GEOLOGICAL AND NATURAL HISTORY SURVEY OF CANADA.
ALFRED R. C. SELWYN, C.M.G., LL.D., F.R.S., DIRECTOR.

# REPORT

## ON THE GEOLOGY

OF THE

# RAINY LAKE REGION.

BY

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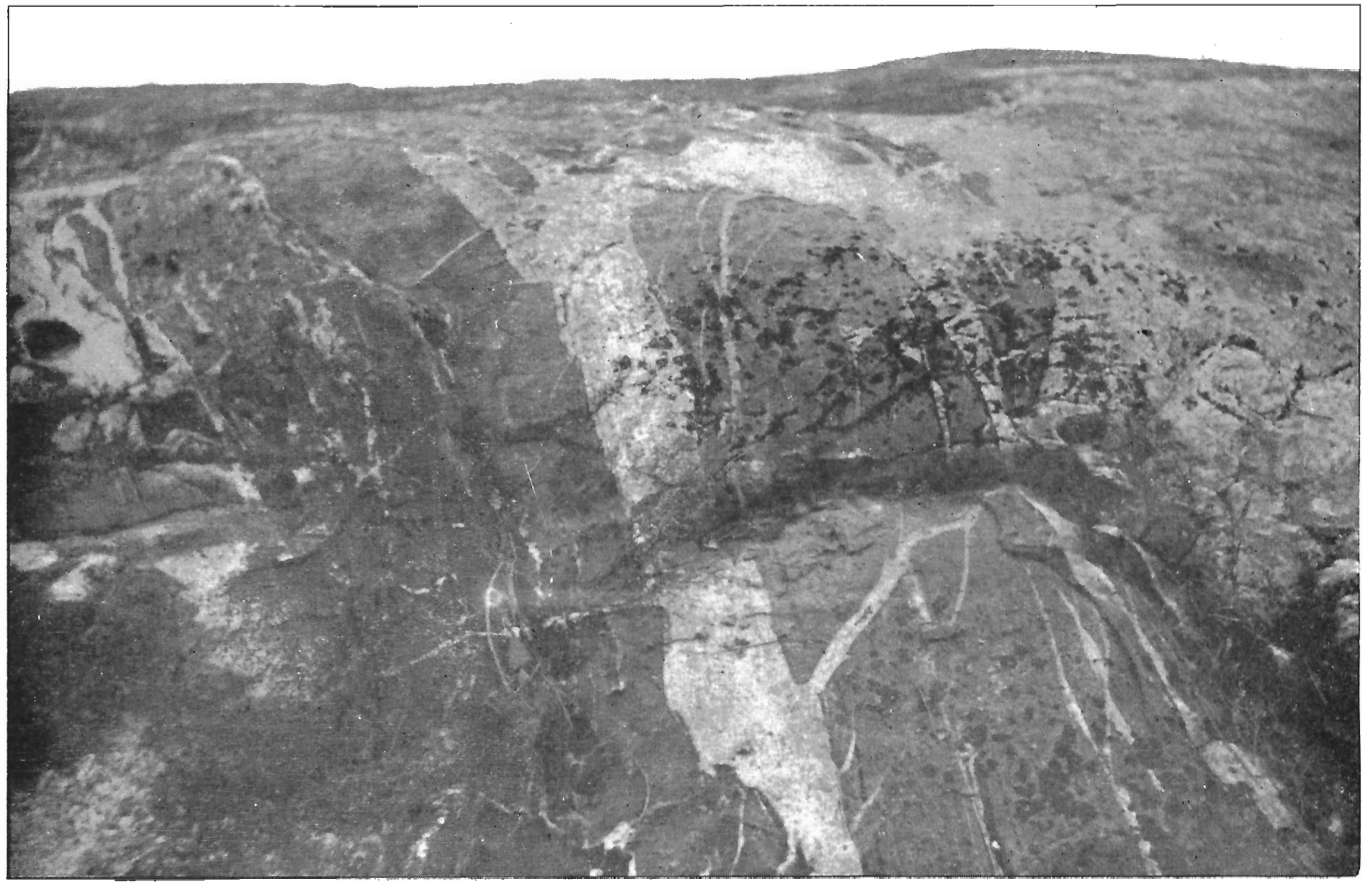


A. C. LAWSON, PHOTO., 1886. G. E. DESBARATS & SON, ENGRAVERS & PRINTERS, MONTREAL.

Contact of Laurentian gneiss and schists of the Coutchiching series, on island between Gash Point and Back Point, Rainy Lake. The gneiss (light colored portion) penetrates the schists in all directions. It extends away continuously to the right, while the schists (shaded portion) extend to the left.

To A. R. C. SELYWN, C.M.G., LL.D., F.R.S.

*Director of the Geological and Natural History Survey of Canada.*

SIR,—I herewith submit to you my report upon the physical and geological features, and economic resources of portions of the Rainy Lake and the Lake of the Woods regions, including the country through which the Rainy River flows; also a geological map of the same, in two sheets, on a scale of $\frac{1}{4}$ of an inch to the mile; each sheet embracing an area of 72×48 miles. The topographical surveys necessary for the construction of the map, upon which to represent the geology, occupied a much larger portion of the time devoted to field work than did the geological examination. With the exception of Rainy River, all the topography on the Canadian side, in the Rainy Lake sheet, is from our own surveys, checked by a few exploratory lines that had previously been run through the country.

Our warmest thanks are due to Mr. and Mrs. Pither of the Indian Agency at Coutchiching, for their most generous hospitality to myself and party during the seasons we have been at work in the country around Rainy Lake.

I have the honor to be,

Sir,

Your obedient servant,

OTTAWA, March 4, 1888. ANDREW C. LAWSON.

NOTE.—Bearings have reference to the true meridian, and read from 0° (N.) around to 360°.

# REPORT

ON THE GEOLOGY OF THE

# RAINY LAKE REGION.

## INTRODUCTION.

The present report, with the accompanying geological maps, is an instalment of the results which are accruing from the systematic prosecution of a topographical survey and geological investigation of country north-west of Lake Superior. The northern portion of the Lake of the Woods was first surveyed and the results published in the Annual Report, Volume I, 1885. In continuation of this work, Rainy Lake and the region adjacent to it were, in 1885, next subjected to survey, as promising the most satisfactory results on account of their accessibility, and the abundance of rock exposures. Of the two sheets now ready for publication, the one embracing the Rainy Lake Region, or the "Rainy Lake sheet," is the more interesting and important. The other or "Rainy River Sheet," embracing the greater part of the Rainy River and the Lake of the Woods, from about the latitude of Turtle Portage and Driftwood Point southward, is much less satisfactory, and represents much less work, from the fact that only a portion of it is within Canadian territory; and of that the greater part is covered either by the waters of the Lake of the Woods or by the post-glacial deposits through which the Rainy River flows. In 1885, I was assisted by Messrs. A. E. Barlow, W. H. Smith and C. S. Morton. These gentlemen were engaged till the close of the season in the prosecution of topographical surveys of portions of Rainy Lake and of the Kishkutena canoe route, while my own work consisted of a geological reconnaissance of the whole field, as sketched briefly in my summary report for that year. A portion of the season was also devoted to the survey of those islands of the Lake of the Woods which come within the Rainy River sheet.

Progress of survey.

Maps.

Field work in 1885.

In 1886, I was assisted in the field by Mr. W. H. Smith. The season's operations were begun at Wabigoon, where Mr. Smith was instructed to carry a micrometer and compass survey from a fixed point on the Ca-

Field work in 1886.

Manitou route.

nadian Pacific Railway through to Rainy Lake, by way of the Manitou canoe route, to connect with the system of township surveys on Rainy River. The west side of the lakes on this route was mapped in detail as far as the middle of Manitou Lake, from which point onwards both sides were embraced in the survey, being within the limits of the Rainy Lake sheet. Several weeks were next occupied by Mr. Smith in completing the survey of the north western expanse of Rainy Lake from Coutchiching northward to the Devil's Cascade. In addition to the usual micrometer and compass survey, a transit line was run between the two latter points, as a basis upon which to check the variation of the compass, which does not appear to be uniform throughout the district. This done, Mr. Smith next made a survey of an important chain of lakes extending from the bottom of Redgut Bay, Rainy Lake, to Lake Manitou, which it is believed has never hitherto been explored. During the last few weeks of the season, Mr. Smith was engaged in completing certain detached surveys near the mouth of Rainy River and in the south part of the Lake of the Woods, which stress of weather or other adverse circumstances had interfered with the previous season; so that nearly all the topographical material requisite for the mapping of the Rainy River sheet was secured.

Rainy Lake.

Otukamamoan route.

Lake of the Woods.

After having, at the beginning of the season, provided Mr. Smith with men and equipment requisite for his survey of the Manitou route, I left him at Wabigoon and proceeded to Rat Portage. Here two or three days were spent in the usual preliminary arrangements, and in inquiring into the state of the mining industry of the district, after which I proceeded to make a topographical and geological survey of the canoe route which extends from Lake of the Woods to Rainy Lake *via* Crow Lake and Pipestone Lake. The route consists of a chain of large lakes which have never hitherto been mapped. The west side of Crow Lake had previously been traversed by the survey; so that the work was begun in the neighborhood of Turtle Portage, and carried along the south side of Crow Lake; thence through Boulder, Sand-hill and Schist Lakes into Pipestone Lake, and then through Stonedam, Loon, Jackfish and Footprint lakes to the North-west Bay of Rainy Lake. The survey was made by means of a Massey's patent log, the portages being chained, and was checked at various points on previous surveys.

Pipestone route.

Geological work.

The belt of Keewatin rocks which crosses the Kishkutena route between Lake Kishkutena and Lake Despair was studied in detail, and traced in continuous connection with the area of the same rocks examined earlier in the summer on Crow Lake and Pipestone Lake. Some three or four lakes, of which Kahtimiagamak Lake is the most important, were surveyed, and added to the topography of the route. The

geological features of the northern part of the Manitou route were mapped by the aid of the topographical sheets supplied by Mr. Smith's survey. I returned to Rainy Lake by the Little Canoe route, making a log survey of the several lakes which form it, and mapping the geological features exposed on their shores.

In the southern part of Rainy Lake, some time was spent in working out the geological features of the islands and part of the south shore, as well as of those portions of the north shore which required special investigation in the light of the previous season's work; and considerable additions were made to the topography.

Pigeon River route.

For the purpose of acquiring a knowledge of the geological features of the south-eastward continuation of the Rainy Lake formations, and at the same time of becoming familiar, in a general way, with the features of the country between Rainy Lake and Thunder Bay, the last few weeks of the season were devoted to an examination of the shores of the canoe route along the Canadian side of the Minnesota boundary, and the field work was brought to a close at Port Arthur.

Field work in 1887.

In 1887, I was again assisted by Mr. W. H. Smith. More than half of the season, till about the middle of August, was required for the completion of the surveys and examinations necessary for the construction of the Rainy Lake sheet. My own work comprised: a further examination of a few critical points on the Kishkutena and Pipestone routes, with some slight additions to the topography; a survey and examination of Yoke, Strawberry, Bluff, Sucker, Furlonge, and Kaiarskons Lake; of the lakes of the Lake Harris route, within the limits of the sheet; of the lakes of Big Canoe River route; a geological examination of portions of Rainy Lake not previously examined; a geological examination of the Otukamamoan route, with additions to the topography, and an examination of the formations of Rainy River and the south part of the Lake of the Woods, together with a portion of Sabaskong Bay.

Mr. Smith's time was taken up with an exploration of the country between Big Turtle Lake and Heron Lake, resulting in a survey of a number of lakes; a survey of the lower part of the Little Turtle River, of the lakes of the Little Kishkutena route, and of the route between Stanjikoming and the North-west Bays; and more especially of the shore and islands of the east arm of Rainy Lake.

Character of country and methods of survey.

These various surveys and examinations, occupying our time up to about the middle of August, completed all the work that was deemed necessary for these two sheets, and our field of operations was moved further east. The country is devoid of roads or trails, and accessible only by the net-work of lakes, rivers and canoe portages, which is spread over its surface. All our travel was, therefore, effected by

means of canoes, with occasional excursions on foot through the woods. The surveys were such as enabled us to work rapidly and yet to afford sufficiently accurate data for the geological elucidation of the region and its cartographical representation on the scale adopted. Measurements on shore lines were made by the micrometer telescope or the Massey log, together with a compass triangulation having the lines so measured from point to point as bases. Portages or bush traverses were measured by the tape or by pacing. All bearings were made with reference to the magnetic meridian by means of the prismatic compass, except on a check line from Coutchiching to the Devil's Cascade on Rainy Lake where the transit was used.

Previous surveys.

The following surveys and sketches which had been made prior to ours, have served as checks and aids to our work, on the Rainy Lake sheet:

The Dominion Lands Rainy River Township Survey.

The Minnesota township surveys along the south side of the International boundary.

The Canadian Pacific Ry. exploratory line from Wabigoon to Coutchiching through the Manitou canoe route by Mr. W. Kirkpatrick.

A similar exploratory line from the Canadian Pacific Ry. to Rainy Lake by the Sand Island River route.

The Canadian Pacific Ry. exploratory line from White-fish Lake to Heron Lake.

The Indian Reserve surveys.

The timber limit surveys were of little service, and in some instances were ignored in our compilation.

The sketches of Thompson's Boundary survey have been superseded by our own, except for a few miles of the south-east side of Redgut Bay where his sketch was adopted.

A transit and chain line by Mr. Saeger, from the Indian Reserve at Wabigoon down the Manitou route to about half way to Fort Frances, was kindly placed at my disposal by that gentleman, and has also been used as a check.

For the Rainy River sheet, the surveys and sketches at our disposal in addition to our own, were :—

The Dominion Lands Rainy River township surveys.

C. F. Miles' survey of Sabaskong Bay for the Department of the Interior, 1875.

Joint maps of the North American Boundary Commission, 1878.

Cartographical work.

In the cartographical work we have had the advice and assistance of Mr. Scott Barlow, chief draftsman, who has laid down the projection of the sheets, and determined, as nearly as possible, the position of the more important points. The general compilation and drafting of the

Rainy Lake sheet has been the work of Mr. W. H. Smith; while the Rainy River sheet is by Mr. A. E. Barlow.

