits. So the faulting occurred after the deposition of the vein material.

Neither the direction of movement nor the extent of the throw of the fault is known. Slickensided faces on the footwall of the zone just above the mine are horizontal, showing that the latest movement was horizontal. In attempting to determine the relative movement of the two segments, there are two well-marked structural features which may be of assistance. These are: (1) the 40-foot dyke of basic material on the east of the brook, 100 feet above the mine; (2) the strongly-banded zone of gneiss at the lower tunnel on the west of the brook. Detailed work in the brecciated zone might show which way the breccia from these has moved.

Relation Between Ingonish Gneiss and the Clyburn Formation.

The contact between the Ingonish gneiss and Clyburn formation runs about parallel to the general structure of the latter, and is exposed on the south side of Clyburn brook, at the mouth of Blue brook. About 200 feet from the contact, the medium-grained gneiss begins to grade into a dark, banded, porphyritic felsite, showing tiny lenticular phenocrysts of pink feldspar, with the elongation of the phenocrysts, and the banding parallel to the contact and to the bedded structure of the slates. The banded porphyritic felsite, in turn, grades into a dark felsite which so closely resembles the slates that at first sight the felsite appears to grade into slate. Closer examination, however, shows a sharp contact between the two. The slates show no megascopic evidence of contact metamorphism. But the phenomena all show that the Ingonish gneiss was intruded as a molten magma into the Clyburn formation.

Relation of Ingonish Gneiss to Franey Granite.

The presence of dykes of Franey granite cutting the gneiss and the aspect of the granite at the contact show that the Franey granite was intruded into the gneiss after the latter had solidified and taken on its present gneissoid and banded structure.

Relation of Ingonish Gneiss to Lower Carboniferous Formation.

The contact between the Ingonish gneiss and the Lower Carboniferous is exposed on the south side of Middle head. Here the basal conglomerate of the Carboniferous lies directly on the Ingonish gneiss, and is made up largely of subangular to rounded boulders from the gneiss.

Age of Ingonish Gneiss.

The nature of the contacts shows that the Ingonish gneiss is younger than the Clyburn formation and older than the Franey granite, but there is no clue to the age. The gneissoid structure and pronounced jointing show that the rock has suffered considerable deformation, suggesting that the rock is older than the Devonian granites in Nova Scotia. There are Pre-Cambrian granites in Cape Breton and it is probable that the Ingonish gneiss is Pre-Cambrian as mapped by Fletcher.

FRANEY GRANITE.

Two areas of Franey granite were seen in the vicinity. One lies north of the Clyburn brook with its southern boundary running roughly parallel to the river from Dauphinee brook almost to the sea. From local reports this area probably extends several miles north. Another area occurs on Smoky mountain and forms the reddish bluffs of Cape Smoky. A good place to study the rock is at Franey Chimney.

In general appearance the Franey granite is a coarse porphyritic granite, reddish in colour, made up of phenocrysts of pink orthoclase or microcline set in a groundmass of orthoclase, albite, quartz, biotite, and muscovite. Near the border the texture varies more, becoming in some instances pegmatitic, and in others, aplitic. The joint planes are straight and well spaced and the rock breaks into large rectangular blocks often 8 to 10 feet in diameter.

Dykes of Franey granite are common, cutting all the other rocks of the locality except the Lower Carboniferous. They have a pronounced pinkish tint and vary in texture from dense felsites to macrocrystalline rocks resembling the fine-grained mother rock in the contact zone. The dykes are very irregular in form and size and commonly run zigzagging across the structure in all directions, often pinching to thin persistent lines of pinkish, feldspathic material. The irregularities of form and strike are sharply contrasted with the basic dykes which generally follow the gneissic structure of the gneiss and the bedding planes of the Clyburn formation.

Contact of Franey Granite and Clyburn Formation.

The contact of the Franey granite and the Clyburn formation runs across the structure of the Clyburn formation, and is well exposed in Blue brook and Slate brook. In both instances the granite for a few hundred yards from the contact is fine grained. At the contact, dykes cut across the slates in all directions, and blocks of slate 20 feet or more in diameter are completely surrounded by granite. The granite cutting the slate is aplitic and pegmatitic in texture and accompanied by irregular masses of bluish white quartz often several feet in diameter and carrying galena.

Contact of Franey Granite and Ingonish Gneiss.

The contact of Franey granite and Ingonish gneiss is well exposed in the bluff at Franey Chimney. The contact is a sharp line cutting across the structure of the gneiss. Large angular blocks of the gneiss are included in the granite and numerous dykes of granite extend into the gneiss, and cut across the bands of lamprophyric material. There is no megascopic evidence of contact metamorphism in the gneiss. But the granite shows a contact zone varying in width up to hundreds of feet, which shows all grades of aplitic, pegmatitic, and granite texture, sometimes within a few feet.

Contact of Franey Granite and Lower Carboniferous.

The contact of typical Franey granite with the Lower Carboniferous was not seen; but on the south side of Middle head, where the Carboniferous rests on the Ingonish gneiss, the latter is cut by dykes of Franey granite, and boulders from the dykes are common in the basal conglomerate of the Carboniferous.

Age of Franey Granite.

Thus we see that the Franey granite is older than the Lower Carboniferous and younger than the other rocks of the pre-Carboniferous. Furthermore, it cuts across the structure of the Ingonish gneiss and the Clyburn formation, and shows no internal results of great deformation. Thus it was probably intruded after the deformation that folded the Clyburn formation and produced the gneissoid structure of the Ingonish gneiss. Franey granite is called syenite by Fletcher and mapped as Pre-Cambrian, but in view of the above facts it is probable that the Franey granite is younger than the Cambrian and that it may be as late as Devonian.

CARBONIFEROUS.

Not much attention was given to the Carboniferous rocks lying along the shore. On the south side of Middle head, about halfway to the point, the Carboniferous lies almost flat on the Ingonish gneiss. The lowest member of the series is about 8 feet of a dark, coarse conglomerate made up of rounded boulders of Ingonish gneiss and dykes of Franey granite. The conglomerate grades upward into a greyish sandstone followed by about 4 feet of gypsum, then more dark sandstone and shale. Near the mainland there is a few feet of fossiliferous, brownish dolomitic limestone which apparently overlies the sandstone and shales above the gypsum. On the south side of South bay at Iugonish beach, there are apparently thick deposits of red conglomerate and sandstone.

RECENT.

The floor of the Clyburn valley is covered with an unknown depth of river alluvium, and there are the remains of a river terrace made up of poorly-stratified sands and gravels about 75 feet above the level of the river, and the tributaries have built small alluvial fans at their mouths. The walls of the valley are covered with heavy talus. There is very little boulder clay in the valley and no glacial striæ were observed. Throughout the country in general the bedrock is covered with debris, moss, and soil, so that outside the areas of active stream erosion, rock outcrops are seldom seen.

SUMMARY OF RELATIONS AND AGES OF ROCKS.

It would be unfair to make detailed deductions concerning the geological history of the whole region from observations made in a small detached area, but the following facts are clearly indicated in the Clyburn valley. The Clyburn formation was intruded by the Ingonish gneiss and the two were subjected to great deformational processes before the intrusion of the Franey granite. Furthermore, it is probable that there has been no period of great folding since the intrusion of the Franey granite. Thus, it would seem that the pre-Carboniferous group is made up of a series of rocks varying greatly in age. Some of these rocks may be Pre-Cambrian, but the Franey granite is more likely of Palæozoic age. So it seems advisable for the present, to drop the term Pre-Cambrian as applied to this group, and adopt the term pre-Carboniferous as used by Chas. Robb in the Report of Progress for 1874-75, in referring to the group of rocks underlying the Lower Carboniferous.

Economic Geology.

Prospecting has been carried on locally for about four years and as yet only one deposit has been developed to any extent. Enough work has been done, however, to show that the metalliferous deposits belong to more than one group, and that some of the non-metalliferous deposits are of economic importance.

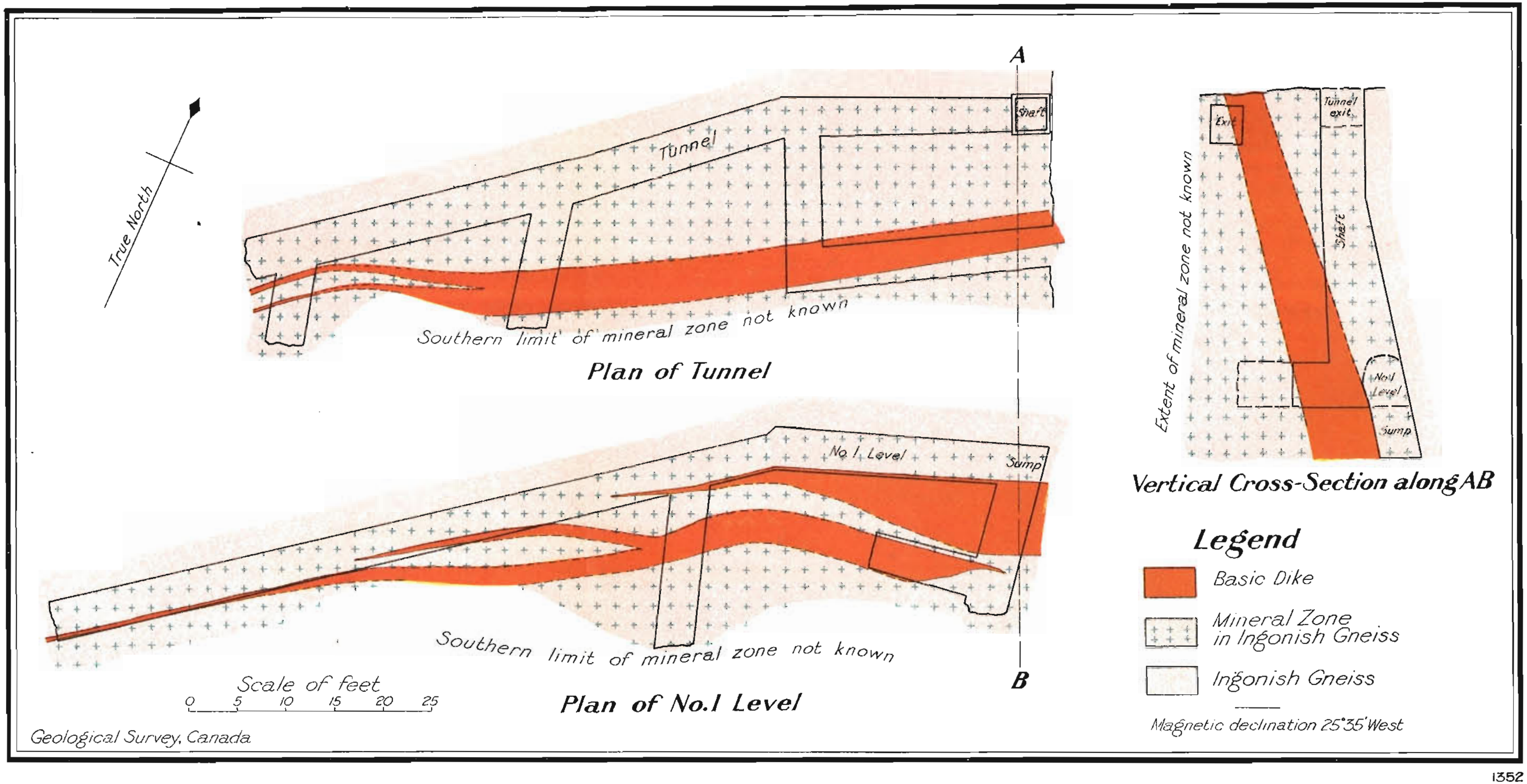
The various deposits of the locality as far as known may be grouped as follows: gold; lead and silver; iron; limestone; gypsum; building stone.

GOLD.

Gold occurs in auriferous pyrite associated with banded quartz in Ingonish gneiss. Several prospects have been opened on ores of this type, showing that the metal is not of local occurrence, but the most promising deposit and the one which is being developed at the present time is the Franey gold mine.

Franey Mine.

The Franey mine is located on the north side of Clyburn brook about 4 miles from the sea. The mine is opened on the outcrop of the lead on the steep west bank of Franey brook, and the workings follow the lead westward. The lead has not been found on the east bank of Franey brook.



Underground workings, Franey Mine, Victoria County, Nova Scotia

To accompany Summary Report by W.J. Wright, 1913

History.—Gold was discovered in a large boulder by J. H. Brown in May, 1910, and in the following September he located the outcrop of the lead on the west bank of Franey brook on which the mine is located. In the following October, J. H. Brown, O. Theriault, J. Gannon, and H. M. Rogers organized a company and have carried on the development. In August, 1911, Theriault and J. C. C. Brodeur took an option on the property on the east side of Franey brook, hoping to locate the lead there. They finally took up the option, but although they have spent about $40,000, they have failed to locate the lead.

Geology.—The lead follows the general structure of the Ingonish gneiss. The gneiss of this locality varies greatly in texture and composition, showing all gradations from a coarse gneiss to a dark green felsite. In addition to the felsite occurring as bands in the gneiss, there are dykes of similar material which follow the general structure, but distinctly cut the quartz veins and gneiss of the ore body.

The lead is made up of interbanded pyritiferous zones of bluish-white quartz veins and Ingonish gneiss, and is divided into two parts by a dense lamprophyric dyke which follows the general trend of the veins.

The quartz occurs in banded zones and in small stringers. The banded zones are made up of numerous veins separated by thin layers of greenish chloritic material and gneiss. The veins have a general trend parallel to the lead and vary in width up to 5 inches, and show neither banding nor open cavities lined with crystals. Under favourable conditions the layers of greenish material are seen to be the continuation of thin bands of the gneiss. The relative amount of gneiss increases toward the border of the quartz zones and there is generally a gradation from zones of quartz to zones of gneiss showing small veins of quartz.

The relation of the basic dyke to the lead is shown in the plan of the mine. The central portions of the larger masses show distinct crystalline structure, but the contact zone and the small stringers cutting across the structure are dense.

Pyrite is the only sulphide observed. It is confined chiefly to the quartz veins and the gneiss in the vicinity of the quartz veins and seldom shows crystal faces. Occasionally there are solid masses of pyrite 2 inches across and one or more feet long. Pyrite is common in the dyke, especially in a 5-inch contact zone, and here it often shows crystal outline. In the quartz, it is segregated in pockets and irregular zones roughly parallel to the vein and shows a marked tendency to follow the greenish lines in the veins. In the granite the lines of segregation follow the gneissic structure.

No free gold has been seen, although assays of rich specimens have shown values as high as $130 per ton.

It is impossible to trace the lead by natural outcrops. In the first place, the outcrop as shown in Franey brook was inconspicuous and was only located by assays. Then outside the gulch of Franey brook, the surface is so covered by talus that outcrops are rare. However, two suggestions as to the extent of the vein are shown by the surface: (1) the vein does not outcrop on the east side of Franey brook in the place where we would expect it; (2) boulders of good ore similar to that in the lead have been picked up in the talus for 2,000 feet west of Franey brook. But our actual knowledge of the extent of the vein is confined to the mine workings.

In cross-section, the mineral zone is limited on the north by a well-defined hanging wall dipping north 75 degrees. The wall is marked by horizontal slickensides, and faced by 1 or 2 inches of greenish gouge. The southern limit of the belt has not been reached in the crosscuts. In this belt, assays show that there are zones of good ore separated by lean zones. Thus far the best zone is the one between the dyke and the hanging wall, followed by the two main drifts. Development has not gone far enough to show how much of the remainder of the belt can be profitably mined. However, the dyke never carries more than a trace of gold and can readily be separated from the remainder of the belt.

Along the strike of the lead the zone of quartz is fairly regular in width, averaging about 2 feet. The values taken from the log assays of the laboratory show that the values vary along the strike. There are two high grade zones in the last 60 feet of the lower tunnel. No regular assay plan was kept of the upper tunnel, and the work has not gone far enough yet to show whether the richer zones are in the form of oreshoots continuous in depth or not.

We have seen that the lead lying on the west of Franey brook ends abruptly at the brecciated zone in the creek bottom. A company took over the property on the east of the brook hoping to locate the lead east of the breccia. But although the $40,000 they spent was not put to the best advantage, they have proved that the vein does not continue in line with its location on the west of the brook. The absence of the vein is explained by the fault along Franey brook.

Two possibilities arise depending on the relative ages of the faulting and the intrusion of the vein. If the faulting took place before the deposition of the vein matter, the fault breccia may have formed an impervious layer through which the mineralizing solutions did not pass. In this case the vein may never have extended east of the fault. On the other hand, if the vein material was deposited before the faulting, in all probability it extended to the east as well as the west. But we have seen that there has been movement along the fault since the intrusion of the dykes of basic material and Franey granite, and that these dykes were intruded after the deposition of the ore. So in all probability the vein continues somewhere on the east of the brook.

As far as is known there is no fault west of the Franey brook, and the presence of auriferous quartz among the talus suggests that the lead continues to the west. Hoping to prove the lead farther west and open it at a point favourable for a mill site, the west tunnel was driven 1,400 feet west of Franey brook. A strong belt of quartz was cut, but this was not carrying the values and it is probable this tunnel does not cut the lead. The question arises as to whether this tunnel should have cut the lead. In other words, does it rationally prove that the lead does not continue.

Reference to the map shows that if the lead continues along the direction of the tunnels at Franey brook, it would cross south of the mouth of the tunnel and would never be cut by the tunnel. On the other hand, all of the banded quartz zones of the area lie parallel to the structure of the gneiss. The lead in the east tunnel follows the structure of the gneiss, and it is reasonable to suppose that it will continue to do so to the end. The map also shows a distinct bend in the structure 700 feet east of the brook, and that the structure in the west tunnel is along a different line from that in the east tunnels. The line showing the general trend of the structure shows that if the lead does continue along the structure as far as the west tunnel it lies north of the end of the tunnel, and thus the presence or absence has not been proved because the tunnel has not cut the ground where we would expect to find the lead.

Locations of Values.—The results of numerous assays made of ore, gangue, and various types of country rock show the following: (1) pyrite is always present in samples assaying for gold, and the gold is roughly proportional to the amount of pyrite; (2) the pyrite is associated chiefly with quartz veins and the wall-rock of the adjacent gneiss; (3) the lamprophyric dyke never carries more than a trace of gold.

Genesis.—The auriferous pyrite is found associated with quartz veins and with the gneiss of the walls of the veins. The dykes which cut the lead show only minute traces of gold, while the stringers of Franey granite are barren; moreover, the variations in value along the strike of the lead are independent of the presence or absence of these dykes.

From these facts we conclude that the auriferous pyrite was deposited in the quartz and granite before the intrusion of the dykes, and that the auriferous pyrite was probably brought in by the quartz veins and deposited partly in the veins and partly as replacement deposits in the granite along the walls.

The origin of the quartz veins is unknown. In view of the presence of so much igneous activity it seems natural to expect that it had its origin in some of the igneous activity that has taken place. As far as we know there were no intrusions between the intrusion of the Ingonish gneiss and the deposition of the gold. So it would appear that the quartz probably had its origin from the Ingonish gneiss, and that it was deposited in a cooled part of the batholith by solutions coming from an uncooled part.

Mining.—The ore and country rock as a mass, are solid, so that no timbering has been necesssary in the drifts and tunnels, and very little water has been encountered. But in reality the rock is highly jointed, so that the ore blasted from the face is very fine and rarely occurs in chunks more than 6 inches in diameter. At present mining is carried on by hand drills. The ore is wheeled to the foot of the shaft in barrows, hoisted and piled on the dump. A 5 horse-power boiler and small hoisting engine furnish power for hoisting, pumping, and ventilation.

Metallurgy.—Thus far no definite method of extracting the gold has been decided upon, but experiments have been made by C. E. Locke, of the Massachusetts Institute of Technology, and by J. C. Pryor. Another series of experiments is now under way by Prof. Sexton at the Technical College of Nova Scotia, Halifax.

To give an idea of the nature of the ore, the results of Locke's experiments are given below. The sample used was about 1 ton in weight, made up of pyritiferous quartz, gneiss, and basic dykes.

Analysis.

	Per cent.
SiO_2 by fusion	66.0
Fe	5.5
S	2.8
Al_2O_3	13.8
CaO	4.4
MgO	1.2
Total	93.7
Insoluble	83.00

Summary of Various Methods of Treating the Ore.

(1) Small amalgamation test recovered, 12·5 per cent of gold.

(2) Cyanide test on amalgamation tailings recovered, 34·4 per cent of gold.

(3) Direct cyanide test. The best results were obtained from ore ground to pass through a 200-mesh sieve with cyanide solution of 0·05 per cent. Time of agitation, forty-five hours. The results were not affected by increasing the strength of the solution and only slightly by increasing the time of agitation. Percentage of gold recovered, 59·4 per cent.

(4) Concentration test. Figured to 100-ton lots; 100 tons concentrated to 7·385 tons containing 75·08 per cent of total gold.

Pryor's experiments were carried on in the laboratory at the mine with small samples. He found minute traces of tellurium, arsenic, and copper, but zinc and cobalt are absent. The best results of extraction of the gold were as follows:—

The sample was crushed and panned. The tailings were crushed to pass 80-mesh sieve and treated with a 0·25 per cent cyanide solution for 114 hours.

Concentrates, 22 per cent by weight, containing 87·45 per cent of total value.
Extraction from tailings by cyanide, 7·51 per cent of total value.
Amount remaining in the tailings, 4·98 per cent of total value.

The consumption of cyanide was not abnormal, the solution giving 0·15 per cent cyanide at the end of the treatment.

From these experiments we see that the ore is not the free-milling variety so common elsewhere in Nova Scotia, and that the best method of treatment is by concentration.

Average Value of Ore.—Regarding the average value of the ore we must remember that the mine is only in the prospecting stage and the basis for estimating average of the ore is confined chiefly to laboratory assays. Numerous assays have been made showing values from a trace to $130 per ton. The ton sample sent to Locke assayed $3.31 per ton, but this included considerable of the dyke, which has since been found to carry only traces of ore and which can readily be sorted. Eliminating the high values, it is safe to say that the ore of the two tunnels at Franey brook will average about $5 per ton.

The general results show that the average ore concentrates to approximately 10 per cent of the original, and the concentrates average approximately $50 per ton.

Development.—The object of the work thus far has been chiefly to prove the extent of the ore body before erecting a mill. In all, about 900 feet of tunnel has been driven and 60 feet of shaft. Of this, 270 feet of tunnel and 30 feet of shaft are on the lead at Franey brook. The remainder of the work was done in an attempt to locate the lead in other places and in prospecting other veins which so far are not very promising.

On the surface a wagon road has been constructed to the sea and cement buildings erected, among which is a well-equipped laboratory.

The present plans are to sink the shaft and open the vein at a new level. If the result is as promising as the present prospect, a 50-ton mill will be erected on Franey brook.

In the meantime experiments are being carried on by Prof. Sexton at Halifax to supplement those of Prof. Locke, to determine the best way of extracting the values.

SILVER-LEAD ORES.

Three prospects have been opened on silver-lead ores in this locality, one on Blue brook, one on Slate brook, and the third on the ridge between the two brooks. The last-mentioned locality was not visited. But on Blue brook and Slate brook, the ore is argentiferous galena associated with quartz and Franey granite in a zone along the contact between Franey granite and the Clyburn formation.

The granite is the fine-grained phase of the Franey granite, considerably shattered and impregnated with pegmatitic material and quartz. The quartz is bluish-white and occurs as small veins and irregular masses up to several feet across. Some of the masses have well-defined boundaries, while others grade into pegmatite and granite. The galena occurs chiefly in small irregular "vugs" in the quartz and granite. The only other sulphides observed are small amounts of sphalerite and pyrite.

An assay of the galena by Locke gave the following: gold, 0·0; silver, 9·37 ounces per ton; lead, 9·6 per cent.

Origin.—The galena was apparently deposited with the pegmatitic and aplitic country rock in which it is found, and no doubt had its origin from the Franey granite.

Future.—Very little work has been done on these ores, and it is perhaps too early to draw conclusions as to the future importance. However, the sporadic nature of the deposits and their association with pegmatite does not look very promising.

IRON ORES.

A deposit of red ochre occurs on the east side of Dauphinee brook about half a mile above Clyburn brook. The deposit is exposed in small springs and rivulets, and appears to be quite extensive. The ochre is relatively pure in some instances, but is generally mingled with soil and talus. A sample of the ochre was examined by Mr. R. A. A. Johnston, mineralogist of the Geological Survey, who reports as follows: "Material of this character is used at times for iron ore. Previous to its use in this way, however, it is necessary to roast it in order to expel the large amount of water which it contains, thus entailing a very considerable initial expense. It also frequently contains a very high percentage of phosphorous which is also objectionable. On the other hand, there is a very active demand for material of this kind for the manufacture of pigments. The specimen under consideration is eminently suited for this purpose as it is quite free from gritty matter and is readily reduced to a nearly palpable powder. If there is any considerable body of this material there is no question but that it could be worked with far greater profit for the manufacture of paint than as iron ore."

LIMESTONE.

There are no limestone deposits in the Clyburn valley proper, but a dolomitic limestone forms one of the important members of the Lower Carboniferous along the shore. At North bay a limestone quarry has been opened and the product is shipped to the steel works at Sydney where it is used as a flux.

GYPSUM.

Gypsum occurs in a thin bed on the south side of Middle head and in a bluff 20 or 30 feet on the southeast corner of the fresh-water lake at Ingonish beach. A company has organized to work this deposit, but as yet no development work has been done.

BUILDING STONE.

The Franey granite is made up of megascopic crystals of pink orthoclase, colourless quartz and plagioclase, biotite, and muscovite. The orthoclase occurs chiefly in phenocrysts averaging about one-half an inch in length. The other minerals average about one-quarter of an inch across. The rock is cut by three series of joint planes, about equally developed; two are perpendicular and at right angles to each other, while the third is horizontal. These planes are about equally spaced, varying from 2 feet to 15 feet apart. The prevailing colour is dark pink, but closer view gives a mottled appearance, due to the grey and black of the groundmass. The pink colour appears to deepen on weathering, but no rusty spots were seen. The jointing causes the rock to fall away from the bluff in relatively large blocks and it is not unusual to find blocks at the foot of the cliff 10 feet square. Judging from these facts it would seem that the Franey granite would be a valuable building and ornamental stone.

FURTHER PROSPECTING.

The prevalent theory of the association of metalliferous deposits with igneous intrusions and the evidence of so much igneous activity in this locality, at once suggest the possibility of metalliferous deposits. The activities at Franey mine have started the usual rumours among the inhabitants and reports of metalliferous deposits are prevalent, ranging from traditional Indian and French mines to the observations of men of the present day. Some of the reported localities outside of the Clyburn valley were visited; in no case had there been any development, but the observations confirm the report that mineralization is common throughout the locality and show that the whole region merits careful prospecting.

CLAYS OF BRITISH COLUMBIA AND ALBERTA.

(Heinrich Ries.)

Interest in the clay deposits of the western provinces continues strong, and each season brings attention to or interest in deposits not hitherto opened up or heard of.

Some time was, therefore, spent in the summer of 1913, examining certain localities not seen before, and in visiting some others which had undergone additional development since the previous year. In several cases these examinations were made at the request of companies or individuals desirous of obtaining some reliable information regarding them. The usual number of samples were also taken for testing.

The localities visited included Princeton, Creston, Blairmore, Coleman, Nanaimo, Kilgard, Cranbrook, Wycliffe, and Blue Mountain. All of these are in British Columbia, except the third and fourth, which are in Alberta. A summary of the information obtained is given below.

PRINCETON, B.C.

In last year's report reference was made to some clays around Princeton, and especially one from the Columbia Coal and Coke Company's mine near Coalmont, which was of interest becase it was a low grade of fireclay. As the mine was closed down in 1913, it was impossible to get any more of the material or gather any further data regarding it, but some additional clays or soft shales were found around Princeton, that were extremely interesting, and one of which closely resembled the Coalmont clay.

As is already known, there are a number of shales associated with the coals in the Princeton district, but they are of variable character, and in the light of our present knowledge it is perhaps difficult to correlate individual beds in different parts of the area. The shales vary in character, some being very sandy in their nature, while others are quite smooth, and with but little grit. The latter also range from those which are quite coaly, to others which appear to be quite free from carbonaceous material.

Good exposures are somewhat rare, but one fine outcrop is to be seen along the east bank of the Similkameen river, just east of Princeton, the beds here dipping to the southwest. At this point, the beds contain so much coaly matter as to be undesirable. Samples collected from the mine of the Princeton Coal and Coke Company show that the shales are very plastic and contain a large amount of colloidal matter, as a result of which they show a high air shrinkage and crack badly in air drying; so much so, in fact, as to render them worthless if used in this condition and moulded by any plastic process. This property, however, does not cause so much trouble if the material is dry pressed. The cracking and high air shrinkage can be corrected, if the clay or shale is first preheated to about 300° C.

Both shales tested from the mine of the Princeton Coal and Coke Company contain a high quantity of colloidal matter, but were improved by preheating. One of these, from a bed lying about 14 feet above the lignite bed being worked, is very similar to the shale from Coalmont described in last year's report, and the tests thus far made show that it remains unaffected at a temperature of 1430° C. (2606° F.).

Other shales are found in the Empire mine, 2 miles from Princeton, near the cement plant, and in the railway cut between the mine and the cement plant.

The former is a soft clay shale which lies between the top of the lignite and the arkose which overlies it. It is quite persistent and could be mined with the coal if needed, but is not in sufficient quantity to be mined alone. It is not refractory, cracks somewhat in drying, and burns to a red colour.

The shale in the cut between the mine and the cement mill is rather deceptive, for it does not have the greasy look of the other colloidal shales found in that vicinity. However, when mixed with water, it shows a high air shrinkage and cracks badly. This shale was selected for some experiments as follows: a sample was preheated to dull redness, which had the effect of destroying the plasticity. It was then mixed with one-third its weight of the raw clay. This gave a mixture that could be moulded without cracking, had a fair tensile strength, and burned to a red brick. A second mixture was then tried consisting of 50 per cent preheated shale and 50 per cent raw shale. This also worked well and gave no trouble.

The preheated material in this case is to be regarded as non-plastic material, and from this it is reasonable to assume that instead of going to the expense of preheating some of the shale, it could be mixed with some of the hard gritty shale that outcrops farther down the track below the cement works.

CRESTON, B.C.

Along the Canadian Pacific railway between Creston and Goat canyon, but near the latter, as well as beyond McNellie station, there are a number of clay cuts, which have given considerable trouble by sliding. Similar clays outcrop near Kitchener.

These deposits in every case consist of silty, laminated clays, which bake hard in dry weather, and run when wet by the rains. All of these deposits are associated with glacial drift, and in some cases probably form lenses in it. The clay is moderately plastic and can be moulded. It is slightly calcareous, but not enough so to produce a cream-coloured brick. The deposit in the deep cut at Goat canyon is probably of considerable size, and burns to a reddish but not very dense brick.

Much better clay is to be found on the road from Creston to Goat canyon, near the site of Lisk and Slater's old mill. This is tough and quite plastic, of fair tensile strength, and burns to a red colour. It not only makes a good brick, but flows nicely through the die of a tile machine. This same clay is exposed at several other points between here and Creston, and represents one of the best brick clays found in this region. Indeed, it is much better than some of those now being used.

If the project of lowering the level of Kootenay lake is carried out so as to unwater the delta lands south of Kootenay Landing, this clay should form material for drain tile, which will undoubtedly be needed for drainage purposes on that tract.

COLEMAN, ALBERTA.

In last year's report reference was made to the black Benton shales occurring west of Coleman on southwest ¼, section 7, township 8, range IV, west of 5th meridian. Tests made on them showed that they could with care be made into dry-pressed brick, but that the use of the material alone was not advised.

Since the material is easily accessible, some additional trials have been made of it, and some other clay found nearby. The first series is being made on the weathered shale that has been lying on the dump for a year or more. This is not proving to be much better than the fresh shale, and in any case is not sufficiently plastic to mould wet. The second series is a mixture of the shale with more plastic clay found in the vicinity, and gives much better results, so that it can be moulded in the plastic state.

BLAIRMORE, ALBERTA.

Considerable interest has been expressed in certain developments which were being carried on along Jackson creek, a branch of the South Fork, southeast of

Blairmore. The structural conditions here appear to represent an overturned syncline of Cretaceous volcanics enclosing a series of carbonaceous shales, interstratified with which there are some grey clays. The strong folding has crushed and broken the shales, and the grey clays included in this series, also partake of the disturbance, resulting in one place at least in pinching of the bed, and at another in slight faulting. These irregularities warrant the assumption that the white clays when followed in from the surface, may show structural variation, and without doing considerable more exploitation than had been done at the time of my visit, it would be unsafe to make any estimate of the quantity present; nor would it be safe to erect a plant until this has been done.

In July, 1913, three openings had been made on the east side of the creek, and one on the west side farther up stream. Two of the first three may belong to the same bed, but the continuation of none of the three has been traced across the stream valley. The dip of the three on the east side is gentle and to the northwest, but that of the fourth on the west side of the valley is quite steep. This shows a strike of about N. 60° W., and dips steeply to east of north. Its maximum thickness is 7 feet, and minimum 4 feet. An attempt was made to find its continuation on the opposite side of the valley, but the heavy covering of gravel had interfered with its discovery up to the time of my visit.

There are several economic problems to be considered in connexion with the development of this deposit, viz.: (1) the method of working must be by tunnels, and stopes; (2) is there enough material here to supply a plant of any size? (3) the character of products (pressed brick) which could be made from this material would call for a large tonnage of clay, and the narrow character of the beds would not cheapen the extraction of the desired quantity.

PASSBURG, ALBERTA.

Reference was made in a previous report[1] to the shales, interbedded with sandstones, that outcrop along the railway between Lunbreck and Bermis. These shales show a variable dip, owing to the abundant folding of the ridges bordering the eastern edge of the mountains. They do not always form extensive outcrops, and along the river are often covered by heavy gravels of the stream terraces. During the year 1913, prospecting was done at several points, among others on section 11, township 7, range III, west of 5th meridian, where the shale is found outcropping in the face of the terrace escarpment on the south side of the Oldman river. The beds, of which there are several, appear to lie in a syncline, and vary in thickness from 4 to 12 feet.

Tests are being made on samples from several of these beds, and the results thus far obtained indicate considerable uniformity in the character of the several beds. All are of good plasticity, red burning, and work either wet moulded or dry-press. If the deposit is utilized, it would probably be necessary to work the clay by underground methods, as the gravelly overburden is somewhat heavy. The material is better for brickmaking than the Benton shales near Coleman and Blairmore, but not as easily worked.

CRANBROOK AND VICINITY, B.C.

The calcareous silts in the valley at Cranbrook have been utilized for several years to make a somewhat porous cream-coloured brick, but in 1913, another yard was established about 2 miles north of Cranbrook. The deposit worked here lies not in the main valley, but behind a low ridge separating it from the valley proper. It seems to be a separated basin of clay, unrelated to the calcareous silty material along the St.

[1] Memoir No. 24, Can. Geol. Surv.

Mary river; and it is certainly more plastic and of better working quality, so that it can be used for both brick and tile.

Examination was also made of the Pre-Cambrian metargillites at Wycliffe station, which it is claimed have been utilized to make bricks for use at the smelter at Marysville, B.C. The rock is hard schist, at times quite quartzose in its character, and while it might develop a little plasticity if exposed to the weather for a long period, I was unable to find any material that looked at all promising for brick making. Even when finely ground it does not develop enough plasticity to mould. It can with care be moulded dry-press, but strong firing is required to give a hard brick.

BLUE MOUNTAIN, B.C.

This mountain contains one of the thickest shale deposits seen in British Columbia, and of the localities thus far observed, ranks next to Sumas mountain. Blue mountain is about 4 miles north of Whonnock on the Canadian Pacific railway. The slopes of the mountain are heavily wooded, and show practically no outcrops, but at an elevation said to be 2,500 feet, there are several steep ravines, in which one sees exposed a series of beds of shale, with some sandstones, sandy shale, and fine-grained conglomerate. The section exposed more or less continuously in a ravine tributary to one known locally as Gold Stream ravine, must be at least 150 feet thick, which has clean shale of red and grey colour in the lower half of the section.

In Gold Stream ravine the shale does not reach as low a level, and the material below the heavy red shale deposit is a conglomerate, consisting of boulders of igneous rock from 1 to 2 feet in diameter, and resting in turn on granitic rock.

The tests on these shales are not completed, but those thus far made are very encouraging. All of the shales are smooth, and burn either to a red or buff colour, and one at least stands 2600° F. without showing any signs of fusing, while a second appears to be nearly as refractory. The objection to some is that they do not readily develop plasticity by ordinary mixing, so that the clay would probably yield better results on grinding and tempering in a wet pan.

It is a little too early to prophesy the various uses to which these shales can be put, but they are being tried out for building brick, roofing tile, sewer pipe, etc.

The red shale makes a most acceptable slip for covering clay wares.

A question that cannot be overlooked in the discussion of these shales, is the transportation method to be used for bringing the ware down to a factory located near the railway. The deposits are about 7 miles distant from the river, and about 2,500 feet above it, but the clay could be brought down by aërial tram.

NANAIMO AND VICINITY, B.C.

Development and promotion of the Northumberland shales on the islands south of Nanaimo goes on almost uninterruptedly. Several new deposits have been opened up in the last year, preparatory to using them for brick, but the material excavated does not differ materially from that previously described from this region. A word of caution was sounded in the reports of preceding years, and the writer feels that these remarks were justified, for the shales are not well adapted to stiff-mud moulding, nor do they represent a satisfactory dry-press brick proposition, and better material should be sought. It can be found on the mainland as shown in earlier reports.

SUMAS MOUNTAIN, B.C.

Since my last report, the plant at Kilgard has been completed for making pressed brick, fire brick, and sewer pipe, but at the time of my visit in August, 1913, had not yet begun permanent operations. The plant at Clayburn continues in operation, and the addition of a fireproofing plant was contemplated.

REPORT ON PROGRESS OF INVESTIGATION OF CLAY RESOURCES.

(Joseph Keele.)

During the early part of the summer of 1913 the examination of the clay and shale deposits of the province of Quebec, begun the previous year, was finished for the time being.

Later in the season, at the close of the meetings of the International Geological Congress, certain localities were visited in the western provinces.

QUEBEC.

No attempt has been made to search for materials outside of the settled areas of this vast province, as clay and shale deposits, to be of economic value, must be situated close to transportation facilities, and within reasonable distance of markets for the finished wares produced from them.

Last season this work was confined to the region in the St. Lawrence valley lying between the cities of Montreal and Quebec, while this season localities as far east as the Atlantic seaboard at Gaspe were examined.

The relation of deposits of materials which are sought for by manufacturers of clay products to the geology of the province was outlined in the Summary Report for 1912. These deposits appear to be confined principally to two formations, the Pleistocene surface clays, and the shales of the Utica-Lorraine. A few small patches of the reddish Medina shale in Nicolet county will furnish good brick or fireproofing material, but these are situated rather far from the larger centres where clay wares are chiefly sold.

