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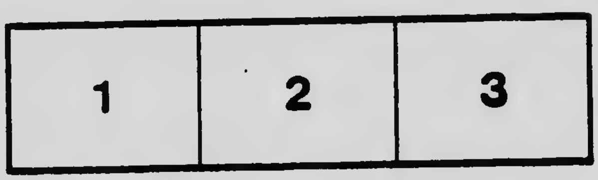
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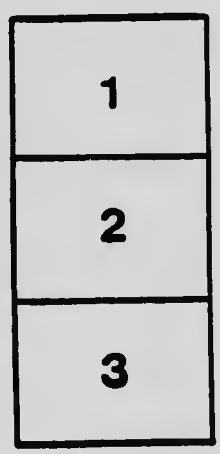
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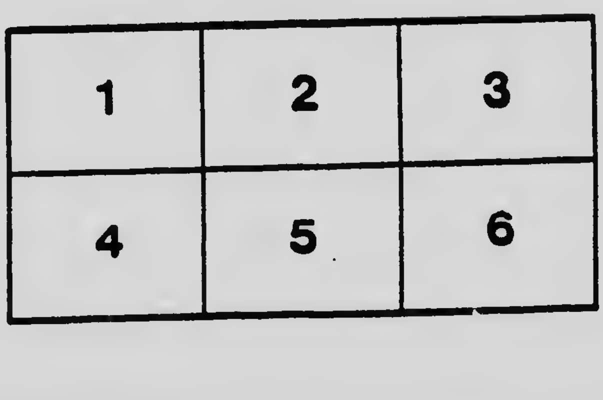
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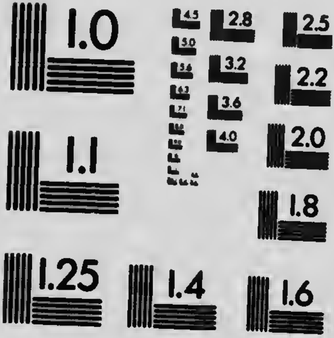

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GEOLOGICAL SURVEY

R. W. Brock, Director.

MEMOIR 40

No. 24, GEOLOGICAL SERIES

The Archæan Geology of Rainy Lake Re-studied

BY

Andrew C. Lawson

OTTAWA
Government Printing Bureau
1913

No. 1288

PLATE I.

Seine conglomerate; west of Mathieu, Canadian Northern railw

36570—Frontispiece

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Hon. Louis Coderre, Minister; A. P. Low, Deputy Minister;

GEOLOGICAL SURVEY
R. W. Brock, Director.

MEMOIR 49

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PREFACE.

The present memoir is the result of investigations carried on in northwestern Ontario by Dr. A. C. Lawson during the season of 1911. It will be remembered that in the eighties, Dr. Lawson, then a young geologist on the staff of the Geological Survey, was engaged in a reconnaissance in this region, and that his reports on the district became classical. At that time the district was difficult of access and covered with primeval forest, so that geological work was carried on under great difficulties, and only a reconnaissance was possible. In the interval of time that has elapsed, a vast amount of detailed work has been carried on by the United States Geological Survey and the various state surveys to the south of the International Boundary line that has added largely to the knowledge of the Pre-Cambrian. It was felt that it would be of great interest and value to have Dr. Lawson revisit his old field, and study it under the more favourable conditions now prevailing.

Since the principal object is to present Dr. Lawson's position and his mature opinions based on his re-examination and more detailed study of the district, the memoir is printed without alteration as submitted in manuscript by Dr. Lawson.

(Signed) **R. W. Brock.**

THE ARCHÆAN GEOLOGY OF RAINY LAKE RE-STUDIED.

CHAPTER I.

INTRODUCTORY.

In a field so complicated and so extensive as that presented by the Archæan terranes of Canada it is not surprising that as investigation proceeds there should be conflict of opinion. The early records of the earth's history are obscure and difficult to decipher. They are susceptible in their imperfection of more than one interpretation. The acquisition of facts is so slow and laborious that no one geologist can hope to become familiar with the details of more than a very small portion of the entire field. The work to be done is appalling in its magnitude; yet none shrink from the task. There is so much that is fundamental to the science of geology in the elucidation of the Archæan that everyone interested in this branch of the subject feels constrained to contribute what little he may to the general effort which the vastness of the problem calls for. What cannot be done by the individual shall be done by co-operation.

Naturally this co-operation resolves itself into the study of small discrete areas by individual workers and a comparison and discussion of the results there obtained, until eventually we arrive at that consensus of opinion which is commonly accepted as scientific truth. In this discussion, which proceeds slowly through years and decades, conflict of opinion is inevitable. Owing to the variation of conditions the conclusions which are reached in one area fail of verification in another. Disputes thus arise which can only be settled by a careful restudy of the facts concerned in the question at issue.

An interesting case in point is the discussion which has arisen out of my report on the geology of the Rainy Lake region. Up to the time of the publication of my reports on the Lake of the Woods (1885) and Rainy lake (1887) the notions which prevailed almost universally regarding the Archæan of North America were quite different from those which have obtained general acceptance since then. The Archæan consisted of two main divisions known as the Laurentian and Huronian, the latter lying unconformably upon the former on the northeast margin of the type Huronian area, with a basal conglomerate. The Laurentian comprised certain metamorphic rocks, notably the limestones of the Grenville series, and with these there were associated certain gneisses which were also held to be metamorphic. Below the Grenville series was a vast expanse of granitoid gneiss, sometimes referred to as the Ottawa Gneiss or the Fundamental Gneiss, or the lower Laurentian. Above the Grenville series was the Norian series or upper Laurentian consisting of gneissic anorthosite and allied rocks. All of the gneiss of the Grenville series, and all of the Fundamental Gneiss as well as the anorthosite of the Norian series were regarded as metamorphic sedimentary strata. With the progress of reconnaissance mapping it was found that the rocks of the type of the Fundamental Gneiss were by far the most extensively distributed throughout Canada, and these rocks came to be designated simply as Laurentian on many maps and in many reports, without any change in the current conception of their origin, viz., that they were metamorphic sediments. This practice prevailed not only in Canada but also in the United States, and it extended to various other countries.

My reports of 1885 and 1887 showed that these granitoid gneisses of the Fundamental Gneiss type, which form so large an element of the Archæan, were not metamorphic sediments, but were in reality plutonic igneous rocks, and a new point of departure was thus established for the study of the Archæan. The old notion of the metamorphic origin of these rocks became rapidly obsolete and the interpretation which I advocated was confirmed by observers in other fields and has become generally accepted, with all that it implies as to the extraordinary conditions which prevailed in the earth's crust in Archæan time.

In these same papers, particularly in that on Rainy lake, I described and mapped two series of metamorphic rocks as constituent members of the Archæan, which had not hitherto been fully recognized. These were the Keewatin and the Coutchiching. These were both shown to be older than the rocks then commonly called Laurentian. The Fundamental Gneiss thereupon lost its fundamental character from a chronological point of view; for instead of being the basement upon which the Coutchiching and Keewatin were deposited it was found to be an igneous rock intrusive in both. In the reconnaissance maps of both Canada and the United States the Keewatin had been confounded with the Huronian. Its segregation from the latter as a series of rocks quite distinct from and much older than the Huronian has been fully confirmed by the work of the past 25 years and the name Keewatin has been generally accepted.

The Keewatin series has been found to have a wide-spread distribution and persistent character over a large part of the continent. It is made up chiefly of volcanic rocks with subordinate admixture of sedimentary strata.

Below the Keewatin on Rainy lake I described and mapped as a series of metamorphic sedimentary strata free from volcanic admixture, the Coutchiching. My views of the geology here, however, have not met with the same favour among geologists as did my interpretation of the Laurentian and my recognition of the Keewatin. The conclusions as to the stratigraphic position of the Coutchiching series set forth in the report of 1887 have been called in question both by officers of the United States Geological Survey and by an international committee of geologists appointed to harmonize as far as possible conflicting usage with regard to the nomenclature of the Archæan. In view of the growing economic importance of the Archæan rocks and the extension of detailed mapping of them in various parts of Canada it seemed to the Director of the Survey that the issues thus raised should be settled if possible. At his request, therefore, I devoted the field season of 1911 to a restudy of the southern portion of Rainy lake with particular reference to the stratigraphic position of the Coutchiching. The result of this investigation has been to confirm the conclusion reached in 1887 that the Coutchiching underlies the Keewatin. A fuller statement of the facts and the argument in support of this conclusion are set forth in the present report. In the prosecution of this work I have made other observations and reached other conclusions of even more importance from a general point of view than this regarding the stratigraphic position of the Coutchiching.

Although, since the publication of my reports of 1885 and 1887, the old ideas of the metamorphic origin of the granitoid gneisses have been entirely abandoned and they are now generally recognized as of igneous plutonic origin, yet the term Laurentian was retained for these rocks and it was supposed for many years that they represented but one general period of plutonic activity. This usage of the term Laurentian has been confirmed by a decision of the International Committee on Geological Nomenclature.

But in recent years it has become apparent to a number of observers that the rocks classed under this term were not all of the same age. I have found during my field studies on Rainy lake and the Seine river in 1911, the most satisfactory evidence that the rocks which have been usually called Laurentian in this region really belong to two widely separated periods of time within the Archæan. For the older of these periods I have retained the name Laurentian in accordance with the definition of the term by the International Committee, and for the later period I propose to use the term Algoman, from the old district of Algoma. The full recognition of the dual age of the plutonic rocks hitherto commonly referred to the Laurentian I regard as a most important step in the elucidation of the Archæan of Canada.

Two other series of rocks occur in the region examined, one known as the Steeprock series, and one which I have named the Seine series, and these are probably the correlatives of the two divisions of the Huronian of Lake Huron. In the lower Huronian, or Steeprock series, I was fortunate enough to find well preserved fossii remains which have been described in Memoir No. 28. These appear to be the oldest fossil remains at present known. The only other matter of interest referred to in the report is the discovery of a small outlier of Palæozoic strata near Fort Frances at a point 200 miles distant from the nearest formerly known exposure of these rocks in Manitoba.

During the season I was ably assisted in the field by the late lamented Dr. J. D. Trueman, who was exceptionally efficient and well qualified for the work, by Dr. R. C. Wallace of the University of Manitoba, and by Mr. H. C. Cooke.

A geological map on a scale of one mile to the inch accompanies the report.

In the preparation of the report no attempt has been made to again discuss the physiography of the region; nor is any effort made to restate the Pleistocene geology; and for information on these matters reference must be made to the report of 1887. From a petrographic point of view the rocks of the region are of great interest, but an exhaustive discussion of this phase of the geology would be a task of great magnitude, beyond the limits of my present opportunities; and I have had to content myself with a microscopic examination of a limited number (125 in all) of thin sections of representative specimens of the rocks mapped to determine their character and classification. It seemed to me that the most desirable contribution to the petrography of these rocks would be careful chemical analyses of some of the more important types. I have, therefore, had thirteen analyses made in the laboratory of the Survey and these are incorporated in the present report.

CHAPTER II.

GEOLOGY

ARCHÆAN GEOLOGY: GENERAL STATEMENT

The oldest rocks of the Rainy Lake region are a thick series of sedimentary strata, now chiefly metamorphosed to mica schist and paragneiss, to which in the report of 1887[1] I gave the name Coutchiching series. This series is free from volcanic admixture. Resting on the Coutchiching series is the Keewatin, a series made up chiefly of volcanic rocks, but comprising also sedimentary strata intercalated with these. Included with the Keewatin as belonging to the same general geological period are certain gabbros which are intrusive in that series.

Intrusive in both Coutchiching and Keewatin are certain granites and granite-gneisses for which the term Laurentian is retained, in accordance with general present usage. This was followed by a period of erosion which exposed the Laurentian batholiths extensively at the surface. Upon this eroded surface there accumulated the Steeprock series of sediments and volcanics including several hundred feet of fossiliferous limestone. This series is tentatively correlated with the lower Huronian. After an interval of uplift, deformation, and erosion, in which the Steeprock series was extensively denuded, the region was again depressed and there accumulated upon it the Seine series comprising conglomerates, quartzites, and slates. Minor intrusions of lamprophyric rocks traverse the conglomerates. The Seine series is tentatively correlated with the upper Huronian (the middle Huronian of some writers), there being only two divisions of the Huronian recognized. After the deposition of several thousand feet of Seine strata the region was again invaded by vast batholiths of granite-gneiss and syenite-gneiss. For these post-Huronian plutonic rocks, which have heretofore been commonly confused with the older Laurentian rocks of similar character, the name "Algoman" is here proposed. The next event which it is possible to recognize in the history of the region is a protracted interval of profound erosion which I have elsewhere designated the "Eparchæan Interval." Upon the vast peneplain resulting from degradation during the Eparchæan Interval were deposited the Animikie sediments. The Animikie is thus separated from the Huronian by an enormous interval of geological time. On the far side of that interval

[1]Geol. and Nat. Hist. Survey of Can. Ann. Rept., N.S., Vol. III, Pt. I, 1887-88.

the earth's crust was affected by plutonic activities, involving the Coutchiching, Keewatin, and Huronian similarly, which have not recurred in the region so far as is known on the near side of that interval. In other words, the Huronian is allied in its geological history with the Coutchiching and Keewatin and is part of the Archæan, while the Animikie (Algonkian) is allied with the Palæozoic.

THE COUTCHICHING SERIES.

Within the limits of the territory embraced in the accompanying map the rocks of the Coutchiching series occur in three distinct areas. The first of these is an annular belt encircling a central mass of sheared granite or granite porphyry which is well exposed on the shores of Rice bay. The mica schists of the Coutchiching completely enclose the granite and dip away from it in all directions in the form of an anticlinal dome. The second area is in the form of a broad belt which extends from Redgut bay southwest and west to the western limits of the map. This belt is also anticlinal in structure, and in its full breadth is best exposed in the vicinity of Bear passage and may be referred to as the Bear passage belt or area. At its northeastern end the belt splits up into a number of tapering tongues or prongs which extend into the granite gneiss of Redgut bay, on the margin of a great batholith. Southwesterly from Bear passage the belt encloses successively three separate batholithic areas of granite or granite gneiss. Throughout its extent this belt of Coutchiching is flanked on either side by Keewatin rocks. The third area of Coutchiching is the most extensive and is that occupying a large part of the Minnesota coast of Rainy lake and the Canadian territory, south of Bleak bay, Cliff lake, and part of the Seine river, its limits to the south remaining undefined. In describing the series and its field relations these three areas will be considered in turn.

THE RICE BAY AREA.

The mica schists of Rice bay occupy a closed belt of flattened oval shape encircling a central mass of intrusive granite-gneiss. The width of the belt varies from less than half a mile to over three-fourths of a mile and averages about half a mile. The disposition of the mica schists about the granite is anticlinal. The dip of the schists is away from the granite. At several localities, particularly on the western nose of the anticline, this is at an angle of from 40° to 50°, but on the flanks of the anticline the dip is steeper, usually from 60° to 70°. The schists

A

B

A. Coutchiching on the north side of Rice bay; showing stratification.

B. Coutchiching on the west side of Rice bay; showing massive bed interstratified with more fissile schists.

in many sections show evidence of bedding, apparent in contrasts of colour and texture, and the schistosity is in general parallel to the bedding. There are numerous granitic intrusions in the schists. Those which are parallel to the bedding and schistosity are interpreted as sills and will be here so designated. Those in any way transverse to the bedding and schistosity will be referred to as dykes. These dykes and sills are most numerous in the vicinity of the central granite-gneiss mass, and they are regarded as apophyses of that mass, not only from this fact, but also by reason of their petrographical similarity to the main intrusion. Besides these granitic sills and dykes there are also in the schists occasional long, narrow belts of hornblende schists which are regarded as very probably being basic sills which, originally injected into sedimentary strata, have been reduced to hornblende schists by the same dynamic action which converted those strata into mica schists. There are also some beds interstratified with the mica schists which consist very largely of feldspar, quartz, garnet, and epidote with some pyrite, and which do not fall into the general category of mica schists. These are regarded as beds which were originally calcareous rather than argillaceous and have consequently yielded a different product as a result of metamorphism.

Nearly all the rocks of this area, including both the central granite gneiss and the annular belt of schists which surrounds it, show in a remarkable degree the effects of intense compression and shearing. The granite-gneiss is somewhat variable in mineralogical composition and this variation is expressed chiefly in the development of the orthoclase. The rock is prevailingly a very quartzose biotite granite and in some of its facies the orthoclase is abundant in large well formed crystals, while in other cases the orthoclase is much less conspicuous and the quartz is prominent in abundant large crystals. In other facies neither orthoclase nor quartz are especially prominent and the rock has more the texture of an ordinary medium grained granite. But whatever its local habit, the rock has been so sheared that it has a distinctly foliated and schistose character. Where either orthoclase or quartz are porphyritically developed, this shearing gives rise to an *augen*-gneiss structure. This is most perfectly and most commonly developed, however, in those facies which have porphyritic quartzes. The latter are characteristically reduced to very flat lenses, the major diameters of which are not uncommonly an inch and even 2 inches in length. The major diameters of the lenses lie parallel to the dip of the schistosity. The pronounced foliation which has been induced in the central granite mass is parallel to that of the encasing schists, both as to strike and dip. It thus has also an anticlinal disposition and the dip of the planes of foliation at the western end of the anticlinal structure, i.e., in the direction of the anticlinal axis, is as low as 35°. The strike of the foliation of the granite-gneiss here swings around in perfect conformity with the curve of the outcrop of the schists. The intrusions in the encasing schists, particularly in the sills, have the same characteristics. They were evidently similar mineralogically and structurally to the central mass, have suffered the same deformation, and have yielded the same results.

The dykes which traverse the schists transversely have been contorted due to a shortening in the direction of their strike, which has caused them to double upon themselves in sigmoid curves, which are sometimes rather acute. The compression to which they have been subjected has very clearly diminished the width of the sills and the length of the dykes. The compression has without doubt similarly reduced the original thickness of the mica schists into which they are intrusive. The compensation for this reduction in thickness has been an elongation, chiefly in the direction of the dip, with a less marked elongation in the direction of the strike. The present apparent thickness of these schists I estimate to be about 1500 feet. But the original thickness may have been very much greater. The underlying granitic rock which occupies the core of the anticline has displaced the basement upon which the original strata were deposited. In displacing that basement it has also displaced the basal portion of the Coutchiching series. How much cannot be stated. But it is quite possible that we are dealing here with only the upper part of the series. As to how the displacement was in detail effected, I will not here enter upon the discussion of so large and so interesting a problem, but will simply point out that the extremely quartzose character of the granitic gneiss suggests an enrichment of silica by resorption of the encasing acid rocks; and that the porphyritic development of the quartz in a plutonic rock indicates that this enrichment resulted in a super-saturation of silica which caused it to crystallize out first in accordance with the eutectic law.

Now it must be evident in view of the facts stated that the compression and shearing have affected both the central granite and the encasing schists after the consolidation of the former. This being the case, it follows that this post-granite deformation contributed in no small measure to the appression of the anticline, and that whatever dips the encasing schists had away from the central granite before the advent of this deformation, these have been greatly steepened in consequence of that deformation. Indeed this deformation has probably played so large a rôle in the development of the present anticlinal structure of the encasing schists that we must suppose that they at one time rested upon granite in comparatively

A

B

A. Coutchiching on the north side of Rice bay; showing stratification.
B. Coutchiching on the north side of Rice bay; showing stratification.

flat attitudes. It is this conception of the development of the structure which has led me to interpret the granitic intrusions parallel to the bedding of the schists as sills rather than dykes. It is quite evident from this intensely sheared condition that they too were intruded anterior to the period of compression, and, therefore, at a time when the schists were in much flatter attitudes than at present.

Outside of this annular belt of mica schists and concentric with it is a belt of typical Keewatin rocks comprising chiefly hornblende schists, ellipsoidal greenstones, massive greenstones, greenstone schists, chloritic schists, and gabbros, with subordinate intercalations of mica schists, chert, limestone, and conglomerate.

The boundary line between the Keewatin and the Coutchiching mica schists skirts the northwestern corner of Lower Rice bay a little back of the shore. Thence following it in a northeasterly direction it lies in the peninsula between Rice bay and Hopkins bay, being on the traverse line shown on the map 17 chains north of the shore at the narrows between Upper and Lower Rice bay and passing through the northeast inlet of Upper Rice bay. The general dip of the mica schists in the numerous exposures along the northwest side of Rice bay varies from 60° to 70° and averages about 65° to the northwest, carrying these schists below the Keewatin, the dip mentioned being true of the bedding as well as the schistosity. Beyond the northeast corner of Rice bay the strike of the contact of the Coutchiching and Keewatin swings around to east and then to southeast. The contact is next intersected on a north-south traverse at a point about 15 chains north of Pocket pond where the rocks strike 123° and dip N.N.E. at from 65° to 70° and again on a parallel traverse 30 chains east of this. It is again intersected on a parallel traverse a mile farther east and again on an east-west traverse 30 chains to the southeast. To the southeast and south, between this point and the Canadian Northern railway, the position of the boundary line between the two series of rocks was located as mapped on three traverse lines at intervals of 30 chains, 55 chains, and 30 chains respectively. Following the boundary southwesterly it intersects the line of the Canadian Northern railway at a point about midway between mile-posts 212 and 213 and again with a westerly strike at a point on the railway about a fourth of a mile east of mile-post 214. The dip of the schists along the railway is about vertical. Leaving the railway the boundary line between the two series passes to the north of Nickel lake and was intersected 12 chains north of its north end. It was again intersected a few chains south of the southwest corner of Rice bay and again where it crosses the

Narrows between Rocky Islet bay and Rice bay. North of the Narrows for about three-fourths of a mile the Keewatin is interrupted by an intrusive mass of mica syenite-gneiss upon which the Coutchiching schists abut, but this syenite is otherwise completely surrounded by Keewatin rocks.

These various points at which the boundary between the two series has been specifically located, together with the knowledge of the general distribution of the Keewatin rocks away from the actual line of contact, make it certain that the Rice Bay anticline of Coutchiching mica schists is completely surrounded by Keewatin rocks and that the former is the older and underlying series. The definition of this anticline is a distinct improvement over that of my report of 1887 and the mapping of the geological boundaries is more accurate and less conjectural. But the essential features of the structure were clearly recognized in the report of 1887, and upon that structure was based one of the chief arguments for the view then advanced—that the mica schists underlie the Keewatin. These mica schists were named the Coutchiching series and the argument still holds. I have shown that a residual volume of the Coutchiching series, the lower part of which has disappeared, is domed about a central intrusion of granite-gneiss and dips under an area of Keewatin rocks which completely encircles it.

But the International Committee on Geological Nomenclature[1] and the U.S. Geological Survey[2] deny the existence of such a series of rocks below the Keewatin. Neither of these authorities has, however, so far as their published utterances indicate, visited Rice bay. The facts which I have recited are open for verification to any geologist and the region is easily accessible. Would it not be well for these eminent authorities before wiping out the Coutchiching series utterly, to examine the Rice Bay section?

THE BEAR PASSAGE AREA.

In and about Bear passage, the strait which connects Redgut bay with the main body of Rainy lake, the relation of the Coutchiching to the underlying granite gneiss on the one hand, and to the Keewatin on the other is well revealed in excellent exposures. The general structure is here again anticlinal. The Coutchiching mica schists wrap around and dip away from an intrusive mass of granite gneiss. The longer diameter of this mass extends southwesterly from Bear passage about $2\frac{3}{4}$ miles; the shorter diameter transverse to this is about $1\frac{3}{4}$ miles. This mass differs from the Rice Bay

[1] Jour. Geol. Vol. 13, 1905.
[2] Mon. LII, 1911.

granite gneiss in that there is little if any evidence of the compression and shearing which have affected that intrusion since its consolidation. The rock is a medium grained fairly homogeneous biotite granite, with on the whole a feebly developed foliation, although locally the foliation may be pronounced. There are few pegmatitic or aplitic dykes traversing it; and inclusions of the encasing rocks are scarce except in the immediate vicinity of the intrusive contact. This contact is splendidly exposed at the south end of Bear passage. Here, at the entrance of the strait, on the west side, the prevailing rock is granite with large inclusions of mica schist; on the east side it is mica schist traversed by irregular apophyses of granite, the schist dipping easterly or northeasterly at 30° to 45°. About 14 chains north of the entrance on this side we come to the actual contact of the schist and granite. From this point northerly along the shore or a little back of it there may be seen the roof of the batholith resting upon the granite. The schists lie upon the granite at quite low angles, the angle of dip decreasing as we pass northerly from 45° to 30° at the entrance to from 30° to 25°, and then to from 25° to 20°; and in some places it is as low as from 15° to 10°. These figures give not only the dip of the schists reposing upon the granite but also the attitude of the contact plane between the granite and the schists, this contact being exposed in the face of cliffs having various salients, and re-entrants. In the granite there are numerous quartz veins which extend up to the contact but do not penetrate the overlying schists, except to a very slight extent in an irregular way. In several of these quartz veins the widest part is at the contact and they taper in width as they [illegible] into the granite. It is evident from these relations that the granite, after consolidation suffered a greater contraction of volume than did the overlying schists, and that this resulted in cracks in general normal to the contact. These cracks became subsequently the seat of vein deposition. Although these veins are thus so intimately connected with the granite contact, there is nothing to suggest that the deposition of the quartz can be referred to the magmatic waters of the granite.

The curvature of the trace of the contact followed northerly carries it below the waters of the strait for about 48 chains, and we next find it on the west side about a mile from the entrance. Here the strike of the contact plane and of the schists has swung around to 258° and the dip is northerly at angles of from 38° to 46°. Beyond this the details of the contact are obscured by forest and marsh.

At the southwest end of the granite mass in the vicinity of Breeze bay, the encasing mica schists of the Coutchiching series in the bottom of this bay and on its east side at a distance of from 20 to 25 chains from the contact, lie at low angles of from 10° to 15° dipping away from the granite, and are cut by dykes of the granite; but close to the granite the dip steepens, and at the contact is nearly vertical. The northern boundary of the granite is located approximately as mapped from data obtained on two northerly traverses from the lake shore.

From the facts above described, it is clear that the mica schists of the Coutchiching lie above and upon the granite which invades them from below; and also that the basement upon which the schists were originally deposited as sediments has been displaced by the granite, and that the displacement has involved the lower part of the series so that we have to deal with a residual volume of it; further it is apparent from the map that as we go away from the contact at the strait known as Bear passage we come upon typical Keewatin rocks resting upon the Coutchiching mica schists, at a distance of about half a mile. In this distance the dip of the bedding of the mica schists is prevailingly about 30° to the northwest, or away from the granite and towards and under the Keewatin. Locally the dip may be as high as 45°,but near the contact with the Keewatin it is as low as 25° to 20°. That we are dealing with bedding as well as schistosity in the observation of these dips is apparent from the usual evidence whereby the fact of bedding is established, viz., the contrasts of colour, weathering, texture, and composition of the different strata. These contrasts are not everywhere apparent but they are well displayed in the vicinity of the contact about 35 chains south of the Canadian Northern railway. Here the contrasts are accentuated by the effect of contact metamorphism referable to the granite intrusion. Certain beds, usually less than a foot in thickness, have had developed in them large numbers of crystals of secondary silicates of alumina which weather out prominently on the surface, while adjacent beds of comparable thickness are devoid of these crystals or nearly so . In consequence of this the rock is distinctly banded and the banding expresses a difference in original composition, which in a sedimentary series must be stratigraphic. There is a rather frequent display of repeated alternations of this sort in sharply marked stratigraphic arrangement in the Coutchiching rocks in proximity to intrusive granites.

The line of the contact emerges on the shore in a little bay about 20 chains south of the railway, where the Coutchiching and Keewatin rocks are not more than about a chain apart. Followed in from the shore in a southwest direction for a few chains the two series of rocks may be seen in actual contact, on the face of a steep little slope facing the southeast. In the lower part of this slope are the Coutchiching mica schists and in the upper part, the Keewatin greenstone; and the two are so close together that they may both be touched at once, without stretching the arms. Here the mica schists dip under the greenstone at an angle of about 30° and the superposition of the greenstone upon the schist cannot be questioned. From the little bay above mentioned where the contact emerges at the shore line, the boundary between the two series of rocks may be followed northeasterly for about 2 miles on the west side of Redgut bay. In this stretch, unfortunately, it lies for the most part below the waters of the lake, but owing to the irregularities of the shore line and the disposition of various islands, it can nevertheless be located very closely, and the dip of the Coutchiching mica schists is very uniformly from 30° to 40° to the northwest or under the Keewatin, the bedding being quite apparent at a number of places. Where the contact line skirts the points of the shore on the west side of Redgut bay the dip of the greenstone schists and hornblende schists above the Coutchiching conforms to that of the latter and is northwesterly 30° to 45°. The same relation holds for a belt of hornblende schists 15 chains to the west of the contact, where on an island half a mile north of the railway the dip is W.N.W. at an angle of 35° to 40°. Here well within the Keewatin terrane the hornblende schists are associated with some beds of interstratified mica schists and quartzite, the former, however, differing somewhat from the typical mica schists of the near-by Coutchiching. On another island 30 chains north of this is an interbedding of rather massive green schists with quartzose mica schists similarly dipping W.N.W. 35° to 40°. For the next mile northerly the contact is below the waters of Redgut bay, and where it again enters the shore at a point about 2½ miles north of the railway the strike has swung around to the northwest but the dip is still under the Keewatin or to the southwest at an angle of 60° and away from the area of granite gneiss which has cut away the greater part of the series on the northeast.

The facts here recited in regard to this line of contact, particularly near the railway on the shores of Bear passage and the south end of Redgut bay, taken in connexion with the relations of the Coutchiching to the granite, appear to me to prove conclusively the superposition of the Keewatin upon the rocks mapped by me as Coutchiching in the report of 1887. I invite the attention of the International Committee and of the U.S. Geological Survey to this section and challenge them in view of the facts there apparent and easily accessible, to deny the relations of the Keewatin and Coutchiching as I mapped and described them a quarter of a century ago. The fact that these eminent authorities have denied *in toto* the existence of the Coutchiching series as a constituent member of the Archæan below the Keewatin, without any attempt to verify the very explicit statement of the evidence in regard to this section contained in the report of 1887[1], places them in a curious light from the point of view of scientific method. The evidence above set forth as to the superposition of the Keewatin upon the Coutchiching is practically the same as that published in 1887. In the course of the work of the past field season this has been supplemented by other observations which support the conclusions then arrived at.

The area of Coutchiching mica schists, the western contact of which with the Keewatin I have just been discussing, is an anticlinal fold in the northeastward prolongation of the longer axis of the granite mass exposed so well at Bear passage. The width of the area transverse to its general trend is from 2 miles near the granite to 1½ miles on the section through Bear Pass Station. The anticline is asymmetric, the dips on the east limb being on the whole steeper than on the west, so that the axis of the anticline lies about two-thirds of the width of the belt from its western margin. This position is, however, approximately coincident in direction with the longer axis of the Bear Passage granite mass. The dips of the Coutchiching rocks are well exposed at numerous places on the shores of the south end of Redgut bay, on the shores of Bear passage, and along the line of the Canadian Northern railway between the bridge over Bear passage and Bear Pass Station. At many of these exposures it is apparent that the schistosity is coincident with the bedding. The dips on the west side of the axis are uniformly westerly or northwesterly at angles ranging generally from 28° to 45°, and on the east side of the axis the dips are uniformly easterly or southeasterly at angles ranging generally from 40° to 60°. Along the line of the axis of the fold the strata are prevailingly at very low angles and the fold is here a low buckled arch, and in one of the buckles exposed on the south shore of Redgut bay the strata may be seen dipping in opposite directions in the same cliff-face. The flat dips, however, are best seen perhaps along the cuts of the Canadian Northern railway where, just on the east side of the axis of the anticline, the strata dip southeasterly at 15° for some distance before acquiring the steeper dip which characterizes this limb of the fold.

At the eastern margin of the anticlinally folded Coutchiching area the mica schists pass beneath the Keewatin rocks on the line of the railway at an angle of about 60°. The actual contact is well exposed in a rock cut about a mile southwest of Bear Pass Station. Here on the face of the cut the Keewatin greenstone may be seen reposing upon the Coutchiching mica schist. The greenstone is finer grained at the contact than it

[1]Ann. Rept. p. 103F.

is a few feet above it, a phenomenon which suggests a chilling of the base of a flow. The top of the Coutchiching is very quartzose and presents the appearance of bands of quartzite interstratified with mica schist, but the rocks are somewhat obscured by an ochreous deposit due to the oxidation of pyrite in the rocks near the contact. On the Keewatin side of the contact the greenstone gives place in a short space to stratified green schists. There is no conglomerate or other erosional detritus at the contact. The underlying Coutchiching is somewhat crumpled. This contact may be followed for over a mile into the brush north of Bear Pass Station with the same general features, and for nearly 2 miles to the south, where it comes to the shore on the north side of Swell bay. Here the chilled margin of the basal bed of the Keewatin greenstone is well displayed in immediate contact with the mica schist,

Supplementary to this stratigraphic and structural proof of the fact that the Coutchiching antedates the Keewatin and underlies it is an interesting observation that I made in a rock cut on the line of the Canadian Northern railway 20 chains west of mile-post 211. Here the Keewatin hornblende-gabbro contains angular inclusions, some several feet in diameter, of mica schist. The mica schist clearly antedates the gabbro and is quite similar in its essential features, particularly as to its composition, to the schists of the Coutchiching, though it lacks some of the evidence of deformation to which the latter have been subjected. With little doubt it represents an altered pre-Keewatin sedimentary rock which was caught up by the gabbro magma in its passage upward.

If there is anything further needed to establish the fact that the Coutchiching rocks are disposed in an anticline domed around an intrusive mass of granite and that they pass on both flanks of the anticline beneath the Keewatin, I should be very glad to have the International Committee or the U.S. Geological Survey point it out. If there be nothing further needed to complete the proof of this relationship, it would seem to be incumbent upon these eminent authorities that they should reconsider their somewhat dogmatic denial of the existence of such a series of rocks as I have described under the name of the Coutchiching.

North of the south shore of Redgut bay the mile and a half wide belt of Coutchiching rocks just described encounters another extensive mass of granite, which is locally quite gneissic, and in doing so it breaks up into at least three tongues. The middle one of these lies along the axis of the anticline and is exposed on the shores of Moose point. Here, as farther south in the same situation, the Coutchiching mica schists are almost quite flat over an area of half a mile by a fourth of a mile.

But a little north of Moose point the same schists dip down to the southeast into the granite, in which they are embedded, at angles varying from 25° to 30°, and the foliation of the granite gneiss has the same dip. This tongue of schist is traversed by numerous apophyses of the granite and the neighbouring main mass of granite holds numerous inclusions of the invaded rock. It is evident that we have here a remnant of the actual roof of the batholith, reposing in flat attitudes upon the granite in the axis of the anticlinal fold which was domed up by and arched over the granite magma at the time of its consolidation. This domed or arched relation of the invaded rocks to the underlying batholith is characteristic of several of the smaller batholiths of this region. It is noteworthy that it is the same structural relation as that which obtains in the case of laccoliths. It is one which must be taken into consideration in any complete account of the mechanics of batholithic intrusion.