Geologically, the Rainy River region has hitherto been almost a *terra incognita*. The literature of the field is very scanty, and has reference only to the shores of Rainy Lake itself.

Previous geological work

Literature.

Dr. J. J. Bigsby has the honor of being the first to attempt a geological description of Rainy Lake. In the Quarterly Journal of the Geological Society of London, for Jan., 1854, Vol. X, he published a paper on the "Geology of Rainy Lake, South Hudson's Bay," accompanied by a geological map of the lake on a scale of four geographical miles to the inch. In his paper on the "Erratics of Canada," in the same journal for April, 1851, Dr. Bigsby's notes, so far as they apply to Rainy Lake, are interesting, and indicate a considerable amount of attention to superficial phenomena.

Bigsby.

Owen.

In the Report of the Geological Survey of Wisconsin, Iowa, and Minnesota, by D. D. Owen, 1852, there is a paragraph on page 319 devoted to brief notes of the rocks observed on a two days voyage through the lake from Kettle Falls to Rainy River.

Bell.

In the Report of Progress of the Geological Survey of Canada for 1873, Dr. Bell in his "Notes on the Geology of the Region between Lake Superior and Red River," devotes about a page (88-89) to notes of geological observations made in passing through Rainy Lake and down Rainy River.

Hind.

In the "Report on the exploration of the country between Lake Superior and the Red River settlement," 1858, Prof. H. Y. Hind has a chapter devoted to a description of Rainy Lake and river. The most interesting of his notes from a geological standpoint are those descriptive of Rainy River. No attempt is made to add to Dr. Bigsby's description of the geology of the lake.

Hector.

Hector, in his paper "On the Geology of the Country between Lake Superior and the Pacific Ocean," Q. J. G. S., Vol. XVII, has a brief reference to the geology of Rainy Lake.

Dawson.

The literature bearing on the geology of the south part of the Lake of the Woods has already been cited in my report for 1885. The "Geology and Resources of the 49th Parallel" by Dr. G. M. Dawson gives an account of the southern portion of the lake, particularly the United States side, which my own notes on the Canadian side, where rock surfaces are more abundant, will serve to supplement.

## Physical Features—their Dependence upon Geological Conditions.

Surface of country.

The surface of the country mapped on the two sheets accompanying this report presents a natural division into two portions, the respective characters of which are in striking contrast. These are :—

1. *The rocky lake country.*
2. *The alluvial plain, or river country.*

Alluvial plain.

The latter differs from the former essentially in the fact that the rocky, hummocky surface, the depressions of which would naturally form lake basins, is covered by a thick, uniformly spread blanket of post-glacial deposits. The surface of these deposits forms a comparatively flat, well wooded plain; and on the United States side, across northern Minnesota, this plain appears to merge into the prairie country. On the surface of the plain there are almost no lakes, the undrained water accumulating in wooded or treeless "muskegs." Drainage is effected by rivers of the usual sort, which cut their way through the soft horizontal strata so as to form shallow cañons.

Rocky lake country.

The rocky lake country presents the character of a plateau which, regarded on the large scale, is remarkably flat and devoid of prominent elevations, although the surface, in detail, is extremely uneven and hummocky or mammilated. It presents, for the most part, the glaciated surface of the rocks, either quite bare or covered only by forests and forest loam. There is a marked absence of alluvium or fine drift, except in occasional patches and small areas. The plateau abounds in lakes which lie in rocky basins. Rivers are few and short, being mostly mere connecting links or series of rapids between lake basins. Rivers of the cañon type can scarcely be said to occur at all, except, as in the case of the Big Turtle River, a small area of soft, flat-lying strata, through which it flows, presents the conditions which determine its character as such locally. These being the broad distinctions between the surface aspects of the two portions into which the region under consideration is divided, we may proceed to consider each portion somewhat more in detail.

### *The Rocky Lake Country.*

Characteristic feature.

The feature of this portion of our field which is of most prominence and interest, is that of the lakes. In my report of 1885, I have drawn attention to some of the more salient characteristics of the Lake of the Woods, and shall, therefore, not now refer to it again, although portions of it fall within the field under consideration. I shall attempt, by a reference to Rainy Lake, and to the chains of lakes tributary to it, to point out briefly the close relationship which exists between geo-

logical conditions and topographical contour. A glance at the map shews that Rainy Lake is a receiving basin or reservoir for the drainage of an extensive circle of country. At its south-west corner the waters of the lake are dammed back by a low escarpment of post-glacial clays, save for the gap where this formation has been cut through, and the waters of the lake break over the jagged upturned edges of an underlying ridge of schists, forming the Coutchiching rapids, the beginning of Rainy River. To the N.N.W.,N., N.E., E. and S.E. of the lake, the surface of the country rises very gradually, forming an amphitheatre-like slope, upon the various stages of which lie lakes linked in chains, or linear series, which converge upon the receiving basins. This slope, although distinctly recognizable as such, by following the drainage of the lakes from stage to stage, has a very slight incline, and is practically, as before stated, a plateau. The average slope can at most be but a few feet in the mile, but the figures are difficult to arrive at, on account of the rough, uneven character of the surface, and the absence of systematic levels. The drop from Lake Manitou to Rainy Lake was estimated by Mr. Kirkpatrick, in his exploratory survey of the Manitou route for the Canadian Pacific Ry., to be 107 feet. This in a distance of about 12 miles, gives a mean slope along the water course of nine feet in the mile. On the Sand Island River route, the drop of the water from the N.E. corner of the region mapped on the Rainy Lake sheet to the level of Rainy Lake is estimated to be about 120 feet. The distance being about 24 miles, this gives a mean slope of about five feet in the mile.

Rainy Lake, a receiving basin for extensive circle of country.

The slope to Rainy Lake.

The absence of great contrasts of elevation, associated with the remarkable hummocky or mammilated surface, already mentioned, which characterises this plateau, are features which it has in common with the Archæan plateau in general of which it forms a part. Taking the surface of Rainy Lake as a local datum level, there are few portions of the country that rise to an elevation of 100 feet in the immediate vicinity of the lake. The only exception to this is the ridge of schists on the north side of the lake between the Bear's Passage and Open water Narrows. This ridge attains a height of about 250 or possibly 300 feet above the lake. From its crest a vast sweep of country may be seen in all directions, and when travelling on the lake, it forms a prominent land mark. Further to the northward, the surface of the plateau slope has a general maximum elevation of 200 feet above the lake. Two or three notable exceptions may be mentioned, although they do not seriously affect the general statement. One of these is the group of conical or dome-like hills of granite or granitoid gneiss which rise to an elevation of about 300 feet above Lake Harris at its west end. This would be about 450 feet above

Hummocky surface.

Elevations.

Rainy Lake. These hills stand very prominently above the general level of the country and can be seen from Manitou Lake many miles to the north-east. Kishkutena ridge, which forms the divide between the waters running into Sabaskong Bay, and those running into Rainy Lake, is probably 500 feet above the assumed datum level. The land lying to the south of Crow Lake rises in an east-and-west trending ridge, which is in somewhat prominent contrast to the surrounding country. With a few exceptions like these, the surface is remarkably uniform in general elevation, within the limits mentioned; and it is only the endless diversity of detail, the ever-changing harmony of water, rock, and forest, in all the various atmospheric keys, that conceals the monotonous flatness of the region. Such being the general maximum elevation of the region, it becomes a matter of interest to ascertain the minimum elevation or maximum depression. All the depressions or basins of the plateau which have a continuous rim, nowhere as low as the bottom of the basin, are filled with water, and form lakes, each of which, under ordinary conditions, is in a constant state of overflow into the next lower basin. In very dry seasons, the overflow and evaporation exceed the amount of precipitation gathered from the country tributary to any particular basin, and the water of the lake is temporarily stagnant. This is particularly the case with lakes at the head of a chain. These head-water lakes are sometimes, as in the case of Kishkutena Lake, the largest of the chain to which they belong, and may, under the conditions mentioned, be seen with the level of their surface several inches lower than the rim of the containing basin at the outlet. To form an approximate estimate of the depth of the depressions in which these lakes lie, a series of soundings has been made, which, although by no means complete, affords sufficient data upon which to base an estimate of the general depth of the basins. A list of these soundings is given below. The figures indicate that the depth of these depressions, below the contour line afforded by the lake shores, approximates as nearly as can be judged to the general elevation of the country above that line. Thus, if land and water surfaces were in equal proportions, the level of the water would be the mean elevation of the rocky surface of the region; or rather the mean slope of the chains of lakes would be the mean slope and elevation of the plateau. But as the land surface very much exceeds the water, the mean elevation of the plateau must be somewhat higher than the shore line contour.

Highest point of Rainy Lake region.

Depressions.

Soundings.

Relationship of depressions to elevations.

Deepest lake.

The greatest depth of water anywhere observed was that of Pickerel Lake on the Manitou route, where the sounding showed a depth of 165 feet. The next deepest sounding was on Manitou Lake, where I found 158 feet of water as the maximum of a series of soundings in the lower

part of the lake. It is of interest to note that these maximum depths of water are in a line of depression which appears to be connected in origin with the fault observable at Cedar Narrows on Pickerel Lake. The lowest depression of the region is that of the south arm of Rainy Lake south of Little Rocky Narrows or opposite the mouth of Seine Bay, where the water is 110 feet deep. This is the maximum depth found anywhere on Rainy Lake, and taken in connection with the low level of the surface of the lake, compared with that of the other lakes draining into it, it gives for the bottom of the lake at this place the minimum elevation of the region. The maximum elevation of the region was found to be the summit of Kishkutena Ridge, which was placed at about 500 feet above the surface of Rainy Lake. The difference between the maximum and minimum elevation, or the range of altitude of the various parts of the plateau is thus 600 feet. Reference has not been made to the sea level, because the altitude of our local datum level is not known with sufficient accuracy to be of service.

Greatest depth in line of fault.

Maximum depth of Rainy Lake.

The following is a list of the various determinations that have been made for the elevation of Rainy Lake above the sea:—

Elevation of Rainy Lake above sea.

| | | FEET. |
|---|---|---|
| 1. | Colonel Lefroy, barometrical, as quoted by H. Y. Hind | 1,160 |
| 2. | S. J. Dawson, by way of Pigeon River route | 1,045 |
| 3. | " " Seine River " | 1,029 |
| 4. | " " Dawson route | 1,035 |
| 5. | Major Long (Lake Superior 595 feet.) | 1,100 |
| 6. | W. B. Kirkpatrick, by way of Manitou route | 1,094 |

I am inclined to regard the first of these determinations as being nearest the truth. Of S. J. Dawson's determination Nos. 2 and 3, are taken from his official report. They are based upon actual measurements of falls and estimations of rapids and currents on the two canoe routes mentioned, from Lake Superior to Rainy Lake. No. 4 is given by Hind in his report on the Red River exploring expedition, and credited to Mr. Dawson, with the statement that the level of Lake Superior is taken at 600 feet above the ocean. All three determinations are under-estimated. Since they were made the levels along the line of the C. P. R. afford an important check upon them. These levels place the surface of the Lake of the Woods at its lower end at 1,062 feet above the sea. The Rainy River affords abundant testimony of a very marked difference of elevation between Lake of the Woods and Rainy Lake. If we assign to the Coutchiching Rapids a descent of 5 feet; to the falls of Fort Frances, 22 feet; to the Manitou Rapids, 5 feet; to the Longue Sault Rapid, 10 feet; and to the general current of the river, which is remarkably strong and swift, a descent of 1 foot in the mile or 75 feet, all of which estimates are moderate, we would

Discussion of data for level of Rainy Lake.

have, as the difference of level between Lake of the Woods and Rainy Lake, 117 feet, to which may be added 3 feet for the difference in the level of the upper and the lower end of the Lake of the Woods, making a total difference of 120 feet. This added to the level of the Lake of the Woods, as determined by the C. P. R. engineers, would give us, as the elevation of Rainy Lake, 1,182 feet. Assuming its correctness, the highest land within the region mapped, the crest of Kishkutena ridge, is about 1,700 feet above the sea level; and the lowest hollow, Rainy Lake south of Little Rocky Narrows, about 1,072 feet above the same level.

