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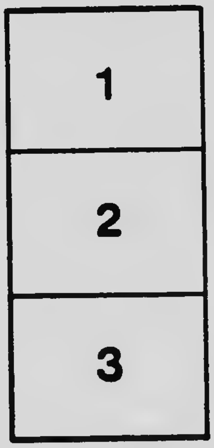
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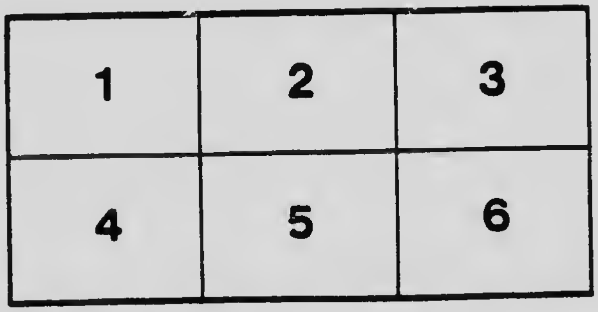
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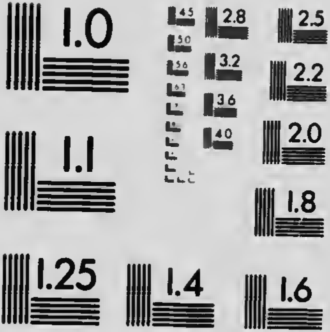

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GEOLOGICAL SURVEY

MEMOIR 92

NO. 74, GEOLOGICAL SERIES

Part of the District of Lake St. John, Quebec

BY
John A. Dresser

OTTAWA
GOVERNMENT PRINTING BUREAU
1916

No. 1642

Ouiatchouan falls.
(From "Waterpowers of Canada," Dept. of the Interior, 1915.)

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Part of the District of Lake St. John.

CHAPTER I.

INTRODUCTORY.

Lake St. John is a beautiful sheet of water, nearly round, and covers 350 square miles in the county of the same name, 120 miles north of the city of Quebec. From its numerous inlets, three of which are rivers more than 200 miles in length, Lake St. John receives the surplus waters of an area of approximately 30,000 square miles, and discharges them into the St. Lawrence river, 120 miles distant, through the Saguenay, a river well known for its scenic beauty. The lower 90 miles of the river is at tide level and is navigable for ocean going vessels.

The district about Lake St. John is distinguished geologically by the occurrence of Palæozoic sediments far within the limits of the great Pre-Cambrian "shield" of northern Canada, and for the structural causes which have preserved them. The enormous development of the unusual rock, anorthosite, is another feature of geological interest. The region is now economically important for its agricultural and forest products, while its water-powers, and, in a less degree, the clay deposits, and the iron ores which are associated with the anorthosites, promise to make the district one of still greater importance in the future.

PREVIOUS WORK.

The occurrence of Palæozoic strata in this district was first noted by Major General Baddeley, R.E., in 1828.

In 1830 Saguenay river was charted under the direction of Captain Bayfield, R.N., who noted the principal varieties of rock occurring along the shores.

The first work of an exclusively geological character was performed by James Richardson, under the auspices of the

Geological Survey, in 1857. In an exploration which was made from the mouth of the Saguenay to Lake Mistassini, 250 miles northwest of Lake St. John, Richardson noted the occurrence of Palæozoic sediments in the vicinity of Lake St. John and the existence of considerable areas of rocks rich in labradorite (anorthosite). His report appears in the annual volume of the Geological Survey for the year 1857 and a summary of the report and of other observations is given in the Geology of Canada, 1863, pages 164–5, 220, and 923.

In 1883–4 the late Abbé Laflamme carried on an examination of the district extending from Chicoutimi to the west and north of Lake St. John. He discovered several areas of Palæozoic rock in addition to those already known and indicated the probable limits within which such formations might be found, except to the westward. Laflamme prepared no maps, but published a general report in the annual volume of the Geological Survey for 1884.

During the same years, Dr. F. D. Adams made an examination of a large portion of the anorthosite areas, as a part of the broader investigation in which he determined the relations of the anorthosite to the Laurentian, as well as the petrographic characters of the former. Summary reports of the progress of this work were published, but no map nor final report was issued by the Geological Survey, under whose auspices the work was done. A detailed petrographic description of the anorthosites, with a concise statement of their structural relations, accompanied by a small scale map, was published in the Neues Jahrberch für Mineralogie, Beilageband VIII, Stuttgart, 1893 (Ueber das Norian oder Ober-Laurentian von Canada). This was followed by a translation into English by the late N. J. Giroux, in the Canadian Record of Science, Montreal, 1896.

In 1900 G. A. Young of the Geological Survey spent the field season in an investigation northeast of Lake St. John along several of the tributary rivers. The results appear in the Summary Report of the Geolcgical Survey for the year 1900, but Mr. Young's transference to another field prevented the completion of the work.

PRESENT WORK.

The aim of the present investigation has been to ascertain the present and possible resources of the district and to find out the conditions of geological structure on which they depend. Accordingly, a reconnaissance was made for 35 miles east and west of Lake St. John, and an area of approximately 200 square miles around the south half of the lake was examined in detail. This area is shown on the accompanying map. In preparing this map the township plans of the Department of Crown Lands, on a scale of 40 chains to 1 inch, were used as a base and the positions of rock exposures and other geological features were determined by stadia survey. The field work was performed between June 1 and September 26.

Mr. H. A. Honeyman accompanied the party and made a study of the flora and agricultural conditions of the district.

To Dr. A. Stansfield, professor of metallurgy in McGill university, I am much indebted for a chapter of this report on the applicability of electric smelting to the iron ores of this district. I would also acknowledge with thanks many courtesies received from Mr. T. C. Denis, superintendent of mines of Quebec; Mr. Jos. Girard, M.P.; Colonel B. A. Scott, general manager of the Quebec Development Company; Mr. Guy Tombs, general freight agent of the Canadian Northern railway, Montreal, and other officials of the same company.

SUMMARY AND CONCLUSIONS.

The district about Lake St. John consists of two parts which are quite distinct from each other in relief and in economic value, as well as in the geological structure by which these features are controlled. One which may be distinguished as the lowland, has a general altitude between 340 and 500 feet above sea-level. Its surface is comparatively even; the soil is deep and generally fertile and the land is well tilled, and quite thickly populated. It includes the lake and the bordering flat country on either side. Measured in a northeasterly direction across the lake it has a breadth of about 40 miles. Towards the southeast it narrows rapidly but extends an unknown distance to the northwest, apparently with increasing width.

The lowland is underlain in many places by sedimentary rocks of Ordovician age; and the conditions suggest that these rocks, which have been deeply eroded, formerly occupied the greater part, if not the whole of this depression and possibly also covered the adjacent highland. Besides the Ordovician sediments, the lowland contains granites, anorthosites, and gneisses of Pre-Cambrian age.

The highland which bounds this depression has a general altitude between 800 and 1,000 feet above sea-level. The surface is hilly and rocky, the soil shallow and poor, and there are few inhabitants. It has the general characteristics of the Laurentian peneplain of which it is a part. The rock complex by which it is underlain, consists of Laurentian gneiss with small areas of Grenville limestone; anorthosite intrusive into Laurentian; and a microcline granite, frequently gneissic, which is intrusive into all the earlier rocks.

The structural relation between the lowland and highland is one of faulting. Wherever the Ordovician strata have been found at the edge of the lowland, there is evidence of a fault contact between them and the adjacent Pre-Cambrian. Within the lowland, too, numerous faults are found. An essential part of the faulting, perhaps all of it, has evidently taken place since Ordovician time.

Economically considered, the two parts are sharply distinguished from each other. The highland furnishes a very important supply of pulp and lumber, and the district includes some of the largest pulp manufactories in Canada; but these are the only industries in the district that derive their raw materials from the highlands. The lowland is essentially a valuable agricultural section. Of minor industries and resources, limestone is quarried in many places both for use in making lime and for road metal. Granite of good quality and in abundance is quarried for building purposes and is used in the principal public buildings. Clay is used for brick making in several places and some remarkable deposits on tide water at Terres Rompues seem worthy of attention for clay or cement industries.

Iron ore occurs in important quantities in association with the anorthosite rocks. In all cases known, however, it is highly titaniferous and so awaits improved means of reduction. This is discussed at length in Chapter VI, by Dr. A. Stansfield.

The water-powers of the district promise the largest industrial development for the future. The immense amount of water collected by Lake St. John, and the immature character of its outlet, as well as the fall line that is developed in the lesser rivers by the escarpment which separates the lowland from the highland, afford facilities for the development of water-power that are almost unlimited. Under the title of the Quebec Development Company, influential Canadian and United States capitalists are preparing for an extensive developing of the water-powers of the entire upper Saguenay for electrochemical and other purposes.

CHAPTER II.

GENERAL CHARACTER OF THE DISTRICT.

TOPOGRAPHY.

The surface of the country in the region of Lake St. John presents the usual aspects of the Laurentian peneplain of northern Canada. It is a region of moderate altitude, generally between 800 and 1,200 feet above the level of the sea, and of rather low relief. While it nowhere shows the features of a plain, there is a concordance of level of the major portions of the region that gives an even skyline, broken only by an occasional residual hill or ridge of greater resistance to erosion, or by narrow trench-like valleys which are a more common cause of relief in the landscape. These valleys are most frequently found to run in one or other of two principal directions, east-northeast or west-northwest. Their persistence in nearly straight lines across different formations suggests that in many cases at least they are due to faulting. The region has been heavily glaciated. Excluding many local variations, the general direction of ice movement has been towards the south or southwest. The filling of valleys by glacial debris, thus occasioned, has given the region an immature drainage marked by an abundance of lakes, waterfalls, and rapids.

Saguenay Trench.

The best known of the trench valleys and one of the largest is the trench or gorge of the Saguenay. The scenic beauty of this river has long made it famous as a tourist route. The valley belongs to the series which has a west-northwesterly direction. It is distinguished from others by its great depth and the nearly vertical walls which enclose it. For about 90 miles from its junction with the St. Lawrence the Saguenay is at sea-level and in many places the bottom of the channel is several hundred feet below average tide level. Besides the steepness of the walls, there is a notable absence of points or spurs projecting from the shore-line. These features indicate that this trench has been eroded by glacial action converting the usual V-shaped trench into a U-shaped valley. The Saguenay trench, however, runs nearly at right angles to the direction of general ice movement in the region. Its deepening and widening, if caused by glacial action are, therefore, due to local, rather than to general ice movements. The Labrador ice-sheet, moving south or south-southwesterly, on meeting a fault scarp, 800 feet or even more in height along the southwest side of Lake St. John and Lake Kenogami, would be deflected to the southeast in its earlier and later stages at least, if it did not continue as an undercurrent in this direction even after the ice had filled the Lake St. John-Saguenay depression and was again moving in its general course to the southwest. Whatever the details of these movements have been, the Saguenay presents the general appearance, on superficial examination, of a fault trench that has been rounded and deepened into a fiord estuary. The unusual depth of the channel apparently ceases at the St. Lawrence. The Saguenay trench offers an interesting subject for detailed study as a physiographic problem.

Ste. Marguerite Trench.

Parallel to the Saguenay and at a distance of 4 to 6 miles from it on the northeast side, is a trench 70 miles or more in length. It is occupied by Ste. Marguerite river for the greater part of its length, and for shorter distances by Rivière du Moulin à Baude and a branch of the Valin. As far as seen this trench is as wide and as well defined as the Saguenay gorge, but it is largely filled by sand and glacial debris, the streams within it being much smaller than the Saguenay and at a higher level. It appears to be a filled instead of an eroded trench.

Between these trenches the country has the general altitude of the Laurentian peneplain for a distance of 70 miles from the St. Lawrence or nearly to the entrance to Ha Ha bay. Thence westward the belt between these trenches declines below the general altitude of the region on the north or south, and falls to the level of post-glacial submergence.

Lake St. John Lowland.

The south wall of the Saguenay and the north wall of the Ste. Marguerite trench appear as pronounced escarpments, facing each other. The valleys widen in going westward and eventually coalesce, forming a distinct lowland in which Lake St. John is situated. The breadth of this lowland, measured northeasterly near the southeast side of Lake St. John, is 35 miles, and the escarpments continue to diverge westward.

On Ashuapmuchuan river the northwesterly limit of the lowland is at Pimonka rapids, about 30 miles from Lake St. John. From this point the escarpment extends in a northeasterly direction nearly to the northwest border of Normandin township. The northerly limit in the vicinity of Mistassini river is not known.

The surface of the lowland is generally even; there are few rock exposures; and the altitude varies between 340 feet, which is near the high water level of Lake St. John, and 600 feet, which is approximately the upper limit of post-glacial submergence (Plate II A).

DRAINAGE.

Owing in a large measure to the great depression about Lake St. John, the lake has become a reservoir for the collection of the water from several large rivers of the region. The largest of these rivers is the Peribonka, which enters the lake on the northeast side. This river is 300 miles or more in length and has a drainage area of some 12,000 square miles. It is navigable for a distance of 14 miles from its mouth where its width is more than 3,000 feet.

Mistassini river enters Lake St. John from the north. It is 200 miles in length, drains an area of 9,000 square miles, and is navigable at certain seasons for a distance of 18 miles.

The Ashuapmuchuan enters at the west side of Lake St. John. It is navigable for 9 miles from its mouth and is about 200 miles long.

The Ouiatchouan drains several large lakes from 20 to 40 miles south of Lake St. John, which it enters at the southwest side. Metabetchouan, Koushpaganish, and Belle are other rivers which enter Lake St. John on the south side. The accumulated waters from these and the smaller streams which enter the lake are discharged through the channel of the Saguenay. Saguenay river flows out of Lake St. John at an altitude varying between 314 and 341 feet from low to high water, and in a course of rather less than 30 miles descends to high tide level. The outlet is effected through two main channels, known as the Grande-Décharge and the Petite-Décharge, which unite at a distance of 9 miles from the lake. The land enclosed between the outlets and the lake is known as Alma island. The upper Saguenay is characterized by strong currents, rapids, and cascades. The channel is narrow and gorge-like, with steep rock walls. It is essentially a young channel. Throughout the remainder of its course to the St. Lawrence, some 90 miles, the Saguenay runs in a deep, U-shaped valley with steep rock walls, often as much as 1,000 feet high, and is properly an estuary of the fiord type.

The principal tributaries that enter the Saguenay from the north are the Shipshaw, the Valin, and the Ste. Marguerite; and from the south the Sable and Chicoutimi which are outlets of Lake Kenogami. These are the chief tributaries that drain the part of the region under consideration.

A feature of the lowland area is the occurrence of lakes along the border of the depression at the foot of the escarpments which bound it. The largest of these is Lake Kenogami which, with a chain of smaller lakes, follows the south boundary of the lowland for a distance of 30 miles or more. Lake Tahistagama, which is drained by Peribonka river, appears to be similarly situated with relation to the north boundary. Other small lakes occur in like position.

The late Abbé Laflamme believed that the Kenogami series of lakes represent a pre-Glacial outlet of Lake St. John, which emptied into Ha Ha bay. From the limited observations that it has been possible to make during the past season, this view seems probably correct, though further examination would be necessary to prove it. The entire question of the pre-Glacial drainage of the district offers an exceedingly attractive problem for an independent investigation.

Lake St. John has a wide range between high and low water. From midsummer until late autumn it is a very shallow lake and is navigable only with difficulty. The large rivers, Ashuapmuchuan, Mistassini, and Peribonka, in high water carry an immense amount of matter in suspension and are rapidly silting up the northern part of the lake. A shoal at the mouth of the Ashuapmuchuan, apparently built by the deposits from that river, is now as much as 7 miles in length and necessitates a long detour for boats going between St. Felicien and Roberval. The conditions near the mouths of other rivers are similar.

Plans for a large industrial plant, now projected by the Quebec Development Company, include the raising of the low water level of the lake by some 20 feet. This when completed will doubtless improve the facilities for navigation.

WATER-POWERS.

The water-powers are an important feature of the industrial potentialities of the district of Lake St. John. The abundance of waterfalls, the immense supplies of timber in the region tributary to the lake and to the upper part of Saguenay river, and the proximity of the whole to tide water navigation afford conditions for manufactures that in many respects are unexcelled.

The following summary of the water-powers of the district is quoted from "The Water Powers of the Province of Quebec" by Mr. F. T. Kaelin, which was published in 1915 by the Water Powers Branch of the Department of the Interior. Mr. Kaelin says, "Although a vast amount of water power is available in the region directly north of Quebec City, a comparatively small quantity only has been developed. The electrical supply for Quebec City is at present only partly obtained from a number of nearby small developments, mainly on the north shore of the St. Lawrence. The larger water powers in this district are practically to be found upon rivers flowing to or from Lake St. John, and especially upon the Saguenay River, which connects Lake St. John with the St. Lawrence.

"The junction of the Saguenay with Lake St. John is situated about 120 miles due north of Quebec City, which is connected with the various places on the shore of the Lake and the Saguenay, by the Quebec and Lake St. John Railway.

"This district is famous for the variety of sport in the nature of hunting, fishing and boating, which it has to offer, and is consequently scattered with a number of holiday resorts. Lake St. John has an area of 350 square miles, and a tremendous volume of water flows therefrom, down the Saguenay.

"At Grand Discharge, where the lake empties its waters into the Saguenay, there are two main falls, which are capable of generating 375,000 h.p., and the water rights have been secured by the Quebec Government, who have in view a storage scheme whereby the above available power would be increased to over 1,000,000 h.p. Construction work on this development is expected to commence in the near future.