The Pleistocene clays are the most widespread materials used in the clayworking industry. Small plants making common brick are located on them, at intervals between the Ontario boundary line and the town of Rimouski, the latter point being the farthest east in the province at which these clays are worked at present. These are all easily fusible, red-burning clays, their range of usefulness being confined to the manufacture of common building brick or field drain tile. They are unsuitable for dry-pressed brick or vitrified wares.

The necessity for underdrainage in a large portion of the agricultural districts in this province is being gradually recognized, and inquiries are coming to this department regarding deposits of raw material suitable for the manufacture of field drain tile. The investigation of the clays of Quebec includes experimental work with reference to their use for this very essential product. No tile is produced in the province at present, but many of the clays now being used for the manufacture of common brick as well as several unused deposits, are suitable for making field tile.

The most important result of this season's investigation was the discovery of paving brick and sewer pipe shales in part of the Lévis and Sillery formations, in the vicinity of the town of Lévis and at St. Charles de Bellechasse. These materials are not quite plastic enough for the manufacture of pipe with smooth surfaces, but they can be improved by the addition of a small amount of plastic surface clay and grinding in wet pans. These shales stand quite a high degree of heat without softening or deforming, and take a uniform bright salt glaze at cone 3 (1,190° C.).

With the exception of the kaolin deposits at St. Remi d'Amherst, no other fireclays or high grade pottery clays have been found so far in this province.

The chief event in the clay industry of the province during the season of 1913, was the erection of a huge plant at Varennes, by the Mount Royal Brick Company, of Montreal, for the manufacture of common brick. The plant is located on a terrace of marine clay fronting the St. Lawrence river, on the line of the Quebec, Montreal, and Southern railway, about 20 miles east of Montreal. It is designed for an output of 350,000 end cut, stiff-mud brick per day, and is supposed to be equipped with all the latest devices in clay-working machinery, and continuous kilns, having removable tops, to facilitate setting and unloading. This plant was not completed at the close of the year.

The material at Varennes is a greyish, highly plastic Pleistocene clay, a fairly typical variety of the low-level marine clays which occur so widespread in this region. A sample of this clay collected at the plant was tested, but it failed to pass the drying test. The clay cracks badly in slow drying even with the addition of 33 per cent sand.

MANITOBA.

An examination was made of the shale deposits which are interbedded with the dolomitic limestones at the quarries in Stony Mountain and Stonewall. Although these shales are hard and gritty, they become fairly plastic when finely ground and mixed with water, and are capable of being moulded in clay working machinery. Their lime content, however, is so high that they burn to a porous chalky body at all temperatures up to cone 3 (1,190° C.). They could not compete with the surface clays of the district, which require no grinding and burn to a dense body at lower temperatures.

Samples of dark grey shales from Mafeking, sent to the laboratory for testing, were probably taken from the Benton division of the Cretaceous, which outcrops in this locality. These shales contained so much carbonaceous matter, as to be practically useless for the manufacture of clay wares. The carbon burns out of these shales with a bright flame, when they become heated to about 500° C., behaving in this respect like oil-shales.

A plant for the manufacture of clay products is under construction at Carmen, this point being selected on account of the distributing facilities it offers for the manufactured wares. It is proposed to use the Niobrara shales from the Pembian mountains near Leary, on the Carmen-Hartney branch of the Canadian Northern railway. A carload of this shale was brought to Toronto during the winter and tested on a commercial scale in a sewer pipe plant. The working and drying qualities of this shale were good, and a fairly satisfactory product with a bright salt glaze was turned out of the kiln. Owing to the Carbonaceous matter and gypsum which this shale contains, the burning of wares made from it will be attended by some difficulties, until they are overcome by experience. A mixture of the Niobrara and Pierre shales, both of which occur abundantly in the Pembina mountains, will be found to give better results for sewer pipe.[1]

A consignment of clay samples from Sprague was tested in the laboratory. These on testing were found to be very similar to the surface clays at Winnipeg. They consist of an upper, buff burning, brick clay and a lower, red burning clay. It is impossible to use the lower clay on account of its defective working qualities, but the upper clay makes an excellent common building brick.

SASKATCHEWAN.

An examination was made of the clay deposits in the vicinity of the city of Saskatoon, and several samples were collected for testing. The results of the tests

[1] Clay and shale deposits of the western provinces, part ii, p. 93.

were not encouraging, as the materials present certain difficulties for successful working, and when these are overcome only the common grades of clay wares can be made from them.

Clay deposits at the town of Kamsack were investigated, the materials available at this point being buff burning, surface clay overlying Niobrara shales of the Cretaceous formation. The surface clays will make good building brick if burned sufficiently hard, but there is a tendency towards underburning and the consequent production of soft porous wares. The Niobrara shale in this vicinity is unworkable by wet moulded processes, owing to its excessive shrinkage, and cracking in drying. This shale might be used for red dry-pressed bricks if the losses through fire-checking did not run too high. There is an extensive shale deposit almost precisely similar to this at Swift Current, an examination of which proved it to be subject to the same objections.

The Laramie formation in southern Saskatchewan contains clays which are the most valuable in the province. The most important materials of this formation are the white or light grey, often sandy fireclays, and other deposits of a similar nature, but containing impurities which for want of a better name are called semi-refractory clays. The fireclays of this region have fusing points between cone 27 (1,670° C.) and cone 32 (1,750° C.), while the semi-refractory fail in the fire test at cones 15 (1,430° C.) to cone 25 (1,630° C.)

Certain deposits of these types have already been described in published reports,[1] but their occurrence at a number of additional localities was recorded during the season of 1913, by Mr. B. Rose of the Geological Survey, and the writer, brief notes of which are as follows:—

Fireclay occurs on section 14, township 11, range XXVIII, west of the 2nd meridian. This deposit is situated near the north end of Lake of the Rivers, not far from the Expanse branch of the Canadian Pacific railway, and the Avonlea branch of the Canadian Northern railway. Lignite also occurs in this vicinity.

Greyish white, soft clay, which is very gritty, was found in section 30, township 6, range XVIII, west of the 2nd meridian. This clay has good plasticity and drying qualities. It burns white to grey, vitrifies about cone 10, and uses at cone 20. This deposit is situated near Brooking, on the Canadian Northern railway line.

A deposit of greyish white clay with rusty lumps, which farmers in the vicinity use as a plaster, occurs on section 31, township 3, range XXIV, west of the 2nd meridian. This clay is very plastic, stiff, and sticky. Its shrinkage is rather high, and its drying qualities are unknown. It burns to a buff colour, vitrifies at cone 10, with numerous dark fused spots on surface of test pieces. It fuses at cone 20.

A bed of light-grey highly-plastic clay was found about 7 miles south of Mortlach, on section 17, township 16, range I, west of 3rd meridian. This clay is said to be about 9 feet thick. It is overlain by a thin seam of lignite, and a bed of brown clay, containing gypsum particles. It burns to a cream colour at lower temperatures, and becomes grey at high temperatures. It is vitrified at cone 9, and fuses at about cone 20. It resembles a stoneware clay, being very smooth and plastic, but the shrinkages in air drying and burning are rather high.

Some samples of semi-refractory clay from southern Saskatchewan were sent to the clay-testing laboratory for examination. The amounts of clay sent were small, and no data were given regarding quantity or distribution of the deposits. One from the banks of the Frenchman river, near Eastend, resembles a stoneware clay, as it has good plasticity, is rather smooth and burns to a grey vitrified body at cone 5. It fused at cone 15.

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[1] Preliminary report of the clay and shale deposits of the western provinces, chapter iii. Part II. Clay and shale deposits of western provinces, chapter iii.

A small sample of clay was received from one of the smaller areas of the Laramie formation, north of the south branch of the Saskatchewan, section 17, township 21, range X, west of the 3rd meridian. This is the first specimen to be recorded from this area. It is a greyish-white, rather sandy clay, with good plasticity and working qualities. It burned to a grey vitrified body at cone 9, and fused at cone 20. No information was received regarding the extent of the deposit or its distance from the nearest railway.

Several samples of easily-fusible, red-burning clays were also collected at various localities from the Laramie formation in southern Saskatchewan. Most of these are open to objection on account of their poor drying qualities, and excessive shrinkages. It is possible that some of them can be used when mixed with the grey-burning semi-refractory clays to produce bodies suitable for sewer pipe, face brick, or fireproofing.

A sample of Pleistocene surface clay was received from Davidson, on the Regina branch of the Canadian Northern railway. This clay cracked so badly in drying that it cannot be used for brickmaking by any of the ordinary processes.

An effort will be made to use this clay by what is known as the ante-fired process, which consists in first calcining the clay in heaps as it comes from the bank. The calcined clay is ground in dry pans, mixed with a small percentage of lime, and pressed into brick shapes, which are hardened in cylinders under a pressure of 120 pounds of steam. The method of procedure after the burned clay is ground is the same as in making sand lime brick. This process is in the experimental stage at present, but it may provide a way for using those clays which crack in drying.

Drying defects in clays are a serious difficulty in many of the Saskatchewan localities, and is one of the reasons that there are no brick plants along the main line of the Canadian Pacific railway in this province. The probable cause of this defect, and a method of treatment to overcome it, were given in one of the reports of the Geological Survey.[1]

ALBERTA.

Our investigations up to the present time have not succeeded in recording the occurrence of fireclays in this province. It is possible that fireclays, similar to those in Saskatchewan, will be found in the small area of the Laramie formation which extends into the southeastern portion of Alberta when the line of the Weyburn-Lethbridge branch of the Canadian Pacific railway now under construction, reaches that locality. Only a few localities in Alberta were visited during the limited time at my disposal this season; these will be referred to briefly.

The occurrence of white clay near Nevis on the Lacombe branch of the Canadian Pacific railway was brought to my attention earlier in the season by Mr. J. O. Williams, of Camrose. This deposit was visited and samples collected for testing. The material is a hard white or light grey shale about 4 feet in thickness. It is overlain by impure brown clay and underlain by grey shale impregnated with "bentonite." The white shale is extremely plastic when ground and mixed with water, and cracks on drying. It burns to a white to grey body, vitrifies at cone 9, and fuses at cone 16. It is not a fireclay.

The margin of the Porcupine hills nearest to the town of Macleod was also examined, and samples taken from three outcrops of shale at different levels. None of these proved to be refractory when tested.

A further examination was made of the shale deposits at Didsbury. The samples collected at this point were satisfactory with regard to their working and burning properties, but a complete section of the beds could not be obtained. It is impossible to state whether there is a workable body of shale or whether the sandstone beds were

[1]Clay and shale deposits of the western provinces, part ii, chapter vii.

in excess. These shales are in the Paskapoo formation, which yields the best material so far found in the province, for the manufacture of wire-cut brick, face brick, or fire-proofing.

Four samples from the clays and shales of the coal measures at Castor, sent to the laboratory for examination, were found to be defective in their drying qualities. These were from the Edmonton formation.

Drying defects in the clays of both the Edmonton and Belly River members of the Cretaceous are quite common. A drying test should always be made in the preliminary examination of these materials. A chemical analysis of a clay or shale is useless; the physical tests are the only guide to their value.

REPORT OF THE VERTEBRATE PALÆONTOLOGIST.

(Lawrence M. Lambe.)

In vertebrate palæontology the results attained during 1913 have been most satisfactory. In all branches of the work, in the laboratory, in the museum, and in the field, very decided progress has been made; in the field especially unusual success was achieved. The collections brought in include many forms new to science, of which descriptions of some have either been already published or are in the hands of the printers.

Field Work.

The principal field work consisted of an expedition to Red Deer river, Alberta, to collect dinosaurian and other vertebrate remains from the Belly River Cretaceous in the neighbourhood of, and below Berry creek (Steveville). The party was composed of Mr. Charles H. Sternberg and three assistants, and its success is to be attributed not only to the skill and experience of those forming the party, but also to the manner in which it was equipped. The party was on Red Deer river from June 20 to October 3.

The beds of the Belly River formation in Alberta have become famous for their richness in well-preserved dinosaurian and other reptilian remains. The collection from these rocks, made by the expedition of 1913, reveals in a striking manner the wonderful variety of the dinosaurian life of the period. The forms represented are ancestral to those described some years ago by Leidy, Marsh, and Cope from higher horizons in the Cretaceous, and are, with few exceptions, the oldest known Cretaceous types on this continent. The differentiation already attained by the dinosaurs at the time the Belly River beds were deposited is surprising, and no doubt further collecting at this locality will augment the number of both plant- and flesh-eating species of many genera already known from this varied fauna. The field collection of 1913 includes members of the Ceratopsidæ (horned dinosaurs, quadrupedal, plant-eaters), Trachodontidæ (duck-billed dinosaurs, and their allies, bipedal, plant-eaters), Theropoda (bipedal, flesh-eaters), and Stegosauridæ (heavily armoured quadrupedal, plant-eaters). Plesiosaurs, crocodiles, turtles, amphibians, and fishes are abundantly represented, and some mammalian remains were also found.

The most notable specimens of the 1913 collection are:—

(1.) A splendidly preserved skeleton about 30 feet long, including the head, of a carnivorous dinosaur belonging to the new genus and species *Gorgosaurus libratus*, Lambe. In this specimen the full series of abdominal ribs are preserved and one, at least, of the fore limbs, complete and in place. As this is the first time that the front limb and the full number of ventral ribs of a Cretaceous carnivorous dinosaur have been found, the discovery is of unusual interest; a description of these parts is now being prepared. This magnificent specimen is in the hands of the preparators and will be exhibited as it occurred in the rock.

(2.) A skull of a trachodont dinosaur remarkable for the elongation backward and upward of the nasal bones and the unusual development of other cranial elements which add greatly to the depth of the head. The specimen belongs to the species described by the writer in 1902 under the name *Trachodon marginatus* and reveals characters which necessitate the establishment of the new genus *Stephanosaurus* for the reception of the species. Some of the principal bones of the skeleton were obtained with the skull, the whole proving the correctness of the original specific description. The scale pattern of this species, now known from natural moulds and casts discovered last summer, consists of conspicuous, limpet-shaped tubercles placed at intervals, with small polygonal ones intervening.

(3.) A splendidly preserved skull, over 6 feet long, of the new genus and species of ceratopsian which has been described under the name *Styracosaurus albertensis* (the spike-dinosaur of Alberta). This specimen lacks the lower jaw.

(4.) A skull of a trachodont dinosaur, over 3 feet long, with the lower jaw in place, remarkable for its depth in advance of the eyes. This specimen is in a splendid state of preservation, with all the bones in place. It represents an undescribed genus and species now named *Gryposaurus notabilis*. Some parts of the skeleton, with distinctive skin impressions, were obtained with the skull.

(5.) A skull, nearly 5 feet in length, of the horned-dinosaur *Monoclonius belli*, Lambe, with the vertebral column, most of the axial and appendicular skeleton, and with skin impressions. This specimen reveals structural characters which necessitate the removal of the species to the new genus *Chasmosaurus*. The very large neck frill is in a perfect state of preservation and the rami of the lower jaw are present, but the facial part in advance of the small, upright, supraorbital horn cores has suffered from exposure. The skin impressions prove that the animal was covered with small, polygonal scales, not unlike those of some species of trachodonts, and did not possess a dermal armour of bony scutes hitherto generally ascribed to the Ceratopsia as a group.

(6.) A magnificent skull, 5½ feet long, of *Centrosaurus apertus*, Lambe, described some years ago from the parietal frill only. Whereas in *Chasmosaurus* the crest appears disproportionately large for the abbreviated anterior part of the skull, in *Centrosaurus* the head is extremely massive and terminates behind in a relatively small neck frill. The large nasal horn core curves forward, and there were no horns over the eyes. The lower jaw of this specimen was not found.

(7.) A complete shell of the turtle *Boremys pulchra*, Lambe, a species of which the plastron and the anterior half only of the carapace were previously known. The specimen of the 1913 collection gives the details of structure for the whole of the carapace.

The collection made last summer, by Mr. C. H. Sternberg and his assistants, from the Belly River Cretaceous on Red Deer river, Alberta, is a remarkable one. Our knowledge of the dinosaurian and vertebrate fauna generally, of this portion of the Cretaceous, is greatly advanced by the results of their enthusiastic work, with the application of modern methods, as collectors in the field, as well as by their skill as preparators in the laboratory.

During the summer season of 1913, I took part officially in Excursion A1 of the International Geological Congress as one of the guides through eastern Quebec and the Maritime Provinces from July 13 to August 1. I acted in a similar capacity on Excursion C 1, which left Toronto on August 14 for Victoria, B.C., by the main line of the Canadian Pacific railway through Kicking Horse pass. Leaving the excursion, on its return trip, at Revelstoke, I proceeded south via Kootenay landing and Crowsnest pass to the south fork of Oldman river, where the occurrence of vertebrate remains in rocks of Jurassic age had been reported by Mr. D. B. Dowling.

The rocks in which the remains were found are rather hard, slightly greenish, dark grey shales, at the water's edge, on the north bank of the river a short distance east of Web creek, in section 7 of township 6, range III, west of the 5th meridian. on the property of the Coal Securities, Limited, and about 25 miles from Blairmore by the road past Lea lake.

The fossil remains were found to consist of eight or nine vertebræ, ribs, what appear to be abdominal ribs, and some limb bones and a tooth, of a reptile. The vertebræ are disc-shaped, slightly biconcave, and about $2\frac{1}{2}$ inches in diameter. These remains, which will probably prove to be plesiosaurian, were removed from the rock and shipped east. In the same beds were large numbers of well preserved belemnites and poorly preserved fossil wood. My thanks are due to Mr. James Farmer, of Blairmore, manager of the Coal Securities, Limited, to whose house on the mine property I went at his invitation, and was hospitably received and aided in many ways by Mr. M. G. Rhynas, in charge of the property. The rocks yielding the fossils are about 2 miles above the house, within easy walking distance by the trail.

The palæontological evidence of the fossils obtained corroborates Dr. Dowling's assignment of Jurassic age to these beds.

From Oldman river I proceeded to Exshaw, Alberta, on the main line of the Canadian Pacific railway, east of Banff, near which place Dr. J. A. Allan, of the University of Alberta, Edmonton, had recently discovered, in the Fairholme range, a thick bed of hard shale of supposed Jurassic age holding scattered vertebrate remains exposed on the upper surface of the rock. These bones were examined, and although probably reptilian, they are, on account of their unsatisfactory state of preservation, not determinable with certainty. The results to be expected from their removal from the rock were not considered to be commensurate with the expense of quarrying. The beds holding these fossils are about 4 miles northeast of Exshaw railway station and can be reached by following up the second creek below Exshaw to near the head of the ravine in which the creek runs.

Travelling east I stopped at Brooks, Alberta, and drove to our palæontological party's camp on Red Deer river, below Steveville. Here I found Mr. Sternberg and the members of the party greatly encouraged by the success of the season's work. The weather conditions had been good, and pre-arranged general plans, for the exploration of the Belly River formation below Berry creek and the collection of its vertebrate fauna, had proved most satisfactory both as regards the number and value of the specimens obtained and the time saved by adequate transportation facilities. Five days were spent with the party before returning to Ottawa.

Laboratory.

This very necessary adjunct to a modern museum was equipped during the early part of the year with the following machinery and appliances: an overhead trolley system consisting of steel railing bolted to the ceiling, a trolley, and hoisting block, by means of which heavy specimens up to two tons in weight can be moved with ease from one part of the laboratory to another; a gas-blast furnace with rotary blower, for forging, and an electric drill, both operated by means of a two horse-power electric motor; an anvil, all necessary tools for working in metal and wood, as well as special awls, chisles, knives, etc., for the removal of rock from specimens; a small dental electric motor for operating circular brushes and emery wheels when it is necessary to clean or remove matrix from delicate specimens without jarring them.

These, with other necessary and time-saving appliances, are now in use in the laboratory for rapid work, with the best results, in removing rock from specimens, in mending, restoring, and cleaning them, in making metal supports for fossil skeletons, and finally in mounting them for exhibition in the museum. It may be said that the laboratory is now equipped in most particulars in the best possible and up-to-date manner.

During the early winter months Mr. Sternberg, assisted by his son, C. M. Sternberg, finished the preparation of, and mounted in high relief, the very perfect specimen of a Trachodon or duck-billed dinosaur to the discovery of which in the Edmonton formation reference was made in my summary report for 1912. Other specimens collected in 1912 from the same formation in Alberta were also prepared for study or exhibition. Since the return of the field party all efforts have been put forth in the laboratory to prepare for study and later exhibition as much of the material of the 1913 collection from the Red Deer river as possible. Good progress had been made at the end of the year with the large carnivorous dinosaur Gorgosaurus (hitherto tentatively referred to Deinodon), with the skull of the trachodont dinosaur *Gryposaurus notabilis,* with that of *Chasmosaurus belli,* and with the head of *Styracosaurus albertensis.* Many hundreds of small specimens representative of the general fauna of the Belly River formation have been unpacked, cleaned, mended, and restored, and rendered available for study.

Museum.

The most striking addition made to the exhibit in the Hall of Fossil Vertebrates during the year was the panel mount of the Trachodon from the Edmonton formation of Red Deer river, Alberta (Upper Cretaceous collection of 1912). This splendid specimen, 32 feet in length, was placed on exhibition in July, and has proved a source of great interest to the general public.

The attractiveness of the exhibit has been much enhanced by a number of bromide enlargements of photographs of mounted skeletons and restorations of fossil vertebrates illustrating the more important groups of reptiles and mammals of the later geological periods.

The magnificent skull of *Styracosaurus albertensis* which was not discovered in the "bad lands" of Red Deer river (Belly River formation of Alberta) until late in September was placed on exhibition in December, on the completion of the removal of the rock from its upper and side surfaces.

The following also were placed on view: plaster casts of specimens illustrating foot structure in the primitive ungulates, in later hoofed mammals, and in an early carnivore (creodont); unique specimens of Cretaceous and Oligocene turtles; and a series of fifty-five casts of the crowns of upper molar teeth of ungulates illustrating the lines of differentiation from the simple tritubercular tooth up to the more complex forms.

The Hall of Fossil Vertebrates was first opened to visitors on January 20.

The public has not been slow to take advantage of the opening of the museum on Sunday afternoons when the fossil vertebrates have received their full share of attention, the hall being generally crowded up to the hour of closing.

Much of my time during the year has been given to the study of our vertebrate collections, and to the description of new material, particularly that of the Edmonton Cretaceous collection of 1912, and of the Belly River Cretaceous collection of 1913, which latter includes an unusual number of hitherto imperfectly known, or undescribed generic forms.

The proper equipment of the laboratory, the direction and superintendence of work in progress in the same as well as of the installation of new exhibits in the museum have also claimed a large share of my time.

The weekly Library Committee meetings, and those of the Museum Committee have been attended as usual.

Early in the year a "Bibliography of Canadian Zoology for 1912 (exclusive of Entomology)" was prepared, and later presented and accepted for publication at the annual meeting of the Royal Society of Canada, in May.

The following descriptive and illustrated papers were published during the year:—

"The manus in a species of Trachodon from the Edmonton formation of Alberta."

"Description of a new species of Testudo, and of a remarkable specimen of Stylemys nebrascensis, from the Oliogocene of Wyoming, U.S.A."

"A Canadian monster of three millions of years ago"; popular article with illustration.

"A new genus and species of Ceratopsia from the Belly River formation."

Additions to the Vertebrate Palæontological Collections During 1913.

Collected by Officers of the Geological Survey.

Sternberg, Charles H., and party.—A large and valuable collection of vertebrate remains, dinosaurian for the most part, from the Belly River Cretaceous of Red Deer river, Alberta. The collection includes the following:—

(1) *Gorgosaurus libratus,* Lambe; carnivorous dinosaur; nearly complete skeleton including head with lower jaw. Found by C. M. Sternberg, 3½ miles below the mouth of Berry creek, on south side of river, near prairie level.

(2) *Stephanosaurus marginatus,* Lambe; head with lower jaw, footed-ischium, long bones of legs, etc.; found by Charles H. Sternberg, one-quarter mile west of No. 1.

(3) Trachodont dinosaur; right maxilla and dentary, with teeth; found by Charles H. Sternberg, west of Nos. 1 and 2.

(4) *Stephanosaurus marginatus,* Lambe; large areas of skin impression femur, footed-ischia, front feet, etc.; found by Charles H. Sternberg, one-half mile north of No. 1 in bad lands, south side of river, 3½ miles below Steveville (mouth of Berry creek). Photographs 1, 2, 3, 4, and 13.

(6) *Gryposaurus notabilis,* Lambe; skull 3 feet 3 inches long, with mandible, including 20 feet of the skeleton, in clay ironstone concretion; found by C. M. Sternberg, on high point 100 feet above and near river, one-half mile above camp.

(7) *Boremys pulchra,* Lambe; carapace (10 inches long and 8 inches broad) and plastron; found by L. Sternberg, south of and 100 feet above river.

(8) *Chasmosaurus belli,* Lambe; most of the skeleton including head with lower jaw, and skin impressions, found by Charles H, Sternberg, in coulée one mile south of camp.

(9) *Styracosaurus albertensis,* Lambe; squamosal, jugal, postfrontal, showing orbital opening; found by Charles H. Sternberg, three-quarters of a mile south of camp, at same level as and near No. 1.

(10) Turtle; 20 feet above and near No. 2; found by Charles H, Sternberg.

(11) Turtle; found by Charles H. Sternberg, with No. 10.

(12) " " " " "

(13) " " " " "

(14) Trachodont dinosaur; most of cervical and dorsal vertebræ hind legs and feet, ribs, and 6 feet of the tail, no skull; found by C. M. Sternberg, in coulée 2½ miles west of camp, near crossing of One Tree creek, on way to Brooks.

(15) *Aspideretes subquadratus,* Lambe; carapace in good condition; found by G. F. Sternberg, 1½ miles south of Steveville, at head of ravine near prairie level.

(16) *Ornithomimus altus,* Lambe: long bones of legs, several bones of feet, five caudal vertebræ; found by G. C. Sternberg, in coulée 1½ miles south of Steveville.

(17) Ornithomimus: three of the toes in place; found by C. H. Sternberg.

(18) Turtle: carapace; found by C. M. Sternberg, one-half mile east of No. 14.

(19) Trachodont dinosaur: ramus of mandible; at head of coulee off One Tree creek one-quarter mile south of Steveville.

(20) Trachodont dinosaur; dorsal vertebræ with most of the ribs, hind legs with foot, pelvic arch, one-half length of tail with skin impression; total length preserved 15 feet 9 inches; found by L. Sternberg, one-quarter mile east of No. 14, at base of hill, on east bank of coulée which empties into One Tree creek.

(21) Trachodont dinosaur; ramus of mandible; found by C. H. Sternberg near No. 20.

(22) Carnivorous dinosaur; maxilla; found by C. H. Sternberg near No. 20.

(23) Large footed-ischium; found by George F. Sternberg, north side of river opposite camp.

(24) Trachodont dinosaur; large metatarsal; found by G. F. Sternberg on north side of river.

(25) Trachodont dinosaur; maxilla and dentary bone; found by G. F. Sternberg in ravine 1½ miles south of Steveville, near No. 16.

(26) *Euoplocephalus tutus,* Lambe, large plate of; same locality as No. 25, found by G. F. Sternberg.

(27) Plesiosaur sp.; several verterbræ, both femora, several tarsals and phalanges; found by C. H. Sternberg, on south side of river, below "Happy Jack" ferry.

(28) *Centrosaurus apertus,* Lambe; fine skull about 5½ feet long, large nasal horn, no lower jaw, found by C. H. Sternberg, at high point 500 yards south of "Happy Jack" ferry.

(29) *Styracosaurus albertensis* Lambe, the "Spike dinosaur"; skull over 6 feet long, no lower jaw, found by C. H. Sternberg, near "Happy Jack" ferry.

(30) Large carnivorous dinosaur; parts of maxilla and dentary; found by C. H. Sternberg, at head of first left lateral ravine that enters the large coulée at "Happy Jack" ferry. (Bones of the skeleton left in rock.)

Also many hundred of separate bones and teeth representative of the varied fauna of Belly River times.

Lambe, Lawrence M.—Large cycloid scales of ? Strepsodus, with shells of ostracods and Anthracomya in abundance, on fragments of limestone from Joggins, N.S.; Coal Measures, Division IV of Joggins section.

Plesiosaurian reptile; a number of vertebræ, with ribs, abdominal ribs, some limb bones, and a tooth, from Jurassic shale on the south fork of Oldman river, Alberta.

Fragments of bone showing structure, from reptilian remains in shale of supposed Jurassic age, on second creek east of Exshaw, Alberta.

Presented.

Topley, W. J., Ottawa, Ont.—Two clay nodules, each containing a specimen of *Mallotus villosus* (Müller), capelin. Pleistocene. From the Leda clay, at Besserer grove, about 8 miles below Ottawa, Ont.

Billings, Walter, Ottawa, Ont.—Caudal vertebræ of *Delphinapterus leucas,* and lower end of femur of large ungulate, Bison? from Pleistocene gravel on lot 15, concession V, of the township of Nepean in the vicinity of Jock river, Ont.

Monckton, G. J., Duncan, B.C.—Part of left mandibular ramus with teeth, of "dog"; part of right ramus, with teeth, and part of leg bones of deer. From a low bank between the Canadian Pacific Railway line and Thompson river, about half a mile west of the bridge at Savona, B.C., with Unio shells; Pleistocene? (White silt formation).

Johansen, Fritz—Naturalist to the Stefansson Expedition, through Walter H. Johnson, Acting Superintendent, Bureau of Education, Nome, Alaska.—One molar tooth of mammoth, Teller, Alaska. Pleistocene.

McTaggart, W. E. D.—Superintendent of Buffalo Park, Wainwright, Alberta, through the courtesy of Mr. J. B. Harkin, Commissioner of Dominion Parks, Department of the Interior, Ottawa.—Skeleton of bull bison (*Bison bison,* Linn), from Wainwright. As the animal had broken one of his horns, a head of another individual of similar size has been substituted in the mounted skeleton.

Purchased.

Kadiak bear (*Ursus middendorffi,* Merriam), skull with mandible of, from Alaska; for comparison with skull of *Arctotherium yukonense,* Lambe, Pleistocene of Yukon, and that of *Ursus spelæus*, Rosenmüller, Pleistocene of Europe.

Bison crassicornis, Richardson. Cranium with nasal bones and horns sheathing horn cores; no lower jaw. Head of 18th pup, Dominion creek, 2,000 feet above Dominion creek, Klondyke district, Yukon, 10 feet from surface, in muck. Pleistocene.

Bison crassicornis, Richardson. The back portion of two skulls with horn cores, from upper Dominion creek, Yukon. Pleistocene.

Portion of socket of incisor (tusk) of mammoth?; from Upper Dominion creek, Yukon. Pleistocene.

Mastodon, molar tooth of; McQueston creek, Stewart River district, Yukon. Pleistocene.

In this tooth a hard substance occurs in the bottom of two of the valleys between the transverse cusp-ridges. With regard to the composition of this substance Mr. R. A. A. Johnston has supplied the following note: "The material in the valleys of the crown of this tooth consists of *struvite* (a hydrous phosphate of ammonium and magnesium) intermixed with small quantities of organic matter. This material is not identical in composition with ordinary tartar of the teeth; this latter substance, which is a product of the serum of the blood having the power of instipating the saliva of the mouth and thereby attaching itself more or less firmly to the teeth, consists of phosphate of calcium, animal organic matter, and some uncertain organic salts."

REPORT OF THE INVERTEBRATE PALÆONTOLOGIST.

(E. M. Kindle.)

Field Work.

The field activities of this section are directed with a view to close co-operation with the work of the geologists of the Survey who are engaged in economic and areal geology. The reliability and permanence of the work of the field geologists rests in a large degree upon the accuracy of the correlations made by the palæontologist. It is, therefore, desirable whenever possible that the palæontologist should secure a detailed personal knowledge of one or more sections of the formations for whose correlation he is held responsible. The resulting collections of fossils are much larger than those ordinarily supplied by the geologist whose time for this part of the work is limited, and the determinations of horizons have a correspondingly broader basis of faunal evidence. For these general reasons the field work of this section has extended during the last season over a wide area.

Mr. L. D. Burling has made large collections of Cambrian and other Palæozoic faunas in the Maritime Provinces, British Columbia, and the Yukon Territory along the International Boundary. The western collections made by Mr. Burling have added considerably to the limited data previously available for correlation in the areas studied.

In southwest Nova Scotia, Mr. E. J. Whittaker spent about six weeks in the latter part of the summer collecting fossils from the Palæozoic formations. These fossils are expected when supplemented with additional field work, to throw light on the relations of the early and later Palæozoic formations of that district.

In southwest New Brunswick, Mr. Olof Nylander was engaged for two months in collecting fossils near the International Boundary, which will be available for correlating the rocks of southern Quebec and New Brunswick with those of Maine. The work of Williams and Clarke on the Devonian fauna of the latter state makes the Maine section the nearest standard for comparison in matters of correlation relating to those parts of Quebec and New Brunswick adjacent to the St. John River valley.

My own field work began in Ontario and adjacent parts of New York state and ended in Manitoba. This field work was divided into two periods separated by an interval in midsummer devoted to the work of the International Congress of Geologists. Participation in two of the longer excursions of the Congress in the capacity of guide and attendance at the sessions of the meetings in Toronto occupied my time from July 13 to August 17. The field work was begun in June with a study of the type section of the Clinton formation at Clinton, N.Y., in company with Mr. M. Y. Williams. A few days were devoted to a study of other Silurian sections in western New York, with which correlations of the Silurian formations of Ontario are to be made. A series of representative sections of the Silurian rocks of the Ontario peninsula along the Niagara escarpment was next examined by Mr. Williams and myself. The stratigraphic work thus begun in the Ontario peninsula was left in charge of Mr. Williams while I proceeded to Quebec, Gaspe, and other points in the Maritime Provinces. The geologic features of the particular localities which were visited by Excursion A1 were studied until July 13, when I joined the excursion at Quebec. I remained with the excursion until July 30, leaving it at Cabano, Que., to review the work done by Mr. Olof Nylander in that vicinity. Mr. Nylander spent about two months in that region collecting fossils which are to be used in correlating the formations of this part of Quebec with those of adjacent parts of Maine.

After the close of the sessions of the Congress at Toronto, I went west with Excursion C1, leaving it at Winnipeg. Field work was resumed at Le Pas, which is the present terminus of regular train service on the new Hudson Bay railway. It was expected that the rock exposures made by the construction of the road beyond Le Pas would afford valuable information regarding the geology of this region. Through the courtesy of the chief engineer of the road in placing transportation at my disposal, I was able in a brief period to examine a number of these exposures between Le Pas and the end of steel. From Le Pas I proceeded down the Saskatchewan river by canoe in order to study the stratigraphic relations of the rocks exposed along the lower part of the river and the shores of Cedar lake. After reaching the mouth of the river at Grand Rapids I joined a party of the Waterpower Division in chartering the only sailboat available there. From Grand Rapids we skirted the north shore of Lake Winnipeg and fossils were collected from the best exposures of the Ordovician limestone on the north shore. On arriving at Warren Landing, I sailed by the steamer *Wolverine* for Selkirk.

Field work in Manitoba was concluded by a trip of Lake St. Martin and other points in the Gypsumville district. This work supplemented that of last season in the same general region and enabled me to see the unique inliers of Pre-Cambrian rock in the islands and on the shores of Lake St. Martin, as well as the whole of the section exposed between Lakes Manitoba and St. Martin. The geologic results of the Saskatchewan River work are recorded elsewhere in this volume.

Office Work.

The appointment early in the year of Mr. L. D. Burling, formerly of the Smithsonian Institution, Washington, D.C., to the staff of the Geological Survey as a palæontologist has very materially increased the ability of this division to furnish reports promptly on the many collections of fossils referred to it after the close of each field season. The determination of the Cambrian and some other faunas which are referred to this division for determination has been assigned to Mr. Burling.

The urgent need of assistance in preparing fossils for study and exhibition purposes has been met by the appointment of Mr. E. J. Whittaker, preparator in invertebrate palæontology. Mr. Whittaker has also furnished valuable aid in collecting fossils in the field.

Miss A. E. Wilson has rendered very efficient assistance in the office and museum, chiefly in connexion with the cataloguing and numbering of fossils, assisting in the preparation of several hundred palæontological photographs, and work on the catalogue of type fossils in the museum.

In the Invertebrate Hall of the museum, five new cases of exhibits have been added to the exhibition series during the year. One of these illustrates the various processes of fossilization which are commonly met with. Another case shows representative slabs of fossils from the several formations found near Ottawa. This local exhibit is supplemented by two geologic cross sections showing the stratigraphic succession and some of the structural features of the Ottawa district. A special exhibit which has been prepared from ripple-marked sandstone and coal measure tree stumps from Nova Scotia shows these fossils in their assumed original relations with a background of restored Carboniferous vegetation. A representative series of Palæozoic corals is shown in one of the two new cases acquired for invertebrate palæontology. The other new case has been filled with a series of the remarkable Cambrian fossils from Field, B.C. For this collection the Survey is indebted to the courtesy of Dr. C. D. Walcott, secretary of the Smithsonian Institution.

Papers dealing with problems on which the field work of the last season has furnished data have been published in the scientific journals and under the titles indicated below:—

(1.) An inquiry into the Origin of "Batrachoides the Antiquor": of the Lockport limestone of New York, Geol. Magazine, N.S., December 6, vol. I, pp. 158-161, pls. VIII, IX, 1914.

(2.) A comparison of Cambrian and Ordovician ripple-marks found at Ottawa, Canada: Jour. of Geol. In press.

(3.) Columnar Structure in Limestone: Victoria Memorial Museum Bull. No. 2, pp. 35-44, pls. II, III, 1914.

4. What does the Medina Sandstone of the Niagara section include? Science, New Ser., vol. XXXIX, pp. 915-918, 1914.

The accessions during the year to the collections of invertebrate fossils are indicated below:—

Additions to the Invertebrate Palæontological Collections During 1913.

Presented.

Clarke, J. M., Albany, N.Y.—A large block of fossiliferous Devonian limestone from Percé, Gaspe, Que. Access. No. 168.

Harris, G. D., Cornell University, Ithaca, N.Y.—A small collection of fossils from the Tertiary of North Carolina, U.S.A. Access. No. 158.

Lambert, H. F. J., International Boundary Survey.—One Carboniferous fossil coral from the 141st meridian, 96 miles north of the line crossing Porcupine river, Alaska. Access. No. 105.

Lenthall, R. E., Newport Centre, Gaspe, Que.—A fossil from l'Anse l'Enfer near Port Daniel, Gaspe, Que. Access. No. 145.

McIsaac, Mr., Ottawa, Ont.—A small collection from the Collingwood formation near Ottawa. Access. No. 157.

Radcliffe, J. B.—An ammonite from Aspen Grove near Golden Sovereign mine, B.C. Access. No. 141.