### List of Soundings in Rainy Lake and in some of the Lakes Tributary to It.

| | Feet. |
|---|---|
| Manitou Sound, 1½ miles S. E. of Devil's Cascade | 39 |
| " " opposite mouth of Little Canoe R | 54 |
| Ash Bay, North arm | 80 |
| " West of Boreas Island | 32 |
| Channel between Boreas Island and Gube Point | 31 |
| Off S. E. shore of Argyle Island | 29 |
| Off S. E. shore of Boom Island | 25 |
| Alexandria Bay, north channel | 31 |
| Off south side, Cherry Island | 30 |
| One mile N. of Hanging stone Point | 23 |
| Half mile N. of N. W. end of Woodchuck Island | 27 |
| West of N. W. end of Woodchuck Island | 24 |
| North West Bay, Camp Narrows | 30 |
| " " opposite Brown Inlet | 35 |
| Off S. E. end of Woodchuck Island | 27 |
| Off West side of Rebecca Island | 36 |
| Off S. W. end of " " | 33 |
| Half mile N. N. E. of Standing-stone Point | 32 |
| Channel south of Chamberlin Point | 60 |
| North-east Bay, 4½ miles west of Frog Portage | 60 |
| " 3½ " " | 55 |
| Channel S. E. of Rebecca Island | 27 |
| " East end, Cheery " | 43 |
| " West " " | 42 |
| Off Tug Point | 50 |
| 1½ miles W. S. W. of Blaze Point | 57 |
| 2½ " " " | 63 |
| 2 " S.W. " | 72 |
| 1 mile N. W. of Reef Point | 60 |
| One mile W. of Reef Point | 45 |
| Between Homestretch and Risky Islands | 37 |
| ¾ mile S. of Homestretch Island | 38 |
| Opposite entrance to Stanjikoming Bay | 49 |
| " Hay Marsh Bay | 40 |

| | FEET. |
|---|---|
| Sand Bay | 23 |
| One mile S. S. E. of Little Rocky Narrows | 70 |
| Two miles S. " " | 110 |
| " S.E. " " | 105 |
| Channel between Dry Weed Island and south shore | 33 |
| Opposite mouth of Seine Bay | 105 |
| 2 miles E. of Hallelujah Point | 80 |
| 2 " E. of Brulé Narrows | 22 |
| 4 " E. " " | 60 |
| 5½ " E. " " | 74 |
| S. of Vague Point | 82 |
| S of Breezy Island | 59 |
| Off N. side of Oak Point Island | 59 |
| One mile S. W. of Pine Narrows, Redgut Bay | 45 |
| Opp. mouth of Crow Rock Inlet, " | 45 |
| " " Porter Inlet, " | 22 |
| Parry Strait, " | 6 |
| | |
| Mainville Lake, north end | 27 |
| " " middle | 18 |
| Obikoba Lake, south end | 16 |
| " " north " | 14 |
| Captain Cuttle Lake, south part | 31 |
| Sam Weller Lake | 16 |
| Twist Lake | 36 |
| Dog Fly Lake, middle | 68 |
| " " | 92 |
| | |
| South end of Grant Lake | 90 |
| Middle " " | 42 |
| North end " " | 126 |
| Sairey Gamp Lake | 27 |
| Lake Harris | 99 |
| Missus Lake | 75 |
| Lake, west of Missus Lake | 66 |
| | |
| Kaiarskons Lake | 118 |
| Furlonge Lake | 30 |
| | |
| Crack Shot Lake | 27 |
| Sakwite Lake | 63 |
| South end of Kahopskikomak Lake | 48 |
| Middle " " | 34 |
| Kahwawiagamak Lake | 45 |
| Memekwesi Lake | 67 |
| Down-grade Lake | 43 |
| Smooth-rock Lake Narrows | 76 |
| " " S. end | 30 |
| Windigons Lake | 87 |

| | FEET. |
|---|---|
| Pickerel Lake | 165 |
| Manitou Lake, opposite Snare Bay | 60 |
| " " N. E. of mouth of Hidden River | 96 |
| " " N. E. " Peep Bay | 158 |
| " " N. E. of Paddle Portage | 129 |
| " " 1¼ miles N. E. of Paddle Portage | 117 |
| " " 2 " " " | 87 |
| " " 2¾ " " " | 110 |
| Clear-water Lake, S. end near Burnt Narrows | 50 |
| " " middle | 56 |
| " " north end | 28 |
| First Quill Lake | 47 |
| Narrow Lake, S. W. end | 75 |
| " " middle | 122 |
| " " N. E. end | 40 |
| Height of Land Lake, S. end | 63 |
| " " N. end | 44 |
| Kishkutena Lake, near narrows | 52 |
| Kahtimiagamak Lake | 50 |
| Pipestone Lake, S. end | 105 |
| Three Island Lake | 50 |
| Bat Lake | 40 |
| Cold Lake | 42 |
| Strong Lake | 47 |
| Vane Lake, N. end | 60 |
| " S. end | 50 |

Average.

The average of the soundings in Rainy Lake, 51 in number, is 47·4 feet, which is probably not far from the average depth of the lake, as the depth of the water does not depend so much, in these rocky basins, upon the distance from shore, as it does in lakes lying in soft or shelving strata. The average of the soundings, 54 in number, in the lakes higher up on the plateau, is 63·6 feet, which represents not an average depth of these lakes, but rather their average maximum depth.

Dependence of contour upon geological conditions.

The intimate dependence of topographical contour upon geological conditions which was observed upon the Lake of the Woods is equally well exemplified upon Rainy Lake, and on the other lakes of the region. The shapes and disposition of the lakes and the trend of the ridges and depressions are always a function of the character and disposition of the rocks; and show that the agencies of erosion have acted along lines and with varying intensities, which were determined by the nature of the rock itself long before those agencies had access to it. This fact comes out much more strongly, of course, in those portions of the region which are occupied by the schists of the Keewatin and Coutchiching series, or in the more gneissic portions of the Laurentian, than

in the more granitoid portions of the latter. Still the principle is well illustrated even here by the irregular shape of the lakes, and the more irregularly hummocky character of the surface. Since in the more granitoid country there are few or no structural lines to give direction to decay and erosion, and these, therefore, act with equal ease in any direction.

Leaving the lakes which lie in the more granitoid of the Laurentian gneisses, and passing to the consideration of those lying in more evenly laminated or schistose rocks, it will only be necessary to draw attention to a few of the many instances which illustrate the principle in order to emphasize its force. Beginning with Rainy Lake itself, we find that it consists of two main arms, an east arm and a north arm, diverging at right angles from its outlet at the south-west corner. The east arm comprises three distinct basins or troughs, viz.:— Illustrations of this dependence.

1. From the outlet at Coutchiching to the bottom of Swell Bay, a trough 20 miles long and very narrow, compared with its length. That portion of it which is east of Open-water Narrows has an average width of one mile and its axis or mean course is 70°. The portion west of Open-water Narrows has a bearing from the narrows to Coutchiching of 75°, and its average width is something over two miles. A glance at the geologically colored map will show that these bearings are very closely those of the mean strike of the rocks at these two portions of the trough. First trough.

2. From Grassy Narrows to the bottom of Seine Bay, a trough 21 miles long. The axis measured along the longest line of open water has a bearing of 76°. The trough has a width, at its middle part, of about four miles and tapers towards Grassy Narrows almost to a point while to the eastward it passes into Seine Bay, a stretch of water seven miles long with parallel shores one mile apart. Second trough.

These two troughs are separated by a long, narrow, tapering ridge of rocks, which, westward of Little Rocky Narrows, is continued in a belt of narrow, elongated islands, separated by very short transverse channels. This dividing ridge has a trend coincident with that of the water-filled troughs on either side of it, and strictly coincident with the mean strike of the schists of which it is composed. Separating ridge between troughs.

The parallelism of the shore lines which form the rim of this second trough or basin to the strike of the schists is everywhere observable even in great detail. The divergence of the shores which makes the middle of the basin wider than the ends, is due to a similar divergence of the strike, the rocks on the north side having a strike of about 75°, while on the south shore, from Black Bay to Brulé Narrows, the strike is east and west. Dry-weed Island and the islands near the mouth of Seine Bay and Brulé Narrows are all long and narrow, and have their longest axes parallel to the strike of the rocks.

Seine River, a continuation of second trough.

The Seine River and its lake expansions forms a trough whose mean axis is strictly parallel to that of the trough just described. The trough extends from Bleak Bay, with a bearing of 75°, 22 miles to the limit of the region mapped. The minor deviations from the mean line or axis always follow curves in the strike of the rocks.

Third trough.

3. The last of these troughs or basins which, together, make up the east arm of Rainy Lake, is that which lies between Brulé Narrows and Kettle Falls. It is separated from the second trough by points of land which approach each other at Brulé Narrows. Its greatest length is 19 miles along the line extending on a bearing of 97° from the bottom of Saginaw Bay to the bottom of Stokes Bay. This line of greatest length is not, however, the true axis of maximum erosion, and to bring out the parallelism of the maximum erosion and of the trend of the shore lines to the strike of the rocks, it will be necessary to regard this trough as made up of two sub-troughs. The axis or longest diameter of the first of these extends 85° from the bottom of Saginaw Bay, 13 miles to the bottom of Cormorant Bay. This line coincides very closely with the mean strike of the rocks. The second sub-trough extends from Big Island to the bottom of Stokes Bay, a distance of 12 miles. Its axis and the mean strike of the rocks, from which there is but little deviation, are both east and west.

Composed of two sub-troughs

North arm of Rainy Lake, its cross-shaped basin.

The north arm of Rainy Lake has a trough which takes the form of a cross. The portion of the trough corresponding to the larger bar of the cross, often 5 to 6 miles wide, has for its mean course a due north-and-south line extending from the south shore of the lake past Squall Point to the vicinity of the Devil's Cascade, a distance of 24 miles. The portion corresponding to the transverse or narrower bar is somewhat curvilinear, concave to the north, and extends from the west end of the North-west Bay to the east end of Redgut Bay, by way of Frog Portage, a distance of 38 miles. The whole of this cross-like basin lies in Laurentian gneiss, which is, for the most part, distinctly foliated or laminated; and both the N. and S. and the E. and W. trending troughs, which together form the basin, conform strictly to the strike of the planes of foliation of the gneiss. The irregularities and apparent exceptions to the rule are due, for the most part, to masses of granite which cut the gneiss in places. From the Devil's Cascade at the extreme north end of the lake down to the entrance to the North-west Bay on the west side, and to the entrance of the North-east Bay on the east side, this coincidence of shore line with the strike of the rocks is perhaps best exemplified. From the Devil' s Cascade southward, the trend of the rocks diverges, curving around on the one side so as to strike up the North-west Bay, and thence through Foot-print Lake, Jack-fish Lake and Loon Lake, the strike of the rocks making a complete circle, and

Coincidence of shore line with strike.

closing again on itself at the Devil's Cascade. This circular disposition of the foliation is closely followed by the shores of Manitou Sound, Ash Bay, Alexandria Bay, the Islands of Manitou Sound, the shores of the North-west Bay and the lakes above named. On the other side, the curve of the strike is first to the south-east into the North-east Bay, and then east through Macdonald's Inlet, Black Sturgeon Lake, Crow Rock Inlet and Redgut Bay. Where the rocks cross the lake with an east and west trend, the long axes of the islands all lie in the line of strike. From Standing-stone Point southward, the rocks curve around from east and west to north and south, and the shore and off-lying islands have the same trend. On the east side of the lake, between the North-east Bay and Gash Point, the shores of the bays and the more prominent points are coincident with the strike.

Circular disposition of strike of gneisses.

Among the more striking instances of the minor lake basins showing parallelism of contour to the strike of the schists in which they lie, may be mentioned the following: Narrow Lake, north of the N. E. end of Sabaskong Bay; the south part of Crow Lake; the whole of the waters of the canoe route from the south-east end of Crow Lake to the North west Bay of Rainy Lake by way of Boulder, Schist, Pipestone, Link, First Quill, Clearwater, Minomin, and Despair lakes. This chain of lakes forms a Z-shaped trough lying almost entirely in the Keewatin schists. The two sharp bends in the water course, at the N. E. end of Pipestone Lake and at the south end of Clearwater Lake, correspond closely to two sharp bends in the strike of the rocks. The lakes are all narrow in proportion to their length. Manitou Lake, Grant Lake, Missus Lake, Strawberry Lake, and other smaller lakes in this portion of the Keewatin belt, are remarkable for the fidelity with which they adhere to the strike of the rocks and for their long, narrow shapes. The exceptional case of Pickerel Lake, with its irregular shape and long axis, transverse to the strike, finds its explanation, doubtless in the two granite bosses which interrupt the strata, and in the fault which dislocates them at Cedar Narrows. Dog-fly and Vista Lakes conform in their general contour to the strike of the rocks, but are somewhat irregular in shape as are most basins eroded out of agglomerates. Kahopskikamak and Sakwité lakes on the Otukamamoan route, Little Turtle Lake, Tésup, Big Sawbill, Otter and Mainville lakes, are notable instances of basins in Laurentian biotite gneiss which are long and narrow, and have their shores determined by the position of the planes of foliation. These various instances here cited are only the more prominent ones which come out in the mapping, but on the scale on which the map is published there is a host of details lost, in which the topographical contour is in the closest dependence upon the character and structure of the

Instances of minor lake basins coinciding in shape with strike of rocks.

Exceptional case due to fault and irruptive granite.

rocks. This dependence impresses one very forcibly in the field, but cannot here be more than alluded to, except where, as above sketched, it affects the main topographical features of the region.

*The Alluvial Plain or River Country.*

Extent of alluvial plain.

Its slope.

The wooded plain which extends from the south-west corner of Rainy Lake to the Lake of the Woods is on a slight but distinctly lower level than that of the "rocky lake country." Its slope is apparently the continuation of that of the rocky plateau just described. The highest part of the plain, so far as I was able to observe, is where the scarped face of the bedded clays which underlie it overlook Rainy Lake near Coutchiching, with an elevation of 10 or 12 feet above the surface of the lake. Down the Rainy River to the Lake of the Woods, the plain has practically the same slope as the river, and on the Lake of the Woods between Hungry Hall and 49th parallel, the edge of the plain has an elevation of from 10 to 20 feet above the surface of the lake, and according to Mr. Bolger* extends back with "extreme levelness" over townships one and two, south ranges XXIII and XXIV. Between these two points of maximum and minimum elevation of the surface of the plain, the slope is apparently gradual and uniform, the average incline in a W. N. W. direction, being probably two feet in the mile. Occasionally, as to the north-west of the Indian Reserve at the Longue Sault on Rainy River, the country is rolling or undulating, an appearance which is probably due to the ridged character of the concealed rocky surface, at a place where the covering of post-glacial deposits is thinner than usual. Occasionally too, a knob of rock projects through these deposits, which has been either exposed by local denudation of the clays, as at different rapids of the river, or which appears to have been a small islet in the vast lake in which these deposits were laid down. Such island-like knobs of rock have usually a more or less distinct formation of shore gravel about their base, as, for instance, the knob which projects above the plain on the northern limit of the Longue Sault Indian Reserve, or the portion of trap dyke observed at the back of Mr. Lutterel's farm. The uniform flatness of the plain affords no depressions which serve as lake basins, and none are known beyond a few mere ponds. Drainage is effected by the numerous creeks and rivers which flow into the Rainy River. These all cut channels down through the clayey strata, and afford excellent sections of a thickness varying from 10 to 30 feet. The most important tributary, on the Canadian side, is Pine River, a narrow stream, sluggish at low water, whose principal branches flow in the bottom

Rock exposures

Drainage.