"Some 20 miles below the Grand Discharge, is a series of rapids having an available power of over 240,000 h.p., none of which is yet developed. At Chicoutimi, a few miles farther down the Saguenay, where it is joined by the Chicoutimi River, a hydro-electric plant is developing 7,500 h.p., which represents about half of the power available. From Chicoutimi to the St. Lawrence, the Saguenay is navigable. There are considerable available water powers on some other tributaries of the Saguenay, chief of which are the Shipshaw River with 8,000 h.p. available, some of which is being developed, and the Peribonka River with 120,000 h.p. available.

"A number of tributaries of Lake St. John, flowing from all directions, have their courses broken by numerous falls and rapids, which might be turned to great industrial use, although but small demand has yet arisen from these powers.

"Of those rivers running into Lake St. John, the most important from an industrial standpoint, are the Ashuapmuchuan River with 250,000 h.p. available.

"The Mistassini and Muskosibi Rivers each with 12,000 h.p. with Metabetchouan River with 11,000 h.p. available, and the Ouiatchouan River, whose falls are capable of generating 13,000 h.p. of which 5,000 h.p. is already developed.

"It will now be apparent that a vast amount of power is obtainable in the Lake St. John region, most of which could be transmitted electrically to Quebec City, if desired, or used on the spot for electro-chemical processes and other purposes. This district is also richly timbered, and should prove attractive to those interested in the pulp and paper industry."

MEANS OF COMMUNICATION.

The district is reached by rail from the city of Quebec by means of the Lake St. John division of the Canadian Northern Railway system. The main line from Quebec to Chicoutimi is 227 miles in length. At Chicoutimi connexion is made with the Saguenay line of the Canada Steamships Company, whose boats ply regularly between this point and Quebec during the season of navigation.

From Chambord Junction, on the main line of the Canadian Northern railway 176 miles from Quebec, a branch line of railway extends to Roberval, 13 miles distant. Construction is also well advanced on continuation of this branch for 31 miles farther to the westward through the townships of Ouitachouan, Ashuapmuchuan, and Demeules, ending in Dufferin. The completion and operation of this extension would greatly benefit these parishes and would also aid in the development of the fertile district of La Doré, Ste. Methode, Normandin, and Albanel, farther to the north.

There is a local boat service on Lake St. John during the summer season, connecting the principal villages about the lake and affording a limited passenger and freight service. There are small docks at Roberval, St. Félicien, Ste. Methode, Peribonka, near the Petite-Décharge, and at St. Jerome and Chambord.

Throughout the lowland the public highways are numerous and many of them are maintained in excellent condition (Plate II B). Availing themselves of the aid for permanent roads that is given by the government of the province of Quebec, many parishes are building macadamized roads on the principal routes of travel. While there are still intervals of difficult road, it is possible to go entirely around the lake by automobile.

Local telephone service extends throughout the district, and rural mail delivery has been established in many parishes.

TOWNS.

The largest town in the part of this district that is shown on the accompanying map is Roberval which has a population in excess of 3,000. Other places of importance are Val Jalbert, formerly Ouiatchouan Falls, which is the site of one of the mills of the Chicoutimi Pulp and Paper Company; Chambord, at the junction of the Quebec and Lake St. John railway; Desbiens Mills, at the mouth of Metabetchouan river; St. Jerome on the lake at the mouth of Koushpaganish river; St. Gédéon and Hébertville on the Belle; and Hebertville station and St. Joseph d'Alma near the eastern side of the map-area. All of these villages are situated on the railway, except Hébertville, which is 4 miles distant, and Alma some 8 miles from Hébertville station. The latter, which is on the Petite-Décharge, the more southerly of the two outlets of Lake St. John, is expected to be soon connected with Hebertville station by railway. Alma is also the proposed site of large industrial works that are projected by the Quebec Development Company.

AGRICULTURAL CONDITIONS.

The district is a northern one by comparison with the cultivated region of eastern Canada. Lying at latitude 48° 30′ north, nearly 3 degrees north of Ottawa, it is comparable with the clay belt region of Abitibi and Timiskaming, rather than with southern Quebec or Ontario. Yet, apparently, as good crops are raised about Lake St. John as in the Ottawa district. The season is short but the growth is rapid. There is no doubt that the winters are long and cold, yet it is equally true that farmers live in the Lake St. John district in health, comfort, and prosperity.

The settlement of the district was begun about 1860, lumbering operations along the upper Saguenay attracting attention to the excellent agricultural land around Lake St. John. For more than twenty years the only access was by way of the

Saguenay river, or by colonization roads from Quebec and Baie St. Paul; but with the building of the Quebec and Lake St. John railway, between 1885 and 1890, settlement rapidly advanced.

The surface of the farming district is in the main uniform, but is broken in places by streams flowing down from the highland to the lake. These streams have cut deep, narrow, V-shaped valleys through the fertile lands and in places increase the work of tilling the soil. Many of these coulées are 100 feet or more in depth and in their winding courses cut up the land in a way that is very unfavourable to its cultivation.

The soil is diversified. All gradations are found from heavy clay to very light, sandy soil, but a large part of it is well suited for farming purposes. It is generally free from stones and easy to work, and modern machinery is in common use.

Roots, hay, wheat, oats, and barley are the principal crops. Rye and flax are also quite extensively cultivated. Much interest seems to be taken in gardening and the common varieties of vegetables, including cabbages, turnips, carrots, and other kinds, excel. It would be hard to find better fields of wheat, oats, and barley than could be seen in the past season in the parishes of Roberval, Chambord, La Croix, and in other places. The principal grasses grown are timothy and the principal clover is red, with less alsike, and white. Corn is a small or unsuccessful crop. Apples are rarely grown.

The usual varieties of live stock are raised. Horses, sheep, swine, and fowl are commonly of good quality, but there is ample room for improvement in the quality of the cattle. Some attempts are being made towards improvement and these should be pressed vigorously. It might aid this movement if the farmers would agree to raise some one breed of cattle for a few years.

Dairying is a leading industry and is well organized. The factories are commonly fitted for making both butter and cheese, the former being the principal product while the stock is stall fed, and the latter while the stock is on pasture. The quality of the products is good. They are largely marketed in Montreal.

The following statement of farm produce shipped from various stations in the Lake St. John district during the year 1914 has been furnished by Mr. Guy Tombs, general freight agent of the Canadian Northern railway, Montreal.

Stations	Hay tons	Fruit tons	Potatoes tons	Grain tons	Live stock tons	Butter and cheese tons
Lac Bouchette	15	31	19	3	403	52
Chambord Jct	3	31	426	11	120	152
Roberval	147	294	307	23	1,065	880
Metabetchouan	363	5	160	125	501	396
St. Gédéon	223	....	170	2	502	188
Hébertville	748	19	14	120	1,334	333
Jonquiere	....	....	....	95	301	261
Ha Ha bay	....	....	....	....	46	297
Chicoutimi	....	....	....	....	852	....

The hay went principally to various lumber camps; the fruit, consisting of [illegible] to Montreal; potatoes were distributed locally and to Montreal; the grain went to the lumber camps; the live stock to Montreal and Quebec; the cheese practically all to Montreal; and the butter was sold locally and in Quebec city.

In several parishes there are public systems of water supply. The water is obtained from lakes or streams in the highlands and conveyed by pipes along the main roads and thence to each house and farm along the way. The farmers thus have running water in their houses, stables, and pastures or wherever it may be useful. The quality of the water is excellent and the supply adequate.

The water systems are owned by private individuals or companies in some places; in others they are installed by the municipality. In one parish the cost of installation was met by an issue of 6 per cent debentures amounting to $40,000. Water is supplied in this parish at a flat rate of $25 per annum to each consumer and the revenue thus obtained is said to be slightly more than 9 per cent on the debenture issue.

There is still undeveloped land in the district that is suitable for farming. Much of it, however, is on the north or northwest side of the lake where farming cannot be equally profitable with that on the south side until better means of access can be had. The completion and operation of the Quebec and Lake St. John railway from Roberval to the vicinity of chute à l'Ours, which is already in an advanced stage of construction, will bring a portion of the undeveloped district into use; but railway facilities on the north side of the lake will still be needed.

FOREST.

In an early year of the settlement, 1869, an immense forest fire, which is believed to have extended from the headwaters of the St. Maurice river to the vicinity of the Romaine, 400 miles or more northeasterly, swept over the Lake St. John district with a width of at least 100 miles and probably of much more. This entailed great immediate hardship on the settlers in loss of buildings and food supplies and even cost lives. But it seems to have facilitated the clearing of the land, and as there was little if any market for most of the timber then in growth on the farm lands, the progress of these settlements was ultimately advanced by this appalling conflagration. The national loss in the more valuable timber that was destroyed over the immensely greater area that is suitable only for timber growth was, of course, almost inestimable.

On the south side of Lake St. John the present forest is principally on the highland. Stumps and logs remaining from the original forest indicate that a growth of large pines once covered much of this district. Pine logs for lumber and jack-pine ties are still brought down the principal streams; but pulpwood, principally spruce, is by far the leading product of the forest. The timber is a comparatively young growth in many places, probably much of it has grown since the fire of 1869, though trees of greater age are frequently found. The total quantity of timber in the district is still large.

Mr. J. C. Langelier, superintendent of forest ranges of Quebec, has estimated that the upper Ashuapmuchuan basin alone contains 10,000,000 cords of spruce pulpwood.

In the part of the district examined there is only one pulpmill. This is at Ouiatchouan falls (Plate I) and is one of the mills of the Chicoutimi Pulp Company.

The same company has also established large mills on the Chicoutimi at its entrance to the Saguenay. The total production of ground wood pulp at these mills was stated in 1913 to be 285 tons per day. The Jonquières Pulp and Paper Company has also very large mills on the Sable near its junction with the Saguenay, but no statistics of production are available. While these larger mills are outside of the immediate area under consideration they are essentially important to it as offering a market for pulpwood.

The following trees and shrubs were found by Mr. H. A. Honeyman about the south shore of Lake St. John and in the adjacent district. The list shows the general character of the forest and it may also help to express the varied conditions of soil, climate, and other factors by comparison with the trees and shrubs that are characteristic of other localities.

Trees and Shrubs.

Acer pennsylvanicum	
“ *spicatum*	common
“ *saccharum*	sugar maple, only a few trees were found
“ *rubrum*	red maple, not common
“ *negundo*	Manitoba or ash-leafed maple
Betula lutea	yellow birch
“ *pumila*	low birch
“ *papyrifera*	white birch
“ *glandulosa*	dwarf birch
Alnus mollis	both common
“ *incana*	
Corylus americana	hazelnut, common on the hills along the border of the highland
Salix nigra	
“ *lucida*	
“ *rostrata*	willows, common
“ *discolor*	

Salix candida	
“ *cordata*	
“ *petiolaris*	
Populus tremuloides	aspen, on the hills as a rule
“ *balsamifera*	
Ulmus americana	rare
“ *fulva*	
Pyrus americana	mountain ash, common but not large.
Prunus pennsylvanica	
“ *virginiana*	
“ *pumila*	
Spiræa salicifolia	
Fraxinus pennsylvanica	
“ *pennsylvanica var. lanceolata*	
“ *nigra*	
Viburnum opulus	
“ *pauciflorum*	
Cornus canadensis	
“ *suecica*	
“ *circinata*	
“ *sericea*	
“ *stolonifera*	
Sambucus canadensis	
“ *racemosa*	
Amelanchier canadensis	
Myrica gale	abundant in damp pastures near the lake
Rhamnus alnifolia	
Pinus banksiana	common
“ *resinosa*	red pine
“ *strobus*	rare
Picea mariana	
“ *canadensis*	abundant at one time
Abies balsamea	balsam
Larix laricina	tamarack, mostly in wet ground
Thuya occidentalis	common cedar
Taxus canadensis	ground hemlock

INHABITANTS.

The people are almost entirely of French-Canadian origin. A few English speaking people are found in the manufacturing centres; there are none in the farming communities. Scotch family names are frequent, probably indicating the absorption of Scottish soldiers from Wolfe's army, who were disbanded at Quebec after the conquest of Canada by the British in 1763, and were induced to settle in the then new country of the lower St. Lawrence.

The present population of the counties of Lake St. John and Chicoutimi is in excess of 55, 000. Farming is the principal occupation and is as yet the only industry of importance besides lumbering and pulp manufacturing.

Education seems to be well provided for in the district. Public schools are numerous and appear to be well equipped. High school education is provided in the convents for girls, and for boys by the Christian Brothers. At Chicoutimi there is a classical college for young men and a normal school for the training of teachers for the public schools of the district.

CHAPTER III.

GENERAL GEOLOGY.

The district of Lake St. John lies within the great Pre-Cambrian protaxis of North America, commonly referred to as the Canadian shield, which extends from the lower St. Lawrence river northward to Hudson straits and westward to the vicinity of Mackenzie river. This vast area is underlain by ancient rocks of Pre-Cambrian age, but within it outliers of later rocks of Palæozoic system are known. The latter are relatively small in extent and widely separated, but they are a matter of keen interest and much importance in investigations bearing on the early geological history of the North American continent. Two small outliers are found in the district of Lake St. John, and their character and relations to the earlier formations are essential features of the geology of the region.

REGIONAL.

The Palæozoic outliers about Lake St. John, so far as known occur only between 80 and 150 miles west of Tadousac on St. Lawrence river which there follows the southeastern edge of the Pre-Cambrian protaxis. Other isolated occurrences of Palæozoic rocks are found nearly 200 miles to the northward in the vicinity of Lake Mistassini. These are of Cambrian age, those of Lake St. John are middle and upper Ordovician. Three hundred and fifty miles westward of Lake St. John, Silurian strata of Niagara age occur near Lake Timiskaming; and larger and more remote occurrences are known of Cambrian in Labrador peninsula and of Silurian southwest of James bay. The intervening areas between these widely separated outliers are very imperfectly known nor are we any better acquainted with the conditions by which the outlying remnants have been preserved.

LOCAL.

The area that has been studied in detail (see map) includes a large part of one of the Palæozoic outliers near Lake St. John as well as a portion of the adjacent Pre-Cambrian; it measures approximately 30 miles from east to west and 15 miles from north to south, giving it an area of 450 square miles. Of this area about one-half is occupied by the lake in which there are a few islands. The length of shore-line included in the map from Pointe Bleue on the northwest to the Petite-Décharge on the northeast is approximately 40 miles.

The area comprises the country adjacent to the south half of Lake St. John for distance from the lake of 4 miles or more to the west, the same distance on the south, and 6 miles eastward.

TABLE OF FORMATIONS.

Quaternary			Alluvium and swamp deposits
			Stratified clays and sands
			Boulder clay
		Unconformity	
Palæozoic	Ordovician	Richmond	Limestone
		Utica	Shale
		Trenton	Limestone
		Unconformity	
Pre-Cambrian		Roberval	Granite and gneiss
		Intrusive contact	
		Saguenay	Anorthosite
		Intrusive contact	
		Laurentian	Gneiss
		Intrusive contact	
		Grenville	Limestone

DESCRIPTION OF FORMATIONS.

Seven formations exclusive of the Quaternary, occur in the district and all but the Grenville are developed sufficiently to occupy integral parts of the map-area. Owing to the deep soil in the lowland area the boundaries of the formations as shown on the map in that part of the field are far from precise and in many places are little more than conjectural. The actual rock exposures are shown on the map and the boundary lines presented are the best inferences that could be made, while in the field.

In the highland it was not found practicable to differentiate the different members of the Pre-Cambrian. The rocks there are well exposed, but the relations of the different members in many places are so intricate that they could not be shown except on a map of very large scale, not less than a few hundred feet to the inch. This part of the area, too, is generally wooded and difficult of access and even an approximate differentiation of the various members of the Pre-Cambrian would necessitate more work than could be accomplished in the season. As there is no economic question involved, and as the general structure could be ascertained from the lowland and border of the highland the members of the Pre-Cambrian were not separately designated on the map of the highlands. The highland, however, was traversed in all parts, but the extreme southwest corner, at intervals of a few miles at most. Its more detailed mapping would have involved an unwarranted labour and expense.

Grenville.

Distribution. The Grenville formation is represented by two small occurrences in lots 1 and 3, range I, of the township of Metabetchouan. Neither exceeds a few hundred square feet in area. The occurrence on lot 1 is on the wall of the fault scarp which bounds the lowland area about 400 feet above the level of Lake St. John, where it has been quarried for road metal. The exposure is from 4 to 15 feet wide and extends for 150 feet northwesterly. The other occurrence in lot 3, less than half a mile distant, is nearly 100 feet higher. It is exposed through the drift principally by a small solution cavern in the rock 6 or 7 feet in diameter.

Lithology. The Grenville here found consists essentially of crystalline limestone or calcite, white in colour, and coarsely crystalline. In many places there are seams of cherty material running along the cleavage planes of the calcite. A small development of a micaceous schist, composed almost entirely of biotite, is probably an extreme phase of the alteration of the crystalline limestone.

Structural Relations. The Grenville is intruded by the Roberval granite, especially by a porphyritic phase of that rock, in lot 1, range I, of Metabetchouan, and by anorthosite at the edge of the solution cavern mentioned as occurring in lot 3. Near the latter locality, also, a small exposure of Grenville is cut by a gneiss which is itself intruded by a phase of anorthosite. This gneiss is believed to belong to the Laurentian rather than to the later Roberval type, although the exposure in itself does not give other indication of its age.