The easterly of the three tongues of the Coutchiching belt skirts the east side of Redgut bay in juxtaposition to a similar tongue of the Keewatin and the two together form a point or prong tapering out to nothing in the granite less than a mile north of Bear Pass Station on the Canadian Northern railway. The westerly tongue is a residual strip of the main Coutchiching belt left between the intrusive granite of the north end of Redgut bay and the Keewatin of the west side of the bay. This tongue swings around so as to enter the shore with a northwesterly strike and a southwesterly dip of from 55° to 60° below the Keewatin. The exploration of the country south of Base-line bay indicates that this tongue is cut out by the granite so as to bring the latter against the Keewatin at a point less than a mile inland.

To the southwestward of Bear passage the main belt of Coutchiching mica schists bifurcates and, as has been stated, encloses the granite mass which extends southwesterly to Traverse inlet. The two arms of the bifurcation coalesce between Traverse bay and Joint bay and at the latter the belt opens out again to embrace another small batholithic dome of granite, which extends with a major diameter of 3¼ miles west nearly to Goose island. The greatest north and south diameter is a little over 1¼ miles. This granite mass may be referred to briefly as the Knuckle Island granite. It is even more homogeneous, less gneissic and freer from pegmatitic and aplitic dykes than the Bear Passage granite and it also contains very few inclusions of the encasing schists except at the immediate contact. The phenomena of intrusion are, however, well displayed at the contact, both by the contact metamorphism of the encasing rocks and by the apophyses from the main mass of the granite cutting the schists. It is the same

A

B

A. Horizontal joints in granite at contact with Coutchiching on Joint bay.
B. Contact of granite and Coutchiching on the west side of the entrance to Blind bay.

kind of granite as that of the Bear Passage area, and is doubtless continuous with it below the schists. The latter have a width of about 1½ miles between the southwest end of the Bear Passage granite and the east end of the Knuckle Island granite. In this space the Coutchiching mica schists lie in a syncline-anticline node. That is, they are synclinally disposed with reference to the two granite masses and anticlinally disposed with reference to the belt of Keewatin which bounds them on the north and another on the south in the islands which extend through the main body of Rainy lake. The axes of the two folds intersect in the vicinity of Breese bay, where, as has been stated, the mica schists lie in very flat attitudes.

The relations of the Coutchiching mica schists to the Knuckle Island granite are well exposed on the northeast side of Joint bay. At the point where the contact intersects the shore, the strike of the contact and the encasing schists is north and south, with an easterly dip of the schists of 35°. The bedding of the schists is again in this locality more or less apparent. The differences are due to the effect of contact metamorphism upon the different beds, some being characterized by a great abundance of secondary silicates, which weather out on the surface in wart-like forms, while other beds have this feature in a much less marked degree or lack it altogether. Numerous dykes of the granite cut the schists and there are numerous inclusions of schist fragments in the granite. Followed inland for a few hundred yards the strike of the contact swings around to the northwest and then west-northwest, the angle of dip increasing to 50°. On the larger of the two islands just south of the point on the shore where the contact is revealed, the strike of the mica schists curves from 68°at the southwest end of the island to 43° at the northeast end and the dip is southeasterly or away from the granite at 40° to 45°. The contact of the granite and schist to the north of the bay was intersected by a traverse made from its middle part at a distance of 13 chains from the shore. The strike of the schists here is 102° and the dip 45° to the north. All the shores of the bay west of the contact are granite so that it is perfectly clear that the schists wrap around the not very obtuse east end of the granite mass and that the strike of the schists conforms to the contour of the intrusive body. In other words, the schists are domed about the granite. At the contact the granite contains an abundance of quartz veins, usually about a foot or less in width, which, while they do not so sharply abut upon the contact as in the case described at Bear passage, are clearly analogous phenomena. They represent the infilling of shrinkage cracks in the granite below the over-arching roof of schist. The granite is also characterized by a remarkably even and sharply defined horizontal jointage in the vicinity of the contact.

Eastward from the contact along the shore the angle of dip increases to 60° and then to 67° and then gets rapidly lower again in Breeze bay. Southwestward from Joint bay the contact is, for about a mile, below the waters of the lake, and then skirts the outer points of Knuckle island. Here following the contour of that island it swings to the west and enters the main shore about a mile west of Knuckle island. Beyond this point this contact swings to the west-northwest and the mica schists dip away from the intrusive granite at angles varying from 55° to 75° for an observed stretch of a mile. Beyond Marsh island the contact passes between Ben island and John island and is next observed on the northwest side of Noon island, where the mica schist is in immediate contact with the granite dipping away from it to the north 30°. On the north side of Goose island these mica schists also dip north at angles of 45° to 50°. It is evident from a consideration of the map that, in the interval between Ben island and Goose island, the schists have swung sharply around the west end of the Knuckle Island granite. The northerly dip of the mica schists on Noon island and Goose island at the very moderate angles mentioned, 30° to 50°, is towards and under the Keewatin schists of the mainland and these dip also northerly at about 60°. The mica schists of Noon island are traceable across the head of Duck bay where they as before dip below the Keewatin at 50° and the observed dip of the latter is 60° a little north of the contact. This belt of Coutchiching lying between the granite and the Keewatin tapers out easterly so that it is eventually cut out entirely by the granite and the granite comes against the overlying Keewatin, as may be seen in a section northerly from Blind bay.

By way of summary, it may be said that the Knuckle Island granite is in all essential particulars similar to the Bear Passage granite, that it underlies the Coutchiching schists which are domed around it, and that the latter dip away from it below the Keewatin rocks which flank them, which relationship is particularly clear as regards the Keewatin on the north side of the dome.

To the southwest of the Knuckle Island granite, the Coutchiching belt again bifurcates and embraces a mass of intrusive plutonic rocks which extends from Sand Point island westward through Rainy lake in an ever widening area to the western limits of the map. The southern portion of this area is chiefly occupied by biotite granite gneiss which appears to terminate between Last island and the outlet of the lake. The northern part is occupied by mica syenite-gneiss, which extends with increasing breadth westward to the west side of the lake and thence indefinitely beyond. Between the granite-gneiss and the syenite-gneiss there is a narrow belt of Coutchiching mica schists extending from Last island to Nowhere island, a distance of about 3 miles. The width of this schist belt is only a few chains. The eastern end of this complex plutonic mass is about one-fourth of a mile west of the northern extremity of Sand Point island. Here the width of the mica schists separating this intrusive mass from the Knuckle Island granite is a little less than one-fourth of a mile. From this point of bifurcation, the northern arm of the Coutchiching belt extends through John island, Goose island, Lichen island, and the southern part of the peninsula lying south of Commissioners bay from Back point nearly to Gash point, where it ends in a point. The southern arm extends through the north part of Sand Point island, Angling island, Red Pine island, Jackfish island, Stop island, and the south shore of the lake from Medouganak point to Coutchiching at the outlet of the lake and for an indeterminate distance beyond.

West of Noon island the contact of the Coutchiching against the Keewatin which lies to the north of it, is first seen on the shore about 35 chains north of Back point. Here both mica schists and the hornblendic schists of the Keewatin dip northerly at an angle of from 65° to 75°, but a precise line of demarcation between the two series cannot be located in this section. For 200 feet or more across the strike, hornblende schists alternate with mica schists and it is probable that the conditions of sedimentation which prevailed in Coutchiching time persisted after the volcanic activity of the Keewatin had set in in neighbouring parts of the region, this volcanic activity yielding strata of basic material which became intercalated with the uppermost beds of the lower series. West of this the contact as mapped is characterized by high dips, about 80° to the north, in both series, and the evidence of the superposition of the Keewatin on the Coutchiching depends upon the continuity of the rocks of both series with those farther east, where, as above described, the relations are clear.

In the foregoing description of the central anticlinal belt of Coutchiching, extending on the map accompanying this report from the middle of Redgut bay to the lower end of Rainy lake, attention has been directed chiefly to the relations of the mica schists of that series to the underlying intrusive granites on the one hand and to the Keewatin, which lies above it on the other side of the belt. It remains to describe briefly the southern boundary of this belt and its relations to the Keewatin, which lies to the south of it.

The eastern boundary of that portion of the Coutchiching belt exposed in the vicinity of Bear passage has been described as skirting the west side of Finger point half a mile east of the entrance of Bear passage. The belt of Keewatin rocks with which the Coutchiching is here in contact, is, however, narrow and tapering to the south. On the east side of Finger point is another belt of Coutchiching schists which skirts the shore on that side and occupies all of the north and east side of Shelter cove. This belt has a width across the strike of the schists of about half a mile. Between the Bear Passage belt of Coutchiching and the Shelter Cove belt the tongue of Keewatin tapers to the south, but includes two small islands off the point, and is, beyond these, no longer seen on any of the islands. To the north it widens for about 2½ miles and then bifurcates about a southwesterly projecting lobe of the large and irregular granite area which extends easterly from Redgut bay. At the point of bifurcation the Keewatin rocks have a breadth across the strike of nearly a mile. Both arms of the bifurcation are apparently cut off by the granite, the west one in about a mile and the east in 2 miles. This area of Keewatin has thus the shape of an acute spearhead, the converging sides of which are bounded on both sides by Coutchiching rocks and the re-entrant base of which abuts upon and partially encloses an intrusive mass of granite. This relationship is interpreted as the tapering end of a synclinal trough sunk in and closely appressed in the underlying Coutchiching, the larger part of the fold having been cut away by the intrusion of the granite. But the dip of the rocks on both sides of the contact on the shores of Shelter cove is southeast at 60° to 70°, so that if we interpret the Keewatin as an appressed syncline we must also regard it as an overturned one. Similarly the Shelter Cove belt of Coutchiching becomes an overturned anticline since the dip is fairly uniform across its breadth.

The Shelter Cove belt of schists is traceable inland as mapped for about 4 miles, having been intersected by a traverse made northerly from the extreme north part of Swell bay along the west boundary of the Indian Reserve 26A, and again by a traverse from the south end of Little Ottertail lake. The rocks of the belt show stratification very plainly at a number of places, particularly on the shores of Shelter cove, and the schistosity is parallel with the bedding.

Petrographically the rocks of the Shelter Cove belt as exposed on the shores of Shelter cove are not identical with those of Bear passage. The differences are, however, clearly ascribable to the fact that the sediments are less altered. In general the character of the Coutchiching rocks is in notable degree a function of their distance from the granites which invade them. Near the granite they are typical harsh mica schist hornfels with, in some beds, an abundant development of contact minerals particularly cordierite. These weather out on the surface in a wart-like fashion, and where the rock is broken the presence of these crystals gives the rock a nodular appearance, the schistosity accommodating itself to their contours. At a distance from the granite these minerals are not developed, but the rock may be a well defined fine grained mica schist. Still farther away some of the beds may be mica schists while others interstratified with them are scarcely more than phyllites, or quartz slates in which the mica is present only on a microscopic scale. On the basis of mineral composition some might indeed term the latter quartzites, but this term as usually employed suggests if it does not definitely imply, that the original rock was a sandstone, whereas the rocks here referred to appear never to have been sandstones but rather extremely fine siliceous silts. In their present condition, in view of the poverty of our nomenclature, they are better termed quartz slates. Now in addition to the mica schists of the Shelter Cove belt there is a considerable proportion of phyllites and quartz slates, which might easily have become mica schists had they been subjected to more intense metamorphic action. Indeed this same belt if followed about 4 miles along its strike to the vicinity of the granite on the south side of Little Ottertail lake, changes its character and the rocks composing it become well defined mica schists. This only partially metamorphosed facies of the Coutchiching sediments characterizes the southern margin of the main belt of these rocks as traced through the islands of Rainy lake from Shelter cove to Stop island, a distance of about 12 miles. But beyond this along the strike they assume the characters of mica schists; and wherever we pass from the margin towards the granites which occupy the central part of the belt we may observe similar evidence of more intense metamorphism.

The mapping of the southern boundary of the main central belt of Coutchiching where it is in contact with the Keewatin to the south is based upon practically continuous tracing as far as the insular nature of the exposures would permit. Besides the exposures observable on the two traverses north from the north side of Swell bay the contact of the two series may be seen on the west side of Wreck point, where the Coutchiching strata, here mica schists, dip under the Keewatin greenstone at an angle of 70°. For the next mile to the southwest it is concealed by the waters of the lake, and then cuts across the south side of Dude island with a strike of 53° and dip of 75° to 80° to the S.E. Three-fourths of a mile beyond this it similarly cuts across the south side of Morton island, the dip here being vertical.

On both Dude island and Morton island the conditions at the contact are the same. Feebly micaceous schists and phyllite and siliceous slates in which bedding is more or less apparent stand in highly inclined or vertical attitudes in juxtaposition to greenstone schists, traversing which are bands of chlorite schist. On Morton island the chlorite schist is in contact with the Coutchiching. The schistosity of the Keewatin rocks is parallel to the contact plane.

The contact is next seen on the eastern end of Armot island 2½ miles to the west-southwest, where it is very similar to that on Morton island, but more difficult to locate with precision, owing to the evident gradation from one set of rocks into the other. The dark green chlorite material of the Keewatin whether derived from volcanic ashes or from the waste of volcanic rocks accumulating in the region, is evidently intermixed with the uppermost beds of the Coutchiching and for a space of 100 or 200 feet it would be difficult to say where one series ends and the other begins, although the exposures are excellent. It is evident that there is no erosional break or unconformity between the two sets of beds. The schists are in vertical attitudes and as we go from the transition zone, we pass on the north side into rocks which have no chlorite and on the south side into rocks which have a wholly volcanic origin.

Quite similar conditions obtain at the section afforded by the Narrows between Armot and Sand Point islands, and again at the west end of Sand Point island and the south side of Angling, Red Pine, and Red Sucker islands. Throughout this stretch it is practically impossible to locate a definite precise boundary between the two series, although on either side of a transitional zone these two series are strongly contrasted as to physical properties and origin. On the south side of Jackfish island, however, the line of demarcation between the two series appears to be more sharply defined. Here a portion of the shore is occupied by typical Keewatin greenstone schist and to the north of this lie the mica schists of the Coutchiching with a narrow intervening strip of rather fissile chloritic schist. At all of the localities above mentioned from Morton island to Jackfish island the dips of the schists at the contact and the contact plane itself are either vertical or northerly at angles ranging from 90° to 70°, so that little can be certainly inferred as to the question of the superposition of one series on the other. There is, however, nothing in this attitude of the rocks inconsistent with the view previously expressed as to the anticlinal character of the belt of Coutchiching lying to the north of this contact. The significant facts connected with this line of contact are the mutually confirmatory observations:—

(1) That there is a transition from one series into the other, which may be explained by basic volcanic ashes having been contributed to the basin in which the last of the Coutchiching sediments were accumulating, in advance of the outpouring of lavas, and

(2) That there is no trace of conglomerate or other evidence of erosional interval between the two series.

Beyond Jackfish island the contact lies in the channel north of Grassy island and passes into Rat-root bay where, however, it appears to be cut off at the surface by the transgression of the conglomerate which occurs there. The relation of this conglomerate to the Keewatin and the Coutchiching will be discussed in a later part of this report.

THE SOUTHERN BELT.

The area embraced within the special map accompanying this report includes the northern part of the great body of mica schists mapped as Coutchiching in the report of 1887.

The northern edge of this terrane is in contact with the main Keewatin belt of Rainy lake along a line which extends across the map from east to west. It was the examination of this line of contact, particularly in the vicinity of Rat-root bay and at Shoal lake on the Seine river, which led the International Committee to conclude that the stratigraphic relations of the Coutchiching and Keewatin were just the reverse of my statement of them contained in the report of 1887.

The following paragraph, quoted with approval from the report of the Committee, by the U. S. Geological Survey[1] clearly expresses the views of my critics:—

"In the Rainy Lake district the party observed the relations of the several formations along one line of section at the east end of Shoal lake and at a number of other localities. The party is satisfied that along the line of section most closely studied the relations are clear and distinct. The Coutchiching schists form the highest formation. These are a series of micaceous schists graduating downward into green hornblendic and chloritic schists, here mapped by Lawson as Keewatin, which pass into a conglomerate known as the Shoal Lake conglomerate. This conglomerate lies upon an area of green schists and granites known as the Bad Vermilion granites. It holds numerous large well-rolled fragments of the underlying rocks, and forms the base of a sedimentary series. It is certain that in this line of section the Coutchiching is stratigraphically higher than the chloritic schists and conglomerates mapped as Keewatin. On the south side of Rat-root bay there is also a great conglomerate belt, the dominant fragments of which consist of green schist and greenstone, but which also contain much granite. The party did not visit the main belts coloured by Lawson as Keewatin on the Rainy Lake map, constituting a large part of the northern and central parts of Rainy lake. These, however, had been visited by Van Hise in a previous year, and he regards these areas as largely similar to the green-schist areas intruded by granite at Bad Vermilion lake, where the schists and granites are the source of the pebbles and bowlders of the conglomerate."

The views here expressed are so positive that in the re-examination of the field I was prepared to find that my early inter-

[1]Mon. LII, p. 147, 1911.

pretation of the relationship of the two series was erroneous. I felt that when a body of scientific men acting in a judicial capacity reviewing a colleague's work could come to a unanimous decision that the Coutchiching series was above the Keewatin, there must be some very convincing and unequivocal evidence of this relationship. I have, however, failed to find this proof. All the facts which I have been able to observe are quite consistent with the superposition of the Keewatin upon the Coutchiching established by the Rice Bay and Bear Passage sections.

The principal argument advanced by the International Committee in favour of the supposed superposition of the Coutchiching upon the Keewatin is based upon the significance of the conglomerate which occurs at Shoal lake and Rat-root bay. In the report of 1887 I placed this conglomerate at the base of the Keewatin. In this I erred. The observations of the International Committee led them to the conclusion that this conglomerate is post-Keewatin, since it contains pebbles of the Keewatin rocks, and in this conclusion I now concur fully. The Committee, however, went further and stated that the conglomerate was at the base of the Coutchiching, and in this I am unable to concur as a statement of observation or of fact inferred from observation. If the contention of the Committee is well founded, the conglomerate should occur between the Keewatin and Coutchiching rocks on the line of contact which extends along the north side of the Seine river and thence westerly through Rainy lake to the vicinity of Rat-root bay. How far this is true will appear from the following account of the conditions which obtain at this contact wherever it is observable within the field including both Shoal lake and Rat-root bay. Beginning in the country east of Shoal lake, a little beyond the limits of the map, the contact will be traced westward.

On the south side of Wild Potato lake is a small creek coming in from the south at a point about half a mile west of meridian 92° 30′ as it is laid down on the map of 1887. Half a mile up the creek is a waterfall over the outcrop of a diabase dyke. The south shore of Wild Potato lake and the country to the south of it for half a mile beyond this waterfall is occupied by quartzites, slates, and greywackes of the Seine series. These are followed to the south by a belt of Keewatin exposed in a bare prominent ridge about 6 chains wide. The rocks comprising this ridge are greenstone schists and chlorite schists having a strike of 78° and a vertical dip. Immediately in contact with these Keewatin rocks on the south flank of the ridge are the mica schists of the Coutchiching, having the same dip and strike, and thence these rocks extend southerly for an indefinite distance. The contact is so sharply and clearly exposed that one may stand with one foot on Coutchiching and the other on the Keewatin. There is no trace of conglomerate or other evidence of erosional unconformity at the contact. The contact plane is parallel to the schistosity of the rocks on either side. This same belt of Keewatin comes to the Seine river just above Wild Potato lake, on the south side of Partridge Crop lake (Piniemuta lake) and again above Sturgeon Falls, with the rocks of the Seine series lying to the north of it.

On the south side of Shoal lake a traverse made by my assistant, Mr. H. C. Cooke, from a point about south of Bell City, encountered this same belt of Keewatin at from 55 to 70 chains south of the lake shore. To the north of the Keewatin belt lie the pebbly grits, quartzites, and greywackes of the Seine series, and on the south side, the mica schists of the Coutchiching. About 1½ miles east of this another parallel traverse was made by Mr. Cooke, but the place where the Keewatin belt is due is occupied by a muskeg with the rocks of the Seine series on the north of it and the mica schists of the Coutchiching on the south. Still another traverse, made by myself 2 miles to the east of the last, encountered a belt of muskeg and glacial drift, about half a mile wide, between the Seine series and the Coutchiching, the latter being exposed as typical mica schists with a strike of 73° and a vertical dip at a point about 1½ miles south of the Seine river.

At the mouth of the creek which enters the Seine river just east of the portage to Rat river, the Keewatin belt is again exposed, with the pebbly grits and quartzites of the Seine series on the north of it and typical Coutchiching mica schists on the south. The strike of the rocks is east and west and the dip departs little from the vertical. From this point westerly the Keewatin rocks occupy the south side of Grassy lake for a distance of 3 miles and comprise greenstones, greenstone schists, and chloritic schists. Short traverses south from the lake shore reveal the Coutchiching mica schists immediately to the south of the Keewatin. Nowhere was any conglomerate found at the contact of the two series, but the conglomerates, quartzites, etc., of the Seine series are exposed at a number of places on the north side of Grassy lake to the north of the Keewatin belt. West of the lower end of Grassy lake, along the Seine river, the exposures are so poor that little information can be obtained as to the relations of the two series, but it appears that the basal conglomerate of the Seine series, which on Shoal lake lies wholly within the Keewatin area, obliquely crosses to the contact between the Coutchiching and the Keewatin. This is its position for 2 miles along the north side of Cliff lake. This is the only place that I know of where the conglomerate actually lies between the Coutchiching and Keewatin, and the only place at which, taken alone, it might be interpreted as a basal conglomerate of the Coutchiching. But this interpretation is so inconsistent with many other sections across the contact of the Coutchiching and Keewatin and with the general distribution of the conglomerates within the Keewatin area, that it is very probable the interpretation suggested is fallacious. The position of the conglomerate on Cliff lake may be readily explained on the supposition that a gravelly flood-plain, which for the most part was spread out over the Keewatin rocks, at this place covered the contact between the Coutchiching and Keewatin and subsequently became infolded and schistified at the time of the acute deformation of the region. The conditions under this supposition would then be quite analogous to those at Steeprock lake, where, as I have shown[1], the basal conglomerate of the Steepock series was spread across the contact between the granitoid gneiss (Laurentian) and the Keewatin and subsequently infolded in vertical attitudes between these two sets of rocks. Smyth[2] in his description of the geology of Steeprock lake, failed to recognize this infold, included the Keewatin with the later series, and regarded the conglomerate as plunging indefinitely beneath the combined assemblage. A similar misconception of the structure might well arise at Cliff lake if the conditions there were considered without regard to information obtainable in other sections.

Another illustration of the infolding of a conglomerate at the contact of two different formations, both older than the conglomerate, is afforded by the Seine conglomerate on Shoal lake, as I shall show on a later page.

West of Cliff lake, the conglomerate is not exposed for some miles, but on the east shore of Bleak bay and on some of the islands on the north side of that bay, the Keewatin rocks are succeeded on the south by a detrital formation which doubtless represents the conglomerate horizon, and the next rocks observable to the south of this on the shores and islands of Bleak bay are the regular Coutchiching mica schists.

Beyond Bleak bay, to the west, the contact of the Coutchiching and Keewatin is concealed by the waters of Rainy lake for about 8 miles. It is next observable on the Minnesota coast a little west of the line between St. Louis and Itasca counties, whence westward it skirts the shore for 2½ miles to the entrance of Black bay. Here the condition at the contact of the two series is very much like that on Armot and Sand Point islands and the line mapped as the boundary must be more or less arbitrarily chosen in a transition zone.

[1] Dept. Mines, Geological Survey, Mem. 28, 1912.
[2] Structural Geology of Steeprock lake, Am. Jour. Sci. 142, p. 317 et seq. 1891.

South of the line adopted, the rocks are prevailingly highly altered mica schists with an east and west strike and an approximately vertical dip. To the north of this lie alternating beds of chloritic schist, grey phyllites, and quartz slates, with greenstone schists on some small islands off shore. There is no conglomerate at the contact; but the rocks of the Coutchiching to the south are notably more highly crystalline and metamorphosed than those of the Keewatin to the north and this fact is made use of in deciding where to draw the line between the two series. Followed westward across the mouth of Black bay, the contact lies between a group of three small islands and the main shore. The islands are composed of typical Keewatin greenstone schists; the rocks of the main shore a few chains to the south are typical Coutchiching mica schists. Half a mile west of the islands the contact intersects the main shore again with the Keewatin schists on the north and the Coutchiching on the south. There is no conglomerate or other evidence of erosional unconformity at the contact. A little less than an eighth of a mile to the north of the contact, beyond the belt of Keewatin, is a conglomerate; but as will be shown later, this lies in a synclinal trough within the Keewatin area just as it does at Shoal lake. A mile and a fourth west of this the belt of Keewatin which intervenes between the Coutchiching and the conglomerate is again seen at the bottom of a small bay just east of the line between concessions XXII and XXIII and again at the mouth of the creek which enters the lake just south of Grassy narrows. Westward from this creek the country is low and marshy and other exposures are not known.

The general conclusions arrived at from a consideration of the conditions which are observable at the contact of the main southern area of the Coutchiching with the Central Rainy Lake belt of Keewatin are:—

(1) There is no proof of the superposition of the Coutchiching upon the Keewatin.

(2) The post-Keewatin conglomerate which has been supposed to be the base of the Coutchiching lies for the most part well within the Keewatin area and not at the contact of the two series.

(3) The conglomerate prior to the last folding of the region lay across the Keewatin and Coutchiching rocks indifferently and the occurrence of the conglomerate at the contact on Cliff lake is best explained as an infolded syncline.

(4) With this assumption for Cliff lake and at all other points on the contact without such assumption, the conditions are quite consistent with the superposition of the Keewatin upon the Coutchiching established by the Rice Bay and Bear Passage sections.

A re-examination of the section of the Coutchiching south and southeast of Bleak bay as far as Cormorant bay by my assistant, Dr. R. C. Wallace, confirms my interpretation of the structure as given in the report of 1887. On Cliff lake and on the shores of Bleak bay the dip of the Coutchiching rocks diminishes as we go southerly across the strike from vertical to 70°N. At Hallelujah point it is 55°N. In the next mile across the strike it diminishes from this to 35° and from the narrows to Cormorant bay it diminishes to 15° and in places it is almost flat. From Cormorant bay to Deer's Horn point the northerly dip ranges from 20° to 55°. On some of the islands between Deer's Horn point and Vague point is a granite intrusion and beyond this to the south the dips are southerly. In the report of 1887 I interpreted the line of change of dip as an anticlinal axis and I find no reason to change my view. The rocks between this axis and the Seine river occupy structurally the northern limb of an anticlinal fold of bedded mica schists and paragneisses and the thickness of the strata involved is about 4½ miles. The chief objection that has been urged to this interpretation is the great thickness of the strata. But when we compare it with the 29,000 feet or 5½ miles of monotonous sandstones and shales in the Cretaceous section of California, I fail to see that excessive thickness can be urged as an argument against my interpretation of the structure.

The absence of any valid objection to the plain implication of the observed dips of the Coutchiching rocks between Bleak bay and Cormorant bay renders unavoidable the recognition of this belt of strata as the north limb of an anticline. Consequently the Coutchiching rocks underlie the Keewatin This conclusion will be confirmed by showing on a later page that the structure of the Keewatin belt to the north is synclinal.

PETROGRAPHICAL NOTES.

From the south side of Lower Rice bay a number of representative specimens of the Coutchiching mica schists were taken for petrographic examination.

One of these is a fine textured grey mica schist, with a pronounced sheen on the cleavage surfaces. Microscopically it appears in thin section as a mosaic of quartz and brown biotite in the ratio of three to one, these two minerals making up four-fifths of the rock. The other important mineral is zoisite which occurs rather abundantly, partly in well defined but irregularly terminated prisms and partly as allotriomorphic granules. The mineral thus identified has a very low double refraction, but a high refraction. It is biaxial and is optically positive, with a negative elongation. It shows cleavage parallel e elongation and the extinction is approximately straight. Associated with the zoisite there is also some epidote. There are occasional crystals of apatite, titanite, and pyrite, and traces of chlorite and calcite.

The biotite is disposed with its cleavage parallel to the plane of schistosity, and has its greatest elongation in that plane.

Another specimen presents the same general appearance of a typical grey mica schist, but the spangles of mica which reflect the light from the cleavage surfaces are larger, and these surfaces have a distinctly lustrous appearance.

In thin section this rock is also a mosaic of quartz and biotite, but the latter is olive green rather than brown in positions of maximum absorption. The rock contains some zoisite but not nearly so much as in the last specimen. This deficiency of zoisite is made up for, however, in the abundance of pale wine coloured garnet. This mineral shows no idiomorphism, but occurs as lenses and elongated granules disposed parallel to the schistosity. The boundaries are allotriomorphic to both quartz and biotite. There are a few granules of pyrite in the rock and an occasional crystal of epidote is observable.

Another specimen is a fine textured grey schist having a laminated appearance and having wart-like protuberances upon its weathered surfaces.

Examined microscopically the rock presents the appearance of a mosaic consisting chiefly of quartz, fresh feldspar, and brown biotite, with a pronounced parallel structure due to the disposition of the biotite in layers. The feldspar predominates over the quartz and comprises orthoclase, microcline, and albite. Along with the biotite is considerable muscovite. Garnet occurs in occasional large anhedrons, and there is a fair sprinkling of magnetite and less pyrite. Zoisite, apatite, and titanite are sparingly represented. The wart like protuberances observed upon the weathered surfaces prove to be nests of cordierite, which in this way makes up perhaps 10 per cent of the rock.

At the outlet of Rice bay on the north side the rock is a fine grained grey garnetiferous mica schist. Microscopically the rock appears to consist chiefly of quartz and greenish biotite with some feldspar, garnet, and clinozoisite. The feldspar comprises both orthoclase and acid plagioclase and some of it is partially kaolinized. The garnet occurs in irregular, but usually elongated anhedra and the larger of these have a pronounced poikilitic structure due to the inclusion of small grains of quartz. The mica plates have a marked parallel orientation and are elongated in the plane of schistosity; but the feldspar and quartz lie in a mosaic showing no elongation.

Interstratified with the fine textured grey schists above described are bands of coarser mica schist in which the spangles of mica range from one to several millimetres in diameter and give the rock a spangled appearance on all fracture surfaces. Notes on three of these follow:—

One of the specimens referred to is a light grey schist in which the mica foils are for the most part silvery white. In thin section the rock consists apparently wholly of an aggregate of quartz, pale brown biotite, and colourless muscovite. Both micas are greatly elongated in the plane of cleavage of the schist and are quite thin as a rule in the direction transverse to their own cleavage.

The second specimen has a greenish tinge and presents a lumpy or uneven cleavage fracture. The mica foils are irregularly warped. In thin section the rock is seen to be chiefly an aggregate of quartz, green biotite and muscovite with some acid plagioclase. The muscovite occurs not only in large foils but also in nests showing an aggregate polarization effect between crossed nicols as if it were a pseudomorph after feldspar. There is considerable filmy chlorite present as a result of the alteration of the biotite. The schistose structure in thin section is confused and irregular.

The third of these coarse mica schists has a dark to black appearance on the weathered surface, and on fresh fracture the mica is rusty black. The weathered surface is more or less pitted by the removal of the softer parts of the rock.

Microscopically examined the rock appears as an aggregate of brown biotite, muscovite, and quartz, the latter being subordinate in amount to the micas. The rock in general has a coarse texture and the schistose structure is rudely developed; but in thin section there appear oval areas half an inch in larger diameter, composed of the same minerals with a much finer texture and in addition the mineral clinozoisite in rather large stout prisms.

Interstratified with the mica schists of the south side of Lower Rice bay are occasional bands of black glistening fine textured hornblende schist, with thin lenses of quartz disposed parallel to the schistosity. One of these in thin section appears as mosaic of quartz and green hornblende with a laminated structure due to the alternation of bands rich in hornblende with bands which are chiefly composed of quartz.

The hornblende is for the most part elongated in the plane of schistosity, but is occasionally transverse to it. Associated with the hornblende is a little brown biotite. Magnetite in small granules is disseminated through the rock.

A little north of the outlet of Rice bay on the west shore the mica schists have interstratified with them a bed about 10 feet thick of peculiar character, dipping westerly at an angle of 40°. This bed is distinct from the mica schists above and below it owing to its massive or non-schistose aspect, but is irregularly laminated. The rock has the texture of an indurated sandstone, and is of a grey colour blotched with greenish yellow due to the abundance of epidote. In some parts it appears to be garnetiferous and in others pyritiferous. Mica is conspicuously absent. In thin section the rock is found to be highly feldspathic in composition. One section shows it to be composed chiefly of quartz, fresh acid plagioclase and epidote with considerable titanite in scattered grains and rare prisms of hornblende and a little calcite.

Another section shows very little quartz, the rock being composed almost wholly of fresh acid plagioclase and epidote and fairly abundant hornblende in green prisms which lie obliquely to the bands in which the epidote is disposed. Titanite as before is present but not quite so abundantly. The lamination of the rock appears to be due to the disposition of the epidote in bands. Neither the quartz nor feldspar have any elongation but occur in a mosaic of roughly equidimensional grains.

The rock is evidently the result of the metamorphism of a peculiar bed of an original composition quite different from that of the beds with which it is associated.

The belt of Coutchiching mica schists which extends from Bear passage to the vicinity of Gash point is fairly uniform in petrographic character. The rock is prevailingly a fine grained distinctly crystalline grey, or rusty grey, schist which always shows a sheen or lustre on the cleavage faces due to the reflection of light from the mica foils.

In thin section the basis of the rock appears as an aggregate of roughly equidimensional anhedra of quartz, or of quartz with some alkali feldspar, showing no parallelism of orientation. Through this are disposed plates of brown biotite in parallel orientation, sometimes uniformly distributed and sometimes segregated in layers with intervening layers poor in mica. Associated with the biotite there is not uncommonly a quite subordinate amount of muscovite. Occasionally a prism of hornblende may be observed. The biotite is often in part greenish due to partial chloritization, and in certain areas this chloritization may be complete. A few grains of magnetite may usually be noted.

In the vicinity of the contact with the Keewatin, as for example to the north of Back point, there are bands of the mica schist in which prisms of green hornblende appear more abundantly, the rock still retaining its typical character as a mica schist. Still other beds interstratified with the schists in such localities may have so much hornblende that they are more properly designated hornblende schists. Such intercalated beds of hornblende schist are, however, of quite limited thickness.