Reagan, Albert B., Nett Lake, Minn.—Several pieces of fossiliferous limestone from Woodson county, Kansas, U.S.A. Access. No. 115.

Smithsonian Institution, Washington, D.C.—A large collection of fossils from the Middle Cambrian Burgess shale near Field, B.C. Access. No. 112.

A collection of silicified crinoidal columns from Louisville, Ky. Access. No. 116.

A collection of silicified fossils illustrating the development of geodes. Access No. 114.

Some fossils of Lower Cambrian age from Mumm peak, northwest of Yellowhead pass, Alberta. Access. No. 182.

Several specimens of Middle Cambrian Medusæ from Coosa valley, Alabama. Access. No. 183.

Spreckley, J. Alfred, Ottawa, Ont.—A specimen of trilobite from Ottawa, Ont. Access. No. 148.

Taylor, Chas. E.—A small collection of fossils from township 45, range VIII, Alberta. Access. No. 154.

Wells, J. D., Kitselas, B.C.—Six fossils from 5 or 6 miles up Copper river, British Columbia. Access. No. 119.

Collected by Officers of the Geological Survey.

Allan, J. A.—A small collection of Cambrian fossils from Castle mountain, B.C. Access. No. 161.

Some fossils from near Crowsnest pass, Beaverfoot range, British Columbia, and Sawback range, Alberta. Access. No. 153.

A collection of Ordovician fossils from the Ice River district, British Columbia. Access. No. 177.

Ami, H. M.—Pre-Cambrian fossil from Steeprock lake, Ontario. Access. No. 173.

Burling, L. D.—A collection of fossils from Rivière-du-Loup and Bic, Que. Access. No. 162.

A large collection of fossils, Cambrian to Carboniferous, from the Yukon-Alaska boundary. Access. No. 150.

Ordovician fossils from Ottawa and vicinity; a collection of Cambrian fossils from several horizons in the Dogtooth mountains, west of Donald, British Columbia. Access. No. 179.

Several collections of fossils from George River station, Cape Breton. Access. No. 179.

Cambrian fossils from Cap Canon, near Percé, 2 miles south of Cap Rosier, Quebec. Access. No. 179.

Silurian corals from Black cape, Quebec. Access. No. 180.

Many slabs of Lingula (*Lingulepis*) *acuminata* from the Potsdam sandstone east of South March, Carleton county, Ont. Access. No. 180.

A large collection of Cambrian fossils from Hanford brook and vicinity, New Brunswick. Access. No. 180.

A large collection from the Middle Cambrian, Albertella zone, on Mount Bosworth, British Columbia. Access. No. 180.

Ordovician graptolites from two horizons, Lévis, Que. Access. No. 180.

Burling, L. D., and Hayes, A. O.—A large collection of Ordovician graptolites from Navy island, St. John, N.B. Access. No. 181.

Collections from many places in the city of St. John, N.B. Access. No. 181.

Cambrian fossils from Long island, Kennebecasis bay, New Brunswick. Access. No. 181.

Burling, L. D., and Schofield, S. J.—Cambrian fossils from four horizons in the Burton shales near Elko, B.C.; Devonian fossils near Elko, B.C. Access. No. 172.

Cook, C. H.—A collection of material from Nanaimo series from Cowichan lake and vicinity and from Malahat volcanics, Duncan sheet, Vancouver island. Access. No. 184.

Daly, R. A.—Fossils from north bank of Thompson river, British Columbia. Access. No. 156.

Fossils from the Upper Cambrian from Canadian Pacific Railway cut, 54·5 miles from Field, and about 2 miles west of Donald station, B.C. Access. No. 156.

Harvie, R.—A small collection of fossils from the neighbourhood of Knowlton Landing, Lake Memphremagog, Que. Access. No. 113.

A collection from Lake Memphremagog. Access. No. 151.

Hayes, A. O.—Two large conglomerate limestone boulders from Courtenay bay, St. John harbour, New Brunswick. Access. No. 120.

A few fossils from Milkish head, New Brunswick. Access. No. 149.

Ingall, E. D.—Ordovician fossils from Ottawa and vicinity. Access. No. 178.

Johnston, W. A.—A small collection of Pleisteocene fossils from Lake of the Woods and Fort Frances, Ont. Access. No. 164.

Kindle, E. M.—A collection from Selkirk, Manitoba. Access. No. 134.

Fossils from Lake St. Martin, Manitoba. Access. No. 139.

A small collection from Le Pas, Manitoba. Access. No. 130.

Some fossiliferous rock from the Pre-Cambrian of Steeprock lake, Ontario. Access. No. 155.

Some fossils from Gaspe, Quebec, collected during the Geological Congress Excursion A1. Access. Nos. 133, 135.

A collection of fossils from Middleton, N.S. Access. No. 136.

A box of fossils from Clinton, N.Y., and Lockport, N.Y. Access. No. 144.

Lambe, L. M.—A collection of Middle Cambrian fossils from Mount Stephen, British Columbia. Access. No. 142.

A collection from the South Fork of the Oldman river, Alberta. Access. No. 147.

Lawson, A. C.—Fifteen specimens of fossils from Cambrian of Steeprock lake, Ontario, transmitted by Mr. C. D. Walcott. Access. No. 111.

MacKenzie, J. D.—A large collection of Mesozoic fossils from the Queen Charlotte islands, British Columbia. Access. No. 175.

Nylander, Olof. O.—A collection of fossils from Mount Wissick section, Lake Temiscouata, Quebec. Access. Nos. 121, 122, 132, 140.

Fossils collected in New Brunswick at St. Basil, Green river, Ligas, Siegas river, and along the International railway. Access. Nos. 125, 126, 129, 137.

Schofield, S. J.—Cambrian and Devonian fossils from Elko, B.C. Access. No. 118.

Sternberg, C. H.—A small collection of Laramie fossils from Wyoming, U.S.A. Access. No. 143.

Stewart, J. S.—A collection of fossils from Livingstone range, Alberta. Access. No. 152.

Wallace, R. C. and McLean, A.—A collection of Silurian and Devonian fossils from Manitoba. Access Nos. 146, 166.

Wallace, R. C.—A collection of Ordovician fossils from one of the city wells in Winnipeg, Man. Access No. 174.

Whittaker, E. J.—Fossils from Nictaux area, Nova Scotia. Access. No. 128.

A collection of fossils from Bear River area and Kentville, N.S. Access No. 131.

Williams, M. Y.—A collection of Silurian fossils from New York, Niagara peninsula, and the western peninsula of Ontario. Access. No. 169.

Wilson, A. E.—Fossils from Cement quarry at Hull, Que. Access. No. 138.

Wright, W. J.—A small collection of Carboniferous fossils from Moncton, N.B. Access. No. 159.

Purchased.

Grebel, Wendler & Co., Geneva.—A collection of fossils from the Devonian of Bohemia. Access. No. 123.

Acquired by Exchange.

Hill, Thos. S.—A box of fossils from Oklahoma, U.S.A. Access. No. 124.

Reports on Fossils.

Reports on fossils have been furnished to a number of members of the staff, as well as to various persons sending fossils to the Survey for determination. Such of these reports as include data of palæontologic interest are appended to this report.

Mesozoic and Palæozoic Fossils from Frank, Alberta.—The following notes relate to a report on a collection of Palæozoic and Mesozoic fossils made by Mr. W. W. Leach in the vicinity of Frank, Alberta.

Lots 7 (179[1]), 9 (181), and 10 (182), represent the older fauna. The same general fauna is represented by these three lots and includes the following species *Fenestella* sp., *Cyathophyllum* sp., *Diphyphyllum* sp., *Productus* sp., *Spirifer* cf. *cameratus, Spirifer* cf. *marcoui, Spirifer* sp. This fauna is of Mississippian age. The beds holding it probably represent the northern extension of the Madison limestone of the northern Rocky Mountain states.

Lot No. 8 (180) includes a single specimen, a fragment of an undetermined species of *Scaphites.* A horizon of Cretaceous age is indicated by this fossil.

Lot No. 6 (178). This lot comprises several fragmentary specimens of *Belemnites* sp. undetermined. These are probably of Jurassic age, but do not alone afford decisive evidence that the horizon represented is not Cretaceous. The occurrence of this representative of a strictly marine order of invertebrates in the generally barren shales of the Fernie is of interest in indicating that these beds are in part at least of marine origin.

Coal Measure Fossils from St. John, N.B.—A small collection of fossils made by Mr. A. O. Hayes from the Milkish Head peninsula, near St. John, N.B., contains a number of specimens all referable to a single species, *Estheria* cf. *dawsoni.* This fossil has been reported from the Horton series of Nova Scotia and the Lower Carboniferous of Soctland. Its recorded range is confined to the Lower Carboniferous. Its occurrence near St. John, therefore, appears to indicate a horizon below the limits of the Coal Measures.

Devonian Fossils from British Columbia.—Specimens of dark dolomitic limestone containing corals were transmitted to me for examination by Prof. J. A. Allan (No. 1407). These contain a branching coral which is one of the common fossils in the Jefferson limestone of Montana. I have referred it to *Favosites* cf. *limitaris* in collections which have previously come to my notice. This specimen in all probability is of Devonian age and doubtless represents the Jefferson limestone.

Devonian Fossils from Fossil Mountain, Alberta.—I have examined with some care the collection, transmitted to me by Prof. J. A. Allan for determination, which was made at Fossil mountain, Alberta. I recognize in it the following species: *Cladopora* sp., *Syringopora* cf., *perelegans* Billings, *Phillipsatræa verrelli* Meek, *Diphy-*

[1] Numbers in parentheses refer to the museum locality catalogue.

phyllum cf., *arundinaceum* Billings, *Productella hallana* Walcott, var., *Stropheodonta demissa* (Conrad), *Schuchertella* cf. *chemungensis* var. *arctorstriatus* (Hall), *Atrypa reticularis* (Linn.), *Schizophoria striatula* (Schlotheim), *Spirifer whitneyi* (Hall).

The collection also includes numerous sponge spicules and two undetermined brachiopods which are probably new species.

This fauna represents a horizon of the upper Devonian. The presence in it of such well known diagnostic upper Devonian fossils as *Sp. whitneyi* and a variety of *P. hallanus* places its Devonian age beyond question.

Devonian Fossils from the Athabaska River Valley.—A collection of Devonian fossils left with me for determination by Mr. J. E. Narraway, from a locality 50 miles east of Ft. Murray, Alberta (R. VI., T. 89, W. 4th Meridian), includes the following species:—

Atrypa reticularis.
Atrypa spinosa var.
Schizophoria striatula.
Cyrtina hamiltonensis.

The fauna represents a horizon of late middle or early upper Devonian age.

Fossils from Lake Memphremagog.—A collection of fossils made by Mr. Robert Harvie and Mr. L. D. Burling, comprises four lots.

The material from Knowlton Landing, Lake Memphremagog (on shore of lake), is represented by a single species.

Favosites cf. *basaltica.*

The remainder of the collection comprises three lots numbered 2 (1651), 3 (1652), and 4 (1650), from west of Mountain House, Owl's Head mountain, Lake Memphremagog. These include the following species:—

Crinoid stems.
Favosites basaltica.
Favosites, sp.
Zaphrentis sp.
Spirifer cf. *arrectus.*
Actinopteria?
Panenca?
Proteus, sp.

The three lots combined in this list of fossils from rather closely adjacent localities appear to belong to the same general fauna. The deformation and partial metamorphism of all of the material renders any determinations beyond generic highly problematic except in the case of one of the two species of Favosites which is either identical with or closely related to *F. basaltica.* The very poor state of preservation of the fauna prevents close comparison with other faunas and the most that can be said regarding its correlation is that it is highly probable but not entirely certain that the fauna is of middle or lower Devonian age.

Devonian and Silurian Fossils from Manitoba.—The following memoranda relate to a collection of fossils from Manitoba submitted to me for study by Prof. R. C. Wallace.

The species which have been recognized are given in the two faunal lists below, grouped according to the horizons represented. The numbered specimens which do not appear in the list are represented either by material too poor for determination or by specimens having only lithologic or petrographic interest.

Favosites favosus
No. 8, Fairford.

Favosites cf. *favosus*
Nos. 1 and 4, Davis pt.

Favosites cf. *niagarensis*
Nos. 9 and 10, Fairford.

Favosites sp.
No. 22, Fairford.

Cyathophyllum sp.
No. 3, Davis pt.

Halysites catenulatus var.
No. 20, between Fairford and Hilbre, No. 18, west of Arbourg, 18 miles.

Stropheodonta acanthoptera
Nos. 24, 25, and 27, Hilbre.

Loxonema sp.
Hilbre.

Leperditia hisingeri
Nos. 14, 23, and 25, Hilbre.

The above listed species all belong to the upper Silurian fauna of Manitoba.

Streptelasma cf. *prolifica*
No. 67, Winnipegosis.

Amplexus or *Diphyphyllum* cf. Whiteaves, Pl. XXXV, fig. 2. Cont. to Can. Pal., Vol. I, Pt. IV.
Nos. 56 and 57, Road to Sandy bay.

Favosites cf. *hamiltonae*
No. 61, Limekiln, Sandy bay.

Atrypa reticularis
Nos. 69 and 84, Winnipegosis.

Atrypa cf. *missouriensis*
No. 71, northwest side bridge, Winnipegosis.

Cyrtina hamiltonensis
No. 82, Henderson.

Spirifer inutilis
No. 72, northwest side of bridge over Mossy river, Winnipegosis.

The Devonian fauna of the collection is represented by the species listed above. The several lots represented by the above list have apparently all been derived from the Manitoba limestone with the exception of lots 56 and 57, road to Sandy bay. These two lots are represented by poorly preserved corals which probably represent the Winnipegosan dolomite fauna.

The specimens from Ashern, 35 and 36, consist of reddish-buff and brownish-red dolomite, apparently without fossils. These specimens are identical in physical features with the highest beds of the Silurian, which I observed southwest of Fairford, just east of the eastern border of the Devonian limestone (Elm Point limestone). They doubtless represent this horizon in the vicinity of Ashern.

Palæozoic Fossils From Elko, British Columbia.—A collection of fossils from Elko, B.C., made by Stuart J. Schofield, includes a number of small lots of fossils which are discussed below.

Lot 1 (S. J. S. Nos. 11-16). The specimens of this lot represent several specimens of tube-like bodies lying apparently parallel and normal to the bedding. These cylindrical impressions, which doubtless represent annelid borings, remind one of *Scolithus canadensis* Billings of the Potsdam sandstone. Like other impressions of their type, however, they afford no reliable criteria for inferring the age of the beds represented.

Lot 2 (S. J. S. Nos. 1, 2, 3, 9, 23, 24, 34, 35, 37, 38, 39, 41, 42, 44, 45). The preceding numbers are represented only by fragments of corals in a black dolomite too poorly preserved to permit determination. They appear, however, to resemble and are probably identical with one or two species which characterize the Jefferson limestone of Montana.

Lot 3 (S. J. S. No. 28) contains the following species:—

Atrypa reticularis.
Atrypa cf. *missouriensis.*
Spirifer englemanni.
Strophostylus sp. *undet.*

Lot 4 (S. J. S. Nos. 30-31). Two species are represented in this lot, viz.: *Stropheodonta demissa* and *Schizophoria* n. sp. near *S. striatula.*

Lots 3 and 4 are of middle and upper Devonian age. The fauna of lot 3, though a small one for purposes of close correlation, is believed to represent the fauna of the Jefferson limestone of Montana. Lot 4 probably represents the same fauna.

Post-Cambrian Faunas from the Yukon-Alaskan Boundary.—The faunas collected by D. D. Cairnes during the survey of the 141st meridian show that each of the five great systems of the Palæozoic rocks from the Cambrian to the Carboniferous is represented in the section surveyed between the Yukon and the Porcupine rivers.

Ordovician.—Two small lots of fossils composed almost entirely of corals are referred to the upper Ordovician. One of these (XI k 46) includes two species of corals which are identical with forms collected by the writer in the Seward peninsula, Alaska,[1] where the middle or upper Ordovician age of the fauna is fully established by a long list of Ordovician brachiopods and gasteropods. The two lots listed below are believed to represent the same horizon as these western Alaskan collections which occur in the upper part of the Port Clarence limestone and belong to the same Ordovician fauna which was collected along the 141st meridian by Dr. Cairnes during the season of 1911. This is a later horizon of the Ordovician than that represented by the fauna of the graptolite beds on which Messrs. Burling and Ruedemann have reported.

Lot XI k 46 (185) contains *Columnaria alveolata* Goldf. *Calopœcia canadensis* Bill. *Favosites aspera?* d'Orbigny, *Halysites catenulatus* var. *gracilis* Hall, and *Endoceras* cf. *proteiforme* Hall.

The second lot, XII x 37 (207), contains a badly preserved shell which appears to represent a Macluria. This lot should also be referred to the Ordovician if this provisional generic determination is correct.

[1] The faunal succession in the Port Clarence limestone, Alaska, Am. Jour. of Sci., vol. xxxii, 1911, pp. 344-346.

Middle Silurian.—The lots which follow represent a fauna which is comparable with the middle Silurian fauna found in the states adjacent to the Great Lakes. The presence in it of *Spherexochus romingeri, Spirifer niagarensis,* and an Illaenus closely related to if not identical with *I. imperator,* suggest that a larger collection would show still other resemblances to the Silurian limestone fauna of Indiana and Illinois. This fauna represents the same general horizon as the Silurian fauna which was discovered in eastern Alaska on the Porcupine river.[1] The principal species in the several lots which are considered to represent this general fauna will be listed separately.

Lot XIn44 (187)

Conchidium Knighti (Sowerby).

Lot XIo45 (189)

Camaretoechia cf. *indianensis* (Hall).
Camaretoechia? sp.

Lot XIXs28 (275)

Pholidops cf. *squamiformis* Hall.
Atrypa sp.
Atrypa cf. *marginalis* Dalman.
Orthis flabellites Foerste.
Dalmanella cf. *elegantula* (Dalman).
Whitfieldella cf. *nitida* Hall.
Anoplotheca sp.
Illaenus cf. *imperator* Hall.

Lot XIXf31 (258)

Stropheodonta sp.
Rhipidomella n. sp.
Gypidula? sp.
Clorinda cf. *fornicata* (Hall).
Sphaerexochus sp.
Illaenus cf. *imperator* Hall.

Lot XIXh31 (260)

Stropheodonta sp.
Orthis flabellites Foerste.
Dalmanella cf., *elegantula* (Dalman).
Meristina sp.
Spirifer radiatus Sowerby.
Spirifer sp.
Sphaerexochus romingeri Hall.
Illaenus cf. *imperator* Hall.
Brontiopsis sp.

Lot XIXm6 (270)

Cladopora sp.
Favosites sp.
Zaphrentis sp.
Camarotoechia (?) cf. *acinus* Hall.
Camarotoechia (?) cf. *indianensis* (Hall).
Atrypa sp.

[1] Kindle, Bull. Geol. Soc. Am., vol. 19, p. 325, 1908.

Atrypina sp.
Nucleospira cf. *pisiformis* Hall.
Trematospira cf. *camura* Hall.
Sieberella n. sp.
Mytilarca (?) cf. *sigilla* Hall.
Platyceras sp.
Orthoceras sp.
Dalmanites sp.

Lot XVIIh13 (233)
Camarotoechia cf. *indianensis* (Hall).
Stropheodonta sp.
Atrypa reticularis (Linn.) var.
Spirifer radiatus Sowerby.
Reticularia cf. *proxima* Kindle.
Pterinea, small sp.
Proetus sp.

Lot XIIl30 (192)
Favosites gothlandicus Lamark.
Heliolites interstinctus Linn.
Halysites catenulatus Linn. var.
Cyathophythina sp.

Probably Late Silurian:—

Lots XIIv30 (202), XIIt32 (199), XIIn32, XIIv34 (204), XIIv37 (205), XIIv42 (206), XIIr45 (198).

The preceding small lots of fossils, each representing usually only two or three species, appear to represent the same geologic horizon. They are referred provisionally to a late Silurian horizon, chiefly on the evidence of two or three large species of Ostracodes which are believed to be of Silurian age. This reference, however, needs the confirmation of additional evidence, since the *Martinias,* which in one case are associated with the ostracodes, suggest a Devonian horizon.

The fossils represented in these lots include the following:—
Stropheodonta, small species.
Meristella sp.
Retzia? sp.
Martinia sp.
Leperditia sp.
Isochilina sp.

Three other lots and their included fossils which probably represent a late Silurian horizon follow:—

Lot XIh43 (183)
Diphyphyllum sp.

Lot XIr43 (190)
Diphyphyllum sp.
Encrinurus sp.

Lot XIIv29 (201)
Cyathophyllum sp.
Alveolites? sp.
Leperditia sp.

Devonian.—The Devonian fauna is represented by several small lots of fossils. While these include rather a small number of species they represent a considerable number of localities, and it is significant that none of the several lots include any characteristic upper or lower Devonian forms. There is for example no trace of either *Spirifer disjunctus* or *Sp. Whitneyi*, which have a very wide distribution in the upper Devonian throughout North America. Nor are there any representatives present of the strongly plicated Spirifers or other peculiar forms of the lower Devonian. The greater part of the faunules suggest a middle Devonian horizon and are probably of upper Onondaga or somewhat later age. There appears to be no doubt that this fauna is identical with the Devonian fauna which was found by Kindle[1] in the Salmontrout limestone on the Porcupine river. The same fauna has been collected by Brooks and Kindle on the Yukon opposite Woodchopper creek.[2] The presence of *Atrypa* cf. *flabellata* Goldf. and other peculiar undescribed species in both the Boundary collections and those from the Porcupine and Yukon rivers places this correlation on a secure basis and indicates a wide distribution of the Salmontrout limestone within the large triangular area bounded by the Porcupine, the 141st meridian, and the Yukon river.

In the following list of the Devonian fauna the species are given in connexion with the various lots in which they were collected during the progress of the survey.

Lot XIm45 (186)

Lingula sp.
Camarotoechia sp.
Stropheodonta sp.
Gypidula sp.

Lot XVIIp4 (249)

Favosites sp.
Camarotoechia sp.
Pugnax cf. *pugnus* (Martin).
Atrypa reticularis Linn. var.
Leptæna rhomboidalis (Wilck.).
Schizophoria striatula (Schlot.).
Reticularia sp.
Anoplotheca cf. *acutiplicata* (Con.).
Platyceras sp.
Cytherella sp.
Cyphaspis cf. *bellula*.

Lot XVIIj16 (244), j17 (246), i16 (239), i15 (238)

Atrypa reticularis (Linn.).
Atrypa spinosa Hall.
Schizophoria striatula (Schlot.).
Reticularia? cf. *subundifera* (M. and W.).
Reticularia sp.
Athyris? n. sp.

Lot XVIIj, k, 16 (245)

Zaphrentis sp.
Favosites sp.

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[1] Geologic reconnaissance of the Porcupine River valley, Alaska, Bull. Geol. Soc. Am., vol. 19, 1908, pp. 327-329.

[2] Palæozoic and associated rocks of the upper Yukon, Alaska, Bull. Geol. Soc. Am., vol. 19 1908, p. 283.

Stropheodonta sp.
Atrypa reticularis (Linn.).
Schizophoria striatula (Schlot.).
Gypidula sp.

Lot XVIIh19i19 (241) ?

Crinoid stems.
Productella sp.
Atrypa reticularis (Linn.).
Reticularia cf., *lævis* (Hall).
Reticularia cf. *subundifera* (M. and W.).
Nucleospira sp.
Fish bone.

Lot XVIIi14, 113 (237)

Cyathophyllumn sp.
Atrypa reticularis (Linn.).
Camarotoechia contracta Hall?
Stropheodonta arcuata Hall.
Reticularia sp.
Nucleospira n. sp.
Proetus sp.

Lot XVIIh, i, 18, 19 (234)

Favosites cf. *basaltica* Goldf.
Favosites cf. *canadensis* (Billings).
Alveolites sp.
Schizophoria striatula (Schlot.).
Chonetes sp.
Atrypa reticularis (Linn.).
Martinia cf. *maia* (Billings).
Nucleospira sp.
Proetus sp.

Lot XIXh19 (259)

Zaphrentis sp.
Atrypa reticularis (Linn.).
Stropheodonta sp.
Camarotoechia sp.
Meristella? sp.
Meristella cf. *laevis*.
Pugnax pugnus (Martin) var.
Gypidula sp.

Lot XIXi20 (262)

Stropheodonta sp. (identical with *Stropheodonta* sp. in XIXh19).
Productella cf. *spinulicosta* Hall.
Atrypa reticularis (Linn.).
Schizophoria striatula (Schlotheim).
Gypidula sp.

Lot XIXp10 (272)

Cyathophyllum? sp.
Atrypa reticularis.
Leptaena rhomboidalis (Wilck.).
Spirifer sp.

Lot XIX23q (274)
Fenestella sp.
Atrypa reticularis (Linn.).
Atrypa cf. *flabellata* Goldf.
Stropheodonta cf. arcuata Hall.
Conocardium cf. *cuneus* Conrad.

Lot XIXi, j, h, 23, 22 (263)
Atrypa reticularis (Linn.).
Stropheodonta sp.
Schizophoria striatula (Schlot.).
Cryphaeus? sp.

Lot XIXd22 (255)
Cyathophyllum cf. *quadrigeminum* Goldf.
Crinoid stems.
Atrypa reticularis (Linn.).
Camarotoechia sp.
Gypidula sp.
Conocardium cf. *cuneus* Conrad.
Platychisma? sp.

The Devonian collection includes two lots which may represent a formation distinct from the Salmontrout limestone. They appear to belong in a middle Devonian horizon, but the absence from these lots of any species tying them to the others indicates the propriety of provisionally treating them as possibly distinct.

These lots include the following species:—

Lot XVa, b, 35 (214)
Cladopora cf. *dichotoma* Hall.
Phillipsastraea verneuilli M. Edwards.
Proetus cf. *macrocephalus* Hall.

Lot XVIIj15 (243)
Productella? sp.
Atrypa sp. nov.?
Martinia cf. *maia* Bill.
Stropheodonta sp.
Proetus cf. *machocephalus* Hall.

Lots Provisionally Referred.—In a few cases the fragmentary character of the material or limited number of species present precludes a definite statement concerning the horizon represented. These may be provisionally referred as follows:—
Lot XIX27t (276) represented by *Whitfieldella* sp. and *Atrypa reticularis.*

Probably Silurian:—Lots XVIIi18 (240), XIX122 (268), XIX123 (269), XIO 44 (188), XII141 (193) are represented by poorly preserved corals. These are provisionally referred to the Devonian.
Lot XIVs4 (211) is represented chiefly by poorly preserved bryozon and fragments of a *Productus*-like shell. The horizon is probably Carboniferous. The following lots are probably of Devonian age:—

Lot XVIIp5 (250)
Favosites sp.
Camarotœchia sp.
Hercinella? sp.

Lot XVIIp4, 5 (249)
Cyathophyllum cf. *quadrigeminum* Goldf.
Favosites sp.

Lot XII141 (193)
Favosites cf. *hemisphericus* Yandell and Shumard.
Cladopora cf. *criptodens* Billings.

Lot XIIv33 (202½)
Atrypa reticularis (Linn.).

Lot XIIw33 (203½)
Stropheodonta sp.
Proetus sp.

Lots XIIp, q, 24, 25 (196)
Section of gasteropod shell.
Dalmanites?

Lot XIIv33
Atrypa reticularis.

REPORT BY LANCASTER D. BURLING.

Field Work.

The writer was appointed to the Geological Survey of Canada on January 27, 1913. Prior to assuming this position he had spent four field seasons upon the Pre-Cambrian, Cambrian, and Ordovician of British Columbia and Alberta. His experience in the eastern part of Canada had been confined to a brief reconnaissance in the northern portion of the Lake Champlain region, however, and the preparation for and participation in the Maritime excursion of the Twelfth International Geological Congress gave him a much-needed opportunity to familiarize himself, in part at least, with east Canadian stratigraphy.

The field work of the writer during the field season of 1913 covered approximately five months and comprised: (1) visiting field parties for the purpose of examining sections and collecting fossils as follows: with R. Harvie near Lake Memphremagog, Quebec; with A. O. Hayes near St. John, N.B.; and with S. J. Schofield near Elko, B.C.; (2) work in type Cambrian and lower Ordovician localities of Quebec, New Brunswick, and Nova Scotia, in preparation for the Maritime excursion of the Twelfth International Geological Congress; (3) an intensive study of the lower Palæozoic stratigraphy and palæontology along the Alaska-Yukon boundary in the immediate vicinity of the Tatonduk river; and (4) the collection for study and correlation purposes of Cambrian fossils from the Dogtooth mountains and the main range of the Rocky mountains in British Columbia.

QUEBEC.

The work in the province of Quebec was mainly preparatory to the Maritime excursion of the International Geological Congress. The writer familiarized himself with the principal outcrops and fossil localities at Quebec, Lévis, Montmorency Falls, Rivière-du-Loup, and Bic, and was fortunate enough to secure additional information as to the systemic position of the different members of the stratigraphic section at both of the latter localities.

Lake Memphremagog and Vicinity.—Several days were spent with R. Harvie and party in the region immediately west of Lake Memphremagog. Additional collections were made from the Silurian and Devonian localities already discovered, but an attempt to secure palæontological evidence for the "Cambrian" age of the rocks immediately overlying the "Pre-Cambrian" was unsuccessful.

Rivière-du-Loup.—At Rivière-du-Loup fossils were secured from four limestone bands and from the matrix of three limestone conglomerate bands in the red, green, and black shales outcropping in that portion of the town lying south and southeast of the railway cut just northeast of the Intercolonial Railway station. Upper Cambrian fossils have been secured from the pebbles of these conglomerate bands and the series has been referred to a position between the Upper Cambrian and the Beekmantown. The recently secured palæontological material from the red, green, and black shale series is fragmentary.

Bic.—At Bic, large collections were made from the interesting limestone conglomerates which are so typically exposed at that point, and fossils were secured from the matrix of the conglomerates exposed just back of the home of Emile Berube about a mile and a half west of the railway station.

The pebbles of these conglomerates have not been known to contain fossils younger than the Lower Cambrian and the previous complete absence of palæontological evidence for the age of the surrounding matrix has led to its assignment either to the Cambrian or the Ordovician. The fossils found in the matrix consist of the fragile tests of trilobites and can hardly be explained as the redeposition of fossils weathered out of previously consolidated material.

Quebec Bridge.—Several days were spent in an examination of the drill cores and records of the borings that had been made in connexion with the location of the piers of the National Transcontinental Railway bridge across the St. Lawrence river east of Cap Rouge. At this point the river flows through a narrow steep-walled post-Glacial channel or gorge, the old bed of the river being the broad valley occupied in part by the St. Charles river. The Quebec bridge, as it has been called, spans the St. Lawrence at its narrowest point, but to do this is forced, in its approaches, to cross both the ancient valley of the St. Lawrence immediately to the north and the gorge of the Chaudière river immediately to the south. Eighteen holes were put down in the present channel of the St. Lawrence river and in each case the rockfloor was penetrated for a distance of 20 to 30 feet. The only rocks encountered either in the banks of the river or in the borings were the sandstones and shales of the Sillery formation.

Percé, Cap Canon.—The beds exposed in the cliff of Cap Canon southeast of the court-house in the village of Percé, have been referred to the Ordovician or Ordovician-Cambrian. Ordovician fossils have been referred to this outcrop, but their presence has been explained by the transportation to the locality, for the purposes of limeburning, of Ordovician limestones from Cap Blanc, a mile or so to the south.

An oolitic limestone, clearly in place in the central portion of the massif and at about high-tide level, was found to contain numerous trilobite fragments, though these are unidentifiable specifically or even generically. A large loose block of thin-bedded limestone from the same locality contained fine specimens representing two types of inarticulate brachiopods, but the age relations of this material have not yet been determined.

Cap Rosier.—Southeast of Cap Rosier a shale and thin-bedded limestone series is exposed at frequent intervals along the shore. Near the lighthouse, Ordovician graptolites have been discovered, but 2 miles to the south, near the fault contact with the overthrust St. Alban beds of the Devonian, no fossils have been secured and the age of the shales has remained in doubt. About 200 feet north of the cliff marking the fault contact, four interbedded limestone bands were found to contain numerous fragmentary portions of the tests of trilobites similar to those obtained in the oolitic limestone at Percé.

NEW BRUNSWICK.

St. John.—Several days were spent with A. O. Hayes in the vicinity of St. John. Collections of Cambrian and Ordovician fossils were secured from outcrops near the Suspension bridge, near the corner of Duke and Wentworth streets, on the site of the new post-office on Prince William street, on the Carleton shore below the Suspension bridge, and at the head of Seely street. A large collection of Ordovician graptolites was secured from beds exposed at low tide on Navy island in the harbour, and extensive collections were made from the Cambrian sections exposed on Long island in Kennebecasis bay.

Hanford Brook and Vicinity.—A week or more was spent in the vicinity of Hanford brook, measuring and collecting from the Cambrian section exposed along that stream, and collecting from other Cambrian outcrops, notably that near Porter brook. The relations here have not been much disturbed by folding or faulting and the study was undertaken as an aid to the unravelling of the complicated structure in the city of St. John.

CAPE BRETON.

The section in the vicinity of George River station was examined in an attempt to secure information that would facilitate the guiding of the members of the Maritime excursion of the International Geological Congress to the fossiliferous horizons in the vicinity. A considerable number of Cambrian fossils were secured and a short trip was made to some of G. F. Matthew's type localities in the valley of McLeod brook (or Barachois river) in the vicinity of Boisdale.

YUKON.

The geological investigation of the Yukon-Alaska boundary carried out by D. D. Cairnes during the field seasons of 1911 and 1912, indicated the presence in an easily accessible portion of the boundary just north and south of the Tatonduk river of fossiliferous sections exposing strata ranging in age from the Cambrian to the Carboniferous. It seemed advisable to make an intensive stratigraphic and palæontologic study of a field so favourably located and so important for the delineation of the geology of the extreme northwest, and the writer was detailed for the work. He left Ottawa at noon July 29, and was in camp and performed his first field work upon this boundary section on August 14.

The collections secured were so extensive that it will be impossible here to give more than a brief outline of the character of the material which was brought back to Ottawa. The collections include material from nearly two hundred localities, and represent a hundred or more horizons, ranging in age from Middle Cambrian to Carboniferous. The Upper Cambrian beds appear to grade insensibly into the lower Ordovician and both are exceptionally fossiliferous. Four sections, of which nearly every foot was exposed, cross the boundary between the Cambrian and Ordovician and of these all extend downward into the Middle Cambrian (no Lower Cambrian fossils were secured), and three pass upward into the Devonian or the Carboniferous. The thickness and fossil content of the Upper Cambrian and lower Ordovician portion of these four sections may be summarized as follows: (1) ± 400 feet, twelve fossil horizons; (2) ± 200 feet (lost interval?) six fossil horizons; (3) ± 300 feet, twenty-three fossil horizons; (4) ± 300 feet, twenty-two fossil horizons. Of the Silurian, little material was secured. The Devonian, consisting of a lower limestone member and an upper shale member, passes gradually into the Carboniferous which is all but absent from the area studied. A few miles to the west, Calico bluff, and a short distance to the east, as evidenced by abundant Carboniferous boulders in the westward-flowing streams, the Carboniferous is extensively developed and remarkably fossiliferous. The relations of the limestone and shale members of the Devonian were studied in some detail and in two sections fossils were secured from several horizons immediately above and below the contact. In a preliminary examination of the shale material Kindle has recognized a Portage fauna.

BRITISH COLUMBIA.

Elko.—In company with S. J. Schofield, the writer spent several days in the vicinity of Elko, B.C. The following section was measured in the slope just above the Burton mine, about 2 miles northwest of Elko:—

Section of Burton Formation Near Elko, British Columbia.

	Section.	Feet.	Fauna.
Elko limestone (Pre-Devonian, exact age unknown).			
Burton shale (early Middle Cambrian).	5. Greenish black shales with interbedded limestones, the limestone being in the form of lenses and stringers 1 to 3 inches in thickness and more or less continuous, but making up a very small proportion of the strata.	60	In interbedded limestones within 5 feet of the base: *Micromitra (Paterina), Micromitra (Iphidella) pannula, Obolus* sp., *Acrothele* sp., *Acrotreta* sp., *Agraulos* sp., *Ptychoparia* sp., *Albertella* sp., *Olenoides* sp., *Bathyuriscus* sp., and *Crepicephalus* two species.
	4. Massive, dirty grey, sandy limestone	10	Near top: *Micromitra* sp., *Micromitra (Iphidella) pannula, Agraulos* sp., Trilobite fragments two species. Near base: *Micromitra (Iphidella) pannula*, Trilobite fragments two species, one suggesting *Olenellus*.
	3. Green micaceous shale badly sheared......	4	One trilobitic fragment.
	2. Rubbly weathering, calcareous grit, with annelid-like borings in top layer.	3	Annelid borings, *Micromitra (Paterina)* sp., *Acrotreta* sp., Trilobite fragments one species.
	1. Hematite conglomerate	1	
	——unconformity——		
Roosville siliceous metargillite (Pre-Cambrian).			

The inclusion of *Albertella, Bathyuriscus,* and *Crepicephalus* in the fauna of No. 5 of the section, suggested its comparison with the *Albertella* fauna of Montana and British Columbia and the Pioche formation of Utah and Nevada, horizons which have both been referred to the Lower Cambrian. An analysis of these faunas[1] yielded so large a mass of evidence opposed to their Lower Cambrian age and corroborating not only their reference to the Middle Cambrian but their correlation with the Burton formation that the latter is now referred with some degree of certainty to the Middle Cambrian.

The formation is readily divisible into a basal sandstone member 20 feet thick and an upper shale member about 40 feet thick, and while the faunas which have been secured from these beds all appear to be referable to the early Middle Cam-

[1] Burling, 1914, Victoria Memorial Museum, Bull. No. 2, pp. 116-125.

brian, it is hard to resist the impression that the clastic basal portion of the Burton formation may represent the Lower Cambrian. Beds 1 to 4 are so clearly distinct from No. 5 as to suggest their different formational reference and the Burton formation is interpreted to be a more or less heterogeneous formational unit apparently referable as a whole to the early Middle Cambrian but easily separable into upper shale and lower sandstone members if such a division should be warranted by future work upon the faunas of its basal portion.

Donald.—As early as 1893[1] fossils were reported from the outcrops along the Canadian Pacific railway 2 miles west of Donald, B.C., but they were then referred to the Lower Cambrian. Daily has recently[2] announced the discovery of Upper Cambrian fossils at the same locality and the writer spent a few days in the vicinity in an endeavour to correlate the section there exposed with the one near the continental divide 60 miles to the east and the one in the northern portion of the Galton range near Elko. He measured the section and secured fossils from numerous horizons, all of which appear to be referable to the Upper Cambrian.

Field.—The field season was so far advanced when the writer reached the main range of the Rocky mountains near Field that work at high altitudes was impossible, but several days were profitably spent in collecting Cambrian fossils from the *Albertella* and related zones of the early Middle Cambrian.