Laurentian.

Distribution. The Laurentian does not appear on the accompanying map as separately occupying any considerable area. It, however, forms an important part of the underlying rock in the area shown as undifferentiated Pre-Cambrian. It appears in the northwest part of lot 1, range II, of the township of Roberval, and it is well shown in lot 21, and elsewhere in range III, of the township of Ouiatchouan. In the township of Metabetchouan it is the rock of the numerous exposures along the Quebec and Lake St. John railway from range II, southward to and beyond the limits of the map-area.

Lithology. Typically, this is a grey crystalline rock with a fine gneissic structure. The grey colour of the rock as a whole is produced by the narrow, alternate banding of the black or dark ferromagnesian minerals with the quartz and feldspar, which are white or slightly pink.

In the thin section the essential minerals may be seen to be plagioclase of medium basicity, orthoclase, hornblende, quartz, and biotite. The noticeable accessory constituents are magnetite, pyrite, and apatite. The hornblende is green, somewhat pleochroic, the absorption scheme being $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. The highest extinction angle measured in the zone of the clinopinacoid was 24 degrees.

Metamorphism. As is commonly found in this formation, the Laurentian gneiss is finely and evenly banded. The segregation of the light coloured from the dark coloured minerals is very complete and narrow individual bands of each colour persist to great length. Bands a few inches in width preserve their identity and parallelism in places for distances of 50 or even 100 feet, and often closely simulate the bedded structure of sedimentary rocks. The fineness and evenness of the gneissic banding indicates an original fluidal arrangement of the magma as its cause, rather than mechanical deformation.

Structural Relations. As has been already stated, the Laurentian gneiss has intruded the Grenville. It has also been intruded by the next two succeeding formations, the anorthosite and the Roberval granite. It is these features that determine its relative age, and lead to its correlation with the Laurentian of other parts of the Pre-Cambrian shield.

A structural feature that frequently distinguishes the Laurentian from the Roberval is that the prevailing strike of the Laurentian, where not locally disturbed by later intrusions, is north 8 or 10 degrees west with high dip, while the gneissic phases of the Roberval commonly strike 30 or 40 degrees east of north and have lower dips.

Anorthosite.

Distribution. Anorthosite occupies the southeastern part of the map-area, and extends far beyond it to the north, east, and south. In the southwestern part of the area examined, anorthosite also occupies a large part of the area between the Ouiatchouan river and the township of Caron. But it is here so intimately associated with granite of the Roberval type that it was not found practicable to represent them separately on the map. The anorthosites in both parts of the area are probably only portions of a large area of this rock which has been shown by Dr. F. D. Adams to extend northeasterly between the Shipshaw and the Little Peribonka rivers for a long distance beyond Lake St. John, and to comprise a total area of not less than 5,000 square miles.

Lithology. This formation has been described in detail by Dr. F. D. Adams, whose description[1] is briefly summarized. The Saguenay anorthosite consists of basic plagioclase, in some places labradorite, in others bytownite. Augite, hypersthene, and at times also hornblende, and biotite are other constituents. Olivine also is frequently present, and occasionally spinel. Ilmenite forms large masses in certain places.

The rock is of medium texture, but the coarseness of grain varies considerably and often quite abruptly from place to place. The crystals of the coarse granular varieties frequently increase in size until the plagioclase individuals reach a foot or more in diameter.

Where olivine is the principal ferromagnesian mineral the rock becomes a troctolite. Olivine crystals are surrounded by very well developed corrosion zones. In typical cases these zones consist of two differently orientated parts, an inner zone of colourless pyroxene and an outer one of green actinolite. [2]This phenomenon is ascribed to the influence of the plagioclase magma on the olivine before the complete solidification of the former.

Metamorphism. Foliation more or less complete can be seen in the anorthosite in many places. Even in cases of extreme granulation there is no change in the chemical composition of the rock. This mechanical deformation is regarded by Dr. Adams as an unusual kind of kataclastic structure that has been developed slowly, under great pressure and a high temperature.

Structural Relations. The anorthosite is intrusive into the Laurentian and is intruded by the Roberval granite.

Evidence of Age. The age of this peculiarly interesting formation cannot be precisely determined. It is post-Laurentian and appears to have suffered much less diastrophism than that formation. It is also older than the Roberval granite which is provisionally classed with the Pre-Cambrian, but is only actually known to be of earlier age than the Trenton in this district.

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[1] Neues Jahrbuch für mineralogie etc. Beilageband VIII, Stuttgart, 1893.

[2] F. D. Adams, "Notes on certain silicates occurring about olivine," Am. Nat., Nov. 1885.

Roberval.

Distribution. This formation is widely developed in the district and forms a large if not the major part of the area shown on the map, as undifferentiated Pre-Cambrian. It is most conspicuously developed, however, in the townships of Roberval and Ouiatchouan, where it is the principal rock that is exposed above the drift.

Lithology. The rock of this formation is a pinkish or flesh-coloured granite of coarse texture. Feldspar is the most conspicuous constituent, and gives the general colour to the rock. Quartz is present in variable amount, and biotite and hornblende are also visible in hand specimens.

In the microscopic section the feldspar is found to be mainly microcline. There is also a little oligoclase and occasionally a crystal of labradorite. In sections considered typical of the larger masses quartz is next to feldspar in abundance. Biotite and hornblende are the remaining essential constituents. Pyrite, magnetite, sphene, and apatite are commonly present in accessory amounts. Much of the rock has a gneissic structure and where this structure is well developed the coarse feldspars give rise to a well pronounced augen-gneiss (Plate III A).

Chemical Composition. A sample of the Roberval granite selected from one of the quarries in the township of Roberval was analysed by M. F. Connor of the Department of Mines, Ottawa. Its composition was found to be as follows:

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K	TiO_2	H_2O	Tota
70·67	14·87	0·84	1·62	0·20	1·72	3·64		35	0·20	=99·65

The following is norm of this rock ca according to the methods of the quantitative classification

Orthoclase	35·58	per cent
Albite	30·30	“
Anorthite	6·39	“
Quartz	22·50	“
Ilmenite	0·61	“
Magnetite	1·16	“
Diopside	1·67	“
Hypersthene	1·36	“
	99·57	

Its place in the quantitative classification is, therefore,

Class I	Persalane
Order IV	Britannare
Rang 2	Toscanase
Sub-rang 3	Toscanose

The actual mineral composition of the rock corresponds very closely with the norm. The principal exception is that the minerals hornblende and biotite actually present are represented by the standard minerals diopside and hypersthene.

Examination in the field and in thin sections shows that the Roberval granite in the eastern part of the district contains less quartz, the feldspar becomes largely microperthite, and the rock in character approaches a syenite. It probably passes by gradation into a basic syenite described by Dr. Adams, which is prominent in the vicinity of Chicoutimi and of Ha Ha bay.

The Roberval may be compared with the Picton granite of the Thousand islands, and the basic syenites with rocks of similar character in the Adirondack region described by Professor Cushing.[1]

Metamorphism. In the major portion of this formation there is a more or less plainly developed gneissic structure, but in many parts the rock is better described as a massive granite. In large individual bosses that have been denuded by ice action, the central portions appear to be massive, while near the margin gneissic structure is quite apparent. This seems to indicate that the gneissic structure is due to original fluidal arrangement rather than to secondary mechanical deformation. One possible exception to this is worthy of note. In lot 5, range B, of the township of Roberval, where several small quarries afford good exposures, the granite cannot be said to show any decided foliation. There is a slight "rift" parallel to the jointing such as is found in practically all granites, but nothing that could be called a marked foliation. At a quarry in lot 1 of the same range, half a mile north of the last, the granite shows a slight but noticeable tendency towards foliation. This foliation becomes uniformly more pronounced in going northwards. At a farther distance of 2 miles, where the fault

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[1] Cushing, H. P., Bull. N.Y. State Mus., No. 145.

is reached, which gives rise to the Côte St. Prime, a ridge 100 feet in height above the plain on the northwest, the rock has become a well-defined gneiss. The average strike is north 40 degrees south and mean dip is south 50 degrees east. The trend of the fault is north 60 degrees east and the downthrow on the northwest side 35 degrees. The dip is, therefore, away from the fault. This progressively increasing foliation as the fault is approached suggests that the foliation is in this case, at least, a feature of dynamic metamorphism.

On the other hand it must be observed that in exposures of the granite, found to the west of the massive rock seen on lot 5, range B, of Roberval, foliation also becomes noticeable. On the south and west of the massive granite the rock is covered by drift or limestone. The suggestion that the granite tends to become gneissoid towards the periphery of the mass may still be true, this feature being accentuated in the vicinity of the fault mentioned.

On the Côte St. Prime fault-scarp, on the east side, the road leading from Roberval to St. Félicien, is the only later dyke that has been found in the Roberval. It is 15 inches wide, standing vertically and running north 50 degrees west. The contact is not welded to the wall rock and it apparently was intruded after the granite had thoroughly cooled. The rock of which the dyke is composed is a minette.

Structural Relations. The Roberval is intrusive in relation to the earlier formations. Its relation to the Grenville is well shown in lot 1, range I, of Metabetchouan; and in lot B of the same range anorthosite is intruded by the Roberval. The relation of the Roberval to the Laurentian is best seen in the township of Ouiatchouan, especially in range III. Here stocks of Roberval granite occur within the Laurentian deflecting its strike, and sending off dykes and irregular arms into that formation. A small stock in this locality is represented in Figure 1.

The succeeding Trenton formation is unconformable to the Roberval and was deposited on it after a long period of erosion (Plate IV B).

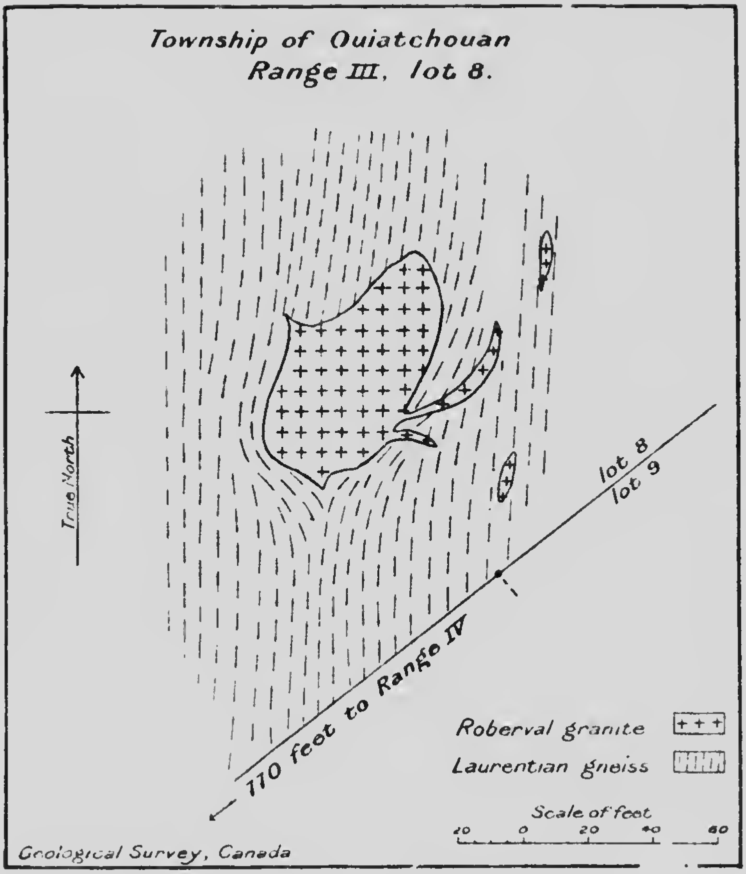

Figure 1. Stock of Roberval granite intrusive in Laurentian gneiss.

Trenton.

Distribution. The Trenton is confined to the lowland, where its precise distribution is greatly obscured by the deep soil. The map shows the actual outcrops in the area examined in detail and the boundary lines that were assumed in the field from the outcrops and topography. Generally speaking the

Trenton, in places overlain by Utica, occupies the lowland west of the anorthosite, except where certain hills and ridges of underlying granite are exposed. Near Pointe Bleue the ridge known as Côte St. Prime extends from the front of the highland nearly to the lake; and in the township of Metabetchouan the rim of the lowland basin also approaches so near to the lake as to almost divide the Trenton area. But in both places the Trenton appears along the water's edge so frequently as to justify the assumption that it persists beneath the lake and is continuous, barring local faults, with the Trenton of Isle à Pierre à Chaux near the Petite-Décharge.

West of Côte St. Prime, the Trenton area again widens out from the lake and is found in the vicinity of St. Félicien outside of the limits of this map, in such altitude and position as to indicate that it underlies much of the Ashuapmuchuan valley as far as the township of Demeules at least, and may extend even farther westward, possibly to Pimonka rapids.

In the eastern part of the area examined, Trenton was not found east of the Koushpaganish river. The anorthosite usually presents a more rugged topography than the granites and gneisses, and the surface is generally higher, which seems to account for the absence of Trenton outliers within the larger anorthosite area.

A Trenton outlier was reported by Abbé Laflamme near Ha Ha bay, but it was not visited. A larger area of limestone, also discovered by Laflamme, north of Chicoutimi, was, however, examined along the line between the townships of Simard and Tremblay. The mode of occurrence is similar to that near Lake St. John, and it is at approximately the same altitude, that is below 450 feet above sea-level. There is thus, as Laflamme has pointed out, an area 70 miles in length over which Trenton deposits now occur in isolated outliers. The topography indicates that the Trenton area originally was, and probably now is, much larger.

The thickness of the Trenton was estimated by Logan at 100 feet. This thickness is apparent in several places, but no conclusive evidence of a greater thickness has been found. The difference in level of exposures in places amounts to several hundred feet, but the prevalence of post-Ordovician faulting makes calculation of thickness on this basis very unsafe.

Lithology. The Trenton is a grey, rather compact limestone, in fairly uniform beds of a few inches in thickness. It is generally fossiliferous, and in places highly so. In a few instances pebbles of the underlying granite are included in the limestone forming a basal conglomerate, but this is rarely noticeable and nowhere prominent.

Metamorphism. The major part of this formation appears to rest in the attitude in which it was originally deposited. An average dip of 5 degrees towards the lake prevails along the south shore, and the portions that vary from this are relatively very small. Yet faults are numerous. Within the formation many local faults probably of small displacement are found. The disturbance of the strata caused by them is only local and apparently of small amount.

Around the margin of the basin there are faults of larger displacement and of greater significance. In all places where the Trenton has been found within a few hundred feet or less of the foot of the escarpment which separates the highland from the lowland, the Trenton is tilted so as to dip away from the older crystalline rocks of the escarpment at angles higher than those of the original bedding planes. The tilted beds are irregularly warped and in places broken into a confused mass nearer the actual contact (Plate III B).

Erosion is evidenced by solution along joint planes, and the development of caverns and sink holes by "lost" streams.

Structural Relations. As the preceding paragraph suggests, the relation of the Trenton to the older formations is one of unconformity to the underlying rocks and of faulting against the adjacent edge of the highland. Faulting is also well shown along the northwest foot of Côte St. Prime west of the Pointe Bleue Indian reserve, well within the lowland basin, where the Trenton is brought into abrupt contact with the Roberval granite-gneiss. This fault is expressed in relief by a scarp which stands from 80 to 100 feet above the plain on the northwest (Plate II B). The trend of the fault is about north 60 degrees east or 20 degrees east of the strike of foliation in the gneiss, which dips to the southeast at an angle of 35 degrees. At the foot of the scarp the Trenton is tilted at angles of 25 degrees to 55 degrees away from the fault (Plate IV A), but this dip decreases in a few yards to 5 degrees or 6 degrees. Similar structural relations are to be seen along the foot of the escarpment which separates the lowland from the highland. Four hundred feet from the foot of the Ouiatchouan falls, Charlevoix, range II, lot 22, Trenton limestone, exposed in a small quarry, dips away from escarpment at an angle of 32 degrees. This dip declines to 5 degrees in the next 300 feet away from the falls. The escarpment over which the river falls is 245 feet high and has a general slope of 35 degrees (Plate I).

In range I of the township of Metabetchouan the escarpment bounding the lowland closely approaches the lake shore from lot 30 to lot 40. In parts of this section the escarpment presents a precipitous face, which rises near lot 30 to a height of 800 feet above the lake. Anorthosite which seems to preserve cliff faces better than the gneisses forms the main part of the escarpment there.

Along the lake shore the Trenton is generally exposed in a narrow and faulted band. In following this band eastward along the lake shore a succession of changes in the attitude of the rock is found. The lowest dip is usually 15 degrees in a northeasterly direction. From this the attitude of the strata rapidly changes in going east to a higher and more easterly dip until the dip becomes 50 degrees due east. After passing a short covered interval the strata reappear at a dip of 15 degrees or 20 degrees and after passing through the same changes of dip and strike, again abruptly disappear.

Small patches of Utica commonly overlie the Trenton where the dip is low, but disappear as the beds become more highly tilted. Five of these warped blocks occur within a mile, evidently separated by faults which run about north 10 degrees east from the foot of the escarpment easterly beneath the lake. Their direction is approximately parallel to an offset in the course of the escarpment which takes place between lots 39 and 42 in the first range of Metabetchouan.