An interesting petrographic feature of the rocks of this belt, particularly in the vicinity of the granite masses which the belt encloses, is the development of nodules up to half an inch in diameter which on the weathered surface appear as wart-like lumps and on fresh fractures as smooth ovoid bodies about which the foliation of the schist is wrapped. These nodules are in some cases sporadically distributed and in others they are closely crowded. In several instances noted they are strati-form in their disposition, that is, there occur sharply marked layers charged with the nodules separated by layers in which the nodules are sparingly present or are entirely absent. Inasmuch as the nodules are clearly a product of contact metamorphism, this disposition of the nodules appears to indicate differences in the composition of the original strata. The schist matrix of these nodular rocks does not differ from the ordinary mica schist above described. The nodules, however, are made up of a different aggregate of minerals. The most abundant and most noteworthy mineral is cordierite. It is usually poikilitic and occurs as a mosaic of anhedra when viewed in thin section. With the cordierite, and partially enclosed in it, occur the usual minerals of the schist such as biotite, muscovite, and quartz but in relatively less abundance.

On the north side of Sand Point island the mica schists of the Coutchiching have a finer texture than elsewhere and in some places the mica is so small and inconspicuous that the hand specimens show but little of the sheen or lustre so commonly exhibited by these rocks, particularly on their cleavage faces. The rocks appear originally to have been fine very siliceous silts and the metamorphism to which they have been subjected appears to have been relatively weak. These rocks have a fairly distinct cleavage and when studied in the field they were noted as siliceous slates rather than as mica schists, although it was apparent that there were insensible gradations from such slates, through phyllites into typical mica schists.

When these siliceous slates are studied microscopically, however, they are seen to be well charged with minute plates of secondary brown biotite, presenting the character of a hornfels. The basis of the rock is an aggregate of quartz, with some feldspar grains of variable size, but in general of smaller dimensions than the quartz usually observed in the better developed mica schists. This aggregate of quartz grains which forms the bulk of the rock appears to retain, in some cases observed, its original clastic structure; since it does not differ essentially in appearance from the structure observable in ordinary unaltered siliceous slates. And from this condition there are gradations into that in which the rock has been wholly reconstructed and presents the mosaic appearance characteristic of the typical mica schist. In the less altered rocks in which the original clastic structure may still be detected, the biotite, though abundant, shows but a feebly developed parallelism of orientation, and a rather pronounced tendency to accommodate itself to the periphery of the larger quartz and feldspar grains. The latter are characterized by indentate boundaries as if affected by solvent action. The lack of parallelism of the mica plates in these rocks is the probable explanation of their failure to exhibit sheen or lustre on their broken surfaces; and their fissility is probably a true slaty cleavage rather than schistosity.

The rocks which in the field were distinguished from the typical mica schists by the designation "phyllite" are found on microscopic examination to differ from the mica schists chiefly in fineness of texture, although they also show traces of the original clastic structure.

The mica schists of the southern belt, extending from Seine river to Rainy river, are perhaps more thoroughly crystalline and somewhat coarser in texture, and represent the product of a more intense and more uniform metamorphism than is true of the schists of the same series in the Bear Passage belt, where as has just been shown, phyllitic and siliceous slates occur intercalated with the typical mica schists. These mica schists of the southern belt often show pronounced lamination as well as schistosity, and bedding or stratification is often plainly exhibited, by differences of texture, composition, and colour in adjoining strata. The schistosity in all cases observed is parallel to the stratification.

In thin section some of these schists are noteworthy as revealing the fact that the schistosity is due not only to the parallelism of the mica plates but also due to the elongation and parallel disposition of the constituent quartz grains. The mosaic of quartz which makes up the most of the section is not composed of roughly equidimensional grains, but of elongated grains, from two to three times longer than broad. This elongation of the quartz has, however, no reference to the crystallographic axes of the mineral.

CHEMICAL COMPOSITION.

In the hope of eliciting some further information regarding the Coutchiching rocks I submitted four samples to the chemical laboratory of the department for analysis. Three of these were selected as typical or representative specimens of the bulk of the rock of the series and one was of an abnormal or rare type. The analyses of these samples by Mr. M. F. Connor, are given in the following tabulation. Of the three normal types, numbered I, II, and III, No. I from the shore of Rainy lake north of Back point, and No. II from the immediate vicinity of the contact with the Knuckle Island granite on Joint bay, are more highly metamorphosed than No. III, which is from the south shore of Lower Rice bay. The evidence of this appears in the nodular bodies rich in cordierite which characterize the two specimens. In column IV is given the average of these three analyses, and in V is a composite analysis of fifty-one Palæozoic shales for purposes of comparison. In column VI is the analysis of the abnormal rock found in the midst of the Coutchiching as a massive bed about 10 feet thick on the west side of Lower Rice bay.

	I.	II.	III.	IV.	V.	VI.
SiO_2	59·42	58·32	57·08	58·27	60·15	[illegible]2
TiO_2	0·60	0·69	1·08	0·79	0·76	[illegible]
Al_2O_3	19·69	18·89	13·52	17·37	16·45	[illegible]
Fe_2O_3	2·36	1·93	3·43	2·57	4·04	[illegible]
FeO	4·94	5·71	7·83	6·16	2·90	[illegible] 57
MnO	0·10	0·10	0·09	0·10	trace.	0·11
CaO	1·96	3·04	1·32	2·11	1·41	7·66
BaO	0·04	0·04	0·03	0·04	0·04	0·04
MgO	3·84	2·44	6·84	4·37	2·32	0·72
Na_2O	2·04	3·44	0·24	1·91	1·01	1·60
K_2O	2·96	3·10	5·28	3·78	3·60	3·10
H_2O-	0·24	0·40	0·38	0·34	0·89	0·19
H_2O+	2·64	1·73	2·12	2·16	3·82	0·32
P_2O_5	0·18	0·18	0·21	0·19	0·15	0·16
CO_2	....	....	....	....	1·46	....
SO^3	....	....	....	....	0·58	....
S	0·01	0·02	0·15	0·06	....	0·03
Cl	none	none	trace	....	....	0·10
Cr_2O_3	none	none	none	....	....	none
SrO	trace	0·02	....	0·01	....	0·04
C	....	....	....	....	0·88	....
	101·02	100·05	99·60	100·23	100·46	99·53

I. Coutchiching mica schist with cordieritic nodules from shore of Rainy lake north of Back point. Analyst M. F. Connor. II. Coutchiching mica schist with cordieritic nodules from near contact with Knuckle Island granite on shore of Joint bay, Rainy lake. Analyst, M. F. Connor. III. Coutchiching mica schist from south shore of Lower Rice bay, Rainy lake. Analyst, M. F. Connor. IV. Average of I, II, and III. V. A composite analysis of fifty-one Palæozoic shales, by H. N. Stokes. (The Data of Geological Chemistry, U.S.G.S. Bull. 491, p. 522). VI. Abnormal massive bed in midst of Coutchiching mica schists on the west side of Lower Rice bay. Analyst, M. F. Connor.

From an inspection of these analyses it appears that I, II, and III, and particularly their average, IV, representing, as far as may be by so limited a selection, the composition of the prevailing type of Coutchiching rocks, agrees fairly well with the composition of the Palæozoic shales shown in V. The chief differenee appears to be in the ratio of Fe_2O_3 to FeO; but this difference is in accord with the process of deoxidation which commonly takes place in the passage of a sedimentary rock into a crystalline schist[1]. The proportions of silica and total alkalies and the ratio of the magnesia to lime accord with the general characteristics of sedimentary rocks, as distinguished from granites, mentioned by Adams. [2]The analysis VI does not sustain so clearly the suggestion that this rock is also an altered sediment and it is apparent that, if it be a sedimentary rock, as supposed, its original composition was quite different from that of the sediments which, by the same process of metamorphism, gave rise to the normal mica schists.

THE KEEWATIN SERIES.

GENERAL CHARACTER AND DISTRIBUTION

The Keewatin rocks of the region examined comprise: (1) fine grained greenstones showing frequently ellipsoidal or amygdaloidal structures or both; (2) coarser textured greenstones showing neither ellipsoidal nor amygdaloidal structures; (3) greenstone schists of varying degrees of schistosity; (4) rather massive chlorite schists; (5) evenly fissile chlorite schists; (6) irregularly cleaved chlorite schists; (7) black glistening hornblende schists, usually on the periphery of the Keewatin belts where they come in contact with granitic intrusions; (8) grey felsites, sometimes amygdaloidal; (9) sericitic schists; (10) various stratified greyish green schists probably ash beds; (11) agglomerates; (12) grey siliceous slates and schist; (13) banded cherts; (14) mica schists; (15) limestone.

Besides these there are certain intrusive rocks which may be conveniently included in the Keewatin, since, although they are of later age than the aggregate of rocks above listed, they are confined so far as is yet known to the Keewatin areas and were injected into the series before its chief deformation and metamorphism. They thus partake of the structural features of the Keewatin belts. These intrusions appear to have been of the nature of thick sills and comprise two types of gabbro, both of very coarse texture. One is highly feldspathic, consisting almost wholly of basic feldspar, and would be classified as an anorthosite. The other is highly hornblendic. The two gabbros are strongly contrasted in colour, the one being whitish and the other very dark. In some of their occurrences they are both thoroughly schistified, but for the most part they are massive and unsheared.

[1] Van Hise. U.S.G.S. Mon. XLVII, p. 897.

[2] A further contribution to our knowledge of the Laurentian. Am. Jour. Sci. Vol. L. p. 65.

The distribution of these Keewatin rocks may be best ascertained by a glance at the geological map. There it appears that they occur in two principal areas. One of these extends from Redgut bay to Prospect bay and consists of an annular belt, concentric to and outside of the Rice Bay anticline of Coutchiching strata, and a prolongation westward, in the shape of a fishtail, which terminates in so far as the land area is concerned, at Gash and Reef points. It may be referred to as the Northern Area. The other area occupies a belt extending across the quadrangle embraced in the map from its northeast corner near Mine Centre to its southwest corner near Rat-root bay. East of Swell bay this belt is much interrupted by intrusive masses and is irregular in form; but from Swell bay westward it tapers very regularly from a breath of about 6 miles to almost a point at Rat-root bay. Besides these two principal areas there are two minor belts, one on the south side of Shoal lake and another on the south side of Grassy lake, both extending eastward beyond the limits of the quadrangle mapped.

THE NORTHERN AREA.

The first mentioned area of Keewatin, annular about the Rice Bay anticline, is composed chiefly of ellipsoidal greenstones, hornblende schists, and chloritic schists. On the shores of Prospect bay there are some micaceous schists interstratified with the hornblende schists; and on Grassy Portage bay and Nickel lake, there are coarser textured greenstones which are not ellipsoidal. On the line of the Canadian Northern west of Nickel lake are bands of siliceous schists and mica schists and near Nickel lake are banded cherts or quartzites.

Beginning at the west, the south boundary of this area of Keewatin intersects the shore between Gash point and the line of the Canadian Northern railway, where it lies in contact with the Coutchiching. It lies to the north of the railway for about a mile and is then south of or coincident with the railway for another mile, partly on the shores of Commissioners bay, the rocks being hornblende schists in nearly vertical attitudes. It then bends slightly to the south away from Commissioners bay and emerges on the shore at a point less than half a mile north of Back point where, as already mentioned, there is an apparent gradation from the Coutchiching to the Keewatin indicated by an interstratification of hornblende schists and mica schists in a narrow transitional zone. The southern boundary of the Keewatin is next seen on the shore north of Noon island, the hornblende schists here dipping north away from the Coutchiching at an angle of 60°. At the head of Duck bay it is again seen with similar northerly dip, the Coutchiching here being a very narrow band between the Keewatin and the granite. On a traverse north from Blind bay the Keewatin is found with northerly dip in immediate contact with the granite, the Coutchiching having locally been cut out by the latter. On a traverse north from Joint bay the southern boundary of the Keewatin was next located, but here with the Coutchiching mica schists again intervening between it and the granite; and a similar relation was established on a section north from the head of Traverse bay. It was next observed where it intersects the shore of Bear passage, about a fourth of a mile south of the Canadian Northern railway. Here as already described the Keewatin lies upon the Coutchiching at comparatively low angles. From this point northerly the boundary of the Keewatin skirts the shore and islands of Redgut bay for about 3 miles as mapped, at all exposures dipping away from the Coutchiching. On the west side of Redgut bay the boundary of the Keewatin curves from northeast to northwest and intersects the shore at a point about three-fourths of a mile south of the entrance to Base-line bay. But while the strike of the rocks thus curves, the dip of the Keewatin is steadily away from the Coutchiching which adjoins it. The location of the boundary of the Keewatin westward from Redgut bay is determined as mapped by a series of traverses in the woods. Three of these were made from the south shore of Base-line bay; one from Niven's base line south at a point between Black Sturgeon lake and Base-line bay; two southward from Black Sturgeon lake; three north or northwest from Rice bay, one from Hopkins bay to Black Sturgeon lake; five between Rocky Islet bay and Hopkins bay, and one between Prospect bay and Hopkins bay.

These observations serve to determine with a very fair degree of precision the outer boundary of this Keewatin area and show that it is completely encircled by other rocks. The only other boundary of the area is the inner one of the annular belt where it comes in contact with the Rice Bay anticlinal dome of Coutchiching. Within the area thus enclosed is the intrusion of mica syenite and its basic facies which occupy so large a part of the shores of Rocky Islet bay, as a mass of irregular shape with maximum diameters of nearly 2½ and 1¾ miles.

A notable feature of this area of Keewatin is the curved or hook-like belts of coarse dark hornblende-gabbro. The larger of these extends from the mouth of Commissioners bay, along the south side of Grassy Portage bay. Thence crossing the Canadian Northern railway between Grassy Portage bay and Redgut bay, it has been traced northward on the shores of the latter and by traverses in the woods to the vicinity of the south shore of Base-line bay. Its width has been determined approximately as mapped by seven completely transverse traverses and some partial ones. This belt of gabbro lying entirely with the Keewatin has a length of about 11 miles Its maximum width, about three-fourths of a mile, is in its middle part. At its western extremity it appears to split up into a number of narrow tongues which are injected into the Keewatin rocks parallel to the strike of the latter. The belt curves in general with the strike of the Keewatin so that like the latter it is concentric to the Rice Bay anticline. At its northern extremity it swings around to the northwest, and appears to end in a hook, abutting upon the granite-gneiss south of Base-line bay.

The second belt of hornblende-gabbro extends from a point on the north shore of Grassy Portage bay about a mile from its mouth, along the line of the Canadian Northern railway to Nickel lake. It occupies all the west side of this lake, its eastern boundary making a short curve through the middle of this narrow body of water and thence striking westerly from its northwest end. An attempt to follow the belt farther by traverses in the woods showed that beyond the end of Nickel lake it rapidly tapered to a point. Its northern and western boundary was approximately determined by traverses, and particularly where it crosses the small lake west of Nickel lake. The belt thus has the configuration of a fishhook. Another narrow belt of the same gabbro is traceable for nearly 3 miles along the north side of Grassy Portage bay with Keewatin greenstones on both sides of it part of the way. This, however, is probably a branch from the large belt first referred to. Another small belt half a mile long lies to the north of the railway and east of Nickel lake. Contacts of this gabbro with the Keewatin greenstones and hornblende and chloritic schists are exposed at a number of localities, particularly on the shores of Grassy Portage bay, the cuts on the railway, the shores of Redgut bay, and the shores of Rainy lake. At the more favourable exposures it is perfectly evident that the rock is intrusive in the Keewatin. At some it shows a chilled selvage and at others it contains angular fragments of the Keewatin rocks. On the railway between Grassy Portage bay and Redgut bay it also contains angular fragments of the underlying Coutchiching mica schist.

It is evident from the mapping that the intrusion of the gabbro into the Keewatin partakes of the general deformation which has affected the rocks of that series. That it also participated in the more intimate structural deformation is evident from the fact that at a number of localities the gabbro is thoroughly sheared and schistose. The fact that this gabbro is wholly confined to the Keewatin area suggests that the intrusion has the character of a sill, or a series of sills, injected into the Keewatin prior to its deformation. If this be so, then we should expect to find the present disposition of the sill or sills conform to and be expressive of the general structure of the Keewatin belt. Now the disposition of the fishhook like areas of gabbro lying to the west of Nickel lake is distinctly conformable to the synclinal structure of that portion of the Keewatin belt. The Keewatin rocks south of Rice bay dip south away from the southerly dipping Coutchiching, and on the line of the Canadian Northern railway between the entrance to Rocky Islet bay and Nickel lake the Keewatin rocks dip north on both sides of the gabbro belt and in the vicinity of mile-post 217 this angle of dip is as low as 43°. At this exposure, which may be followed at intervals for over half a mile, the gabbro may be seen resting with a chilled selvage at its bottom upon the stratified Keewatin rocks which dip under it. The gabbro sheet, itself, therefore, appears to have a northerly dip. In view of these facts there can be no doubt but that the structure of the Keewatin terrane in the section south from Rice bay to mile-post 217 is synclinal and that the gabbro sheet partakes of this same structure. The hook-like eastern end of the gabbro at Nickel lake may thus safely be interpreted as the nose of the syncline. The axis of the syncline has a nearly east and west trend, passing through the middle of the bend of Nickel lake, and the pitch of the syncline is westward, probably at a very moderate angle. This syncline is the complement of the Rice Bay anticline and confirms the conclusion previously drawn, that the Keewatin rests upon the Coutchiching.

Following this line of section through mile-post 217 to the south of the gabbro the northerly dipping Keewatin rocks have a width of about a fourth of a mile, and south of this we encounter the larger belt of gabbro with a width of a little less than half a mile, and then another belt of Keewatin extending across the strike about a fourth of a mile to the contact with the Coutchiching. The Keewatin rocks on both sides of the large gabbro belt dip northerly and would thus appear to form part of the southern limb of the syncline, the axis of which passes through Nickel lake. It is very probable, however, that the middle belt of Keewatin between the two gabbro belts in this section is a subordinate anticline between two synclines. This interpretation finds support in the fact that the low dips at mile-post 217 become much steeper and are almost vertical on the south side of the Keewatin belt. In this view of the structure the Keewatin belt would be a synclinorium and the two belts of gabbro would be detached portions of the same intrusive sheet, which appears to me to be very probable.

At the head of Grassy Portage bay the Keewatin rocks dip southeast away from the Coutchiching mica schists of the Rice Bay anticline at high angles, about 70°; but on the shores of Redgut bay in the vicinity of the railway and in Bear passage south of the railway, the Keewatin dips northeast at much lower angles, about 30°. We thus have again, in this section, a syncline of Keewatin rocks between the Rice Bay anticline and the Bear Passage anticline. In the middle part of this syncline lies the larger belt of gabbro with a breadth on the line of the railway of about half a mile. In this section there is but one belt of gabbro and no indication of a double syncline. It would, therefore, appear that, of the two synclines indicated for the section south of Rice bay, the northern one spoons out near Nickel lake, while the southern one is the persistent fold of the Keewatin belt. It is probable that this syncline persists through Commissioners bay to Prospect bay, and that its axial line is indicated by the small wedge of conglomerate to be later described as occurring on the shores of Prospect bay.

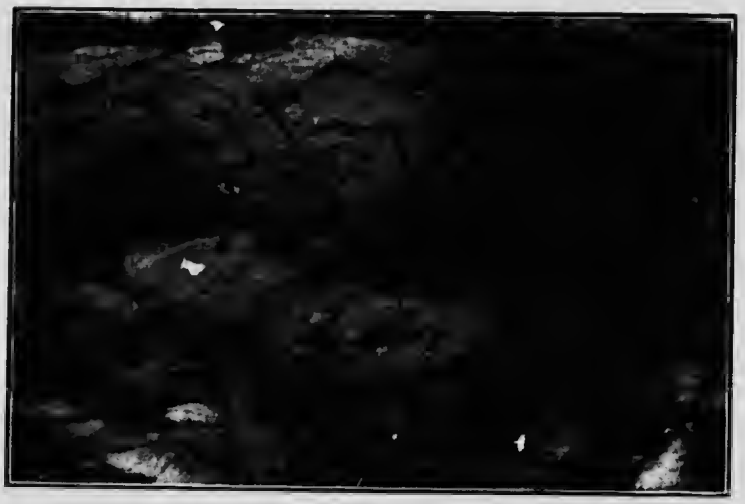
In general, then, it may be said that the southern half of the Keewatin belt which encircles the Rice Bay anticline is synclinal in structure and is flanked on the south, southeast, and east by the Coutchiching anticline which is so well revealed in the vicinity of Bear passage.

When, however, we turn to the northern part of the Keewatin annular belt extending from the east side of Redgut bay to Reef point, we find that it is flanked to the north throughout this stretch by batholithic intrusives. These comprise the granitoid gneiss of Redgut bay and the mica syenite gneiss of Black Sturgeon lake and Hopkins bay. The former cuts off the extension of the Keewatin syncline, and the underlying Coutchiching in the region south of Base-line bay. The syenite gneiss having its margin more nearly coincident with the strike of the Keewatin belt, has wholly displaced the Coutchiching on the north side of the Keewatin and has also carried away the greater part of the north limb of the Keewatin syncline. For a distance of 2 miles in the isthmus between Hopkins bay and Rocky Islet bay the margin of the syenite-gneiss is apparently nearly coincident with the axis of that syncline, as is indicated by the fact that it comes in contact with a remnant of the Seine conglomerate which is regarded as having been an inpinched fold reposing upon the Keewatin.

THE SOUTHERN AREA.

The second great belt of Keewatin, extending diagonally across the quadrangle as mapped, is of varied stratigraphic composition, but it comprises chiefly greenstones, greenstone schists,

A



B

A. Sheared facies of anorthosite, east end of Seine bay.

B. Granite (below) intrusive in anorthosite (above); Finger bay, Bad Vermilion lake.

hornblende schists, and chloritic schists. In addition to these there are notable occurrences of grey felsites and felsite schists and at the Golden Star mine near the east end of Bad Vermilion lake there is a bed of limestone. In the lower part of the series there are well stratified grey and greenish grey schists, some mica schists, and some coarse detrital rocks.

On its northern side the Keewatin belt is bounded by plutonic intrusives from Little Turtle river to the vicinity of Bear Pass Station on the Canadian Northern railway. These intrusives are two in number and are differently related to the Keewatin. From Little Turtle river to a point about a mile west of the west end of Turtle lake the Keewatin lies against the edge of a great batholith of banded or streaked gneiss having a quartz porphyry selvage, and for this stretch of 10 miles the boundary of the Keewatin is comparatively straight and even, with an east-west strike. Beyond this point westward to Bear Pass Station, the Keewatin comes against a more granitoid gneiss which shows no banding, and this intrusive makes an extensive embayment southerly into the Keewatin belt, robbing the belt locally of a large part of its normal width. Into this embayment project tapering tongues of the schists into which the granitoid gneiss is intrusive. From the vicinity of Bear Pass Station west-southwest to Rat-root bay the Keewatin is bounded on the north by the Bear Passage anticlinal belt of Coutchiching.

The southern boundary of the belt from the eastern limits of the quadrangle to the mouth of the Seine river is a mass of granite, sometimes gneissoid, known as the Bad Vermilion granite. But for the first 3 miles the contact of the Keewatin and granite is covered by a synclinal trough of Seine conglomerate. From the mouth of the Seine river to Bleak bay, the Keewatin is flanked on the south by the Coutchiching with a narrow intervening strip of conglomerate on the north side of Cliff lake, which is regarded as an infolded remnant of the Shoal Lake syncline. South of the east end of Dryweed island on the Minnesota coast and thence westward to the vicinity of Rat-root bay the Keewatin belt is in contact on the south with the Coutchiching mica schists.

In this belt of Keewatin we may include for convenience the coarse, highly feldspathic gabbro or anorthosite of Bad Vermilion lake. This rock is intrusive in the Keewatin, as is proved by many dykes cutting the Keewatin greenstones on the shores of Seine bay and by the contact phenomena on the north shore of Bad Vermilion lake; but the intrusion took place at a time anterior to the severe deformation of the latter, as is indicated by the fact that it is locally intensely sheared and schistose. The area occupied by the anorthosite has the form of a tadpole; the bulging head to the east includes most of the area of Bad Vermilion lake and the long slender tail extends westward through Seine bay into the open part of Rainy lake. The total length of the mass is about 18 miles and the maximum width at Bad Vermilion lake is about 3 miles. On the west side of Bad Vermilion lake it is almost cut in two at its widest part by a deep embayment of granite which is continuous with the more extensive granite area lying to the south of the lake. This granite is intrusive in the anorthosite. It is probable from the areal relations of the Keewatin, anorthosite, and granite that the basic plutonic mass was intruded into the Keewatin in the form of a laccolithic lens, tapering westward to a sill or dyke and that later when both Keewatin and anorthosite were invaded by the granite, the bottom of the central part of the lens was displaced by the granite, either by doming or by engulfment and resorption, thus appearing as an embayment at the present surface of erosion. Besides the anorthosite there are minor occurrences of dark hornblende gabbro similar to that of Grassy Portage bay already described. These occur chiefly in the country north of Seine bay and associated with them are outcroppings of titaniferous magnetite. This iron ore has attracted the attention of prospectors and an effort is being made at the present time to determine its extent by drilling operations. Certain marginal facies of the anorthosite on Bad Vermilion lake also grade into a similar dark gabbro and this suggests that both types are differentiation products of a common magma.

Within the southern Keewatin belt are two areas of intrusive granite. One of these referred to as the Mud Lake granite extends from the middle of the peninsula between Swell and Seine bays to a point north of the west end of Bad Vermilion bay, having a total length of over 10 miles. The width of this granite rarely exceeds half a mile. Being nowhere exposed on the shores of Rainy lake or its tributary lakes, its existence was unknown in 1887 and its area has this year been determined by traverses in the woods.

The second area of granite occurs on Grassy island. Here there are two granites of different ages and the later one extends from Grassy island along the south shore of Rat-root bay. The total length of the area is probably about 3 miles, but its eastern end is concealed by the waters of the lake and it may be longer. Its maximum width is less than half a mile.

The most noteworthy feature, from a structural point of view of the belt of Keewatin above outlined, is its tapering form to the west-southwest. This tapering end of the belt is bounded on both sides by the Coutchiching mica schists and the areal relations of the two series of rocks are undoubtedly due to folding. The pointed western end of the belt is either the tip of a synclinal spoon of Keewatin rocks sunk down into the Coutchiching in a closely appressed fold, or it is the nose of an anticline pitching westerly below the Coutchiching. Which of these alternative interpretations is the correct one is fortunately resolved by evidence so clear-cut and positive that little room is left for doubt. This evidence consists in the recognition of the Dryweed Island syncline of Seine conglomerate and quartzites already described. This syncline of Seine rocks is so closely appressed that the conglomerate on both limbs of the fold is in vertical attitudes. Both the flanking conglomerate and the median quartzite are deeply sunk into the Keewatin, and are wholly surrounded by Keewatin from the east end of Dryweed island to the mouth of Hay creek and beyond. The Seine rocks are as thoroughly schistose and otherwise dynamically metamorphosed as are the underlying Keewatin rocks. It is perfectly evident and certain that the rocks of the Seine syncline have participated in the major folding and deformation of the Keewatin. It therefore, follows that the Keewatin belt is also synclinal in structure and rests upon the Coutchiching.

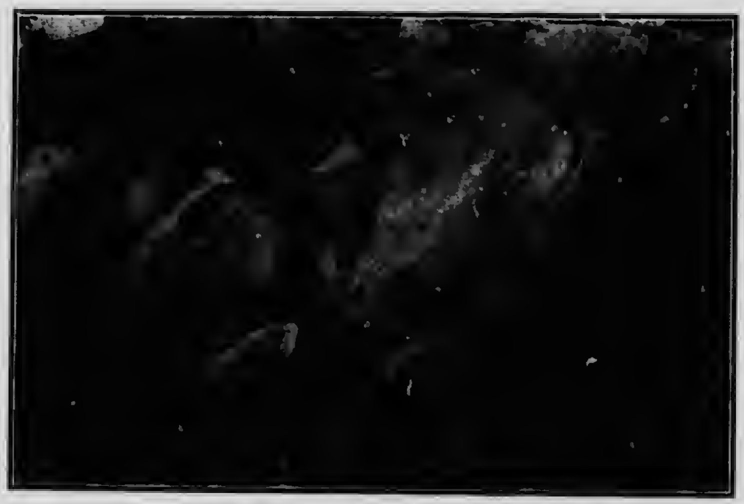
Farther east in the Bleak Bay section it has been shown that the Coutchiching rocks between Bleak bay and Cormorant point have the general structure of the northern limb of a great anticlinal fold. Agreeing with this the Keewatin rocks north of Bleak bay dip northerly. On the south side of Seine bay the angle of dip is high but on the north side it is in places as low as 35°, and ranging from this up to 65°. This northerly dip appears to prevail as far as the south side of Swell bay, a distance of a little less than 4 miles across the strike. From this distance there may be deducted, however, nearly a mile for the space occupied by intrusive gabbro and granite. On the south side of Swell bay the prevailing dip is about 70° northerly; on the north-east shore of Swell bay the prevailing dip is 70° southerly. This dip applies to the bedding as well as to the schistosity. Although these opposing dips are at angles too high to be relied upon for the location of axes of folds, they nevertheless suggest a synclinal structure with an axis passing through the southeast corner of Swell bay. This suggestion is borne out by the occurrence of a small patch of boulder conglomerate at the south-east corner of Swell bay, which may be fairly regarded as an inpinched remnant of the Seine conglomerate, and therefore, in itself indicative of a synclinal axis.

In the north-south section through Mine Centre from Turtle lake to the Golden Star mine the Keewatin belt has a width across the strike of about 2 miles, and in this width the dip is isoclinal and to the north. On the south the Keewatin lies against the intrusive Bad Vermilion granite, the contact passing below the Seine conglomerate; and on the north it is in contact with the margin of a great batholith of banded and streaked gneiss. There is thus little in the section except the dip to indicate which is the top and which the bottom of the section. Where the dips are at high angles this is not a very safe guide, even where it is certain, as is the case in this section, that the dips apply to the bedding as well as to the schistosity. It may be said, however, that on the south margin of the belt the dips are lower than on the north belt. In the immediate vicinity of the Golden Star mine, is a cropping of a bed of cherty limestone 8 feet thick which has a strike of 88° and a northerly dip of 48°. The limestone is grey in colour, medium grained crystalline in texture, and has scattered through it crystals of brown mica, which are so minute as to easily escape observation. In the midst of the limestone are discontinuous bands of chert, and in parts of the formation there are numerous small angular fragments of chert projecting like warts above the weathered surface. Resting immediately upon the limestone is a 2 foot bed of brecciated chert which grades at the top into a porphyritic, dense "felsitic" lava. The phenocrysts in this rock are feldspar and ferromagnesian minerals are not apparent. This top layer of chert differs in appearance from the chert interbanded with the limestone, being greenish in colour. The limestone in its general aspects, particularly in regard to the disposition of the chert in it, the brecciation of the latter, and the occurrence of small angular fragments of chert embedded in it, resembles in a marked degree many occurrences of freshwater limestones in the late Tertiary of California, some of them occurring as lenses, without other associated sedimentary rocks, between sheets of lava. The general appearance of the outcrop is shown in Plate VI, in which B shows the alternation of limestone and chert, as measured in the field. The rocks below this limestone bed as well as those above are extremely fine textured or dense porphyritic lavas of dark grey colour, weathering whitish, in which the mineralogical composition of the ground-mass cannot be made out. They are rocks that the field geologist generally describes in his notes as "felsites".

Inasmuch as the chemical composition of these geologically early limestones is a matter of interest from a theoretical point of view, an analysis by Mr. H. A. Leverin of a sample of the Golden Star limestone is here given:—

Insoluble matter	9·12
$Fe_2O_3 + Al_2O_3$	0·66
$CaCO_3$	89·25
$MgCO_3$	0·35
	99·38

A



B

A. Exposure of limestone in Keewatin; Golden Star mine, at the northeast end of Bad Vermilion lake. A, dark grey or black chert; B, limestone with continuous bands of chert; C, chert; D, limestone with discontinuous narrow bands of chert: E. greenish, finely brecciated chert; F, felsite.

B. Another exposure of the same limestone at the same locality, showing bands of chert, and chert fragments in the limestone.

The interesting feature of the analysis is the very small proportion of magnesium carbonate present. The insoluble matter is probably composed largely of brown mica which doubtless contains magnesia in the form of silicate formed at the expense of the carbonate.

This bed of limestone dipping with the felsites northerly at an angle of 48° with nearly the whole of the Keewatin section to the north of it suggests that we have here the lower part of the section. But as the belt lies between two different batholiths of different dates of intrusion this conclusion is not altogether certain. On the south and north sides of the east end of Bad Vermilion lake, the Keewatin rocks consist of various greenstone schists, chlorite schists, and hornblendic schists standing at much higher angles. Along the line of the railway, the schists, while still dipping northerly, depart but little from verticality. On the south shore of Turtle lake the dip ranges from 60° to the north to vertical. In general the data is insufficient to determine the upper and lower sides of the Keewatin in this section and this is commonly true of bands of schists bounded on both sides by plutonic irruptives.

OTHER BELTS OF KEEWATIN.

Of the two subordinate belts of Keewatin to the south of this which have already been alluded to in the discussion of the Seine rocks, it is only necessary to say that the one which lies along the south side of Shoal lake and is exposed for the width of a mile at the east end of the lake, is composed chiefly of ellipsoidal and amygdaloidal greenstones, greenstone schists, and chloritic schists; while the belt which occupies the south side of Grassy lake and extends thence eastward is composed of greenstone schists and chloritic schists. In both of these belts the dip of the schistosity is nearly vertical and little can be made out of their internal structure, although it is clear that the first one is anticlinal with reference to the folding which affected the Seine series and produced the synclinal troughs on each side of it.

PETROGRAPHICAL NOTES.

A limited number of thin sections of the more characteristic Keewatin rocks have been examined microscopically and the results of this examination are here summarized:—

The more massive greenstones show no remnants of pyroxene. This mineral appears to have been first altered to green hornblende and the latter then partially or wholly chloritized. The chloritization, however, in most cases, appears to have left the form and cleavage of the hornblende intact, and even the pleochroism is often pronounced; it is only the prevailing very weak double refraction that shows we are dealing not with hornblende but with the pseudomorph chlorite. In general the plagioclase is fairly well preserved but varies greatly in the proportion in which it occurs in the various greenstones examined. Some of these greenstones are chiefly feldspathic in composition and in thin section present a ground-mass of micro-granular feldspar in which are embedded blades of fresh or chloritized hornblende. In such rocks zoisite, clinozoisite, titanite, and ilmenite or magnetite usually appear in varying degrees of abundance. A rude parallelism in the orientation of the constituent minerals may be in some instances detected.

In others of these greenstones an ophitic structure is apparent and there is little doubt but that the rock was originally a dolerite or diabase. Some of these chloritized diabases have much titanite in them and this in many instances is clearly pseudomorphic after ilmenite. Epidote in small granules and occasional larger crystals is commonly observable.