* Report, Commissioner of Crown Lands, Ontario, 1886, p. 48.

of the low valleys in the undulating surface above referred to. Several much larger streams feed Rainy River from the American side. The undrained water rests on the surface of the plain in the form of muskegs and swamps. Mr. Bolger estimates that "perhaps 30% of the area is swamp, most of which can be drained and made tillable land." Rainy River has, at the mean height of the water, a depth which, from a number of soundings in mid-stream, appears to vary from 15 to 21 feet. At the Longue Sault and Manitou Rapids it is, of course, shallower, but not so shallow as to obstruct navigation except at very low water, when the boulders in the channel of the Longue Sault obstruct the passage of the small screw-steamers which ply between Rat Portage and Fort Frances. The serious obstacle to navigation is the falls of Fort Frances. The completion of the locks at Fort Frances, all the heavy and expensive work of which is done, would extend navigation very much, and stimulate the development of this portion of the country. The general features of the river have been well described by Bigsby*, Hind†, Long‡, and S. J. Dawson§.

Extent of swamp.

Depth of Rainy River.

Lock at Fort Frances.

## ARCHÆAN GEOLOGY.

### GENERAL STATEMENT.

The Archæan rocks of the Rainy Lake region, like those of the Lake of the Woods, are clearly separable primarily into two main divisions, viz.: An upper, chiefly schistose, bedded, and metamorphic: and a lower, of the granitic or syenitic type of mineralogical composition, but mostly gneissic in structure. In the upper division there can be recognized at least two distinct groups. One of these is identical with the Keewatin series of the Lake of the Woods,¶ and has been traced stratigraphically in direct continuity with it. The other is prominently developed in the southern part of the region, and occurs between the base of the Keewatin series and the Laurentian. Being unable to correlate this second series with any with which I am acquainted, I have named it, in a preliminary notice ** of the geology of the region, the Coutchiching series. †† In the lower division distinctions of stratigraphical sequence and relationships, if any such ever existed, have been obliterated. For this assemblage of rocks or lower division of

Upper and Lower Archæan

Distinctive characters.

Keewatin series.

Coutchiching series.

* Geol. Journal, Vol. VII, 1851, and Vol. X, 1854.
† Report of the Red River Exploring Expedition, 1858.
‡ Sources of Peter's River, Keating, 1825.
§ Appendix to XVII Vol. of Journals of Legislative Assembly, 1859.
¶ Annual Report, Geological and Natural History Survey, 1885, Part CC.
** Am. Jour. Sci., Vol. XXXIII, June 1887.
†† This series presents interesting lithological resemblances to the Montalban series, but has not the geological position which has been assigned to the latter.

the Archæan, the term Laurentian is retained. The Laurentian rocks in this particular field can be classified only on a petrographical basis. The different kinds of rocks which are comprised within the assemblage so named are susceptible of a geographical separation into zones or areas, but, as above stated, are not geologically separable into strata or bedded formations, though often stratiform.

Schematic representation.

The leading divisions of the Archæan for this region may, from what has been stated, be arranged in the following scheme, according to the order of which the geological features of the region will be considered in detail:—

| | | |
|---|---|---|
| Archæan. | Upper division. | *a.* Keewatin.—(Huronian ?) |
| | | *b.* Coutchiching. |
| | Lower division.—Laurentian. | |

A more comprehensive statement of the results arrived at, together with a discussion of their theoretical bearing, will be given in the summary, after the facts, upon which these and other generalizations are based, have been set forth.

## Keewatin Series.

### *Limits of the Area of the Keewatin Rocks—Conditions of Contact with Lower Rocks.*

Keewatin series on Lake of the Woods.

At the S. E. corner of the Lake of the Woods map, 1885, the Keewatin rocks are represented as in contact with the Laurentian gneiss on the shore of Sabaskong Bay, at a point a little to the east of the portage road which leads from that bay to Arrow Lake, through the Indian Reserve 35 C. From this point eastward, the line of contact curves to the north, around the extreme N. E. inlet of Sabaskong Bay, the trend of the shore being approximately parallel to the curvature of the line of contact. The shores of this inlet are all very coarse granitoid gneiss or granite. The contact line lies in the ridge of land which divides the waters of Sabaskong on the south from those of Arrow Lake and Crow Lake, on the north and north-east, and runs much closer to the former than to the lakes named. The last exposure on the Lake of the Woods at which the Keewatin rocks and the Laurentian gneisses are seen in contact is at the northern extremity of the S. E. arm of Sabaskong Bay, close to the south end of Crow portage. In coming over Crow portage, from Crow Lake to Sabaskong, the rocks passed over are black-green, hornblende schists. They are first seen about one-third of the way from Crow Lake, with a strike of 130° and dip at high angles to the north-east. Four chains farther south they have a strike of 140° with

Rocks on Crow Portage.

the same dip. Beyond this to the end of the portage they are seen at intervals with a uniform S.E. strike; dip N. E. At the end of the portage, on the shores of the bay, on the west side, the schists come in contact with a medium-grained, flesh-tinted, or reddish to grey, biotite gneiss, which exhibits, for the most part, a very distinct and even foliation of the constituent minerals, quartz, felspar and biotite. This foliation is approximately parallel to the schistosity of the hornblende schists; the contact is, however, a brecciated one, the gneiss being apparently injected into the schists, which seem to have been more or less shattered in a brittle condition, so as to admit of the passage of the gneiss in its former soft and plastic state within the fissures of the schist, which are sometimes parallel and sometimes transverse to its cleavage planes. The strike of the rocks at the contact is 130°, dip N. E. < 60° to 70°. Contact of Keewatin and Laurentian.

The next place where this line of contact was crossed by our surveys is on Kah-timi-agamak Creek. The interval between the last described point of contact, at the south end of Crow portage and this creek is about nine miles. But although the line of contact has not been actually traced out for this interval we know that it must occupy approximately the position given to it on the map, from our knowledge of the distribution of the Laurentian rocks to the south, on the shores of Sabaskong Bay, Kah-kabik-kitchiwan Lake, Crooked-pine Lake, Big-pine Lake and Wigwam Lake, and of the Keewatin rocks to the north on the shores of Crow Lake and Kah-timi-agamak. The contact of the gneiss and hornblende schist occurs on the creek about half way between Wigwam and Kah-timi-agamak lakes. The actual contact is not well exposed, but the rocks on either side can easily be traced along the creek and shew that a very granitoid, reddish, biotite gneiss comes in contact with a dark, green, hornblende schist, which gives way, a little further up the creek, to green agglomerate schists. Contact on Kah-timi-agamak Creek.

To the south-eastward of Kah-timi-agamak Creek the line of contact appears to continue in the same general direction for about four miles, when it begins to curve around to the south, so that on the north side of Night-hawk Lake, where the contact is next seen, the strike is about north and south. Following it across Night-hawk Lake and thence for nearly a mile and a-half to Kishkutena Lake, we find that the line of contact curves rapidly to the S. W., and from the last named lake onward it has a course which makes an angle of 70° degrees with that which it formerly held between the south end of Crow Portage and a point to the north of Night-hawk Lake. The west side of Night-hawk Lake is occupied by a rather coarse, reddish, granitoid, biotite gneiss or granite, composed of quartz, in large grains, and orthoclase in about equal proportions with a subordinate proportion of biotite. This rock Contact at Night-hawk Lake.

is not only observed to occupy this shore of the lake, but is seen to make up the bare burnt hills which extend for some miles to the westward. The east side of the lake is occupied by the Keewatin rocks which form a comparatively high ridge with an abrupt face to the north-west. This ridge runs from this point south-westward for several miles and extends to the south of the 49th parallel, forming the divide between the waters flowing into the Lake of the Woods and those flowing into Rainy Lake. The rocks of the Keewatin series which compose this ridge, particularly on its north-west side, differ from the ordinary hornblende schists which are usually found in contact with the Laurentian gneisses, in being very much more compact and often quite devoid of schistose structure. The rock appears, to the naked eye, to be, like the schists, composed mostly of hornblende, but has, in addition, numerous large porphyritic crystals of white felspar, studded all through it, so that on the large scale, on the face of a cliff for instance, the rock presents a distinctly and curiously mottled aspect although in hand specimens it is often difficult to get more than one or two porphyritic crystals. This rock is very probably an altered porphyrite, and grades into more schistose varieties with the disappearance of the felspar. The same rock has been noted at the contact of the Keewatin series with the Laurentian on the north side of White fish Bay, Lake of the Woods.* The contact of this altered porphyrite with the granitoid gneiss runs along the base of the cliff which forms the north-west side of the ridge above mentioned, and as the rocks are well bared, may be traced easily from the south end of Night-hawk Lake to the N. E. end of Kishkutena Lake.

Kishkutena Ridge.

The rocks composing the ridge.

The granitoid gneiss is here mixed, only to a very limited extent, with the Keewatin rocks, a fact doubtless due to their unusual compactness and toughness at this locality. At the north-east end of Kishkutena Lake, one-quarter of a mile from Kishkutena portage, the actual contact is not exposed, and between the nearest exposures of the granitoid gneiss and the porphyrite, there is a small exposure of a greenish, grey quartz porphyry made up of an aphanitic ground-mass in which are imbedded crystals of felspar. Whether this porphyry is only a local porphyritic facies of the granitoid gneiss, or whether it is a later intrusion, or even an older formation incorporated with the porphyrite, there is no evidence to determine. For two miles farther to the S. W., the line of contact runs under the waters of the lake, the rocks on one side of the narrow arm being the altered porphyrite of the Kishkutena ridge, and those on the other the Laurentian granitoid gneiss. This gneiss is here often quite devoid of foliation and is then more properly a granite, though both the foliated and non-foliated

Quartz-porphry at contact.

Continuation of the line of contact.

* v. Annual Report, 1885, pp. 38-39 cc.

varieties are part of the same geological mass. After leaving the south side of Kishkutena Lake, the line of contact of the Laurentian and Keewatin rocks continues for five miles in the same S. W. course, and is next intercepted on Little Kishkutena portage one mile south of the 49th parallel. The conditions of contact are here quite analagous to those noted between Night-hawk Lake and Kishkutena Lake. The same ridge of Keewatin rocks composed of hornblende schists and altered traps, schistose or massive, has been traced for six miles farther to the S. W. through the lakes of the Little Kishkutena route to the west end of Off Lake. Here the schists have a strike of 50° and dip to the S. E. at $< 70°$. Throughout this distance the actual contact of the Keewatin rocks on the N. W. side of the ridge with the Laurentian gneisses has not been observed, but there is little doubt but that it follows the same line as to the N. E. of Little Kishkutena, the strike of the rocks and the trend of the country remaining constant. To the west and south-west of Off Lake the country becomes low and flat, with little or no exposure of rock, so that the course of the contact of the Keewatin rocks with the gneisses cannot be accurately determined. The rocky surface of the country passes under the post-glacial deposits of Rainy River valley, and for 16 miles, in the direction of the strike where last observed at Off Lake, we have no evidence as to the distribution of the rocks. The black, green, hornblende schists of the Keewatin are next seen in considerable volume on Rainy River. They crop out along the river from a point about one-quarter of a mile above the Longue Sault Rapids to near the foot of the same, where they appear to be in contact to the south with a rather coarse-grained, reddish, granitoid gneiss, which is exposed on two small islands at the foot of the rapids opposite the chief's house. The strike of the schists along the rapids is with the direction of the river or E. and W., and the dip is northward at angles which are, at places, as low as 45°. In passing northward from the river through the woods on the Indian Reserve, the schists are occasionally observed projecting through the soil, and on the northern limits of the reserve between four and five miles from the river, across the strike of the schists, they are exposed over several acres on the crest of some *roches moutonnées*, and have a strike of 80° with a southerly dip at an angle of 65°.

Contact on Little Kishkutena Portage.

Keewatin rocks on Rainy River.

On a small creek that empties into Rainy River about three miles and a half below the Longue Sault, I am informed by Mr. Cameron, who resides on the river near the place, that there is a small exposure of similar schists, and that on a logging road, which runs four miles back from Rainy River, there are three other exposures of similar rocks.

The next place where I have seen these rocks myself is where they are crossed by Pine River some seven miles west of the exposure

Keewatin rocks on Pine River.

described on the north side of the Longue Sault Reserve. At the first rapids on Pine River, about four miles up from Rainy River, a fine-grained, green, compact, hornblendic rock is exposed with a schistose structure only slightly developed in it. For a mile and a-half farther up Pine River, to the second rapids, there are several exposures of the same rock. From this point, up stream, as far as it is possible to travel, there are no further rock exposures.

Thus combining all the evidence at our disposal regarding the distribution of these Keewatin rocks on the north side of Rainy River, below the Longue Sault, we find that they have an extensive development; and although they are for the most part concealed by post-glacial formations, it appears to be tolerably certain that they have a breadth across their strike of at least eight miles. The main branch of Pine River flows in a W.S.W. direction in a shallow valley which has for its southern boundary a fairly well marked ridge. This ridge, though covered with soil and well rounded, is, I take it, the continuation of the Kishkutena ridge, which makes itself apparent in spite of its mantle of post-glacial formations. It was found at Night-hawk Lake, Kishkutena Lake, and at Little Kishkutena portage, that the line of contact of the Laurentian gneiss and the Keewatin rocks lies in the valley or depression which skirts the Kishkutena ridge on its north-west side, and it seems probable that the conditions which were observed there continue to prevail to the south-west, so that the valley of the main branch of Pine River corresponds with that in which lies Night-hawk, Kishkutena and Little Kishkutena Lakes, and the line of contact of the Laurentian and Keewatin coincides approximately with the course of Pine River from Sec. 36, tp. 3 S., R. XXVI, to Sec. 18, tp. 3 S., R. XXV.

Kishkutena ridge indicates probable line of contact.

Other exposures on Rainy River.

West of Pine River, the next exposure of the Keewatin rocks on Rainy River is at the mouth of Rapid River on the American side. The rocks here are not, however, hornblende schists or altered traps, but fine-grained, grey, compact, clastic rocks, such as occur in the upper portion of the Keewatin series. They are distinctly bedded and in places slightly schistose and micaceous, and dip N. W., $< 60°$, the strike corresponding with the course of Rainy River immediately above Rapid River. The only other formations observed on Rainy River, from Rapid River down to the Lake of the Woods, are of post-glacial origin.

Keewatin and Laurentian rocks on S.E. coast of Lake of the Woods.