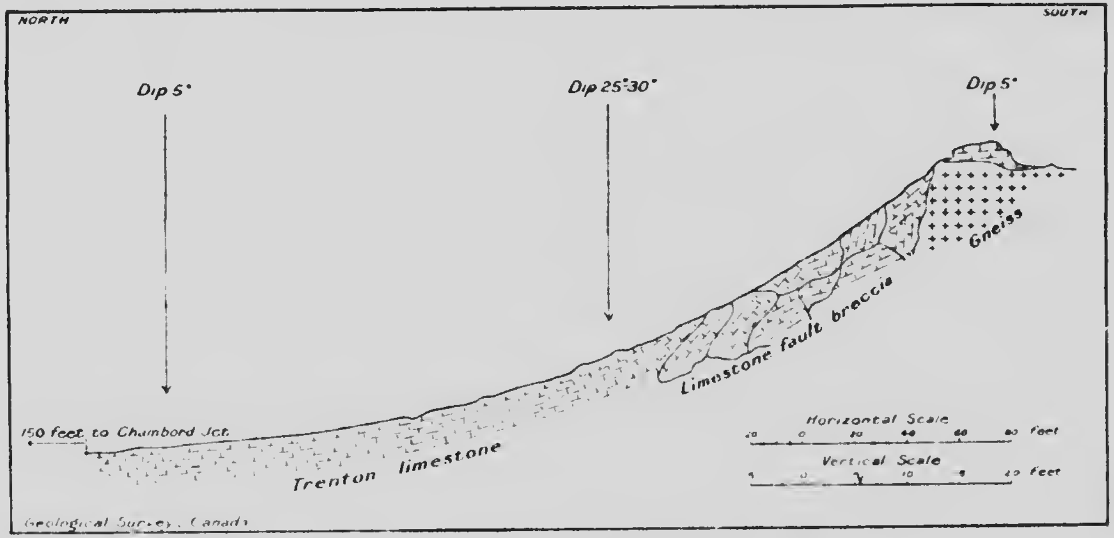

Figure 2. Fault scarp near Chambord Junction.

Some of these faults find expression in series of small step-faults which appear to extend only a short distance into the foot of the escarpment. They cause a succession of sharp rises and flat intervals along the wagon road.

The relation of the Trenton to the older formation is also well shown a few yards south of the railway station of Chambord Junction (Figure 2). The front of the escarpment is low at this point, about 50 feet above the Quebec and Lake St. John Railway track, which runs at its base. At the railway, 550 feet above sea-level, and on the top of the escarpment, the Trenton limestone dips towards the north at an angle of about 5 degrees. For 240 feet south of the railway the surface rises, but it is only in the last 100 feet of this section that the dip is increased. In the following 225 feet the limestone has a dip of 25 or 30 degrees, or is broken and tilted out of position. At this point a front of Laurentian gneiss is exposed with a thin covering of limestone resting on it, apparently undisturbed, at the normal angle of deposition, dip about 5 degrees to the north. This is the greatest altitude at which the Trenton has been found in place, viz., 600 feet above sea-level.

Very similar conditions of contact between the Trenton and gneiss are found in the south part of range VI, in the township of Ashuapmuchuan, near the boundary between lots 41 and 42. This is 7 miles west of the map-area.

Where the Trenton is exposed in undisturbed contact with the underlying rocks, a striking feature is the small development of basal conglomerate. Such an exposure is found in a cutting on the Quebec and Lake St. John Railway extension, about 1,000 feet north of the [illegible] boundary of the Pointe Bleue Indian reserve (Plate IV B). The granite (Roberval) is slightly rusty for a distance varying from 1 to 12 inches below the contact, but is in no sense notably decomposed. At the base of the limestone a layer less than one inch thick contains small scales of the underlying granite in places, and commonly the scales are perceptible only on minute examination. The lowest beds of limestone follow the undulations of the surface of the granite, but these undulations are soon lost with the thickening of the beds in proceeding upwards so that the limestone a few feet above the contact assumes a uniform, even bedding.

At the contact of the Trenton with gneiss near Chambord station, mentioned above, the gneiss is disintegrated for 2 feet or more below the contact, but there is very little development of basal conglomerate.

In lot 6, range A, of the township of Roberval, a small granite boss is exposed above the drift flanked by a few feet of limestone. On the south side of this hill a few pebbles of quartz and granite can be seen in the limestone for a distance of 12 or 15 inches from the contact. The pebbles are noticeably well rounded and smooth, suggesting that they were waterworn before they were included in the limestone. Similar occurrences are noted in other places but nowhere with any noteworthy amount of conglomerate.

Mode of Origin. The only places where the base of the limestone is exposed are near the present margin or on the sides of some bosses of underlying granite. These are above the level of the lake, while the Trenton limestone and overlying Utica pass beneath the lake. Consequently the character of lowest beds of the Trenton is not known.

Since the formation is composed wholly of limestone, as far as can be seen, without any noticeable amount of argillaceous material, it may thus be considered to be a deposit formed in comparatively deep water which was brought in by a rapid submergence. Shallow water deposits of early or pre-Trenton time may, and probably do, occur under the limestones in the central part of the basin.

Age and Correlation. The age of these isolated sedimentaries has long been recognized on fossil evidence as Trenton. Collections of fossils made during the past season have been submitted to E. M. Kindle, invertebrate palæontologist of the Survey. These collections were referred by him to Dr. P. E. Raymond who has a personal knowledge of this district. Dr. Raymond's report includes the Utica fauna and will be found in connexion with the discussion of that formation (page 38).

Utica.

Distribution. The Utica occurs at intervals along or near the shore of Lake St. John in the townships of Roberval, Charlevoix, and Metabetchouan. The best exposures are at Pointe Bleue, the mouth of the Ouiatchouan, Isle de la Traverse, and on the lake shore, north of Chambord Junction. It is not improbable that several or all of these exposures are connected beneath the lake. At low water the shales of Isle de la Traverse can be followed nearly, if not quite, to the nearest point on the mainland.

In range A of Charlevoix, beside the road which follows the lake shore, the rock thrown out in excavating a well on lot 4 (?) is Utica shale. The well is said to be 21 feet deep, the lower 11 feet being in shale. The aqueduct of the parish of Chambord has been cut in shale in several places along the line between ranges B and I, Charlevoix, between lots 1 and 5.

Near St. Jerome there are beds of rock debris composed almost exclusively of fragments of shale, which suggest that the underlying solid rock is Utica. But, since no actual exposure was found, the Utica is not indicated on the map, hough it is probably present. The debris is well shown beside the road between the townships of Metabetchouan and Caron, a few hundred yards south of St. Jerome church.

The thickness of this formation was estimated by Logan to be 100 feet or less. No evidence has been found that its thickness is even as great as this; yet, owing to local faulting, the maximum can only be conjectured.

Lithology. Argillaceous shales form the prevailing rock of this formation. Dark grey or black in colour, they weather to a light or rusty brown, according to the amount of included pyrite that is oxidized along joint and cleavage planes. The lower beds which are transitional from the Trenton to the Utica are in places alternately calcareous and argillaceous. The purely argillaceous beds immediately above these appear to be more highly bituminous than the rest of the formation. Some of these might be characterized as oil-shales.

In some beds, especially near the Ouiatchouan river and on Isle de la Traverse, graptolite remains are so plentiful as to occupy 20 or 25 per cent of the surface on bedding cleavage planes.

Metamorphism. The Utica shale yields readily where it is exposed to wave erosion around the lake shore. The rock debris thus formed accumulates in places to many feet in thickness. The rock particles being flat are commonly arranged in rude parallelism, and rest either horizontally or inclined at a common angle. Through the percolation of calcareous waters from the shore, this "shingle" becomes consolidated in places and forms a recent conglomerate. Examples may be found on the lake shore near the Ouiatchouan river or on the east side of Isle de la Traverse. Similar, but unconsolidated material occurs near St. Jerome. This has been noted above.

The Utica is very regularly jointed and in much smaller blocks than are found in the Trenton. The direction of the major joint planes is north 60 degrees east, the minor being at right angles to this direction (Plate V).

Faults occur in the Utica as well as in the Trenton. In lot 6, range A, of Roberval, a fault trends due north along the lake shore, affecting both Trenton and Utica (Plate III B). The downthrow is on the east side. A band of friction breccia up to a foot in width is developed along the fault line, and the rock on the downthrow side is tilted at high angles for about 10 feet from the fault. This fault can be traced in a curving line, southwards, for 4,000 feet.

The faults described as affecting the Trenton in the first range of Metabetchouan also affect the Utica.

In lot 45, range I, of Metabetchouan, 200 yards from the lake shore, a fault occurs giving a dip to the strata of 19 degrees towards the lake. In lot 56, range C, of the same township, and lot 1, range B, of Charlevoix, two small step faults were found on the road between these townships. The steps are well expressed in the topography in several places between this and the locality referred to as in lot 45, and can also be traced some distance northwestward in the township of Charlevoix.

Structural Relations. The Utica has not been found in contact with the Pre-Cambrian except for a short distance near the lake shore in range I of Metabetchouan where the contact is due to a fault which brings the edge of the downthrown Utica against anorthosite. In its relation to the underlying Trenton, the Utica is quite conformable wherever the relations are exposed. This is plainly the case at Pointe Bleue, in range A of Roberval, on the Ouiatchouan river, and in range I of Metabetchouan.

Mode of Origin. The shales of which this formation is mainly composed are consolidated muds and silts. They were, therefore, marginal or shallow water deposits. The material composing them is finely comminuted debris which was probably derived from the shores of the Ordovician sea.

Age and Correlation. The stratigraphic relations show the Utica to be the next younger formation to the Trenton and to have followed it without any time break between them. The palæontological evidences for the correlation of the formations here referred to the Trenton and the Utica are given in the following report on the fossils collected.

Report by P. E. Raymond on a Collection of Fossils from Lake St. John. Collected by Mr. John A. Dresser.

The fossils are in two kinds of matrix, a light-coloured limestone and a dark carbonaceous shale.

The fossils in the limestone are:

ANTHOZOA.

Streptelasma corniculum Hall, r.

BRACHIOPODA.

Rafinesquina alternata (Emmons), r,
R. minnesotensis Winchell, r,
Strophomena filitexta Hall, r,
S. emaciata Winchell and Schuchert, r,
Plectambonites sericeus (Sowerby), c,
Rhynchotrema increbescens Hall, c,
Zygospira recurvirostris (Hall), r,

PELECYPODA.

Ctenodonta nasuta Hall, r,
Cyrtodonta parva? Ulrich and Scofield, r,

Vanuxemia rotundata Hall, r,
V. dixonensis Meek and Worthen, r,

GASTROPODA.

Archinacella subrotundata Ulrich and Scofield, r,
Scenella affinis Ulrich and Scofield, r,
Bellerophon cf. *B. subglobosus* Ulrich, r,
Bellerophon sp. ind., r,
Tetranota obsoleta (Hall), r,
Phragmolites compressus Conrad, r,
Eccyliomphalus contiguus Ulrich, r,
Eotomaria dryope ? Billings, r,
Lophospira peracuta Ulrich and Scofield, r,
L. bicincta (Hall), c,
Hormotoma bellicincta (Hall), r,
Hormotoma sp. ind., r,
Trochonema beloitense Whitfield, r,
T. umbilicatum Hall, c,
T. rugosum ? Ulrich and Scofield, r,

CEPHALOPODA.

Oncoceras sp. ind., r,
Orthoceras 2 species, r,

TRILOBITA.

Ceraurus dentatus Raymond and Barton, r,
Thaleops ovatus Conrad, r,
r, signifies rare; c, common.

The most notable thing about this fauna is the preponderance of the mollusca. Brachiopods are not only few in species, but actually rare. The collection contains few significant species, but seems to indicate a horizon either in the Black River or at the very base of the Trenton, more probably the latter. It seems to be about the horizon of the Rockland beds of the Ottawa district, the strata on Grand island in Balsam lake in the Simcoe district, and the basal Trenton at Jacksonburg, New Jersey.

The fossils of the shale are:

GRAPTOLITHIDA.

Glossograptus (*Orthograptus*) *quadrimucronatus* (Hall), c,

BRACHIOPODA.

Leptobolus insignis Hall, c,

CEPHALOPODA.

Endoceras proteiforme Hall, r,

TRILOBITA.

Triarthrus glaber Billings, c,

The fauna of the shale is one that is ordinarliy called Utica, but in recent years it has several times been hinted that the shales in the Lake St. John district were of Trenton age. In the fauna listed above there is only one fossil of any stratigraphic importance, namely *Glossograptus quadrimucronulus.* Lake St. John is the type-locality for this species, and Ruedemann has given varietal names to the forms of this species found in New York, so that the position in the Ordovician can not be determined from American localities. In Europe the typical form seems to be present. In Scandinavia it is common in the upper part of the zone with *Pleurograptus linerais*, that is, in beds corresponding to our upper Trenton and Utica. In Great Britain it occurs abundantly in the zone of *Pleurograptus linearis*, the horizon of our Utica. I am, therefore, inclined to continue the established [illegible] of calling the shale at Lake St. John, Utica.

Richmond.

Distribution. So far as known the principal occurrence of the Richmond formation is on Isle aux Couleuvres or Snake island where it occupies the entire island. The island is somewhat more than a mile long and less than half a mile wide. It lies about 2 miles east of the town of Roberval, which is on the nearest part of the adjacent mainland. The rocks are exposed, *in situ*, at only two places on the island, but the abundance of angular loose rocks on the greater part of the shore-line probably makes it safe to conclude that the silty soil which covers the greater part of the island is everywhere underlain by this formation at no great depth. The thickness of rock actually exposed is only a few feet. The beds are nearly or quite horizontal.

There is also a small exposure of Richmond on the adjacent mainland at Pointe Platte. It occupies only a few hundred square feet and is nearly horizontal in position. It is surrounded by heavy clays which obscure its relations to other rocks.

Lithology. The rock is a grey limestone, somewhat argillaceous in certain places, and in others, cherty. Some of the coral remains that occur in it are more or less silicified.

Metamorphism. A fractured appearance of the surface, which is very noticeable, especially on the west side, appears to be due to original mud cracks, rather than to later jointing.

A point which projects north-northwesterly from the northern part of the island, is continued beneath the water as a reef of broken rock, for half a mile or more. Accentuated by boulders which have been accumulated against it, it is a serious obstacle to navigation at low water. It seems quite possible that this represents a continuation of the fault noted in the Utica near the shore-line of the lake in range A of Roberval.

Structural Relations. There is nothing definitely ascertainable as to the structural relations. The clayey character of the limestone on the south side of Isle aux Couleuvres suggests that it may have been deposited in regular sequence upon the Utica, thus indicating a renewed submergence near the close of the Ordovician. But in view of the numerous faults in the district it is very probable that, however it may have been deposited, this isolated occurrence has been faulted into its present position.

The reef of jagged rocks on the northwest side of the island referred to in the preceding section may indicate a fault. The rock can be seen beneath the water, nearly at the surface, in extremely low water. The downthrow of the fault which corresponds in direction and position with this reef on the mainland is on the east side.

Correlation. The following discussion of the correlation of the beds and faunas of Snake island by Dr. Aug. F. Foerste[1] is based upon collections made by Dr. Foerste.

"Outcrops occur on Snake island only in a small patch along the southeastern shore, near the northern end of a rocky beach; but most of the fossils occur in loose and more or less rounded fragments of rock which cover the beach for a distance of 400 or 500 feet along the shore, and for 50 to 160 feet inland, as far as the most distant points reached by the waves in the roughest weather. A second area covered with fossiliferous rock fragments lines the shore a short distance north of mid-length on the eastern side of the island.

"At the small patch of exposed rock on the southeast shore the dip is eastward at about 5 or 10 degrees. The bedded rock does not rise more than 2 feet above lake level, the surface

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[1] Foerste, A. F., Geol. Surv., Can., Mem. 83, 1916, pp. 155-157.

being glaciated. The glacial striæ are approximately north and south in direction. In winter the ice freezes tight to the rock and pulls it loose. The waves break up the ice and throw it upon the shore; here the ice melts later and releases the rock. The rock which is *in situ* contains: *Streptelasma rusticum*, *Columnaria alveolata*, *Calapoecia huronensis*, *Lyopora goldfussi*, *Tetradium huronense*, *Stromatocerium huronense*, and *Palaeophyllum divaricans*.

"It is probable that the loose specimens of *Beatricea undulata*, and those of *Ortonella hainesi* which occur in the same rock fragments as *Calapoecia huronensis* originate at about this same horizon.

"The horizon containing the above-named fossils apparently corresponds to the Gore Bay coral zone of Manitoulin island and belongs about the Waynesville member of the Richmond.

"It is evident, however, that another horizon must be present below water level. The rocks from this source are known only from the fragments tossed up by the waves. These strata contain quite a different fauna and some of the loose rock fragments are distinctly different lithologically from the actual exposures on the island. They are thinner bedded, more compact in texture, and bluer in colour. From the loose fragments coming from these lower horizons the following species were obtained:

Rhombotrypa quadrata.

Strophomena, of the *planumbona* type, with about the same triangular outline as those identified as *fluctuosa* at Vars, east of Ottawa, but without any evidence of concentric folds.

Strophomena resembling *sulcata*.

Platystrophia clarksvillensis.

Catazyga headi; the proposed variety *borealis* evidently has no standing whatever.

Ortonella hainesi

Orthodesma canaliculatum

Modiolopsis cf. *concentrica*

Pholadomorpha pholadiformis, *Ctenodonta* cf. *albertina*.

Archinacella, *Cyrtolites ornatus*, *Oxydiscus*, *Liopsira micula*, *Helicotoma*.