Some varieties of these massive greenstones show a porphyritic structure. This was particularly observed in one case in which large phenocrysts of a ferromagnesian mineral, now completely changed to chlorite, were embedded in a ground mass consisting chiefly of a felt of small chlorite blades, with some calcite, zoisite, and magnetite. In some rather coarse greenstones, sheaves of nearly colourless amphibole, which in some cases resemble altered phenocrysts, lie in a ground-mass consisting chiefly of chlorite, zoisite, and feldspar with or without titanite.

A massive whitish green rock of limited occurrence that is found associated with the greenstones of the north side of Seine bay may be here mentioned. It appears in thin section to be composed almost wholly of divergent sheaves of clinozoisite and subordinate zoisite in stout prisms. There is a very small amount of interstitial plagioclase and nests of calcite occur through the slide.

In some of the more feldspathic greenstones there is considerable siderite due, doubtless, to the carbonatization of the iron of the ferromagnesian silicates, and this siderite shows all stages of alteration to limonite.

In still other varieties of greenstone there is but a very small amount of feldspar present. The rock, which in such cases is exceptionally coarse textured, is composed of an aggregate of large areas of chlorite showing residual cores of hypersthene, or remnants of a well marked diallage structure. Besides the chlorite there is usually considerable secondary hornblende, epidote, zoisite, and ilmenite partially altered to titanite.

These various greenstones of massive aspect, particularly those of finer texture, very commonly grade into greenstone schists and these cannot be clearly segregated from the less fissile varieties of chlorite schist. Such chlorite schists are probably in almost all cases nothing more than greenstones in which, by a process of internal shearing, chlorite has not only been developed at the expense of all other ferromagnesian constituents but has been rendered more apparent by its parallel or sub-parallel orientation.

The finer textured greenstones and greenstone schists very commonly show a well marked ellipsoidal structure, and less commonly an amygdaloidal structure. The ellipsoidal structure appears to differ in no essential particular from that characteristic of many lavas and intrusive rocks of later geological periods.

The only amygdaloidal greenstone schist which has been submitted to microscopic examination is one from the east end of Shoal lake. Here the greenstones are very distinctly schistose and exhibit at several excellent exposures a well marked ellipsoidal structure. In this section the amygdaloidal rock presents a ground-mass of feldspar and green hornblende, the latter being disposed in parallel orientation. In this ground-mass are numerous well preserved phenocrysts of rather acid plagioclase. The rock is probably an altered andesite. The amygdules are apparent as lenses of quartz in aggregates showing a mosaic arrangement in section. At the ends of these flattened amygdules there is usually some calcite. The amygdules are, however, much more satisfactorily observable on the glaciated rock surface and in hand specimens than in thin sections, many of the amygdules being over half an inch in length.

The more typical chlorite schists appear to consist chiefly of a felt work of chloritized hornblende with occasional residues of fresh hornblende; the feldspar is usually quite subordinate in amount. Zoisite and clinozoisite are usually prominent constituents. Titanite is also fairly common. Quartz may or may not be present. One or two crystals of pyrite may usually be observed. In some cases, however, feldspar may be abundant as a ground-mass.

The hornblende schists in the field are usually easily distinguished from the various phases of greenstone schist and chloritic schist by their black colour, their even cleavage with transverse joints and the glistening lustre of the cleavage faces. They occur characteristically in the proximity of granites or granite gneisses intrusive in the Keewatin, and appear, therefore, to represent the result of contact metamorphism upon the greenstones from which they are derived, and into which they pass insensibly away from such irruptive contacts.

In thin section these rocks are noteworthy for the almost complete absence of chlorite. They are composed of green hornblende feldspar and quartz, with usually a little magnetite. The hornblende is in rather stout prisms and is always disposed in more or less parallel orientation. The feldspar (and quartz) usually form a mosaic which may or may not show elongation of the constituent anhedra. In some instances the hornblende greatly predominates over the feldspar, but in most cases these two minerals are fairly equally represented. Rarely the feldspar predominates and the hornblende is disposed in parallel layers or zones in the feldspathic aggregate.

The grey felsites and felsite schists which occur in some portions of the upper part of the Keewatin, particularly on the shores of Swell bay, are interesting as showing the variation in the character of the lavas which make up the bulk of the series. In these rocks the original character of the lava appears to be better preserved than in the case of the more basic flows. In thin section they show characteristically a fine ground-mass of rather variable texture consisting of quartz and feldspar, in which are embedded well defined phenocrysts of orthoclase, oligoclase, and quartz. Usually there is some secondary biotite in minute scales disposed in parallel orientation and some chlorite, the latter in part derived from the biotite and in part occurring in nests as if the result of the alteration of some pre-existing phenocryst. In some of these rocks there are also minute plates of sericite. Calcite is sometimes present in nests. The quartz phenocrysts are the cross sections of dihexahedral crystals, but these are in some cases rounded by corrosion and show also corrosion embayments. The deformation of the rock is plainly apparent in some sections showing the flow of the ground-mass around the phenocrysts.

Some of these felsites are plainly amygdaloidal, the amygdules being sometimes quite plump or rounded and sometimes drawn out into lenses. Some of the amygdules have hollow centres showing that they did not completely fill the cavity. They consist so far as observed of white quartz. In thin section the quartz of the amygdules resembles vein quartz and is of much larger grain than the ground-mass. The quartz aggregate of the amygdule is sharply marked off from the rest of the rock. In other cases, lenses of similar quartz occur which are probably also amygdules squeezed out of their normal shape.

Interstratified with the Keewatin rocks of volcanic origin are certain siliceous sedimentary beds which are so fine textured as to be properly designated cherts. A notable occurrence of this kind is at the northeast end of Swell bay. Here the rock is distinctly bedded and some of the beds are finely laminated while others are not. The schistosity is parallel to the bedding. On one side these siliceous beds are seen in sharp contact with a rather massive green chloritic schist, and the bedding is parallel to the plane of this contact. The chert is of a dark grey colour and varies somewhat in texture. Microscopically it consists of a very fine aggregate of apparently clastic grains of quartz, so fine in parts as to be unresolvable by the high power of the microscope, the diameter of the grains being much less than the thickness of the slides. In this are nests and lenses of coarser aggregates of quartz and others of calcite. There are minute scales of sericite sparingly distributed, some filmy chlorite, and a few crystals of pyrite.

Another chert from the extreme east end of Sand Point island is dark grey to black in colour and has small nodules of white quartz in it the size of a pea. These pea-like bodies are disposed in bands separated by bands of chert in which they are absent. Some are drawn out in lenses. They are sometimes crowded together and sometimes well spaced. Their disposition resembles that of spherulites in certain rhyolites; and it is possible though not probable that in this case we have to deal with a thoroughly silicified spherulitic rhyolite. Microscopically it consists of a fine aggregate of quartz grains with minute scales of biotite, the whole disposed in many irregular layers. These layers wrap around the pea-like nodules. The latter consist of relatively coarse quartz presenting in this section the mosaic arrangement of vein quartz.

The dark gabbro, which though intrusive in the Keewatin is included with it as belonging to that geological period, is prevailingly a coarsely granular rock of plutonic aspect. In the field the chief constituent minerals hornblende and feldspar are easily identified, the former usually predominating. At many localities magnetite may also be recognized on careful inspection. Whenever the rock is encountered there is a strong local variation of the compass.

When examined in thin section the rock is found to consist essentially of the three minerals named. The feldspar on optical study proves to be labradorite. The amphibole is ordinary green hornblende. The magnetite is variable in its distribution being abundant in large irregular shaped grains in some cases and almost absent in others. The labradorite is for the most part fresh and shows the usual multiple twinning in broad lamellæ. Occasionally, however, it is altered to an aggregate of epidote and zoisite. It occurs in large anhedrons allotriomorphic to the hornblende, but is everywhere charged with abundant small prisms of hornblende of an earlier generation. The hornblende occurs also in large anhedrons which have, however, a pronounced elongation in the direction of the prismatic axis, and thus appears to have a closer approximation to idiomorphism than the feldspar. This hornblende is poikilitic in structure owing to the inclusion within it of numerous small anhedrons of untwinned feldspar. These are often so abundant as to give the hornblende in cross section the appearance of a sponge. The hornblende in some cases also occurs as aggregates of diversely oriented individuals; and these polysomatic areas of hornblende have the same relation to the labradorite that the larger individuals of hornblende have, but in this case interstitial feldspar occurs in small anhedrons between the members of the aggregate. In some cases there is a very small amount of quartz associated with the feldspar.

CHEMICAL COMPOSITION.

In order to contribute in some small measure to our knowledge of the chemical composition of the Keewatin rocks, two specimens were selected for analysis. One of these was taken from the schistose ellipsoidal greenstone which occurs on the first island inside of the entrance to Rocky Islet bay. Its composition is shown in column I. The other specimen was taken from a black glistening hornblende schist near a granite dyke in the belt between Rice bay and Hopkins bay. Its analysis is shown in column II.

	I	II.	III.	IV.
SiO_2	46·28	47·50	49·58	49·80
TiO_2	1·70	0·58	1·00	0·95
Al_2O_3	14·24	17·03	16·37	13·76
Fe_2O_3	3·93	4·15	1·73	3·09
FeO	11·62	6·67	11·55	11·97
MnO	0·02	0·15	0·17	0·10
CaO	11·28	14·90	10·26	10·25
BaO	trace.	trace.	trace.	....
MgO	7·40	6·70	5·37	5·02
Na_2O	2·48	0·76	2·14	3·00
K_2O	0·81	0·76	1·05	1·1[illegible]
H_2O-	0·05	0·12	0·14	....
H_2O+	0·28	0·88	0·44	....
P_2O_5	0·15	0·07	0·03	trace.
CO_2	....	....	....	0·22
S	0·06	0·035	0·05	....
Cl	0·08	0·09	0·25	....
Cr_2O_3	0·01	0·04	none.	....
SrO	trace.	0·02	trace.	....
	100·39	100·45	100·13	99·31

1. Ellipsoidal greenstone schist. Island in Rocky Islet bay, Rainy lake. Analyst, M. F. Connor. 11. Hornblende schist from belt between Lower Rice bay and Hopkins bay, Rainy lake. Analyst, M. F. Connor. III. Hornblende gabbro. South side of Grassy Portage bay, Rainy lake. Analyst, M. F. Connor. IV. Basalt, Kilauea. Analyst O. Silvestris (Quoted from Washington's Chemical Analyses of Igneous Rocks. U.S.G.S. Prof. Paper 14.)

These analyses agree fairly well with each other except that there is a defect of soda in the hornblende schist, and that more of the iron is in the ferric condition in that rock than in the greenstone schist. The agreement indicates approximate identity of original composition. Both analyses also agree fairly well with many analyses of basaltic lavas.

In column III is given an analyses of the hornblende gabbro which forms so large a feature of the Keewatin in the central portion of the territory mapped; and for comparison is given in IV the analysis of the basalt of Kilauea.

THE LAURENTIAN ROCKS.

The term Laurentian is here reserved, in accordance with the decision of the International Committee on Geological Nomenclature, for those Archæan granites and granite-gneisses which are of pre-Huronian age.

Within the territory covered by the accompanying geological map. there are several areas of granite and granite-gneiss which are referred to the Laurentian in this sense of the term. These are the Bad Vermilion Lake granite, the Mud Lake granite, the sheared granite of Grassy island, and the granite-gneiss of Rice bay. All of these are post-Keewatin. Some of them are certainly pre-Seine (upper Huronian) in age and others are believed also to be pre-Seine on the basis of their correlation with those for reasons set forth in the following account of their occurrence.

THE BAD VERMILION LAKE GRANITE.

Area.

This mass of granite has been found to be more extensive in its surface distribution than was indicated on the map accompanying the report of 1887. It occupies the shores of the southwest part of Bad Vermilion lake, and this area is in direct continuity with a main curving belt from 1 to 2 miles wide, extending from the Golden Star mine to the vicinity of the mouth of the Seine river, a distance of about 12 miles. On its northern border, including the lobe extending into Bad Vermilion lake from the main belt, this granite mass is bounded for the greater part of its extent by the anorthosite (gabbro)of Bad Vermillion lake, but at its northeastern and southwestern ends it is also in contact with the Keewatin. On the southeast border of the main belt, from the vicinity of the Golden Star mine to the middle of Grassy lake on the Seine river, the granite is flanked by the basal conglomerate of the Seine series; but west of this, to the mouth of the Seine, a strip of Keewatin appears to intervene between the granite and the conglomerate.

Petrographical Character.

The rock composing this mass is prevailingly a medium coarse textured, light coloured, biotite granite, poor in biotite and grading by a diminution of this constituent into a binary granite or alaskite. Orthoclase is the dominant feldspar, but there is also a notable proportion of acid plagioclase, and both are usually cloudy with decomposition products, including calcite, which may be locally abundant. The biotite is more or less altered to chlorite, and in some cases is charged with slender needles, probably rutile, intersecting at 60° in the plane of the cleavage. A few plates of muscovite may also be occasionally observed. There is usually some secondary epidote present in the rock.

In its field aspects this rock often presents a bleached appearance and near the contact with the overlying Seine conglomerate, it is usually quite yellowish, the yellow colour fading away gradually a few hundred feet from the contact of the overlying rocks. There is, however, no indication of important secular decay by chemical decomposition of the granite where it immediately underlies the Seine strata. Locally the granite presents a foliated aspect, but this is apparently in all cases observed due to deformation by shearing and is not an original structure of the rock. Besides this dominant facies, the granite presents interesting variations in character, particularly on its borders. The most common of these local marginal facies is due to the assumption of a finer texture and a darker colour. Microscopically the rock is then seen to have a holocrystalline ground-mass of quartz and feldspar, in which are embedded phenocrysts of feldspar. The ground-mass also contains chloritized biotite and epidote is usually present. This facies of the rock in some localities grades into a more basic facies in which it is difficult to detect any quartz with the aid of a lens. The basic facies occasionally appears coarser grained as on Reserve bay, where, at a number of exposures, it has the aspect of a medium coarse diorite which grades into a quartzose granitic rock.

A quite different facies, which occurs at the contact of the gabbro and in apophyses cutting the latter, is a very fine grained and light coloured, practically white, rock containing no ferromagnesian constituents, but having scattered through it rather sparsely, large dihexahedral phenocrysts of quartz, some of which are half an inch or more across. This marginal facies of the granite is particularly observable on the north side of Obashinsing lake.

There are very few pegmatite dykes in the granite and these are all quite small. There are, however, a good many quartz veins and some of these have been mined.

Relations to Adjoining Rocks.

The Bad Vermilion Lake granite is intrusive into the anorthosite (gabbro) of Bad Vermilion lake. The intrusive relation is shown not only by the marginal modifications of the granite above referred to, but also by actual irruptive contacts. One of the best of these contacts is to be seen on the west side of Finger bay, where a dyke of the granite 20 feet wide cuts squarely across the banded structure of the gabbro. On the north side of Obashinsing lake, apophyses of modified granite cut the gabbro at numerous places. On the west side of the south part of Bad Vermillion lake inclusions of gabbro were observed in the dark marginal facies of the granite. Nowhere was any marginal alteration or modification of the gabbro observed at these contacts. The peculiar distribution of the granite and anorthosite (gabbro) in the Bad Vermillion Lake district is suggestive of a definite structural relation. In the southwest part of the lake there is an obtusely triangular area of granite almost completely surrounded by the anorthosite (gabbro), but connected by a narrow strip with the main belt of granite. This mapping indicates that the anorthosite existed as thick sill or attenuated laccolith intrusive in the Keewatin. After solidification, the intrusion of granite magma was inserted below the anorthosite sill, doming it somewhat in its central part. The truncation of the region has since pared away the top of the dome, leaving the central mass of granite surrounded by the earlier basic intrusive. It seems fairly certain at least that the contact surface between the anorthosite (gabbro) and the granite is a domed surface and that the granite is beneath the anorthosite.

Since, as has been shown, the anorthosite (gabbro) is intrusive in the Keewatin, it may be positively inferred that the granite is also intrusive in the rocks of that series. This inference is confirmed by direct evidence of the intrusive relation at the contact of the granite with the Keewatin rocks. Near the Golden Star mine on the road from Mine Centre Station to Shoal lake, the granite holds angular inclusions of the near-by Keewatin rocks and on the east side of Island bay there are numerous inclusions of greenstone in it. At the west end of the main granite belt, near the mouth of the Seine river, the granite may be seen in intrusive relation to the hornblende schists of the Keewatin.

The relation of the granite to the Seine series of rocks which flanks it on the southeast is plain and unequivocal. The basal conglomerate of that series rests indifferently upon the eroded surface of the granite and the Keewatin. It is certain that after the intrusion of the granite into the Keewatin and the anorthosite (gabbro) the region was profoundly degraded and that on the erosional surface thus established, the Seine beds were deposited. The interval between the Keewatin and the Seine series is a very long one and is one of the important facts in the historical geology of the Archæan.

THE MUD LAKE GRANITE.

To the north of Seine bay there is a remarkably linear belt of granite which extends from a point east of Wind bay to beyond Porcupine lake, a distance of over 10 miles. This granite belt has been crossed by seven traverses into the woods north of Seine bay, and its width as thus determined is very uniformly about half a mile. On both sides of the belt are Keewatin rocks. The extension of the belt to the northeast of Porcupine lake is indeterminate, and it may possibly have a greater prolongation in that direction than is indicated on the map. Mud lake appears to lie wholly in this granite and it may, therefore, be conveniently distinguished by that name.

The granite is similar in its general characteristics to the Bad Vermilion Lake granite, but is more bleached in appearance and is more commonly sheared and schistose. In many of its exposures it is apparently devoid of mica and hornblende or so nearly so that it may be called alaskite. It is prevailingly very quartzose and shows no porphyritic structure so far as observed. Portions of the granite which have been exceptionally sheared have a thinly sheeted or slaty structure.

The only rocks with which the granite is in contact are those of the Keewatin, and although the contacts are not well exposed in the woods, on two of the traverses which crossed the granite the latter was observed to have an intrusive relation to the Keewatin.

There appears to be no reason for doubting that this granite is chronologically as well as petrographically the equivalent of the Bad Vermilion Lake granite.

THE SHEARED GRANITE OF GRASSY ISLAND.

On Grassy island, near Rat-root bay, there are two very distinct granitic rocks traversing the island from northeast to southwest in two belts in juxtaposition. One of these is greatly sheared and otherwise altered, the other is not sheared and is fresh. It is evident that the sheared granite is an intrusive mass distinct fron the unsheared granite, that it has suffered deformation antecedent to the advent of the other granite, and that it is, therefore, an older intrusion. This inference as to the relative age of the two granites is proved also by the contact phenomena observable on the east side of Review island. Here the two granites may be seen in contact on bare rock surfaces and the older granite is seen to be cut by apophyses of the later granite and to occur as angular inclusions in the latter.

In its general field aspect this granite resembles the more sheared portions of the granite of the Bad Vermilion Lake and Mud Lake areas. In some of its exposures it presents a bleached appearance, but for the most part it has a stained appearance varying from pinkish to yellowish. It is in places far more sheared than the granite of the Bad Vermilion Lake and Mud Lake areas and the granitic structure is entirely obliterated. From this thoroughly deformed and petrographically obscure condition, it grades into less sheared facies, where it has the characters of an alaskite or a biotite granite poor in mica. This rock in turn grades on its southern margin into a dense compact microgranite or quartz porphyry, where it comes in contact with the Keewatin of the south side of Grassy island. At the immediate contact it presents the phenomena of a chilled edge against the rocks into which it is intrusive. The effect of shearing is not observable except to a quite limited extent in this finer grained facies of the intrusive rock near the contact. The rock further resembles the granite of Bad Vermilion lake in the fact that it is traversed by quartz veins, some of which have attracted the attention of prospectors. The belt of older sheared granite with its marginal quartz porphyry facies extends not only across Grassy island, but also occupies the south part of Review island and the small island which lies between these two. It probably crosses the strait between Grassy island and the mainland, but does not extend through to Rat-root bay. On its northern side it is in contact with the later granite, which, as already stated, is intrusive into it.

THE RICE BAY GRANITE GNEISS.

The granite gneiss which occupies the centre of the Rice Bay anticlinal dome, and which is exposed chiefly on the shores of Rice bay is remarkable for the intensity of the deformation to which it has been subjected. The deformation has produced in the rock a very pronounced foliation, which is disposed both as to strike and dip, particularly on the periphery of the mass, in planes parallel to the contact with the overlying and surrounding Coutchiching schists. The least deformed facies of the granite is exposed on the southeast side of Upper Rice bay in the central part of the area. Here it is a rather coarse porphyritic rock with large idiomorphic quartzes and orthoclases, embedded in a granitic ground-mass of quartz and feldspar and a little biotite. This facies varies considerably in the size and abundance of the porphyritic crystals. In some cases it is very similar to the granite porphyry facies of the granite of Bad Vermilion lake. This rock grades rapidly into an *augen* gneiss in which both orthoclase and quartz crystals occur as rather plump lenses in parallel orientation: and from this condition there is an easy gradation into more acutely deformed facies in which the porphyritic crystals have been drawn out into very thin lenses of remarkable length, the maximum diameter of the lens being oriented parallel to the dip of the foliation. Many of these lenses, particularly those of the quartz, are over 2 inches long and appear when viewed with a pocket lens to be a homogeneous quartz individual with vitreous lustre and conchoidal fracture. They are, however, in reality, probably aggregates of quartz individuals. The same phenomena of deformation are observable in the numerous dykes or sills of this granite, which occur in the encasing Coutchiching schists, and it is evident in all cases closely observed, that the maximum elongation of the rock has been in the plane of the dip, and at right angles to the strike.

The deformation to which this intrusive rock has been subjected, suggests very strongly that the present ratio of length to breadth in the horizontal section of the mass of about 3 to 1 is due to the same deforming process which has reduced the constituent crystals to lenses. It was probably originally nearly equidimensional in horizontal section, and was undoubtedly intruded into the Coutchiching when the latter was itself comparatively little deformed; since the granite itself appears to have been as greatly affected in this respect as the schists encasing it. If this be so then we may properly think of the intrusion as having had originally a quite flat roof of the Coutchiching strata over it. Thus the mass may well have been originally a flat laccolith or sill rather than a batholith. This possibility is in a measure sustained by the peculiarly porphyritic character of the rock, which suggests hypabyssal rather than plutonic condition of cooling. The excessive shearing of the mass indicates a peculiar susceptibility to this kind of deformation, and this in itself perhaps also indicates a laccolithic relationship to the encasing rocks rather than that of a batholith; since in the general deformation of the region a laccolith would participate in the folding and so more easily be brought into a position favourable for intense compression;

whereas a deep rooted batholith would be more stable and might act rather as a buttressed mass against which the surrounding rocks would be compressed. The occurrence of numerous sills of the granite found in the encasing and overlying Coutchiching schists also lends strength to this view. Similar sills of amphibolitic schist may with great probability be interpreted as intensely sheared and dynamically metamorphosed basic rocks, perhaps lamprophyres, satellitic upon the main intrusive body. The term granite is given to it in a general sense. In a strict petrographical classification, it would probably be placed with the granite-porphyries.

This Rice Bay granite mass, whether it be structurally a batholith or a laccolith, with little doubt belongs to the earlier Archæan or Laurentian granite-gneiss. The great deformation which it has undergone differentiates it quite sharply from other less deformed granitic rocks, yet to be described in the same region. Its petrographical characteristics as well as its sheared and bleached condition ally it with the granite of Bad Vermilion lake, which has been shown to belong to the earlier period. The fact that it was intruded into the Coutchiching before the latter had been greatly deformed agrees with and supports this conclusion. The mass is, therefore, placed in the same category with the Bad Vermilion Lake, Mud Lake, and Grassy Island granites, as belonging to the Laurentian.

PETROGRAPHICAL NOTES.

A few specimens of the sills or dykes which traverse the Coutchiching mica schists in the vicinity of the Rice Bay granite were examined microscopically. One of these was taken from the north side of the outlet of Rice bay in the narrows leading to Rocky Islet bay. Here an acid sill cuts the mica schists parallel to the schistosity, the dip being S. W. at 45° to 60°. The rock is light grey in colour but is stained locally yellowish by traces of limonite. The rock has a fine grained granular texture and a pencilled structure; that is it has schistosity chiefly parallel to a direction rather than to a plane. In fracture surfaces parallel to this direction, the schistosity is marked, while in fractures transverse to this it is scarcely apparent. The direction of pencilling is that of the dip. Notwithstanding this general structural characteristic, the rock contains numerous quartz lenses, many times longer and broader than thick, and these determine a cleavage parallel to the plane of the dip. The rock has evidently been subjected to great deformation and the quartz lenses are the result of the drawing out or squeezing of large crystals of quartz, and the direction of elongation of the rock as a result of this squeezing has been that of the dip. In the midst of the rock there are here and there small nests of molybdenite, and some small stringers of quartz traversing the rock also contain molybdenite.

In thin section the rock is seen to be composed chiefly of alkali feldspar and quartz with a quite subordinate amount of brown biotite in discrete plates lying in various azimuths. The feldspars which make up the bulk of the rock are fresh, and both these and the quartz are throughout allotriomorphic. The large quartz lenses are seen to be polysomatic. Since the shearing to which it was once subjected the rock has evidently been reconstructed, for little evidence of cataclastic structure remains. In this respect it is analogous to the adjacent mica schists in which all trace of the original clastic structure has been effaced by the processes of reconstruction due to metamorphism.

A specimen of a similar sill fron the south side of Rice bay shows the same general features in thin section, except that there are bands of finer grain alternating rudely with bands of coarser grain, indicating zones of granulation due to shearing.

A few specimens of the basic sills were also taken for microscopic examination. One of these from the west side of Lower Rice bay appears in the field as a band of black, glistening, hornblende schist, flanked on either side by mica schist, and conforming in dip to the latter. In this section the rock is seen to be composed of nearly equal parts of green hornblende and feldspar together with a very considerable amount of ilmenite and titanite. The structure is that of an allotriomorphic granular aggregate with a feeble manifestation of parallel structure. The hornblende shows only occasionally a pronounced elongation in the prismatic axis. The feldspar is for the most part unstriated. The occasional twinned crystals belong to the basic end of the plagioclase series and the unstriated crystals have a higher refractive index than balsam. The ilmenite usually has a border of titanite or is enclosed as residual nuclei in the latter.

Another specimen from the north side of Lower Rice bay appears as a black hornblende schist with glistening cleavage faces and streaks of light yellow colour. On microscopic examination the rock is found to consist chiefly of green hornblende and zoisite with some felspar. The hornblende is commonly elongated in the direction of the prism and disposed in parallel orientation giving the rock a well defined schistosity. The yellow streaks are due to the predominance of zoisite and clinozoisite over the hornblende, the latter being lacking in certain bands.

A specimen from another of these basic sills on the south side of Lower Rice bay is also a black glistening hornblende schist, but is composed of hornblende, feldspar, quartz, and titanite, with a pronounced parallel arrangement. The titanite is in the form of long narrow zones parallel with the schistosity and encloses numerous nuclei of ilmenite.

An analysis by M. F. Connor of a specimen of one of the acid sills on the south side of Lower Rice bay, which brings out prominently the contrast between these intrusive sheets and the Coutchiching mica schists, is herewith given:—

SiO_2	70·00	K_2O	2·99
TiO_2	0·20	H_2O-	0·07
Al_2O_3	16·00	H_2O+	0·52
Fe_2O_3	1·28	P_2O_5	0·05
FeO	0·51	S	0·05
MnO	0·08	Cl	trace.
CaO	2·30	Cr_2O_3	none.
BaO	0·04	SrO	0·01
MgO	0·50		
Na_2O	5·34		99·94

THE SEINE SERIES.

The term "Seine" is here given for temporary convenience to a post-Keewatin series of sedimentary rocks that are typically exposed at many places along the Seine river. The series doubtless has its correlative in standard sections elsewhere in the Lake Superior region and it will appear from the discussion in the sequel that it is very probably the equivalent of the upper Huronian, if we exclude the Animikie from the Huronian and regard the latter as made up of but two subdivisions, an upper and lower. For the present I prefer to use a local name which may be abandoned later, when the correlation of the Lake Superior Archæan has been finally worked out.

The Seine series consists of two parts:—

(1)—A basal conglomerate.

(2)—A thick volume of quartzites (often pebbly), sericitic schists, grits, greywackes, and clay slates and phyllites.

THE SEINE CONGLOMERATE.

The Shoal Lake Area.

The typical exposure of the Seine conglomerate is on the north side of Shoal lake on the Seine river. Here it occupies a well defined synclinal trough with the lower part of the Seine quartzites lying in the middle of the syncline, the axis of which passes through Old Mine Centre. The axis of the fold has a northeast-southwest trend; but both to the northeast and to the southwest of Shoal lake the axis of the fold curves to a more nearly east-west trend. The strata both of the conglomerate and of the overlying pebbly quartzites are nearly vertical and the schistosity which characterizes both sets of rocks conforms for the most part, though not everywhere, to the stratification.

The northwest limb of the syncline rests upon the Bad Vermilion granite, which is well exposed a short distance from the shore of the lake to the north of the Foley Mine landing, and which comes to the shore of the lake southwest of the landing. The southeast limb of the syncline rests upon Keewatin rocks which occupy a belt a mile or more in width at the east end of Shoal lake. The conglomerate is thus clearly spread over the contact between the Keewatin and the Bad Vermilion granite and is sharply infolded between them. The Keewatin rocks on the southeast of the syncline are typical greenstone schists with ellipsoidal and amygdaloidal structures abundantly apparent; with these are subordinate bands of chloritic schists.

The conglomerate contains a large amount of debris derived from the waste of the Keewatin rocks, but the pebbles and boulders, usually well water-worn, consist chiefly of different varieties of granite with a subordinate proportion of pebbles of greenstone, quartz, quartzite, and quartz porphyry, and there are occasional pebbles of chert such as are associated with some of the Keewatin limestone and iron ores. Professor Coleman[1] records also the occurrence of boulders of coarse grained anorthosite similar to that of Bad Vermillion lake in this conglomerate. The well rounded water worn pebbles range in size from that of a marble to diameters of about a foot; but in other localities in this same conglomerate may be found occasional boulders of granite as much as 3 feet in diameter. As a general rule the matrix of the conglomerate is of a dark green colour, more or less chloritic in composition and thoroughly schistified. The schistosity adapts itself to the contours of the pebbles and boulders and it is evident from an inspection of sections afforded by the glaciated surface that the deformation of the rock has caused the matrix to flow around them, and has oriented them with the plane of their major axes parallel to the schistosity. The granite pebbles and boulders are rarely, if ever, deformed in the Shoal Lake section of the conglomerate; but in the same formation a few miles to the northeast on the line of the Canadian Northern railway the boulders have in many instances been pulled apart by the flowage of the rock induced by lateral compression. The result of this sundering of the boulders of the conglomerate is the appearance of one or two or three, or rarely more, transverse gashes in the boulder filled with quartz veins having a columnar structure, the prisms of quartz being

[1] Rept. Bureau of Mines, Vol. VII, Pt. 2, Toronto, 1898, p. 153.

A

B

A. Seine conglomerate; west of Mathieu, on the Canadian Northern railway.
B. Fanglomerate at the base of the Seine conglomerate, near Golden Star mine.

arranged normal to the walls of the gash vein thus formed, or parallel to the direction of flowage of the rock while yielding to deformation. These gash veins range in width from over an inch to less than an eighth of an inch, and the width is usually approximately uniform across the boulders. It is evident from the fact that the matrix does not flow into these gashes in the boulders that they opened slowly, and that the deposition of the quartz proceeded *pari passu* with the opening. Attempts were repeatedly made to determine whether or not the fragments of the Keewatin rocks, these being usually schistose, had acquired their schistosity before enclosure in the conglomerate, or had had their schistosity developed in them at the time of the deformation of the conglomerate. But these efforts were not very successful. The fragments of the Keewatin schist are usually elongated and are schistose parallel to the elongation and to the schistosity of the matrix; and in most cases, moreover, it is not easy to discriminate such pebbles from the enclosing matrix. In the field it seemed probable in a number of cases that the greenstone pebbles and their schist matrix had been schistified at the same time; but in other cases elongated pebbles of schist were found slightly oblique to the stratification of the conglomerate and the schistosity was parallel to the elongation of the pebble rather than to the cleavage of the matrix, indicating that the schistosity of the pebble antedates its enclosure in the conglomerate. The prevailing elongated habit of the schist pebbles, moreover, is itself an indication that schistosity had determined their form as pebbles. Many of the pebbles and boulders of greenstone schist are strongly epidotic, but epidote is not a notable constituent of the matrix.

On the northwest margin of the northwest limb of the conglomerate syncline, at a point near The Golden Star mine about 2½ miles north of Shoal lake, on the wagon road from Old Mine Centre to Mine Centre Station, there is a very fine exposure of the base of the conglomerate. Here it crosses almost transversely the contact between the Bad Vermilion granite and the Keewatin, which consists of a dense fine grained felsitic rock. The bottom portion of the conglomerate formation, while very clearly detrital, is neither water worn nor far transported. The fragments which compose it are angular detritus of a desert alluvial slope. Where it rests upon the granite the detritus is nearly all derived from the underlying granite, blocks of granite being enclosed in a coarse quartzitic arkose matrix; and where it rests upon the nearby Keewatin, it is nearly all derived from the underlying rocks of that series, but with considerable quartz in some parts of the matrix.

This facies of the accumulation is very evidently the same as that which I have described elsewhere under the name of fanglomerate.[1] The deposit is well cemented but is only feebly schistose. It has a thickness of about 100 feet and grades into the ordinary waterworn conglomerate, beneath which it dips with rude stratification. The strike of the basal beds of the fanglomerate where it rests on the granite, on the road to the Golden Star mine, is 28° and the dip is easterly 35°. Here the rock is scarcely if at all schistose, and the absence of deformation is one of the notable features of the section. A little farther northeast where the fanglomerate rests on the Keewatin, the strike is 66° and the dip is much steeper. With the steepening of the dip there is a marked increase in schistosity.

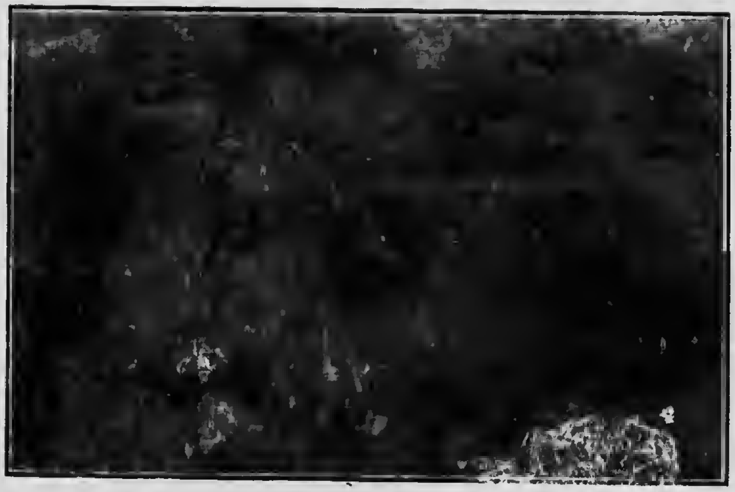
The character of the deposit and the condition of the underlying rocks indicates that the detritus accumulated by a process of mechanical disintegration of the underlying rocks without important chemical decay. The underlying granite has a peculiar yellowish colour in the vicinity of the overlying fanglomerate, but otherwise it is a fairly sound rock. The yellow stain is very dilute and is not evenly distributed. It appears to be due to the downward percolation into the granite of meteoric waters charged with the products of feeble surface oxidation. It may, therefore, with much probability be regarded as a weathering effect of the time when the fanglomerate was accumulating. The same colour appears in many of the granite fragments in the detrital deposit.