Office Work.

During the past year the writer has transmitted written reports upon the collections noted below. He also made a preliminary study of a large collection of Cretaceous fossils made by J. D. MacKenzie in the Queen Charlotte islands. The identifications and study of material collected by the writer have been extensive, but the results will appear over his signature and need not be listed here.

Cambrian Fossils, Collected by D. D. Cairnes in 1912, Along the Alaska-Yukon Boundary.—The faunas included in the collection from these localities bear no close resemblance to any of the described faunas of the Upper Cambrian or lower Ordovician. Minute preparatory work on the few pieces of rock available has more than quadrupled the number of species first observed from the different localities, and has brought to light some contradictory evidence. For example, the lower Ordovician *Illaenus?* in XIXj32 is hardly at home with the Cambrian *Micromitra* (*Iphidella*) *pannula* which was worked out of the fragments of rock associated with the former genus. The entire Upper Cambrian and Ordovician section is here less than 500 feet thick and it is hard to dispossess oneself of the belief that some of the collections may include specimens from both sides of the line separating the Cambrian from the Ordovician. Transition faunas bearing close resemblances to both the over and underlying systems are, however, common and the faunas under discussion may belong in this category.

Locality XXi34 is to be referred to the Cambrian and may even be upper Middle Cambrian in age, a statement which would also hold for XIXj32, if it were not for the inclusion of *Illaenus?*. So far as our present information goes, however, all of the localities, with the exception of XXi34, are referred to the upper part of the Upper Cambrian (XIXj9, 17 and 18, and 31 being especially comparable), but it will be necessary for us to await the measurement and careful collection of fossils from one definite section along the boundary, or for further collections from the localities already represented before we can be certain of this correlation.

[1] Ann. Rept. Geol. Surv., Can., vol. v, 1893, p. 79AA.
[2] Geol. Surv., Can., Guide Book No. 8, part ii, 1913, p. 204.

The Museum locality number is given first and is followed by Cairnes' field number.

Locality 264 (XIXj9)

Obolus sp.
Lingulella sp.
Acrothele cf. *coriacea?*
Acrotreta 2 sp.
Agnostus 2 sp.
Ptychoparia sp.
Anomocare sp.
Liostracus sp.
Levisia sp.

Locality 265 (XIXj17, 18)

Obolus (*Westonia*) cf. *stoneanus.*
Lingulella sp.
Acrothele cf. *coriacea?*
Schizambon cf. *typicalis.*
Undetermined trilobite.

Locality 266 (XIXj31)

Foraminifera?
Obolus 2 sp.
Obolus (*Westonia*) cf. *stoneanus.*
Lingulella 2 sp.
Dicellomus? sp.
Curticia? sp.
Acrothele cf. *coriacea?*
Acrotreta sp.
Orthoid.
Coral?
Ostracod.
Agnostus sp.
Eurycare? sp.
Three unidentified trilobites.

Locality 267 (XIXj32)

Micromitra (*Iphidella*) *pannula?*
Obolus 2 sp.
Obolella? sp.
Acrothele cf. *coriacea?*
Acrotreta 2 sp.
Ostracod.
Illænus? sp.

Locality 273 (XIXp20)

Obolus 2 sp.
Lingula sp.
Acrotreta 2 sp.
Asaphus? sp.

Locality 279 (XXc29)

Obolus sp.
Acrotreta sp.
Agraulos sp.
Ptychoparia sp.
Anomocare sp.
Solenopleura sp.

Locality 279 (XXe39)

Curticia? sp.
Acrotreta sp.
Agnostus sp.
Dicellocephalus? sp.

Locality 282 (XXi34)

Foraminifera.
Hyolithellus? sp.
Stenotheca 2 sp.
Conularia sp.
Micromitra (Iphidella) **pannula?**
Acrotreta 4 sp.
Ostracods 4 sp.
Agnostus 3 sp.
Agraulos 3 sp.
Ptychoparia 2-3 sp.
Anomocare sp.
Dorypyge? sp.
Neolenus? sp.
Solenopleura 3 sp.

Ordovician Fossils Collected by D. D. Cairnes in 1912 Along the Alaska-Yukon Boundary.—Locality 195 (Cairnes' No. XIIo44): Referred to the Ordovician after considerable discussion among Messrs. Kindle, Ulrich, and the writer. It has been found impossible from present information to make a closer correlation, as no identifiable species have been found. The following will give an indication of the forms represented:—

Ostracod.
Monticuliporoid coral.
Atrypa?
Prœtus-like trilobite.

Locality 280 (XXi25): The apparent correlation of these fossils is with the Normanskill of the middle Ordovician and a provisional identification of the fossils is as follows:—

Ostracod.
Obolus sp.
Dicranograptus?
Isotelus?
Harpes?-like form.

That they are middle Ordovician is reasonably certain, and Mr. Ulrich, who agrees with me in this correlation, showed me somewhat similar forms from the Athens shale.

The graptolites were separated and forwarded to Doctor Ruedemann, who identified *Dicranograptus* cf. *ramosus* (Hall), *Retiograptus geinitzianus* Hall, *Diplograptus foliaceus incisus* Lapworth, and stated that he would refer the horizon to the Normanskill or a little younger.

Cretaceous Fossils Collected by C. H. Clapp in Queen Charlotte Islands.—Locality 1681 (Clapp's No. 1071): Haslam formation, Nanaimo series, Upper Cretaceous. North shore of Departure bay, one-quarter mile east of biological station. Contains the following:—

Gyrodes excavata (Michelin)?
Inoceramus sp.?
Ostrea sp.
Trigonia evansana (Meek).
Anomia?
Protocardium?
Meretrix nitida (Gabb)?
Linearia sp.
Cymbophora ashburneri (Gabb)?

Locality 1682 (Clapp's No. 1072): Haslam formation, Nanaimo series, Upper Cretaceous. Horsewell bluffs, 1 mile east of biological station. Contains the following:—

Trigonia evansana (Meek).
Lima multiradiata (Gabb).
Tellina quadrata (Gabb)?
Cymbophora ashburneri (Gabb)?
Meretrix nitida (Gabb).

Locality 1683 (Clapp's No. 1093): Cedar District formation, Nanaimo series, Upper Cretaceous. East branch of Nanaimo river, one-quarter mile south of Stovely. Contains the following:—

Pelecypod, may be *Cytherea.* Tube-like bodies resembling worm borings. Unidentified plant remains, a part of a leaf resembling *Populus* (according to Mr. W. J. Wilson).

Locality 293 (Clapp's No. 1214): Maude island, British Columbia:—

Contains abundant flattened and more or less comminuted specimens of a species comparable with *Astarte carlottensis* Whiteaves, a species which is known only in the form of uncompressed and thick shells from beds on the east end of Maude island referred by Whiteaves to the Middle Cretaceous. So far as the writer has been able to discover the species has not hitherto been collected or described, and affords no satisfactory evidence either for referring the shales in which it occurs to the Cretaceous or against placing them in the pre-Cretaceous, a reference which is suggested by the field relations.

PALÆOBOTANY.

(*W. J. Wilson.*)

No field work was done by the writer during the year, the time being occupied in the study of collections brought in by the field officers, and in examining collections made in former years but which had not been studied. Considerable time was spent in arranging specimens which have been named, in drawers, so that they are readily available for comparison. Among these collections is one from the Riversdale and Harrington River series identified and named by Dr. Robert Kidston, Scotland. Another is a portion of one from the "Fern Ledges," St. John, N.B., in part named by Dr. G. F. Matthew to whom the whole Survey collection from that locality and Lepreau, N.B., was sent some years ago for study. Several small collections so arranged are from the Kootenay series of British Columbia and Alberta and were named by Dr. F. H. Knowlton and the writer. A table case of fossil plants showing specimens from the Silurian to the Tertiary was prepared for the general exhibit to illustrate the work of the Survey at the meeting of the International Geological Congress. This case, together with Sigillarian stumps and other specimens, has since been placed on exhibition in the Palæontological Hall.

Some progress was made in the study of the large mass of material from the north shore of the Bay of Fundy and Minto, N.B. It is believed when these plants are all carefully named it will be possible to fix the age of the rocks from which they were collected within reasonably close limits. Among the fossils identified from Cape Enrage in the above district, are *Calamites suckowi* Brongn. with *Spirorbis carbonarius* Dawson attached. *C. undulatus* Sternberg, *C. arenaceous* Brongn., *C.* cf. *sacksei* Stur., *Lepidodendron* cf. *L. aculeatum* Sternberg, *Alethopteris decurrens* (Artis), *Cordaites cf. C. mansfieldi* Lesqx., and a large specimen of *Sphenopteris obtusiloba* Brongn.

During the summer of 1912, Mr. Chas. H. Sternberg brought in a few fragmentary specimens of dicotyledonous leaves and a conifer from 1 mile southwest of Wigmore Ferry, Red Deer river, Alberta, Edmonton series, from which the following were provisionally named: *Populus speciosa* Ward, *Populus* sp. *Viburnum* cf. *V. limpidum* Ward, and *Sequoia* sp.

Among the collections brought in during the year, mention may be made of the splendid specimen of *Dioonites borealis* Dawson got by Mr. D. B. Dowling from Coal Creek mines, British Columbia. In size and completeness this fossil surpasses any Cycad hitherto found in Canada. Four fronds are shown on one slab of rock, one being 53 cm. long and over 26 cm. broad, with twenty or more pairs of pinnules, some of which are subopposite. The pinnules vary in size according to their position on the frond, the largest being 23 mm. broad with at least twenty-six parallel veins. The angle formed by the pinnules and the rachis changes from broad near the base to very acute at the summit. This species was founded by Sir Wm. Dawson[1] on a fragment with a rachis only 6·4 cm. long, bearing three broken pinnules on one side. Later he figured[2] another specimen from Martin creek 16 cm. long and 11 cm. broad.

[1] Trans. Roy. Soc., Can., vol. i, sec. iv, p. 24, pl. 3, fig. 37.
[2] Ibid, vol. iii, sec. iv, p. 6, pl. 1, fig. 2.

Another important collection was made by Mr. S. J. Schofield from the interglacial clays and silts of the Kootenay valley, British Columbia. This lot was sent to Dr. Arthur Hollick of New York, who has made a special study of Pleistocene fossil plants, for examination. Dr. Hollick reports that he has found new species of *Hicoria, Alnus, Fagus, Ficus, Ulnus, Cabatha, Cissampelos, Platanus,* and *Vitis* (See Mr. Schofield's report, page 130).

Dr. E. M. Kindle donated part of a trunk of *Lepidodendron veltheimanum* Sternberg, from Indiana, U.S.A., and was instrumental in obtaining a large specimen of *Pseudobornia inornata* (Dawson), from the upper Devonian of the Huron river, Ohio, U.S.A. Both specimens have been placed on exhibition and are valuable for study and comparison. Dr. Kindle also brought in an excellent specimen of *Psilophyton robustius* Dawson, from Campbellton, N.B.

Mr. Chas. H. Sternberg collected a large number of valuable specimens from Steveville and vicinity, Red Deer river, Alberta. Three of the most common species in this lot are *Castalia stantoni, Cunninghamites pulchellus* and *Dammara acicularis.* These species were described and figured by Dr. F. H. Knowlton[1] from material obtained from one locality on Willow creek, Fergus county, Montana, U.S.A., and are now reported for the first time in Canada.

After studying the different collections, a number of specimens and photographs were sent to Dr. F. H. Knowlton, Washington, who kindly revised my determinations and extended the list. The following are from his report:—

Accession No. 44. Red Deer river, 4 miles below Steveville, Alberta.—

I am not able to distinguish this from *Sequoia ambigua* Heer, as figured by Berry from the Lower Cretaceous of Maryland, but it is manifestly unsafe to place too much dependence in a single specimen of a cone. The age is said to be Belly River, but if so, the presence of this species is an addition to our knowledge of this flora.

Accession No. 55. Red Deer river, 3½ miles below Steveville, Alberta.—
Geinitzia formosa? Heer. Age, Belly River.

Accession No. 60. Red Deer river, 4 miles below Steveville, Alberta.—
Dicotyledonous leaf, but not determinable.

Accession No. 48. Red Deer river, Alberta, near Steveville.—
Dammara acicularis Knowlton.
Castalia stantoni Knowlton.
Cunninghamites pulchellus Knowlton.
Fern, apparently new.

This material from near Steveville is undoubtedly Belly River in age. The dicotyledons all appear to represent a single species, namely *Castalia stantoni.* I only had one specimen when I named and described the species, and these add very materially to our knowledge of it. They show a considerable range in size and some details of the basal configuration as well as the fact that the margin is certainly toothed. The conifer identified as *Cunninghamites pulchellus* I am not quite so certain of, though I believe it is this form. I only had the branchlet figured and it was from a portion that did not show the tips of the branchlets. The leaves are not all so nearly at right angles as in mine, but otherwise I see little difference. The scales of *Dammara,* although without the spine, are with little doubt referable to my *D. acicularis.*

Accession No. 45. Coal Creek mines, British Columbia, 4 miles from Fernie.—
Two splendid photographs. This is undoubtedly the same as Dawson's *Dioonites borealis,* but it is not a *Dioonites* as at present understood. It will be

[1] U.S. Geol. Surv., Bull. No. 257, pp. 134, 136, 147.

very hard to separate it from *Clenopsis latifolia* (Font.) Berry, Lower Cretaceous, Md., pl. lv, figs. 1, 2. If it is Kootenay, as it appears to be, it is of approximately the same age as *Ctenopsis latifolia.* It is related to certain Jurassic forms as well.

Accession No. 56. Battle river, mouth of Gratton creek, Alberta.

This is a very peculiar specimen, which appears to me to be a leaflet of a cycad, perhaps a Zamia. Although there are cycads in the Belly River, I know none that is like this one. More material will be necessary before it can be placed satisfactorily.

Accession 6, 64. From 70 to 80 miles south of Regina, Sask.

(61) Stems, unknown to me.

(61) Stems, apparently of grasses or sedges, but of no diagnostic value.

(62) A very peculiar organism that I do not know at all. I have seen it before in Upper Cretaceous rocks (none in the Fort Union as I recall), but I have never been able to place it.

(62) Branchlet, apparently of *Sequoia ambigua* Heer. This is a Lower Cretaceous species and I cannot believe that it came from the Fort Union or Paskapoo. It is a very small branchlet, however, and is not suffcient for a positive age determination.

(62) *Cyperacites?*

(62) Unknown to me. I have not much of an opinion to express regarding the age of 62 except that it is Cretaceous rather than Tertiary.

(63) Bark, not determinable.

(64) Palm, apparently the same as *Sabalites fructifer* Lesqr., from the Denver formation of Colorado (Tert. Fl., pl. xi, fig. 3). If this is correctly identified the age may well be Fort Union or Paskapoo.

Additions to the Palæobotanical Collections During 1913.

Presented.

Shanks, John, per Dowling, D. B.—One large specimen of a fossil Cycad, *Dioonites borealis* Dawson, from the roof of No. 4 seam, Coal Creek mine, British Columbia (4 miles from Fernie). Acc. No. 45.

Also one fossil fern, *Cladophlebis.* Acc. No. 46.

Taylor, Chas. E., per Dowling, D. B.—One specimen from section 4, township 45, range VIII, west of 4th principal meridian, mouth of Gratton creek, Battle river, Alberta. Acc. No. 56.

Collected by Officers of the Geological Survey.

Kindle, E. M.—Part of trunk of *Lepidodendron veltheimanum* Sternberg, from Braxton whetstone quarry, 2 miles west of French Lick Springs, Indiana, U.S.A. Acc. No. 42.

One specimen of *Psilophyton robustius* Dawson from west side of Campbellton, N.B., on Chaleur bay. Acc. No. 50.

Two specimens of *Sphenoprysllum cuneifolium* (Sternberg) from the Hardscrabble mine, Joggins, N.S. Acc. No. 51.

One specimen of *Stigmaria ficoides* Brongn. from Joggins, N.S. Acc. No. 52.

Schofield, S. J.—Sixty-eight specimens of fossil leaves (mostly dicotyledons) from the interglacial clays and silts exposed in the Kootenay valley on the St. Mary river in the vicinity of Eugene Mission. Acc. No. 43.

Sternberg, Chas. H.—One fossil cone from 4 miles below Steveville (mouth of Berry creek) Red Deer river, Alberta. About 150 feet above water-level in river. Acc. No. 44.

Thirty specimens of fossil plants, dicotyledonous and coniferous leaves and cone scales from Steveville, Red Deer river, Alberta (100 yards above the ferry, at low water-level). Acc. No. 48.

Three good specimens of fossil wood from near Steveville, Red Deer river, Alberta. Acc. No. 53.

Three specimens of silicified fossil wood and one fossil cone from the bad lands 3½ miles below Steveville, Red Deer river, Alberta. Acc. No. 55.

One large dicotyledonous leaf found with dinosaurian bones about 4 miles below Steveville, Red Deer river, Alberta. Acc. No. 60.

Lambe, Lawrence M.—Eight small fragments of fossil wood from the south fork of Oldman river, near mouth of Web creek, township 6, range III, west of 5th meridian, section 7, on north bank, on property of Coal Securities Co., Blairmore, Alberta. Acc. No. 47.

Cairnes, D. D.—Two small fragments of fossil wood from the White River district, Yukon Territory. Acc. No. 54.

Wright, W. J.—Eight small pieces of shale with fragments of fossil plants, mostly indeterminable, from the east bank of the Petitcodiac river, about 1 mile north of Belliveau village, N.B. Acc. No. 57.

Two specimens of fossil plants (Indt. stems or rootlets) from south of Round hill in dribblet flowing west, Quarry series, Albert county, N.B. Acc. No. 58.

Fourteen specimens of coarse-ribbed stems from Frederick brook, about 1 mile below Albert Mines, N.B. Quarry series underlying Quarry limestone. Acc. No. 59.

Rose, B.—Four fragments of fossil plants from clay above coal at Coal Mine lake, section 3, township 5, range XXIII, west of 2nd meridian, Saskatchewan. Acc. No. 61.

Ten specimens of fossil plants from shale above coal and clay, section 5, township 4, range XXI, west of 2nd meridian, Saskatchewan. Acc, No. 62.

One specimen of fossil plant from section 34, township 5, range XXIX, west of 2nd meridian, near Mullrany, Sask. Acc. No. 63.

One specimen of fossil plant from section 27, township 7, range XXVII, west of 2nd meridian, near Verwood, Sask. Acc. No. 64.

Hayes, A. O.—About 34 specimens of fossil plants from the most northerly point of Kennebecasis island, St. John county, New Brunswick. Acc. No. 65.

Seven fragments of fossil plants from a point on mainland northeast of most northerly point of Kennebecasis island, New Brunswick. Acc. No. 66.

Seven specimens, *Anmularia,* etc., from the "Fern Ledges" at foot of stairway, St. John, N.B. Acc. No. 67.

Six specimens, Cordaites, etc., from Duck cove, St. John, N.B. Acc. No. 68.

LeRoy, O.E.—One specimen of a plant impression from Jackson basin on divide between the towns of Sandon and Whitewater, Slocan district, British Columbia. Acc. No. 69.

One specimen from Reco mountain, same divide, near Sandon, British Columbia. Acc. No. 70.

By Purchase.

One specimen of *Pseudobornia inornata* (Dawson) from the bed of the Huron river, near Milan, Erie county, Ohio, U.S.A. Acc. No. 49.

MINERALOGY.

(*Robt. A. A. Johnston.*)

Owing to illness during the early part of the year I was obliged to vacate my office for several months, during which time Mr. Robt. Harvie took charge and discharged the duties of mineralogist.

In the month of March, Mr. Eugene Poitevin, a graduate of L'Ecole Polytechnique, Montreal, was appointed assistant curator in succession to Mr. Stanley P. Graham. Since entering upon the duties devolving upon him, Mr. Poitevin has devoted himself assiduously to the work assigned to him and has shown excellent aptitude and judgment throughout.

Mr. A. T. McKinnon has, as heretofore, rendered conscientious service. His time has been fully occupied in collecting minerals for and assembling the collections of minerals for schools and other institutions.

During the year nearly five hundred specimens have been received for identification or an expression of opinion as to their possible value; the replies to such inquiries have either been given verbally or by memorandum, as circumstances demanded.

Amongst the specimens which have been under examination during the year, special mention may be made of the following:—

Eosphorite.—This mineral is now for the first time recorded as occurring in Canada, and the credit of its identification belongs to Mr. Poitevin, who observed it in a specimen sent to the department by Mr. Charles Keddy, New Ross, Nova Scotia. The locality as given by Mr. Keddy is "30 rods north of the molybdenite mine on Larder river, New Ross, Lunenburg county, Nova Scotia."

In the specimen under consideration the mineral occurs in the form of small compact masses or patches distributed through a greenish, chloritic rock. These patches are generally covered with a thin film of a greenish alteration product; on this film being removed, the fine pink colour of the mineral is revealed; it possesses the ordinary characters of and gives the usual reactions for eosphorite.

Struvite.—Among the specimens collected by Mr. D. D. Cairnes during the field season of 1913, was a molar of a mastodon, obtained in the neighbourhood of McQueston creek, Stewart river, Yukon. In the course of his examination of this molar, Mr. L. M. Lambe's attention was attracted to a peculiar deposit formed in the valleys between the cusps. This deposit has a dirty grey or greyish-white colour and in some parts has a thickness of a quarter of an inch and is very firm and compact in its texture. Examination of the substance by the writer proved its identity with struvite. It may be of interest to note here that this is the second occurrence of this mineral recorded in Canada, the other having been recorded by Dr. G. C. Hoffmann (Geol. Survey of Canada, Ann. Rep., 1899, pages 13-14 R); in the latter instance the mineral struvite constituted a portion of the material replacing parts of the tusk of a mammoth found on Quartz creek, a tributary of Indian river, Yukon.

Ullmannite.—This mineral was identified by Mr. Poitevin in a specimen brought to the department by Mr. H. N. Nelson, Ottawa, who stated that the material had been noted in small quantities at the O'Brien mine, Cobalt, Nipissing district, Ontario. It forms small irregular patches with an indistinct crystalline, granular structure and high metallic lustre in pink crystalline calcite.

Apatite, Axinite, Garnet, and Vesuvianite from Black Lake, Megantic County, Quebec.—Some very interesting occurrences of these minerals have been noted in some specimens collected by Mr. Harvie at the locality given. The examination of the specimens is not complete and only a few notes are inserted here.

The apatite occurs in white, translucent to transparent tabular crystals attaining sometimes a diameter of three-quarters of an inch, attached to the walls of pockets in a white, translucent quartz; while calcite and earthy brown oxide of iron are also more or less abundant as associated minerals.

The axinite of Black Lake forms confused coarse crystalline aggregates; so far as observed it is unusually pale in colour and at times is all but pure white.

In some of the specimens from this locality are to be observed small dodecahedrons of garnet; some of them are colourless and transparent; some are honey-yellow and translucent; some have a pinkish tinge; while still others are of a dark green colour.

The vesuvianite occurs in groups and masses of small crystals; many of these are of a beautiful bright pink colour, while still others have a fine green colour.

Quartz and Opal.—During the season of 1913, Mr. G. F. Sternberg, while excavating for fossil vertebrates near Steveville, Red Deer, Alberta, came across a very interesting occurrence of these minerals. The deposition appears to have taken place along narrow fissures in a clay-ironstone. The quartz takes on various forms; at times it occurs in radiating groups of colourless translucent crystals; generally though it takes the form along with the opal of milk-white to grey, translucent, shell-like aggregations of circular discs composed of overlapping concentrically arranged rings; in a few instances the larger discs, which measure up to an inch across, are seeen to be made up of groups of small discs; the general appearance of these discs is suggestive of some sort of hydro-thermal action having had something to do with occasioning the peculiar structure which characterizes the specimens. Some of the fragments show both the quartz and the opal in a series of small rhombohedral forms; these are pseudomorphous probably after siderite.

Additions to the Mineral Collection During 1913.

The following additions have been made to the Canadian section of the mineral collections:—

Presented.

Mr. Alex. Bush, Reynoldston, Ont.—Hematite from lot 1, concession VIII, Hichinbrooke; sphalerite from lot 7, concession X, Hinchinbrooke, Frontenac county, Ontario.

Mr. A. W. Dingman, Calgary, Alberta.—Petroleum from 13 miles west of Okotoks, Alberta.

Dr. James Douglas, New York, N.Y.—Series of seventy-seven specimens of rocks and minerals from the region about the lower reaches of the Coppermine river, North West Territories.

Mr. Robert Elliott ,Toronto, Ont.—Talc from lot 1, concession I, township of May, Sudbury district, Ontario.

Mr. H. J. Fetler, Fort George, B.C., per Collingwood Schreiber, Esq., C.M.G., Ottawa, six clay concretions from Nechako river, British Columbia.

Mr. Thomas Morrison, Bancroft, Ont.—Cube of Bancroft marble.

Mr. H. N. Nelson, Ottawa, Ont.—Ullmannite from the O'Brien mine, Cobalt, Ont.

Mr. R. W. Racey, Rossland, B.C., per O. E. LeRoy.—Large group of apophyllite crystals; six specimens of rocks and ores from the LeRoi mine; specimen of ore from the War Eagle mine; seven samples of rock and one of ore from the Centre Star mine; specimen of actinolite from the Jumbo mine, Rossland, Trail Creek Mining Division, British Columbia.

Mr. H. H. Shallinger, Spokane Falls, Washington, U.S.A., per O. E. LeRoy.—Brown hematite and limestone from Boundary creek, near junction of Pend d'Oreille river, British Columbia.

Mr. J. A. Teit, Spences Bridge, B.C.—Quartz geode from mountains a few miles south of Spences Bridge, Ashcroft Mining Division, British Columbia.

Prof. R. C. Wallace, Winnipeg, Man.—Selenite from Elephant hill, Gypsumville, anhydrite and fibrous gypsum from the Manitoba Gypsum Company's quarry.

Collected by Officers and Employees of the Department of Mines.

Mr. Charles Camsell.—Epsomite from the west side of Osoyoos lake, Osoyoos Mining Division, British Columbia.

Mr. C. H. Clapp.—Series of four samples of coals and lignite from Graham island, Queen Charlotte Mining Division; coal from the Wellington seam, coal from the Douglas seam, coal from the Suquash mine—Nanaimo Mining Division; lignite from Jordan river over Kirby creek, Sooke area; basalt from Metchosin volcanics, north of Sooke basin; amygdaloidal basalt from Metchosin volcanics, south of Leech river; staurolite schist from Jordan river; magnetite-hematite schist from Saltspring island; sandstone with honeycomb weathering from Maple bay; shale showing rectangular jointing from Pine island; banded quartz diorite gneiss from West Saanich road; polished specimen showing galena, zinc blende, chalcopyrite, and pyrite from the Sterling mine—Victoria Mining Division—all in the province of British Columbia.

Mr. D. B. Dowling.—Coal from 2-inch seam, township 76, range XXVI, west of 6th meridian, on branch of South Pine river, Alberta; drift lignite from Killarney, Man.; coal from 8-inch seam, Loch Lomond, Richmond county, N.S.

Mr. B. Rose.—Hyalite from a point north of Ashcroft, B.C.

Mr. S. J. Schofield.—Cerussite and pyromorphite from the Society Girl claim, Fort Steele Mining Division, British Columbia.

Mr. G. F. Sternberg.—Series of specimens of opal and quartz from a point about 4 miles east of Steveville, Red Deer, Alberta.

Purchased.

Specimen of native platinum from Tulameen river, Similkameen Mining Division, British Columbia, from Mr. Charles W. Thompson, Tulameen, B.C.

Collection of fifty-six specimens of silver ore representing the principal producing properties of the Cobalt area, Nipissing district, Ontario, from Major E. J. Holland, Ottawa, Ont.

The following additions have been made to the foreign division of the mineral collections:—

Presented.

University of California.—Suite of specimens from localities in California, U.S.A., embracing kunzite, lepidolite with rubellite, black tourmaline and amblygonite from Pala, San Diego county; dumortierite from Dehesa, San Diego county; mariposite from Tuttle Town, Tuolumne county; axinite from Deer Park; pectolite from Fort Point; benitoite and neptunite from San Benito county; lawsonite from Reed Station, Marin county.

Messrs. Curran and Hudson, New York, N.Y.—Carnotite from Colorado.

Mr. Robert Harvie, Ottawa.—Suite of specimens from localities in Massachusetts, U.S.A., embracing fayalite, cyrotlite, hedenbergite, fergusonite, and curved feldspar with ilmenite from Rockport; margarite from Chester.

Mr. A. O. Hayes, Ottawa.—Chrome iron ore from Salisbury, Rhodesia, South Africa.

Mr. Shimmatso Ichikana, Ritashingo Mura, Fukui-New, Japan.—Native arsenic from Akatani; native arsenic from Shimoadimi-Mura; native arsenic from Ono Gun —all in the province of Echizen, Japan.

Mr. M. Inouye, Tokio, Japan.—Series of thirty-two rock specimens, five specimens of copper ores, one of cobalt, and two of tungsten, together with seven specimens of coal, making in all a very interesting series from various Japanese localities.

Messrs. S. and E. Triefus, London, England.—Two small diamonds from British Guiana.

Educational collections of minerals have been distributed as follows:—

Province.	Grade 1.	Grade 2.	Miscellaneous.
Alberta	1	2	1
British Columbia	10	....	1
Manitoba	5	3	....
New Brunswick	....	1	1
Nova Scotia	....	1	....
Ontario	12	8	6
Prince Edward Island	....	1	1
Quebec	21	5	....
Foreign	....	....	3

During the season, Mr. McKinnon has collected over nineteen and a half tons of materials for use in connexion with the various activities of the division.

The thanks of the department are specially due to the following gentlemen for much kindly assistance in securing materials:—

Mr. L. M. Adsit, Eustis, Que.; Dr. A. E. Barlow, Montreal, Que.; Mr. W. A. Clerihue, Black Lake, Que.; Mr. Henry Elston, Magog, Que.; Messrs. Fraser and Davis, New Rockland, Que.; Mr. E. P. Hall, Eustis, Que.; Mr. William Johnston, Gooderham, Ont.; Mr. John Leslie, Beebe Junction, Que.; Mr. Thomas Morrison, Bancroft, Ont.; Mr. C. J. Osman, Hillsborough, N.B.; Mr. Alexander Parker, Eganville, Ont.; Mr. N. S. Parker, Eastman, Que.; Major James Phinney, Wilmot, N.S.; Mr. James Robertson, Albert Mines, N.B.; Mr. F. M. Thompson, Hillsborough, N.B.; Mr. Bush Winning, Ottawa, Ont.

BOREHOLE RECORDS (WATER, OIL, ETC.).

(E. D. Ingall.)

Boring was active throughout Canada during the year, the chief interest being connected with the operations prosecuted in continuing the explorations of the oil and gas fields of Moncton, N.B., and adjacent districts; the borings in Ottawa made by the city corporation in search of a pure water supply and the very active operations throughout the northwest provinces in search for gas and oil.

From Nova Scotia the regular official report of the operations of the Government core drills shows a total amount of 7,602 feet bored; 5,782 by diamond drills, and 1,820 by calyx drills. "The cost of a foot for boring for minerals was $2.08. The greatest cost per foot for boring by diamond drills was $4.60, the lowest cost was $0.25. The greatest cost per foot for calyx drills was $3.22¾, the lowest cost was $1.24."

Thanks to the courtesy of the Maritime Oil Fields Co., sets of samples and logs of their recent borings have been placed on file with the department.

For the Ottawa group of wells it was found possible to obtain complete sets of samples which throw considerable light on the thickness of the various beds of the Palæozoic column overlying the Pre-Cambrian surface constituting the floor of the old Palæozoic sea. One well in particular—that at Dundonald park—was of great importance in this respect, penetrating as it did all strata from the top of the Trenton limestone and finishing in the underlying gneissic series. The thickness of 1370 feet of sediments thus proved casts new light upon the section and provides important corrections of some of the accepted dimensions formerly built up from outcrops observed in different parts of the district. For their co-operation in this matter thanks are due to Messrs. Storrie and Campbell, late of the city engineer's staff, and to the following firms of drilling contractors, viz.: Messrs. H. Friend, Aylmer, Que.; D. G. Friend, East View, Ont.; W. Beatty, of Beatty and Helmer, Ottawa, Ont.; A. Campbell, L'Orignal, Ont.; J. E. Feely & Son, St. Armand, Que.; and the Wallace Bell Co. of Montreal. All the above used churn drilling plants. One hole was put down by the Des Marais Machine and Well Drilling Co., of Ottawa, who preserved the cores for the department. A number of boxes of cores obtained by Mr. James Kelly, drilling contractor of Ottawa, in testing the rock formation under Nepean bay, were also handed over to the department by Mr. A. W. Beer, the engineer in charge of the city waterworks.

In the old gas and oil districts of the peninsula of Ontario, boring operations are being constantly prosecuted in search for new pools, the most important of these being the testing of the deeper strata in the Oil Springs district. Thanks to the officials of the Oil Springs Oil and Gas Co., a full set of samples of the strata passed through and a log of the deep bore made by them have been placed on file with the department.

A very interesting set of drilling was received, through the courtesy of Mr. Leo A. Wilson, from a deep well in Caradoc township, Middlesex county, Ontario.

The set of samples from one of the wells bored at the eastern end of Manitoulin island, supplied by Senator P. Poirier from the operations in Bidwell township of the New Ontario Oil and Gas Co., are of great interest. These operations are a continuation of efforts which have been made from time to time for many years in following up the belief in the probable existence of gas and oil pools on the island, based on local indications and on the existence of anticlinals shown on the geological maps of the district.

Boring has been very active throughout the northwestern provinces in search of gas and oil. Whilst it has been impossible to keep in touch with or obtain the co-operation of all the numerous operators, sets of drillings have been sent in from some of the important districts. In the Sheep River oil and gas district near Calgary, samples and logs of a number of borings have been sent in through the agency of Mr. S. E. Slipper, who was sent by the department to study that field.

Through the courtesy of the Wallace Bell Co. of Montreal, a very important set of cuttings was obtained from the deep well at Moosejaw, Sask. Following the unfortunate demise of Mr. John Bell, the supervision of the boring was undertaken by Mr. Chas. E. Hildreth, through whose efforts valuable fossil evidence was obtained from the strata pierced in the bottom of this well. The determination of these as of Jurassic age by Mr. T. W. Stanton throws an entirely new light upon the sedimentary section of the central part of the prairie provinces.

To Mr. H. M. Sutherland, secretary-treasurer of the town of Canora, Sask., thanks are due for continuing to send sets of samples from borings done for that corporation.

Borings for the purpose of testing the well-known "tar-sands" of the Athabaska river have been prosecuted actively for the past year or two, but no very definite or reliable particulars have been obtainable so far.

Whilst during 1913 considerable data of value were added to the records of the boring operations which were prosecuted throughout Canada. there are, of course, hundreds of shallow borings put down which can never come to the notice of the department, and no complete review of the results of boring activities could be presented except through the activity of a large staff and with considerable expenditures.

The function of the branch involving the giving of geological information to operators has been frequently called upon and, as in the past, research has been made into the various sources of information and the result placed at the disposal of those interested, either verbally or in the form of memoranda.

Whenever time has been available from the carrying out of the routine, studies have been made of the samples sent in from the various borings throughout the country with a view to preparing final and detailed logs for publication. Carried on in this necessarily spasmodic way, the attainment of final results in this important part of the work is necessarily slow of accomplishment, and the logs of borings from which samples have been recorded can only be worked out a step at a time.

In pursuance of suggestions made to the Director, and concurred in by him, advantage has been taken of any excavations made in Ottawa to obtain any details relating to the formations thus temporarily exposed.

Close personal touch has been kept with the numerous borings which have been made during the past season in Ottawa, and sets of cores and samples have been obtained. Every assistance possible has been rendered the engineers in charge in the way of geological information and its application to the problems involved. The more intimate understanding of boring methods thus gained will be of great value in future co-operation with drillers in the work of the branch.

As in the case of other members of the Survey staff, a certain portion of time was absorbed by duties connected with the convention of the Canadian Mining Institute and the International Geological Congress, in the latter case acting as "secretary" on Excursion A11, and in obtaining and placing the boulder for the Logan Memorial of Ottawa. Assistance was also asked and rendered the engineer in charge of the surveys for the Ottawa water supply investigation.

TOPOGRAPHICAL DIVISION.

(W. H. Boyd.)

Part I.

Introduction

The staff of the Topographical Division now consists of a chief topographer, one triangulator and computer, and seven junior topographers—three junior topographers being appointed this year. Mr. Chipman, a junior topographer, was appointed geographer to the Southern party of the Canadian Arctic Expedition, and left for the north with that expedition in the spring. He was accompanied by Mr. J. R. Cox, as assistant geographer. Mr. Cox has been employed in former years with this division.

The regular field work of the division was allotted as follows:—

Mr. W. E. Lawson, the White River map-area, Yukon Territory.

Mr. F. S. Falconer, the East Sooke map-area, Vancouver island, British Columbia, and the Flathead coal basin map-area, British Columbia.

Mr. E. E. Freeland, the completion of the Bridge River map-area, British Columbia.

Mr. A. G. Haultain, the completion of the Windermere map-area, British Columbia.

Mr. A. C. T. Sheppard, the Crowsnest sheet, British Columbia and Alberta.

Mr. D. A. Nichols, the Thetford-Black Lake map-area, Quebec.

Mr. B. R. MacKay, the New Glasgow map-area, Nova Scotia.

Mr. S. C. McLean, the triangulation for the control of the New Glasgow and Thetford map-areas, respectively, and the triangulation in the Similkameen and Osoyoos districts, British Columbia, for use in controlling future topographical mapping.

The reports relating to the above work are submitted separately, also a report on the primary levelling work in the New Glasgow area.

The writers visited some of these parties during the summer and found good progress being made. Owing to the unfortunate illness of Mr. B. R. MacKay, it was necessary to close the field work in the New Glasgow area early in August.

White River Map-Area, Yukon Territory.

(W. E. Lawson.)

The field season of 1913 was spent in mapping a portion of that section of Yukon Territory commonly referred to as the White River district. The area mapped lies between latitudes 61° 42′ N. and 62° 30′ N., and longitudes 140° 15′ W., and 141° 00′ W. The northern boundary of the map-area lies just north of Snag and Beaver creeks. The southern boundary lies to the south of the valley of the White river where it crosses the International Boundary line. The White River and the Alaska-Yukon International Boundary line form the eastern and western boundaries, respectively.

The district is rather difficult of access. The party left Whitehorse on May 14 and did not reach the White river at the mouth of Koidern river (or Lake creek as it is locally called) until June 8. Field work was commenced on reaching the White river and continued with some interruptions due to unfavourable weather, until September 7.

The main control of the area was based on the triangulation station established by the Alaska-Yukon International Boundary survey. From these stations graphic triangulation was extended, by means of plane-table and telescopic alidade, eastward to the White river, several stations being located on the wide bars of the White river.