"These fossils, notwithstanding the low eastward dip of the few layers of rock seen *in situ*, are regarded as belonging to a lower horizon than the coral zone which forms the actual exposures on the island. They occur lower at all other localities in the provinces of Ontario and Quebec, so that, no matter what their range may be elsewhere, in these provinces they indicate a lower horizon. This horizon is correlated with the Waynesville member of the Ohio Richmond."

Quaternary.

Distribution. The surface deposits are much more abundant and more diversified on the lowland than in the highland portion of this district. In the glaciation of the region, the lowland apparently trapped a large share of the till and other glacial debris. Also, during the following submergence, the lowland was entirely covered by water, and so became an area of deposition, while the highland, being above water level, was correspondingly denuded. Consequently, the Quaternary deposits on the lowland are commonly from one to several hundred feet in thickness, while on the highland they are scanty and irregular.

Glaciation. The general direction of ice movement in this region was towards the south-southwest. A. P. Low[1] has given the mean direction as south 5 degrees west and adds that the variation from this mean does not exceed 10 degrees on either side. He also noted that the Labrador ice-sheet crossed the Lake St. John basin and carried blocks of limestone in that direction for 20 miles and to a height of 1,100 feet above the highest present exposure of that rock in the basin, and inferred that the ice had crossed the height of land between the watersheds of Lake St. John and the St. Lawrence river.

The late R. Chalmers[2] found indications of ice movement from Lake St. John southeasterly down the Saguenay river, and believed the ice to have come from a gathering ground near the present height of land between the St. Lawrence river and James bay.

The late A. E. Barlow[3] found considerable local variation

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[1] Geol. Sur., Can., Ann. Rept., vol. V, part L, pp. 47–48.

[2] Geol. Surv., Can., Ann. Rept., vol. XVI, part A, pp. 257–263.

[3] Geological and mineral resources of the Chibougamau region, Dept. of Mines, Quebec, 1911, p. 128.

in the direction of ice movement in the region between Lake St. John and Lake Mistassini The general direction of the ice striæ he stated to be south, 30 degrees west, in the northern part of the region with a gradual change to a more southerly direction in going southwards.

On the hummocky surface of the highland the general direction of glacial movement seems to vary between southwest and south-southwest. Locally, there are evidences of movement even east of south.

In the part of the lowland area that was examined in detail opportunities for precise observations of glacial striæ are not numerous. Rock exposures are comparatively few and many of them are rounded bosses of resistant igneous rock which have locally deflected the ice movement. Few striæ are preserved on the shales and they are only rarely well marked on the exposed surfaces of the limestones.

Several compass readings of the direction of striæ were taken at each of the following localities, where conditions were found most favourable. All the striæ are on practically horizontal surfaces of limestone exposed in a generally level plain. The readings given are on the magnetic meridian, the variation being approximately 19 degrees west.

Direction of Glacial Striæ.

Town of Roberval, lake shore		highwater level	S 47° W
Town of Roberval, quarry near railway	20 feet above	“	S 50° W
Roberval, range A, lot 4	40 feet above	“	S 10° W
Charlevoix, range I, lot 21		“	S 30° W
Metabetchouan, range I, lot 43	175 feet above	“	S 5° W

These readings show a wide variation in the direction of glacial movement, but they show also that the general movement took place across the Lake St. John basin in a southwesterly direction.

Character of the Formation. On the highland the soil is principally till but little assorted by water, except in places along the valleys of larger streams. Swamp deposits are numerous, but of relatively small extent and shallow depth. The drift mantle on the whole is thin and unevenly distributed.

On the lowland the Quaternary deposits are deep, commonly between 100 and 200 feet in thickness, and in places they are still deeper.

In descending order the deposits are:

Recent alluvium, lake and swamp deposits
Stratified clays
Sand and gravel
Boulder clay.

Glacial moraines and small areas of boulder clay are exposed in places. Sand plains are more numerous; but in general the soil is clay or clay loam, well stratified and free from stones for many feet below the surface. Two well developed kames are noticeable features of the landscape near St. Jerome. One occurs about a mile west of the village, the other a somewhat less distance on the east. They form long narrow ridges at least a mile in length and trend in a direction about south 50 degrees east. At the northwest ends they are approximately 75 feet above the surrounding plain, and decline gradually to its level on the southeast. They are composed of boulders, waterworn pebbles, gravel, and sandy soil. The pebbles and gravels appear to be finer towards the southwest.

Elevated shore-lines are seen in many places. The highest that were observed are, as nearly as could be measured, 225 feet above the high water level of the lake, or 566 feet above mean sea-level; they occur near the foot of the Ouiatchouan falls. Water assorted drift occurs at somewhat higher levels in the second and third ranges of the township of Ouiatchouan, west of the Ouiatchouaniche river, where it is found at an elevation of at least 600 feet. Stratified gravels occur at about 600 feet near the Quebec and Lake St. John railway, 3 miles west of Chambord Junction, but it is not clear whether they are deposits of the Champlain period or are part of a recent delta formed by a small stream which now cuts through the gravel beds. They are probably of Champlain age. Dr. Barlow[1] has reported evidences of post-glacial submergence at Pimonka rapids, 25 miles to the west of this locality, at an altitude of nearly or quite 650 feet.

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[1] "Geology and mineral resources of Chibougamau region," Dept. of Mines, Quebec, 1911.

CHAPTER IV.

STRUCTURAL AND HISTORICAL GEOLOGY.

GENERAL STRUCTURE OF THE REGION.

The geological structure of the region is intimately associated with the origin of the Lake St. John basin. The detailed descriptions given in the foregoing pages show that the lowland is bounded by a series of faults, and that it is also intersected by faults. All the faults observed are normal or gravity faults, and the displacement as far as known is chiefly vertical. It was, therefore, a region of tension rather than of compression. The direct subsidence of portions of the area, and the more effective erosion of blocks not so depressed seem to account for the basin and its peculiarly definite boundaries.

All of the direct evidence obtainable goes to show that the faulting took place after the Ordovician sedimentaries were deposited. On the other hand the extent of the faulting, the comparatively few places where the contacts can be actually seen, and the small amount of dislocation shown by the sedimentary rocks at such places suggest that a part of the faulting may have taken place earlier, or that it may have been progressive over a long period of time. Kindle[1] and Burling in a review of very similar conditions in the Ottawa district argue very effectively that the faulting took place entirely in late Palæozoic time. The Lake St. John district furnishes no direct evidence to the contrary.

The original extent of the Palæozoic formations in this region is largely a matter of conjecture. They are at present limited to the lowland area and lower levels of the adjacent highland. But as they have been relatively lowered by faulting, the sea-floor on which they were deposited may have been

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[1] "Structural relations of the Pre-Cambrian and Palæozoic rocks north of the Ottawa and St. Lawrence valleys," by E. M. Kindle and L. D. Burling. Bulletin No. 18, Geological Survey, 1915.

on the same general elevation as the surrounding highland. Palæozoic rocks of earlier age than those in Lake St. John basin occur near Lake Mistassini, and, with the rocks of Lake St. John, may indicate a continuous Palæozoic sea from the Atlantic to James bay where the Silurian is more largely represented.

SUMMARY OF GEOLOGICAL HISTORY.

Grenville. The earliest geological record in the district is furnished by the Grenville limestone. The remnants found are only sufficient to establish its identity, but from its character and associations elsewhere it is known to be a formation of sedimentary origin and of widespread occurrence, especially in the southern and eastern parts of the Canadian shield. It occurs in many places and has probably once occupied a large part of this vast region.

Laurentian. The Grenville was intruded by the Laurentian granite, which is now largely gneiss. While the gneissic structure may be primary in a considerable part, the Laurentian apparently suffered much mechanical deformation before the later formations were introduced.

Anorthosite. Next in order the anorthosite was intruded into both the Laurentian and the Grenville. It, too, is gneissic in places but the structure is probably primary, or rather was produced while the rock was in a somewhat plastic condition.

Roberval. The Roberval granite was subsequently intruded into the three older formations. It, also, has a gneissic structure in places, which is probably due in part to dynamic metamorphism. The better preservation of both the anorthosite and the Roberval suggest that they are relatively much younger than the Laurentian.

Period of Erosion. A long period of erosion appears to have followed the introduction of the Roberval. Whether the igneous rocks were intruded into overlying sediments or pierced them and formed active volcanoes cannot be told. In any event the surface must have been deeply eroded and denuded, for the Ordovician which followed was deposited on a surface of plutonic rocks, which were evidently formed at depth. The surface at the time of the deposition of the Trenton was and surprisingly free from erosional detritus.

Ordovician. In early Trenton time the present basin of Lake St. John, and probably a much greater area, was submerged and continued to accumulate marine deposits, at least until the close of the Ordovician. At some later period, possibly near the close of the Carboniferous, which was a time of important dynamic disturbance in the Maritime Provinces, extensive faults occurred in the region, resulting in a general lowering of the level of the present basin.

Glacial Period. The next event of which we have record is the glaciation of the country in Pleistocene times. This swept the surface of the country in a southwesterly direction, removing erosional detritus from the highland and depositing large amounts of the material in the down faulted lowland. Any portions of the lowland that had not been reduced to the general level would be attacked with increased force by the degrading agents and consequently there are only a few small granite bosses that rise above the present level of the plain.

Champlain. Following or accompanying the retreat of the ice the region was submerged during the Champlain period to a depth of about 600 feet. During this period the till and glacial detritus were assorted by the waters and the stratified sands and clays were laid down.

Recent. When the land was again elevated above the surface of the Champlain sea the drainage of the district assumed its present channels. In places, where the drainage is less effective, swamp and bog deposits are being formed. Many of the present streams follow pre-Glacial channels, others have been largely readjusted. By the rapid deepening of their channels in the deposits of the glacial and Champlain periods they carry much material into Lake St. John and are accordingly silting up the lake.

CHAPTER V.

ECONOMIC PRODUCTS.

Aside from farm products and lumber, the economic products of the district are clay, limestone, granite, and iron ores.

CLAY.

The clays, as far as known, are all of Quaternary age. Those most likely to be useful for manufacturing purposes are deposits of the Champlain period, which are frequently found in thick beds, free from boulders or sand beds. The best from an economic point of view are found a few miles east of the map-area, on the east bank of the Saguenay river, at the mouth of the Rivière aux Vases. The thickness of exposed clay at this point is more than 100 feet. The deposit is adjacent to a wharf at the head of tide-water on the Saguenay.

A sample of 25 pounds from this locality was submitted to Mr. Jos. Keele, in charge of the clay testing laboratory of the Mines Department, who reports on it as follows:

"This sample was taken from the upper portion of a bed of clay about 100 feet thick at Les Terres Rompues, near mouth of Rivíére aux Vases, Chicoutimi county.

"The clay is similar in character to many other deposits found near water level along the banks of Saguenay river. It is greyish in colour, and contains rather a high percentage of lime, but appears to be free from pebbles or stone. When worked up with the proper amount of water, it forms a fairly plastic mixture, but is inclined to be rather flabby in the wet state. After being moulded into shape this clay can be dried quickly, provided the temperature of the drier does not exceed 150 degrees F.; otherwise it may crack. The clay burns to a porous body of light red colour at the ordinary temperature obtained in burning common building brick.

"Its use, as far as the manufacture of burned clay products is concerned, is confined to making common brick by the softmud process. It might be used for making the smaller sizes of field drain tile, but owing to its poor working properties in the raw state, it does not appear to be suitable for making large size tile or hollow-ware. The clay would not be suitable for the manufacture of vitrified ware."

LIMESTONE.

The available limestone belongs to the Trenton formation. It is quarried in many parts of the district for use in making lime and for road material. A small quarry at Chambord Junction is operated by the Jonquières Pulp and Paper Company of Jonquières for the various uses of that extensive plant. A few miles east of Chambord Junction buildings were erected a few years ago for a cement plant. The project appears to have been initiated with the intention to use the limestone and clay, both of which are abundant at this point. The company is said to have been unfortunate in its organization and to have exhausted its capital before a plant was even installed. The promoters lived in other parts of the province and little definite information could be obtained in the locality.

GRANITE.

Granite of excellent quality for building purposes, and apparently quite suitable for ornamental uses, is quarried at different places, especially in the township of Roberval. It is a massive rock, coarse in texture and has a reddish colour. Polished columns in some of the cemeteries show that it withstands weathering satisfactorily.

In large buildings its appearance is very favourable. It may be seen in the court house and post-office at Roberval, the church at St. Prime, and in other public buildings. Inferior qualities are used in macadamizing the principal roads.

IRON ORE.

Magnetite occurs in important quantities in association with intrusions of anorthosite. The principal deposits known are a short distance east of the map-area and so were not examined. They have been known for many years through the reports of Dr. F. D. Adams and the late Abbé Laflamme. More recently they were specifically examined by Professor Dulieux of Montreal whose report to the Provincial Department of Mines of Quebec was published during the past year.

All these ores are titaniferous and none have yet been utilized. In view of the prospect of an early and ample supply of water-power in the district at exceedingly low cost, arrangement was made with Dr. Alfred Stansfield, professor of metallurgy at McGill university, to write a summary report on the commercial feasibility of smelting such ores in the electric furnace. Professor Stansfield's report follows.

CHAPTER VI.

ELECTRIC SMELTING AS A MEANS OF UTILIZING THE IRON ORE OF THE ST. CHARLES DEPOSIT.[1]

Two miles west of the village of St. Charles, on the north shore of the Saguenay river, is a large deposit of titaniferous magnetite which has been estimated to contain from 1,000,000 to 5,000,000 tons of iron ore. In view of the intended hydro-electric development in this vicinity, it is desirable to consider whether this ore can be utilized for the production of pig iron, or steel, in the electric furnace.

Electric power will probably be obtained at two points on the Saguenay river, one being about 9 miles west and the other about 12 miles east of the ore deposit. The electric power could be carried to a point near the ore deposit so as to smelt the ore with the least transportation of material; but as the eastern dam is to be constructed near the outlet of the Shipshaw river, close to the point at which navigation begins, it would almost certainly be preferable to erect furnaces near this point and to carry the ore to the furnaces by means of the railway which is to be constructed. The pig iron, steel, or other products of the smelting operation could thus be shipped by water, and supplies of all kinds could be imported at a cheap rate. For the electric smelting of iron ores, charcoal and limestone would be needed, and these can be obtained conveniently in this locality.

NATURE AND AMOUNT OF THE ORE.

Professor Dulieux, on page 54 of his "Report on the minerals of iron in the Province of Quebec," 1915, describes the ore as titano magnetite occurring as enormous segregation masses in anorthosite or (page 237) gabbro. The ore has not been opened up sufficiently to obtain exact knowledge of its amount, but Dulieux estimates this at 1,000,000 tons or possibly as much as

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[1] Written by Alfred Stansfield, professor of metallurgy, McGill university.

5,000,000 tons. One million tons of ore is not a large supply for a modern blast-furnace plant, but in view of the smaller requirements of the electric furnace we may regard the size of the deposit as entirely sufficient.

A sample of the ore (page 56 of the report) was found to contain 50·53 per cent of iron and 10·55 per cent of titanium, with 0·02 per cent of sulphur and 0·03 per cent of phosphorus. The amount of gangue matter is not stated, but would probably be about 12 per cent. Magnetic concentration of the ore, crushed to pass through a 20-mesh sieve, gave a concentrate amounting to 77 per cent of the original ore, which contained 56 per cent of iron and 8·3 per cent of titanium. This test was made on a small amount of ore and cannot be depended on as giving the average composition of many thousands of tons; but in view of this and other tests on similar ores, we must conclude provisionally that magnetic concentration will remove part of the titanium from the ore, but will not serve to produce a non-titaniferous product. For the purpose of calculation we may use the figures given by Dulieux as if they were representative of the whole deposit. The character of the ore, and the concentrate and tailings obtainable from it may be represented as follows if we make reasonable assumptions with regard to the nature of the ore and gangue.[1]

	Original ore	*Concentrate* (77%)	*Tailings* (23%)
Iron	50·53%	56·2%	30·9%
Titanium	10·55	8·3	19·7
Titanium oxide	17·6	13·8	32·8
Silica	5·2	3·2	11·4
Alumina	4·4	2·7	9·6
Lime and magnesia	2·4	1·5	5·3
Gangue	12·0	7·4	26·3
Sulphur	0·02	0·015	0·04
Phosphorus	0·03	0·015	0·08

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[1] Prof. Dulieux sized the ore into three products and concentrated each separately. I have combined all the concentrates together and all the tailings together in this table. The amount of gangue is calculated on the assumption that the ore has the formula $FeO\ TiO_2 + nFe_2O_3$. The gangue is assumed to have the formula of anorthite, $CaO.Al_2O_3.2SiO_2$.

It will be clear from the above table that whether magnetic concentration is employed or not, the material available for smelting is a titaniferous magnetite with a moderate amount of gangue and nearly free from sulphur and phosphorus. The only obstacle to its use as an iron ore is the amount of titanium it contains.

SMELTING OF TITANIFEROUS IRON ORES.

Much doubt still exists with regard to the metallurgy of these ores, and it is, therefore, advisable to make a careful examination of the evidence available and the opinions that have been expressed.