Since the fanglomerate is without doubt a sub-aerial formation and since it grades up into a conglomerate in which the boulders and pebbles are well waterworn, it seems a fair inference that the conglomerate represents a gravelly flood-plain rather than the beach of a transgressing sea. If this be true then in a general way the distribution of the conglomerate as outlined on a general geological map of the region indicates the course of a river. The conglomerate has been traced from Rat-root bay on Rainy lake to Atikokan on the Seine, a distance of 76 miles in an east and west direction. This suggestion as to the course of an Archæan river in this region, furthermore, gives us some clue as to the orientation of the dominant structural lines of the region at a time which antedates the intense plication which folded and deformed the conglomerate. That orientation thus judged appears to have been approximately the same as that of the later structural features referable to that plication.

The interpretation of the structure of the conglomerate on the north side of Shoal lake as synclinal, is based not only upon the symmetrical disposition of the strata on either side of a median axis, but also upon the fact that in the quartzites which rest upon the conglomerate the upper side of the beds on the

[1] Bull. G. S. A. Vol. 2., P. 72, 1912.

A



B

A. Seine conglomerate; island on north side of Rat-root bay.
B. Seine conglomerate; Prospect bay.

southeast side of that axis face northwest and on the northwest side face southeast. These quartzites are strongly cross-bedded and on the upturned edges of the strata this structure is very apparent on glaciated surfaces. Figure 1 is a photographic reduction of the cross-bedding as it appears on a smooth horizontal surface in one of the many instances noted. It was

FIG. 1. Cross bedding of Seine quartzite; Shoal bay.

made by laying paper on the rock surface and making a pencil rub of the bedding planes as etched in the rock by weathering agencies. In such cross-bedded rocks, before uptilting the concavity of the curves of the cross-bedding invariably faces up, so that even when the strata are tilted into vertical attitudes, they indicate clearly and unmistakably which is the upper and which the lower side of the bed.[1] The application of this method to the rocks on the north side of Shoal lake, where there are many instances of cross-bedding quite as clear as the one shown in Figure 1, proves conclusively that a synclinal axis runs through Old Mine Centre.

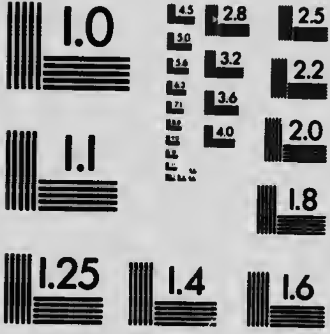
East of Shoal Lake.

In regard to the distribution of this belt of conglomerate, I shall first briefly indicate its extension eastward from Shoal lake and then westward to Rat-root bay. The wagon road from Mine Centre Station on the Canadian Northern railway to Old Mine Centre, and the branch roads to the Golden Star mine, Island bay, and the Foley mine, afford access to the northwest margin of the syncline at a number of points, one of which near the Golden Star mine has already been referred to. There is, therefore, very little conjecture involved in the mapping of the line between the conglomerate and the Bad Vermilion granite for a distance of about 5 miles. On the southeast flank of the syncline the conglomerate is exposed in a bare ridge extending northeast from Bell City for about 2 miles. Three miles beyond this it is exposed again in the timber at a point about 12 chains

[1] This simple and extremely useful means of determining the upper and lower side of upturned sedimentary strata has recently been brought to notice by Mr. W. O. Hotchkiss of the Wisconsin Geological Survey, and although he has not yet published it, he has kindly permitted me to use the method. I am indebted to the late Dr. J. D. Trueman for calling my attention to it.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



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north of the north side of Wild Potato lake. It is certain that for this stretch of 5 miles, and probably for 4 or 5 miles farther, the conglomerate rests upon the Keewatin rocks so well exposed at the east end of Shoal lake and on the northern and eastern shores of Wild Potato lake.

It is probable that the quartzites which on Shoal lake rest upon the conglomerate in the middle of the syncline, occupy a canoe-shaped area having its greatest width on Shoal lake, and tapering out to the east; for where the conglomerate belt intersects the line of the Canadian Northern railway, these upper beds are absent. The exposures on the railway extend from a point 4½ miles west of the Seine River railway bridge to a point about one-eighth of a mile east of the bridge. In this stretch of 4⅝ miles there are numerous rock cuts, all affording splendid exposures of the conglomerate, and as the trend of the railway is but slightly oblique to the strike of the conglomerate, the latter may be safely considered as occupying the entire distance. The geological section revealed in the most westerly of these cuts at the northern margin of the conglomerate belt is interesting. In passing from north to south, or from the Keewatin to the overlying conglomerate after leaving an interval of low ground with no exposure, we encounter at the ninth telegraph pole west of mile-post 178:—

(1) Glossy purplish grey sericitic schists with isolated grains of clear quartz, probably a sheared rhyolite, strike 85°, dip N.85°. Thickness 330 feet.
(2) Green chlorite schists, same strike and dip. Thickness 30 feet.
(3) Greenstones with shear zones. Thickness 300 feet.
(4) Grey and black slates and grey quartz schists. Strike 83°, dip N.80°. Thickness 50+ feet.
(5) No exposure. 300 feet.
(6) Conglomerate; strike 83°, dip N.75°. Thickness probably one-half mile.

It is here noteworthy that the dip is overturned a little beyond the vertical and that the conglomerate is not immediately in contact with the Keewatin greenstone, but is separated from it by at least 50 feet of fine grained sedimentary rocks, which must be regarded as the local base of the Seine series. The appearance of the conglomerate in one of the cuts near its northern margin or base is well illustrated by the photographs shown in Plates I and VIIIA.

Above the Seine River bridge the conglomerate is not so coarse and it appears to have split up into comparatively narrow tongues intercalated with quartzites which are generally schistose and sericitic. The northern edge of the conglomerate belt where it is in contact with the Keewatin is intersected by the Seine river at the bend below Sand Hill portage. From this point the contact with the Keewatin on the north and the Seine series on the south trends somewhat south of east until it is intersected by the line of the Canadian Northern railway at a point 2⅓ miles east of Seine Station. But at this point the conglomerate at the base of the series is absent. From this point eastward the contact of the two series lies on the south of the railway for 3 miles to a point near Mayflower Station, where the railway bends to the south, leaving it on the north. It is next seen at the embayment of the Seine river at the head of Nonwatin lake. Thence it follows the river to near Banning, the Keewatin being on the north side and the Seine series on the south, except for minor irregularities of the shore-line. Near Banning the line passes to the south of the river and the railway for about 2 miles and emerges again on the south shore near the east end of Pike lake. Here a well defined conglomerate occurs at the contact. The conglomerate is found again in excellent exposure on the north side of Perch lake at the contact of the two series. From Perch lake eastward the line between the Keewatin and the Seine series lies just south of the Seine river for 8 miles to the mouth of Atikokan river. Just west of Atikokan Station the conglomerate is well exposed on the north bank of the river. East of this the contact follows the Atikokan river to Sabawe lake and in this stretch no conglomerate was observed at the contact. About a mile east of Atikokan Station the contact is thrown by a fault, the strike of which appears to be northeast-southwest. The effect of the fault is to let down the northwest side so that the Seine strata abut upon the Keewatin for about a fourth of a mile or more. The fault is in the prolongation of one which was recognized at the south end of the east arm of Steeprock lake, having the same strike and throw; and the two are regarded as probably one and the same fault.

The line of demarcation between the Keewatin and Seine series, thus sketched from Shoal lake to Sabawe lake, is a very simple and even line. This simplicity characterizes also the strike and dip of the Seine strata south of the line. The strike is parallel with the contact and the dips rarely depart far from verticality. They are sometimes slightly overturned, as for example, west of Hematite Station on the railway, the strata dip north at from 70° to 75°; but east of Hematite they dip south at 65°.

The structural discordance of the Seine series with the Keewatin is apparent at the Golden Star mine, where the basal beds lie across the contact of the granite and the Keewatin and across the Keewatin formations which here dip northerly, while the conglomerate dips southerly. It is also apparent in the vicinityt of Steeprock lake. Here the strike of the underlying Keewatin varies from north-south to northwest-southeast, and the strike of the Seine strata is evenly east-west. Similar discordances are observable at Nonwatin lake and at other places along the Seine. In general it is evident that the Keewatin rocks were disturbed and more or less folded in pre-Seine time; and of course the relations at the Golden Star mine prove that not only had the Keewatin been invaded by a granite batholith, but also that denudation had proceeded so far as to expose the batholith extensively at the surface before the beginning of the accumulation of the Seine sediments in that region.

An interesting and economically important feature of the contact of the two series is the occurrence of iron ore deposits at a number of localities. The largest of these lies just to the east of Sabawe lake, where they have been mined for some years. Considerable deposits also occur west of Hematite Station and there are other minor deposits along the Seine river. These iron ores occur either at the contact or very close to it where there is no conglomerate. The ore and conglomerate thus appear to be in a certain sense complementary features of the base of the Seine series. It is interesting to note in this connexion that the pre-Seine surface of the Keewatin greenstones where it emerges from beneath the Seine series is commonly heavily charged with carbonates (including siderite or ankerite) and limonite. This condition in some sections obtains for several hundred feet away fron the contact and with little question it represents the effect of the weathering of the Keewatin surface in pre-Seine or early Seine time. It suggests a supply for the iron ore that is found in workable bodies and in less important prospects along this contact. The concentration may have been effected in bogs in early Seine time, a possibility which harmonizes with the absence of conglomerate at such points on the contact; or it may have been concentrated by underground circulation after burial of the weathered and iron-rich surface by the Seine sediments. However this concentration may have been effected, the contact of the Keewatin and the Seine series is certainly a favourable and easily followed geological horizon for prospecting for iron ore in this region.

By way of summary it appears from the foregoing observations:—

(1) That the northern margin of the basal conglomerate of the Seine series, which is synclinally folded on Shoal lake, extends thence eastward continuously as far as La Seine Station on the Seine river, a distance of 22 miles following the curves of the outcrop; and that between this point and Atikokan, a

distance of 29 miles, there are three occurrences of conglomerate in the same geological relation to the two series.

(2) That from the Golden Star mine, north of Shoal lake, to the iron mines east of Sabawe lake the Seine series rests upon the Keewatin.

(3) That the line of contact is a remarkably simple and even one, with a general east-west trend except at Shoal lake, where the deformation of the region has caused the later formation to accomodate itself to the contours of the resistant mass of the Bad Vermilion granite.

(4) That the unconformity of the Seine series upon the Keewatin is proved not only by the basal conglomerate, but also by structural discordance.

(5) That the conglomerate originated as a sub-aerial accumulation.

(6) That the Keewatin greenstones below the Seine beds, particularly where the conglomerate is absent, are prevailingly charged with carbonates and limonite, a condition which was not observed away from the contact. This fact is taken as an indication of sub-aerial weathering antedating the burial of the Keewatin surface by the Seine sediments.

(7) Workable deposits of iron ore occur at or close to the contact of the two series, where no conglomerate is present. This suggests that the iron ore may be due to a concentration of the product of the oxidation of the Keewatin greenstones, either in bogs in early Seine time, or by underground circulation after the burial of the weathered surface of the Keewatin. It also suggests a very definite and easily followed clue to the prospecting for iron ore in this region.

The Conglomerate West of Shoal Lake.

At the west end of Shoal lake the canoe-shaped area of pebbly quartzites which occupies the middle of the syncline in the Old Mine Centre section appears to pinch out about half a mile north of the outlet of the lake, where a narrow band of cross-bedded quartzite appears to be all that is left of that formation. The conglomerate here and beyond to the west is practically a single belt made up of the appression of the two limbs of the syncline between the Bad Vermilion granite on the north and the Keewatin on the south. The Keewatin is part of the same belt which flanks the southeast limb of the conglomerate syncline at the east end of Shoal lake. But whereas at the east end of the lake the Keewatin belt is a mile wide, at the west end its width is only a fourth of a mile. The closely appressed synclinal trough of conglomerate continues westward on the south side of the granite to the west end of Grassy lake, a distance of 4 miles. It is well exposed on the north side of Grassy lake. The stratification and schistosity are vertical and the synclinal character of the belt is inferred from its very evident continuity with the well defined syncline of Shoal lake. Westward of Grassy lake the conglomerate is concealed by fluviatile deposits for a little over 2 miles. It is next seen on an island at the outlet of Cliff lake and thence westerly it skirts the points of the north shore of that lake for 1½ miles. In this stretch the Keewatin lies to the north of the conglomerate and the waters of the lake, to the south. On the south side of the lake are typical Coutchiching mica schists with northerly dips ranging from 75° to 90°. No section showing the juxtaposition of conglomerate and Coutchiching could be found. There is, however, no reason to doubt that the synclinal structure of the conglomerate belt so well displayed on Shoal lake continues through to Cliff lake.

Going westward through Rainy lake, the next occurrence of the conglomerate which is worthy of discussion is on the islands off the Minnesota coast north of the mouth of Black bay. Here as the map shows, the conglomerate occurs as a well defined elongated syncline enclosing a considerable body of quartzites which are usually sericitic and pass into quite fissile sericitic schists. The syncline lies wholly within the Keewatin area and the conglomerate nowhere comes in contact with the great southern belt of Coutchiching. At its western end, however, where the synclinal trough pinches to a very narrow belt and the quartzites are cut out an attenuated band of conglomerate probably extends through and connects with the conglomerate of Rat-root bay, which is probably in contact with the Coutchiching rocks of the north side of the bay. And these are part of the central belt of Coutchiching which in general lies to the north of the Keewatin. The northern limb of this conglomerate syncline at its eastern end is well exposed on the small island immediately east of Dryweed island. The conglomerate here is flanked on the north by Keewatin greenstone schists and the sericitic quartzites lie to the south of it. The strike is 90° and the dip is vertical. Westward from this exposure the conglomerate may be traced as a narrow band intervening between the Keewatin and the sericitic quartzites cutting across the northeast point of Dryweed island, and thence skirting the north shore of that island to its western extremity. It is next observed on the northern extremity of Grindstone island, all the rest of that island to the south being occupied by the sericitic quartzites. The next exposure is on the shore of the mainland about 28 chains west of the west end of Grindstone island, and it occupies this shore for nearly a mile to Frank bay.

The southern limb of the conglomerate syncline is exposed on the south side of Dryweed island near its eastern end and again nearer the middle part of the island. It occupies an island south of the western end of Dryweed island and is next encountered on the main shore on the south side of Neil point. At Frank bay this southern limb of the syncline appears to converge upon the northern limb, for beyond this the quartzites appear to have been pinched out and the conglomerate itself is traceable only by the characteristic appearance of the matrix and is at best a very narrow band.

The area thus enclosed by these two belts of conglomerate converging at both ends, has the shape of the cross section of a lens. Its length is about 6 miles and its maximum width about three-fourths of a mile. Within the area thus enclosed lie the sericitic quartzites and sericitic schists. Inasmuch as the conglomerate is clearly post-Keewatin and rests upon it, there can be no question as to the correctness of the interpretation of the structure. It is certainly a closely appressed syncline. The conglomerates of this area come nowhere in contact with the Coutchiching mica schists to the south. A belt of Keewatin rocks intervenes. The sericitic quartzites and schists which lie upon the conglomerate in the middle of the syncline in no way resemble the mica schists of the Coutchiching to the south. There is thus no suggestion in the conditions which obtain here, that the conglomerate is the base of the Coutchiching, and that the latter is superposed upon the Keewatin. On the contrary, the facts are a sufficient proof of sequence as I stated it in 1887. For if the Seine conglomerate and quartzite occupy a closely folded syncline, there appears to be no escape from the conclusion that the belt of Keewatin upon which it lies is also synclinal in structure, and that the Coutchiching rocks of the Minnesota coast, therefore, underlie the Keewatin—a conclusion which is in harmony with that previously reached, that the Coutchiching rocks of the Bear Passage belt are anticlinal and underlie the Keewatin.

West of Frank bay well defined conglomerate cannot be traced, but a peculiar schist which serves as a matrix of portions of the conglomerate on the shore between Neil point and Frank bay is found to extend through from Frank bay to the mouth of Hay creek. Beyond this it is lost in marshy ground. Both on Frank bay and at the mouth of Hay creek, Keewatin greenstones lie to the south of this, as well as to the north. It thus occupies the position of the conglomerate syncline and with little doubt represents the attenuated prolongation of the western tapering end of the synclinal trough. Whether this is continuous below the marsh and timber to Rat-root bay is uncertain, but in the prolongation of this belt on the shores of that bay little more than a mile distant we find the conglomerate again in excellent exposure. There can be no reasonable doubt but that the Rat-root Bay conglomerate is the same geological formation as that of the Dryweed Island syncline. The trough which is nearly pinched out between Frank bay and Hay creek, here swells out again. On the shores of the bay the conglomerate is exposed on the south side, at the head of the bay and on a small island near the north side.

The conglomerate on the south side of the bay lies on the south side of a belt of hornblende schists which in turn flank an intrusive mass of granite gneiss of rather variable composition. This granitic rock occupies the south side of the bay for the first three-fourths of a mile. It is intrusive in the Keewatin and at one locality on the north side of Grassy island, not far from the contact of the Coutchiching and Keewatin, it holds included blocks of typical Coutchiching mica schist. It is, therefore, later than both Keewatin and Coutchiching.

The conglomerate is remarkably coarse. It consists in part of a dark green chloritic schist matrix in which are embedded large boulders of granite and granite-porphyry, some well rounded and some angular or sub-angular. Several of these measured over a foot in diameter, some over 2 feet, and one over 3 feet. While the matrix shows abundant evidence of shearing and stretching, the boulders are not notably deformed and show no transverse gash veins like those observed east of Shoal lake. A few have their longer diameters transverse to the schistosity. Some are quite plump and even spherical in form, but the most of them are elongated oval in shape. The rounded ones have all the appearance of water-worn boulders. The formation may fairly be interpreted as a torrential deposit. A little farther west, along the same shore, the boulders are more sporadic and have more of a quartz porphyry facies. With these are some boulders of quartzite. Associated with the boulder beds are others free from boulders or pebbles, which have the character of micaceous schists. The absence or extreme scarcity of small waterworn pebbles is a notable feature of this conglomerate.

The conglomerate at the head of Rat-root bay and on the island near the north side presents quite a different facies from that just described on the south shore. The pebbles are more abundant and much smaller and are usually well waterworn, though prevailingly elongated rather than round. The matrix of the conglomerate, greenish grey in colour, is generally schistose but is made up chiefly of quartz, the clastic origin of which is scarcely if at all masked by the secondary minerals and the schistosity. The pebbles range in size ordinarily from 1 to 4 inches and are mostly about 2×3 inches. Occasionally larger ones are observed, the maximum dimensions being 7×11 inches. The pebbles are mostly a whitish quartzite, but nearly as many are composed of a grey quartzose rock. I found no pebbles in any way resembling the Keewatin greenstones. The grey pebbles vary much in texture. Many are fine grained micaceous schists, while others are coarser and show on the weathered surface protuberant grains of quartz. They may very probably represent a sheared granitic rock, such as the older granite of Grassy island. There are also a considerable number of white quartz pebbles and these are for the most part well waterworn and plump or spherical. In contrast to these the grey pebbles are lenticular in form, a fact which is probably in part due to an original cleavage which determined their shape as pebbles and perhaps in part also to their greater susceptibility to deformation and stretching when the conglomerate was schistified.

The strike of the schistosity of the conglomerate is 69° and the dip varies from 80° to 90° to the north. Oblique to this schistosity is banded structure, due to bands nearly or quite free from pebbles alternating with others charged with them. The bands vary in width from 6 inches to several feet and are marked by differences of texture observable on the weathered surface as well as by the absence or presence of pebbles. The pebble-free bands are in some cases discontinuous or abruptly tapering and grade into the pebbly parts of the formation. This banded structure reveals with little question the original bedding of the deposit. The strike of the bedding is 98° and the dip appears to be vertical. The schistosity thus locally makes an angle of 29° with the bedding.

Traversing the conglomerate are numerous stringers of quartz, some of which cut across the pebbles and most of which appear to have been affected by the shearing action involved in the schistification.

It is of interest to note that this facies of the conglomerate is apparently in juxtaposition with the Coutchiching of the northern belt which is geologically continuous from Bear passage to Coutchiching. Consistently with its unconformable relation to the Keewatin, the Seine conglomerate, having a more nearly east and west trend than the Keewatin belt, has crossed the latter obliquely to the north side, and lies upon the Coutchiching where the Keewatin had been removed from it in the erosional interval immediately preceding the Seine period of deposition. The fact that the Keewatin belt, which has a width of about 6 miles in the meridian of Bleak bay, tapers steadily to the west-southwest until in the vicinity of Rat-root bay it is probably not more than a fourth of a mile wide, and that the Seine conglomerate, which rests upon it unconformably and is synclinally sunk into it, extends down to the point of this tapering trough and beyond it so as to come against the Coutchiching of the north side, proves clearly that the Keewatin in the vicinity of Rat-root bay was relatively very thin at the time of the deposition of the Seine conglomerate, and that the latter extended out over its edge on to the underlying Coutchiching.

Petrographical Notes.

A number of the specimens of the conglomerate of Rat-root bay, both pebbles and matrix, were taken for microscopic examination. From this study it appears that the quartz pebbles which are so abundant are probably chiefly vein quartz. These pebbles consist practically wholly of quartz showing in section the usual mosaic arrangement of vein quartz with no trace of deformation except perhaps a slight undulatory extinction. In one of these quartz pebbles there was found considerable epidote in irregularly shaped grains and some cubes of pyrites with a shell of limonite.

Some of the pebbles consist of black chert of dense texture or lack of texture of flint. The material resembles closely certain bands of black chert occurring in the Keewatin on Sand Point and Red Sucker islands. Microscopically this black chert consists of a murky aggregate of exceedingly fine quartz grains with numerous small elliptical areas which have a clear periphery and murky centre like the general matrix. These elliptical areas are suggestive of organic remains, but whether they are so or not could not be established.

One pebble was found to be a very quartzose biotite granite composed chiefly of quartz and partially decomposed orthoclase with some oligoclase, brown biotite, and a few irregular grains of pyrite.

The pebbles of grey rock of medium fine grain which are perhaps the most abundant in the conglomerate appear to have the character of alaskite or alaskite-porphyry. They consist chiefly of quartz, orthoclase, and acid plagioclase, with small amounts of biotite, chlorite, epidode and zoisite, and generally some calcite. In some of these rocks there is an interstitial matrix consisting of a finely granular aggregate of quartz and feldspar, the rock having the character of an alaskite porphyry. In other cases this ground-mass is absent and the structure is hypidiomorphic granular. In these cases, however, the feldspars have a strongly marked poikilitic structure as if they had incorporated an incipient ground-mass. These grey alaskite and alaskite-porphyry pebbles resemble certain local facies of the Bad Vermillion Lake granite (alaskite).

The matrix in which these pebbles are embedded is a sheared and schistified quartzite, with secondary biotite, chlorite, calcite, pyrite, and magnetite. Both the original clastic structure and the cataclastic structure which has been imposed upon it are quite apparent in thin section. A stratum devoid of pebbles which lies embedded with the conglomerate appears under the microscope as a quartz-chlorite schist. The clastic structure is apparent. Scattered through the rock are numerous well formed stout hexagonal prisms of some unknown mineral now completely replaced by an aggregate of epidote and zoisite. Besides these there are a few grains of pyrite.

The large boulders in the conglomerate on the south side of Rat-root bay appear from three representative specimens examined to be rather fine grained granite. They are composed of a hypidiomorphic granular aggregate of quartz, orthoclase, and plagioclase and biotite. The feldspars are fresh but the biotite, which is not abundant, is often chloritized. A few grains of pyrite occur in the slides.

Other Occurrences of Conglomerate.

There are three other minor occurrences of conglomerate within the area studied which may be tentatively referred to the Seine series, although their relations are not entirely clear. One of these occupies a portion of the shore of Prospect bay between Gash point and Reef point, as indicated on the map. It lies in the midst of a Keewatin belt, which for reasons already set forth, is probably synclinal in structure, and it is probable that the conglomerate is the portion of an inpinched fold of a deposit resting unconformably upon the Keewatin. The conglomerate contains numerous pebbles up to 4 or 5 inches in diameter and boulders up to a foot in diameter. Nearly all of these are more or less deformed by the compression to which the country has been subjected, so that the pebbles and boulders present the appearance of having been flattened into lenses. This deformation of the pebbles has, however, been differential. Of the two major axes of the lenticular ellipsoid to which each pebble or boulder has been reduced, the longer lies invariably in the direction of the dip and the shorter in the direction of the strike. It is evident that the diminution of the thickness of the formation due to compression has been compensated for by elongation chiefly in the direction of the dip and to a notably less extent in the direction of the strike, an effect which agrees with that observed at many other localities in this region.

The pebbles contained in this conglomerate comprise:—

(1.) Light grey medium grained biotite granite gneiss, with foliation always parallel to the longest axis. This is the most common type of rock represented by the pebbles but the degree of foliation is quite variable.

(2) A dark grey feldspar hornblende rock of dioritic facies.

(3) Hornblendite.

(4) Porphyritic grey gneiss.

(5) A fine grained dark grey gneiss; notably finer textured than No. 1.

(6) Whitish quartz or quartzite.

(7) A fine grained grey quartzose rock.

In the conglomerate are bands nearly or quite free from pebbles. These bands alternating with the pebbly beds afford an excellent indication of the bedding. The strike is 98° and the dip is vertical. The matrix of the pebbles is thoroughly schistose and the schistosity appears to make a slight angle with the bedding, but this could not be clearly observed. The conglomerate is exposed for a distance of from one-eighth to one-fourth of a mile along the strike and for a width of about 100 yards. On both sides of this it is concealed. A careful search was made for the continuation of the conglomerate eastward between this locality and Commissioners bay, but it was not found. The conglomerate is cut by several dykes comprising biotite granite gneiss, aplite, and mica syenite. Some of these dykes where they happen to be coincident in strike, or nearly so, with that of the conglomerate, have been pulled apart into discrete lenses and have been flattened just as the pebbles in the conglomerate have been. Where the dykes, however, are transverse to the strike of the conglomerate they have been doubled upon themselves and more or less plicated. The dykes are with little doubt apophyses of neighbouring batholithic intrusions of similar rocks, and their deformation thus affords evidence of the interesting fact that a large part of the more intense deformation of the region has been subsequent to these intrusions; and the fact that they cut the conglomerate shows clearly enough that some of the intrusions at least occurred in post-Seine time.

The second occurrence of conglomerate is located on the northwestern margin of the Keewatin belt which lies between Rocky Islet bay and Hopkins bay just where that margin comes against the great mass of porphyritic mica syenite so well exposed on Hopkins bay. This conglomerate is a narrow band, nowhere observed to be more than 100 feet wide, and is obscurely exposed in the timber at intervals for a distance of about 2 miles. The matrix of the conglomerate is a mica schist and associated with the conglomerate on the south side of it are similar schists free from pebbles. The pebbles and boulders in the conglomerate range up to a foot in diameter, and as far as could be observed, are all granite. The strike of the beds is from 42° to 48° and the dip is vertical. The coarse porphyritic mica syenite is intrusive in both the conglomerate and the Keewatin. A well defined contact metamorphic zone is locally developed in the conglomerate where it lies against the syenite. The Keewatin conglomerate, and syenite are all three cut by dykes of reddish quartzose binary granite or alaskite, of quite small width, and also by dykes of pegmatite. It is by no means certain that this conglomerate is post-Keewatin, but from analogy with other conglomerates already described, such is probably the case. If so then the narrow belt of Keewatin lying between the two areas of intrusive syenite, the one on Hopkins bay and the other on Rocky Islet bay, is probably the remnant of a synclinal trough in the midst of which lies the conglomerate, but the northern limb of which has been carried away by the intrusion on that side, leaving the conglomerate locally in contact with the syenite. This interpretation is, however, more or less conjectural.

The third occurrence of conglomerate is on the shore of Rainy lake at the southeast corner of Swell bay and is briefly referred to in the report of 1887. It is chiefly interesting as an indication of the position of a synclinal axis in the Keewatin belt at this locality.

THE SEINE QUARTZITES, SERICITIC SCHISTS, AND SLATES.

Resting upon the basal conglomerate of the Seine series is a thick volume of sedimentary strata of somewhat variable characters, the clastic origin of which is everywhere apparent except quite locally where they are highly schistose and are completely reduced to sericitic schists resembling those derived from the acute deformation of quartz porphyries or rhyolites. In their typical and most extensive development along the Seine river they are well stratified, often distinctly cross-bedded in the coarser strata and characterized at certain horizons by the presence of pebbles usually of quartz or quartzite. The pebbles are generally sporadically distributed in the beds in which they occur but are sometimes aggregated in conglomerate lenses. The finer textured strata are more thinly bedded than the coarser and have a more distinct cleavage. They have the properties of clay slates where exceptionally fine, and these are sometimes phyllitic; but there are all gradations from the finest to the coarsest sediments. The cleavage in all these rocks is parallel to the bedding. In the coarser beds at various localities one may observe, with the aid of a lens, secondary biotite or muscovite or both, but the reconstruction of the rock has never proceeded far enough to conceal the clastic structure, which is usually very apparent on the weathered surface of glaciated areas, as well as in fragments examined with a lens. The prevailing colour of these rocks along the Seine varies fron light grey to greenish grey and the weathered surfaces are generally whitish, or at least much lighter in colour than the fresh fracture. Where these rocks have been intimately sheared and reduced to schists, however, they are commonly yellowish. The quartzites and sericitic schists of the Dryweed syncline are prevailingly yellowish with purplish tints in the more schistose facies.

A partial account of the distribution of these rocks has been given in the foregoing description of the basal conglomerate of the series and this may now be supplemented. It has been pointed out that in the Shoal Lake section the Seine quartzites lie in the middle of a synclinal trough tapering at both ends, the structure of which is established not only by the symmetrical disposition of the strata, but more particularly by the cross-bedding of the quartzites, which clearly points to a synclinal axis passing through Old Mine Centre. It has further been pointed out that this trough lies across the contact between the Bad Vermilion granite and the Keewatin, the former being on the northwest flank of the syncline and the latter on the southeast flank.

These relations at once suggest that the mile-wide Keewatin belt on the southeast flank is an anticline. This suggestion, unfortunately, cannot be directly verified, by an examination of the Keewatin rocks of that belt. These are chiefly greenstone schists with amygdaloidal and ellipsoidal structures in which original depositional planes are difficult to observe and in which the prevailing schistosity is vertical or nearly so. But on the south side of this Keewatin belt we have another belt of Seine rocks in which we find evidence of a synclinal structure. This belt consists chiefly of cross-bedded quartzites, pebbly quartzites, and a subordinate proportion of beds approximately slates in their fineness of texture. It extends along the south side of Shoal lake and Wild Potato lake and thence up the Seine river. To the west it appears to pinch out in Grassy lake, but it may extend a little farther down the Seine, the insufficiency of exposure leaving this somewhat uncertain. This body of Seine quartzites lies between the mile-wide belt of Keewatin on Shoal lake and another belt of Keewatin which parallels it on the south at a distance of from a mile to less than half a mile. This southern belt of Keewatin occupies the south shore of Grassy lake for about 3 miles from its east end. The synclinal structure of the Seine quartzites between these two belts of Keewatin is not only indicated by its position taken in conjunction with its known superposition upon the Keewatin, but is also proved by independent evidence.

On a section made south from a point on the Seine river between Shoal lake and Wild Potato lake, the quartzites are strongly cross-bedded in the northern part of the section, and the curves of this cross-bedding clearly show that the upper side of the nearby vertical beds faces the south. Farther south the cross-bedding is much less in evidence, the rocks being finer textured, but at one locality, about a mile south of the river going across the strike of the strata, in a group of pebbly quartzites the cross-bedding is quite plain, and shows that the upper side of the beds faces the north. The strike of the strata here is about 78° and the dip 75° to 80° to the south, the beds being slightly overturned. It is evident from these facts that between this point and the river there is a synclinal axis.

Again on the south side of Wild Potato lake in a small bay about 2 miles west of the Indian village at the head of the lake, the Seine beds swing around rather sharply from a strike of 75° or 80° to north and south and there is clearly exposed on the shore of the bay the tip of a westerly pitching syncline. At the tip of the spoon-shaped structure the beds dip westerly down the synclinal axis at an angle of 30°. The beds are coarse textured and gritty with angular fragments up to a quarter of an inch in diameter. They are also strongly and generally cross-bedded and the curves of the cross-bedding are concave upward, showing that the beds are not overturned. The evidence is positive and unmistakable that we have here to do with a synclinal axis; and this axis lies in the middle part of the Seine belt a little north of midway between the Keewatin belt on the north side of Wild Potato lake and the southern belt of Keewatin which parallels it to the south of the lake.

A general conclusion from these observations and deductions is that the narrow southern Keewatin belt dips under this syncline of Seine strata separating the latter from the still lower and petrographically distinct mica schists of the Coutchiching.

In my report of 1887 I failed in this general section to recognize the separate existence of the Seine series and placed part of it in the Keewatin and part in the Coutchiching. That error is doubtless in some measure the cause of the later mistake of the International Committee and the U.S. Geological Survey in asserting that the Shoal Lake conglomerate is the base of the Coutchiching and that the latter rests upon the Keewatin.

Up the Seine river above Wild Potato lake the quartzites of the Seine series become less pebbly and there is a larger proportion of slaty rocks. These rocks are abundantly exposed on the shores of the Seine river and its lake-like expansions and in numerous cuts and natural outcrops along the line of the Canadian Northern railway. They have thus been traced through practically continuously to the eastward of Sabawe lake, with very little variation in their general features and with great constancy of strike and dip. The stratified and clastic character of the rocks is everywhere apparent, but in general they appear to become finer textured towards the east and to have a less pronounced and less common cross-bedding. The belt of Keewatin rocks which flanks the Seine series on the south was traced at intervals to a point a little above Sturgeon Falls. Beyond this various attempts were made to determine the relations of the series to the Coutchiching rocks on the south in the course of a reconnaissance trip up the Seine river, but the actual contact was not found in any of the sections examined. Wherever the two sets of rocks were found near each other there was observed to be a sudden and abrupt change from the obviously clastic and comparatively little altered Seine rocks to the highly metamorphic mica schists of the Coutchiching with no trace of clastic structure remaining. The sections examined for this purpose comprise one south from the south end of Nonwatin lake to Pine lake, one south from Perch lake at the inlet of the creek draining McCauley lake, and a third south from the Seine river, through Jackfish lake to the lake lying to the southeast of it.