Elevations were based on those determined by the boundary survey and were reduced to mean sea-level. The detail over the area was obtained by the plane-table intersection method. All trails and the larger portions of the White river, Beaver creek, Snag creek, and Sanpete creek, were traversed, using the Boston sketching table with double pacing for distance and the aneroid for elevations.

All field work was done on the scale of $\frac{1}{192000}$, the scale of publication to be $\frac{1}{250,000}$. A contour interval of 500 feet was adopted.

The narrow strip of topography along the 141st meridian, mapped by the International Boundary survey, was used for this portion of the map.

Mr. C. B. Bate was attached to the party as field assistant, and rendered efficient service.

East Sooke and Flathead Coal Basin Map-Areas.

(F. S. Falconer.)

According to instructions, the field season was spent in mapping the East Sooke peninsula, Vancouver island, and the Flathead coal basin, British Columbia. The East Sooke map-area comprises about 12 square miles and lies approximately between latitudes 48° 18′ 45″ N. and 48° 22′ 30″ N., and longitudes 123° 37′ 00″ W. and 123° 43′ and 00″ W. The Flathead coal basin map-area comprises 47 square miles and lies between latitudes 49° 01′ 51″ N. and 49° 08′ 20″ N., and longitudes 114° 29′ 12″ W. and 114° 37′ 25″ W.

Field work in the East Sooke map-area was started on June 4 and was completed on July 16. Rainy weather delayed the progress of the work to some extent. The primary control of this area consisted of the two U.S.C. and G.S. stations on Donaldson island and near Beechy head. The secondary control consisted of a transit-stadia traverse carried around the peninsula and connected to the two stations mentioned above. Owing to the heavy underbrush and to the scarcity of trails, the mapping was almost entirely done by the plane-table-tape traverse method, using the aneroid for determining the elevations. The datum for the elevations was obtained by observations at low tide and the tide tables. The scale of the field work was $\frac{1}{24,000}$ with a contour interval of 20 feet.

On the completion of the East Sooke work the party was transferred to the Flathead coal basin map-area, where field work was commenced on July 23.

The primary control of this area consisted of the two stations established by the triangulation of the Crowsnest sheet and a few locations established by the three-point method. Bench-mark No. A1 256 on the International Boundary was used as a datum for the elevations. The elevations were checked with those determined for the two triangulation stations used as primary control.

The roads, trails, rivers, and larger creeks, and in many cases the boundary lines of the coal claims where these were cleared, were traversed by plane-table and stadia. The remainder of the mapping was done by the plane-table and tape traverse method, using the aneroid for elevations.

For the field work a scale of $\frac{1}{48,000}$ was used with a contour interval of 50 feet, publishing scale to be $\frac{1}{62,500}$. Field work was completed on September 21.

Efficient service was rendered by the following assistants: Messrs. M. M. O'Brien; W. H. Miller; R. G. Scott; E. C. Evans.

Bridge River Map-Area, British Columbia.

(*E. E. Freeland.*)

Field work during the season of 1913, in connexion with the topographical mapping of the Bridge River map-area in the Lillooet district, British Columbia, commenced about the end of the third week of May and continued until the end of September.

The mapping of this area was commenced in 1912 by Mr. W. E. Lawson and the writer's instructions were to complete the work. The usual methods of photo-topography were followed, twenty-seven camera stations being occupied. The main trails in the district that had not been traversed the previous summer were run by pace and compass, using the aneroid to determine the elevation. Two triangulation stations were occupied and the angles observed by repetitions, three direct clockwise and three reverse counter-clockwise, using a Berger transit reading to one minute.

The weather, except during the last week of July and the first of August, was very unfavourable, on account of a great deal of snow and rain. The spring was very late, a great deal of snow remaining in the country until the end of July.

Messrs. L. Sewell, C. P. Ilsley, and E. M. Abendana were attached to the party as student assistants and all performed their work in a very satisfactory manner.

Windermere Map-Area, B.C.

(*A. G. Haultain.*)

The summer of 1913 was spent in completing the topographic mapping of the Windermere map-area, which was started in 1912 by Mr. K. G. Chipman.

Work was commenced about the middle of June and continued until the end of October. Two months were spent on plane-table traverse in the Columbia valley; the remainder of the season was devoted to occupying camera stations and traversing the pack trails not surveyed the previous summer.

The main portion of the camera work this year controlled the area lying between Toby and Dutch creeks, the head of Toby creek, and the eastern side of the Columbia valley. A few stations were taken in the vicinity of Boulder and Law creeks.

The following assistants were attached to the party for the field season: Messrs. W. K. Thompson, N. E. D. Sheppard, F. M. Wood, E. R. Jones.

Crowsnest Sheet, British Columbia and Alberta.

(*A. C. T. Sheppard.*)

The Crowsnest sheet comprises approximately 3,110 square miles, and is bounded on the north by the 50th parallel, on the south by the 49th parallel or International

Boundary, and on the east and west by the 114th and 115th meridians, respectively. One-half of the area lies in British Columbia and the other half in Alberta. My instructions were to map the above-mentioned area on a compilation scale of $\frac{1}{192,000}$, for publication on the scale of $\frac{1}{250,000}$. The contour interval adopted was 200 feet.

On June 7, field work was commenced. Operations were started in the south-west corner of the district and about 750 square miles in this locality were completed. This was mapped by the photographic method, supplemented by pace traversing of all the trails and the most important creeks. Twenty camera and triangulation stations were occupied and approximately 250 miles of traverses were run. Early in the season, control was established for the Flathead coal basin map-area. On June 26 a subcamp was located in the prairie country to the east, H. J. Heinonen being placed in charge of this party. Approximately 200 square miles were mapped by this party, by the traverse method, in townships 5, 6, 7, and 8, ranges I and II, west of the 5th meridian.

The horizontal control was obtained by triangulation. This was extended from the Flathead triangulation executed by Mr. S. C. McLean of the Topographical Division, in 1912. Six additional stations were located. The entire scheme was connected to the triangulation of the Boundary Survey by occupying the Boundary Survey stations Kishinena, Hefty, Canada, and Baldy. Vertical control was carried forward from the elevations of the Flathead triangulation stations. These elevations were based on the elevation of Blairmore station on the Crowsnest branch of the Canadian Pacific railway.

The topography of the strip of country along the portion of the 49th parallel included in the sheet, was taken from the maps of the International Boundary Survey. The topography of a tract of country in the vicinity of the Dominion Government coal reserve was taken from the map of "The Crowsnest Coal Area" by A. O. Wheeler, D.L.S.

A considerable amount of time was lost during the season, due to the excessive rainfall. Field work was completed on October 13.

The following men were attached to the party as student assistants: H. J. Heinonen, W. R. Fraser, and N. Bunker. These men performed their duties in a satisfactory manner.

I wish to express my thanks to many residents of the district for much useful local information.

Thetford and Black Lake Map-Area, Quebec.

(D. A. Nichols.)

According to instructions, the field work on the Thetford-Black Lake map-area was commenced on May 28. This area comprises about 245 square miles in Wolfe, Megantic, and Beauce counties, in the province of Quebec. It contains a portion of the serpentine belt which consists of a strip approximately 6 miles wide, on each side of the Quebec Central railway and extending from about 1 mile south of D'Israeli station to about 3 miles north of Thetford Mines station. The map-area includes the asbestos mines of Black Lake and of Thetford Mines, and the asbestos and chrome properties in the vicinity of Belmina, Breeches, and Little St. Francis lakes.

The compilation scale of the map was $\frac{1}{48,000}$, with a contour interval of 20 feet, the publication scale is to be $\frac{1}{62,500}$.

The control of the sheeet was obtained by triangulation, by Mr. S. C. McLean of the Topographical Division. This triangulation was connected to the geodetic station established by the Geodetic Survey of Canada on Thetford mountain. The datum for elevations was the elevation of the rail of the Quebec Central railway in front of the station at Black Lake, as given in White's "Altitudes of Canada." From this datum the elevations of the nearest triangulation stations were obtained by a transit-stadia-traverse with double checked vertical angles. The differences in elevation of these triangulation stations, as determined by the transit and stadia traverse, were compared and found to agree very closely with those determined by double zenith distances during the triangulation, though it had been feared that the varying refraction over this area would render these values unreliable. From the series of triangulation stations numerous three-point stations were located and a system of transit-stadia and plane-table-stadia traverses were run. In this manner, the area was divided into blocks of convenient size for filling in the detail by means of the plane-table-stadia and the plane-table-tape aneroid method. Great difficulty was experienced in using the compass because of local attraction; on this account, the backsight method of orienting the plane-table had to be adopted throughout. This lessened very considerably the speed at which the work could be accomplished.

By the end of September, about 50 square miles were mapped, when the party was reduced in numbers. After this date, with a smaller field party, a detailed map of the area adjacent to the asbestos mines at Thetford Mines was made. The detailed map comprises an area of approximately 1 square mile. It was mapped on a scale of 1,000 feet to 1 inch, with a contour interval of 10 feet. This was completed on November 9, on which date the field work was closed for the season.

The student assistants were as follows: Messrs. L. A. Badgley, J. E. Forbes, A Quenneville, and M. L. Dobbin. On August 9 the party was reinforced by the addition of Messrs. M. F. Fredea, M. J. McMillan, E. J. Sproule, A. M. James, J. A. Macdonald, and C. H. Freeman, the three latter remaining until the close of the season. All rendered efficient service.

New Glasgow Map-area, Nova Scotia.

(B. R. MacKay.)

Field work in connexion with the mapping of the New Glasgow map-area commenced on June 1 and continued until August 8, when the work had to be abandoned on account of the illness of the writer.

The map-area embraces 65 square miles and is rectangular in shape, being 11·4 miles east and west and 5·7 miles north and south. It includes the towns of New Glasgow, Stellarton, Westville, Thorburn, and the extensive coal fields of the Acadia and Intercolonial Coal Companies.

The field scale used was 2,000 feet to 1 inch, with a contour interval of 10 feet.

The primary horizontal control was obtained by triangulation, by Mr. S. C. McLean of the Topographical Division. The primary vertical control was obtained by lines of levels carried in closed circuits from the bench marks established by the Public Works Department, and which are based on mean sea-level. During the season, 24 miles of these primary levels were run. Permanent standard bench marks were established at all the working mines of the Acadia and Intercolonial Coal Companies, and at intervals of 3 miles along the routes followed. The elevation to the nearest foot was stamped on the bench marks. The exact location and elevation of these bench marks are on record in the Topographical Division and are available, should they be required in local engineering work.

The plane-table-traverse method was used altogether in filling in the detail. Between the triangulation points main-stadia-traverses were run along the roads, shore-lines, and railways. Betweeen stations on the main traverses minor traverses were carried, from which the remaining detail was obtained. Owing to the short field season, the mapping was limited to 10 square miles in the neighbourhood of New Glasgow.

Messrs. C. H. Freeman, A. M. James, E. J. Sproule, M. F. Fredea, J. A. Macdonald and M. J. MacMillan were attached to the party as student assistants and rendered efficient service.

My thanks are due to the officials of the Acadia and Intercolonial Coal Companies, the town engineer of New Glasgow, and the superintendent of the Intercolonial railway, New Glasgow, for information and kindly assistance.

Triangulation Work.

(*S. C. McLean.*)

The early part of the field season was spent in executing local triangulations at New Glasgow, N.S., and Thetford, Que., while the latter and greater part of the season was devoted to a chain of secondary triangulation in the Similkameen district, British Columbia. Mr. R. C. McDonald, student assistant, was an efficient aid throughout the season.

New Glasgow Triangulation.

This is a local triangulation required for the primary control of the New Glasgow map-area; a detailed map on the scale of 2,000 feet to 1 inch.

Details of Work.—A base line, 1,710·15 feet long, was measured along Washington street, New Glasgow, and an expansion made therefrom to the necessary control points. Fourteen main stations were signalled and observed. In addition to these, about fifteen other prominent points, including church steeples, mine chimneys, etc., were cut in. The necessary azimuth was obtained from an observation on Polaris. No control for elevation by vertical angles was attempted, as the results obtainable in this type of country are not sufficiently reliable on account of the refraction.

Instruments and Methods.—A 6¼-inch Berger transit, with horizontal circle reading to 10 seconds was used. All the angles of a triangle were observed, the method being by directions, one direct and one reverse constituted a set. One set under good observing conditions was considered sufficient, but in most cases two, and sometimes three, sets were made. Good figures were obtained, having fair angles and giving frequent check distances. The signals were poles carrying a flag, or small tripods on centre. The centres were nail heads in the top of stout wooden hubs. Of these hubs, the ones that are convenient for the use of local engineeers and surveyors or that are necessary for connecting at some future date this triangulation to a correct geographical position are to be replaced with permanent station marks.

Computations.—Computations of the distances and azimuths between stations and their relative positions were completed before leaving the field and, with other information obtained, were sent to Mr. B. R. MacKay, the officer in charge of the topographical party.

Field work was begun on April 24, and finished May 24.

Thetford Triangulation.

This is a local triangulation required for the primary control of the Thetford map-area, Quebec; an area of 245 square miles, which is being mapped on the scale of 1:48,000.

Details of Work.—A base line, 4,721·14 feet long, was established and measured along the meadows, just north of Black Lake. The necessary geographical position is that of "Thetford," a primary triangulation station of the Geodetic Survey of Canada. This station was included in the local triangulation. Azimuth was derived from observations on the sun at the south base. Sixteen main stations, including the expansion from the base, were signalled and observed, and about ten other points, church steeples, flags, etc., were cut in. A vertical control by double zenith distances gave satisfactory results.

Instruments and Methods.—A 6½-inch Berger transit, with horizontal circle reading to 10 seconds and vertical circle to 30 seconds, was used. All the angles of a triangle were observed, the methods being by repetitions—three repetitions direct clockwise and three reverse counter-clockwise constituting a set. Good figures having no material angle under 30 degrees and giving frequent check distances were obtained. The signals were tripods with centre poles carrying a flag. The station marks are temporary, such as chisel marks on solid rock, or a stout wooden hub firmly fixed in a rock pile. Of these station marks, the ones that are required for the use of the local engineers and surveyors, or for other reasons, are to be replaced with permanent marks.

Computations.—Computations of the distances and azimuths between stations, and geographical positions and elevations, were completed and given to Mr. D. A. Nichols, the officer in charge of the topographical party.

Field work began on May 14 and finished on July 14. About a week's delay was caused by wet weather. Mr. Nichols and members of his party rendered considerable assistance.

Similkameen District.

This is a chain of secondary triangulation planned to extend from the International Boundary to the British Columbia railway belt. It will connect the International Boundary triangulation with the trigonometric survey of the railway belt by the Topographical Surveys Branch of the Department of the Interior. The main purpose is to furnish the primary control for topographical work.

Details of Work.—"Lakeview," "Princeton," and "Frosty," stations of the International Boundary triangulation, were selected as base and the scheme developed from these. The base stations were first visited, and, where necessary, re-signalled. Seven new stations were selected and signalled. Of the ten stations thus obtained, seven were re-visited and observed.

The area embraced by this triangulation is an elevated plateau between north and south mountain ranges and is cut into a series of flat-top, timber ridges by deep V-shaped valleys. Suitable stations near the centre of the area were, consequently, hard to obtain. At one station vistas had to be cut out, and at another an observing tower 35 feet high had to be constructed. This, with the necessary roundabout travel between stations, greatly delayed progress.

Instruments and Methods.—A 15- by 15-inch plane-table was used for the reconnaissance. A 6¼-inch Berger transit with horizontal circle reading to 10 seconds, and a vertical circle reading to 30 seconds was used for the angular measurements. All the angles of a triangle were observed, the method being by repetitions; six direct clockwise and six reverse counter-clockwise constituting a set. For vertical control double zenith distances were observed. The centre marks are C. G. S. standard brass plate bench marks cemented in a drill hole in solid rock. The signals were either rock cairns, or tripods, with centre poles and targets.

Computations.—Preliminary computations of distances, azimuths, and geographic positions have been completed and are available for control of topographic mapping. When all the stations have been observed the triangulation will be adjusted by the method of least squares. Field work began on June 24, and continued until November 6. Weather conditions up to October 1 were favourable; after this date a continuous series of snowstorms delayed the work for two consecutive weeks and hampered the progress of the party for the remainder of the season.

Part II.

Spirit Levelling Near New Glasgow, N.S.

Levels were run in two short circuits in the New Glasgow map-area; the first circuit was along the Intercolonial railway from Stellarton railway station to the Allan shafts of the Acadia Coal Company, thence via the Albion Mines railway to the McGregor slopes of the same company, returning via wagon roads to the starting point; the second continues along the Intercolonial railway from the Allan shafts to Woodburn station, thence along the wagon road via Weirs Mills to Thorburn, and the Vale Colliery railway back to the Intercolonial railway. The instrument work was done by Mr. B. R. MacKay.

Instruments and Methods.—A 15-inch Y level and New York target rod were used. The line was run only once. Both levelman and rodman read the rod independently and kept separate notes. Temporary benchmarks were established about every mile, and permanent standard bench marks, with the elevation stamped thereon to the nearest foot, were established about every 3 miles, and at points convenient for local use. The standard bench marks are of two kinds, a plate for use in rock and masonry, and a pipe for use in soil. The plate bench mark is a brass plate, 3¾ inches in diameter, bearing the inscription "B. M. Geological Survey of Canada, Elevation . . . . Feet"; on the under side is a fluted bolt 3 inches long, whereby the plate is cemented into a drill-hole in rock or masonry. The pipe bench mark is a heavy, 3-inch iron pipe 5 feet long, the lower end of which is split for about 9 inches and spread out to form a T-bearing surface; on the upper end is riveted a brass cap bearing the inscription "B. M. Geological Survey of Canada, Elevation above sea. . . Feet." This pipe is buried to within 8 or 10 inches of the surface of the ground.

Datum.—The elevations are based on mean sea-level as carried to Stellarton, N.S., by the precise levels of the Geodetic Survey of Canada. The datum used was B. M. MCCC of the Department of Public Works. Two determinations of the elevation of this bench mark have been made, one by the Department of Public Works and one by the Geodetic Survey, with the following results; the values given are rod readings without adjustment:—

B. M. MCCC of Department of Public Works.

	Feet.
Elevation as determined by the precise levels of the Department of Public Works..	64·91
Elevation as determined by the precise levels of the Geodetic Survey.. ..	64·61

The adjusted elevation not being yet available, the Geodetic Survey value, 64·61 feet, has been adopted.

Closures.—The first circuit, 4 miles long, closed to — 0·005 feet; the second, 16 miles long, to — 0·123 feet. These closures have been adjusted in the different circuits proportionately to the distance.

Descriptions and Elevations of Bench Marks.

	Elevation in feet.
Stellarton.—I.R.C. station, in the east corner of south wall, second course above concrete platform. Copper bolt B.M. MCCC of Department of Public Works: Geodetic Survey of Canada determination. Datum.	64·61
Stellarton.—On Intercolonial railway, 3,900 feet north of station. Road crossing..	20·9
Allan shafts of the Acadia Coal Company.—On top of a concrete foundation pier of the bank head, north side, third pier from northwest corner. Standard plate B.M.	44·78
On same pier. Iron bolt B.M. of Acadia Coal Company	44·88
Albion slopes of the Acadia Company.—On a concrete foundation pier of trestle from mouth of slopes to bankhead; first pier on west side. Standard plate B.M..	183·14
McGregor slopes of the Acadia Coal Company.—On the concrete foundation pier of trestle from mouth of slopes to bankhead; only pier on east side. Standard plate B.M..	189·55
Lourdes station.—Top of rail..	20·7
New Glasgow.—Junction of I.R.C. and Vale Colliery railway, on east side of wooden culvert under tracks. Top of large spike...	28·72
New Glasgow.—I.R.C. station; road crossing betweeen station and freight shed..	32·1
New Glasgow.—On the east end of north abutment of Intercolonial Railway elevated crossing over Dalhousie street, near the ornamental gate-post of the New Glasgow post-office. Standard plate B.M.	23·34
New Glasgow.—On Intercolonial railway, on base of switch at junction of Pictou Harbour branch. Top of spike in northeast corner..	34·2
New Glasgow.—Opposite the Dominion Bridge Works, on the electric signal of the Intercolonial railway. Top of iron base plate, south corner..	91·6
New Glasgow.—On the base of the electric signal of the Intercolonial railway at the Little Harbour road crossing. Top of south bolt.. ..	132·8
New Glasgow.—2·8 miles east of; 75 feet east of a small stone culvert, on a boulder 3½ feet by 3 feet projecting from south side of a cut on the Intercolonial railway between Mileposts 45 and 46 from Truro. Standard plate B.M...	204·86
Woodburn.—On south end of east abutment of Intercolonial Railway crossing over stream, 600 feet west of Woodburn station. Standard plate B.M...	137·85
Woodburn.—I.R.C. station; base of rail opposite	142·4
Weirs Mills.—On east corner of south abutment of wagon bridge over stream, foot of Weir's dam. Brass nail and washer, temporary B.M...	34·74
Thorburn.—At vale colliery of Acadia Coal Company, on the east side of mouth of main slope near base of trestle. Standard pipe B.M...	229·97
Ten feet northwest, at mouth of main slope, between tracks of trestle. Iron pipe B.M. of the Acadia Coal Company..	228·97

Elevation in feet.

Thorburn.—0·5 mile southwest of, in the east corner of south abutment of overhead crossing of New Glasgow road over the Vale Colliery railway. Brass nail and washer, temporary B.M. . . . . 227·6

Thorburn.—1·5 miles west of, on the Vale Colliery railway. Marsh road crossing. . . . . 168·6

New Glasgow.—Two miles east of, on the Vale Colliery railway. Thorburn road crossing. . . . . 132·0

New Glasgow.—On the Vale Colliery railway, East River road crossing. . . . . 70·2

BIOLOGICAL DIVISION.

BOTANY.

(John Macoun.)

It having been arranged that I should reside on Vancouver island and continue my studies of the flora of the island, the whole year was spent there, my botanical investigations being confined to the vicinity of Victoria and Sidney, with short visits to adjacent islands. Much botanical work of a general character had been done on Vancouver island, but little critical work, except in phanerogams. The climate permitted me to work out-of-doors in the winter and for the first time I had an opportunity to study cryptogams critically. The result was that very large collections of cryptogams were made and many new species added to the known flora of the island. These have nearly all been determined by specialists, the musci by Mrs. E. G. Britton and Prof. O. E. Jennings, the lichens by Mr. G. K. Merrill, the hepaticæ by Miss C. C. Haynes, the sea-weeds by Mr. F. S. Collins, and the woody fungi by Mr. C. G. Lloyd. One paper on the lichens has been published in *The Ottawa Naturalist* by Mr. Merrill and another is being got ready for the press. Eight new species and sub-species were described in the paper referred to above. Over 400 species of flowering plants were collected, which have been named and mounted. These include twelve species not before recorded from Vancouver island.

[1] The Ottawa Naturalist, vol. xxvii, p. 117-120.

BOTANY.

(J. M. Macoun.)

The most important work to be done in connexion with the botanical branch at the beginning of the year was the determination and arrangement of the collections that had accumulated in the herbarium. These included parts of collections made as long ago as 1905, and the greater part of the writer's time during the year was devoted to this work, the result being that before spring it will have been completed. A much larger number of Canadian specimens were mounted than in any previous year, and, with the assistance of specialists, these have all been named and sorted into the herbarium, so that for the first time in thirty years it may be said that all the botanical material in the herbarium has been put into the condition that it is readily available for study and reference by anyone. During the early winter months the writer, in conjunction with Dr. M. O. Malte, made keys for the Ottawa Flora originally written by Prof. Macoun, and the collecting season was spent in the vicinity of Ottawa revising these keys by studying the growing plants and collecting in new localities. Several additions were made to the known flora of the region. Further study of critical species is needed, but it is expected that the Ottawa Flora will be ready for publication during the coming year.

The herbarium of the Geological Survey being the only one in Canada that contains anything like a complete collection of Canadian plants a large number of specimens are each year sent here for comparison and determination. As the specimens sent are frequently very poor, a great deal of time is consumed in this work, but it is the best medium we have for keeping in touch with other collectors, both professional and amateur. The most important collections named were: for Mrs. Henshaw, Vancouver, B.C.; Miss Moodie, Calgary (for Alberta Government); Dr. J. Dearness, London, Ont.; Prof. J. E. Howitt, Guelph, Ont. (for Guelph Agricultural College); Prof. B. J. Hales, Brandon, Man. (for Normal School); and Dr. Carl Skottsberg, Upsala, Sweden, the latter collection being a very large one made by Dr. Skottsberg across the continent with the Geological Congress. Many specimens were also named for Dr. E. Sapir of the Geological Survey staff, and for botanists connected with other Government departments at Ottawa. The most important collection that has come to the herbarium from those connected with the Geological Survey staff was that made by D. D. Cairnes along the Alaskan boundary. Among other important collections received was one made by Mr. Radford between Lake Athabaska and Chesterfield, and another made by Mr. E. W. Nesham along the Alaskan boundary. Lists of the collections made by Dr. Cairnes in previous years have already been published, the following being a list of the species not collected in 1911-12:—

Stellaria longipes Goldie, var. *Edwardsii*, Wats.
Claytonia N. sp. A beautiful little plant apparently unrelated to any known species.
Saxifraga flagellaris Willd.
Potentilla biflora Lehm. New to Canada.
Oxytropis campestris, DC., var. *melanocephala* Hook.
Polemonium humile Willd.
Eritrichium related to *E. Howardii* and the Siberian *E. rupestre*, but neither species. Apparently undescribed.

Pyrola. A species collected before in Yukon but as yet undescribed.

A small collection of mosses and lichens made near Canyon City included the following species:—

MUSCI.

Rhytidium rugosum (Ehrh.) Kindb.
Dicranum lævidens R. and W.
Thuidium abietinum (L.), Bry. Eur.
Polytrichium juniperinum Willd.

LICHENS.

Cetraria nivalis Ach.
" *juniperina* (Linn.), var. *terrestris* Schær.
" *furcata* (Huds.) Schrad.
" *sylvatica,* var. *sylvestris* Ord.
Thamnolia vermicularis (Sw.) Schær.
Stereocaulon tomentosum (Fr.) Th. Fr.

Contributions to the herbarium were received from:—
The New York Botanical Garden.
The Gray Herbarium, Cambridge, Mass.
Prof. Carleton R. Ball, Department of Agriculture, Washington.
H. F. J. Lambart, International Boundary Surveys, Ottawa.
Prof. L. S. Hopkins, State Normal School, Ohio.
Dr. M. O. Malte, Experimental Farm, Ottawa.

Dr. Malte collected across the Dominion from Prince Edward Island to Vancouver island in 1911, 1912, and 1913, and has worked up his collections at the Geological Survey herbarium. As he did this he laid aside for our herbarium specimens of all species that were not well represented from the districts in which he collected, or which were additions to the Canadian flora. These specimens are a most valuable addition to our herbarium as he collected at many localities that have not been visited by ourselves. One hundred and eighty-four sheets of specimens were purchased during the year, 3,789 sheets, chiefly Canadian phanerogams, were mounted; and 2,246 sheets of duplicates were distributed to large herbaria in the United States and Europe; 450 official letters were received and answered.

The only herbarium assistance during the year, except that voluntarily given by Dr. Malte, has been from Miss Marie C. Stewart who, in addition to the usual clerical work, has rearranged the herbarium, sorted in mounted specimens, and performed the other duties of an herbarium assistant. The Ottawa collection is now in her charge.

ZOOLOGY.

(*P. A. Taverner.*)

The progress during the past year, of the Zoological Division, has been most gratifying. A great part of the cataloguing and arranging of the old collections has been done; office routine has been well established; a preparatory department has been organized, and while no permanent exhibits have been installed, a good start has been made on such exhibits, and temporary ones have been set up as far as casing facilities permitted.

During 1913 the zoological staff was augmented as the result of several appointments. Mr. R. M. Anderson was appointed mammalogist. Immediately after his appointment, Mr. Anderson left on the Canadian Arctic expedition and as officer in charge of the southern party will remain for several years in the north country. Mr. Clyde L. Patch was appointed taxidermist; Mr. Patch has had a wide experience in all branches of zoological preparatory work in some of the largest museums in America. Miss Winnifred Bentley was transferred to this division and has since occupied the position of general assistant and typist in a most satisfactory manner. For a short time during the summer, Mr. Frank Hennessey was temporarily attached to the division and performed his work in his usual efficient manner.

The greatest need, at present, of this division is the appointment of additional technical officers to take charge of the lower vertebrates and the invertebrates. An entomologist is especially necessary. Our entomological collections are large and important, and although Dr. Hewitt, of the Experimental Farm, has generously assumed the advisory duties of Honorary Curator of Entomology, yet the work demands all the time of a specialist, and more than Dr. Hewitt's other duties allow.

Owing to delays incidental to the choosing and procuring of satisfactory exhibition cases, it has been impossible to place permanent exhibits in the Museum halls. Meanwhile several experimental cases have been prepared and much work has been done with material which it is planned to incorporate in the permanent exhibits and which, in the meantime, has been in part used to form temporary exhibits.

As the city of Ottawa and vicinity was threatened in 1913 with a plague of tent caterpillars, it was deemed expedient that the Museum should early call attention to the danger and means of combating it. Consequently a special exhibit of the tent caterpillar was installed in the main entrance hall of the building. This exhibit showed the life history of the species, and the means of control, both by natural and artificial agencies. It was accompanied by plainly written labels aiming to be both interesting and instructive, and attracted a considerable amount of attention. The daily papers took the matter up and, as a result of the advertising, a wide interest was taken and serious effort made by the general public towards combating the pest. Though the early summer months were disagreeable to everybody by the prevalence of the disgusting caterpillars, it was evident that matters would have been much worse had it not been for educational movements inaugurated by the Museum.

Our collections have been used extensively by others, outside of our own staff, and the following have availed themselves of loan or examination privileges: Dr. C. Hart Merriam, who is making an extensive study of the bears of North America; H. C. Oberholser, A. H. Howells, and Wells W. Cook, of the United States Biological Survey; Dr. B. A. Bean, of the United States National Museum; Mr. J. H. Fleming, of Toronto, during the course of the preparation of his "Mammals of the Toronto Region" for the Geological Congress; Mr. Allan Brooks, of Okanagan Landing; Mr. Frank Hennessey, of Ottawa; and the Entomological Division of the Experimental Farm, Ottawa.

The local schools have also taken advantage of our collections. Classes have been brought to study the exhibits, students have come for special information, and mounted specimens have been loaned to their instructors for class work. This is a branch of Museum activity that it is hoped to see greatly enlarged in the future.

Our study and exhibition collections have considerably increased during the year through the usual channels of donation, purchase, and museum expeditions. The more notable of the accessions are mentioned in the following accounts.

In my summary report for 1912, I anticipated the presentation of an important collection from Mr. J. H. Fleming, of Toronto. This material has been received, and consists mainly of mounted birds, admirable specimens of taxidermic art, and contains representatives of many species not already represented in our collections, and a number of interesting Canadian records. With these were also some valuable mammal material, on loan, including large game heads, a fine series of bison horns, and the only two Ontario-killed panthers known to be extant. These latter are especially valuable as they form the only basis of judgment now obtainable as to the characters of the eastern representative of this species in the Dominion. Another specimen of popular interest is a wolf, one of the original pack made famous by Ernest Thompson-Seton in his animal classic, "Lobo, King of the Corrumpaw."

We have been the recipient of many favours from the Dominion Parks Branch in the way of skins and skeletons of larger ruminants, that have died or have been necessarily killed in their parks. I hereby desire to thank the various officers of the Dominion Parks Branch and their director, Mr. J. B. Harkins, for their courtesies.

The great number of smaller donations received from various friends of the Museum, have been most gratifying, and indicate an increasing amount of interest in the institution amongst all classes. The gifts have come from various parts of the Dominion from Nova Scotia to Vancouver island. The donors deserve the full thanks of the Museum for their practically applied goodwill.

In exchange we have received, from the Department of Marine and Fisheries, the birds and eggs collected by A. P. Low during his voyage of the S.S. *Neptune* in 1904. A list, with annotations, of this material has been published, but not until now has the material upon which it has been based been available for further reconsideration or confirmation in the light of our constantly increasing knowledge of Arctic faunas.

By purchase we have also largely added to our collections, both in numbers of specimens and interest. Principal among these accessions is the Lewis collection of birds and mammals from the Teslin Lake region, Yukon Territory. This consists of:—

24 moose,
20 caribou,
35 mountain sheep,
16 bear, black and grizzly,
7 lynx,
9 beaver,
54 hares,
24 gophers,
30 red squirrels,
16 weasels,
5 mink,
1 wolverine,
1 otter,
27 marmots,
14 porcupine,
44 muskrats,
10 chipmunks,
56 mice and shrews,
1 pika,
5 wood rats,
1 bat, etc.

Totalling 380 mammals and 211 birds.

The scientific value of such an extensive mammal collection from a limited area, showing all conditions and pelages of summer and autumn, can hardly be over-estimated. The birds are of almost equal interest, and include most of the larger species, some of them in considerable series. Particularly may be mentioned amongst them the horned owls and dusky grouse, the latter being probably subspecifically new to science, and forming the basis of a paper nearly ready for press.

The entomological collections have been increased by acquisition of a finely-prepared collection of local lepidoptera numbering some 22,000 specimens collected by Mr. C. H. Young, previous to his appointment to this department in 1907.

Much valuable material has also been secured by members of this division. On May 16, a party composed of the writer, Messrs. C. H. Young, and C. L. Patch, established themselves on Point Pelee, Essex county, Ontario, for the purpose of studying the most southerly forms of life occurring in the Dominion, and to collect material for a large landscape group, showing the character of the so-called Carolinian or Upper Austral fauna, as it occurs in Canada. While the exhibitional phase of our work occupied the greater part of our time, the scientific collections were not neglected, and advantage was taken to fill some of the gaps in our southern Ontario representation of specimens. Some interesting records of specific occurrences were made and important specimens collected in all branches of zoology possible under the circumstances.

To date, one accession has been received from Mr. R. M. Anderson and his assistant naturalist, Mr. Fritz Johansen, both of whom accompanied the Canadian Arctic expedition. The accession received from Mr. Johansen consists chiefly of interesting invertebrates.

Mr. C. H. Young, of this division, while on a trip to England, late in the autumn, took advantage of his opportunity to collect a few common English birds for the Museum. Though it was too late in the season to secure all the species desired, the results were highly satisfactory, and he brought back a very nice collection of well-made skins suitable for mounting.

The staff of the other divisions of the Geological Survey has shown an increasing interest in the Museum, and through the year brought in some lots of specimens. Among these can be specially mentioned the lepidoptera secured through the influence of D. D. Cairnes, from Mr. Nesham of the Alaska Boundary Survey; and the birds brought in by M. Y. Williams from the Bruce peninsula, Ontario, a locality very poorly represented in any collection.

With the routine office work, much has been accomplished. A new system of recording our mounted birds by means of cards and photographs has been evolved, and the work in connexion with it has been largely completed. A new system of pamphlet filing has also been installed. Several thousands of cards have been added to the species bibliography of Canadian birds, and this bibliography is beginning to assume helpfully workable proportions and to contain a large part of the information that has appeared since the publication of Macoun's Catalogue of Birds in 1909. As soon as it is complete back to this date, it is intended to include the earlier authors and dates, especially those unavailable at the time the above catalogue was written. While in New York, attending the meeting of the American Ornithologists Union, advantage was taken of the opportunity to go over the private collection of Dr. Jonathan Dwight, and a list was made of all his Canadian records. This extends the available data on bird distribution in the Dominion and has been added to the above index. There are a number of other private and public collections in the United States that will have to be examined in the same manner before our records are complete.

During the year there has been only very little time available to spend on study or original work, but work has commenced on the bird collections and a considerable proportion has been critically examined and determined. In all cases of doubtful identity we have had the advice of the best specialists in the various families considered; and I have to thank Dr. Jonathan Dwight, of New York; Dr. Lewis Bishop, of New Haven; and H. C. Oberholser, Gerrett D. Miller, and Dr. B. A. Bean, of the Smithsonian Institution and the Biological Survey, Washington, D.C., for courtesies in this direction.

Additions to the Zoological Collections During 1913.

Presented.

Accession Nos.

13-1. By E. G. White—
One Hooded Merganser, collected by H. D. Bates, at Rondeau, Ont. Catalogue No. 6427.

13-2. By Abraham Knehtel, Ottawa—
One Huskie Dog, Norway House, H. B. Catalogue 1891.

13-3. By D. A. McNaughton—
Fragment of Moose skull, collected at Lake Timiskaming, near provincial boundary. Catalogue 1805.

13-4. By J. H. Fleming, Toronto—
Various mounted birds, collected mostly at Toronto. Catalogue Nos. 6106-6426, 6428, 6429, 6464-6467.

1355. By Mrs. R. Rosenthal, jun.—
Mounted Loon, no data. Catalogue No. 6432.

13-10. By W. E. Hyndman—
One skeleton Black Fish, collected at Tracadie Beach, P.E.I. Catalogue No. 1892.

13-12. By Dominion Parks—
One antelope skin, collected at Wainwright, Alberta, 1913. Catalogue No. 1813.

13-14. By Dominion Parks—
One Antelope skeleton, collected at Wainwright, Alberta, 1913. Catalogue No. 1893.

13-15. By Frank Shumacker—
Thirty-five Tiger Beetles, collected in Nebraska, 1906-1909.

13-17. By M. C. Ives—
Seventy-five land shells, collected at Miscouche, P.E.I.

13-18. By Experimental Farm, Ottawa—
Twenty-eight Tent Caterpillars, collected at Ottawa by Arthur Gibson.

13-20. By G. E. Sanders, Bridgetown, N.S.—
Two shells, collected at Grosses Coques, N.S., 1913.

13-21. By C. H. Young, Ottawa—
Five mounted birds, collected at Hurdman, Ottawa, Ont., 1903. Catalogue Nos. 7025-7028, 6679.

13-22. By Dominion Parks—
One Buffalo skin and skeleton. Catalogue No. 1896.

Accession
Nos.

13–27. By Dominion Parks—
One Elk skeleton collected, 1913. Catalogue No. 1895.

13–28. By Dominion Parks—
One Buffalo skin and skeleton. Catalogue No. 1896.

13–30. By Dr. Marcellus—
One head and skull of walrus, collected near Fort Churchill, H.B.

13–31. By Dominion Parks—
One Black Bear skull, collected at Summit Main Range near Waterton Mill, Alberta. Catalogue No. 1899.

13–35. By Mrs. Gerard, Ottawa—
One mounted Cincereous Owl, no data. Catalogue No. 6779.

13–39. By H. Korton—
Birds and Mammal skins. Catalogue Nos.: Birds, 6993-7007; Mammals, 2286.

13–41. By Dominion Parks—
One Cow and Calf Yak, captive animals, Banff, Alberta. Catalogue No. 1912-1913.