It appears that some sixty years ago, at a time when iron ores were still largely smelted with charcoal, titaniferous ores were regularly employed for iron making in the Adirondacks and elsewhere, and as far as we can judge, no difficulty was experienced.[1] As charcoal was replaced by coke there has grown up a very serious prejudice against these ores, it being held that as little as 1 per cent of titanium is sufficient to interfere with the working of the furnace. It was not urged that titanium detracted from the quality of the pig iron, titaniferous iron being admitted to be if anything better than other iron, but it was claimed that titanium made the slag sticky and infusible, caused the formation of infusible deposits in the furnace, and required the use of an abnormal amount of fuel. On the other hand the use of titaniferous ores has been championed for a number of years by A. J. Rossi, who states that no difficulty will be experienced in smelting if the oxide of titanium, TiO_2, is regarded as so much silica, sufficient limestone being added to flux it off, and that the slag will be more fusible if dolomite is used instead of limestone. These statements have, of course, more weight than the vague prejudice against the use of such ores, but there has perhaps been a feeling that Rossi was biased in his views and that there must be some foundation for such widespread prejudice. A paper written in 1882 by W. M. Bowron[2] appears

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[1] A. J. Rossi, "The metallurgy of titanium," Trans. Amer. Inst. Min. Eng., vol. XXXIII, 1903, p. 181.

[2] W. M. Bowron, "The practical metallurgy of titaniferous ores," Trans. Amer. Inst. Min. Eng., vol. XI, 1883, p. 159.

to throw some light on the situation. Bowron gives an account of the smelting in England, about the year 1868, of a Norwegian ilmenite containing 39 per cent of titanic acid. Coke was used for fuel and old red bricks or similar material was used, in addition to limestone, to flux off the titanium; even with this addition the slag contained 36 per cent of titanic acid. The furnace ran satisfactorily; but on account of the small amount of iron in the ore the coke consumption was abnormally high, being nearly 3 tons for each ton of iron made, and the operation was ultimately discontinued. The analysis of the resulting iron is unfortunately not given. A report is also made of the smelting, by Prof. David Forbes[1] of ores containing 15 per cent and 7 per cent of titanic acid. These ores were smelted with charcoal and were fluxed, first with quartz, then with limestone, and finally with a mixture of quartz and limestone. The amount of charcoal used per ton of iron was about 20 per cent greater than the normal amount, but the ores only contained 42 per cent and 39 per cent respectively of iron. Forbes found the furnace to work satisfactorily, provided the titanium was not over 8 per cent of the ore. In conclusion Bowron states: "The whole secret of working these ores successfully and continuously is to keep the heat so low as just to reduce the iron and not reduce the titanic acid. The iron will be white, or at best mottled, if there is much titanic acid to contend with. Titanic iron is essentially a forge iron. Foundry iron can only be produced when the titanium is low, and then only by making a large quantity of cinder, so as to 'wash' the titanic acid out of the furnace." Turning now to A. J. Rossi's paper in 1903,[2] we find, writing of the pig iron made from titaniferous ores, "It is essentially an open-hearth stock. Analyses of the pig-iron made by us at Buffalo and that of the Adirondacks (the same ores were used in both cases) showed phosphorus traces; silicon, 0·11 to 0·13; carbon from 1·86 to 3·50 per cent, practically all combined; the fracture had very much the appear-

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[1] Professor D. Forbes. Chemical News, Dec. 11, 1868.

[2] A. J. Rossi, "The metallurgy of titanium," Trans. Amer. Inst. Min. Eng, Vol. XXXIII, 1903, p. 187.

ance of that of steel. It is eminently a chilling-iron, well adapted for car-wheel mixtures."

Collecting the data from the foregoing and other papers we may conclude that titanic acid can easily be fluxed off in the slag, in large amounts, provided that one is content to make a white iron low in silicon. If, however, it is attempted to make a grey iron from a highly titaniferous ore, titanium is reduced and enters the pig iron, and part of the reduced titanium combines with the cyanides in the furnace to form the well known copper coloured cyanonitride of titanium or similar compounds which give rise to obstructions in the furnace.

In order to obtain direct evidence on the fusibility of slags containing titanic acid, the writer is making, with the assistance of Mr. W. A. Wissler, M.Sc., a series of tests on the melting temperatures of various mixtures. Enough has already been done to show that fusible slags can be made containing as much as 35 per cent of TiO_2, but that this oxide does not really replace silica in a slag as it is necessary to have some 15 per cent or 20 per cent of silica, in addition to the titanium, in order to obtain easy fusibility.[1]

An important experiment has been made recently on the smelting of titaniferous ores in the blast furnace[2] using coke as the fuel. The experiment was made by the MacIntyre Iron Company, owners of a large deposit of titaniferous iron ore, in a blast furnace at Port Henry, N.Y., belonging to the Northern Iron Company. The test was carried out under the general direction of Mr. F. E. Bachman the general manager of the MacIntyre Company, who has written a very interesting account of the whole investigation.[3] The ore was a titaniferous magnetite from the Sanford Hill district in New York state, containing 47·5 per cent of iron and 12·6 per cent of titanium. Magnetic concentration yielded concentrates of about 55 per cent of iron and 8 per cent of titanium. The furnace, which produced more than 200 tons of iron per day, was supplied with local magnetite

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[1] Stansfield, Alfred and Wissler, W. A. "The smelting of titaniferous ores of iron," Trans. Roy. Soc. Can., 1916, ser. III, vol. X, p. 33.

[2] Edwin F. Cone, "Titanium ores in the blast furnace," Iron Age, Oct. 22, 1914, p. 936·

[3] Frank E. Bachman, "The uses of titaniferous ore in the blast furnace," Year Book American Iron and Steel Institute, 1914.

ores to which from one-eighth to five-sixteenths of the titaniferous concentrates had been added. Using one-eighth of the concentrates a foundry iron was made without any serious difficulty and with a normal consumption of fuel; the iron contained 0·5 per cent of titanium and the slag about 4 per cent of titanic oxide. With larger proportions of the titaniferous concentrates (about 25 per cent of the ore charge) "malleable" iron was made; that is a pig iron low in silicon suitable for the production of malleable castings. With this amount of concentrate the iron contained about 1 per cent of silicon and 0·45 per cent of titanium, while the slag contained about 6 per cent of titanium oxide. Neither the output of the furnace nor the consumption of coke per ton of iron was materially affected by the use of the concentrates and as the test was continued for more than two months, during which several thousand tons of titaniferous ore was smelted, we can depend upon the results obtained.

The results of this experiment confirm the conclusions drawn from previous observations, showing that titanium does not form infusible slags or deposits in the furnace when suitably fluxed, but that so little as 2 per cent of titanium in the ore (25 per cent of the 8 per cent concentrate) interferes with the production of foundry pig iron. Titanium behaves like silicon in the furnace, and the conditions of high temperature and abundant fuel that are essential for obtaining a high silicon or foundry iron also cause titanium to enter the iron, and somewhat to the exclusion of the silicon. It is possible that with an increasing amount of titanium in the pig iron there would be formed the infusible titanium deposits of which so much has been heard. In connexion with this test some very interesting investigations were made with regard to the melting temperature and fluidity of slags containing titanium oxide, and the strength and microscopic structure of the titaniferous pig iron produced. An account of these will be found in the paper by Mr. Bachman already referred to.

ELECTRIC SMELTING OF TITANIFEROUS ORES.

The electric furnace has been suggested for the treatment of these ores in the belief that the slags produced would be infusible in the blast furnace, and that a higher temperature, such as could be produced in the electric furnace, would overcome the difficulty. It has just been shown that titaniferous slags are easily fusible and that a moderate temperature is sufficient for the treatment of these ores. The electric furnace may nevertheless prove satisfactory for smelting titaniferous magnetites and it will be desirable in the first place, to review the results that have already been obtained.

In the year 1906 Dr. E. Haanel[1] carried out at Sault Ste. Marie a series of tests on the production of pig iron from Canadian ores in a small electric furnace of 200 kilowatts. In run 19, the last of the series, he smelted a titaniferous magnetite containing 10·7 per cent of titanium and 43·6 per cent of iron. The charge consisted of 400 pounds of ore, 110 pounds of charcoal, 50 pounds of limestone, and 80 pounds of fluorspar; the last item being reduced later to 50 pounds. The metal produced contained 5·9 per cent of silicon, 2·95 per cent of carbon, and 0·43 per cent of titanium: the slag contained 12 per cent of titanium oxide. Unfortunately the run was discontinued and we cannot tell whether the ore could have been smelted without the use of fluorspar or what consumption of electrical energy, charcoal, and flux would have been needed in the regular operation of the furnace.

The Elektrometall furnace that was operated at Hardanger in Norway[2] during the year 1912 has been discussed by Dulieux (page 195 of his report) because the Rodsand ore, containing 50 per cent of iron and 8 per cent to 9 per cent of titanium oxide, formed a part of the charge. A lower grade Rodsand ore contained 30–45 per cent of iron and larger percentages of titanium, but was concentrated magnetically to yield a product containing 65 per cent of iron and 3·6 per cent of titanium oxide. As, however, the ore charge only contained some 20 per cent of this concentrate, the remainder being a non-titaniferous briquette from Sydvaranger, the operation does not throw much light on the subject.

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[1] Eugene Haanel, "Experiments made at Sault Ste. Marie, Ont., under Government auspices, in the smelting of Canadian iron ores by the electro-thermic process." Ottawa, 1907.

[2] M. Paul Nicou, "Le haut fourneau electrique," Annales des Mines, March and April 1913.

In the report of the experimental operation of the Elektrometall furnace at Trollhättan[1] (Sweden) in the year 1910-11, there is given on page 120 the analyses of the slags produced, which frequently contained about 2·5 per cent of titanium oxide; the pig iron produced at the same time contained only 0·5 per cent of silicon; 2·5 per cent of titanium oxide in the slag indicates as little as 0·4 per cent of titanium oxide in the ore mixture, so that this example does not afford much information with respect to the smelting of highly titaniferous ores.

In a paper by Gustave Gin[2] in 1907 he describes two experiments in the electrical reduction of titaniferous ores. In the first, made in France in 1901, a Norwegian ore containing 53·76 per cent of iron and 16·40 per cent of titanium oxide was treated. The charge contained 100 parts of ore, 15 parts of limestone, and 25 parts of coke. Two hundred and seventy-four kilograms of this mixture was treated in 4 hours, yielding 102 kilograms of pig iron. The average load was 71·5 kilowatts, equivalent to 2,800 kilowatt hours or 0·43 horse-power year per metric ton of pig metal. The pig contained 3·1 per cent of carbon, 0·86 per cent of silicon, and 0·10 per cent of titanium; the slag contained 32·5 per cent of titanium oxide, 20·8 per cent of silica, 4·1 per cent of alumina, 8·1 per cent of iron oxide, and 32·7 per cent of lime.

The second experiment was made in the year 1906 on a titaniferous concentrate from Java. The ore, containing 57 per cent of iron and 16 per cent of titanium oxide, was mixed with limestone and 'carbon' (charcoal?) and smelted in an electric furnace using 32 kilowatts for an hour. Pig iron was obtained weighing 42·6 kilograms and containing 3 per cent of carbon, 0·37 per cent of silicon, and a trace of titanium. The slag contained 8·9 per cent of silica, 38·7 per cent of titanium oxide, 5·18 per cent of alumina, 10·03 per cent of ferrous oxide, and 34·8 per cent of lime. The data for calculating the power consumption in this test are apparently incorrect.

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[1] Leffler, Odelberg och Nyström, "Rodogörelse für Jernkontorets [illegible] verk i Trollhättan." Stockholm, 1911.

[2] Gustave Gin, "The electrical reduction of titaniferous iron o[illegible]" Trans. Am. Electrochem, Soc., vol. X1, 1907, p. 291.

The foregoing particulars refer only to the production of ***pig iron*** in the electric furnace. The electric smelting of titaniferous ores for the production of ***steel*** has been fully demonstrated by J. W. Evans and the writer, and will be described later in this report.

In view of the various tests that have been made in the blast furnace and the electric furnace, it appears to be safe to conclude that a titaniferous magnetite can be smelted readily in an electric furnace with charcoal for the production of a high quality of pig iron. The power consumption should not be excessive unless a very large amount of slag is produced, and, as the slag can carry 35 per cent of titanic acid, this need not be the case with the concentrate under consideration. The cost of smelting can be based on the data given in the writer's report on the electrothermic smelting of iron ores in Sweden,[1] making allowance for any differences in the richness of the ore and quantity of slag.

ELECTRIC SMELTING OF ST. CHARLES ORE AND CONCENTRATES.

Taking first the magnetic concentrate, which I shall assume to have the analysis shown below, a pig iron containing a few tenths each of silicon and titanium could be produced in an Elektrometall furnace, such as is used in Sweden, with a consumption of 0·4 ton of charcoal and 0·5 ton of limestone (or dolomite) per ton of pig iron. The slag might be of about the composition shown and would be 40 per cent of the weight

Concentrate		*Pig iron*		*Slag*	
1·75 tons		1 ton		0·7 ton	
Fe	56·2%	Fe	95·5%	TiO_2	34%
TiO_2	13·8	C	3·5	SiO_2	14
SiO_2	3·2	Si	0·3	Al_2O_3	7
Al_2O_3	2·7	Ti	0 4	CaO, MgO	40
CaO, MgO	1·5	S	0·01	FeO	3
S	0·015	P	0·04		
P	0·015				

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[1] Alfred Stansfield. "Electrothermic smelting of iron ores in Sweden," Ottawa, 1915.

of the ore or 70 per cent of the weight of the iron. The consumption of electrical power would be about 3,000 kilowatt hours or 0·46 horse-power year per ton; and allowing for stoppages, etc., we must charge about 0·55 horse-power year per ton of metal produced. The power used is about one-third more than is needed for the pure magnetites in Sweden; this is on account of the larger amount of limestone to heat and slag to melt in the furnace. In regard to the analysis of concentrate and metal I have assumed the sulphur in the concentrate to be a little less than in the ore, so that there should be no difficulty in producing a pig metal with 0·01 per cent of sulphur, as the charcoal is very low in that element. Phosphorus, on the other hand, is increased in the smelting operation as charcoal always contains an appreciable amount and as scarcely any is removed in the slag. The concentration, however, should reduce the contents from 0·03 per cent to 0·015 per cent, so that the final figure should not be over 0·04 per cent.

To smelt the original ore, assuming that the slag is not to contain more titanium than in the preceding example, we should need 0·4 ton of charcoal, 0·7 ton of limestone or dolomite, and about 3,500 kilowatt hours or 0·54 horse-power year per long ton of pig iron. Allowing as before for irregular use of the power we should charge 0·65 horse-power year for each ton of pig.

Ore		*Pig iron*		*Slag*	
	2 tons		1 ton		1 ton
Fe	50·53%	Fe	96·5%	TiO_2	35%
TiO_2	17·6	C	3·5	SiO_2	10
SiO_2	5·2	Si	0·3	Al_2O_3	9
Al_2O_3	4·4	Ti	0·4	CaO, MgO	43
CaO, MgO	2·4	S	0·015	FeO	3
S	0·02	P	0·08		
P	0·03				

The slag shown above only contains 10 per cent of silica, and experiments that are now in progress indicate that at least 15 per cent is required to produce fluidity at furnace temperatures. It would probably be necessary, therefore, to add some siliceous flux in addition to the limestone, just as in the smelting reported by Bowron, for which old bricks as well as limestone were found necessary, or as in that of Forbes, for which quartz and limestone were employed.

There are at present two entirely different types of electric furnace in use for smelting iron ores. The Swedish or "Elektrometall" furnace has a circular crucible with a central shaft of considerable size. Reduction and preheating of the ore is effected to some extent in this shaft with the aid of a circulation of the furnace gases. This furnace is used in general for the production of a low silicon iron such as must be aimed at when smelting titaniferous ores. The other type of furnace, in use in California, consists of a rectangular crucible or smelting chamber which has no real shaft but merely a number of small chutes for supplying the ore. There is no circulation of the gases and no attempt is made to reduce or even to preheat the ore before it enters the smelting chamber. This furnace is less economical, both in charcoal and power, than the Swedish furnace, but it has been found more satisfactory for the production of foundry iron. It may, therefore, be assumed provisionally, as foundry iron would not be made, that the Elektrometall furnace would be employed for smelting the St. Charles ore, and we can thus take advantage of the large amount of data available with regard to the cost and operation of that type of furnace.

COST OF MAKING PIG IRON ELECTRICALLY.

Any estimate of the cost of smelting titaniferous ores in the electric furnace must be decidedly uncertain, but the following calculation, which is based on the estimates given on page 48 of the writer's report, will give some idea of the probable cost and of the relative advantages of concentrating the ore or smelting it as it comes from the mine.

For the purpose of this calculation I shall assume a plant consisting of three furnaces of 4,000 horse-power each. Such a plant, according to Assar Grönwall, would cost $360,000, erected in Canada. The output of such a plant under Swedish conditions would be about 80 tons per day, taking the average production over a long period. The corresponding output with the St. Charles ore would be about 60 tons from the concentrated ore or 50 tons from the crude ore. The smaller output increases the cost per ton of pig iron, not only for power, but for labour, interest, and many of the other items.

Without more information than is contained in the report of Dulieux it is impossible to foretell, at all accurately, the cost of mining and crushing the ore; and as 2·3 tons of ore must be handled for each ton of iron made, an increase of 40 cents per ton of ore, on these items, would mean $1 per ton on the product.

No charge has been made in the table for the royalty that would have to be paid for the use of the Elektrometall furnace if that were employed.