Near the outlet of Sabawe lake, at Iron Spur on the Canadian Northern railway, the Seine rocks are cut by an intrusive mass of biotite granite-gneiss, which is doubtless the same as that occupying an extensive area to the south and mapped as Laurentian on the Seine River sheet. The phenomena of intrusion and contact metamorphism are well displayed in the rock cuts of the railway, both on the main line and on the spur to the iron mines.

Sufficient work has not yet been done to afford a reliable basis for an estimate of the volume of the Seine series, but it is safe to say that it is several thousand feet thick.

Petrographical Notes.

The sericitic quartzite schist of Dryweed island shows abundant evidence in thin section of its clastic origin notwithstanding the deformation to which it has been subjected. The sections show that it is composed chiefly of grains of quartz with a subordinate quantity of orthoclase and plagioclase. These grains are in some cases fairly uniform in size, while in others the size varies so that there is a matrix made up of very small grains of quartz and in this there are scattered sparsely or thickly larger grains of quartz and feldspar. In those cases where the grains are of fairly uniform size they are separated by sericite so that the latter is disposed in section like the cord of an irregular net, while the quartz and feldspar grains occupy the holes of the net. The breadth of the sericite varies from a mere film to a third of a millimetre, but is everywhere, of course, composed of an aggregate of minute scales. The borders of the clastic grains of quartz and feldspar have lost their original worn contour and are now very commonly indentate or suture-like. It is evident that they have been subjected to solvent action, and that the sericite has been developed at the expense of the peripheral portions of the clastic grains and replaces them in part. Where the rock is of uneven texture with larger grains embedded in a finer matrix, the sericite is not so systematically disposed and tends more to development in nest.

LAMPROPHYRIC ROCKS

Associated with the Seine conglomerate both on Shoal lake and on Dryweed island are certain occurrences of a lamprophyric rock. The rock is composed chiefly of a rather light brown and green hornblende together with some brown biotite, both of which are extensively altered to chlorite. These occur usually in rather large partially idiomorphic crystals, and disposed interstitially is quite a subordinate amount of allotriomorphic feldspar, which for the most part is unstriated, though occasionally polysynthetic twinning may be observed. Epidote is fairly abundant both in rounded granules and in large well formed crystals. Titanite and leucoxene are quite characteristic of the rock but are not as a rule idiomorphic. Apatite occurs very sparingly in minute crystals and magnetite is also represented by sporadic crystals. There is usually present considerable calcite.

On the assumption that the unstriated feldspar is orthoclase the rock would have the mineralogical composition of vogesite. But as the feldspar has not been satisfactorily identified the rock may be referred to under the more general designation of lamprophyre.

The largest area of this lamprophyre is on the northwest side of Shoal lake in the vicinity of the Foley Mine landing. Here it occupies the shore for a fourth of a mile and extends inland for a similar distance The rock is clearly intrusive in the Seine conglomerate and in the granite upon which the latter reposes. The intrusive contact is exposed at a number of places and portions both of the conglomerate and granite occur as inclusions in the eruptive mass. The lamprophyre area interrupts the continuity of the line of contact of the conglomerate and granite and extends into the latter.

A small islet in Shoal lake, half a mile northwest of Old Mine Centre, is composed of a somewhat similar rock, but when examined in thin section it appears to be more of the nature of a minette, since the brown biotite predominates over the chloritized hornblende. There is also a larger proportion of feldspar.

The same lamprophyre occurs on both limbs of the Dryweed Island syncline. The rock here differs from that at the Foley Mine landing, chiefly in being more thoroughly chloritized, in containing more calcite and less epidote, and in having a less proportion of feldspar.

On the south side of Dryweed island it occupies the shore for perhaps a fourth of a mile, near the east end of the island. It here appears to have been intruded into the conglomerate at a time when it was an incoherent aggregate of boulders and pebbles, since the latter occur abundantly as inclusions in the igneous rock, so that it is not easy to draw the line between the intrusion and the conglomerate. The line of contact between the two is extremely irregular. It is possible that here the eruptive is in part effusive.

On the north flank of the syncline the same rock occurs on the south side of a small island lying off the west end of Dryweed island in close proximity to the conglomerate, but not seen in actual contact with it.

The fact that this lamprophyre is known only in association with the Seine conglomerate and that on the south side of Dryweed island it appears to have incorporated numerous boulders and pebbles of the latter while they were still uncemented renders it very probable that this intrusion occurred in Seine time and it is, therefore, tentatively referred to this place in the geological scale.

TWO WIDELY SEPARATED PERIODS OF PLUTONIC ACTIVITY IN THE ARCHÆAN.

On a previous page four areas of granite or granite-gneiss have been described and referred to the Laurentian. These are probably genetically closely allied and represent a single irruptive event in the history of the region. The granite is post-Keewatin in age. It is also quite certainly pre-Seine in age, since on or near the shores of Bad Vermilion lake and Shoal lake, the basal conglomerate of the Seine series may be clearly observed resting upon the eroded surface of the granite and containing boulders and pebbles of it, as has been already described. In its general field aspect it is on the whole quite granitoid or but feebly gneissic in structure, but frequently has a locally pronounced foliation due to shearing.

Now the Seine series may be followed continuously along the strike eastward from Shoal lake to the vicinity of Sabawe lake, where it comes in contact with the granite gneiss of the Seine River and Lake Shebandowan sheets of the Survey. At the contact, as seen on the Canadian Northern railway at Iron Spur, the relations of the granite gneiss to the Seine series are abundantly exposed and it is quite certain that the granite gneiss is intrusive in the Seine rocks. This granite gneiss is, therefore, post-Seine in age. But the granite-gneiss is one of the most extensive areas of rocks mapped as Laurentian in the region. It occupies a very large portion of the area covered by the Seine River and Lake Shebandowan sheets, and extends eastward beyond the limits of the latter to Lake Superior.

Again, it has been shown by H. L. Smith[1] that the basal conglomerate of the Steeprock series rests unconformably upon the eroded surface of the granite-gneiss of Steeprock lake. This granite-gneiss is typical of much of the rock referred to the Laurentian and is so mapped upon the Seine River sheet of the Survey. As a result of the past season's observations in this region I have shown[2] that the Steeprock series rests unconformably not only upon the Laurentian granite gneiss but also upon the Keewatin and that the series is very probably older than the Seine series and separated from it by an unconformity. The superposition of the Steeprock series upon the granite gneiss of Steeprock lake is but a few miles from Iron Spur, where the Seine series may be seen to be intruded by the great mass of granite gneiss above referred to and also mapped as "Laurentian". From these observations it is clear that we have in this region two granite-gneisses widely seperated in time and both commonly referred to the "Laurentian". The interval between the development of these two batholithic intrusions comprises:—

(1) The post-Keewatin interval of erosion which uncovered the earlier batholithic masses and supplied their detritus as pebbles to the basal conglomerate of the Steeprock series.

(2) The accumulation of the Steeprock series, including from 500 to 700 feet of fossiliferous limestone.

(3) The deformation of the Steeprock series and its complete erosional removal over the region a few miles to the south of Steeprock lake.

(4) The accumulation of the quartzites and slates of the Seine series to a thickness of several thousand feet.

The effect of this clear cut segregation of the granite-gneisses of the region into two widely separated periods upon the significance and use of the term Laurentian, will be discussed later.

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[1]Structural Geology of Steeprock Lake, Ontario, Am. Jour. Sci. 142, 1891.
[2]Memoir 28, Geol. Survey Branch, Dept. of Mines, Canada, 1912.

For the present, having restricted the term Laurentian to the older, or pre-Huronian, granite rocks, we may recognize the need of a name for the similiar intrusives of post-Seine, i. e. post-Huronian, age, and refer to them and to the period in which they were developed as Algoman.

THE ALGOMAN ROCKS.

The Algoman rocks within the territory mapped comprise four areas of mica syenite-gneiss, three areas of banded biotite granite-gneiss, two belts of porphyroid gneiss occurring as a marginal facies of the banded granite-gneiss, and five areas of massive granite and granite-gneiss quite distinct in character from the banded type first mentioned.

The mica syenite-gneiss is intrusive in the Seine conglomerate and is, therefore, post-Huronian in age. There appears to be little doubt as to the general correlation of the five areas of massive granite and granite-gneiss, one with another; some of these have a marginal facies which grades into the typical mica syenite-gneiss, and they are for that reason believed to belong to the same general period of plutonic activity as the syenite. The banded granite-gneiss and its marginal facies of porphyroid gneiss cut both the syenite-gneiss and the massive granite and granite-gneiss. We thus seem to have good warrant for classing all of these plutonic masses as post-Huronian. In the following pages brief descriptions are given of these Algoman rocks and their relationships area by area.

MICA SYENITE GNEISS.

There are within the area mapped several notable masses of granitoid gneiss which consist chiefly of orthoclase and biotite, and which, therefore, fall into the class of the syenites rather than the granites. These rocks are prevailingly coarse grained and light coloured or flesh tinted, and have a pronounced porphyritic structure, due to idiomorphic development of orthoclase in large crystals. They grade on the one hand into porphyritic biotite granite, but with quite subordinate quartz, and on the other hand into hornblende syenites, in which case the porphyritic habit is much less pronounced and is often not developed. Besides these gradations, which are usually gradual, there are quite abrupt transitions from the normal type of mica syenite into dark basic facies, such transitions occurring usually on the margins of the normal facies. These basic facies in some cases are composed of feldspar and a dark ferromagnesian silicate and have the appearance of very hornblendic diorites; in other cases the feldspar is absent, in so far as can be determined by field inspection, and the rock has the appearance of a medium grained hornblendite. The normal light coloured facies of the mica syenite, with its abundant porphyritic crystals of orthoclase and the dark hornblendic facies, are both regarded as differentiation products of the same intrusive body of magma. Occasionally the basic rock occurs as an isolated dyke, as in the case of that cutting the Coutchiching schists in Bear passage. In other cases it is found in limited belts in the midst of the normal facies of the mica-syenite, not apparently related to the margin of the mass, as is true of some minor occurrences on the north shore of Crow Rock inlet.

The normal facies of the mica syenite has almost always a distinct gneissic foliation. In some cases this appears to be due to an original flow movement in the solidifying magma, but in many cases it is apparent that the rock has suffered deformation since its solidification which has produced or at least greatly accentuated the gneissic foliation. The basic facies are very commonly perfectly massive, but in other instances they show varying degrees of schistosity.

The mica-syenite gneiss has not only a very distinct foliation wherever observed, but at many localities it has a streaked or banded appearance, due to the incorporation in the mass of the syenite of elongated lenses of rock which have many of the features of the basic facies above referred to. Some of these included lenses are fine grained pepper and salt grey rocks in fresh fracture with occasional large porphyritic crystals of orthoclase. These lenses are in some instances which were measured, twelve times as long as they are wide in the horizontal plane. They are disposed parallel to the foliation of the syenite and in most cases are sharply delimited from the normal syenite on either side. In other cases the boundary is vague and gradational. There are also other lenses of still darker rock similarly disposed. They are all probably inclusions of the more basic first products of differentiation caught up in the later and more acid magma, and, by imperfect assimilation, give the latter a heterogeneous character.

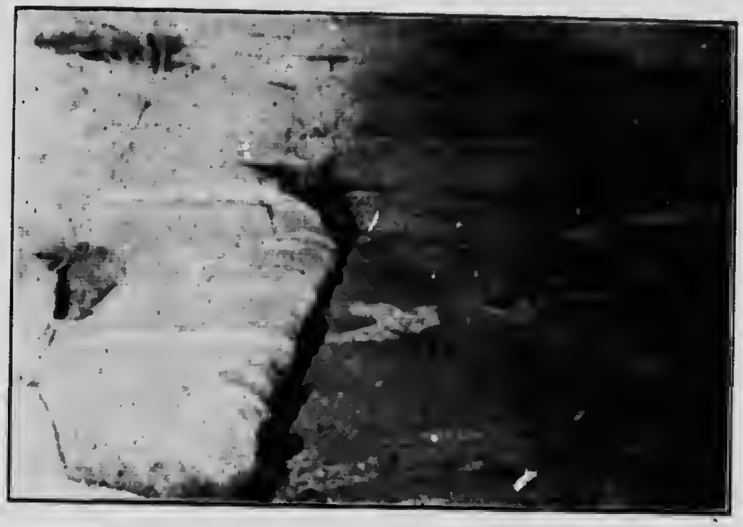
The Rocky Islet Bay Area.

Perhaps the most interesting, though the smallest of the areas occupied by the mica-syenite and its differentiation products is that of Rocky Islet bay. On the map accompanying the report of 1887, the basic marginal facies of this intrusive body was confounded with the Keewatin and mapped as such. The more careful studies of the past season have made it possible to distinguish between the two with a fair degree of certainty. The syenite and its basic faces taken together occupy a heart shaped area, in the midst of which lies Rocky Islet bay, the apex of the heart pointing to the northeast. The more important exposures are on the shores and islands of the bay, but where necessary for the proper delimitation of the area excursions were made inland from the shores.

The mass is clearly intrusive in both Coutchiching and Keewatin since it interrupts the continuity of these rocks and shows the usual phenomena due to intrusion at the contact. The relation of the intrusive mass to the surrounding rocks is, however, quite different from that of the neighbouring Rice Bay granite-gneiss. The latter mass, as has been shown, was intruded into the Couchiching before its acute deformation and participated in the deformation to which these rocks were subjected. It is evident from the mapping of the Rocky Islet Bay mass that it was intruded into the Coutchiching and Keewatin at a time subsequent to their main deformation, since the schists of both series abut upon the periphery of the mass and the latter shows little or none of the intensive shearing action so evident in the Rice Bay mass. The foliation of the mica-syenite gneiss is, moreover, parallel to the elongation of the normal facies of the intrusive mass and this is clearly transverse to the elongation of the Rice Bay mass. The directions of compression in the two cases were, therefore, widely divergent. For these reasons the mica syenite of Rocky Islet bay is regarded as belonging to a later Archæan period of batholithic development than that represented by the Rice Bay granite gneiss.

An interesting feature of the Rocky Islet Bay mass is that the dark basic facies predominates over the normal facies of the mica-syenite gneiss. The latter is confined to a lenticular area about 4 miles long and three-eighths of a mile wide at its widest part, lying in the east half of the heart-shaped area. This is completely surrounded by the basic facies, but the breadth of this on the west side is from half a mile to a mile, while on the east side it is only from one-eighth to one-fourth of a mile. The total area of the basic facies is between three and four times that of the normal facies. Of course, this apparent excess of the basic facies over the normal facies may be due to the position of the accidental section afforded by the present surface. If the mass be regarded as a batholith, then the section may be through its upper part, and a deeper section might reveal a much larger proportion of the normal type of rock. If the mass, on the other hand, be regarded as laccolith in type, as seems quite possible, then the section may pass through its basal part in which there might well be an excess of the heavier differentiation product.

On an island on the northern part of Rocky Islet bay, the rock is mostly a gabbro, varying from an anorthosite to a pyroxenite, and is in parts very coarse textured and in others medium in texture. The coarsest textured rock occurs as dykes cutting



A

B

A. Granitic dykes in schists, showing participation in the deformation of the schists; south side of Prospect bay.

B. Granitic dykes intruded into schists after the deformation and schistification of the latter: south side of Base-line bay.

the medium textured gabbro. This gabbro in its varying aspects is probably an extreme differentiation product of the magma, which solidified normally as a mica syenite.

On another island more nearly in the middle of the bay, a large dyke of quartzose biotite granite-gneiss cuts the syenite. The gneissic foliation is distinct and appears to be an original structure of the rock. Mineralogically the rock is composed chiefly of orthoclase, plagioclase, both fresh, and quartz. The biotite is not notably abundant. The rock is in contrast to the mica-syenite, not only in the large proportion of quartz present, but also in the absence of epidote, the abundance of which is characteristic of the syenite.

There are also fairly numerous dykes of flesh tinted binary granite or alaskite, cutting the normal facies of the mica-syenite, but rarely seen in the basic facies. These consist of orthoclase and quartz of medium grained texture, but grading on the one hand into coarse pegmatites and on the other hand into aplites. It is worthy of note that these pegmatitic and aplitic dykes do not show the foliation that is so pronounced in the syenite-gneiss.

On the northeast of the heart shaped syenite area there is a large dyke of granite, somewhat pegmatitic in character, cutting the Coutchiching schists; and on the southeast of the area there is a similar dyke of granite cutting the Keewatin rocks.

These various granitic dykes, both within the area of the syenite and beyond its margin, probably represent the last products of the differentiation of the magma, and were the latest manifestations of the intrusive process.

The Hopkins Bay Area.

The area of mica syenite-gneiss, here designated the Hopkins Bay area, has a remarkable configuration. Within the limits of the map, it extends as an east-west belt from the east end of the north arm of Redgut bay westward through Crow Rock inlet, the north arm of Black Sturgeon lake, along the south side of Macdonald inlet, and the north part of Hostess island as far as the southwest part of Cheery island. Here the belt turns sharply to the southeast, towards Hopkins bay. In this bay it occupies nearly all of the southeast shore and part of the north shore, and it is clear that at the entrance to Hopkins bay the belt again turns, this time to the northeast. At the head of Hopkins bay, the belt bifurcates. The northern prong extends through Black Sturgeon lake, and owing to obscurity of exposures, has not been actually observed beyond the portage from Hopkins bay into Black Sturgeon lake. The southern prong follows the southeast shore of the bay and appears to extend through to the south end of the south arm of Black Sturgeon lake, where there is an extensive exposure of it. Beyond this it ends abruptly, since it is not encountered on any of several traverses in the country east of this; nor does it appear anywhere on the shores of Redgut bay.

The belt occupied by these rocks is thus seen to have the form in ground plan of a fish-hook with a split point. The length of the belt following the curvature is about 35 miles within the limits of the map. The widest part of the belt is at the mouth of Hopkins bay, where it is about 5½ miles from side to side.

The hook of this belt almost completely encloses an area of banded and foliated biotite granite-gneiss, which is the only rock with which the mica syenite-gneiss on the inside of the hook is in contact.

The portion of the syenite belt which corresponds to the stem of the hook, widens eastward from Black Sturgeon lake through Crow Rock inlet and the northern end of Redgut bay. The connexion of this portion of the belt with similar rocks on the Canoe River route to the north of the area mapped is uncertain, the intervening country not yet having been explored. On the map of 1887 the two areas were conjecturally shown as connected. Along the northern border of the stem of the hook, the mica syenite-gneiss is in contact with a well foliated and banded biotite granite-gneiss. On the southern border it is in contact with a much sheared porphyroid gneiss which will be further described on another page.

On the outside or convex side of the hook, the syenite-gneiss is in contact with the well foliated and banded gneiss in Macdonald inlet, with Keewatin rocks on Cheery island, and with Keewatin rocks for the most part on the southeast side of Hopkins bay. In the territory between Hopkins bay and Rocky Islet bay, however, there is a narrow belt of conglomerate, lying against the northwest side of the Keewatin belt and between the latter and the syenite. On a previous page this conglomerate has been correlated with the basal conglomerate of the Seine series, the relationship being regarded as that of a portion of a synclinal fold above the Keewatin, the greater part of which has been removed. This removal is in part due to intrusion. If this interpretation be correct, then the mica syenite-gneiss is post-Seine in age, a conclusion which accords with that arrived at from a discussion of the Rocky Islet Bay area of the same rock. In the sequence of events involved in the development of the Archæan of this region, therefore, the mica-syenite-gneiss appears to belong to the later period of plutonic activity.

The relations of the Hopkins Bay area of mica-syenite-gneiss to the Keewatin are everywhere intrusive, the usual contact phenomena being well exemplified in the form of apophyses of the syenite cutting the Keewatin and of inclusions of the latter in the former near the contact. The Keewatin greenstones near the contact take on the characters of black hornblende schists, as is usually the case near irruptive masses.

The Seine conglomerate at the contact with the syenite shows in a marked degree the phenomena of contact metamorphism, which is, of course, exemplified best in the non-pebbly beds of the conglomerate formation. These beds are rendered highly crystalline and have the characters of a rather massive crystalline hornfels, which grades away from the contact into micaceous schists containing water worn pebbles.

Traversing the mica-syenite gneiss, there are fairly numerous dykes and irregular intrusions of a more granitic type, comprising biotite granite and alaskite. These are the counterpart of similar occurrences noted in the Rocky Islet Bay area and are similarly regarded as later manifestations of the same intrusive process which gave rise to the syenite as the chief product. The basic facies of the syenite which is so pronounced a feature of Rocky Islet Bay area is quite subordinate in the Hopkins Bay area. It appears to be a feature of the inner border of the hook shaped portion of the belt. But even here it is relatively small in amount and non-persistent. Noteworthy occurrences are at the contact of the mica syenite-gneiss with the foliated and banded gneiss on the north side of Hopkins bay, Black island, Sunday island, entrance to Macdonald inlet and nearby islands and the south side of Redgut bay, east of the Indian village. There are, however, other dark, highly hornblendic portions of the mass unrelated as far as can be determined to the margins of the belt, and locally the rock is streaked by bands of such dark rock, indicative of marked heterogeneity prior to solidification.

The Pukamo Island Area.

At the west end of Rainy lake there is a large area of mica syenite-gneiss, extending from Stanjikoming bay south to the Rainy river. The eastern tapering extremity of this area projects into the territory covered by the map accompanying this report. The distribution of the rock within the limits of this map is known almost wholly from its occurrence on a group of islands which lie south of the shore between Gash point and Back point. Of this group Pukamo island is one of the largest and the area may, therefore, be referred to as the Pukamo Island area. Almost the entire shore from the vicinity of Gash point to Back point is occupied by Coutchiching mica schists, the only exceptions being two small headlands about $1\frac{1}{4}$ miles west of Back point, which are composed of the mica syenite. The islands immediately off shore are composed of the latter rock. The boundary between the syenite and the Coutchiching is thus located in the lake just off this shore and parallel to it. The southern boundary so far as it is known from the islands is a narrow belt of Coutchiching mica schist extending from the south side of Last island to the north side of Nowhere island and probably in continuity with the same schists on Goose island. This narrow belt of mica schists separates the mica syenite gneiss from the distinctively quartzose biotite granite-gneiss of the Nowhere Island area. The two boundaries of the mica syenite-gneiss above indicated as the northerly and southerly converge at a point in the lake south of Back point, and it appears possible that the tapering eastern end of the area is in this neighbourhood surrounded by the Coutchiching mica schists. If this be true, then the narrow belt of mica schists extending from Nowhere island to Last island is a tongue extending out from the main area of Coutchiching on Lichen and Goose islands. It seems, however, more probable that the schist belt referred to is isolated, and that the syenite area continues on as a narrow zone under the waters of the lake to the east of Nowhere island and connects with the area of syenite rocks on the south end of Goose island and the northwest end of Sand Point island, which are clearly but a marginal facies of the granite gneiss as will be shown later.

Westward the syenite gneiss is traceable on the islands between Lobstick island and the mainland, followed by the Canadian Northern railway. There is, therefore, no doubt as to the continuity of the Pukamo Island area with the large mass of the same rock at the west end of the lake. Owing to the fact that the boundary of the mica syenite-gneiss lies for the most part in the lake, its contact with the encircling Coutchiching schists is observable only at a few localities. Wherever this contact is exposed, however, as on Last island, Nowhere island, and on the shore west of Back point, the syenite is intrusive into the schists.

The rock of the Pukamo Island area is prevailingly a typical mica syenite-gneiss with orthoclase in large porphyritic development; but associated with this mica syenite-gneiss and grading into it are more basic rocks. These in their extreme facies are massive hornblendite and between this and the syenite the intermediate gradations comprise diorite, mica diorite, and syenite poor in orthoclase but rich in biotite and hornblende. It is very probable that the intermediate gradations include also monzonitic types, but this could not be definitely ascertained.

The transition from the typical mica syenite-gneiss to the massive hornblendite is in this area usually rather abrupt. The dark basic facies of the syenite is notably developed at a number of localities within the area. On the islands between Gash point and Lobstick island it is principally a dark green to black massive rock, composed chiefly of hornblende. The west side of Lobstick island is composed of the same dark rock, and there are bands of it on the north side of Pukamo island and of Cross island.

The Bear Passage Area.

The only other area of rocks of this type to be noted is that occurring in Bear passage. This is a small intrusive mass of dark, coarse textured hornblende rock with occasionally widely spaced crystals of orthoclase. Petrographically it is quite similar to certain of the basic facies of the syenite in the areas above described. In this case, however, there is none of the normal facies of the syenite accompanying the basic rock. At its western end the intrusion is clearly exposed as a dyke about 100 feet wide with mica schist on either side, cutting across an island less than half a mile south of the railway. On its south margin, the dyke appears to be sheared and there are small dykes of granite cutting it. Eastward the dyke widens if we may judge from its distribution as shown on the map, but it appears to terminate rather abruptly, its entire length being not over a mile. The dyke is wholly in the Coutchiching, but is close to the northeastern edge of the Bear Passage granite.

Petrographical Notes.

A few slides of the syenite and its marginal facies have been examined microscopically. The mica-syenite of Rocky Islet bay is composed of fresh orthoclase and microcline, a little acid plagioclase, abundant biotite, abundant primary epidote, some titanite, and a sparing amount of quartz. In quite limited areas, a granophyric structure is apparent. The quartz shows an undulatory extinction but not to a marked degree. The structure is in part cataclastic, but this is not so pronounced as in the same rocks in other areas. In a matrix thus characterized are embedded large porphyritic crystals of orthoclase in parallel orientation. The ground-mass is typically gneissic and the rock as a whole approximates the appearance of an *augen* gneiss.

A specimen of the normal facies of the syenite from the north shore of Crow Rock inlet is composed chiefly of fresh orthoclase and microcline and rather subordinate amounts of biotite and green hornblende. Original epidote is abundant as is also titanite. The latter occurs in large idiomorphic crystals, but it is also found in smaller forms with apatite enclosed in the feldspars. There are also occasional cubic crystals of pyrite. In this matrix are embedded the large crystals of orthoclase. The rock is quite gneissic and in this section shows a pronounced cataclastic structure.

Another specimen from the west end of Crow Rock inlet proves to be similar to that last described, but has little or no hornblende in its composition. Oligoclase occurs among the feldspars and there is a little quartz present. There is the same abundance of epidote. The biotite is largely altered to chlorite and with the latter are granules of magnetite. The rock shows a streaked gneissic appearance and in thin section there is apparent a well developed cataclastic structure.

A specimen of the basic facies of the mica-syenite from the north side of Crow Rock inlet is composed chiefly of orthoclase and microcline with much green hornblende and little or no biotite. There is a great deal of primary epidote, and titanite and apatite are also abundant, the latter in rather large crystals. There is a sparing amount of quartz locally present. The structure is hypidiomorphic granular.

A representative specimen of the prevailing basic facies of Rocky Islet bay is composed chiefly of green hornblende with some biotite and subordinate amounts of feldspar in which an acid plagioclase predominates over orthoclase. There is abundant epidote and considerable titanite and a very little quartz. The structure is hypidiomorphic granular.

Another specimen also from Rocky Islet bay is a granular aggregate of fresh plagioclase and hornblende with some zoisite and titanite.

In some cases the basic rock of Rocky Islet bay has been mineralogically reconstructed. A specimen of this facies of the rock shows that it is composed chiefly of chlorite with a less proportion of an indeterminate prismatic mineral having the characters of an iron free amphibole. There is much magnetite in the slide in the form of fine dust and also in nests. Calcite is fairly abundant. A very little original feldspar and quartz may be detected.

The basic dyke in Bear passage is a coarse granular aggregate of green hornblende with subordinate biotite and accessory titanite. In this aggregate occur occasional large idiomorphic crystals of orthoclase containing numerous inclusions of apatite.

The gabbro, regarded as probably an extreme phase of the differentiation of the syenite of Rocky Islet bay, is more or less thoroughly altered, the feldspar being largely replaced by a saussurite aggregate in which zoisite predominates, the pyroxene being changed to green hornblende.

Chemical Composition.

The chemical composition of the normal facies of the mica syenite gneiss is shown by the analysis in column I of the following tabulation. In columns II and III are given the analyses of two specimens of the basic facies of the syenite from the west side of the intrusive mass on Rocky Islet bay The rock of which III is the analysis shows evidence of general alteration of the ferromagnesian constituents to spherulitic chlorite. Column II is the more representative analysis of the basic facies of the syenite, although as before stated this basic facies varies much.

	I.	II.	III.
SiO_2	64·52	49·40	40·72
TiO_2	0·80	0·90	0·07
Al_2O_3	15·58	:2·22	2·78
Fe_2O_3	2·13	1·87	6·58
FeO	2·18	7·44	24
MnO	0·05	0·17	0·14
CaO	3·88	11·60	8·66
BaO	0·06	0·03	
MgO	2·32	11·80	26·25
Na_2O	3·70	2·16	0·42
K_2O	4·02	0·93	0·27
H_2O-	0·22	0·14	0·26
H_2O+	0·67	0·98	5·51
P_2O_5	0·34	0·17	0·28
CO_2	....	0·25	3·20
S	0·03	0·10	0·70
Cl	0·10	0·13	0·06
Cr_2O_3	none.	0·08	0·28
SrO	trace.	0·04	0·03
	100·60	100·41	100·45
Less O=S	....	....	0·26
			100·19

I. Mica syenite-gneiss from the north side of the entrance of the narrows between Rocky Islet bay and Rice bay, Analyst, M. F. Connor. II. Basic facies of syenite from west side of island in Rocky Islet bay, Analyst, M. F. Connor. III. Basic facies of syenite from northwest shore of Rocky Islet bay, Analyst, M. F. Connor.

BANDED BIOTITE GRANITE GNEISS.

Within the field defined by the limits of the map accompanying this report, there are three areas of well foliated and commonly streaked or banded biotite granite-gneiss. One of these is that enclosed by the hook of the hook-shaped belt of mica syenite-gneiss; the second lies along the northern border of the field in its eastern half, and the third lies along the northern border in the western half. These two last mentioned areas though separate within the limits of the map, may be continuous in the country to the north of the field particularly examined. The triangular area of the same banded gneiss occurring at the west end of Cheery island is probably extensive to the west of the territory mapped and may be considered as a fourth area.

The prevailing colour of this gneiss is grey, but the rock is far from homogeneous and so the colour varies from very dark to very light in accordance with the proportions of biotite and feldspar present. On the whole, however, the light colour greatly predominates over the dark. The light and dark coloured portions are usually disposed in parallel bands, or rather, in alternating layers, but the lighter coloured layers are not sharply separable from the darker. They grade into each other and the appearance in the field is that of a rock resulting from the consolidation of a heterogeneous magma subjected to viscous flow. This suggestion is confirmed by the microscopic examination of a few slides of representative specimens. These show that, in spite of the perfectly developed foliation and banding, there is no cataclastic structure. The light coloured portions are composed mostly of acid plagioclase and orthoclase with subordinate quartz and biotite. As accessories there are considerable epidote and a little titanite, apatite, and pyrite. The minerals are all perfectly fresh and the rock has a hypidiomorphic granular structure in which the individual crystals show but a feeble tendency to parallel orientation. The dark coloured portions have the same minerals but in different proportions. There is a great abundance of biotite and epidote, the latter apparently an original constituent of the rock. Titanite and apatite are also much more abundant than in the light coloured bands. The ratio of feldspar to quartz is about the same as in the light coloured rock. The structure is hypidiomorphic granular, and parallel orientation of the constituent crystals is not notable.

The foliation of the rock within a given band, which is so apparent in the field and in hand specimens, is evidently not due so much to parallel orientation of the minerals, as in the case of the crystalline schists, but rather to a minute banding, whereby very small layers richer in biotite alternate with layers containing little of that mineral.

A thin section across the line between a dark band and a light one showed that the two rocks were the product of crystallization from the same magma, there being a perfect gradation from one into the other.

The streaked or banded structure of the gneiss as seen on glaciated surfaces in the field is most pronounced, of course, where the heterogeneity of the rock affords striking contrasts of colour in adjacent bands, but a similar structure is also apparent where such contrasts of colour are but feeble. On surfaces where the rock is of a nearly uniform light grey colour, a close examination shows that it has a streaked appearance, and in these cases the lines of streaking are very often not straight but are wavy or contorted, sometimes intricately so, and are evidently due to flow movements in the magma prior to its final solidification.

In some localities the banded gneiss takes on a distinctly porphyritic appearance due to the development of orthoclase in large idiomorphic crystals, and these are then disposed in lines or narrow bands.

In the banded gneiss of Little Turtle lake, there is a great abundance of inclusions of hornblende schist, both in the form of large tapering bands and in smaller angular fragments.

Chemical Composition.

A representative specimen of the banded gneiss from the north side of Hopkins bay, near its contact with the mica syenite-gneiss, was analysed by Mr. M. F. Connor with the following results:—

SiO_2	68·62	K_2O	1·31
TiO_2	0·26	H_2O-	0·10
Al_2O_3	15·70	H_2O+	0·56
Fe_2O_3	1·66	P_2O_5	0·10
FeO	1·77	CO_2	trace.
MnO	0·07	S	0·03
CaO	3·56	Cl	none.
BaO	0·02	Cr_2O_3	none.
MgO	1·28		
Na_2O	5·08		100·12

It is apparent from this analysis that the ratio of Na_2O to K_2O suggests that the rock is more properly classed with the soda granites or with the granodiorites than with normal biotite granite or granitite. It would be rash, however, to assume that this one analysis expresses the general composition of a rock at once so extensive and so heterogeneous as the banded gneiss; and until such time as more elaborate determinations can be made it seems better to refer to the rock as a granite-gneiss.

PORPHYROID GNEISS.

Traversing the field from east to west, near the northern limits of the area mapped, is a remarkably linear and persistent belt of sheared granitic rock, which will be referred to as the porphyroid gneiss. This belt has been traced in practically continuous exposure from the east end of Little Turtle lake to Black Sturgeon lake, a distance of 21 miles. It may possibly extend eastward beyond Little Turtle lake and beyond the limits of the map under the marshy flood-plain of the Little Turtle river.

The average width of the belt is about a fourth of a mile. Its maximum width at Pine narrows is a little over half a mile. Another similar belt skirts the north side of Cheery island and embraces several islands to the north of it. The length of this belt is about 4 miles within the limits of the map, but it has an indefinite extent beyond its western boundary.