At the mouth of Rainy River and on the south-east shore of the Lake of the Woods, between Hungry Hall and Little Grassy River, we again meet with the Keewatin rocks, although only in isolated exposures, and then much mixed with the Laurentian gneisses. This portion of the lake is unique in running transverse to the strike of

the rocks, a circumstance due, probably, to the fact that the shore is made up of rocky points, with sands and other post-glacial matter filling up the intervening hollows. Were the loose deposits removed, we would have, as is the general rule in this region, long, narrow bays or channels occupying their place, and lying between the ridges which terminate on the lake shore in the rocky points above mentioned. On these points and at the mouth of the river, the rocks are found to have a very regular strike of W.N.W. to N.W. and it would seem that to the westward of Pine River they gradually curve around from an E. and W. strike to one having a bearing of W. N. W. and then N.W. This inference is borne out and supported by the fact, that the bed of Rainy River curves around precisely in the way indicated, and the close dependence of the physical features of the country upon the geological structure gives such a fact great significance, where direct evidence as to the structure is wanting. Wherever rock exposures have been noted on Rainy River, the strike has been invariably coincident with the course of the river at the particular place where the rocks crop out, and there is good reason for believing that where they are not so exposed, the course of the river indicates the strike of the underlying rocks.*

Evidence of strike drawn from topography.

At the mouth of Rainy River, on a small island near Michel Morriseau's house, and on the lighthouse plot, there are exposed rather massive, black, green, crystalline, hornblende schists, which are composed sometimes of hornblende only, and sometimes of hornblende and felspar. These schists strike N.W. Following the shore northward there is no other rock exposure for six miles, when a low point juts out of the sand which is mostly made up of black, green, hornblende schist, striking 100° to 110°, but with considerable biotite gneiss. The latter is often associated with the schist so as to produce a very evenly banded appearance, but here and there the gneiss cuts the schist transversely, as if the gneiss had been injected along the planes of cleavage of the schist and thus produced the banded appearance presented. Half a mile farther along the shore, a similar point is composed entirely of black-green, hornblende schist, strike 110°, dip vertical. On Burton's Island, the rock is a grey, biotite gneiss, strike 100°, and similar rock occupies the small bare islet just to the north-east of it. On the neck of land which runs out from the main shore, about half a-mile to the N.E. of Burton's Island, the rock is a mixture of hornblende schist and biotite gneiss, often presenting a remarkably even ribanded aspect, but still affording sufficient evidence of the intrusive character

Observations on S.E. coast of Lake of the Woods.

Burton's Island

* Dr. Bell observes in his report for 1873-74, on much less evidence than is at my disposal, that "there is reason to believe that under these superficial deposits a broad band of Huronian (Keewatin) rocks crosses the lower section of the river."

of the gneiss. The strike is here 120°, dip vertical or north at very high angles. Half a mile farther north, the same mixture of hornblende schist and gneiss is observable, strike 115°. On a small shoal about half-way between Burton's Island and the south end of Bigsby Island, which is strewn with huge angular boulders of gneiss, the rock is hornblende schist, strike 155°. On the extremity of Windy Point and on Buzzard Island, as well as the extremity of the point of land which forms Indian Reserve 35 E. the same mixture of hornblende schist and gneiss occurs, the prevailing strike being 145° to 150°, and the dip either vertical or to the north, at angles not less than 75°. On the shore south of the mouth of the Little Grassy River the rock is biotite gneiss. North of the Indian Reserve 35 E, the only rocks exposed are gneisses.

Windy Point.

Little Grassy River.

Thus the trough of Keewatin rocks, one of the confines of which we have traced, with varying degrees of certainty, from the N.E. corner of Sabaskong Bay, and indeed from the extremity of Rabbit Point,* in a sort of a horse-shoe curve, around by the south of Kah-timi-agamak Lake, along the north-west side of the Kishkutena ridge and the south side of the Pine River valley, out to the Lake of the Woods again, appears, as it emerges upon the lake, to be very shallow and diffuse. All that remains apparently of the voluminous series of schists are the bottoms of in-pinched folds, much mixed with the gneiss, in which, in its once soft and plastic state, they appear to have been immersed. To define the limits of the belt in its scattered, diffuse and brecciated condition is not possible, and it only remains to be noted that it is extremely probable that the belt, which has been traced, as above indicated, for five-sixths of a complete circuit, once closed upon itself, before excessive denudation removed the other sixth whose place is now occupied by the waters of the Lake of the Woods between Rabbit Point and Windy Point.

Diffuse character of Keewatin trough on S.E. coast of Lake of the Woods.

Having thus traced out, as closely as field conditions will allow, one of the limiting edges of the Keewatin belt along its line of contact with a great central, more or less circular or elliptical mass of Laurentian gneisses, we may cross the belt at any point and proceed to examine the limits of its distribution to the eastward. We may begin the tracing out of the more easterly edges of the area of the Keewatin rocks in the neighbourhood of Clear-water Lake on the Kishkutena route. Here the belt is narrowest, being not more than three miles wide in a direction transverse to the strike, which is about N.E. and S.W. In crossing the belt, from the granitoid gneiss on the one side to the same rock on the other, we pass over the upturned edges of strata which lie in a sharply folded trough. The rocks on Clear-water

Limits of Keewatin rocks to the eastward.

Clear-water Lake section.

* v. Annual Report, 1885, p. 77, cc.

Lake which occupy the middle of the trough, or the upper portion of the Keewatin series, are very largely volcanic rocks of an acid character, being mostly felsites more or less slaty and schistose, glossy sericitic schists, and felsitic agglomerates (altered quartz-porphyries and their tuffs) with, however, some more basic rocks such as serpentine and agglomerates, or conglomerates (?), in which the matrix is a green, rather massive schist and the inclusions blotch-like masses of felsite. The sides of the trough or basal portions of the series are made up of altered traps and black hornblende schists. On the east side of the trough, portions of the basal formations of the series have been removed by the disturbance associated with the irruption of the great mass of granitoid gneiss with which the belt is in contact, so that the granitoid gneiss comes against the higher formations of the series, or the middle portions of the trough. This mass of Laurentian gneiss on the east side of the Keewatin belt on Clear-water Lake will be found to be the counterpart of the large circular or elliptical mass of Laurentian gneiss described as encompassed by the Keewatin belt from Rabbit Point around by Sabaskong, Kishkutena, and Rainy River to Windy Point on the Lake of the Woods again. In general shape, dimensions and character of rocks composing it, as well as in the nature of their relations to the belt of rocks encompassing them, the two masses or areas are perfectly analagous. I shall, therefore, proceed as before to trace out in such detail as is possible the contact of the edge of the Keewatin belt with this central mass of gneiss, so that there may be no misunderstanding as to the data upon which the mapping is based, nor any confusion between what is observed fact and what conjectural. The most northerly exposure of this contact on the east side of the Clear-water is at the bottom of Sunny Cove three miles and a-half from the north end of the lake. The Keewatin series is represented at the contact by a grey felsite schist with quartz grains (altered quartz-porphyry) which, towards the contact, merges into a fine grained grey gneiss by reason of the development of biotite in plates which lie in the schist planes. The Laurentian gneiss is coarse grained, reddish to gray in color, very quartzose and only very feebly and indistinctly foliated, and in places not at all. The west and south shores of Sunny Cove are occupied by this granitoid gneiss, and also the shore of the lake for nearly half a mile south of the cove to a point directly opposite Hazy Point. South of this the shore is occupied for about one mile by the Keewatin rocks. At the contact opposite Hazy Point an agglomerate made up of a rather massive green schist matrix with blotches like felsitic inclusions comes in contact with the gneiss. This agglomerate, together with a much larger proportion of felsite schists with quartz grains (quartz-porphyries), occupies this mile of

Central schist-encircled area of Laurentian

Contact of Laurentian and Keewatin on Clearwater Lake.

Character of rocks.

shore to the entrance of Gloomy Cove, where the altered quartz porphyries come in contact with the granitoid gneiss, which is here very distinctly foliated in contrast to its more granitoid aspect at Sunny Cove. As before, when the altered quartz-porphyries approach the Laurentian gneiss the alteration becomes more and more pronounced, and they pass into fine grained, gray gneisses by the development of biotite, so that there can be no doubt but that this passage, from a quartz-porphyry to a fine grained gray gneiss, is the result of contact metamorphism, or, more generally, to a metamorphism of disturbance analogous to that which Lehmann states has produced the granulites of Saxony. From the north side of the entrance to Gloomy Cove the shore of the lake and one or two of the off-lying islands are occupied by the Laurentian gneiss, to a point on shore a mile and a-half southward, measured in a straight line. At this point, which is at the mouth of a small stream, half a mile south of Burnt Narrows, the Laurentian gneiss is again observed in contact with the gneissic modification of the altered quartz-porphyries of the Keewatin. On the west side of the lake, less than half a mile from the contact, the Keewatin rocks have been much less affected by the metamorphosing influences of the Laurentian gneiss, and consist of what are ordinarily termed felsite schists (quartz-porphyries), and felsitic agglomerate schists. All along the east side of Clear-water Lake the dip of the schists is to the east or under the Laurentian gneiss at angles varying from 70° to 80°. From the neighbourhood of Burnt Narrows on Clear-water Lake, the trend of the line of contact between Laurentian and Keewatin bends around to the south-east very sharply, in accord with a similar sharp bend in the strata of the eastern portion of the Keewatin belt, and is next seen at a point about five miles and a half distant on the shore of Lake Despair. Here a band of black-green, hornblende schists, the regular basal formation of the Keewatin, comes in between the Laurentian gneiss and the fine grained gray gneisses of the central portions of the Keewatin trough, which are presumably the alteration products of quartz-porphyries. This band of hornblende schists is well exposed on Lake Despair for a distance along the strike of two miles and a-half, and across its entire breadth. Associated with these schists at the bottom of South Bay is a considerable mass of serpentine which will be referred to again. The schists appear to constitute the true basal member of the Keewatin series. The Laurentian rocks with which they are in contact to the north-east are for the most part coarse-grained, reddish to gray, hornblende syenite gneisses, with a sparing amount of quartz and biotite, the latter often appearing to be merely an alteration product of the hornblende. The gneissic foliation is quite distinct. The dip of the schists is uniformly to the north-

Alteration of quartz-porphyry schists to gneisses near the contact of the Laurentian gneiss.

Dip of the Keewatin rocks under the Laurentian gneiss.

Bend in the trend of the rocks.

Hornblende schists on Lake Despair.

Serpentine in middle of the band.

east, or under the Laurentian gneisses, at angles varying from 60° or 65° to 70° or 75°, and the planes of foliation of the Laurentian gneiss are approximately in the same position. In its north-westward prolongation, this band of hornblende schists appears to thin out and disappear at the present surface, since they do not occur, as has been noted, at the contact of the Laurentian with the Keewatin observable near Burnt Narrows on Clear-water Lake. This thinning out is probably not due so much to an original lenticular deposition as to removal by absorption or displacement, incident to the irruption in a state of fusion of so large a mass of granitoid gneiss. With regard to the question of removal by absorption, it is interesting to note that the Laurentian granitoid gneiss on Clearwater Lake, where it comes in contact with the acid altered quartz-porphyries, is a quartzose, biotite granite gneiss, whereas, on the other hand, where it comes in contact with the more basic, hornblende schists on Lake Despair it is a hornblende syenite with, for the most part, only a small proportion of quartz. The occasional occurrence, in certain portions of the gneiss on Lake Despair of a large proportion of quartz, such as would constitute it a granite gneiss, seems indicative of an imperfect mixture.

Thinning out of schists, and its probable explanation.

On the shores of South Bay of Lake Despair, this band of hornblende schists has a breadth across the strike of at least half a mile. In its southward prolongation from this point the band appears to curve around to the south-west, and to strike in the direction of Rainy River, in the neighbourhood of the Longue Sault, where the schists are next seen in considerable volume as already noted. In the interval between the South Bay of Lake Despair and Rainy River, however, the country is mostly covered by post-glacial deposits, and the continuity of the rocks cannot be traced.

Continuation of hornblende-schists of Lake Despair.

North-eastward from the middle of the east side of Clear-water Lake the actual contact of the Keewatin and Laurentian has not been traced out for several miles. The distribution of the rocks on either side of it has, however, been established so well that the line can be mapped with approximate precision. The west side of the north end of Clear-water Lake and all the shores of First Quill Lake, Narrow Lake, Link Lake, and Pipe-stone Lake, are occupied by Keewatin rocks which are mostly altered traps and hornblende schists. A long ridge of these schists runs down the S. E. side of Pipestone Lake with a strike of N.-E. and S.W. This ridge is crossed at two places by depressions through which waters from the south flow into Pipestone Lake, and at each of these places the contact can be accurately located. The first of these is at Stone-dam rapids where Stone-dam Lake empties into a bay of Pipestone Lake. A short distance above the rapids the schists give place to a rather coarse-grained hornblende-syenite gneiss. This gneiss

Line of contact to the N.E. of Clearwater Lake.

Contact on StonedamLake.

is observable, with variations in composition, such as addition of a little quartz occasionally, or the presence of more biotite than usual, in continuous exposure for over twelve miles on Stone-dam Lake, Loon Lake and Jack-fish Lake to its extreme S.W. end. The line of contact between the Keewatin rocks and the Laurentian must lie between this line of exposure and the exposures of the Keewatin rocks on Clearwater, Pipe-stone and intervening lakes. The line of contact is assumed, as is generally the case where clearly observable, to be parallel to the strike of the Keewatin schists. A line drawn, therefore, from the point of contact on Clearwater Lake to that at Stone-dam rapids, parallel to the strike of the schists on Pipe-stone Lake, must be approximately the line of contact which we are endeavouring to trace out.

Contact on Creek flowing into Pipestone Lake.

The second place at which the ridge of the Keewatin schists on the south-east side of Pipestone Lake is crossed, is a little over a mile eastward of Stone-dam rapids where a small creek flows in from the south, and the point of contact is in the projection of the line just sketched, the strike of the rocks being 85°.

Line of contact skirting north shore of Kaiarskons Lake.