13–45. By J. L. Rannie—
One Ruffed Grouse, two Chickadee, two Blue Jays, six Hairy Woodpeckers, one Golden Eye, Red Squirrels. Catalogue Nos.: Birds, 7008-7019; Mammals, 1914-1918.

13–47. By C. H. Young—
One Shrike nest and eggs, collected at Hurdman, Ottawa, Ont.

13–49. By Frank Hennessey—
One American Robin, one White Throated Sparrow, one Phœbe. Catalogue 7033-7035.

13–54. By H. Sampson, Vancouver, B.C.—
One Salamander, one Squirrel, and Wood Rat. Catalogue Nos.: Reptiles, 566 ; Mammals, 2287-2288.

13–56. By G. F. Monckton—
Unio fragments collected on Vancouver island, 1913.

13–58. By Frederic Lambert, Ottawa, Ont.—
One Sharp-tailed Grouse, Ptarmigan eggs, collected in the Yukon Territory. Catalogue No. 7046.

13–61. By Frederic Lambert, Ottawa, Ont.—
One Pileated Woodpecker, collected at Mattawaki, Ont. Catalogue No. 7048.

13-64. One Woodchuck skull, no data or name of collector. Collected near Pembroke. Catalogue No. 2290.

13–67. By E. W. Nesham—
Birds, Butterflies, and Eggs. Catalogue Nos.: Birds, 1865-1868, 7070.

13–68. By Frederic Lambert, Ottawa—
Collections of eggs, about 19 specimens, various species.

Accession Nos.

Transferred.

13–34. From Ethnological Division—
Three Fox skulls and Bear teeth, collected by Capt. Bernier at Melville island, Frank, 1909. Catalogue Nos. 1907-1919.

13–46. From Chemical Laboratory, Museum—
One Blackburnian Warbler. Catalogue No. 7020.

13–51. Palæontological Division—
Various Invertebrates.

13–66. From Ethnological Division—
Fragment of Bison skull, collected at bottom of Pelly river, Yukon Territory, summer, 1913. Catalogue No. 2289.

Collected by Officers of the Geological Survey.

13–25. By Chas. Camsell—
Twenty-one and one-half Fresh-water Shells, collected at White lake, 10 miles from Arnprior, Ont., May 4, 1913.

13–57. By D. D. Cairnes—
Thirty-one Butterflies, collected in the Yukon Territory, 1913.

13–7. By E. M. Kindle—
Ten Fresh-water Shells, collected at west side of Dawson bay, Lake Winnipegosis, Manitoba, September 4, 1912. Catalogue Nos. 2598-2599.

13–24. By W. J. Wintemberg—
Ten Land Shells, collected at Miscouche, P.E.I., by C. Ives, 1913.

13–19. By P. A. Taverner—
Three Photos, Tent Caterpillars, made at Britannia park, near Ottawa, Ont.

13–37. By Museum Expedition—
P. A. Taverner, accompanied by C. H. Young and C. L. Patch, Birds, Mammals, Reptiles, Fish, and Insects. Catalogues Nos.: Birds, 6780-6797; Mammals, 2295-2336, 2341-2355; Reptiles and Amphibians, 501-565; Fish, 1001-1013; Crustaceans, 1176-1180.

13–33. By M. Y. Williams—
Various Birds and Mammals, collected in Ontario, summer 1913. Catalogue Nos.: Birds, 6777-6778.

13–50. By M. Y. Williams—
Various Birds, collected at Bruce peninsula, Ont. Catalogue Nos. 1907-1910.

13–59. By M. Y. Williams—
One Snow Bird and one Blue Jay, collected at Lake Deschenes, Ottawa, November 1, 1913. Catalogue Nos. 7063-7064.

13–62. By M. Y. Williams—
One Green-winged Teal, collected at Demorestville, Ont. Catalogue No. 7062.

Accession
Nos.

13–63. By C. H. Young—
Five Mammals, Mice collected at Meach lake, near Ottawwa, summer 1913. Catalogue Nos. 2282-2283, 2292-2294.

13–69. By C. H. Sternberg—
One Cat skull, collected at Steveville, Red Deer, Alberta.

13–52. By Canadian Arctic Expedition—
Invertebrates, collected at Alaska, summer 1913.

Acquired by Exchange.

13–6. With G. Eifrig—
Bird skins, collected mostly from near Ottawa, Ont. Catalogue Nos. 6433-6460.

13–26. With Department of Marine and Fisheries—
Bird skins, being specimens collected on the S.S. *Neptune* by Dr. A. P. Low, 1904. Catalogue Nos. 6680-6776.

Purchased.

13–8. From M. O. Mills, Geneva—
One mounted Passenger Pigeon. Catalogue No. 6461.

13–9. From H. H. Mitchell—
One mounted Passenger Pigeon, collected near Hamilton, Ont. Catalogue No. 6462.

13–11. From Chas. McConnell—
One Clark's Nutcracker, collected at Robinson, Y.T. Catalogue No. 6463.

13–13. From A. Hyatt Verrill—
Three hundred and forty-five Insect Photographs.

13–16. From Clement Lewis, Yukon Territory—
Birds and Mammals. Catalogue Nos.: Birds, 6468-6678; 6456; Mammals, 1826-1870; 1921-1981-2280.

13–23. From W. E. Saunders—
Five Berlepsch Bird boxes.

13–29. From Dr. Marcellus—
One Polar Bear skin and skeleton, collected at Fort Churchill, Hudson bay, 1910. Catalogue No. 1897.

13–32. From A. W. Puckett—
Three Goats, two Brown Bears, collected at mountains off Lake Bennett, 10 miles from British Columbia line. Catalogue Nos. 1900, 1903-1906.

13–38. From Canadian Arctic Expedition—
One Walrus skull with birdnest inside, collected at Nome, Alaska. Catalogue No. 1911.

13–42. From A. R. Austin—
One Stone's Sheep, collected at Carerose, 1910. Catalogue No. 1820.

Accession Nos.

13–43. From W. A. Puckett—
One White Porcupine skin, collected at Whitehorse, Yukon Territory. Catalogue No. 1902.

13–48. From C. L. Patch—
Two Summer Tanager, collected by R. S. Moore, at Jefferson county, Indiana. Catalogue No. 7021-7023.

13–60. From C. H. Young—
About 22,000 specimens of lepidoptera, collected near Ottawa.

13–70. From Omer Camerle, Namur, Quebec—
One Grey Squirrel. Catalogue No. 2337.

13–71. One Kadiac Bear skull, from Alaska. Catalogue No. 2339.

On Loan.

13–40. From J. H. Fleming, Toronto—
Birds and Mammals. Catalogue Nos.: Birds, 6430-6431; Mammals, 1878-1890.

13–65. From A. H. O'Brien, Ottawa, Ont.—
Mounted Birds. Catalogue Nos. 7049-7061.

ANTHROPOLOGICAL DIVISION.

(E. Sapir.)

Staff.

Three new appointments have been made in the course of the year to the permanent staff of the Division of Anthropology. Mr. W. J. Wintemberg, who had previously done temporary work in the laboratory, field, and office, received permanent appointment on April 1 as preparator in archæology of the Anthropological Division of the Geological Survey. Mr. F. W. Waugh, who had previously been engaged in field research among the Iroquois for the division, received a similar appointment as preparator in ethnology on July 1. Miss Ariel McConnell received an appointment as stenographer on July 1.

The Division of Anthropology at present numbers a scientific staff of five and a clerical staff of two. The organization of the division is as follows:—

E. Sapir, head of Division of Anthropology, and ethnologist in charge of section of ethnology and linguistics.

H. I. Smith, archæologist in charge of section of archæology.

C. M. Barbeau, assistant anthropologist.

W. J. Wintemberg, preparator in section of archæology.

F. W. Waugh, preparator in section of ethnology.

Miss E. Bleakney, stenographer in section of ethnology and linguistics.

Miss A. McConnell, stenographer in section of archæology.

PART I.

ETHNOLOGY AND LINGUISTICS.

(E. Sapir.)

Museum.

Exhibits.—In the course of the year the Hall of Canadian Anthropology has been thrown open to the public. A general statement in regard to the exhibition cases of the hall has been already given in the Summary Report for 1912. During the year 1913, these cases have been provided with ethnological and archæological exhibits, in accordance with the general plan already outlined. Eight of the table cases are devoted to Canadian archæology, and are described in part III of this report. The remaining cases are divided into two main groups, those on the right of the hall as one enters being devoted to exhibits illustrating the culture of the West Coast Indians, while those on the left contain the exhibits of the Eskimo and Eastern Woodlands tribes. As already stated in the Summary Report of the preceding year, the ethnological material from the plains and from the Mackenzie valley and western plateaus has had to be stored for want of adequate exhibition room. This applies also to certain of the tribes of the Eastern Woodlands area, namely the Cree, Algonquin, and Ojibwa. The Division of Anthropology needs at least one other hall for the proper exhibition of the material in its hands. The table and upright cases have been so grouped as to bring ethnological exhibits of the same tribe that have been divided between the two types of case as close together as practicable.

The exhibits for the various West Coast tribes are distributed as follows: three halves of the upright cases deal with the culture of the Nootka Indians, of which one deals with the fishing and hunting implements of these Indians, the second with the basketry and clothing, the third with ceremonial objects. Two halves of table cases have also been assigned to the Nootka Indians, one of these taking up ornaments and games, the other various implements used by men and women. The Coast Salish are represented by a half and a quarter of an upright case, and by a half of a table case. Our collections from these Indians are not as fully representative as might be wished. A quarter of an upright case is devoted to the ceremonial objects of the Bella Coola Indians, half a table case to similar objects of their neighbours, the Bella Bellas. A fairly full collection of the Kwakiutl Indians is on exhibition, embracing two complete and four halves of upright cases, besides two halves of table cases. In the upright cases are exhibited basketry, weapons, implements of various kinds, and ceremonial objects, while the table cases make provision for games, ornaments, carvings of various sorts, and men's and women's implements. Two full upright cases and two halves and one-quarter of the table cases have been employed to exhibit the Tsimshian material, which is grouped into baskets, boxes, grease dishes, and ladles; implements; masks and other ceremonial objects; spoons, charms, and ornaments; smaller masks and musical instruments; and games. Four and one-half of the upright cases and three halves of the table cases take up the Haida material, this tribe being the best represented of the West Coast Indians in the collections of the museum. The material is grouped into boxes; various men's and women's implements; matting and basketry; fishing tackle; canoes and weapons; grease dishes and musical instruments; masks; games and ornaments; carvings of various sorts; ceremonial objects other than those already enumerated; and spoons and other implements. Half an upright case and one-quarter of a table case provide for the exhibited material of the Tlingit Indians of southern Alaska, which consists chiefly of decorated basketry.

The left side of the hall is taken up entirely with material from the Eskimo and tribes of the Eastern Woodlands. Among the latter, chief stress is laid on the Iroquoian tribes. The Iroquois proper are dealt with in five half and one-quarter upright cases, and two halves of table cases. The Iroquois collection, which is believed to be one of the fullest to be found in any American museum, consists of masks, other ceremonial objects, and musical instruments; clothing; basketery; household utensils and articles of transportation; games and weapons; implements and medicinal articles; and ornaments, wampum, and beadwork. Five further groups of Iroquois specimens have been exhibited in temporary table cases. These exhibits consist of samples of native corn and beans; implements connected with fire-making; war clubs, stirring paddles, spoons, and ladles; and models of various types of traps. Two halves and one-quarter of the upright cases and half a table case are taken up with exhibits of the Huron and Wyandot, also members of the Iroquoian stock. The grouping of exhibits is into household utensils, weapons, and musical instruments; clothing and basketry; articles of transportation; house models and food implements; ornaments, silver-work, bead-work and moose-hair embroidery; and various implements connected with basket making and other industries. A series of Huron trap models is exhibited in one of the temporary table cases. The remainder of the space allotted to the Eastern Woodlands tribes is taken up with Algonkin exhibits. A half and one-quarter of the upright cases and one-quarter of a table case provide for the Micmac exhibits; the greater part of half an upright case and one-eighth of a table case for their neighbours, the Malecite; the remainder of the upright and table cases last referred to for the Abenaki, and one-quarter of an upright case and a table case, respectively, for the Penobscot of Maine. The Montagnais and Mistassini exhibit is distributed betweeen two halves of upright cases and half a table case, the objects shown being grouped into clothing, various objects of bark and wood, bead-work and games, and men's and women's implements.

The other half of the left wing of the ethnological exhibits is taken up with cases devoted to the Eskimo of Canada and Greenland, and the Eskimo and Aleut of Alaska. The Alaskan Eskimo material is placed in two halves of upright cases and three halves of table cases. The material is divided into hunting implements and articles of transportation; masks, basketry, and men's utensils; women's implements, fire-making implements, and knives of various types; smaller objects connected with hunting and fishing; and pipes, ornaments, and other decorated objects. The Aleut material, consisting chiefly of basketry and matting, is exhibited in one-half of an upright case. The collection from the Mackenzie Eskimo is small and miscellaneous in character, and takes up part of an upright and part of a table case. The Copper Eskimo of the region of Coronation gulf and Coppermine river are represented by exhibits of clothing and various utensils, which take up the greater part of an upright case and a small part of a table case. The Central Eskimo of the region of Hudson bay are represented by a fairly large collection, which is distributed between two upright cases and a half and two quarters of the table cases. The material embraces harpoons and other implements connected with hunting; spear points of various types, snow-knives, snow-goggles, and various smaller implements; men's and women's knives, pipes, and ornaments; clothing; lamps, pots, bows and arrows, and articles of transportation. Half an upright case and one-quarter of a table case provide for the Labrador Eskimo: the material on exhibition for this tribe is grouped into games, ornaments, and other smaller objects of ivory and stone; clothing, articles of transportation, and bows and arrows. A rather representative collection of the Greenland Eskimo is also on exhibition, and takes up somewhat more than two halves of the upright cases. Two half cases are devoted to a special exhibit of various types of harpoon, spear, and lance, also canoe models and paddles, from various Eskimo tribes.

Besides the space available within the cases, the tops of the cases have, to some extent, been utilized for the exhibition of larger objects, the chief of these being two Eskimo kayaks, a Malecite canoe, an Iroquois fish trap, four models of Iroquois and Wyandot bark houses, two Malecite house models, three fish spears of the Eastern Algonkin tribes, and two Nootka shafts of whaling spears. A series of Indian busts, which the museum owes to the courtesy of the American Museum of Natural History, New York, have been put on top of the appropriate cases. They embrace busts of a Tlingit woman, Haida woman, Coast Salish man, Nootka man and woman, and Bella Bella woman. The wall space of the museum has not yet been utilized to any considerable extent. For the present, three Kwakiutl house posts, two larger models of Bella Coola totem poles, a Nootka house post, and a cast of a rock carving from the east coast of Vancouver island have been placed against the walls. The Bella Coola and Haida totem poles referred to in the Summary Report of the preceding year have been provided with pedestals and now stand at the entrance to the museum. A large Haida totem pole from Skidegate still awaits installation.

A special feature of the anthropological hall is the exhibit of full-sized Indian canoes, all of which, except the Eskimo and Malecite canoes already referred to, are suspended from the ceiling. They include a long Haida war canoe which forms the central object of the hall, a smaller Haida dugout, a Kwakiutl dugout, a Kootenay bark canoe, an Iroquois dugout and elm-bark canoe, and two Ojibwa, one Algonquin, two Montagnais, and one Micmac birch-bark canoes.

No attempt has been made to crowd all of the anthropological material owned by the Survey into the limited exhibition space at its command. The Division of Anthropology has contented itself with selecting such material as seemed most calculated to give the public a general idea of the culture of the more important tribes of Canada, and of the range of implements and other objects in use among the natives. The balance of the material has been carefully stored in the cabinets and alcoves of the hall. The latter, however, will be eventually needed for exhibition; storage in these, as well as in the work-room in the basement, where the skeletal material is now housed, must be considered as only a temporary way out of a real difficulty, namely, that of providing in the building adequate provision for the accessible storage, for research or other purposes, of such anthropological material as is not put on exhibition.

The eask of labelling the various objects exhibited in the hall has been only begun. A set of tribal labels has been installed, but explicit specimen labels, on which such scientific knowledge is to be imparted as would seem to be of interest to both the general public and the special student, have yet to be added. Such labels are already in course of preparation for the Iroquois exhibits, and will be begun for the other tribes at the earliest opportunity.

A special anthropological exhibit was arranged for the Seventh International Geological Congress, which visited Ottawa in the early part of August, 1913. The archæological part of this exhibit will be referred to in part III of this report; the ethnological part of the exhibit consisted of a number of snowshoes from various tribes of the Dominion, illustrating the great diversity of types in use among the natives, a set of photographs selected from the photographic files of the Division, which were intended to show how the Canadian Indians solved the problem of transportation, and a map showing the progress that had been made by the Geological Survey up to that date in anthropological research.

Additions to the Ethnological Collections During 1913.

Over one thousand three hundred (1,300) ethnological objects, obtained either by gift, by purchase in the course of regular field work by the division, or by purchase of material not directly obtained in connexion with field work, have been added in the course of the year to the collections of the museum.

Presented.

Speck, F. G., Philadelphia, Pa.—4 Montagnais-Naskapi specimens.
3 Penobscot specimens from Oldtown, Me.
3 Malecite specimens from New Brunswick.
1 Micmac specimen from Richibucto, N.B.
1 Huron specimen from Loretta, Que.

Weitlaner, R. J., Philadelphia, Pa.—6 Ojibwa drawings from wall of old Indian house at Lac des Quinze.

Hawkes, E. W., Philadelphia, Pa.—1 Eskimo drawing by native of Diomede islands.

Reagan, A. B., Nett Lake, Minn.—1 Ojibwa specimen from Bois Fort, Minn.

Polchess, William, Woodstock, N.B.—1 wooden chain.

Collected in Course of Regular Field Work.

Smith, H. I.—3 Micmac specimens (including birch-bark canoe) from Bathurst, N.B.

Waugh, F. W.—1 Tutelo specimen from Six Nations Reserve, Ont.; 39 Iroquois specimens from Six Nations Reserve, Ont.

Mechling, W. H.—18 Malecite specimens from Burnt Church, N.B.

Mason, J. A.—3 Dog-rib specimens from Fort Rae, N.W.T.

Radin, P.—15 Winnebago specimens.

Goldenweiser, A. A.—2 Iroquois masks from Six Nations Reserve, Ont.

Beuchat, Henri, Ethnologist on the Stefansson Expedition.—11 Alaskan Eskimo specimens, and 39 Siberian Eskimo specimens from Diomede islands, purchased in Nome, Alaska.

The bulk of Dr. Mason's Athabaskan material, though obtained in the course of 1913, will not be received until the following year. This applies also to Dr. Sapir's Nootka collection, the greater part of which was obtained in 1913.

Purchased.

49 Penobscot specimens from Oldtown, Me., purchased from F. G. Speck, Philadelphia, Pa.

102 Montagnais specimens from Lake St. John, Que., purchased from F. G. Speck, Philadelphia, Pa.

27 Algonquin specimens from Maniwaki, Que., purchased from F. G. Speck, Philadelphia, Pa.

95 Algonquin specimens from Lake Timiskaming, Ont., purchased from F. G .Speck, Philadelphia, Pa.

19 Nipissing Ojibwa specimens from North Bay, Ont., purchased from F. G. Speck, Philadelphia, Pa.

87 Objiwa specimens from Lake Timagami, Ont., purchased from F. G. Speck, Philadelphia, Pa.

2 Iroquois wampum belts, originally belonging to Oka, Que., purchased from F. G. Speck, Philadelphia, Pa.

3 Central Eskimo specimens from west coast of Hudson bay, purchased from F. G. Speck, Philadelphia, Pa.
257 Thompson River specimens, purchased from J. A. Teit, Spences Bridge, B.C.
4 Tahltan specimens, purchased from J. A. Teit, Spences Bridge, B.C.
1 Shuswap specimen, purchased from J. A. Teit, Spences Bridge, B.C.
2 Lillooet specimens, purchased from J. A. Teit, Spences Bridge, B.C.
1 Kootenay specimen, purchased from J. A. Teit, Spences Bridge, B.C.
69 Northwest Athabaskan specimens from Teslin lake, Y.T., purchased from Clement Lewis, Whitehorse, Y.T.
25 Ojibwa specimens from Bois Fort, Minn., purchased from A. B. Reagan, Nett Lake, Minn.
47 Iroquois specimens from Six Nations Reserve, Ont., purchased from Simeon Gibson, Six Nations Reserve, Ont.
2 Central Eskimo specimens (kayak and beaded fur coat) from west coast of Hudson bay, purchased from Capt. G. Comer, East Haddam, Conn.
3 Menomini specimens, purchased from A. B. Skinner, New York.
14 Alaskan Eskimo specimens from St. Michaels, Alaska, purchased from E. W. Hawkes, Philadelphia, Pa.
275 West Greenland Eskimo specimens, purchased from Christian Leden, Norway.
3 Iroquois specimens, purchased from L. Thompson, Hull, Que.
1 Algonquin specimen from Maniwaki, Que., purchased from Charles Logue, Maniwaki, Que.
11 Northwest Athabaskan specimens from Ross river, Y.T., purchased from Poole Field.
6 Huron specimens from Lorette, Que., purchased from Caroline Groslouis, Lorette, Que.
2 Iroquois specimens from Six Nations Reserve, Ont., purchased from J. P. Atkins, Six Nations Reserve, Ont.
28 Menomini specimens, purchased from American Museum of Natural History.
7 Winnebago specimens, purchased from American Museum of Natural History.

Photographic Work.—The division has continued adding to its stock of photographs of anthropological interest. These have proved useful as an aid to certain types of research and as supplementary exhibition material. In several cases the Survey has been of direct assistance to various individuals in providing them with prints of ethnological photographs required for various purposes.

The photographic gifts of ethnological interest embrace:—

From F. G. Speck, Philadelphia, Pa.—

128 Montagnais films of photographs from Lake St. John, Seven islands, and Moisie, Que. Prints of these had been received in 1912 as already noted.
2 Malecite photographs.
13 Algonquin photographs from Lake Timiskaming.
68 Ojibwa photographs from Lake Timagami, Ontario.

From Peabody Museum, Harvard University, 1 Malecite photograph.

The ethnological photographs taken by members of the anthropological staff in the field, and by the Photographic Department of the Museum embrace:—

By H. I. Smith, 12 Micmac photographs from Bathurst, N.B.
By F. W. Waugh, 12 Iroquois photographs.
By J. A. Teit.—

284 Thompson River photographs.
31 Okanagan photographs.
3 Lillooet photographs.
2 Shuswap photographs.
31 Tahltan photographs.

By W. H. Mechling.—
21 Malecite photographs.
40 Micmac photographs.

By J. A. Mason, 157 Athabaskan photographs from region of Great Slave lake.

By Photographic Department.—
1 Naskapi photograph.
17 Montagnais photographs.
32 Malecite photographs.
2 Penobscot photographs.
17 Micmac photographs.
6 Huron photographs.
6 Iroquois photographs.
13 Alaskan Eskimo photographs.
1 Sioux photograph.

There have been purchased:—

From F. G. Speck, Philadelphia, Pa., 24 Montagnais photographs from Lake St. John, Quebec.

Fifty-four lantern slides made from negatives of ethnological photographs on file at the Survey have been added to the division's stock for lecture purposes. These embrace 22 Huron and 32 Iroquois slides.

Phonograph Records.—There have been purchased in the course of the year from A. B. Reagan, Nett Lake, Minn., 54 Bois Fort Ojibwa records of Midewiwin or Medicine Lodge songs.

A large number of Northern Athabaskan and other songs were obtained by J. A. Mason in the course of his field trip to the region of Great Slave lake. These, as well as a large number of Thompson River records collected for the Survey by J. A. Teit, of Spences Bridge, B.C., and a set of Nootka songs collected by E. Sapir, have not yet been received and will be reported on in the Summary Report for 1914.

Exchanges.—In exchange for 269 ethnological photographs received from the University of Pennsylvania in 1912, the Geological Survey has forwarded to the Museum of the University of Pennsylvania 200 Huron, Wyandot, and other photographs from Lorette, Que., and Wyandotte Reservation, Okla.

Twenty-eight specimens collected by Captain J. A. Bernier during the cruise of the *Arctic* in 1889 have been forwarded to the Dominion Archives, the interest in these being rather of a historical than a strictly ethnological character.

Field Work and Research.

The ethnological field research undertaken by the permanent staff included a short visit by Mr. F. W. Waugh to the Iroquois of Six Nations Reserve, Ontario, a report of which is appended, and a trip of a little over five months to the Nootka Indians of Vancouver island, undertaken by Dr. E. Sapir in continuation of work begun among these Indians in 1910. As the latter trip included two months of 1914, the report on the results of the field research is reserved for the Summary Report for 1914.

In continuation of his researches on the social organization of the Iroquois, Dr. A. A. Goldenweiser spent about two and a half months among the Iroquois of Six Nations Reserve, Ontario. The work previously begun by Mr. W. H. Mechling and Dr. Paul Radin among the Malecite and Micmac Indians of New Brunswick, and the Ojibwa of southeastern Ontario respectively, was continued during the year; Dr. Radin visited the Ojibwa of Minnesota and Wisconsin in order to gain a basis of comparison with the results that were obtained in the previous year from the Canadian Ojibwa. As a counterpart to the Athabaskan researches begun the previous year by Mr. J. A. Teit among the Tahltan Indians of British Columbia, Dr. J. A. Mason undertook a preliminary reconnaissance, during the open summer season, of some of the easterly representatives of this stock, the Chipewyan, Slavey, Yellowknife, and Dogrib, of the upper Mackenzie valley. This trip met with gratifying results, particularly in linguistic respects and in the obtaining of valuable collections of museum specimens and phonograph records. Summary reports of all these trips are appended, as well as an account of the anthropological progress made by the Canadian Arctic expedition under Mr. V. Stefansson's lead.

In the course of the year the permanent members of the staff were engaged in various lines of research work based on material collected in the field. Dr. E. Sapir made progress on the systematizing of linguistic and ethnological data collected among the Nootka and Comox in 1910. A final report, intended to embrace the Nootka mythological texts collected, was begun. Mr. C. M. Barbeau devoted special attention to the analysis of Wyandot verb forms, particularly from the point of view of comparison with corresponding forms in Mohawk and Oneida. The material on the mythology and folklore of the Hurons and Wyandots was systematized and considerable progress made on the preparation of the final report on these phases of the culture of the Wyandots.

Manuscripts Received.—A considerable number of manuscripts of ethnological interest were obtained during the year as gifts. These embrace:—

From F. G. Speck, Philadelphia, Pa.—

"The Double-Curve Motive in Northeastern Algonkian Art," manuscript of 21 pages, with numerous plates and text figures, and distribution map. (MS. No. 28.)

"The Decorative Art of the Mohegan, Scatticook, and Niantic Indians of Connecticut," manuscript of 14 pages, with plates and text figures. (MS. No. 34.)

"Family Hunting Territories and Myths of the Timiskaming Indians," manuscript of 37 pages, with map. (MS. No. 39.)

"Some Naskapi Myths from Little Whale River," manuscript of 16 pages. (MS. No. 40.)

"Penobscot Mythology," manuscript of 210 pages. (MS. No. 41.)

From Poole Field, Ross river, Y.T.—

"Information on the customs and history of the Athabascan Indians of Pelly River," manuscript of 16 pages. (MS. No. 35.)

From Neil Ferguson, Bear island.—

"Notes on Ojibwa Folklore from Bear island, Lake Timagami," manuscript of 5 pages. (MS. No. 38.)

Several papers were turned in to the division by field men not on the permanent staff. These were based on field work accomplished under the auspices of the Geological Survey. They embrace:—

By P. Radin.—

"Some Aspects of Puberty Fasting among the Ojibwa," manuscript of 7 pages. (MS. No. 46.)

"Some Myths and Tales of the Ojibwa of Southeastern Ontario," manuscript of 158 pages. (MS. No. 29.)

By W. H. Mechling.—

"Information on Malecite Games and Canoe-building," manuscript of 11 pages. (MS. No. 11.)

"Malecite Myths and Tales," manuscript of 308 pages. (MS. No. 33.)

By V. Stefansson.—

"Ethnological Report on the Eskimo of Coronation Gulf Region," manuscript of 91 pages. (MS. No. 21.)

"Distributional and Seasonal Migrations of the Copper Eskimo," and "Journey through the Territories of the Copper Eskimo, April 22, 1910—June 23, 1911," manuscript of 85 pages, with two maps. (MS. No. 24.)

"Prehistoric and Present Commerce among the Arctic Coast Eskimo," manuscript of 20 pages, with map showing trade routes. (MS. No. 25.)

"The Girl who Broke the Taboo," Eskimo text from Upper Noatak River, manuscript of 7 pages. (MS. No. 22.)

"The Blind Boy and his Grandmother," Killegaryumiut Eskimo text, manuscript of 10 pages. (MS. No. 23.)

Ethnological manuscripts purchased in the course of the year embrace:—

From E. W. Hawkes, Philadelphia, Pa.—

"The Inviting-in Feast of the Alaskan Eskimo," manuscript of 20 pages, with 4 figures and 10 plates. (MS. No. 32.)

From A. B. Reagan, Nett Lake, Minn.—

"Material on Quileute Myths, Shamanism, and Other Matters," manuscript of 25 pages, and 55 Quileute drawings of ethnological interest. (MS. No. 37.)

"Indian Myths of the Bois Fort Chippeway Indians," manuscript of 20 pages. (M.S. No. 31.)

25 Ojibwa songs, manuscript of 62 pages. (MS. No. 36.)

Papers Submitted for Publication.—In the course of the year the Division of Anthropology has submitted to the Director of the Survey nine papers dealing with various subjects of ethnological and linguistic interest. All of these, except the Alaskan Eskimo paper by E. W. Hawkes, were based entirely or primarily on field research undertaken by the Geological Survey. The papers include:—

E. Sapir.—

"Abnormal Types of Speech in Nootka."

"Noun Reduplication in Comox, a Salish Language of Vancouver Island."

C. M. Barbeau.—

"Classification of Iroquoian Radicals with Subjective Pronominal Prefixes."

F. G. Speck.—

"The Double-Curve Motive in Northeastern Algonkian Art."

P. Radin.—

"Some Myths and Tales of the Ojibwa of Southeastern Ontario."

E. W. Hawkes.—

"The Inviting-In Feast of the Alaskan Eskimo."

W. H. Mechling.—

"Malecite Myths and Tales."

V. Stefansson.—

"Prehistoric and Present Commerce among the Arctic Coast Eskimo."

P. Radin.—

"Some Aspects of Puberty Fasting among the Ojibwa."

The last two papers are intended to be published in the form of Museum Bulletins, the rest as Memoirs.

ON IROQUOIS WORK, 1913.

(*F. W. Waugh.*)

Two weeks, dating from June 24 to July 8, were spent in supplementary field-work at Grand River Reserve, Ontario. The time was spent very largely in connexion with foods and food preparation, although quite a number of items on other material culture subjects were recorded incidentally. The principal informants employed on this occasion were Peter John (Onon.) and wife (Ca.), and John Jamieson, Jr. (Ca.).

Some of the time was expended in looking up specimens, and a number of these were purchased. Specimens of some kinds, probably quite common a generation or two ago, are absolutely unobtainable at present. In a number of instances, however, old men and women, who were familiar with the articles referred to, were employed to reconstruct them. In this way some very valuable specimens were obtained.

The photographing of technological processes or working methods in various handicrafts and employments was continued and several interesting additions made to our collection in this line.

ON IROQUOIS WORK, 1913-1914.

(*A. A. Goldenweiser.*)

General Remarks.

This season's work—from July 15 to October 1, 1913—again consisted in investigations among the Canadian Iroquois, Grand River Reservation, Ontario. The task of finding an informant to take the place of the late John Gibson proved a difficult one. In fact, no one man at Grand River can compare with the late chief in thoroughness and versatility. On the other hand, several informants proved of great service, especially ex-Chief George Gibson (younger brother of John Gibson), Seneca, and Chief David Skye, Onondaga, for general ethnology; Chief Josiah Hill, Tuscarora, secretary Six Nations Council, and Chief John W. Elliott, Mohawk, for linguistics; Chief David Jamieson, Chief Jacob General, Chief Robert Davy, and Chief Joseph Henry, all Cayugas, for social and ceremonial organization of the Cayuga; and Chief John Danford, Oneida, for Oneida social organization and general ethnology.

The data on the Tuscarora have been considerably amplified. With the assistance of Mrs. Beaver, a Tuscarora woman of great age (about ninety-six), but still preserving all her faculties, a number (about fifty) of Tuscarora individual names were secured, also a list of terms of relationship, and some scanty ethnological data. The latter subsequently gained in volume and definiteness, owing to the co-operation of Chief Josiah Hill, who also furnished a Tuscarora vocabulary (about two hundred and fifty words), and, together with his wife, helped greatly in extending the list of Tuscarora individual names, which now approximates four hundred. Nevertheless the Tuscarora data must still be regarded as relatively unsatisfactory until amplified by additional information, which it seems possible to secure among the Tuscarora at Lewiston, N.Y., where conditions are more favourable for the study of the language and social system of the Tuscarora.

Considerable time was devoted to the study of relationship systems and terms. The original list in five dialects secured from John Gibson was verified and amplified with the assistance of informants belonging to the different tribes. Good progress was made in the linguistic analysis of the terms and the study of the relationship systems in their relation to the social organization of the tribes.

Work on the individual names was pushed with the utmost energy and with gratifying results. A list of about five hundred Mohawk names, and another of about four hundred Tuscarora names, were added to the sets previously secured, and nearly two-thirds of all the names are now carefully translated. In this work, Chief John W. Elliott, Mohawk, proved of great service. After some initial difficulties, he also developed into a good linguistic informant; and, with his assistance, the study of dialectic forms and conjugations in the five dialects proceeded with considerable success. A comparative vocabulary (of about three hundred words) in the five dialects (in part also Tuscarora) was secured, the informants being John W. Elliott (Mohawk), John Danford (Oneida), George Gibson (Seneca), David Jamieson (Cayuga), David Skye and John Jamieson (Onondaga). The Tuscarora equivalents were supplied by Secretary Hill.

The list of the present chiefs and their predecessors, secured from John Gibson, was carefully verified with several chiefs, and finally the entire revised list was submitted to the Council (twenty chiefs present), and was corrected and amplified in the course of lengthy discussions. Thus a number of modern "irregularities" in the election and deposition of chiefs were brought to light, which will prove of some interest.

Additional data on ceremonies and ceremonial officials were contributed by Chiefs Robert Davy and Jacob General, while Chief John Danford furnished a brief but interesting account of the custom of blood revenge in ancient conditions. The recording of songs was continued, the total number of records taken to date being about two hundred, of which some hundred and twenty refer to the Death Feast Society, and about eighty to the Onondaga Medicine Society. The record of songs belonging to these two societies may now be regarded as complete. The translation of the songs, on the other hand—a slow and laborious process—had to be deferred until the next trip.

The remaining pages of this summary statement I propose to devote to a brief discussion of three aspects of Iroquois culture, with reference to which my investigations have brought fairly conclusive results: (1) individual names; (2) the maternal family and the clan; and (3) the Iroquois totemic complex.

Individual Names.

Each clan in an Iroquois tribe has its own set of individual names. Not only are the Wolf Seneca names different from the Bear Seneca names, but they are also different from the Wolf Onondaga names, and so on. In modern conditions, when many names have been forgotten, a name belonging to another clan of the tribe, or to the homonymous clan of another tribe, will sometimes be given to a child; but such instances are rare, and invariably lead to disputes. The existence of such clan sets of individual names made it possible to furnish a fairly conclusive solution of the problem whether such clans as the Great and Little Turtle, the Great and Little Snipe, etc., had originally constituted one clan, or had been genetically distinct, and subsequently became associated through some historical accident. We find that in all such instances the two clans use one set of individual names, which fact may be regarded as sufficient evidence of the former unity of the clans. It may be of interest to note here that no direct use could be made, in this connexion, of the sets of names belonging to individuals now living, and representing the two clans in question. As no two living individuals of a clan may bear the same name, these sets would be different, whether the clans constituted sections of one clan or were distinct. Hence reliance had to be placed on the attitude taken by the Indians themselves; on the statement, namely, that one and the same set of individual names may be used by both clans. This assertion could, however, be verified by an inspection of the names used in both clans by the preceding generations; for then it appeared that some names formerly used, for example, by the Great Turtle people, now belonged to individuals of the Little Turtle clan, and vice versa.

The name is usually decided upon at birth, or even before, by the mother of the child, or its maternal grandmother, or one of those "keepers" of names (male or female) who may be found in most clans, and whose business it is to keep a mental record of the names of their clan. Now that a large number of names have been forgotten, it is to these "keepers" that the young couples turn in their search of suitable names for their babies. The "keeper" is usually ready with a name that is "free"; or, if the remembered names of the clan are actually all being used, he or she may suggest a name of another clan or even tribe. Chief John Gibson was a "keeper" for the Seneca (in this case not only for the Mud-Turtle clan, to which he belonged), and was able in 1911 to dictate to me a list of forty-two Seneca names which at the time were "free," out of a total of over three hundred Seneca names.

While the child is thus provided with a name from its birth, the public bestowing of the name occurs on two ceremonial occasions, the second day of the Green Corn Festival or the second and third days of the Midwinter Festival. The ceremony and prayer attending the bestowing of the name were recorded in Onondaga text.

Later in life an individual, man or woman, may take another name out of the same clan set. The second names are bestowed on the same ceremonial occasions. When the second name has been assumed, the childhood name becomes "free," and may be used again. The custom of taking second names seems to have been widespread in early times; but now, barring individual instances, it has fallen into disuse. It will be seen from the preceding account that no name of the clan set may at any given time be used by more than one individual.

While it is not uncommon to bestow upon the child a name previously used in the same maternal family (see section on "Maternal Family and Clan"), the genealogies do not indicate that this practice has been followed to any great extent, and the opinion of the people themselves is to the same effect. When, however, the practice is followed, the second ascending generation (that is, the generation of the child's grandparents) is often the favoured one. In other such cases a name belonging to a generation much farther removed may be suggested and bestowed, "so that a good name should not be forgotten."

The individual name is never used in either direct address or indirect reference to relatives, the relationship term doing service in all such cases. Even when addressing a non-relative, the individual name is very seldom used, the form of address consisting in a relationship term, according to the relative age of the speaker and the person addressed. Only when non-relatives are referred to in conversation is it customary to use the individual name, which even then will not be used if the context plainly indicates the person referred to. Clearly, the individual name of the Iroquois is only to a very limited extent comparable to our personal name. It must rather be conceived of as a sort of ceremonial designation, and also as a more intimate expression of one's membership in a clan than is involved in his association with the clan name.