The porphyroid gneiss is prevailingly red or flesh coloured but grades into grey. It is characterized mineralogically by being composed chiefly of orthoclase and quartz with little or no ferromagnesian minerals. It is almost always porphyritic, due to the idiomorphic development of an early generation of orthoclase. It generally shows a foliation which is apparently due to shearing since the porphyritic feldspars are reduced to *Augen* and are drawn out in lines on the surface of the rock. In many cases this foliation is accompanied by a marked schistosity or tendency to cleave indefinitely, while in other cases the rock has a platy structure with no appreciable schistosity within the plates.

The examination of a few thin sections from representative specimens of this porphyroid gneiss, shows that it has a pronounced cataclastic structure and that the schistosity of the rock is referable to deformation involving shearing of the mass. Even in the platy facies of the porphyroid gneiss, the constituent minerals of the rock, chiefly orthoclase, have been broken down and in part reduced to a fine secondary matrix into which the residual large crystals are locked in suture like boundaries. The comminuted material is disposed in bands in which have been developed secondary sericite and chlorite. There is some epidote in the rock, but it is irregularly granular in its occurrence and not in idiomorphic crystals.

This belt of porphyroid gneiss grades into the banded gneiss both across the strike and along the strike. From the east end of Little Turtle lake to Farrington on the Canadian Northern railway, the porphyroid gneiss forms the southern border of the large area of banded gneiss in which Little Turtle lake lies. In passing from the typical facies of one rock to the typical facies of the other it is impossible to draw any line at which it can be said: here one ends and the other begins. In approaching the banded gneiss, the porphyroid gneiss loses its red colour, its ground-mass becomes coarser and biotite makes its appearance more and more abundantly, but the rock retains its porphyritic habit and resembles in the weathered aspect the less sheared portions of the porphyroid gneiss. Finally it loses this porphyritic habit and passes into the typical banded gneiss.

A quite similar gradation is observable at the west end of the belt, where it crosses Black Sturgeon lake. Where the belt enters the lake from the east it is the typical porphyroid gneiss with a reddish colour. On the other side of the lake in the line of strike, a mile or so distant, the rocks have lost their red colour but otherwise resemble the porphyroid gneiss except that the ground-mass of the rock is perhaps a little coarser in texture. Here just as on Little Turtle lake the effort, which was constantly made to map the porphyroid gneiss as a thing distinct from the banded gneiss, broke down, and it was practically impossible to find a dividing line between them.

It has been shown that the banded gneiss has no cataclastic structure, that its banding is probably due to viscous flow in a heterogeneous magma and that, therefore, there is no evidence of its having suffered acute deformation since its solidification. The porphyroid gneiss, on the other hand, has been clearly deformed by a process which involved much shearing and a breaking down of the original structure of the rock.

From the statements thus far made it is evident (1) that the porphyroid gneiss should be regarded as a marginal facies of the great batholithic area of banded gneiss which extends north from Little Turtle lake, (2) that it differs mineralogically from the great mass of the batholith in its poverty of ferromagnesian constituents and structurally in the development of a pronounced porphyritic habit, and (3) that it has been deformed, sheared, and schistified, while the main mass of the batholith has not been so affected in so far as observations indicate.

By analogy the belt of porphyroid gneiss on the north of Cheery island may be regarded as a marginal facies of the great area of banded and streaked biotite granite gneiss of the northern part of Rainy lake. Where the porphyroid gneiss occurs in the vicinity of the Keewatin rocks, as between Farrington and the east end of Little Turtle lake, it is in several places charged with numerous inclusions of hornblende schist.

While the interpretation above presented as to the relationship of the porphyroid gneiss to the banded gneiss seems fairly certain, it must be pointed out that there is an important part of the belt occupied by this rock in which it is not marginal to the banded gneiss. This lies between Farrington on the Canadian Northern railway and Black Sturgeon lake, a stretch of about 9 miles. This portion of the belt of porphyroid gneiss serves as a connecting link between the banded gneiss of Little Turtle lake and the same rock occupying the area enclosed by the hooked end of the belt of mica syenite-gneiss. In this 9 mile stretch the belt of porphyroid gneiss is bordered on the north by mica syenite gneiss and on the south by a large mass of biotite granite showing in general but feeble gneissic foliation. At one end of the stretch referred to, the rock grades into the banded gneiss of Little Turtle lake and at the other into the banded gneiss of a similarly expanding but smaller area of the same rock.

It would appear, therefore, that this portion of the belt of porphyroid gneiss or marginal facies of the banded gneiss is of the nature of a great dyke. The mapping shows that this dyke cuts across the granite and granitoid gneiss to the south and its included fragments of Coutchiching and Keewatin schists. That it is also intrusive in the mica syenite-gneiss to the north is shown by the fact that numerous dykes of rather fine grained porphyritic binary granite, resembling closely the porphyroid gneiss or the transitional rock between the latter and the banded gneiss are found cutting the syenite. There are also bands or elongated fragments of the syenite gneiss enclosed in the banded gneiss near the contact of the two rocks. It seems clear, therefore, that both the banded gneiss and the porphyroid gneiss are intrusive in the syenite gneiss, the two former being but different facies of the same intrusion.

Since it has been shown that the syenite gneiss is intrusive in the post-Keewatin conglomerate between Hopkins bay and Rocky Islet bay, which has been correlated with the Seine conglomerate, it follows that in the post-Seine or later Archæan period of plutonic activity there is a definite sequence of irruptions, a syenite followed by granitic. Of these, the former was the more homogeneous magma, but was accompanied by quite basic differentiation products. It owes its gneissic foliation in large part to mechanical deformation after solidification. The later irruption was that of a heterogeneous magma which developed a gneissic banding by viscous flow. A marginal and dyke facies of this rock, remarkably free from ferromagnesian constituents, was, however, subjected to intense shearing which rendered it either schistose or platy.

OTHER GRANITES AND GRANITOID GNEISSES.

Within the field here discussed, there are five areas of granite or granitoid gneiss referable to a later period of intrusion than that which gave rise to the granite extending from Grassy island to Bad Vermilion lake. These areas are: (1) that of the north side of Grassy island and the south side of Rat-root bay; (2) The Nowhere Island area, occupying chiefly the islands of the lake to the south and southeast of Nowhere island; (3) The Knuckle Island area, extending from Noon island to the east side of Joint bay; (4) The Bear Passage area, extending from Traverse inlet to Bear passage; (5) The Redgut Bay area, extending from Base-line bay to the eastward of Barber lake.

The granites of these five areas are for the most part normal biotite granite, with usually a rude or feebly developed gneissic foliation, which, however, locally becomes quite pronounced.

They usually have a fairly abundant proportion of fresh biotite in their composition, and are thus mineralogically distinct from the older granites of Grassy island, Fair lake, and Bad Vermilion lake, which are more closely allied to the type known as alaskite. They are free from the shearing which has affected the older granite, and the contrast between the sheared and the unsheared granite is most pronounced on Grassy island, where both granites occur side by side. These younger granites, moreover, do not exhibit the bleached appearance presented by the older granites, but have often a warm flesh tint or even a distinct pink-red colour. These rocks are all intrusive in the Coutchiching or Keewatin or in both. The evidence of this consists of the usual contact phenomena which are abundantly observable, comprising: (1) fragments of the encasing rocks enclosed in the granite; (2) apophyses of the granite cutting the encasing rocks; (3) intense metamorphism in the vicinity of the contact of the granite with the encasing rock.

The Grassy Island Granite-Gneiss.

This mass has a known length of about 2½ miles and a maximum width of less than a fourth of a mile. It may be regarded as a wide lenticular dyke striking with the general trend of the Keewatin belt in which it occurs. It may have a greater length than above indicated, since at both ends it passes beneath the waters of the lake. On the north side of Grassy island it is in observable intrusive contact with Keewatin hornblende schists, but the granite contains also angular inclusions of mica schist doubtless derived from the near by Coutchiching, which here may be at no great depth below the Keewatin. On the south side, from Review island to the west end of Grassy island, the granite-gneiss is in contact with the older and greatly sheared and decomposed granite previously described. On this side the granite-gneiss presents locally a relatively basic facies resembling certain facies of the mica syenite gneiss. On the east end of Review island the older sheared granite is cut by dykes of this darker facies of the later granite and fragments of the former are included in the latter. The difference in age of the two rocks is thus not merely a matter of inference from the contrast in their physical condition, but is also based on the positive evidence revealed at this contact.

The Nowhere Island Granite-Gneiss.

This mass extends from the northwest end of Sand Point island to some point in the lake between Last island and the outlet of the lake. Its length is probably between 8 and 9 miles.

Its maximum width is about 2½ miles in its middle part. The area thus has the form of an elongated ellipse. It appears, in so far as the insular character of the exposures permits a conclusion, to be enclosed by the Coutchiching mica schists, but to the southwest of Last island and to the east of Nowhere island the granite-gneiss may come in contact with the mica syenite-gneiss of the Pukamo Island area and may even possibly grade into that syenite and be continuous with it. The rock is prevailingly a medium grained, distinctly quartzose, biotite granite-gneiss, with a little muscovite, the gneissic foliation being generally better developed than in other areas of this type of rock. At the eastern end of the area, however, the rock becomes deficient in quartz, hornblende accompanies the biotite, and these two minerals are so abundant that the rock becomes dark in colour. In general it takes on the facies of the less porphyritic portions of the mica syenite-gneiss. Microscopic examination of several thin sections of this rock shows that it also resembles the syenite-gneiss in the fact that there is considerable epidote in it. Besides the dominant minerals, orthoclase, biotite, and hornblende, there is some acid plagioclase and a little quartz. Apatite is present as an accessory. The rock, though distinctly gneissic, shows no cataclastic structure. This more basic or syenite facies of the granite is chiefly developed on the west end of Sand Point island, on the south side of Goose island, and on some of the smaller islands adjacent to these. It appears to grade off insensibly into the biotite-granite gneiss and the gradation again suggests, as in the case of the same rock on Grassy island, that this granite is genetically closely allied to the mica syenite-gneiss already described. On the map it will be seen that this biotite granite-gneiss is separated from the Pukamo Island area of mica syenite-gneiss by a narrow belt of Coutchiching mica schist extending from Last island to Nowhere island. In the description of the Pukamo Island area it was pointed out that the north and south boundaries of the mass appeared to converge at a point beneath the waters of the lake just south of Back point, and that the tapering east end of the area was perhaps enclosed by the Coutchiching. This, however, is but a conjecture and it is equally possible, and indeed equally probable, that the syenite of the Pukamo Island area may be continuous with the syenite facies of the Nowhere Island granite-gneiss of Goose island and Sand Point island. In this event, the narrow belt of mica schist extending from Last island to Nowhere island would be an isolated inclusion, and the syenite of the Pukamo Island area and the granite of the Nowhere Island area would constitute a single irruptive mass, differentiated into two petrographic types. Indeed, the narrow belt of schist separating them is so slight a partition that even if it be regarded as a tongue from the main Coutchiching area, it is difficult to regard the syenite and granite as having any other relationship than that just indicated. I shall, therefore, tentatively adopt this view and regard the granite gneisses here considered as belonging to the same period of irruption as the mica-syenite-gneiss and derived by differentiation from the same magma, though petrographically and geographically sufficiently distinct for the purposes of geological mapping. It follows from this conclusion that these granite-gneisses and granites, being practically contemporaneous in origin with the s[illegible]nite gneiss, belong to the post-Seine or later Archæan period of Plutonic activity.

The Knuckle Island Granite.

The Knuckle Island granite mass, though separated from the Nowhere Island area of granite-gneiss by less than a fourth of a mile of schists, shows none of the basic differentiation facies which is so marked a feature on the southwest side of the separating belt. Mineralogically the rock is identical with that of the prevailing or normal facies of the Nowhere Island granite-gneiss, but it is nearly devoid of gneissic foliation and is more homogeneous in character. It is free from basic inclusions and fragments of the encasing mica-schists are limited to the immediate vicinity of its contact with the Coutchiching. Apophyses of the granite are similarly confined to a narrow zone on the Coutchiching side of the contact. It is also remarkably free from aplitic and pegmatitic dykes and later granitic dykes. The contact metamorphism which it has induced in the encasing schists is, however, strongly marked.

The Bear Passage Granite.

The Bear Passage granite is quite similar to that of the Knuckle Island area. It is a medium grained, fairly homogeneous biotite granite with, on the whole, a very feebly developed gneissic foliation. In some localities, this foliation is not discernible, in others it is quite pronounced. There are few aplitic or pegmatitic dykes cutting it and inclusions of the encasing rocks are practically limited to the vicinity of the contact. The contact metamorphism induced in the encasing Coutchiching schists is even more intensive than in the case of the Knuckle Island granite. The general phenomena displayed at the contact have been described in the discussion of the Coutchiching rocks.

The Redgut Bay Granite.

In the discussion of the structural relations of the Coutchiching to the Bear Passage and Knuckle Island granites, it has been shown that the structure is that of a truncated dome, the encasing rocks having once arched the granite in the fashion of a laccolith roof. The same condition probably holds in regard to the relation of the Coutchiching to the combined Nowhere Island and Pukamo Island plutonic mass, particularly at its eastern tapering end. But where the plutonic mass widens out to the westward, we have a belt of schist extending for at least 3 miles from Last island to Nowhere island, sunk down into the granite. This indicates that the arch of sedimentary rocks over the plutonic mass in this section was not disposed in a simple curve, but was a double arch, with a medial synclinal sag which sank into the molten mass and became congealed in it as a roof pendant, as defined by Daly. The suggestion is that the form of the over arching roof is determined by the size of the intrusive mass or by the extent of the span.

Now when we come to the fifth and last of these granitic areas, the Redgut Bay area, we find that this suggestion is borne out by the observed relations of the encasing rocks to the granite. This area is by far the largest of the series. The prevailing rock has the characters of a medium grained biotite granite in which gneissic foliation is on the whole feebly developed, but may be locally quite marked. The area is not only large but is quite asymmetric in shape and irregular in outline. On the north side it is bounded by a nearly straight east and west line which is the southern border of the belt of porphyroid gneiss already described. The porphyroid gneiss, as a marginal or dyke facies of the banded gneiss, cuts across the granite and terminates it.

On the south side the granite is in contact with both the Keewatin and Coutchiching. This line of contact diverges from the northern boundary from west to east and then swings sharply to the north in the country east of Barber lake, meeting the northern boundary near the line of the Canadian Northern railway, about 2½ miles east of Farrington. The contact is noteworthy for the remarkable interlocking of schist and granite, which it shows. From the west end of Base-line bay to beyond the south end of Little Ottertail lake the granite extends into the Keewatin and Coutchiching terranes in a series of more or less obtuse lobes and between these lobes are sharply tapering tongues of schist extending far into the granite. This arrangement indicates clearly that the roof of Coutchiching and Keewatin rocks which once covered the granite was far from being a simple dome. It is certain that in the parts where the granite lobes extend into the pre-existent terranes, that the granite magmas rose higher into the overlying rocks, and that where the tongues of schist project out into the granite terrane, these tongues represent portions of the roof that were more deeply sunken in the granitic magma in the fashion of Daly's roof pendants. They are roof pendants that are still connected with the margin of the roof. There are, however, numerous isolated included belts of schist in the granite which may be interpreted as portions of roof pendants which have been left discrete by the erosion of the greater part of roof from off the batholith. That they are actually pendants and not loose pieces that have become detached from the roof and sunk into the magma while it was in process of irruption, is indicated by the accordance of the dip and strike of the schists in these isolated belts with the structure of neighbouring portions of the roof still intact. Such isolated remnants of roof pendants are exemplified in several occurences along the west side of Redgut bay. The largest one observed, however, is in the vicinity of Farrington on the south side of the Canadian Northern railway, where a belt of schist 2 miles long and a fourth of a mile wide occurs sunk into the granite. The schist has an east and west strike and a dip varying from vertical to 70° N. The northern half of this belt consists of Coutchiching mica schists and the southern half of Keewatin hornblende schists, and it appears to be in the prolongation of a similarly dually constituted tongue of schist projecting into the granite at Bear Pass Station. On its northern side it has been cut off by the later intrusion of porphyroid gneiss previously described. Around the west end of Base-line bay, there are also rather numerous belts of schist sunk into the granite, some of which appear to be isolated while others are still connected with the main area of Keewatin rocks here encasing the granite.

Besides these roof pendants, connected or detached, which are such striking features of this batholith, there are great numbers of smaller fragments of the encasing schists embedded in all orientations in the granite, which must be regarded as pieces which had become immersed in the granite magma and were sinking in it at the time of the irruption.

It is noteworthy that roof pendants still connected with the encasing terranes and projecting as tongues into the area of the granite are most pronounced where the latter cuts across the strike of the schists, and that where the trend of the encasing formations conforms to the periphery of the granite mass they are not in evidence. This, of course, indicates that the folded structure which prevails in the country south of the granite, persisted into the roof of the batholith. Whether this irregularity of the under side of the roof of the batholith was accentuated by collapse of the roof is not clear, but it seems quite certain that the interdigitation of lobes of granite and tongues of schist at the present surface is but the expression of a similar interdigitation in the vertical sense, and that the latter is in turn an expression of the internal structure of the roof. This relationship of roof pendants to the folded and by analogy, possibly also faulted, structure of the roof, appears to be somewhat difficult to harmonize with the idea of stoping on the large scale as advocated by Daly; and is suggestive of a mode of intrusion more analogous to that of a laccolith. We require, however, a much greater number of field observations, made with these questions in mind, before a settled conclusion can be reached as to how the granites are historically related to the schists which they invade. Of the roof pendants of Redgut bay, that of Moose point is perhaps the most interesting. Here the Coutchiching mica schists lie upon the granite in a belt about half a mile long in almost perfectly flat attitudes. This occurrence lies in the direct prolongation of the axis of the Bear Passage anticline, where, on the south shore of Redgut bay and on the line of the Canadian Northern railway from 2 to 2½ miles to the southwest, the Coutchiching rocks lie in similarly flat attitudes. It may be safely assumed that the schists of Moose point, flat lying as they are, represent the underside of the Bear Passage arch extended in the roof of the batholith well over the granite, the axis doubtless pitching to the southwest. If this be so, then on either side of the axis the schists should dip away and reach lower levels on the flanks of the anticline. But the schists are absent and on either side of the narrow belt of flat lying schists they have been displaced by the granite. Here then we seem to be forced to resort either to stoping or to resorption to explain the relations, and to admit that the control of the internal structure of the roof in determining the vertical interlocking of schist and granite is only partial. If the control were complete and the intrusion were wholly laccolithic in its mode of invading the schists, we should find the granite lobes under the arches of the anticline and the schist tongues in the axes of the synclines. In the case described, this condition is not fulfilled, and we, therefore, cannot explain the relations as laccolithic. One other observation may be made. The disposition of the roof pendants whether connected or detached in the Redgut Bay region, and particularly the one at Moose point, indicates that the present surface of the granite is not much below its original surface as it lay under its roof when the latter was intact. If this be so, then we must further conclude that the under side of the roof was on the whole, notwithstanding the irregularities to which attention has been called, quite flat. Observations pointing to the same conclusion have been made elsewhere in this same general region. The flatness of the roof would appear to be determined by the breadth of the span, for in the case of the smaller Bear Passage and Knuckle Island granite masses, the conclusion was reached that the schists were domed over the intrusive mass, in the fashion of a laccolithic roof.

SUMMARY OF OBSERVATIONS REGARDING THE PLUTONIC INTRUSIONS USUALLY REFERRED TO AS LAURENTIAN.

From the foregoing discussion of the plutonic rocks usually referred to as Laurentian, the following important facts stand out clearly.

(1) In the region there are certain granitoid gneisses and granites which antedate the Seine series, but which are later in origin than the Keewatin. These are specifically the granitoid gneiss of Steeprock lake, the Bad Vermilion granite, the sheared granites of Grassy island and Rice bay, and very probably the intervening granite of the Mud Lake belt.

(2) One of these, the granitoid gneiss of Steeprock lake, antedates the Steeprock series, and probably all of them do.

(3) There are certain other syenite gneisses, granite-gneisses, and granites, which are later than the Seine series and are intrusive in it. These are specifically the granite-gneiss of the southern portion of the Seine River sheet and the greater part of the Shebandowan sheet mapped by the Survey as Laurentian, and the mica syenite-gneiss of Rainy lake, also mapped as Laurentian in 1887.

(4) Associated with this syenite-gneiss are certain areas of granite gneiss which are regarded as practically contemporaneous with the syenite gneiss and probably products of the same eruptive process.

(5) Later than the syenite-gneiss is the banded gneiss and its marginal facies, the porphyroid gneiss. The interval between the syenite gneiss and the banded gneiss is not known and it may be of a minor order.

(6) We thus have in the region at least two groups of plutonic rocks, both of which are commonly referred to as Laurentian, but which are separated by an interval of geological time of a major order.

(7) The interval last referred to embraces:—

(*a*) The time necessary for the degradation of the Coutchiching and Keewatin and the earlier plutonic masses intrusive into them.

(*b*) The time required for the deposition of the Steeprock series.

(*c*) The time involved in the deformation and profound erosion of the Steeprock series.

(*d*) The time of deposition of thousands of feet of quartzites and slates of the Seine series.

It seems quite probable from the distribution of the post-Seine granite-gneisses and syenite-gneisses on the Seine River, Shebandowan Lake, and Rainy Lake sheets that most of the rocks usually referred to the Laurentian belong to the later period of plutonic activity.

In view of the facts above summarized, we may well ask the question: what do we mean by the term Laurentian as applied to the rocks of the Lake Superior region? In recent years it has come to be used as a designation for a group of plutonic intrusions of post-Keewatin age. But if in this group we find that we have in reality two groups of plutonic rocks with vast interval of geological time separating them, are we not obscuring geological history rather than elucidating it by continuing to lump them all under the same designation? What chronological significance can the term Laurentian have under such a procedure? Clearly we must, in the interests of progress and lucidity, either limit the term to one or the other of these two widely spaced periods of plutonic rocks and invent a new name for the other, or we must abandon the term altogether. Before discussing further this interesting question, we may with advantage consider briefly the matter of the correlation of the Steeprock and Seine series with other better known members of the Archæan in the Lake Superior region. The discovery of fossils[1] in the Steeprock series fortunately furnishes the hope and prospect that such a correlation may be placed on a better basis than has hitherto been possible in regard to these ancient formations. For the present all correlations are tentative, but they may with advantage be attempted.

It seems probable that the Steeprock series is the correlative of the lower Huronian. This is the correlation adopted by Van Hise and Leith[2] and it seems well justified.

In suggesting a correlation of the Seine series, I shall, for the present, exclude the Animikie from the Huronian, leaving the sequel to justify that exclusion, and consider the Huronian to consist of two divisions separated by a pronounced unconformity—the lower and upper Huronian. Occupying this point of view, I would correlate the Seine series with the upper Huronian, which is the same as the middle Huronian of Van Hise and Leith[3].

With this correlation it becomes at once apparent that a large part, probably the greater part, of the granite-gneisses usually referred to the Laurentian are not only post-Keewatin but are post-Huronian. They are, moreover, pre-Animikie and antedate the Animikie by the vast interval which I have else-

[1]See Memoir 28, Geological Survey of Canada, 1912.
[2]U.S.G.S. Mon. LII, 1911, p. 147, *et seq.*
[3]*Op. Cit.*

where emphasized as the Eparchæan Interval[1]. This, it seems to me, is ample justification for the view that the Animikic is not in any way connected with the Huronian and that to class it as upper Huronian is to obscure one of the great facts of geological history, viz., the importance of the break between the Archæan and post-Archæan terranes. It may here be noted that the term Archæan as defined by Dana, and as used by the Survey for many years, includes the Huronian, and the recognition of the fact that many, and probably most, of the rocks classed as Laurentian are post-Huronian, thoroughly justifies that definition as against the proposal to extend the Algonkian downward so as to embrace formations on both sides of the Eparchæan Interval.

The dual age of the Laurentian granites and gneisses has in recent years become generally recognized and the time seems to have come to mark that recognition as a step in advance in the general solution of the Archæan problem.

The International Committee on Geological Nomenclature in its report[2] of 1905, lent its authority to the current practice of designating as Laurentian the granite-gneisses of the Archæan, notwithstanding diversity of age. But at that time the fact was not fully appreciated that so large a proportion of the rocks of this type were post-Huronian. The diversity of age was, however, clearly recognized in the following paragraph:—

"For the granites and gneissoid granites which antedate, or protrude through, the Keewatin, and which are pre-Huronian, the term 'Laurentian' is adopted. In certain cases this term may also be employed, preferably with an explanatory phrase, for associated granites of large extent which cut the Huronian, or whose relations to the Huronian cannot be determined."

In 1909, Van Hise and Leith in their paper on the Pre-Cambrian geology of North America call attention[3] to the anomalous use of th[illegible] Laurentian. To quote briefly, they say, "A considera[illegible]f the rocks mapped as 'Laurentian' is intrusive into the A[illegible] (meaning Huronian) but another large part is intrusive only into the Keewatin. 'Laurentian' as used in the broad sense, becomes a catch-all for Pre-Cambrian gneisses and granites of any area where structural relations have not been discriminated. There is danger that unless the narrower and much more desirable application of the term recommended by the committee be emphasized, the discrimination of the Archæan and Algonkian (meaning pre-Huronian and post-Huronian) granites, so important for structural purposes, will be overlooked.

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[1]Bull. Dept. Geo[illegible]., Vol. 3, No. 3, 1902.
[2]Journal of Geology, Vol. XIII, 1905, pp. 89-104.
[3]U.S.G.S. Bull. 360 p. 28.

In 1910, Coleman in his address to the Geological Section of the British Association for the advancement of Science[1] stated the case in the following words:—

"At the end of the Keewatin, the thousands of feet of volcanic and clastic rocks were lifted as domes by the upwelling of batholiths of early Laurentian gneiss. * * * * During the Middle Huronian, or in the interval between it and the Upper Huronian (Animikie), mountain making was renewed on a grand scale, many synclines of Keewatin and Lower Huronian rocks being caught between the rising batholiths of late Laurentian gneiss. * * * The granites and gneisses of this second time of mountain building have not been distinguished in mapping from those of the first in most places, and as they are both of precisely the same habit it will probably never be possible to separate them completely. Thus far, both have been included under the term Laurentian."

Recognizing then, the dual character, from a chronological point of view, of the rocks hitherto classed as Laurentian, the Archæan may be characterized as embracing all of that complex assemblage of rocks both sedimentary and volcanic, which, together with the various, extensive and chronologically distinct plutonic masses invading them, constituted the earth's crust up to the time of the profound erosion interval which was brought to a close by the Animikie subsidence. The length of this interval is recognized by Van Hise and Leith who say "The Upper Huronian (Animikie) was deposited on a remarkably uniform peneplain"[2]. If elsewhere it be found that this interval was so long and so eventful as to have included sedimentary series not now existent in the Lake Superior region, the latter would be classed as Archæan if antedating the post-Huronian plutonics and post-Archæan if resting unconformably upon those plutonics. In other words the Archæan of the Lake Superior is distinguished from the post-Archæan, not only by the vast erosion of the Eparchæan Interval, but also by the prevalence of batholithic intrusives on the far side of that interval and their absence on the proximate side. In this connexion, I may quote Coleman: "Whatever their cause these oval batholiths enclosed by meshes of schist, are the most constant feature of the Canadian Archæan, though in many places erosion has cut so deeply that the meshes have all but disappeared, leaving only straight or curving bands of hornblende schist enclosed in the Laurentian gneiss."[3] The peneplain upon which the Animikie was deposited was carved out of this complex. On both of these counts the Huronian is included

[1]Sheffield, 1910.
[2]U.S.G.S. Mon. LII, 1911, p. 610.
[3]Address. Geological Section, B. A. A. S., Sheffield, 1910.

in the Archæan and the Animikie is excluded from it. This being the case, it seems best, if the term Algonkian is to be used, that it should not be made to straddle the Eparchæan Interval, but should be restricted to the group of formations laid down in the time between the Archæan as above defined and the Cambrian.

If now, we assume that the Animikie and Keweenawan may in this sense properly be designated Algonkian, the geological scale for the Lake Superior region with the present usage of the term Laurentain would appear as follows:—

Algonkian..... { Keweenawan.
Animikie.

Eparchæan Interval

Archæan...... { Laurantian granite-gneisses, etc.
Upper Huronian.
Erosion interval.
Lower Huronian.
Erosion interval.
Laurentian granite-gneisses, etc.
Keewatin.
Coutchiching.

This is obviously a use of the term Laurentian that cannot longer be continued, and this brings us back to the practical question of how we shall dispose of the infelicity arising from the chronologically dual significance of the term. If we reserve the term Laurentian for the plutonic rocks of one period and find another term for the similar rocks of the other period, the difficulty at once arises, that in many cases, where the Huronian rocks are not present, it will be quite impossible to determine whether the plutonic rocks in question belong to the earlier or the later period. The field geologist in preparing his map for publication will either have to guess as to which of the two periods the rocks belong, or will have to forego a reference to either period, leaving the matter undecided. Judging from the conditions which prevail over the greater part of Archæan Canada, this indecision will be a feature of most of the geological maps covering the region. This suggests, of course, that the term Laurentian be dropped altogether, and that the rocks hitherto referred to by that name appear on the maps by petrographical designations with such approximations to their age as is implied in the use of the expressions post-Keewatin, etc. This procedure, while it may be forced upon us in those regions where the Huronian rocks are absent, would, however, not best serve the purposes of geology in those important regions that give us the key to the full sequence of events in the early history of the continent. In these it will be necessary to have distinctive names for the two periods of plutonic activity, and for the geological formations which are the product of that activity. This will be true in many special fields, the careful study and mapping of which will yield far more to the science of geology than the mapping of broad areas where much of the geological record has been swept away. In view of this necessity for two distinctive designations, it is obvious that the term Laurentian should be retained as one, and it should have an application which will be as far as possible in accord both with current usage and with the significance of the term as agreed upon by the International Committee on Geological Nomenclature. I am strongly disposed to think that most of the rocks mapped by the Survey as Laurentian belong to the second period of Archæan plutonic activity, and if this be so it would be warrant for retaining the term for the post-Huronian granites and granite-gneisses. But the International Committee on Geological Nomenclature has explicitly restricted the term to the pre-Huronian rocks[1]. This decision should be authoritative, for the question is one purely of nomenclature, and accepting it as such, the way is cleared for the designation of the post-Huronian granites and gneisses. The designation for these rocks and for the period of time which they record should suggest Canada as the field where they are most extensively developed, and where the problems which they present will find the most abundant data for their solution. The term "Canada" has, however, been already appropriated for the purposes of geological nomenclature, and I, therefore, propose "*Algoman*" as an appropriate term for this division of Archæan time and for the rocks originating in it. The term is derived from the old district of Algoma, in which these rocks occur extensively.

The chronological sequence of the major Pre-Cambrian sub-divisions of the geological scale for the Lake Superior region

[1]Journal of Geology, Vol. XIII, 1905, p. 103.

would then appear, as the general outcome of this discussion, to be as follows:

Algonkian	Keweenawan.
	Unconformity.
	Animikie.
	Eparchæan Interval.
Archæan	Algoman granites, gneisses, etc.
	Irruptive contact.
	Upper Huronian
	Unconformity.
	Lower Huronian.
	Unconformity.
	Laurentian granites, gneisses, etc.
	Irruptive contact.
	Keewatin. } Ontarian.
	Coutchiching. } Ontarian.

KEWEENAWAN DYKES.

Several large dykes of diabase traverse the Archæan rocks of the territory mapped. Three of these are represented in the southwest corner of the map. They have a northwest-southeast strike but exhibit a tendency to convergence to the southeast. Their position is of interest as marking in a general way the boundary between a more elevated region in which Rainy lake lies and a somewhat lower region, mantled with Pleistocene deposits, through which Rainy river flows to Lake of the Woods.

A smaller dyke of the same character occurs on the small islands in the middle of the more open part of the lake, but this has a strike of northeast-southwest. These dykes are sufficiently described in the report of 1887 and no attempt has been made to study them further. It has been found, however, that the rock on the south side of Grassy Portage bay, which in the report of 1887 was mapped as diabase, is in reality a portion of an extensive belt of hornblende gabbro of much greater antiquity. It is described in the present report in the section dealing with the Keewatin. The four dykes represented on the map are identical in character with many others occurring throughout the region of which this is a part. In the vicinity of the Lake Superior coast these dykes have been shown to be a manifestation of the eruptive activity of the Keweenawan, and the diabase dykes of Rainy lake are, therefore, correlated with the products of that period.

PALÆOZOIC ROCKS.

In section 17 of the township of Crozier, about 6 miles west of Fort Frances, there is a small outcrop of cream-coloured fossiliferous limestone, emerging from beneath the glacial drift which mantles the region. A shallow pit has been sunk on the outcrop and in this the dip of the limestone beds is seen to be about 10° in a southerly direction, which could not be exactly determined owing to the smallness of the exposures and the uneven character of the stratification. The extent and thickness of the formation could not be ascertained and I could learn of no other similar outcrops in the neighbourhood. The size of the exposure renders it barely possible, but quite improbable, that the pit has been sunk upon a huge erratic embedded in the drift. There are no large erratics in the vicinity and it is my opinion that we have here to deal with an outlier of the Palæozoic rocks more abundantly exposed in the valley of the Red river in Manitoba.

The rock resembles that described by Tyrrell and Dowling at Stony Mountain and Little Stony Mountain in Manitoba and referred to the Richmond group[1] of the upper Ordovician.

A collection of fossils which I made at the Crozier locality was submitted to Mr. Percy E. Raymond, Invertebrate Palæontologist of the Survey, and he has kindly supplied the following memorandum:—

"I have examined the collection made by you at a point about 6 miles west of Fort Frances, Ont., and find them to be of upper Ordovician (Richmond) age. The following forms have been identified:—

Rhynchotrema capax, Conrad.
Lepterna unicosta, Meek and Worthen.
Plectambonites sericeus, Sowerby.
Rafinesquina alternata, Emmons.
Hebertella, sp. indet.
Trochonema umbilicatum, Hall.
Holopea, sp. indet.
Conularia, sp. indet.
Inocaulis canadensis, Whiteaves.
Onchometopus susae, Whitfield.

"The fauna as a whole is much like that at Stony Mountain, Manitoba."

The discovery of this outlier of Ordovician strata near Fort Frances, at a distance of about 200 miles southeast from the

[1] Ann. Rept. Geol. Survey, Canada, Vol. XI, Part F. 1898, pp. 88-92.

nearest known exposure at Stony Mountain, sheds an interesting light upon the former extent of the Ordovician terrane in this part of Canada. It has a significance analagous to that of the outlier of Niagara at Lake Timiskaming, and contributes to the increasing volume of evidence that the Ordovician and Silurian seas were more widely extended than was once supposed over central Canada, where, by reason of the thinness of the formations, the latter have been almost wholly removed by erosion. The extension of the Ordovician limestone to Rainy lake is also of importance as indicative of the source of the limestone of the grey drift of Minnesota. It may also have an economic importance as a local source of supply of lime for constructional or metallurgical purposes. In this connexion the following analyses of the limestone kindly supplied by Mr. G. A. Stethem, of Fort Frances, will be of interest.