About four miles to the eastward, Kaiarskons Lake affords easy access to the rocks, and the line of contact of the Keewatin hornblende schists and the Laurentian gneiss is found to skirt the northern edge of the lake and to be observable at a number of points, some of which are good exposures. The first of these is at the N.W. corner of Kaiarskons Lake where a small creek flows in from the north. The Keewatin series is represented as usual by a black, glistening hornblende schist. The schists are peculiar in having imbedded in them large crystals or nodules of white altered felspar, which cause them to resemble closely the basal formation of the same series where in contact with the Laurentian gneiss on the north side of White-fish Bay, Lake of the Woods. The Laurentian gneiss is a coarse-grained hornblende-syenite of gray color. The gneiss traverses the hornblende schists in different directions, but most commonly in the direction of the planes of fission. Angular fragments of the schist are also contained in the gneiss. The general strike of both schist and gneiss is about E. and W. The Keewatin rocks extend away to the north, and the Laurentian gneisses have an extensive areal exposure to the southward.

Gneiss traversing hornblende-schists and including angular fragments of the same.

Conditions of contact farther east on Kaiarskons Lake.

Two miles farther east, in the same line, the contact is again observable on both sides of the narrows of the north arm of the lake. The hornblende schists of the Keewatin, which occupy the country to the north, are seen in direct contact with the coarse syenite gneiss of Kaiarskons Lake on the east side of the narrows. The strike of the schists is about 105°, and the dip south, or under the gneiss, at $< 80°$

The schist is traversed by small irregular dykes of the hornblende syenite gneiss which emanate from the main mass. On the west side of the narrows there appears to have been a partial fusion of the schists with the gneiss, and portions of the former are included in the latter.

About half a mile farther to the east, in the same line, at the east end of the north arm of Kaiarskons Lake, the contact can be very closely located, but not actually observed. The same statement is true of the contact half a mile still further east on the opposite shore. In both these cases the two different rocks are traceable on either side to within a very short distance of the contact, so that its location may be said to be definitely determined.

Interception of line of contact on Manitou canoe route.

Eastward of the point on Kaiarskons Lake where the contact was first noted, the line of contact curves around somewhat to the southward along the north side of the lake. After leaving the lake the line continues apparently in this same curve till it is next intercepted on the Manitou route near Cedar Narrows on Pickerel Lake. Where the line crosses the Narrows, there is very clear evidence of a fault, whereby the rocks on either side have suffered a differential dislocation in a horizontal direction of about 2000 feet, the northward thrust being on the east side, and the southward thrust on the west side of the fault line which runs N.N.E. and S.S.W. On the west side of the lake the contact between the Laurentian hornblende-syenite gneiss and the black-green hornblende schists of the Keewatin can be located within a few yards. On the east side the actual contact is visible just at the narrows. Here the hornblende schists appear to have undergone partial fusion with the syenite, and for a few yards there is a sort of transition between the two distinct types of rocks; and within the hornblende schists, distinctly recognisable as such, there may occasionally be detected large crystals of red felspar, which is quite foreign to these rocks, as if the felspathic magmas had penetrated within the schist and crystallized there in the same large crystals in which they are wont to appear in the coarse gneiss. In the belt of gneiss between this point and Rainy Lake, fragments of the black hornblende schist included in the gneiss are not infrequently met with. The strike of the schists at the contact is about 95°, and the dip at the north at $<$ 72° to 76°.

Fault at Cedar Narrows.

Apparent fusion of schists and gneiss at contact.

Inclusions of hornblende schist in gneiss.

Contact on Bat Lake.

East of Cedar Narrows the line of contact bends slightly to the northward in harmony with the northward trend, which the country to the east of the narrows has received. It is next intersected at a point three miles and a-quarter distant on the shores of the north end of Bat Lake on the Little Canoe River route. Here the Laurentian gneiss, instead of being a hornblende syenite, is a very coarse mica-syenite

with only a subordinate amount of quartz. The line crosses the lake half a mile from the portage at its extreme north end, and can be located very closely, though not with absolute precision on either side of the lake. On the east side of the bay which leads up to the portage the hornblende schists of the Keewatin have a strike of 145°, and dip N.E. at < 35°. The country to the north, which is well exposed, is occupied by the Keewatin rocks, while that to the south is Laurentian. It is this known distribution of rocks on either side of the contact line, as well as the knowledge of the precise localities at which it is intersected and observed at irregular intervals, that enables us to trace out, with great certainty, the locus of the contact of the Laurentian and Keewatin across country. The next point of intersection is on the Big Canoe River route near the lower end of Pickwick Lake. Between this point and the last noted on Bat Lake, the line of contact has apparently a N.W. and S.E. course. Just where it crosses Pickwick Lake its course is about due N. and S. and the hornblende schists, whose strike is coincident with this, dip to the E. or away from the Laurentian at angles varying from 65° to 90°. The Laurentian gneiss is a coarse hornblende syenite. The distance from the contact on Bat Lake to that on Pickwick Lake is seven miles and a-half. But the country to the north and east is accessible and known to be occupied by Keewatin rocks, while that to the south is all Laurentian gneiss, where it has been examined along the canoe routes. On Pickwick Lake the actual contact is concealed by a narrow, marshy bay on the south side of the lake, and by the forest coming down to the water's edge on the south side. The rocks on either side of the line have, however, been traced close up to the contact.

Contact on Pickwick Lake.

Contact on Big Saw-bill Lake.

Although the course of the line of contact, where it crosses Pickwick Lake, is locally N. and S., the general course, after leaving that lake, appears to be as before, N.W. and S.E., for, at six miles farther on in this direction the contact is again observed at the N.E. end of Big Saw-bill Lake. Here, however, the black-green hornblende schists of the Keewatin are not, as heretofore, in contact with a coarse syenite gneiss, but with a quartzose, biotite gneiss of much finer texture and occasionally very evenly laminated. The strike of the hornblende schists and gneiss at the west end of the portage leading to Otukamamoan Lake is about 170°; a little farther south the line bends around to a north and south curve, skirting the west side of Big Saw-bill Lake.

Shallowing out of Keewatin trough on Otukamamoan Lake.

South-eastward of Otukamamoan Lake, the Keewatin trough, one of whose edges we have been tracing, suddenly shallows out; and, although on the west side of the lake, it occupies a breadth of nearly eight miles, it breaks up on the east side of the lake and to the south-eastward of it, into three narrow tongues, so that the broad belt

appears to end abruptly in a sort of trident fork. The two more northerly of these tongues appear to taper out altogether some few miles east of the lake. The most southerly appears to be more continuous. Its south-western edge is the continuation of that which has been noted as in contact with the Laurentian gneiss on Big Saw-bill Lake. This tongue of the Keewatin belt has a breadth, measured from the south end of Big Saw-bill Lake to the south end of Otukamamoan Lake, of between four and five miles. South-eastward from this it tapers very rapidly and crosses Redgut Bay of Rainy Lake at Cliff Narrows in the form of an attenuated syncline a few hundred yards in width. This synclinal trough is but a pinched-in remnant of the basal portion of the Keewatin series. The rocks composing it are much shattered, and the underlying gneiss sends apophyses into it in various directions. Fragments of the hornblende schist also are found imbedded in the gneiss to the north and south of this attenuated phase of the belt, quite profusely. The strike of the rocks at Cliff Narrows is about east and west on the average, though it varies much locally. The dip of the schists is distinctly that of a syncline, being to the north on the south side of the band, and south on the north side at high angles. Traced still south-eastward this attenuated band of the Keewatin rocks appears to expand again and merge into the broad belt of these rocks which occupies the country between Little Turtle Lake and Seine River. In the neighbourhood of Little Turtle Lake, this belt appears to bifurcate; one branch, the smaller, striking off to the N-E. accross the narrows of the lake, and across Heron River and Big Turtle River. Where it crosses the narrows of the lake, it is much mixed with the Laurentian gneiss, which penetrates it in all directions, and which holds, in the neighborhood of the contact, great numbers of fragments of the schist which are generally quite angular.

Continuation of belt across Redgut Bay

Fragments of schist imbedded in gneiss.

Keewatin belt on Little Turtle Lake.

The northern edge of the other branch, the Seine River belt of the Keewatin rocks, skirts the the south shore of Little Turtle Lake, that entire shore with the exception of two miles of syenitic gneiss about the middle of the lake, being occupied by green schists. At the east end of the lake and on the north side of the lake between the Big and Little Turtle rivers, there is a band of mica-schists and fine-grained, evenly laminated gneisses between these green schists of the Keewatin and the granitoid Laurentian gneiss. These beds have a thickness of perhaps 2000 feet, and are analogous, both in petrographical characters and in geological position, to the rocks of the Coutchiching series, so voluminously developed on the south side of Rainy Lake, which they seem here to represent. Both the Coutchiching and Keewatin rocks have, at the east end of Little Turtle Lake, a common east-and-west strike, and a dip to the northward under the Laurentian

Seine River belt of Keewatin rocks

Coutchiching series.

Dip of schists under Laurentian gneiss.

gneiss of from 45° to 80°. The schists which skirt the north shore of the lake between the Big and Little Turtle rivers are much traversed by a salmon tinted rock, which has the characters of a felsite or quartz-porphyry. This rock cuts the schists in different directions, but mostly along the planes of fission. In places this quartz-porphyry assumes a distinctly crystalline aspect and shows a gneissic arrangement of the minerals. These characters become more pronounced as the Laurentian gneiss is approached, and it finally appears to merge into the latter rock, the gradation being quite analogous to that often observable at the periphery of a granite boss where the apophyses from the main mass, having cooled more rapidly, appear as fine textured porphyries.

Evidence for mapping line of contact where it is not actually traced.

Resuming again the inquiry as to the position of the edge of the Keewatin belt as it bends around at the west end of Little Turtle Lake and strikes to the W.S.W., we find that the actual contact of the basal beds with lower rocks is not easily observable for about ten miles till it appears on the north shore of Swell Bay on Rainy Lake. The mapping of the line of contact, for this interval, depends on indirect evidence. This consists of the known distribution of the Laurentian gneiss and Coutchiching schists on the shores of Redgut Bay and on Little Ottertail Lake on the one side, and on the other, the known distribution of the Keewatin rocks on Bad Vermilion Lake, Seine River, Seine Bay and Swell Bay.

Keewatin trough on Rainy Lake flanked by the schists of the Coutchiching series.

The Keewatin trough, from its northern edge on Swell Bay, one mile east of the Bear's Passage, to its southern edge on the first bay of the Seine River and north of Halleluiah Point, has a breadth of about five miles. This trough is flanked on either side by the rocks of the Coutchiching series, which dip under it, forming the floor upon which the Keewatin rocks rest, and lying between the latter and the still deeper Laurentian gneisses. At the contact of the two series on Swell Bay, one mile east of the Bear's Passage the mica-schists of the Coutchiching and the green hornblende and chloritic schists of the Keewatin have a common dip of from 60° to 75° E. 15° S., and there is no evidence of an unconformity between the two series, only a marked contrast in their petrographical characters, which is persistent througout the series. The same contact, it may be mentioned, is also observable three-quarters of a mile to the N.N.E. at the bottom of an inlet of Redgut Bay, where the direction of the common dip is 10° more to the south.

Contact of Coutchiching and Keewatin on Swell Bay.

On the south edge of the trough the contact of the basal portion of the Keewatin series, with the upper beds of the Coutchiching, is approximately observable, as already mentioned, at two places, viz.: on the shores of the first bay of the Seine River and again to the north of Halleluiah Point. At both places, the immediate contact is concealed,

but the exposed rocks on either side are only about 100 yards apart. On Seine River the lower series is represented by mica-shists and the upper by soft-green hornblendic and chloritic schists, overlaid by a thick bedded formation of scarcely schistose altered trap. The schists of the two series have a common strike of about 75° to 85°. Farther up stream the contact between the two series can be traced at a number of points, and it appears to adhere very closely to the direction of the river. The Coutchiching schists occupy the south side of the river east of Kettle Point, and the south side of the east end of Grassy Lake, while the Keewatin rocks are on the north side. The contact is crossed on the Rat River portage and farther east it runs through the middle of Wild Potatoe Lake, the Keewatin schists occupying the north shore, and the Coutchiching the south. The same is true of Partridge Crop Lake. In all of these cases the structural planes of the Keewatin rocks are parallel to those of the Coutchiching, and so far as this is indicative of conformity, the two series are conformable. But as will be pointed out in another place there are other weighty facts which indicate an unconformable relationship. The dip of the Coutchiching rocks near the contact is to the north, under the Keewatin or quite vertical. This vertical attitude is, however, only assumed in close proximity to the Keewatin trough, for, a short distance to the south, the Coutchiching rocks dip northward at low angles, and only plunge down vertically on approaching the Keewatin trough, the superincumbence of which is undoubtedly the cause of the higher angle of dip. At the contact between Halleluiah Point and Seine Bay, there are apparently no green schists of the Keewatin series between its massive altered traps and the mica-schists of the Coutchiching.

Contact of Coutchiching and Keewatin on Seine River.

Vertical attitude of Coutchiching rocks as they plunge under the Keewatin.

From the vicinity of the mouth of Seine River and Swell Bay the trough of Keewatin rocks can be traced very distinctly, in a W.S.W. direction across Rainy Lake, for a distance of about eighteen miles in a gradually tapering belt, flanked on either side by the schists of the Coutchiching series. All the islands of the lake have rocky shores and, as a glance at the map will shew, a study of these shores should afford us very much more abundant data for the mapping of the different formations than can ordinarily be obtained inland.

Course of Keewatin trough through Rainy Lake.

Along the northern edge of the trough, from the north side of Swell Bay, the contact of the green hornblendic and chloritic schists of the Keewatin and their associated bedded traps, with the mica-schists of the Coutchiching, has been traced as mapped. It runs across the southern portion of Dude Island, through the middle of Morton, Armot, Sand Point, Angling and Red Pine islands. Red Sucker, Jackfish and Stop islands and Medouganak Point, are occupied by the Coutchiching schists, while Grassy Island and the south and west shores of

Northern edge of trough flanked by schists of Coutchiching.