In form the individual name usually consists of a verb with an incorporated noun, but names consisting of a noun followed by an adjective are also common. Of the content of names, the following may serve as examples: In-the-Centre-of-the-Sky, He-raises-the-Sky, Beyond-the-Sky, He-scratches-the-Sky, or Hanging-Flower, Beautiful-Flower, Beyond-the-Flowers, or He-carries-News, Glad-Tidings, He-announces-Defeat (or Victory), or He-carries-the-Voice, Mighty-Speaker, He-silences-the-Voice, or She-works-in-the-House, She-has-Carrying-Strap-on-her-Back, She-has-Two-Husbands, or The-Place-where-Two-Rivers-meet, The-Crossing-of-the-Roads, etc. Some of the names may be used by men only, others, only by women, still others, by either sex. It will be seen from the above examples that the individual names have no reference whatsoever to the clan eponym: they refer to occupations in peace and in war, to work in the house and in the field, to features of nature, to celestial bodies, and so on. Such is the content of the names, to whatever clan and tribe they may belong. Thus the frequent statements in Iroquoian literature to the effect that an individual's clan may be gathered from his or her individual name, must be regarded as incorrect if interpreted to mean that the clan sets of names have specific clan characteristics. These statements are correct only in the sense that one familiar with Iroquois names may recognize a given name as belonging to a certain clan simply on account of his knowledge of the clan sets of names. This fact may be expressed somewhat differently by saying that the individual names have become socialized in so far as they are segregated in clan sets; but the content of the names has not become socialized, it does not reflect the identity of the clan. In content the names have remained a general trait of the culture of this group of the Iroquois without undergoing any modification through their association with clans.

Among the Mohawk at Grand River the clan-set rule has broken down. I secured a list of over five hundred Mohawk names, any one of which may be used by any Mohawk (allowance, in the case of some names, being made for sex). Now, curiously enough, new names are constantly being invented among the Mohawk; while the Seneca, Onondaga, and Cayuga create practically no new names. On those rare occasions when a new name appears among these tribes, it becomes "free" to all clans after the death of the individual who received it, or may not be used again. It certainly is not included in the clan set of names. The cause of this lies in the fixity of the clan sets. Among the Mohawk, on the other hand, where the check exerted by the traditional sets has been removed, the tendency to create new names has come to life again. It seems that this degenerate condition among the Mohawk may help to solve, in part at least, the problem of the origin of Iroquois names—a subject on which no direct information can be gained from the modern Indians. For the present Mohawk situation reproduces the condition which must have prevailed in all Iroquois tribes before the formation of clan sets. In its incipient stages, the tendency to form clan sets must have consisted in the preference shown by clansmen to use names that were known to have been used in that clan before, and to avoid names that were known to have been used or to be used in another clan. Thus, in the course of time, clan sets developed which, in the case of each clan, may be characterized as a set of individual names remembered to have been used in the clan before, and for that reason used again. Now, the present condition among the Mohawk resembles the ancient condition preceding the clan sets in several respects. There were no clan sets then, nor are there any among the Mohawk; new names were being created then, and they are created now among the Mohawk; moreover, the modern Mohawk names are identical in form and character of content with the old names, from which they cannot be distinguished. Thus it may be plausibly assumed that the processes involved in the creation of names now are like the processes through which the old names came to be. To give one illustration. The name is suggested by some circumstance attending the birth of the child. A boy was born in spring, when the ice was breaking on the river. He was called Ice-floating-down-the-River. Another boy appeared to be dead when born, but revived. He was called He-comes-to-Life-again. Still another boy was born while his mother was very poor, and was called She-is-in-Want. I think we are justified in saying that whereas the names are new, the way is old; and there are other ways to which the same consideration will apply.

The Clan and the Maternal Family.

The characteristics of the Iroquois clan (cf. Summary Report for 1912) were as follows: there existed between the members of a clan a strong but not clearly definable feeling of relationship, of "brotherhood." The clans, in ancient times, were associated with localities and with long-houses, not in the sense of a clan claiming exclusive occupation of a village or a long-house—which, with a system of exogamy, would indeed have been impossible—but in the sense of a clan being regarded as pre-eminently associated, as being "in control," in a village and a long-house. A clan owned its burial-ground; it claimed a set of individual names; the members of a clan could not intermarry; the clan also had certain political functions, in so far as every chief or Lord of the League referred to a certain clan and tribe (although not every clan was represented by a chief in the League Council); the women of a clan participated in the election of a new chief and of ceremonial officials. With reference to the last two functions, however, the maternal family was the unit of greatest concern.

A maternal family embraces all the male and female descendants of a woman, the descendants of her female descendants, and so on. In ancient times the maternal families claimed various religious and ceremonial prerogatives, of which little trace remains among the Grand River Iroquois. The "Real Life" medicine of the Little-Water Medicine Company still tends to be passed on in a maternal family. The present keeper of the medicine, a woman, obtained it in an irregular way, after the death of her father; and this fact is greatly resented by many Pagan Iroquois. But the moral influence exerted by a maternal family over its members continues to be very great. The family may, in fact, be said to constitute a sort of "public opinion," towards which its members display great sensitiveness. The cause for this becomes clear when one considers that the Lords of the League and the ceremonial officials of clans are elective within the limits of maternal families. That the succession of chiefs (barring a relatively small number of irregularities) still follows the lines of maternal families, is concretely demonstrated by the record of successions for several generations. In a total of sixty-eight cases, a chief was followed by a brother in twenty-one cases, by a maternal nephew in thirty-two cases, by a grandson in five cases, by a great-grandson in three cases, and seven successions were irregular. Of the twenty-one successions by a brother, the successor was an "own" brother (younger) in eleven cases, a first-cousin (mother's sister's son) in seven cases, a third-cousin (mother's mother's sister's daughter's son) in two cases, and an "own" brother (elder) in one case. Of the thirty-two successions by a nephew, the successor was an "own" nephew in twenty-three cases, and a mother's sister's daughter's son in nine cases. Of the five successions by a grandson, the successor was a sister's daughter's son in four cases, and a mother's sister's daughter's daughter's son in one case. The three great-grandchildren who became successors to chieftanships were sister's daughter's daughter's sons. Similarly with assistant or deputy chiefs in their relation to the chiefs. In a total of forty-three cases, twenty-six deputy chiefs were brothers to their chiefs, nine were nephews, one was a grandson, one a maternal uncle, and six were irregular. Of the twenty-six deputy chiefs who were chiefs' brothers, twelve were own brothers (younger), eight were first-cousins (mother's sister's sons), four were third-cousins (mother's mother's sister's daughter's sons), one was an "own" brother (elder), and one was a seventh-cousin (mother's mother's mother's mother's sister's daughter's daughter's daughter's son). Of the nine deputy chiefs who were chief's nephews, six were his "own" nephews, and three were mother's sister's daughter's sons.[1]

The relation between the hereditary and elective elements in the succession of chiefs is illustrated by two genealogies representing partial maternal families, which will be analysed in my report on the social organization. What is true of chiefs and deputy chiefs applies also to ceremonial officials, the facts being similarly substantiated by concrete genealogical data.

Here a curious fact must be noted. The clan and the maternal family, notwithstanding the existence of separate terms for the two kinds of social units, are constantly being confounded by even the most competent informants. Several reasons may be assigned for this fact. Notwithstanding their objective and functional differences, the clan and the family are clearly based on the same principle—both social units comprise a group of people united by maternal descent. In the maternal family the relationship correlated with the descent is that of blood, and its degree is definitely known for all individuals of the family. In the clan the degree of relationship between clan mates cannot be defined; but the sense of such relationship is ever there, and, as in the family, it is associated with the maternal line. Speaking analytically, the clan is nothing but an overgrown family, embracing individuals of indefinite relationship. In recent times many clans have become depleted in numbers, owing to migrations or other causes. Thus it happens in individual instances that a clan coincides with a maternal family, in which case the two units can no longer be distinguished. The election of chiefs and ceremonial officials, moreover, while intimately associated with

[1] The preference shown, in the succession of chiefs, to brothers over first cousins, to first cousins over third cousins, and so on, incidentally indicates that these groups of individuals (brothers, first cousins, etc.), although designated by one relationship term were nevertheless distinguished not only in point of relationship involved but also in point of their social status.

the clan, is the particular function of a maternal family within the clan, thus constituting another bond between the two social bodies.

There can be no doubt, however, that the clan and the maternal family are really distinct. It has been shown that the chieftainships regularly descend in maternal families; but outside of these families there are, individual instances excepted, other families, other lines of descent, in the clans to which the chieftainships belong. If the chief's family becomes extinct, or has no males available for chieftainship, the title may be transferred, temporarily or permanently, to another family of the same clan, or even to some family of another clan. In the case of the Mohawk and Oneida, with their three clans and nine chieftainships, each clan must obviously embrace at least three families. The mechanism by which a family is perpetuated from generation to generation differs radically from that operating in the clan. The family has no outward symbol of its unity, and its continuance is due to the memory of the concrete relationships involved. The clan, on the other hand, owing mainly to the presence of a clan name, is handed down from mother to children automatically, so to say, and the clan name suffices to keep all its members identified from generation to generation. As a corollary of this difference appears the fluctuating character of the family and the permanence of the clan. Whereas the clan sustains no loss of members except through actual depletion or some artificial process, such as adoption of its members by another clan, the family of individuals whose relationship is definitely known always carries a fringe of individuals who are known to be related to the family by blood, but the precise degree of whose relationship to individuals within the family has been forgotten. And beyond these there are still other individuals who, in an objective test, would prove to be related to the family by blood, but the fact itself of whose relationship is no longer recognized. Thus the family constantly tends to break up, some lines of descent multiplying, others becoming extinct, and so on.

In view of the importance of the subject, the attempt may not be amiss to demonstrate numerically that the Iroquois clans, say, of the seventeenth century, could not have been identical with maternal families. To secure a maternal family of individuals all living, the calculation must be based on not more than five generations. The average number of children of a woman may be taken as six—three boys and three girls. If, then, every woman in the direct line of descent for five generations has six children, the total number of individuals in the maternal family will be:—

$$\begin{array}{r} 1 \\ 6 \\ 18 \\ 54 \\ 162 \\ \hline 241 \end{array}$$

This figure, however, represents the highest possible number with the above birth-rate, and is entirely too large; for some women will die in infancy, others will not marry, etc. Some men will also die. The more probable figures will fall between 100 and 150. Now, the approximate number of individuals in the five Iroquois tribes in the seventeenth century may be taken as 15,000 (which is a low estimate), and the number of clans as forty (which is high), giving, on the average, 375 individuals for each clan. Thus a clan at that time must have embraced from 250 to 500 individuals. Each clan then, must have consisted of from two to five families.

The Totemic Complex.

Let us recall that wherever there is a totemic complex we find a group differentiated into definite social units, clans, within the limits of which are socialized certain "totemic" features. The specific content of these features differs from clan to clan, but the form they assume is identical for all the clans. In old and new literature on the Iroquois they are always represented as a totemic people, in fact, as a typically totemic people. But we may well ask the question: what are the traits of Iroquois culture which would justify the designation of these people as totemic?

As stated before, the Iroquois tribes are differentiated into clans with animal and bird names. These names are not commonly used in daily intercourse, their place being taken by descriptive terms referring to some trait or habit of the eponymous animal or bird. Thus the people of the Bear clan are known as Those-of-Dark-Complexion, the Snipe clan people are Those-of-the-Pure-Sand, the Deer people, Those-of-the-Small-Hoofs, etc. At the present time the clans are exogamous, and have been so for considerably over one hundred years. It must be noted, however, that satisfactory evidence can be adduced to establish the phratry as the former exogamous unit. The motivation of clan exogamy among the Iroquois is non-totemic. Clan-mates shrink from intermarrying, not because they are Wolves or related to the Wolf, but because they are "brothers" and "sisters." The horror of incest does not enter into Iroquois exogamy. Transgressors of the exogamous rule are open to ridicule, and the belief is entertained that intermarriages of clan-mates will lead to physical and mental deterioration of the stock. There is no taboo on the clan animal, the idea of such a taboo itself appearing ridiculous to the Iroquois. They do not regard themselves as descended from the eponymous animals or birds, nor can trace be found of any other beliefs in physical or spiritual relationship of clan-mates with these creatures. There are no clan-origin legends apart from the Deganawida myth, which may be characterized as emphatically non-totemic, being in fact, a distinctly human epic. We have seen before that the content of the individual names segregated into clan sets has no relation whatsoever to the clan eponym. It may be assumed of sufficient evidence that a carving of the clan animal or bird used to be placed over the doors of the long-houses in which the clan predominated. On the other hand, no indications are available to the effect that the right to carve a clan animal, or to utilize such a carving, was restricted to the clan-mates. One Indian (on the whole, the least reliable of my informants) furnished some data on old hunting-customs, which, although exceedingly suggestive, must be discounted by the character of the informant. He stated that the Bear clan was believed to have particular luck in hunting bear, the Deer clan in hunting deer, and so on. When the Bear people wanted to hunt deer, they would visit the Deer people, then, at a night meeting, tobacco would be burned, and the deer (animals) were asked in a prayer (short text recorded) to be good to the Deer people, and to permit themselves to be killed. One Deer man would join the hunting-party, and he was entitled to a share in the kill. As stated before, these data must be accepted with a grain of salt, although they are evidently founded on a basis of fact.

Now that the Iroquois data bearing on our problem have been briefly reviewed, two questions present themselves. One is partly terminological. Are we justified in designating a tribe as "totemic" merely because it comprises exogamous clans with animal or bird names? The other question is more fundamental. Does the social system of the Iroquois constitute a totemic complex?

To deal with the terminological question first. Animal and bird names given to individuals, societies, social groups, objects, are so common a feature in primitive society, that one may not, without special reasons, ascribe the presence of animal and bird clan names to some "special relation" between the clan-mates and their eponym. In other words, these names may be given or assumed, just as nicknames, local names, honorific names, are given or assumed, and no special significance need be ascribed to them. Similarly, the exogamy of these clans may not have any more to do, either historically or psychologically, with either the names or the eponymous species themselves, than it has with the local names or nicknames of the Haida or Crow clans. In the absence of any special processes, it would not seem justifiable to apply a separate term, the term "totemic," to exogamous clans of animal names, while refusing this appellation to exogamous clans with nicknames, or local names, or names derived from a human ancestor. On the other hand, the animal name may involve a psychological association with the animal in the minds of the givers or the receivers of the name, or of both. The exogamy of the clan may also, from its very inception, be traceable to this association with the animal, either directly or through the medium of the clan name. Here a "special" process could be discerned, and the term "totemic" would be in place as indicating an incipient totemic complex. But this "totemic" source of the name and of the exogamy may become obliterated. It would then be often impossible to decide whether the "totemic" association had taken place or not. In view of the plausibility of the origin of animal names without any special association with the animal, and of the origin of exogamy in animal-named clans[1] without involving any relation either to the animal or the animal name, it seems, on the whole, advisable not to apply the term "totemic" to tribes which, without exhibiting any active totemic processes, comprise exogamous clans with animal, bird (or plant) names, unless it can be shown that in their origin these traits involved an association with the animal. In cases of this latter type, which at best represent but a very small number of instances, one might justifiably use the term "totemic" in view of the origin of the traits, or—with equal justice—abstain from using the term, in view of the actual absence of any totemic processes.

To turn to the more fundamental question. Does the social system of the Iroquois constitute a totemic complex? To this question a negative answer must be given. The processes of specific socialization of "totemic" traits within the limits of social units (clans)—processes characteristic of totemic complexes—are not observable among these Iroquois tribes; nor have they, in the light of the evidence, ever occurred in the past. Even if the data on the carving of clan animals and on hunting-customs are admitted as relevant, the most that can be said is that incipient totemic associations have here and there made their appearance among the Iroquois; without, however, ever assuming a central position, without forming a nucleus around which further totemic processes would cluster, or otherwise constituting an important factor in the social system of the Iroquois.

[1] The chronological order of development of the two traits could be reversed without changing the argument.

ON MALECITE AND MICMAC WORK, 1913.

(W. H. Mechling.)

During the months of August and September, I continued my researches among the Malecite and Micmac Indians of New Brunswick. After leaving Ottawa I went to the Malecite village of St. Mary, across the St. John river from Fredericton. I secured the services of James Paul, who had been my informant on my former trips. I devoted my whole time to the study of ethnology, investigating those points on which I had failed to obtain data on my previous trips, in order to obtain as complete a picture of the life of the tribe as possible at this late date. However, the greatest emphasis was placed on hunting, fishing, and trapping. Several specimens were secured for the museum.

After leaving St. Mary, I proceeded to Burnt Church, a Micmac village on the Miramichi bay. There I remained during the rest of the trip. The work done was chiefly linguistic. Barney Somerville was employed as interpreter and a series of myths was collected from Ex-Chief Peter Joe, sen., as well as a few myths from other individuals. Grammatical notes to the texts were also obtained.

Data were also secured on the ethnology, particularly on the material culture, which proved to be strikingly similar to that of the Malecites. Several specimens were secured for the museum.

The collections in the Victoria Memorial Museum, in the Peabody Museum, and the Museum of the University of Pennsylvania were also studied in order to obtain such data on the material culture as could not be obtained in the field.

ON OJIBWA WORK, 1913.

(*P. Radin.*)

I proceeded to the Ojibwa living near La Pointe and Odanah, Wis., and stayed there for three weeks. Excursions were also made during this time to the Bois Fort and Flambeau reserves in Minnesota and Wisconsin respectively. After leaving Ashland, Wis., only one other reserve was visited, that of Red Lake in Minnesota.

The results of the field-work can be epitomized briefly:—

Habitat.—The Ojibwa of Wisconsin and Minnesota probably represent two separate invasions. Those Ojibwa who entered Wisconsin did so either by way of Mackinaw or by the more circuitous route of the entire peninsula of Michigan. The Minnesota Ojibwa probably entered in two ways, either by way of Mackinaw and the northern shore of Lake Superior or by way of the Rainy River region.

Language.—The language differs from that spoken in southeastern Ontario in few details. Initial vowels never disappear. The slurring of vowels so common in Sarnia is very rare, and as a consequence many of the secondary consonantal clusters found at Sarnia are not met with here.

Mythology.—Very little mythology was collected owing to the large number of collections in existence, most of which, however, are in manuscript.

Religion.—There seems to be no difference in religious beliefs between this and the Ontario division of the tribe, except, of course, the beliefs and their systematic presentation connected with the midéwiwin. This matter was, however, not touched upon this year.

Social Organization.—No new details were added to the information obtained last year. A few clan names were added and about one hundred personal names obtained. No clan origin myths were obtained, and it seems doubtful if they really exist.

ON WORK AMONG NORTHERN ATHABASKAN TRIBES, 1913.

(J. A. Mason.)

My researches during the past summer among the Athabaskan peoples of the Great Slave Lake region were largely in the nature of a reconnaissance. Few, if any, ethnologists had ever investigated north of Lake Athabaska, and it was with an eye to finding problems rather than to settling them that I went thither.

Leaving Athabaska Landing May 26, I reached Fort Resolution, on Great Slave lake, July 1. Although a very slow trip, few opportunities for anthropological investigation presented themselves en route. At Fort Resolution I remained until July 22, working with members of several Athabaskan tribes, until work began to drag, due to the departure of informants. Consequently I proceeded by sail-boat to Fort Rae, on the northern arm of Great Slave lake, remaining there from July 28 until September 7. At Fort Rae I found conditions for ethnological research better than at Fort Resolution, though I was everywhere handicapped by a scarcity of good interpreters and willing informants. Here my investigations were concerned exclusively with members of the Dogrib and Slavey tribes. The return trip by canoe required from September 7 to October 23, when the railway was reached at Athabaska Landing.

Four distinct Athabaskan tribes are met in the region traversed. The Chipewyans and Caribou-eaters occupy the country from Fort McMurray, on the Athabaska, to Fort Resolution on Great Slave lake, and eastward to Hudson bay. The Yellowknives are found at the eastern end of Great Slave lake and the barren-grounds adjacent, but they come periodically to Fort Resolution to trade. The Dogribs occupy the great territory north of Great Slave lake to Great Bear lake and to the edge of the barren-grounds. The Slaveys are found from Hay river at the western end of Great Slave lake throughout the entire valley of the Mackenzie river to Fort Norman at the mouth of Great Bear river.

Although including such an immense stretch of territory, the population is incredibly small. The posts are small and far apart, yet it is rarely that natives are encountered en route between posts. Even at the forts the natives are few. At each post are found some "fort" Indians, who have adopted a semi-sedentary life and live principally on fish, supplemented by game secured on short hunts. The greater part of the population, however, still lead a nomadic life in the "bush" and on the edge of the barren-grounds, subsisting almost entirely on caribou and moose. This is particularly true of the Dogribs. They generally travel in bands of several families, and the camp is moved frequently.

The greater part of my time was spent in linguistic work on the four mentioned languages. These are found to be very closely related and are said to be mutually intelligible on short acquaintance. Most of the differences between them may be explained by the workings of a few rules of phonetic change. The majority of the verbal and noun stems and grammatical elements are identical in all of the languages.

The Chipewyan language is well known through the existence of several grammars. Texts in Chipewyan were taken at Fts. McMurray, Smith, and Resolution. No obvious differences are noticed in the language as spoken at these places. Phonetically, Chipeywan is characterized by dental spirants θ, δ, and $\theta!$, and by the tolerance of consonantal combinations and certain consonantal endings, such as θ, δ, l, t, s, c. It is claimed that Yellowknife was formerly a language much different from Chipewyan, but to-day the difference is only dialectic. Texts were taken in Yellowknife at Fort Resolution, but no difference from Chipewyan is obvious. The Yellowknives, in fact, seem to be losing their tribal identity and becoming amalgamated with the Chipewyans.

Slavey and Dogrib are closely related lexically, forming a sub-group as opposed to Chipewyan and probably Yellowknife. Phonetically they are alike in not permitting consonantal combinations, nor may any consonant except the glottal stop or aspiration stand final in a word. The two languages differ, however, in that Slavey retains the dental spirants of Chipewyan while Dogrib replaces them by labials and labialized palatals. Texts in Slavey and Dogrib were taken from several different informants both at Fort Resolution and Fort Rae. They form the larger body of the material secured. The morphological differences between the four languages are probably very slight.

The social and religious life seem to be quite as bare as heretofore supposed. No evidences appear of any ceremonies or ritualism, totemism, clan organization, civil organization of any kind, theology, or even demonology. The social organization appears to be very weak with little or no recognized authority.

The religious concepts may be summed up in the one word "medicine," which may be interpreted as "supernatural power." Every individual has "medicine," more or less powerful. This "medicine" seems to be generally in the nature of an animal spirit helper, protector, and guardian, but sometimes is a disembodied spirit. With the help of his "medicine," one can command the aid of natural phenomena, such as the wind and the water, cause and cure sickness, prophesy, and perform magical deeds. Before the introduction of Christian ideas, there appear to have been no concepts of theology, and possibly no demonology. To sum up in a single phrase, the impression received is that the culture of these peoples is on a strictly individual basis.

One hundred and thirty-three specimens were secured for the museum, many of them duplicates. These represent the Slavey, Dogrib, Chipewyan, and Yellowknife tribes in respective order of quantitative representation in the collection. Articles of present-day wear, such as moccasins and gloves, articles of household and other use, as birch-bark boxes, canoes and paddles, drums, baskets, bags, awls, knives, bows and arrows, snowshoes, etc., were secured. Models of objects no longer in use were obtained whenever possible.

Not the least important of the tangible results secured was a collection of phonograph records. Fifty-seven records were made, comprising about one hundred and fifty different airs. Most of these are without words. The borrowing of songs in this region seems to be very extensive, as the Cree, Chipewyan, Yellowknife, Beaver, Slavey, Trout Lake, Sikani, Dogrib, Loucheux, and Eskimo types of song are represented in the collection, though obtained from relatively few informants. Dance songs, gambling songs, medicine and prophet songs, love songs, boat songs, battle songs, mourning songs, and myth songs are included.

A considerable number of photographs were taken and much miscellaneous information secured.

ANTHROPOLOGY IN THE CANADIAN ARCTIC EXPEDITION.

(E. Sapir.)

The Canadian Arctic expedition, which has been put under the head of Mr. V. Stefansson, is described elsewhere in the general Summary Report for 1913 of the Geological Survey of Canada. Here it will suffice to state that the scientific staff of the expedition includes two anthropologists, Mr. D. Jenness, of Wellington, New Zealand, who has had considerable anthropological experience in Papua under the auspices of Exeter College, Oxford, Eng., and M. Henri Beuchat, of Paris, well known for his researches on various phases of American ethnology, archæology, and linguistics. Mr. Jenness and M. Beuchat are to undertake between them the thorough scientific study of the Eskimo of Victorialand and the mainland opposite. The study of the language, religion, social organization, and other phases of the non-material life of the natives is to be the special task of M. Beuchat, while Mr. Jenness is to devote particular attention to physical anthropology and technology.

No full reports of progress have as yet been received from either Mr. Jenness or M. Beuchat. Since leaving Port Clarence, Alaska, M. Beuchat has addressed a communication to the Division from on board the *Karluk* near Point Barrow, dated August 3, 1913. Among other things he states, "Jenness and I have made excavations in an ancient cemetery near Teller's Reindeer Mission (not far from Port Clarence), and have found there about ten skulls, two skeletons all but complete, and a certain number of scattered bones. We are sending this to the Division from Point Barrow, along with 200 ethnographic objects bought by Mr. Stefansson at Vigeray, an Eskimo camp at Point Hope."

Letters have also been received from Mr. Jenness. The first of these since leaving Port Clarence is from Cape Smythe, Alaska, near Point Barrow, and is dated August 6, 1913. In this he speaks of the archæological digging referred to by M. Beuchat, as follows: "We remained at Port Clarence a week, waiting for Mr. Stefansson to join us. During the last two days we found an old burial ground, which from the rotten condition of the timber must date from something like half a century back. Clearing away the timber and turf we recovered several skulls and portions of the skeletons, but very little in the way of objects buried with them; probably the graves had been rifled already. We tried to keep separate the contents of each grave, but were only partly successful."

A letter received from Mr. Jenness from Cape Smythe, Alaska, dated October 26, 1913, speaks of the unfortunate fatality by which Mr. Stefansson, Mr. Jenness, and two others of the staff became disconnected with the rest of the party on the*Karluk*. The following is quoted from this letter: "The *Karluk* passed here about August 5 on her way eastward, but was jammed in the ice about ten miles northeast of Flaxman island. For a month she drifted westward until she was in longitude 149° 45′ or thereabouts. Once when not far from Flaxman island, Mr. Stefansson sent Beuchat and myself away on an attempt to reach the shore and travel to Herschel island, but the ice was too rotten to bear the weight of the sleds and 2 miles from the ship we had to turn back. About September 12 she reached the above longitude and there remained for a week without any change in her position. The ice which carried her had grounded in ten fathoms of water. Gradually every lead closed over and it seemed that we were destined to remain there for the winter. On September 20, Mr. Stefansson, McConnell, Wilkins, myself, and two Eskimo, with two sleds and small tents left the ship for a week's caribou hunting on the mainland, to obtain fresh meat for the *Karluk.* The first night we slept on the ice, the second on a low sandy islet, the westernmost of the Jones or Thetis group. The third day we tried to cross to the mainland, but the ice was too thin, so we had to camp on another island. A strong east wind which arose that night opened up the ice and kept us imprisoned on the island for a week. In the meantime the *Karluk* either steamed away in some lead which opened up, or was carried away by the ice; in either case she disappeared. September 28 we were able to cross to the mainland, and spent the next three days in a vain search for caribou. Our provisions were running low, despite the fact that we had shot a large seal on the island, so we had to move either east or west. We came eastward and reached Cape Smythe October 12, where we have remained as Mr. Brower's guests ever since.

"We came away very ill-provided for a long sled trip, and of course without winter clothing of any kind. However, we have been outfitting here. The *Alaska* and *Mary Sachs* got as far as Collinson point, we learned here, and it was proposed to draw them up for the winter. We leave to join them, Wilkins, myself, and two Eskimo, to-morrow. Mr. Stefansson and McConnell come later; we wait for them at Cape Halkett. With them a half-caste boy from here, Alfred Hobson, is coming, and he and I are to spend the winter with the Eskimo at Cape Halkett, while the others go on to join the *Alaska.* The boy is about fifteen and speaks both Eskimo and English, so he is to be my interpreter, but spend most of his time fox-trapping.

"There are left on the *Karluk,* Malloch, Mamen, Mackay, Murray, McKinlay, and Beuchat. All were well. Beuchat was working at Eskimo grammar with the aid of Petitot's and Thalbitzer's works. He had also compiled a short vocabulary from the Eskimo on board. The *Karluk* tied up to a cake of ice one day off Cross island and we went ashore. In some Eskimo ruins there we found one or two interesting articles which we took on board. Beuchat has a brief report written out. I myself have collected a number of cat-cradle figures, and am working at the language, besides making notes of everything of interest.

"The skulls, etc., which were sent from Point Barrow through Mr. Brower were placed on the schooner *Transit,* which was driven ashore 5 miles south of here. Mr. Brower recovered the cases and they will be sent down next summer."

The last heard from Mr. Jenness was from Cape Halkett, in northern Alaska, under date of December 2, 1913. He writes in part: "I am living with two Eskimo families here about 80 miles east of Point Barrow. When I wrote last I was on the point of leaving with the cinematographer, Wilkins, for a small fishing lake, four hours' journey from here. It was October 27 when we left Barrow, and we did not reach the lake until November 8, being caught in a blizzard in the middle of Smith bay, and, after one night in a tent on the ice, being compelled to shelter in an Eskimo house for three days. Mr. Stefansson had told us that he would leave very soon after us and probably reach the lake about November 7. Two Eskimo families were living at the lake when we arrived, but one left the following morning, and the other a few days later. We waited at the lake until November 21, when Mr. Stefansson arrived just before midnight with McConnell and Alfred Hobson, the half-caste boy of fifteen from Point Barrow, whom we had engaged as my interpreter. Mr. Stefansson, with McConnell, Wilkins, and two Eskimo, left this place on November 24 to go east to the *Alaska* and *Mary Sachs.* Since then I have heard nothing, for there are no Eskimo along their route—at least not until they reach Flaxman island.

"The two families with whom I am staying are inland Eskimo from the Colville River region, and have come less into contact with the whites than most of the Eskimo here. One of them, Aluk, was reputed to be well acquainted with the old songs and traditions, but is said likewise to be unwilling to talk about them. He is certainly an expert at cats'-cradles and has already taught me a number, with three or four songs that accompany them.

"Our home is a one-roomed house made of driftwood, about 12 feet by 15 feet, with a slightly gabled roof and a passage of snow blocks laid over a frame-work of sticks. There are two Eskimo with their wives and five children, besides Asecaq, A. Hobson, and myself. In consequence there is not much spare room. They are very kind to me and I am feeling very comfortable. Mr. Stefansson left me a sled and six dogs, and some three hundred pounds of food. Most of this is cached at a place a day's journey away, where our nearest neighbours live, and a stranded whale will furnish dog-meat. A sled is to come from the *Alaska* and bring me a further supply of food and some other things as soon as possible. I expect it some time in January. If all goes well I shall stay among the Eskimo until June or the early part of July, and then join the ships in time to go eastward to Coronation gulf.

"While writing this, it has been arranged that we go to-morrow to bring in my stores with some belongings to my hosts. The place is about 20 miles away and it is said that a woman living there is to go to Point Barrow at Christmas. I am taking this letter to send by her......

"Nothing has been heard of the *Karluk* as yet."

PART II.

ARCHÆOLOGY.

(Harlan I. Smith.)

The archæological work of the Geological Survey during 1913 was carried on in continuation of the general plans outlined at the beginning of archæological work by the division.

Exhibits.—Eight of the new permanent cases in the Museum of the Geological Survey in the Victoria Memorial Museum building, have been assigned for the archæological exhibit. These cases, which are unsurpassed in quality at present in any museum, afford about 25 square feet of exhibition space each, and exhibits have been installed in them. The tentative archæological exhibits, made up of representative selections from our entire national collection, have been increased and improved, as a result of the field work and accessions of the year. They completely fill the new cases and a number of temporary cases. One series has been started to show the types of archæological objects found throughout Canada. The other series contains similar specimens, but is arranged to show the different types of culture or handiwork of the different parts of Canada. The exhibition from the southern coast of British Columbia is good and fairly representative; that from the northern coast of the same area consists of most of our collection from that region, and is less representative. The interior of British Columbia is well represented from our fairly large collection and a handbook of the archæology of the region, interpreting the scientific publications on the subject and illustrating about half of the specimens exhibited, for the use of visitors in connexion with this exhibit, is now in press. The space assigned for the material from the Great Plains is filled with specimens from that region, but the collection must be increased before a satisfactorily representative exhibit may be made. The exhibit from Ontario is large, and that resulting from our exploration at the Roebuck site is representative. Most of the material from Quebec is exhibited, but a larger collection must be made before a representative series can be selected. The exhibit from the Arctic is composed almost entirely of material received this year from the Stefansson Expedition of 1908-12. The exhibition from the Maritime Provinces has been enlarged as a result of the intensive work and reconnaissance carried on in that region during this season, and is in one of the temporary cases. The collections from the Plains, the Arctic, and the Maritime Provinces, will probably be greatly improved as a result of exploration. Satisfactory material from Quebec may be more difficult to obtain until the field is better known.

A special and timely exhibit of the results of intensive exploration at the Roebuck site, Ontario, was prepared for the visit of the Geological Congress to Ottawa, and has since been transferred to the permanent cases. A similar exhibit was made from the results of intensive exploration in a shell-heap at Mahone bay, Nova Scotia, which was carried on this year. This has been installed in one of the temporary cases. A number of labels have been typewritten, and a few have been printed by Mr. Wintemberg.

Our stock of lantern slides has been increased by the addition of slides showing the methods and results of exploration in the village site at Roebuck, Ont., and in the shell-heap at Mahone bay, Nova Scotia. Slides of all the specimens illustrated in the handbook, The Archæological Collection from the Southern Interior of British

Columbia, have also been prepared. At this rate, in a few years we shall have a series of lantern slides showing the character of the archæological types, and of the handiwork of each archæological culture area in the Dominion. Lectures on the archæology of Canada, illustrated with lantern views, have beeen given at Halifax and Ottawa.

Research.

Research work has been carried steadily forward. Additions have been made to the card cataloguc of the literature of Canadian Archæology, and to the files, which now fill two large drawers. One file is arranged by provinces and counties; the other contains the same information arranged by subject matter. Mr. Wintemberg made drawings for these files of the more important archæological specimens in the Provincial Museum and Dalhousie University, Halifax, and Mr. Smith made photographs of the important specimens from New Brunswick, in the Museum of the Natural History Society of New Brunswick at St. John. This collection is probably the largest in existence from New Brunswick. Some single files now contain nearly enough material for a monograph. The cataloguing of specimens has gone forward and it will take some time before the cataloguing of the immeuse collection from the Roebuck site, Ontario, and of the collections from the field-work carried on in Manitoba and the Maritime Provinces during this season can be completed. All the material has been unpacked; nearly all of it has been cleaned and repaired. Some time was given to the study of the human remains from the Roebuck site, Ontario. The monograph on the site has been nearly completed by Mr. W. J. Wintemberg, and one reconstructing the material culture has been begun by Mr. Smith. Mr. Wintemberg's paper on the archæology of Blandford township, Ontario, has been published as article 17, in Bulletin No. 1 of the Victoria Memorial Museum. Mr. W. B. Waterbury of St. Thomas has volunteered to provide us with information about the archæology of Elgin county, Ontario. Mr. George E. Laidlaw supplied us with a bibliography of the archæology of Victoria county, Ontario.

Field Work.

Early in the season Mr. Smith inspected and reported on earthworks in the vicinity of St. Thomas, Ont., at the request of the Commissioner of Dominion Parks.

In July, he carried on an archæological reconnaissance in New Brunswick and Nova Scotia, visiting every museum in the Maritime Provinces in search of archæological information, and inspecting the work of the field party then in New Brunswick. In August, he examined the museum in Winnipeg for archæological specimens, inspected the field work in and about the mounds of southwestern Manitoba, examined the museum at Calgary for archæological evidence, and made a reconnaissance in the vicinity of Banff, Alberta. Near Banff a survey was made of a series of semi-subterranean house ruins, which so far as is known at present, mark the general eastern limit of this style of house. These suggest that the Interior Salish may have ranged as far eastward as Banff, Alta. Following this, he made a reconnaissance of the more northerly portion of the Rocky Mountain region through Yellow Head pass to Fort George. This was done to extend eastward and northward his former archæological explorations in British Columbia. The region, especially in the vicinity of Banff, Edmonton, and Jasper to Fort George, is apparently one where it will be difficult to find rich archæological sites. The material culture from Lac La Hache southward to Ashcroft is apparently similar to that of the Kamloops-Lytton region.

Mr. W. J. Wintemberg spent July and August in a reconnaissance in New Brunswick, Nova Scotia, and Prince Edward Island, especially along the Gulf of St. Lawrence, from Bathurst, N.B., to Merigomish, N.S. Shell-heaps, the remains of ancient villages, are less numerous and of smaller extent in this region than on the coast of British Columbia. Larger shell-heaps are found near St. Andrews, N.B. In September he carried on an intensive exploration of a shell-heap at Mahone bay, Nova Scotia. The material found in this shell-heap was of a crude character. Later he made studies and illustrations of specimens in the museums at Halifax and St. John.

The field work in the Maritime Provinces and the gifts obtained there, added to the previous small and very incomplete collections, give us a fairly complete type collection from that region. The intensive work provided material for a short monograph by Mr. W. J. Wintemberg, and yielded enough specimens for a small exhibit, as well as surplus material which may be sent to other museums. Although the material results of work on this coast will probably never be as large or as striking as those from southern Ontario, Manitoba, and British Columbia, yet there are evidently several important scientific problems to be solved only by exploration around the Gulf of St. Lawrence. The vicinity of Merigomish is apparently one of the strategic points.

Mr. W. B. Nickerson spent about two months in intensive exploration of mounds and other archæological remains in the vicinity of Sourisford, southwestern Manitoba. The few specimens received from the Great Plains practically double our collection from that region. The information consists of a large amount of detail. Such results may not be uncommon in return for small appropriations. The region is probably one in which digging may be done for a long time without finding much, until a rich deposit is struck, not one in which small results will be obtained continuously. In other words, it is probably a region where extremes of success will be met.

A report was made to the Commissioner of Dominion Parks on the desirability of establishing a park for the preservation of an earthwork near St. Thomas, Ont., which, so far as is at present known, is the most perfect earthwork remaining in Canada, east of the Rocky mountains. Remains of ancient semi-subterranean house sites near the town of Banff, Alberta, in the Rocky Mountains Park, came to the attention of the subdivision through Mr. D. B. Dowling of the Survey. The Parks Branch of the Dominion Government was notified and immediately issued orders for the preservation of these sites, so that they have been labelled, and signs have been put up giving warning of the penalty to which anyone injuring them is liable. These are perhaps the first archæological remains to be protected in a Dominion Park. These two incidents establish the beginning of co-operation with the Parks Branch, similar to that which the Division is endeavouring to establish with all of the Government Branches, having facilities for archæological work. The Royal Northwest Mounted Police continued to co-operate, and sent in one accession.