	I.	II.	III.
SiO_2	3·18	2·93	4·48
Fe_2O_3	1·73	2·13	} 2·80
Al_2O_3	1·43	1·02	
CaO	29·76	29·80	29·84
MgO	18·14	18·14	20·29
S	none.	trace.	....
P	trace.	trace.	....
Loss on ignition	45·49	46·02	H_2O 0·04 / CO_2 41·76
	99·73	100·04	99·21

I. Analyst, C. A. Graves, Duluth Testing Laboratory. II. Analyst, C. A. Graves, Duluth Testing Laboratory. III. Analyst, N. L. Turner, Provincial Assay Office, Belleville, Ontario.

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CLASSIFED LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY.

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers, and, therefore, the following list has been prepared to prevent any misconceptions arising on this account.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont. By W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada. By R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories. By Joseph Keele. No. 1097.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario. By Alfred W. G. Wilson.

Memoir 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley Mining district, British Columbia. By Charles Camsell.

Memoir 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert Shales of New Brunswick. By Lawrence M. Lambe.

Memoir 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory. By D. D. Cairnes.

Memoir 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario. By Frank D. Adams and Alfred E. Barlow.

Memoir 7. *No. 6, Geological Series.* Geology of St. Bruno mountain, Province of Quebec. By John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES.

Memoir 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909. By R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902. By Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers. By W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of Lake Timiskaming. By Morley E. Wilson. No. 1064.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec. By W. J. Wilson.

Memoir 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta. By D. B. Dowling.

Memoir 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta. By G. S. Malloch.

Memoir 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario. By J. W. Goldthwait.

Memoir 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906. By Anton Handlirsch.

Memoir 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario. By Frank Springer.

Memoir 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick. By Heinrich Ries, assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

Memoir 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia. By William H. Dall and Paul Bartsch.

Memoirs Published During 1912.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 13 *No 14, Geological Series.* Southern Vancouver island. By Charles H. Clapp.

Memoir 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia. By O. E. LeRoy.

·24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces. By Heinrich Ries and Joseph Keele.

Memoir 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.

Memoir 28. *No. 18, Geological Series.* The geology of Steeprock lake, Ontario. By Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario. By Charles D. Walcott.

Memoirs Published to Date Dur' g 1913.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 18. *No. 19, Geological Series.* Bathurst district, New Brunswick. By G. A. Young.

Memoir 13. *No. 20, Geological Series.* Wheaton district, Yukon Territory. By D. D. Cairnes.

Memoir 25. *No. 21, Geological Series.* Clay and shale deposits of the Western Provinces (Part II). By Heinrich Ries and Joseph Keele.

Memoir 37. *No. 22, Geological Series.* Portions of Atlin district, B.C. By D. D. Cairnes.

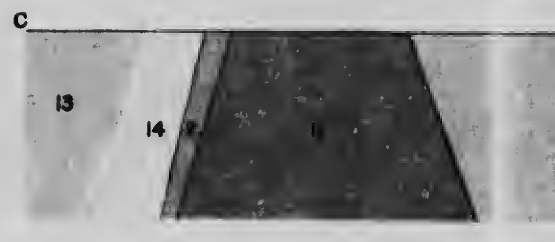
Memoir 23. *No. 23, Geological Series.* Geology of the coast and islands between the Straight of Georgia and Queen Charlotte sound, B.C. By J. Austen Bancroft.

Memoir 40. *No. 24, Geological Series.* The Archæan geology of Rainy lake. By Andrew C. Lawson.

Memoir 32. *No. 25, Geological Series.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C. By R. G. McConnell.

Memoir 19. *No. 26, Geological Series.* Geology of Mother Lode and Sunset mines, Boundary district, B.C. By O. E. LeRoy.

Memoir 22. *No. 27, Geological Series.* Preliminary report on the serpentines and associated rocks in Southern Quebec. By J. A. Dresser.

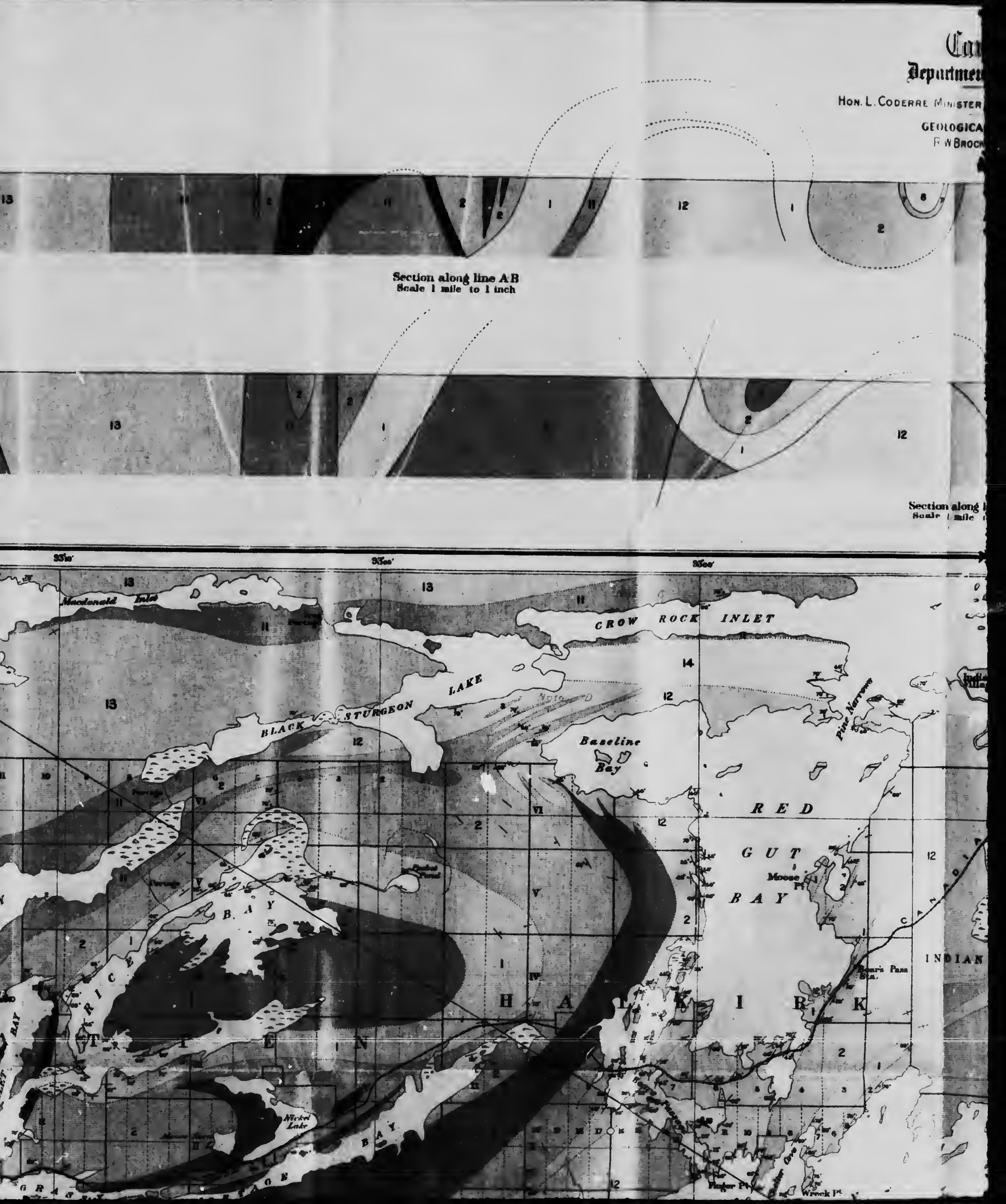


GEOLOGY

LEGEND

ARCHÆAN

- KEWEENAWAN
  - 15 Diabase dykes
- ALGOMAN
  - 14 Porphyroid gneiss
  - 13 Banded and streaked gneiss
  - 12 Granite and granite gneiss
  - 11 Syenite gneiss
  - Basic facies of syenite
  - Lamprophyric rocks
- HURONIAN SEINE SERIES (UPPER HURONIAN)
  - 8 Quartzite and slate
  - 7 Conglomerate
- LAURENTIAN
  - Granite and granite gneiss



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HON. L. CODERRE MINISTER
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R. W. BROCK
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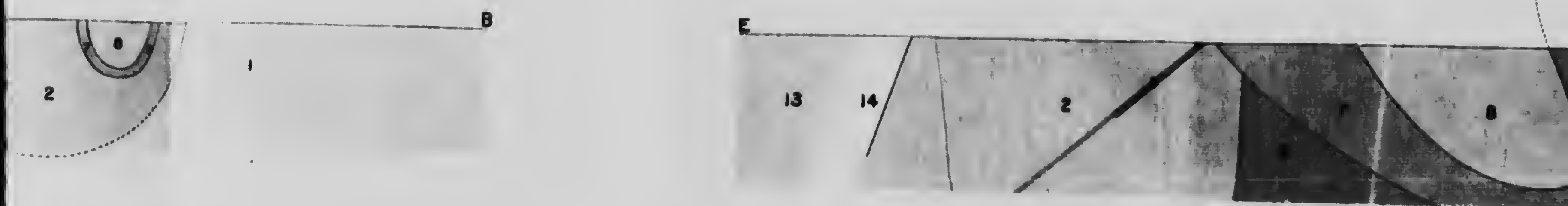
Scale 1 mile
Macdonald Inlet
CROW ROCK INLET
BLACK STURGEON LAKE
Baseline Bay
Pine Narrows
RED GUT BAY
Moose Pt.
INDIAN
RICE BAY
Bear's Pass Sta.
H A L K I R K
T E I N
Nickel Lake
Wreck Pt.

Canada
Department of Mines
L. Coderre, Mini... A. P. Low, Deputy Minister
Geological Survey
R. W. B... Director



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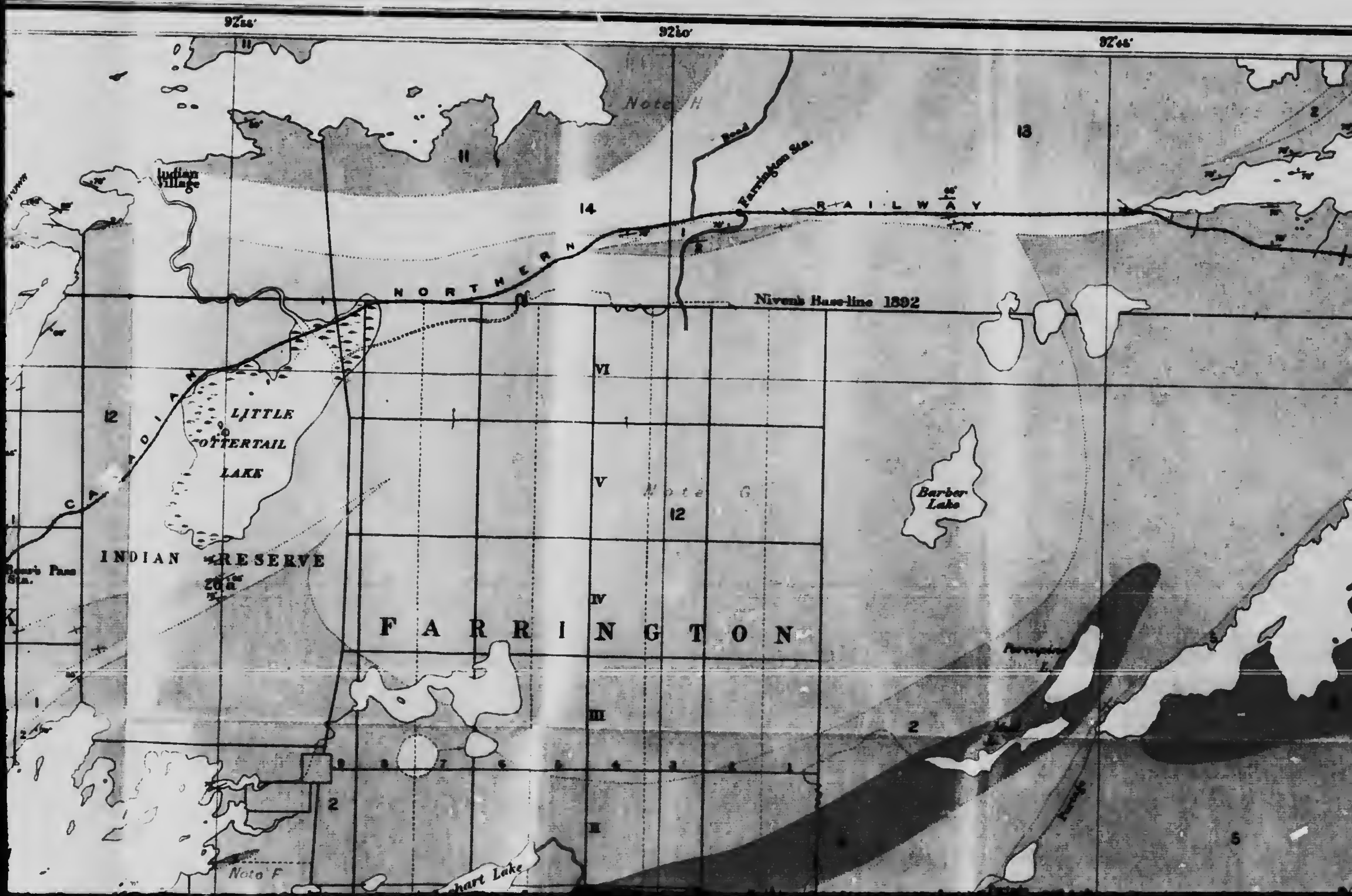

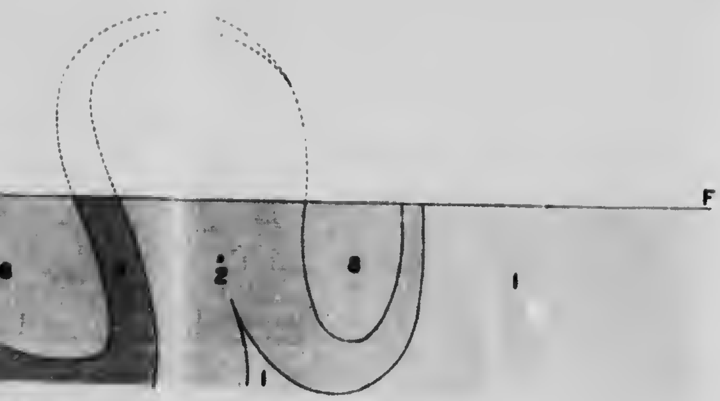

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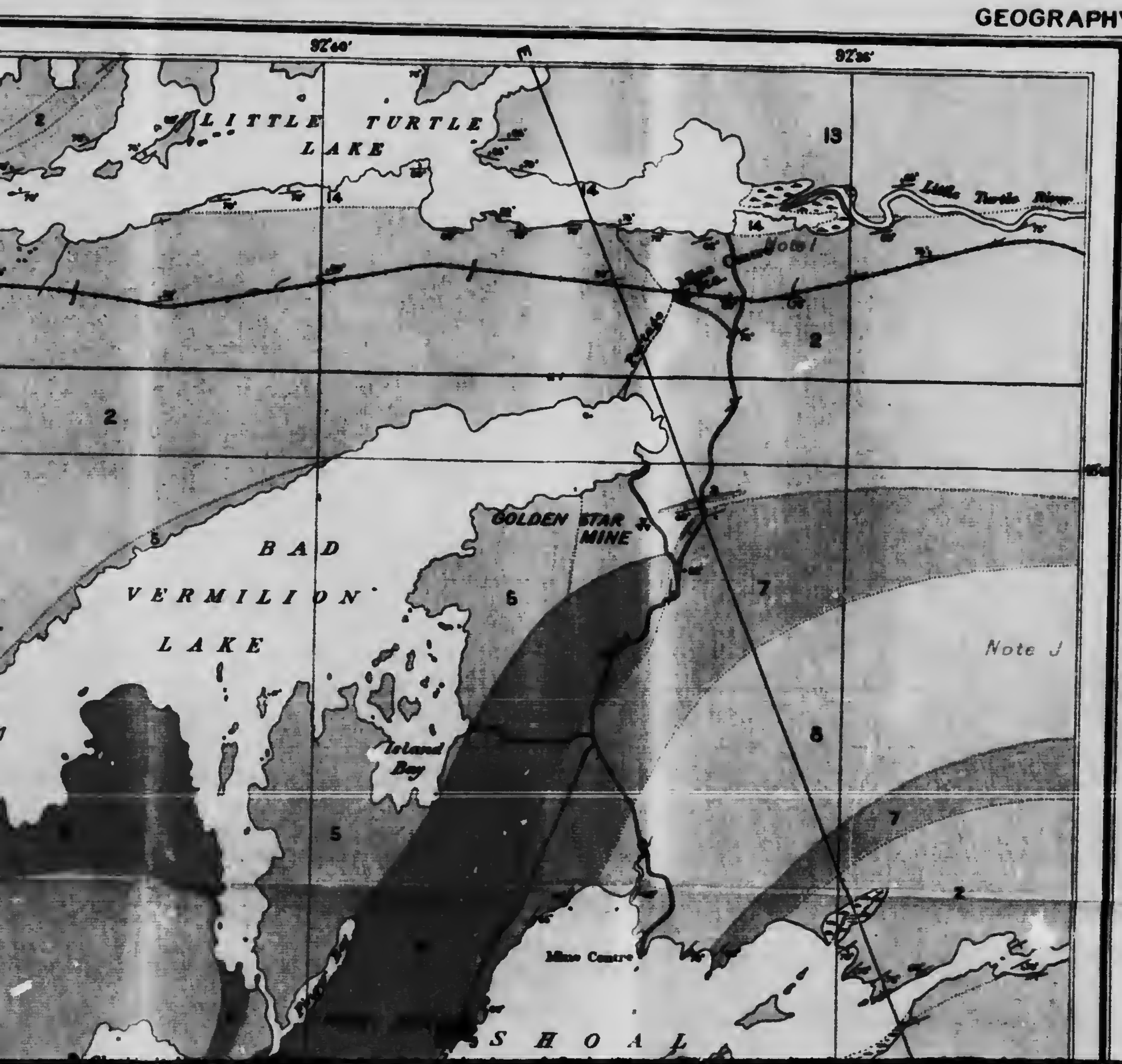
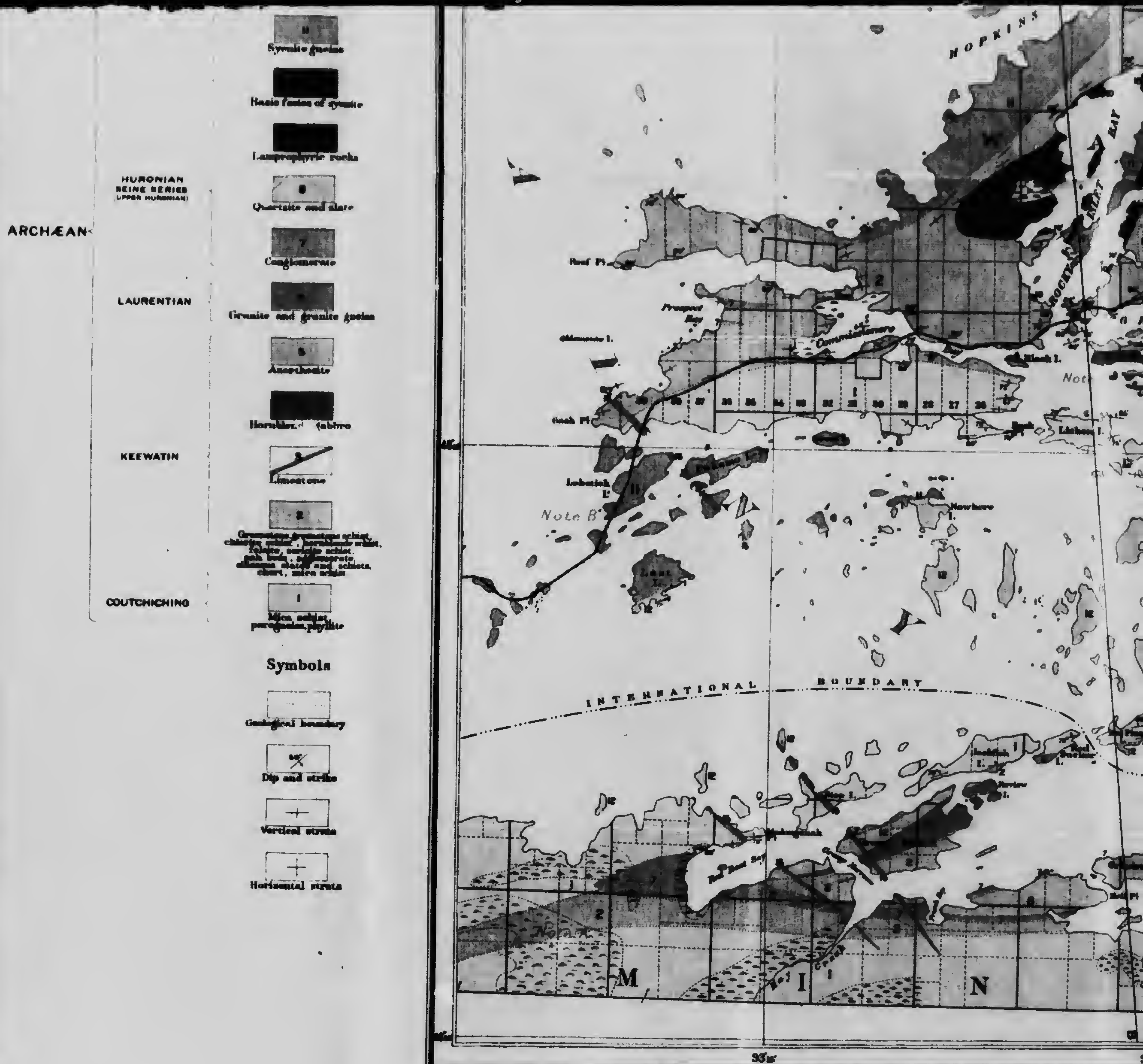
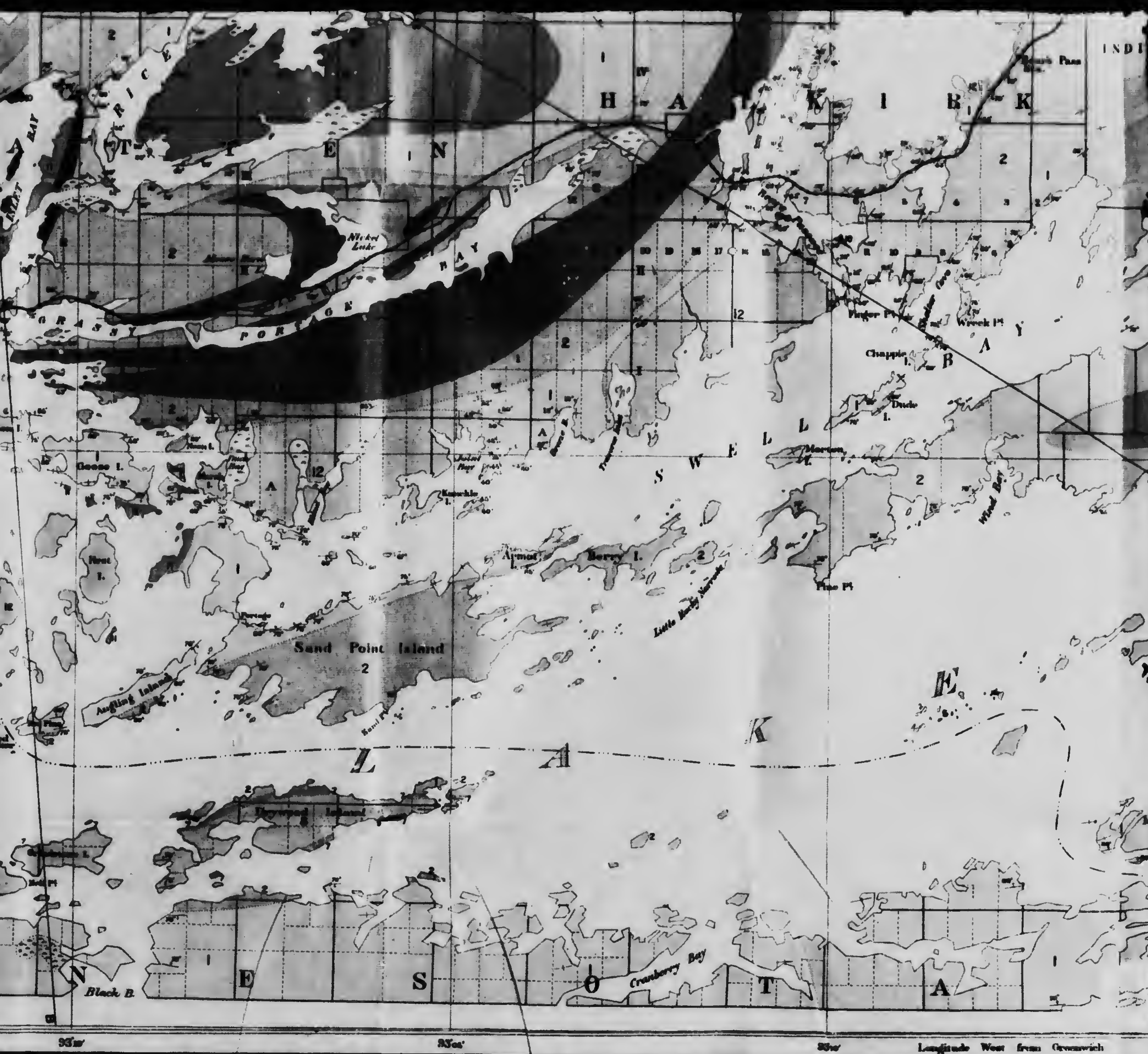
GEOGRAPHY

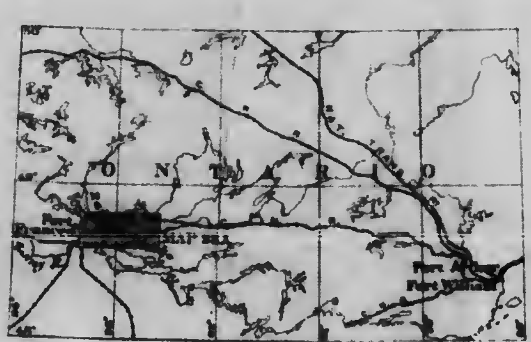




C.O. Senécal, Geographer and Chief Draughtsman.
A.W. Joanes, Draughtsman.

To accompany Memoir by A.C. Lawson





Scale, 70 Miles to 1 Inch

MAP 98
(Issued

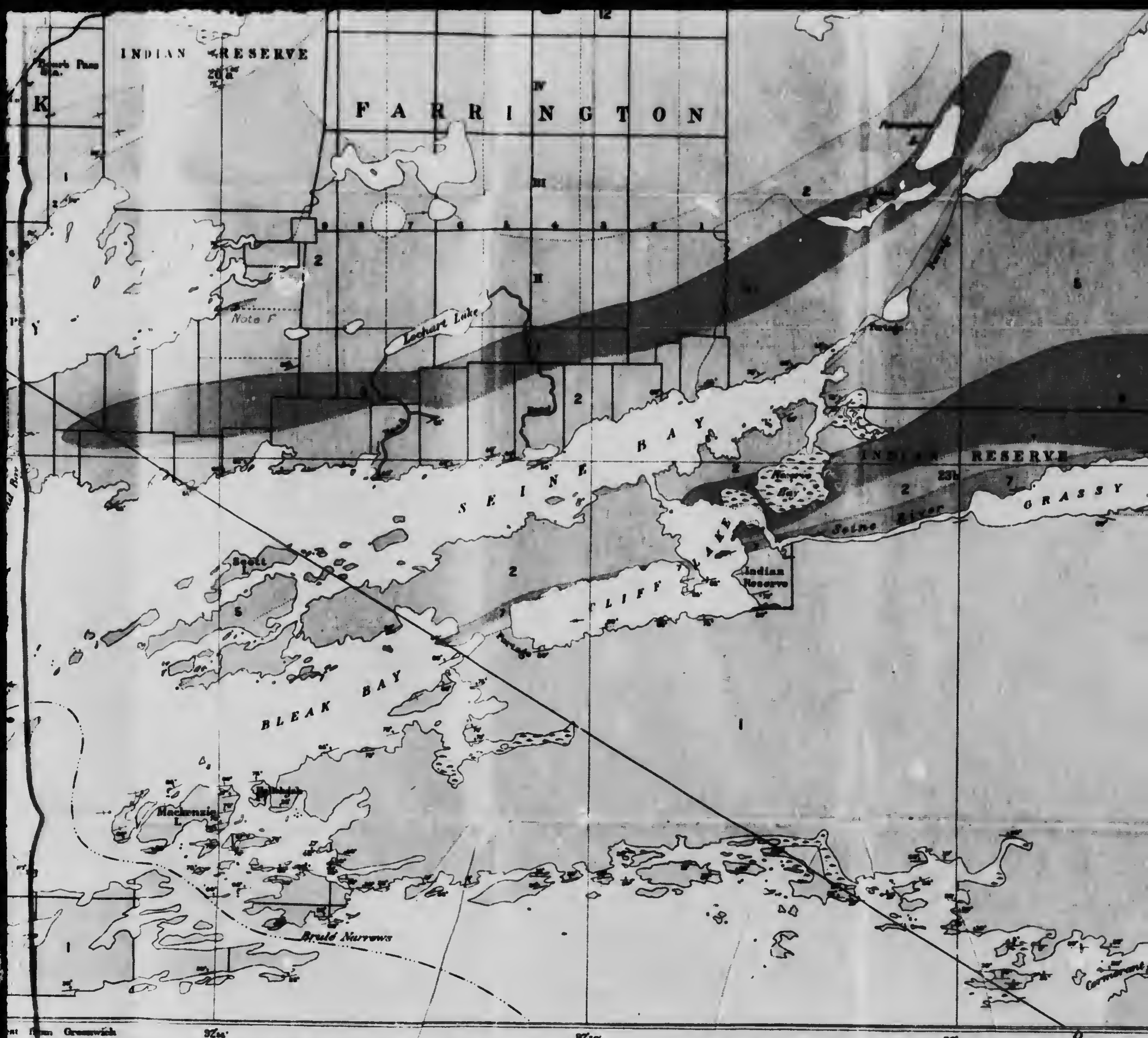
RAINY

RAINY RIVER

ONTA

Scale,
Miles
Kilometers

1 MILE TO



MAP 98A
(Issued 1911)

RAINY LAKE

RAINY RIVER DISTRICT

ONTARIO

Scale, $\frac{1}{63,360}$

Miles

Kilometres

1 MILE TO 1 INCH

GEOLOGY

A.C. LAWSON.

GEOGRAPHY

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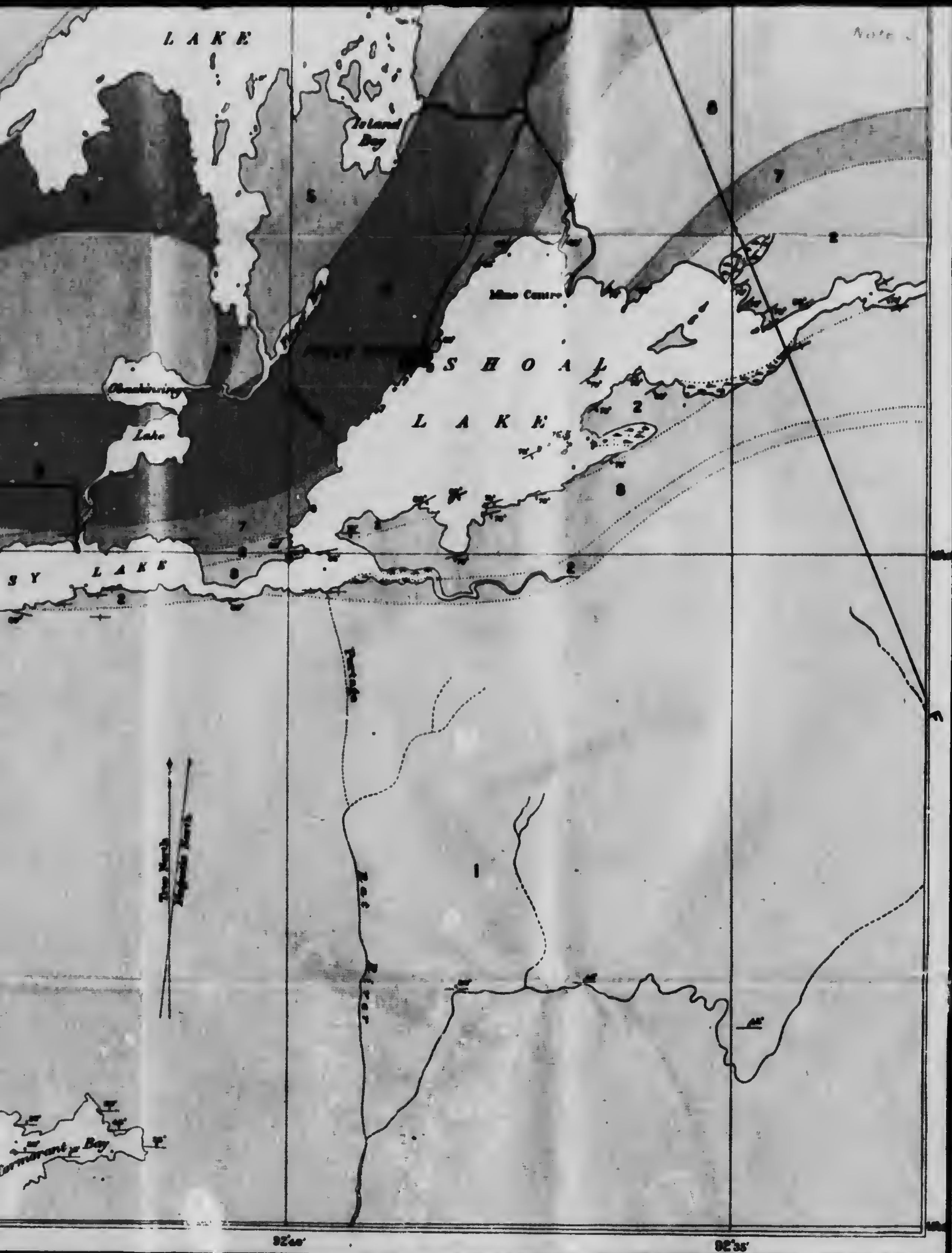
W.H. SMITH,
J.D. TRUEMAN,
DEPARTMENT OF LANDS, FORESTS,
DEPARTMENT OF RAILWAYS & CA



LOGY

1911.

RAPHY

1886.
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FORESTS, & MINES, ONTARIO.
AYS & CANALS.

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