Cost of One Long Ton of Pig Iron.[1]

		Smelting ore		Smelting concentrate	
Mining	at $1.00 per ton	2 tons	$ 2.50	2·3 tons	$ 2.88
Royalty	at 0.25 "				
Preparation of ore.					
Crushing	at 20 cents			2·3 "	0.46
Concentrating	at 30 cents			2·3 "	0.69
Sintering	at 50 cents			1·75 "	0.88
Freight	at 20 cents	2 tons	0.40	1·75 "	0.35
Electric smelting.					
Ore as above		2 tons	$2.90	1·75 tons	$5.26
Limestone	at $1	0·7 "	0.70	0·50 "	0.50
Charcoal	at $10	0·4 "	4.00	0·40 "	4.00
Power	at $7 h.p.yr.	0·65 h.p.yr.	4.55	0·55 h.p.yr.	3.85

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[1] It must be stated clearly that the writer has not had the opportunity of obtaining actual costs for electric power, charcoal, mining, etc., at the proposed location. Possible figures have been assumed, for the purpose of calculation, and corrections can be made when actual data become available.

Electrodes	at 4 cents lb	20 lbs.	0.80	18 lbs.	0.72
Labour...	...at $2.50		2.50		2.00
Office expenses	....		1.00		0.80
Repairs....	....		1.00		0.80
[1]Depreciation,	6% on $360,000 ...		1.20		1.00
[1]Interest,	6% on $500,000		1.65		1.40
General expenses...	....		1.50		1.25
			$21.80		$21.58

In view of these figures it appears that it is as cheap to mine 2·3 tons of ore, concentrate to 1·75 tons, briquette or sinter and smelt the concentrate, obtaining 1 ton of pig iron, as to mine 2 tons of ore and smelt it directly without any preparation. The magnetic concentration has, moreover, the advantage of removing a part of the phosphorus from the ore, so that a very pure pig iron would be obtained, which should be equal to the high quality Swedish pig iron.

The cost of making pig iron from this ore in the electric furnace is so high that it could not possibly compete with ordinary iron in the Canadian market. There is, however, a market for special qualities such as Swedish pig iron for use in the manufacture of tool steel and for raising the quality of iron mixtures for chilled iron wheels and many other purposes where a high quality is more important than a low price. An electric furnace plant using the St. Charles ore would be able to command the whole of this trade in Canada and with an ample supply further uses would no doubt be found.

Assuming that the ore is concentrated and sintered with the addition of sawdust, the plant of the electric furnaces will require (or produce) the following amounts of materials.

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[1] The items of depreciation and interest refer to the electric smelting plant alone. The figures given for mining, crushing, concentrating, etc., are supposed to represent the whole cost of these operations.

Electric Smelting Plant of Three Furnaces—12,000 H P.

	Per day.	*Per year.*
Ore mined	140 tons	50,000 tons
Sintered ore.	105 "	38,000 "
Sawdust for sintering	12 "	4,500 "
Limestone	40 "	15,000 "
Charcoal	25 "	9,000 "
Electrodes	0.5"	180 "
Pig iron	60 tons	22,000 tons

ORE SINTERING.[1]

The crushed and concentrated ore will need briquetting or otherwise agglomerating before it can be smelted in the electric furnace. Mr. G. C. Mackenzie states that this can be effected most efficiently by sintering the ore on a Dwight-Lloyd machine, using about 5 per cent of carbon for fuel besides the gas or other fuel used for igniting. I have supposed that some 12 per cent of wood sawdust, which might be available, would replace the 5 per cent of carbon.

CHARCOAL.[1]

The production of 25 tons of charcoal a day would involve the charring of 50 cords of wood. This would represent a retort plant of moderate size, and would afford acetate of lime, which is in great demand at present. The output from 50 cords of wood would be:

10,000 pounds [illegible] (=2,000 pounds of acetone).
400 ga[illegible]
2,500 b[illegible] coal.

The by-produ[illegible] ped to market cheaply.

In the table [illegible], charcoal has been charged at $10 per ton, but in view of the demand for the by-products from

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[1] The writer wishes to acknowledge information received from G. C. Mackenzie of the Mines Branch, Ottawa, in regard to magnetic concentration and sintering, and from J. S. Bates of the Forest Product Laboratories, Montreal, in regard to the manufacture of charcoal.

the distillation of hardwood it may be expected that $7 or $8 a ton would be a sufficiently high charge. At the latter figure the cost of a ton of iron would be reduced by 80 cents.

PRODUCTION OF FERRO-TITANIUM.

Ferro-titanium is obtained by smelting in the electric furnace iron ores high in titanium, and it should be considered whether the tailings from the magnetic separation, or the slag from the iron furnaces, could be employed for this purpose. A. J. Rossi[1] describes the methods employed for the industrial production of ferro-titanium. Titanium oxide requires a very high temperature for its reduction by carbon and this reaction can only be carried out in the electric furnace. The resulting alloy contains 5 to 10 per cent of carbon and is suitable for use as an addition to cast iron or high carbon steel. A low carbon alloy can be obtained by reducing the titanium by means of metallic aluminum, the operation being carried out in an electric furnace.

For this purpose an ore containing about 24 per cent of titanium and 35 per cent of iron has been found satisfactory. Metallic aluminum is melted in the electric furnace and the titanium ore added. As the charge becomes heated, reaction takes place with vivid incandescence and the iron and titanium form a molten alloy, while the aluminum is oxidized and enters the slag. If carbon is to be used instead of aluminum, scrap iron is melted in the furnace and a charge of titanium ore and charcoal is added. In either case metallic iron may be employed to lower the percentage of titanium in the resulting alloy.

Instead of the natural ore, Rossi sometimes employs a "concentrate" made by smelting a titaniferous iron ore with charcoal and limestone, obtaining a pig iron and a slag rich in titanium and low in silica, which can be employed for the production of ferro-titanium.

In the present case we have available the tailings from the magnetic concentration which contain 19·7 per cent of titanium, 30·9 per cent of iron, and 11·4 per cent of silica, and

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[1] A. J. Rossi. The manufacture of titanium and its alloys. Mineral Industry, vol. IX, (1901) p. 715.

also the slag from the iron smelting which would contain about 34 per cent of titanium oxide (20·4 per cent of titanium), 2 per cent of iron, and 14 per cent of silica. Either of these could probably be used for the manufacture of ferro-titanium. The slag has the higher ratio of titanium to iron, but on the other hand the lime content is rather high. For a very high titanium ferro it would probably be best to remove the bulk of the iron from the tailings by smelting for pig iron and to use the resulting "concentrate" for the production of the ferro.

In view of the desirability of utilizing these tailings and the electric power and other facilities, it seems reasonable to suppose that the production of ferro-titanium might be undertaken; but the market for this product would not be very large.

MARKET FOR PIG IRON.

It has been shown that a very high quality pig iron, which should be equal to the Swedish product, can be produced at a cost of about $21 a ton. Such an iron would have to sell at about $25 a ton in order to be profitable. The writer has been informed that Swedish pig iron would be worth at least $50 per ton in Canada, but the trade returns show very little importation of pig iron from Sweden and that at a low figure. The returns are:

1909	235 tons	$4,900	($21 per ton)
1910	112 "	$2,082	($19 ")

1911, 1912, and 1913, no returns.

The following table shows the importation of pig iron and charcoal pig iron during recent years.

		Imports for Consumption.		*Price*
1912	Pig iron	201,058 tons	$2,495,859	$12.40
	" , charcoal	54 "	$ 618	$11.40
1913	Pig iron	291,813 "	$3,813,034	$13.00
	" , charcoal	91 "	$ 1,183	$13.00
1914	Pig iron	194,376 "	$2,672,941	$13.70
	" , charcoal	957 "	$ 12,904	$13.50
1915	Pig iron	58,911 "	$ 725,989	$12.30
	" , charcoal	25 "	275	$11.00

It will be noticed that the amount of charcoal pig iron imported into Canada is very small and that the price of this iron is scarcely equal to that of pig iron made with coke.

The following table shows the exports of pig iron (charcoal iron not distinguished) from Canada during recent years.

1910	6,346	tons	$228,183	$35.96 per ton
1911	8,976	"	$298,[illegible]46	$33.23 "
1912	5,716	"	$262,393	$45.90 "
1913	6,994	"	$330,002	$47.18 "
1914	9,310	"	$347,347	$37.31 "
1915	10,477	"	$126,975	$12.10 "

It is clear that the exports consist mainly of a small amount of high priced charcoal iron, valued at $35 to $50 a ton. The sudden drop of price in 1915 corresponds with a decrease in the production of this charcoal iron; the output being made up of the lower priced coke iron.

These figures show that the Canadian charcoal furnaces have produced a pig iron that could command a high price even for exportation to the United States where most of the iron was sent.

The writer understands, however, that the foregoing figures apply to a special variety of iron that commanded an abnormally high price. Ordinary charcoal iron would not, under usual conditions, fetch as much as $20 a ton, but special low phosphorus irons might sell for $20 to $25 a ton.

A new industry making a very high grade of iron at a cost of $20 or $21 a ton should be able to find a moderate market at $22 to $25 a ton, and this market should expand as uses for this material are developed.

CHARCOAL PIG IRON.

Many years ago charcoal was used for smelting iron ores for the production of wrought iron, steel or pig iron, and it is still employed in the manufacture of special grades of pig iron. Coke, on account of its cheapness, has largely replaced charcoal as a fuel in the iron blast furnace, but the product is less valuable for many purposes. Coke usually contains about 1 per cent of sulphur, and although most of this can be fluxed off by a liberal use of limestone the resulting metal is not as pure as that made by the purer fuel charcoal. In general, coke iron that is low in silicon is high in sulphur, but charcoal iron can be made low in both silicon and sulphur. With our modern facilities it is comparatively easy to purify a coke iron so that it shall resemble a charcoal iron in chemical composition, and accordingly it has been predicted that charcoal iron will soon become extinct. It is held, however, by some, who have had long experience with cast iron, that charcoal iron is superior to coke iron even apart from the matter of chemical analysis, though such a view is scarcely orthodox at a time when no one cares to admit a belief in anything, even if it is apparently true, unless a reasonable explanation can be given. J. E. Johnson[1] has written a very interesting paper, showing the inherent differences not only between charcoal iron and coke iron, but between one charcoal iron and another. Thus he states that in 1910 warm blast southern and eastern irons were selling at $23 to $33 a ton, while Lake Superior charcoal irons of superior analyses could hardly be sold at $14 to $16 a ton. There are differences in cast iron that are not shown by the chemical analysis and we are still obliged to depend on mechanical and other tests to judge the value of this material.

BLAST FURNACE SMELTING OF THE ST. CHARLES ORE.

This chapter has been devoted to a consideration of the possibility of smelting the St. Charles ore in electric furnaces; but the possibility of using it in the ordinary blast furnace must not be overlooked.

Magnetic concentration of the ore, followed by sintering with the aid of sawdust or other cheap fuel, will afford a product suitable for use in the blast furnace in admixture with other ores. The sintered concentrate, costing perhaps $3 a ton, contains 56 per cent of iron, 8 per cent of titanium, and traces of sulphur and phosphorus. It could be added to any blast

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[1] J. E. Johnson, Jun. The effect of high carbon on the quality of [illegible] iron. Trans. Amer. Inst. Min. Eng., XLIV (1912), p. 314.

furnace charge of non-titaniferous ores to the extent of one-eighth of the whole without prejudice to the operation of the furnace and probably with some improvement of the resulting pig iron. For the production of low silicon iron this sintered concentrate might be added to the extent of one-fourth of the whole charge without producing any trouble. If it were attempted to smelt a charge composed entirely of this sinter or of equal parts of sinter and other ores, trouble might arise in regard to the elimination of the sulphur, brought in by the coke, at the low temperature that is found necessary for titaniferous ores. For smelting such a charge a charcoal blast furnace would be quite suitable and a good quality of iron would be obtained. Comparing the advantages of a charcoal blast furnace and an electric furnace using charcoal, it is probable, with electric power and charcoal at the prices assumed in this chapter, that the electric furnace could be operated at least as cheaply as the charcoal blast furnace and would have the added advantage that with a limited supply of charcoal more than twice as much pig iron could be made, and that the iron would be somewhat lower in phosphorus.

PRODUCTION OF STEEL FROM THE ST. CHARLES ORE.

The most important product that can be made from this ore will be a high quality charcoal pig iron for use in chilled iron and similar castings and for the production of crucible and other high class steels. Swedish experience has shown that the low silicon pig iron, very low in both sulphur and phosphorus, is particularly suitable for the production of high quality steel in the open-hearth furnace. The waste gases produced by the electric furnace are combustible, containing about 70 per cent of carbon monoxide. They represent in fuel value about one-half of the charcoal used in the furnace. If, therefore, the gases from three smelting furnaces were used to heat a small open-hearth furnace of about 10 tons capacity some 40 tons of steel might be made daily from the electric pig iron and imported steel scrap. It might be found preferable, however, to use an electric furnace for steel making and to employ the furnace gases for reheating furnaces, lime-kilns, and other purposes.

In this report attention has been directed to the production of pig iron from titaniferous ores, because this will provide for the use of the ore on the largest possible scale, and because the operation, both in the blast furnace and in the electric furnace, has been demonstrated in commercial operation on a very large scale. The production of open-hearth steel, also, from electric pig iron, has been carried out commercially on a fair scale. The direct production of steel, by smelting titaniferous ores in the electric furnace, is another means of utilizing such ores, and it has been shown by J. W. Evans and the writer[1] that an excellent quality of steel can be obtained in this manner at a moderate cost. The process appears most suitable for the production of tool steel and steel castings. The Tivani Electric Steel Company has two electric smelting furnaces in its plant at Belleville, the larger being of one ton capacity, and commercial operation is to be started as soon as the necessary rolling plant and steel foundry can be added.

CONCLUSION.

The following conclusions have been reached with regard to the deposit of titaniferous magnetite near St. Charles, and the possibility of utilizing it by electric smelting:

The ore is low in sulphur and phosphorus; is sufficient in amount to operate an electric furnace plant for a large number of years, and is conveniently situated for treatment in this way, the only obstacle to its use being the 10 per cent of titanium which it contains.

By crushing, magnetic concentration, and sintering, a product can be obtained, at a cost of about $3 a ton, that is mechanically suitable for smelting in blast or electric furnaces, is lower in phosphorus than the original ore, and contains about 8 per cent of titanium and 56 per cent of iron.

This product could be shipped to Sydney or other blast furnace plant and used to the extent of about one-eighth in

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[1] Evans. J. W., Jour. Can. Min. Inst., vol. IX, 1906, p. 128.

" " " " " " " vol. XV, 1912, p. 123.

Stansfield, A., "Tool steel direct from the ore in an electric furnace," Jour. Can. Min. Inst., vol. XIII, 1910, p. 151.

Stansfield, A., "The electric furnace," 1914, p. 256.

admixture with non-titaniferous ores, providing that the cost was not too high. Such an addition would lower the phosphorus and improve the quality of the resulting pig iron.

The sintered concentrate could be shipped about 14 miles, by a railway which is to form part of the development scheme, to a point at the head of the Saguenay navigation where electric furnaces (or charcoal blast furnaces) could be erected.

The titaniferous concentrate can be smelted in an electric furnace or a charcoal blast furnace, with suitable fluxes, for the production of a low-silicon white pig iron—suitable for making chilled castings or for steel making; but it will not be practicable to produce a grey or foundry iron from this ore.

It is probable, in view of the results obtained in Sweden, that the electric furnace can be operated at least as cheaply as the charcoal blast furnace; more iron can be produced from a given supply of charcoal, and the resulting iron will be more free from phosphorus if the electric furnace is employed.

A suitable plant would consist of three 4,000 horse-power Elektrometall furnaces. It would produce about 60 tons of iron a day or 22,000 tons per annum, and would use per day: 140 tons of crude ore or 105 tons of concentrate, 40 tons of limestone, and 25 tons of charcoal. Such a plant would cost about $360,000 and would employ 12,000 horse-power.

The charcoal could be produced by charring 50 cords of hardwood per day in a retort plant to be erected conveniently with regard to the furnaces and the supply of wood. A sulphite pulp mill is situated at the adjacent village of Jonquiere. The by-products would be 10,000 pounds of acetate of lime (equal to 2,000 pounds of acetone) and 400 gallons of wood alcohol per day. These could be shipped cheaply to market. Charcoal should be produced at a cost of $7 or $8 per ton, but $10 has been allowed in the calculation of costs.

The total cost of a ton of pig iron made by this process would be about $21. Thus the iron could probably be sold at a profit at the prices paid for specially high quality charcoal pig iron.

The present market in Canada, for this high priced iron, would not absorb more than one-third of the proposed output;

but in view of the rapid development now taking place in this country it seems probable that a larger market could be built up in a few years.

One-third or one-half of the output could be converted into a high quality of steel in an electric furnace, or in an open-hearth furnace heated by the waste gases from the smelting furnace; employing a moderate amount of steel scrap.

The magnetic concentrate could also be used, in moderate amounts, for the direct production of high grade steel in the electric furnace by the Evans-Stansfield process.

The tailings from the magnetic concentration of the ore can be utilized in part for the production of ferro-titanium, in an electric furnace.

PLATE II.

A.

View of a typical section of Lake St. John lowland; parish of St. Prime looking westward from the fault escarpment of Côte St. Prime; township of Ouiatchouan, range II, lot 9.

B.

Country road, Lake St. John lowland; fault escarpment of Côte St Prime in the background; township of Ouiatchouan, range I, lot 8.

A.