Rat-root Bay are occupied by the Keewatin schists. Thus the line of division between the two series on the northern side of the Keewatin trough can be mapped with great precision, although considerable portions of it are concealed by the waters of the lake.

Dip of rocks at contact.

Along this line, the dip of the rocks of the two series is the same, and is always at high angles, generally varying between 70° and 90° although occasionally 60°. The dip is very frequently reversed so that the Keewatin rocks dip under the Coutchiching. Thus on Armot Island the dip, although at very high angles, is normal, or south, and the mica-schists of the older series pass under the green schists and traps of the newer. Along the north shore of the eastern part of Sand Point Island the prevailing dip is reversed, or north, so that the newer rocks pass under the older. The dip is also reversed in the vicinity of Medouganak Point where the Keewatin schists pass under the Coutchiching at $< 60°$. For the most part the contact of the two series is one of apparent conformity, and there is even a sort of transition from the one to the other observable in many places where fissile green-hornblendic and chloritic schists are interbedded with more siliceous and micaceous ones. On the north-east end of Red Pine Island, however, a portion of the altered traps of the Keewatin which is associated with the green-schists may be seen breaking through the Coutchiching schists which abut directly upon it. On the shores of Rat-root Bay, the basal beds of the Keewatin are pebble conglomerates, of which the paste is a green schist and the pebbles mostly water-worn, rounded or oval pieces of vitreous or saccharoidal quartz. Some of the pebbles are felspathic, and when so, are occasionally foliated. On the south shore of the bay, boulders of granite are observed to form part of this conglomerate, one boulder being at least eighteen inches in diameter and of a roughly rounded shape.

Basal conglomerate.

Variation in character of basal hornblende schists of Keewatin.

It is extremely significant that nowhere along this line of contact of the Keewatin with the Coutchiching, do we find at the base of the former series those black, or black-green, eminently crystalline, glistening hornblende schists which are so prevalent at the base of that series wherever it is in immediate contact with the Laurentian gneiss. The intervention of the Coutchiching series between the Laurentian gneiss and the basal beds of the Keewatin enables us to see those beds in their least altered aspects. The eminently crystalline, black glistening aspect of these basal beds, when in contact with the Laurentian gneiss, appears to be a function of their proximity to the gneiss. This view is in harmony with many other facts which point to genetic identity of the Laurentian gneiss and irruptive granite. The rocks of both the Coutchiching and the Keewatin series appear generally to be much more altered or metamorphosed, as the contact with the

Laurentian gneiss is approached than they are in the middle of the troughs, or upper portions of the series. This gradation of alteration is analogous to the gradation in a contact zone of slates around a granite boss; and the inference, supported by many other contact phenomena, and by the almost identical character of the rocks, is that the alteration of the rocks of the Coutchiching and Keewatin series bears the same relation to the gneiss that the alteration of slates of a contact zone bears to a granite boss.

"Contact" and "regional" metamorphism.

There is, indeed, a difference in the scale on which the operation in the two cases has been, so to speak, conducted. The molten gneiss being under and around these troughs of Upper Archæan rocks, and the action long continued by reason of confinement under a superincumbent crust, the resulting metamorphism has been more intense and more general, or *regional*, than in the case of a mere local intrusion of granite through higher portions of the crust. But while the metamorphism has been regional, it has been more intense at the actual contact of the basal portion of the firm crust with underlying magmas than in higher portions of the series of formations, and in this gradation of results we have distinct analogy with "local" or "contact" metamorphism, so called. The conception of the igneous origin of the Lower Archæan or Laurentian and the metamorphic character of the Upper Archæan, thus explains very satisfactorily why the basal beds of the Keewatin, where it rests on the Coutchiching, should not be similar to those same beds when resting on the Laurentian, and why, in the latter case, those beds should appear much more altered than in the former.

Southern edge of Keewatin trough flanked by schists of Coutchiching series.

The southern edge of this Keewatin trough which stretches, as sketched, from the Seine River across Rainy Lake to Rat-root Bay, cannot be traced out so satisfactorily as the northern edge, for the reason that it is mostly concealed by the waters of the lake. At the mouth of Black Bay, however, the line of division between the two series, Keewatin and Coutchiching, can be located with comparative precision; and, as the rocks on Grind-stone, Dry-weed, and numerous other smaller islands between the last of these and Halleluiah Point, are well exposed, the distribution of the rocks of the two series is not a matter of doubt. The south shore of the lake from the west side of the entrance to Black Bay to the bottom of Rat-root Bay is a continuous exposure of Keewatin rocks, and affords a section across the trough diagonal to the strike. In this section it is seen to be flanked on either side by the mica-schists of the Coutchiching series.

Continuation of Keewatin trough on S. side of Rainy River conjectural.

Any attempt to follow up this belt of the Keewatin rocks from Rat-root Bay, W.S.W. in the direction of the strike is baulked by the thick blanket of post-glacial formations which conceals the greater part of

the old rocks, and by the absence of any means of access to the country whereby occasional exposures of them might be noted.

Outcrops of Keewatin rocks on Rainy River.

About twenty-five miles distant, however, in the line of the strike, Keewatin rocks belonging probably to this same belt are observable in two or three small exposures on Rainy River. The first of these I have not seen myself, but I am reliably informed that the Indians quarry pipestone from a small patch of green rock that projects through the soil on the river road just at the bend of the river in tp. 6, S., R. XXVIII. Such pipestone is only found in the Keewatin rocks in this region. Farther down the river, in the next township of the same range, I have observed two exposures of hornblende schists, one on either side of the river, and at some distance from its banks. In both instances the reason of this projection of the rocks above the level of the fresh water deposits which cover the country is the protrusion of a trap dyke. That on the American side affords access to a considerable body of hornblende schists which have a vertical attitude and a strike coincident with the direction of the river at this place. The one on the Canadian side reveals only a few small patches of hornblende schist adhering to the side of the dyke, but still quite sufficient to indicate the character of the country rock through which the dyke has cut.

Laurentian and Coutchiching rocks on Rainy River.

These exposures, limited as they are, give us a very satisfactory clue to the structure of the country if they are considered in connection with other facts. The strike of the belt would appear to curve around to the N.N.W., as is further suggested by the sharp bend of the river. In so bending, the belt curves around an area of Laurentian hornblende syenite gneiss which is exposed on Mr. Singleton's farm, tp. 5 S., R. XXVIII, Sec. 8 and 9. From this syenite gneiss it appears to be separated by a band of fine-grey bedded gneiss which is thus analogous petrographically and in geological position to the Coutchiching series of Rainy Lake, though here apparently the series is very much diminished in volume. The exposure at which this fine-grained grey gneiss is seen, on an island about four miles above the Manitou Rapids, indicates that the rocks, again in harmony with the bend of the river curve around to the west, this time probably around an area of granitoid gneiss on the south side of the river, of which there is an exposure at the foot of the Longue Sault Rapids. If the belt of the Keewatin rocks, which we have been tracing, thus curves around here, as all the evidence at our disposal indicates, it must merge into the expansive belt already noted on the Longue Sault Rapids, in the country to the north of it, and on Pine River.

Probable disposition of the rocks beneath the post-glacial formations.

Thus in following up this belt of Keewatin rocks, and tracing out its inner edge, or line of contact with underlying rocks, we find that it forms a complete circuit. From Lake Despair around to

Rat-root Bay by far the greater part of this circuit has been traced in detail. For the portion that is concealed by the post-glacial deposits of the Rainy River country, such outcrops as can be found, together with the other evidence cited above, all point to its unbroken continuity, by way of the Keewatin area north of the Longue Sault, with the greater portion which has actually been traced out. This circuit embraces a great central area which is made up almost entirely of Laurentian gneiss, between which and the Keewatin rocks of the south part of Rainy Lake, there intervenes, however, a comparatively small area of rocks of the Coutchiching series.

The Keewatin rocks traced in in an almost complete circuit embracing a central area of Laurentian.

It now begins to be apparent that a very general areal disposition of the Laurentian gneiss, with reference to the rocks of the upper Archæan, is that of central, circular or oval areas, begirt with a continuous belt of those rocks in the shape of a sharply folded trough.

General relative disposition of Laurentian and upper Archæan rocks.

In the report of 1885, on the Lake of the Woods, one of these areas of gneiss, that comprising the Grande Presqu'ile and White-fish Bay, was described, and the inner edge of the encircling belt of Keewatin rocks defined. In the earlier pages of this report it is shewn that the Laurentian gneiss of Sabaskong Bay and the country to the southward constitutes another of these central areas, also encircled by the Keewatin rocks. And now it has just been indicated that the Laurentian country to the north of Rainy Lake is another, the confines of which as limited by the inner edge of the encircling Keewatin trough have been traced out in detail. There will be frequent occasion to refer to these areas and the most convenient way to do so is by name. The first of these may be called the Obabicon area, from the lake of that name in its central part; the second, the Sabaskong area; and the third, the Stanjikoming area.

Different Laurentian areas named.

The belts of Keewatin rocks which encircle these different areas are all anastomosing or confluent. They form a continuous retiform area, the meshes being occupied by the Laurentian gneiss. At their nodes, or points of confluence, these belts have their greatest width. Elsewhere they are generally narrower, and at times extremely attenuated.

Confluence of encircling belts of Keewatin series.

These three prominent central areas of Laurentian gneiss are not the only ones. If we cross the belt which encircles the Stanjikoming area at its narrowest points, we come upon other schist-encircled areas of gneiss besides the Sabaskong area which lies to the west of it. Some of these cannot be mapped with any degree of precision, on account of the covered character of the country; others extend beyond the limits of the region examined, and can only be partially mapped on the sheets now published. Some of these, however, of subordinate importance, are within the limits of the region mapped. Thus on

Other central or nuclear areas of Laurentian.

Minomin Lake and Lake Despair on the Kishkutena route, there is exposed an area of biotite gneiss of varying texture which is certainly partially and probably wholly surrounded by Keewatin rocks. This area is of comparatively small extent and occupies a position intermediate between the Sabaskong and Stanjikoming areas. It may be referred to as the Minomin area. As has already been noted, evidence was observed of another of these Laurentian areas on the south side of Rainy River in the vicinity of the Longue Sault Rapids, but the country is so covered that it would be hopeless to attempt to determine its extent.

Minomin area.

A course of five miles in a northerly direction from the southern edge of the Keewatin belt, on the north side of Kaiarskons Lake, takes us across the entire width of the belt at this point, at right angles to the strike of the rocks; and we come upon another area of Laurentian rocks. Only the southern portion of this last area comes within the limits of the Rainy Lake sheet. Its contact with the Keewatin rocks has, however, been accurately determined on Harris, Missus and Bluff lakes. The rocks of this Lake Harris area are granites and syenites, in which a gneissic structure is in places almost entirely wanting. The mass is regarded provisionally as the equivalent of the Laurentian gneisses of the Stanjikoming area to the south of the belt. The Keewatin rocks in contact with it are not those of the base of the series, but those of its upper portion, usually observed to occupy the middle of the trough. They are chiefly felsites and felsitic schists, most of which appear to have been quartz-porphyries or their tuffs. The irruptive character of the granite as observed at its contact with those felsites, and felsitic schists is inferred from the dykes or apophyses which ramify from the main mass into the surrounding rocks. When the contact of the granite and schists is observed on the north-west side of Lake Harris about its middle, the schists are much cut by such dykes. From this point, south-westward, the whole of the north-west side of Lake Harris is occupied by granite, while the south and south-east shores are occupied by felsites and felsitic schists, followed to the south-east, across the strike, by felsitic agglomerates. The greater part of the shores in the north-east portion of Missus Lake are granite, while in the south-western portion, the felsitic schists occupy one shore and the agglomerates the other, as mapped. The north shores of the two small lakes to the south-west of Missus Lake are occupied by felsitic schists more or less glossy and sericitic.

Lake Harris area.

Irruptive character of Laurentian.

On Bluff Lake the line of contact between the Laurentian and these same felsites and felsitic schists, crosses the lake about one-third of its length from its outlet, the two rocks being very much mixed along the contact.

Contact on Bluff Lake.

Tuttle Lake area of Laurentian.

If we follow eastward that portion of the Keewatin belt, whose narrowest section is north of Kaiarskons Lake, we find that it rapidly expands and eventually bifurcates into two arms which embrace still another, and apparently very extensive, area of Laurentian gneiss. One of these arms trends to the south-east and bifurcates again in the vicinity of Little Turtle Lake, as has already been described. The other strikes north-east and has been traced, along the shores of the Manitou canoe route, as far as Wabigoon, probably, however, with several lateral ramifications in the interval. The contact of the eastern edge of the Keewatin belt with this Laurentian area which occupies the north-east corner of the Rainy Lake sheet, from the lakes of the Otukamamoan route across to the Big Turtle River, has been fairly well traced within the region mapped. This line crosses Windigons Lake near the north end of the two arms into which it is divided. It next crosses Smooth-rock Lake near its south end. The Keewatin rocks are in both instances black hornblende schists, and the Laurentian coarse granitoid gneiss, which varies in composition from that of a hornblende-syenite or a hornblende-granite to ordinary biotite-granite. From the south end of Smooth-rock Lake, the line of contact has not been closely traced but is known to lie to the west of Kahops-kikamak Lake and Sakwi-té Lake, the shores of both of which are occupied by Laurentian gneiss. The line of contact of the two rocks is next observable on the west side of Otukamamoan Lake, where there is the clearest possible evidence of the rapid thinning out or shallowing of the Keewatin trough and its breaking up into tapering terminal tongues. The disposition of the rocks as mapped on the shores of Otukamamoan Lake has been accurately determined.

Contact of Keewatin belt with this area.

Isolated trough of Keewatin rocks cradled in schists of Coutchiching.

An isolated synclinal trough of the Keewatin schists, cradled, so to speak, in the Coutchiching schists, which are in turn flanked by the Laurentian gneiss, stretches from Gash Point to Redgut Bay, near Grassy Portage. The patch calls for no special description, its relations being the same as the Keewatin elsewhere in the region.