Additions to the Archæological Collections During 1913.

Collected in Course of Regular Field Work.

The chief additions to the archæological collections are as follows:—

Stefansson, V.—Specimens from Eskimo sites at Point Barrow, Birnirk, Point Hope, Isatook, Cape Smythe, and Franklin bay. Accession 71.

Wintemberg, W. J.—Five boxes from intensive exploration of a shell heap on Mahone bay, N.S. Accession 88.

Nickerson, W. B.—Five boxes from intensive exploration in the Souris valley, Manitoba. Accession 98.

Minor additions from expeditions are as follows:—

Smith, H. I.—A small collection from near the Southwold earthwork, and from within the earthwork on lot 2, range I, west of Mill road, both in Southwold township, Elgin county, Ontario. Accession 72.

Wintemberg, W. J.—Box of specimens from Dalhousie, New Brunswick. Accession 76.

Wintemberg, W. J., and Smith, Harlan I.—Material from a small workshop and vicinity at west side of Bathurst harbour, New Brunswick. Accession 77.

Wintemberg, W. J.—Specimens from New Brunswick, Nova Scotia, and Prince Edward Island. Accessions 83, 84, 85, 86, and 87.

Wintemberg, W. J., and Smith, Harlan I.—Specimens from shell heap on Mahone bay, Nova Scotia. Accessions 81 and 88.

Smith, Harlan I.—Specimens from workshop on Lake Minnewanka, Alberta, and interior of British Columbia. Accession 91, 92, and 93.

Collected by Officers of the Geological Survey.

Other accessions received in 1913 include those sent in by officers of the ethnological subdivision and other divisions of the Geological Survey as follows:—

Speck, Frank G.—Four gouges and other objects made of stone from near Oldtown, Maine. Accession 68.

Teit, James A.—Collection from Lower Thompson valley, British Columbia. Accession 73.

—————— Fragment of stone object, from Bellakula, British Columbia. Accession 80.

Freeland, E. E.—Chipped point from British Columbia. Accession 90.

Johnston, R. A. A.—Large cylindrical stone from Skeena river, British Columbia, gift of F. Nevins through Collingwood Schreiber. Accession 95.

Faribault, E. R.—Chipped point, from Bachman beach, Nova Scotia. Accession 99.

Presented.

Nickerson, W. B.—Eleven stone mauls, two grooved stone axes, one hammer-stone and two pieces of a stone hand-mill, found by David Elliott at Sourisford, Man., and presented by him through W. B. Nickerson on Survey Expedition. Accession 67.

Laidlaw, George E.—Right to copy ten maps of sites in Victoria and Ontario counties, Ontario. Accession 69. Two boxes of specimens from Victoria county, Ontario. Accession 70.

Spec, Frank G.—A fragment of quartzite from Maniwaki, Que. Accession 74. Two stone hammers, a club head and three chipped points from North Timiskaming. Accessions 75 and 79.

Sutherland, George D.—Gouge made of stone from vicinity of Bathurst, N.B. Accession 78.

Boa, Matthew.—Chipped point of chalcedony from Rapid City, Man. Accession 82.

Ross, Alexander.—Adze made of stone and a chipped blade made of quartz, from Nova Scotia. Accession 83.

Mackenzie, Findlay.—Celt made of stone from Nova Scotia.

Mackenzie, Wm.—Chipped point, from Nova Scotia.

Robinson, M. M.—Celt made of stone and a point chipped from stone, from New Brunswick.

Ried, Alexander.—Celt made of stone and point chipped from stone, from Nova Scotia. Accession 84.

Smith, Charles.—Two celts from Nova Scotia. Accession 85.

Millar, Peter.—Harpoon of bone and potsherd. Accession 85.

McGregor, George.—Chipped point. Accession 85.

McDonald, Donald.—Celt of stone, chipped point and point of bone. Accession 85.

Manderson, Edward.—Celt made of stone from Prince Edward Island. Accession 86.

Nelson, Samuel.—Two stone celts from Prince Edward Island. Accession 87.

McMillan, John.—Stone celt from Prince Edward Island. Accession 87.

McAllan, Wm. J.—Celt and five chipped points. Accession 94.

Woodcock, Thomas.—Stone hammers from North Antler valley, Manitoba. Accession 98.

Woodcock, William H.—Stone hammer from Souris valley, Manitoba. Accession 98.

Thompson, A.D.—Stone hammer from Manitoba. Accession 98.

ON ARCHÆOLOGICAL WORK ON THE ATLANTIC COAST, 1913.

(*W. J. Wintemberg.*)

Commencing July 2, 1913, I made a reconnaissance of the north coast of New Brunswick, beginning at Campbellton and visiting Dalhousie, Bathurst, Chatham, Loggieville, Burnt Church, Rexton, Richibucto, Buctouche, and Shediac. Information regarding finds and the location of sites was obtained at all these places. Small shell-heaps were found near Dalhousie and on Shediac island. Archæological specimens were secured by collecting and by gift. At Bathurst Mr. Harlan I. Smith and I found several small workshops, where quartzite pebbles had been chipped, and collected a number of specimens. A point for an arrow chipped from quartz was found near Buctouche.

Continuing along the north coast of Nova Scotia, I visited Pugwash, Tatamagouche, Pictou, and Merigomish. Nothing was found at Pugwash. At Tatamagouche a few specimens were secured by gift, and information was obtained about other finds and the location of sites in the vicinity. The country around Pictou and Merigomish was explored, because here the late Rev. George Patterson had found the bulk of the interesting material in his collection, now in Dalhousie University, Halifax. Some of these objects are very much like those in use among the Eskimo. Three shell-heaps were found near Pictou; one being on the south shore of Caribou island, and the others on and near Black point, near Little Harbour. There are six shell-heaps in the vicinity of Merigomish; one being on the mainland, one on Finlayson island, one on Big island, and three on Point Betty island. Some specimens were found, and others were presented by their finders.

On Prince Edward Island, I visited North Rustico and vicinity on the north shore, Brackley beach and Covehead on the same shore but farther east, the country in the vicinity of Georgetown and Lower Montague, on the southeast coast, the vicinity of Summerside on the southwest shore, and the Malpeque region on the north shore, but west of North Rustico. Information regarding finds was obtained at all the places on Prince Edward Island, and I found a number of adzes, celts, an unfinished stone pipe, and other specimens; others were presented. Shell-heaps on Robinson island, Newson point, Oyster Bed bridge, and McMillan point, were examined. All these are within 1 to 15 miles of North Rustico. Indian island and the shore east and west of Summerside, the islands near the east shore of Malpeque bay, and the east and west shore of Darnley basin were visited.

Returning to Nova Scotia, on the south shore, I visited shell-heaps in Lunenburg county, about 70 miles west of Halifax, of which the department had learned through Dr. Charles A. Hamilton, of Mahone Bay, and these were found to be the deepest I had seen in the Maritime Provinces. They comprised two large and several smaller shell-heaps on Mahone bay. I spent nine days, some days with as many as four assistants, excavating one of the largest, the Eisenhauer shell-heap, and secured five large boxes of specimens, all of which were aboriginal, and showed no signs of European influence. This shell-heap is on the north side of the road between the villages of Mahone Bay and Indian Point, about 1½ miles west of the latter place, and is on land owned by James Eisenhauer, to whom we are indebted for permission to excavate on his property. There is a very small deposit of shells in William Hyson's woods, several hundred yards west of this one and at considerable distance from the shore. The deepest and best shell-heap is in the shore of Weihnacht cove, about half a mile east of the Eisenhauer shell-heap, where the owner of the land would not permit excavations to be made. Another small one is on the bank of a creek west of this and about a mile from the seashore. I visited the shell-heap near Martin river and a habitation site on Martin point, about 3 miles from the Eisenhauer shell-heap.

A study was made at Halifax of the archæological collections in both the Provincial Museum and Dalhousie University, and photographs and line drawings of the more important specimens. The catalogue of the Patterson collection in Dalhousie University was copied for our files. The archæological material in the Museum of the Natural History Society of New Brunswick, in St. John, was also studied.

ON ARCHÆOLOGICAL RESEARCH IN THE VALLEY OF THE SOURIS RIVER, SOUTHWESTERN MANITOBA, 1913.

(*W. B. Nickerson.*)

My archæological work for the Geological Survey, in 1913, covering a period of over nine weeks from August 8 to October 12, was confined to the Souris valley at the confluence of the North and South Antler creeks, in township 2 north, 27 west, southwestern Manitoba.

Photographs were taken illustrative of the topography of the district, its plains, its forested valleys, and its streams. Primarily the district is a level plain through which the Souris river flows in a valley a little more than a mile in width. The Antler valleys are only proportionately smaller and break the plain by wide gulches 80 feet deep. The creek bottoms, more especially the South Antler, bear a growth of oak, elm, poplar, and ash, gnarled and stunted as they approach the upper level of the wind-swept plain.

The vegetation of the plain, where not yet under cultivation, or where it has been permitted to relapse to its original condition, is a bunchy buffalo grass and a low growing silver-green sage, dusty green wolf willows, and clumps of poplars called "bluffs."

On the North Antler plain a large horseshoe-shaped earthwork was surveyed and examined by trenching; two rectangular house-sites, one in connexion with a hut-ring; hutrings, pits, and three mounds were also examined.

On the South Antler plain a camp site, one pit, and two mounds were explored and the knob-like expansions at the termination of three long mounds were examined

The South Antler bottoms were tested, by making excavations in twenty-five places, for a village site. Broken bones were found in nearly every excavation, but no potsherds or chips of stone were found.

A village site discovered on the east side of the Souris river opposite the North Antler plain was trenched and material partly illustrating the culture of the site was found.

On the plain above this village two mounds were examined. One of them was circular and contained a burial pit covered in with poles, but the mound had already been dug into and most of the contents of the pit taken.

Another village site on the west side of the Souris between the two creeks was found to extend from the plain down on to the level along the bank of the South Antler.

The material gathered from the village sites comprises great quantities of broken bones, chips of stone, potsherds of a variety of wares and of diverse designs, grooved stone hammers, and a few finished artifacts.

On the plain between the creeks two mounds were examined.

In all I explored eight mounds and dug trenches in four more. The mounds are situated on the plain level and for the most part are small and inconspicuous. Some, however, are of great length. Four of the mounds had been previously opened and in these only parts of skeletons were found. Of the undisturbed mounds, one contained the skeleton of an adult and of a child, both extended at length; a second that of an adult in a flexed position; a third, two similarly huddled skeletons; two were gravel mounds without interments; one contained only three bone whistles and the sharpened poles of the frame of a small wigwam; in two others nothing was found.

A very nice collection of grooved hammers and mauls was presented by Mr. Thomas Woodcock of Elva, Man. These are from the North Antler and supplement those given us last year from the South Antler.

I recommend further exploration of village sites and to find others in both the North and the South Antler valleys, and exploration of the long mounds of sections 10 and 15.

PART III.

PHYSICAL ANTHROPOLOGY.

(E. Sapir.)

Owing to the illness of Mr. F. H. S. Knowles, who began work in this branch of the anthropological activities of the Survey last year, field research in physical anthropology could not be continued in 1913. There is reason, however, to believe that the work thus interrupted will be continued during next year.

The accessions in physical anthropology that were received as gifts during the year embrace:—

From J. A. Teit, Spences Bridge, B.C.—One skull and bones from the north side of Thompson river, British Columbia.

Fragments of skull and other bones from Thompson River valley.

From M. A. Joyce, Sergeant in charge of Moosomin district, R.N.W.M.P., skeleton (except some of the smaller bones) from near Welwyn, Sask.

There were received from D. Jenness, one of the two ethnologists on the Stefansson expedition, thirteen anthropometric schedules from Point Hope, Alaska.

DRAUGHTING DIVISION.

(*C.-Omer Senécal.*)

The numerical strength of the staff of draughtsmen has remained stationary during the past year, namely, one chief officer, twelve draughtsmen, and one clerk. As the work passing through this office is constantly on the increase, the chief in charge was informed by the Director that steps will be taken at an early date for the appointment of one or more assistants in order to cope with the demands made on this division.

With the increase of work assigned to this division there was corresponding increase in the official correspondence on subjects related to map work. There were about 2,000 letters, memoranda, specification sheets, reports, etc., sent and received.

For ready reference to map documents and records which have been accumulating for years, an adequate system of filing has been undertaken. Cabinets and accessories have been installed and the inventory and cataloguing will be proceeded with as soon as assistance is afforded by the appointment of a keeper of records.

Attention was, as usual, given by the chief of this division to the work of the Map Committee and that of the Geographic Board of Canada, of which he was this year re-elected a committee member.

Besides the usual routine of compilation and draughting work for the Geological Division, much time was devoted to drawings for the Anthropological Division, the services of one special draughtsman being now reserved for artistic drawing in connexion with the latter.

As outlined in last year's report, the maps and line-cut drawings accompanying the Excursion Guide Books of the Twelfth International Geological Congress (see accompanying list) were completed and printed in due time for use at the opening of the Congress. There were also several Geological Survey maps reprinted for that occasion.

Besides the above Congress maps, twenty-three maps, diagrams, etc., were prepared and drawn to accompany Geological Congress papers, contributed by representatives of foreign countries.

The maps listed below were, at the end of the calendar year, in the hands of the King's Printer:—

Maps in Hands of King's Printer, December 31, 1913.

Series A.	Publication number.	Title.	Sent to King's Printer.
33	1179	Nanaimo Sheet, British Columbia. Topography.	11 July, 1912.
39	1185	Province of Nova Scotia....................	31 Aug, 1911.
41	1191	Duncan Sheet, British Columbia. Topography..	11 July, 1912.
43	1193	Sooke " " " ...	11 July, 1912.
49	1199	Orillia " Ontario. " ..	17 Oct., 1911.
58	1226	Nelson and Churchill Rivers, Manitoba and Saskatchewan..............................	14 April, 1913.
98	1299	Rainy Lake, Ontario........................	25 Oct., 1913.
99	1298	South Portion of Cranbrook Area, British Columbia....................................	19 Aug., 1913.
101	1301	St. Hilaire and Rougemont Mountains, Quebec.	31 Oct., 1913.
102	1302	Eskimo Trade Routes, Arctic Coast..........	20 Dec., 1913.

The following maps have been drawn and engraved by the office copper engraver, viz.:—

Dominion of Canada.—Scale, 250 miles to 1 inch. Additions and corrections.

Victoria Sheet, British Columbia.—Areal Geology.

Victoria Sheet, British Columbia.—Superficial Geology.

Saanich Sheet, British Columbia.—Areal Geology.

Saanich Sheet, British Columbia.—Superficial Geology.

These four sheets are very nearly completed and are expected to be sent to the King's Printer in a few weeks.

During the year, about 220 sketch maps, diagrams, text figures, indexes, and other drawings were prepared to illustrate memoirs in course of publication, for the different divisions of the Geological Survey.

A special geological map of the province of Ontario and a series of diagrams and illustrations intended to accompany a manuscript report on metalled roads, were also prepared and delivered to the Director.

List of Geological Survey maps, and of Geological Congress guide maps, received from the King's Printer, during the calendar year, are appended herewith.

List of Geological Survey Map Editions Published During the Calendar Year 1913.

Series A	Publication number.	TITLE.	Remarks.
91	1277	Dominion of Canada.—Scale, 100 miles to 1 inch.	Geology.
74 to 90	1260 to 1276	The Forty-ninth Parallel.—Seventeen sheets. Scale, 1 : 62,500	Geology.
—	1296	British Columbia.—Graham Island, Queen Charlotte Group. Scale, 16 miles to 1 inch.	Geology, diagram.
50	1200	" " .—Part of Portland Canal. Scale, 1 : 125,000	Topography.
65	1241	" " .—Coast and Islands. Scale, 4 miles to 1 inch	Areal geology.
—	1277	" " .—Workings, Surf Inlet Gold Mines, Princess Royal Island	Economic geology, diagram.
45	1195	" " .—Tulameen, Yale District. Scale, 1 : 62,500	Topography.
46	1196	" " ,— " "	Geology.
30	1168	" " .—Mother Lode and Sunset Mines. Scale, 400 feet to 1 inch	Economic geology.
62	1237	" " .—Nelson and Vicinity, Kootenay District. Scale, 1 mile to 1 inch.	Geology.
94	1283	" " .—Taku Arm, Atlin District. Scale, 4 miles to 1 inch	Geology, preliminary edition.
105	1287	" " .—Cadwallader Creek Mining Area, Lillooet District. Scale, 2,000 feet to 1 inch	Geology, outline edition.
106	1304	" " .—Groundhog Coal Field. Scale, 4 miles to 1 inch	Geology, outline edition.
104	1303	" " .—Thompson River Valley. Scale, 4 miles to 1 inch	Geology, outline edition.
40	1210	Alberta.—Bighorn Coal Basin. Scale, 1 : 125,000	Topography.
—	929	" .—Cascade Coal Basin, Sheet 1, Panther River. Scale, 1 mile to 1 inch	Geology, reissue.
—	931	" .— " " Sheet 2.—Cascade River. Scale, 1 mile to 1 inch	Geology, reissue.
—	933	" .— " " Sheet 3.—Canmore. Scale, 1 mile to 1 inch	Geology, reissue.
—	935	" .— " " Sheet 4.—Wind Mountain. Scale, 1 mile to 1 inch	Geology, reissue.
103	1295	" Southfork Coal Area, Oldman River. Scale, 3 miles to 1 inch.	Economic geology, outline edition.
107	1307	" Blairmore. Scale, 2 miles to 1 inch	Geology, preliminary edition.
55	1221	Alberta, Saskatchewan, and Manitoba. Scale, 35 miles to 1 inch	Geology.
96	1285	Manitoba.—Wanipigow, Manigotagan, and Oiseau Rivers. Scale, 4 miles to 1 inch.	Geology, route map.
—	664	" Lake Winnipeg and Vicinity. Scale, 8 miles to 1 inch.	Geology, reissue.
64	1244*a*	Ontario.—Gowganda Mining Division and Vicinity, south half. Scale, 1 mile to 1 inch	Geology, advance edition.

64	1244*b*	Ontario.—Gowganda Mining Division and Vicinity, north half. Scale, 1 mile to 1 inch	Geology, advance edition.
—	750	Ontario and Quebec.—Grenville Sheet, No. 121. Scale, 4 miles to 1 inch	Geology, reisssue.
100	1300	Quebec.—Bell River. Scale, 8 miles to 1 inch	Geology, route map.
95	1284	" Broadback River, Mistassini Territory. Scale, 10 miles to 1 inch	Geology, route map.
52	1202	" Northeast Part of Serpentine Belt, Eastern Townships. Scale, 4 miles to 1 inch	Economic geology.
108	1308	New Brunswick.—Carboniferous Areas and Positions of Clay and Shale Deposits. Scale, 20 miles to 1 inch	Economic geology, outline edition.
53	1208	Nova Scotia.—Southeast Portion of the Province. Scale, 1 : 250,000	Structural geology.
—	—	" Ponhook Lake, Sheet No. 72. Scale, 1 mile to 1 inch	Uncoloured, advance edition.

List of Guide Maps for the Twelfth International Geological Congress, Published During the Calendar Year 1913.

Excursions in Eastern Quebec and Maritime Provinces:—

	Scale.
Itinéraires des Excursions	75 miles to 1 inch.
Quebec and Vicinity	4 " 1 "
Lévis, Quebec	1,500 feet to 1 "
Montmorency Falls, Quebec	800 " 1 "
Rivière-du-Loup, Quebec	500 " 1 "
Bic, Quebec	1,200 " 1 "
Eastern part of Gaspe, Quebec	5 miles to 1 "
Percé and Vicinity, Quebec	5,000 feet to 1 "
The Forillon, Gaspe, Quebec	1·75 miles to 1 "
Head of Chaleur Bay, Quebec	49 " 1 "
Scaumenac Bay, Quebec	1·6 " 1 "
Dalhousie, New Brunswick	1·75 " 1 "
Bathurst Iron Mines, New Brunswick	800 feet to 1 "
Dorchester, New Brunswick	175 miles to 1 "
Windsor-Horton Bluff, Nova Scotia	4 " 1 "
Oldham Gold District and Vicinity, Nova Scotia	2 " 1 "
Oldham Gold District, Structural Plan	500 feet to 1 "
Generalized Section St. Lawrence Valley	
Panoramic Sketch of the Sea Front at Percé	
Union-Riversdale, Nova Scotia	3 miles to 1 "
New Glasgow, Nova Scotia	2,500 feet to 1 "
Sydney Coal field, Nova Scotia	3 miles to 1 "
Sydney, Nova Scotia	2 " 1 "
George River Station, Nova Scotia	1,850 feet to 1 "
Arisaig-Antigonish District, Nova Scotia	4 miles to 1 "
Arisaig, Nova Scotia	0·75 " 1 "
Logan's section of the Carboniferous at Joggins Mines, Nova Scotia	1·6 " 1 "
Moncton-Albert Mines, New Brunswick	3·6 " 1 "
St. John and Vicinity, New Brunswick	3 " 1 "
Part of St. John City, New Brunswick	1,250 feet to 1 "
Suspension bridge, St. John, New Brunswick	600 " 1 "
Fern Ledges, New Brunswick	900 " 1 "
Grand Falls, New Brunswick	1,200z " 1 "

Excursions in the Eastern Townships of Quebec and the Eastern Part of Ontario:—

	Scale.
Route Map, Montreal, Ottawa, Kingston, Toronto	28 miles to 1 inch.
Central Ontario, Corundum-bearing Rocks	18 " 1 "
Haliburton-Bancroft Areas in relation to the Laurentian Highlands	95 " 1 "
Route Map, Hastings Road, Ontario	25 " 1 "
Bancroft and Vicinity, Ontario	25 " 1 "
Gooderham and Vicinity, Ontario	25 " 1 "
Craigmont Corundum Belt, Ontario	25 " 1 "
Craig Mine, Raglan Township, Ontario	800 feet to 1 "
The Asbestos District of Quebec	30 miles to 1 "
Route Map, Thetford and Coleraine, Quebec	1·3 " 1 "
Route Map, Sydenham and Glendower	2·5 " 1 "

Excursions in Neighbourhood of Montreal and Ottawa:—

	Scale.
Monteregian Hills, Quebec	4 miles to 1 inch.
Montreal, Quebec	1,760 feet to 1 "
Mount Johnson, Quebec	1,800 " 1 "
Route Map, Buckingham and Emerald Mine, Quebec	5,000 " 1 "

Excursions in the Neighbourhood of Montreal and Ottawa:—Continued.—

	Scale.
Emerald Mine, Buckingham Township, Quebec	400 feet to 1 inch.
Route Map, Papineauville and Côte St. Pierre, Quebec	500 " 1 "
Côte St. Pierre, Quebec	400 " 1 "
Walker Mine, Buckingham Township, Quebec	500 " 1 "
Dominion Mine, Buckingham Township, Quebec	200 " 1 "
Route Map, Cantley, Quebec	2,000 " 1 "
Nellis Mine, Cantley, Quebec	200 " 1 "
South Shoreline, Ancient Champlain Sea	4·6 miles to 1 "
Part of Mount Royal showing upper marine beaches	200 feet to 1 "
Section through Mount Royal along line of C.N.Ry. tunnel	0·66 miles to 1 "

Excursions in Southern Ontario:—

	Scale.
Itinéraires des Excursions	75 miles to 1 inch.
Niagara, Ontario	1,000 feet to 1 "
Niagara Gorge, Ontario	3,300 " 1 "
Hamilton and Vicinity	1·5 miles to 1 "
Hagersville and Vicinity	3·3 " 1 "
Route Map, Thedford and Arkona	1·6 " 1 "
" Guelph and Galt	2·4 " 1 "
" Hamilton and Grimsby	1·5 " 1 "

Excursions in the Western Peninsula of Ontario and Manitoulin Island:—

	Scale.
Route Map, Toronto and Manitoulin Island	28 miles to 1 inch.
" Streetsville and Credit Forks	2·5 " 1 "
Port Colborne	
Eastern portion of Manitoulin Island, Ontario	5·5 " 1 "
Parry Sound and Vicinity	2 " 1 "
Route Map, Collingwood and Craigleith	2·5 " 1 "

Transcontinental Excursions:—

	Scale.
Itinéraires des Excursions	75 miles to 1 inch.
Itinéraires des Excursions (Tronçons de l'Ouest)	75 " 1 "
Loon Lake, Ontario	1·25 " 1 "
Steeprock Lake, Rainy River District, Ontario	1·25 " 1 "
Golden Star Mine, Rainy River District, Ontario	12 " 1 "
Bears Passage, Rainy Lake, Ontario	0·75 " 1 "
Route Map, Calgary and Banff, Alberta	15 " 1 "
Sketch Map, Subdivisions in Southern part of Canadian Cordillera, British Columbia	170 " 1 "
Banff, Alberta	1·5 " 1 "
Laggan-Field, Alberta, British Columbia	1·9 " 1 "
Route Map, Banff and Golden, British Columbia	8 " 1 "
Route Map, Golden and Revelstoke, British Columbia	10 " 1 "
Prairie Hills and Dogtooth Mountains, British Columbia	2·6 " 1 "
Glacier, British Columbia	1·9 " 1 "
Albert Canyon, British Columbia	1·4 " 1 "
Map showing approximate distribution of the Shuswap Terrane Rocks in Central British Columbia	170 " 1 "

Transcontintental Excursions:—Continued.—

	Scale.
Route Map, Revelstoke and Ducks, British Columbia..	10 miles to 1 inch.
" Ducks and Lytton, British Columbia..	10 " 1 "
" Lytton and Agassiz, British Columbia..	10 " 1 "
" Agassiz and Vancouver, British Columbia..	10 " 1 "
Structure Section across Rocky Mountains near the main line of the Canadian Pacific Railway, between Cascade Trough and Columbia Valley..	2 " 1 "
Structure Section of the Selkirk and Purcell Mountains, from Moberly Peak to Revelstoke..	2 " 1 "
Victoria and Vicinity, British Columbia..	1 mile to 1 "
Route Map, Victoria and Nanaimo..	7·7 miles to 1 "
Red Deer Valley in Vicinity of Drumheller, Alberta..	2 " 1 "
Old Beaches, Ethelbert to Pine River, Manitoba..	3 " 1 "
Snake Island and South Shore of Lake Winnipegosis, Manitoba..	7 " 1 "
Dawson Bay, Man..	8·5 " 1
Route Map, Lake of the Woods, Ontario..	2·4 " 1 "
" Medicine Hat and Lethbridge, Alberta..	15 " 1 "
Location of Mines in Lethbridge District, Alberta..	2·2 " 1 "
Map and Section, Crowsnest Mountain, Alberta..	1·5 " 1 "
Route Map, Lethbridge and Elko, Alberta..	15 " 1 "
" Elko and Proctor, British Columbia..	10 " 1 "
" Proctor and Midway, British Columbia..	10 " 1 "
" Arrow and Slocan Lakes, British Columbia..	10 " 1 "
" Midway and Princeton, British Columbia..	10 " 1 "
" Princeton and Spences Bridge, British Columbia..	10 " 1 "
" Edmonton to Edson, Alberta..	15 " 1 "
" Malachi and Winnipeg, Manitoba..	16 " 1 "
" Edson and Tête-Jaune, Alberta..	15 " 1 "
" Richan and Malachi, Ontario..	16 " 1 "
" Bucke and Richan, Ontario..	16 " 1 "
" Nipigon and Bucke, Ontario..	16 " 1 "
" Grant and Nipigon, Ontario..	16 " 1 "
" Kabinakagami and Grant, Ontario..	16 " 1 "
" Alexandra and Kabinakagami, Ontario..	16 " 1 "
" Lake Abitibi and Alexandra, Ontario..	16 " 1 "
Section in Bellevue Mine, Alberta..	330 feet to 1 "
Phoenix Structural Sections, British Columbia..	600 " 1 "
Section across Ore-body, Knobhill-Ironsides Mine, British Columbia..	200 " 1 "
Natural Section, Nickel Plate Mountain, British Columbia..	650 " 1 "
Section through Nickel Plate Mine, British Columbia..	100 " 1 "
Section through Olivine Mountain, British Columbia..	5,000 " 1 "
Diagram showing geological relationships in the region between Lake Nipigon and Winnipeg..	

Excursions in Northern British Columbia and Yukon Territory, Along the Pacific Coast:—

	Scale.
Route Map, Vancouver and Calvert Island, British Columbia..	28 miles to 1 inch.
" Calvert Island and Prince Rupert, British Columbia	26 " 1 "
" Prince Rupert and Telkwa, British Columbia..	12 " 1 "
" Prince Rupert and Frederick Sound, British Columbia	24 " 1 "
" Frederick Sound and Skagway, British Columbia..	24 " 1 "
Physiographic Provinces of Yukon..	195 " 1 "
Submarine Topography of Russell Fiord, British Columbia..	3·75 " 1 "
Turner, Hubbard, and Variegated Glaciers.	1 mile to 1 "
Nunatak Glacier, British Columbia..	0·75 " 1 "
Hidden Glacier, British Columbia..	0·75 " 1 "
General Section along Buckley River from Hazelton to Telkwa, British Columbia	2·65 " 1

LIBRARY.

(M. Calhoun, Acting Librarian.)

During the calendar year, 1913, 1,328 volumes and pamphlets were received as gifts or exchanges, including—besides periodicals—maps, reports, and publications of foreign Geological Surveys, together with Memoirs, Transactions, and Proceedings of the scientific societies of Canada and other countries.

One thousand and eighty-eight volumes were added by purchase, costing $4,163.94.

One hundred and twenty periodicals were subscribed for.

Two hundred and ninety-four volumes were bound during the year.

The above figures, if compared with those in last year's report, will show to some extent, the growth of the library.

The re-cataloguing of the old books, according to the Cutter system of classification, is progressing steadily.

PUBLICATIONS.

The following Reports have been published since January 1, 1913.

No.

1160. Memoir No. 17-E: Geology and Economic Resources of the Larder Lake District, Ontario, and Adjoining Portion of Pontiac County, Quebec. By M. E. Wilson. Published May 30, 1913.

1165. Memoir No. 18-E: Bathurst District, N.B. By G. A. Young. Published February 6, 1913.

1186. Memoir No. 35: Reconnaissance along the National Transcontinental Railway in Southern Quebec. By J. A. Dresser. Published May 2, 1913.

1203. Memoir No. 38: Geology of the North American Cordillera at the Forty-Ninth Parallel, Parts I and II. By R. A. Daly. Published December 2, 1913.

1206. Memoir No. 26: Tulameen Mining District. By Charles Camsell. Published November 28, 1913.

1220. Memoir No. 29: Oil and Gas Prospects of the Northwest Provinces of Canada. By W. Malcolm. Published September 5, 1913.

1228. Memoir No. 31: Report on Wheaton District, Yukon Territory. By D. D. Cairnes. Published February 25, 1913.

1240. Museum Bulletin No. 1. Published October 21, 1913.

Separates—

I.—The Trenton Crinoid, Ottawacrinus, W. R. Billings.

II.—Note on Merocrinus Walcott. By F. A. Bather.

III.—The Occurrence of Helodont Teeth at Roche Miette and Vicinity, Alberta. By Lawrence M. Lambe.

IV.—Notes on Cyclocystoides. By P. E. Raymond.

V.—Notes on Some New and Old Trilobites in the Victoria Memorial Museum. By P. E. Raymond.

VI.—Description of Some New Asaphidæ. By P. E. Raymond.

VII.—Two New Species of Tetradium. By P. E. Raymond.

VIII.—A Revision of the Species Which Have Been Referred to the Genus Bathyurus. By P. E. Raymond.

IX.—A New Brachiopod from the Base of the Utica. By Alice E. Wilson.

X.—A New Genus of Dicotyledonous Plant from the Tertiary of Kettle River, British Columbia. By W. J. Wilson.

XI.—A New Species of Lepidostrobus. By W. J. Wilson.

XII.—Prehnite from Adams Sound, Admiralty Inlet, Baffin Island Franklin. By R. A. A. Johnston.

XIII.—The Marine Algæ of Vancouver Island. By Frank S. Collins.

XIV.—New Species of Mollusks from the Atlantic and Pacific Coasts of Canada. By Wm. H. Dall and Paul Bartsch.

XV.—Hydroids from Vancouver Island.

XVI.—Hydroids from Nova Scotia. By C. McLean Fraser.

XVII.—The Archæology of Blandford Township, Oxford County, Ontario. By W. J. Wintemberg.

All of the above separates were published simultaneously on December 18, 1913.

1242. Memoir No. 33: The Geology of Gowganda Mining Division. By W. H. Collins. Published August 20, 1913.

1255. Memoir No. 37: Atlin Mining District. By D. D. Cairnes. Published November 17, 1913.

FRENCH TRANSLATIONS.

(M. Sauvalle.)

No.

905. Report on the Cruise of the Neptune (Edition de luxe), by A. P. Low. Published January 9, 1913.

1116. Memoir No. 8E, on The Edmonton Coal Fields, Alberta, by D. B. Dowling. Published 1913.

1131. Memoir No. 9-E, on Bighorn Coal Basin, Alberta, by G. S. Malloch. Published January 9, 1913.

1152. Memoir No. 16, on The Clay and Shale Deposits of Nova Scotia and Portions of New Brunswick, by Heinrich Ries, assisted by Joseph Keele. Published April 18, 1913.

1212. Memoir No. 27, on the Report of the Commission Appointed to Investigate the Condition of Turtle Mountain, Frank, Alberta. Published November 17, 1913.

1215. Report on Upper Stewart River Region, by J. Keele. Published April 18, 1913.

1216. Report on Peel River and Tributaries, Yukon and Mackenzie, by C. Camsell. Published April 18, 1913.

1257. Carboniferous System of New Brunswick, by L. W. Bailey and Henry S. Poole. Published, 1913.

1259. Report on the Coal Fields of Souris River, Eastern Assiniboia, by D. B. Dowling. Published April 24, 1913.

ACCOUNTANT'S STATEMENT.

(*John Marshall.*)

The funds available for the work and the expenditure of the Geological Survey for the fiscal year ending March 31, 1913, were:—

—	Grant.	Expenditure
	$ cts.	$ cts.
Details:—		
Amounts voted by Parliament	440,377 89	
Civil list salaries		128,878 05
Explorations in British Columbia and Yukon		41,284 31
Topographical surveys in British Columbia		24,935 85
Explorations in North West Territories		8,724 31
Topographical surveys in North West Territories		10,809 93
Explorations in Ontario		14,740 04
Topographical surveys in Ontario		2,722 53
Explorations in Quebec		9,871 13
Topographical surveys in Quebec		290 50
Explorations in New Brunswick		948 35
Topographical surveys in New Brunswick		7,033 58
Explorations in Nova Scotia		6,205 47
Topographical surveys in Nova Scotia		538 13
Explorations in general		5,581 86
Ethnological investigations		8,952 83
Publication of reports		17,392 06
Publication of maps		6,936 71
Instruments and repairs		15,251 57
Photographic supplies		4,503 29
Wages, temporary employees		4,828 10
Printing, stationery, books, etc		13,253 30
Miscellaneous		8,487 10
Specimens for Museum		11,101 45
Travelling expenses		2,030 20
Advertising		560 00
Clothing for firemen		328 00
Balance unexpended and lapsed		84,189 24
	440,377 89	440,377 89

All of which is respectfully submitted.

I have the honour to be, sir,

Your obedient servant,

(Signed) R. W. BROCK.

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LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY.

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers, and, therefore, the following list has been prepared to prevent any misconceptions arising on this account. The titles of all other important publications of the Geological Survey are incorporated in this list.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and Northwest Territories—by Joseph Keele. No. 1097.

Summary Report for the calendar year 1909. No. 1120.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario—by Alfred W. G. Wilson.

MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiold Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *No. 6, Geological Series.* Geology of St. Bruno mountain, Province of Quebec—by John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES.

MEMOIR 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of Lake Timiskaming—by Morley E. Wilson. No. 1064.

Summary Report for the calendar year 1910. No. 1170.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson

MEMOIR 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

MEMOIR 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

MEMOIR 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

MEMOIR 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.

MEMOIR 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.

MEMOIR 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries, assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

MEMOIR 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs and Reports Published During 1912.

REPORTS.

Summary Report for the calendar year 1911. No. 1218.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.

MEMOIR 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. LeRoy.

MEMOIR 24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.

MEMOIR 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.

MEMOIR 28. *No. 18, Geological Series.* The geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

Memoirs and Reports Published During 1913.

REPORTS, ETC.

Museum Bulletin No. 1: contains articles Nos. 1 to 12 of the Geological Series of Museum Bulletins, articles Nos. 1 to 3 of the Biological Series of Museum Bulletins, and article No. 1 of the Anthropological Series of Museum Bulletins.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa.

Guide Book No. 4. Excursions in southwestern Ontario.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island.

Guide Book No. 8. Toronto to Victoria and return *via* Canadian Pacific and Canadian Northern railways: parts 1, 2, and 3.

Guide Book No. 9. Toronto to Victoria and return *via* Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways.

Guide Book No. 10. Excursions in Northern British Columbia and Yukon Territory and along the north Pacific coast.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.

MEMOIR 18. *No. 19, Geological Series.* Bathurst district, New Brunswick—by G. A. Young.

MEMOIR 26. *No. 34, Geological Series.* Geology and mineral deposits of the Tulameen district, B.C.—by C. Camsell.

MEMOIR 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.

MEMOIR 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.

MEMOIR 33. *No. 30, Geological Series.* The geology of Gowganda Mining Division—by W. H. Collins.

MEMOIR 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.

MEMOIR 37. *No. 22, Geological Series.* Portions of Atlin district, B.C.—by D. D. Cairnes.

MEMOIR 38. *No. 31, Geological Series.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II—by Reginald Aldworth Daly.

Memoirs and Reports Published During 1914.

REPORTS, ETC.

Museum Bulletin No. 2: contains articles Nos. 13 to 18 of the Geological Series of Museum Bulletins, and article No. 2 of the Anthropological Series of Museum Bulletins.

Prospector's Handbook No. 1: Notes on radium-bearing minerals—by Wyatt Malcolm.

Summary Report for the calendar year 1912. No. 1305.

MUSEUM GUIDE BOOKS.

The archæological collection from the southern interior of British Columbia—by Harlan I. Smith. No. 1290.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 23. *No. 23, Geological Series.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C.—by J. Austen Bancroft.

MEMOIR 25. *No. 21, Geological Series.* Report on the clay and shale deposits of the western provinces (Part III)—by Heinrich Riès and Joseph Keele.

MEMOIR 30. *No. 40, Geological Series.* The basins of Nelson and Churchill rivers—by William McInnes.

MEMOIR 20. *No. 41, Geological Series.* Gold fields of Nova Scotia—by W. Malcolm.

MEMOIR 36. *No. 33, Geological Series.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C.—by C. H. Clapp.

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