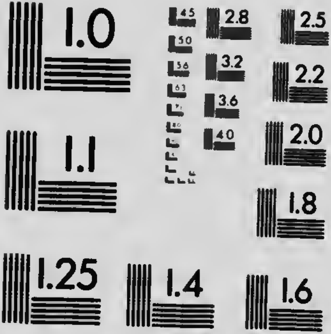
Quarry in massive granite, township of Roberval, range B, lot 5.

B.

West shore of Lake St. John, looking southwards; township of Roberval, range A, lot 4. The beds in the foreground are tilted by a fault away from the horizontal strata shown in the upper right hand part of the photograph. All are Trenton limestone. On the skyline at the left can be seen the escarpment forming the front of the highland, at a distance of 10 miles.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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A.

Trenton limestone tilted by the Côte St. Prime fault, township of Ouiatchouan, range 1, lot 8.

B.

Contact between Trenton limestone and Roberval granite, Quebec and Lake St. John railway—Indian Reserve, Pointe Bleue. The camera case rests on the surface of the granite. The limestone contains no basal conglomerate.

PLATE V.

Utica shales, Isle de la Traverse, looking east from the northwest point of the island.

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PUBLICATIONS OF THE GEOLOGICAL SURVEY.

The Geological Survey was established in 1842 and "Reports of Progress" were issued, generally in annual volumes, from that date to 1885, the first report being that for the year 1843 published in 1845. Beginning with the year 1885, "Annual Reports" (new series) were published in volumes until 1905, the last being Vol. XVI, 1904. Many of the individual reports and maps published before 1905 were issued separately and from 1905 to the present, all have been published as separates and no annual volume has been issued. Since 1910, the reports have been issued as Memoirs and Museum Bulletins, each subdivided into series, thus:—

Memoir 41, *Geological Series 38.*
Memoir 54, *Biological Series 2.*
Museum Bulletin 5, *Geological Series 21.*
Museum Bulletin 6, *Anthropological Series 3*

In addition to the publications specified above, a Summary Report is issued annually; and miscellaneous publications of various kinds including Reports of Explorations, Guide Books, etc., have been issued from time to time.

Publications Issued 1910-1915 Inclusive.

MEMOIRS.

Memoir 1. *Geological Series 1.* Geology of the Nipigon basin, Ontario, 1910—by Alfred W. G. Wilson.

Memoir 2. *Geological Series 2.* Geology and ore deposits of Hedley mining district, British Columbia, 1910—by Charles Camsell.

Memoir 3. *Geological Series 3.* Palæoniscid fishes from the Albert shales of New Brunswick, 1910—by Lawrence M. Lambe.

Memoir 4. *Geological Series 7.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec, 1911—by W. J. Wilson.

Memoir 5. *Geological Series 4.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory, 1910—by D. D. Cairnes.

Memoir 6. *Geological Series 5.* Geology of the Haliburton and Bancroft areas, Province of Ontario, 1910—by Frank D. Adams and Alfred E. Barlow.

Memoir 7. *Geological Series 6.* Geology of St. Bruno mountain, Province of Quebec, 1910—by John A. Dresser.

Memoir 8. *Geological Series 8.* The Edmonton coal field, Alberta, 1911—by D. B. Dowling.

Memoir 9. *Geological Series 9.* Bighorn coal basin, Alberta, 1911—by G. S. Malloch.

Memoir 10. *Geological Series 10.* An instrumental survey of the shorelines of the extinct lakes Algonquin and Nipissing in southwestern Ontario, 1911—by J. W. Goldthwait.

Memoir 11. *Topographical Series 1.* Triangulation and spirit levelling of Vancouver island, B.C., 1909, issued 1910—by R. H. Chapman.

Memoir 12. *Geological Series 11.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906, issued 1911—by Anton Handlirsch.

Memoir 13. *Geological Series 14.* Southern Vancouver island, 1912—by Charles H. Clapp.

Memoir 14. *Biological Series 1.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia, 1911—by William H. Dall and Paul Bartsch.

Memoir 15. *Geological Series 12.* On a Trenton Echinoderm fauna at Kirkfield, Ontario, 1911—by Frank Springer.

Memoir 16. *Geological Series 13.* The clay and shale deposits of Nova Scotia and portions of New Brunswick, 1911—by Heinrich Ries assisted by Joseph Keele.

Memoir 17. *Geological Series 28.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que., 1913—by Morley E. Wilson.

Memoir 18. *Geological Series 19.* Bathurst district, New Brunswick, 1913—by G. A. Young.

Memoir 19. *Geological Series 26.* Geology of Mother Lode and Sunset mines, Boundary district, B.C., 1914—by O. E. LeRoy.

Memoir 20. *Geological Series 41.* Gold fields of Nova Scotia, 1914—by W. Malcolm.

Memoir 21. *Geological Series 15.* The geology and ore deposits of Phoenix Boundary district, British Columbia, 1912—by O. E. LeRoy.

Memoir 22. *Geological Series 27.* Preliminary report on the serpentines and associated rocks in southern Quebec,, 1914—by J. A. Dresser.

Memoir 23. *Geological Series 23.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C., 1914—by J. Austen Bancroft.

Memoir 24. *Geological Series 16.* Preliminary report on the clay and shale. deposits of the western provinces, 1912—by Heinrich Ries and Joseph Keele.

Memoir 25. *Geological Series 21.* Report on the clay and shale deposits of the western provinces, Part II, 1914—by Heinrich Ries and Joseph Keele.

Memoir 26. *Geological Series 34.* Geology and mineral deposits of the Tulameen district, B.C., 1913—by C. Camsell.

Memoir 27. *Geological Series 17.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911, issued 1912.

Memoir 28. *Geological Series 18.* The Geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario, 1912—by Charles D. Walcott.

Memoir 29. *Geological Series 32.* Oil and gas prospects of the northwest provinces of Canada, 1913—by W. Malcolm.

Memoir 30. *Geological Series 40.* The basins of Nelson and Churchill rivers, 1914—by William McInnes.

Memoir 31. *Geological Series 20.* Wheaton district, Yukon Territory, 1913—by D. D. Cairnes.

Memoir 32. *Geological Series 25.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C., 1914—by R. G. McConnell.

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Memoir 34. *Geological Series 63.* The Devonian of southwestern Ontario, 1915—by C. R. Stauffer.

Memoir 35. *Geological Series 29.* Reconnaissance along the National Transcontinental railway in southern Quebec, 1913—John A. Dresser .

Memoir 36. *Geological Series 33.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C., 1914—by C. H. Clapp.

Memoir 37. *Geological Series 22.* Portions of Atlin district, B.C., 1913—by D. D. Cairnes.

Memoir 38. *Geological Series 31.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II, 1913—by Reginald Aldworth Daly.

Memoir 39. *Geological Series 35.* Kewagama Lake map-area, Quebec, 1914—by M. E. Wilson.

Memoir 40. *Geological Series 24.* The Archæan geology of Rainy Lake, 1914—by Andrew C. Lawson.

Memoir 41. *Geological Series 38.* The "Fern Ledges" Carboniferous flora of St. John, New Brunswick, 1914—by Marie C. Stopes.

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MEMOIR 54.	*Biological Series 2.* Annotated list of flowering plants and ferns of Point Pelee, Ont., and neighbouring districts, 1914—by C. K. Dodge.
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MEMOIR 81. *Geological Series 67.* Oil and gas fields of Ontario and Quebec, 1915—by Wyatt Malcolm.

MEMOIR 82. *Geological Series 68.* Rainy River district, Ontario. Surficial geology and soils, 1915—by W. A. Johnston.

MUSEUM BULLETINS.

The Museum Bulletins, published by the Geological Survey, are numbered consecutively and are given a series number in addition, thus: Geological Series No. 1, 2, 3, etc.; Biological Series No. 1, 2, 3, etc.; Anthropological Series No. 1, 2, 3, etc.

In the case of Bulletins 1 and 2, which contain articles on various subjects, each article has been assigned a separate series number.

The first Bulletin was entitled *Victoria Memorial Museum Bulletin;* subsequent issues have been called *Museum Bulletins.*

MUS. BULL. 1. (*Issued* 1913).
Geological Series 1. The Trenton crinoid, Ottawacrinus, W. R. Billings—by F. A. Bather.
Geological Series 2. Note on Merocrinus, Walcott—by F. A. Bather.
Geological Series 3. The occurrence of Helodont teeth at Roche Miette and vicinity, Alberta—by L. M. Lambe.
Geological Series 4. Notes on Cyclocystoides—by P. E. Raymond.
Geological Series 5. Notes on some new and old Trilobites in the Victoria Memorial Museum—by P. E. Raymond.
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Geological Series 11. A new species of Lepidostrobus—by W. J. Wilson.

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Geological Series 17. Early Cambrian stratigraphy in the North American Cordillera, with discussion of Albertella and related faunas—by L. D. Burling.

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MUS. BULL. 6. *Anthropological Series 3.* Prehistoric and present commerce among the Arctic Coast Eskimo, 1915—by V. Stefansson.

MUS. BULL. 7. *Biological Series 4.* A new species of Dendragapus (Dendragapus Obscurus Flemingi) from southern Yukon Territory, 1914—by P. A. Taverner.

MUS. BULL. 8. *Geological Series 22.* The Huronian formations of Timiskaming region, Canada, 1914—by W. H. Collins.

MUS. BULL. 9. *Anthropological Series 4.* The Glenoid Fossa in the skull of the Eskimo, 1915—by F. H. S. Knowles.

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Guide Book No. 4. Excursions in southwestern Ontario, 1913.

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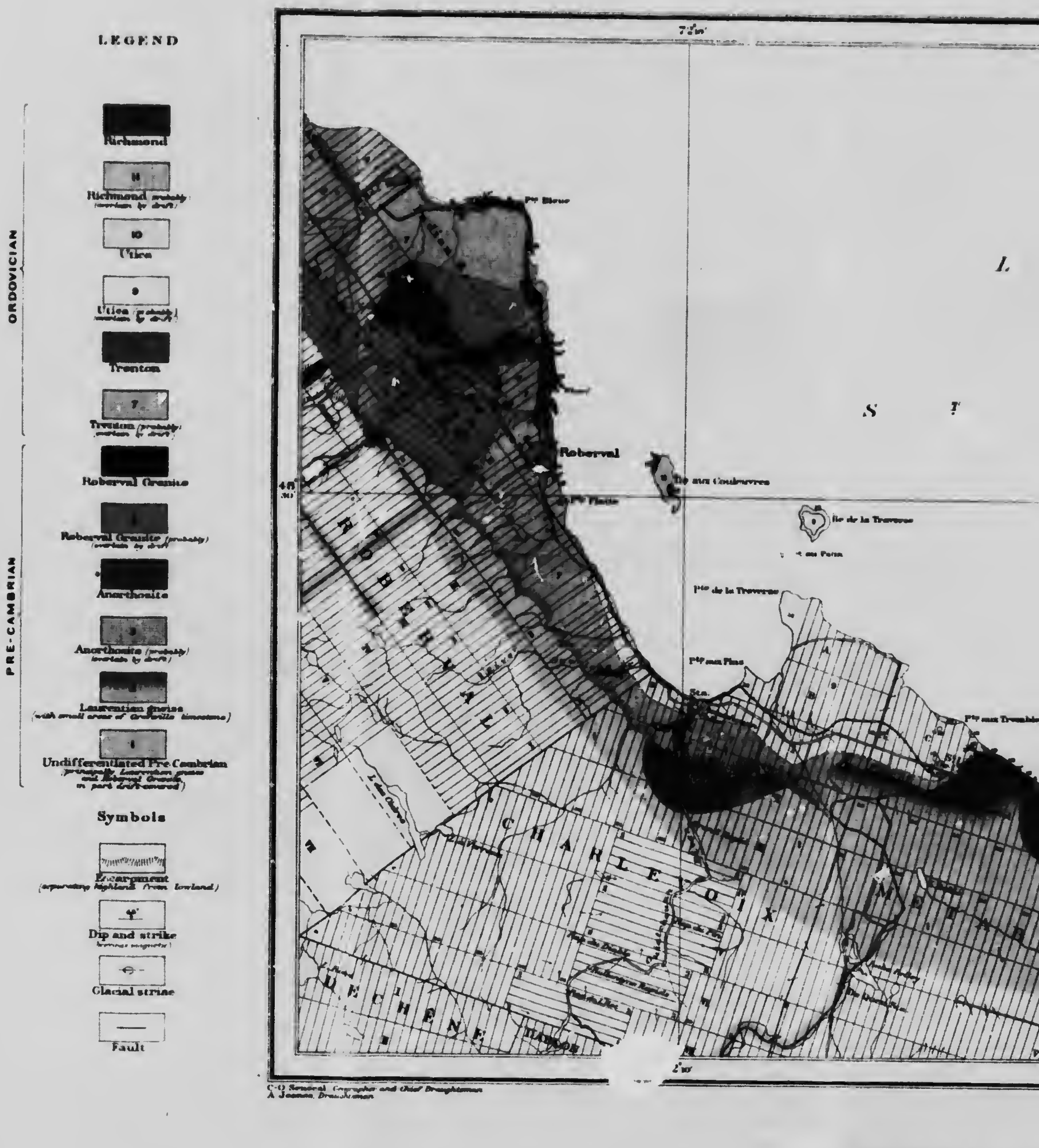
HON P E BLOND



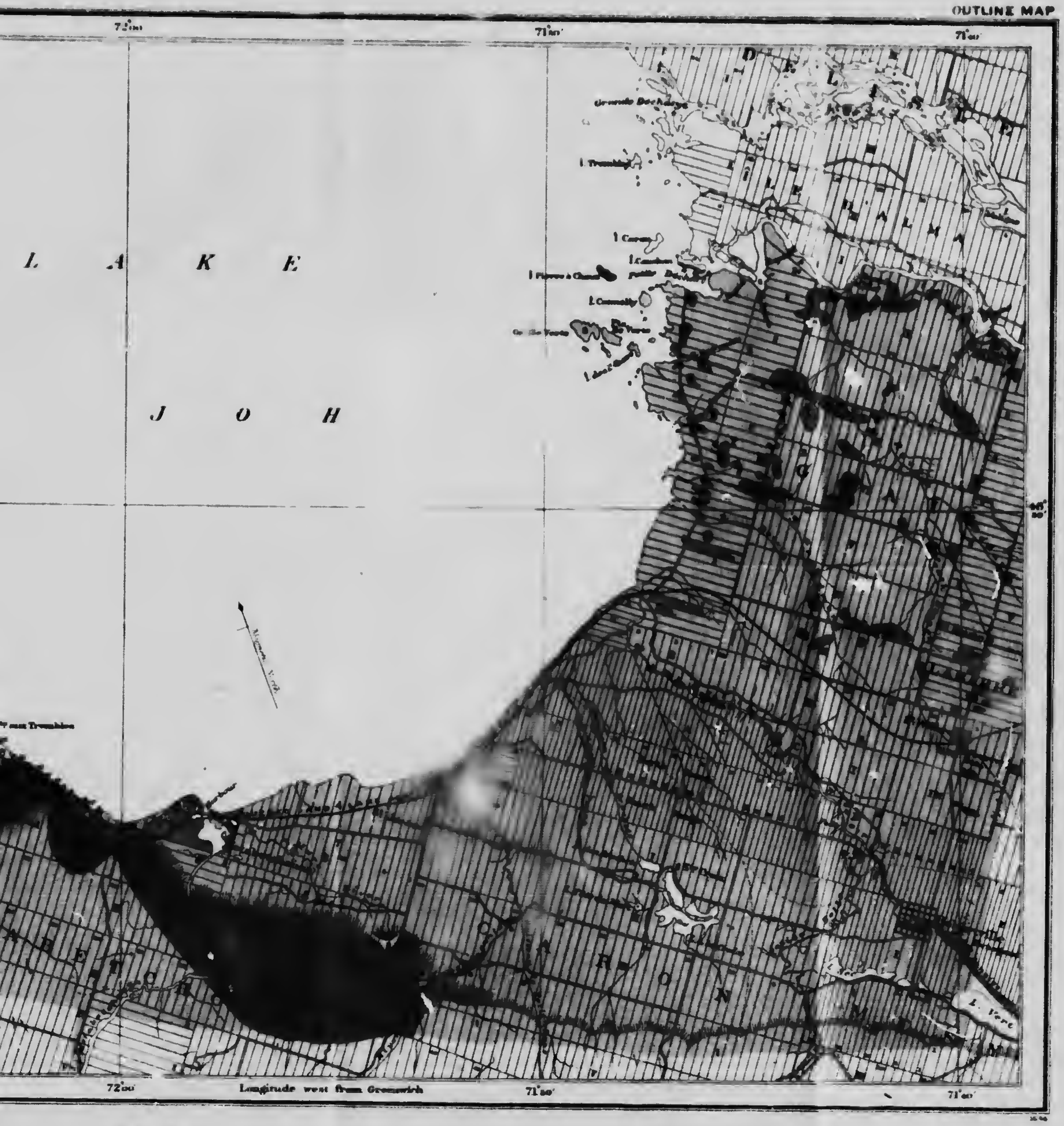
C-O Senecal, Geographer and Chief Draughtsman
A Jeanson, Draughtsman

ROBERVAL, LA

To accompany Memoir by J. A. Dresser

Canada
Department of Mines
P. E. BLONDIN, MINISTER. R. G. McCONNELL, DEPUTY MINISTER

GEOLOGICAL SURVEY



MAP 184 A
(Issued 1916)

AL, LAKE ST JOHN COUNTY, QUEBEC

Scale of Miles
½ 0 1 2 3 4 5

Geology by J. A. Dresser, 1915

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