## Stratigraphical Relations and Structure of the Rocks of the Keewatin Series—Sections.

Stratigraphical composition of Keewatin series

Having sketched briefly the limits of the distribution of the rocks of the Keewatin series and pointed out their disposition relatively to the underlying rocks, we may now consider the stratigraphical composition of the series. It was found that it is usually disposed in a sharply folded trough sinking down into the gneiss which flanks it on either side. I have selected for discussion a number of lines of section where the whole series so far as represented is exposed. The first of

these sections is that afforded by the shores of Clear-water Lake and the lakes of the Little Kishkutena route. It is represented on the map by the diagramatic section A–B.

Section A-B across Clear-water Lake.

The ridge of altered traps and green schists, which has been traced from Kishkutena Lake south-west to Little Kishkutena Lake, and thence to Off Lake, has a breadth across the strike of a mile and a half on the line of section. On the north-westward edge of the ridge at the contact with the Laurentian gneiss, is the massive porphyritic altered trap described as Sec. 1892, p. 72. Occasionally it is schistose, but for the most part on Little Kishkutena Portage, Box and Burnt lakes, it is difficult to detect either bedding or schistosity. Such schist planes, as are observable, seem to dip to the north-west or under the gneiss at high angles. On Panorama Lake, these massive traps give way to much more schistose greenstones and green hornblende schists. These strike with the long axis of the lake or N.N.E. and the dip of the schists, always at very high angles, is sometimes in one direction and sometimes in another. On the line of section, these green schists and schistose greenstones are seen on the west side of Clear-water Lake to be followed by a comparatively narrow band, somewhat less than one-eighth of a mile across the strike, of felsitic schists with quartz grains (quartz-porphyries). This band, like many others of the same or similar rocks, is non-persistent or lenticular. To the north, both this band and the next succeeding band of agglomerate schists taper off rapidly, and do not appear at all in a parallel section across Narrow Lake from Kishkutena Lake to First-quill Lake, only more or less schistose altered traps and hornblende schists being found in the section, the present surface being doubtless below the line at which may be found, the inpinched remnants of the upper portion of the series. To the southward this band of felsitic schists also thins out rapidly, for on the west side of Cedar Lake the green schists of Panorama Lake are in contact with the next succeeding band of agglomerate schists. These agglomerate schists constitute a wide band, tapering to the north east and expanding to the south-west, which occupies the west side of the wide portion of Clear-water Lake, with the exception of Hazy Point. All the shores of Cedar Lake and of the two small lakes to the south-west of it are occupied by these same agglomerates. The agglomerate is throughout highly felspathic, although in places it is also very largely hornblendic or chloritic. The paste is usually very similar in aspect to the included fragments and often grades into glossy sericitic, felsitic schists, being undoubtedly the ash or tuff of an acid volcanic ejection, the massive phase of which is the quartz-porphyry. The included fragments are usually lenticular where the rock is very schistose as a result of pressure deformation, but often they are quite

Details of section—character of different strata and their distribution.

Agglomerates.

angular, sometimes rounded or boulder-like, but not apparently in this case smooth or water-worn, like the pebbles of true conglomerates found elsewhere in the series. On the line of section, this band of agglomerates has a width three-eighths of a mile. To the north-east it thins out and disappears in less than three miles and a half. To the south or south-westward it expands so that at a distance of three miles, on a section across the south end of Cedar Lake and the south end of the wide portion of Clear-water Lake, where the rocks are well exposed, it has a width of a mile and a half. Two miles still farther to the southward on the shores of Off Lake, the coarse agglomerate character of the rock has wholly disappeared and we have nothing but the paste, the felsitic ash or tuff, minus the included fragments of large size. This pyroclastic, felsitic rock is schistose in varying degree and where coarser-grained, a very distinct gneissic arrangement of the minerals has been induced by pressure, and accompanied by the development of secondary mica. The fragmental origin of the rock is, however, apparent, particularly in microscopic sections.

All these agglomerate schists on the west side of Clear-water Lake, have a strike 30° to 45°, and the dip is either vertical or to the S.E. at angles not less than 75°.

On Hazy Point they are followed to the east by a considerable breadth of felsite and felsitic schists, which evidently thin out to the north, and on the line of section have a breadth of probably less than one-eighth of a mile. Felsitic schists.

These schists do not appear at the north end of the wide portion of Clear-water Lake. The agglomerates are here followed by a band of green hornblendic schists which have a strike 25° to 30°, and a vertical dip. Only a small out-crop of these green schists is exposed. They are followed immediately to the east by a band of massive serpentine, which occupies the west side of the lake for a distance of a mile southward from the 49th parallel of latitude. Though not by any means a continuous band this massive serpentine appears to occur with some degree of constancy in the middle portion of the Keewatin trough. On South Bay of Lake Despair a mass of serpentine is found in quite an analogous position to that occupied by the serpentine of Clear-water Lake. They are, probably, the altered remains of olivine rocks which were formed antecedent to the folding of the Keewatin rocks, though irruptive through them. The Clear-water Lake serpentine is flanked on the east by another band of green hornblendic schists and altered traps observable on Pot Island. This appears to thin out to the south and is not visible on the islands or shores of the south part of the lake. It is followed to the east by a coarse, blotchy agglomerate schist, of which the paste is a green hornblendic Hornblende schists. Serpentine. Blotchy agglomerate schist.

schist, and the included fragments, masses of a yellowish-white or grey felsitic rock. The lines of demarkation between inclusion and paste in these agglomerates is vague, it being difficult to say where one begins and the other ends. This agglomerate occupies the shore for about a mile north of the entrance to Sunny Cove. Still to the east of this we come upon another band of felsite and felsitic schists about a quarter of a mile in breadth. These schists occupy the north side of Sunny Cove and the south side of the bay, a mile and a-half to the north of it. They also occupy about a mile of the shore between Sunny Cove and Gloomy Cove, and are observed again on both shores of the lower part of Clear-water Lake, south of the Narrows. To the east they are in contact with the Laurentian gneisses of the Stanjikoming area; and we have thus completed the section across the belt. The full complement of bands of rocks necessary to fill out the structure of the ideal trough is lacking along the line of section. The basal member of the series is not present on the east side. To the north-east of Clear-water Lake it is present in considerable volume, and also to the south-east, where the belt curves across to Lake Despair. The absence of the basal hornblende schists and altered traps is not to be ascribed to their primitive non-existence, but more probably to their removal by the disturbances which brought the granitoid gneiss in contact with the Keewatin rocks in their present folded state. One of the means of removal in the process of such disturbance, would be absorption by fusion, but to what extent the agency has been at play, would be difficult to say. There are not wanting evidences that it has played a very important part.

Felsite schists.

Incompleteness of section.

Lenticular character of formations.

From what has been said of the section across Clear-water Lake, it is apparent that on account of the very marked lenticular character of some of the formations, particularly the agglomerates and felsitic schists, that no two parallel sections would exactly correspond. The agglomerates and felsites, though separable petrographically, so wedge themselves one within the other, that they must be regarded here as forming together a single geological formation; an intimate genetical relationship being indicated by their petrographical characters.

Interpretation of section.

If thus regarded, the actual surface section, which I have described as nearly as it can be ascertained, will bear the simple interpretation shewn in the colored diagramatic section A-B, viz., that of a trough composed of a twice-folded series of two members, a lower or basal one made up of altered traps and green hornblendic schists, and an upper made up of felsitic schists (quartz-porphyries and their tuffs) and agglomerates.

Section C-D. across Kahtimiagamak Lake to Crow Lake.

The second line of section selected, C-D, is one drawn northward from a point north of Kishkutena Lake across Kahtimiagamak Lake and the south-east end of Crow Lake. The section does not take in

more than probably half of the breadth of the Keewatin belt. In its main features it is very analogous to the Clearwater Lake section. It is interesting chiefly as shewing the great width across the strike of the component bands of the belt. Thus the mapping of the band, which comprises the basal member of the Keewatin series, as inferred from the exposures on Kahtimiagmak Creek and Lake, Night-hawk Lake, the south shore of Crow Lake and the west side of Pipestone Lake gives it a breadth of very little less than five miles, the schists being all in a vertical or nearly vertical attitude. The bedding, wherever it can be detected, as it frequently can, is also in vertical attitude. If we take into consideration, however, the enormous jamming together which the rocks have undergone, we can easily imagine as a result the complete parallelism of all the structural planes, affording a false appearance of a continuous section at right angles to the planes of deposition. Hence, it does not seem safe to infer much from the five-mile section of altered traps and green schists as to the original normal thickness of this member of the Keewatin series. It is evident, however, that such thickness must have been enormous. On Kahtimiagamak Lake, moreover, massive or only slightly schistose altered traps in which bedding can be detected only with much uncertainty, preponderate very much over the more distinctly bedded schists; and it is questionable whether these rocks, which shew little or no schistosity, and which occur in great masses, ever have been up-tilted so as to afford a section across their edges. Associated with the green hornblendic schists on Kahtimiagamak, are a few attenuated lenses of agglomerate schist and of greenish-grey felsitic schist with clear quartz grains. These beds are too small to permit of mapping on the scale adopted, but their intercalation with the various beds of green schists, and the bedding of the latter themselves, show that the rocks are in a vertical attitude. But the pressure which would effect the up-tilting of these beds might be inadequate when brought to bear upon a great mass or thick lens of tough crystalline diabase; and the more thinly bedded rocks might be simply crushed into vertical attitude against such mass. Considerations such as these render it unsafe to advance any figures for the thickness of these green schists and traps, based on the measurement of such a section.

Attitude of rocks.

Enormous thickness of basal portion of Keewatin series

True thickness cannot be safely inferred.

This band is followed to the north on the shores of Crow Lake by a wide band of bedded felsites, and felspathic grau-wackes with other clastic rocks, among which there appear some quartzites. The rocks composing this band are continuously exposed on the south shore of Crow Lake in a line oblique to the strike from Patch Island to a point within a mile and a half of the extreme east end of the lake. The rocks along this line of exposure have a general strike of 90° to 110°,

Beds of felsites, grau-wackes, quartzites.

and a prevailing dip to the northward at angles nowhere less than 75°. From the evenly bedded and quite uncrumpled condition in which the rocks are here observed, I am persuaded that there is no duplication in the section, and that the width of the band, corrected for the dip, gives the actual thickness of the formation. The width of the band, as near as can be estimated on the line of section, is about two miles, and a small deduction from this to correct the angle of dip gives us as the thickness of this member of the series 10,200, or say, 10,000 feet. To the westward, in the vicinity of Patch Island, this band appears to thin out very rapidly, and to give way to the agglomerates which occupy Chase Point and the adjacent islands. To the eastward on the shores of Schist Lake and the northwest end of Pipestone Lake, the felsites and grey-wackes which constitute the band on Crow Lake are thickly intercalated with formations of soft, very fissile, greenish grey, more or less glossy schists, which as they do not appear at all on Crow Lake must be presumed to thin out rapidly in that direction as lenses. Some of these very fissile schists are quite nacreous and are apparently only more schistose phases of altered quartz-porphyries and their tuffs, while others are associated with their local beds of pebble conglomerate, and are in places charged with dolomite which, however, appears to be a segregation and not a bedded deposit. Eastward from Schist Lake these finely fissile, grey, glossy schists are very persistent, the distinct clastic varieties prevailing. They will be noted in succeeding sections.

Thickness of band.

Other intercalated rocks in same band.

Agglomerates of Crow Lake.

On the line of section C–D the band of felsites, felspathic grey-wackes and quartzites is followed to the north by a broad band of coarse, well characterized felspathic agglomerates. The greater part of the basin of the south arm of Crow Lake appears to have been excavated in this band of agglomerates. The extreme west end of the lake affords a splendid section across the whole width of the band. Its width here, transverse to the strike, is two miles and a half in continuous exposure. Westward along the basin of the lake the same rocks are well exposed on Shanty Point, Chase Point and Line Point as well as on the numerous islands between the north and south shores of this arm of the lake. In its eastward prolongation this band appears to thin out and give way very largely to the felsites and grey-wackes which prevail on the shores of Yoke and Buff lakes. These agglomerates as seen on Crow Lake are mostly of a light greenish yellow or grey color. They are usually schistose, with the inclusions of lenticular shape all lying with their greater planes parallel. Not infrequently, however, no schistose structure has been developed in the rock and the inclusions are not at all lenticular, but sharply angular. Instances of the latter variety are prominent on the Boulder Portage where the paste is a non-schistose,

greenish-grey fragmental rock (pyroclastic) of rather fine grain, and the inclusions are sharply angular blocks of a light greenish yellow or dirty white felsite.

Thickness of agglomerates.

What relationship exists between the present breadth of the band, viz: two miles and a half in a direction transverse to the strike of rocks in a nearly vertical attitude, and the original normal thickness of the formation is uncertain. But to me it seems difficult to avoid the conclusion that this measurement, enormous as it is, represents approximately the actual thickness of the formation.

Gabbro.

This band of agglomerates is followed to the north on the line of section by a mass, the extent of which is yet only partially known of a coarse gabbro which crops out at intervals behind the agglomerates on the north shore of this arm of the lake for a distance of about four miles. This gabbro appears to have been irruptive through the agglomerates, but probably antecedent to the time of the folding. It is much decomposed, and in places quite altered to serpentine. Two small patches of serpentine which occur farther west, one on Slim Point and one on Line Point, are very probably genetically associated with this gabbro.

The two following sections traverse that portion of the Keewatin belt which is pinched in between the Stanjikoming area of Laurentian gneiss and the Lake Harris area of the same rocks. The complete trough does not appear to be represented, since the rocks of Lake Harris break through the Keewatin in such a way as to bring the gneiss or granite, for it is often devoid of foliation, in contact, not with the base of the Keewatin series, but with its upper portion.

Section E-F. From Kaiarskons Lake to Bluff Lake.

The line of section E–F from the narrows of Kaiarskons Lake to Bluff Lake shows a sequence very analogous in its general features to those revealed by the sections A–B and C–D. At the base of the Keewatin series at the narrows of Kaiarskons Lake, black hornblende schists in nearly vertical attitude, in contact to the south with a broad area of hornblende-syenite gneiss, which at the immediate contact is mixed with the schist. The observed strike of the schists at this point as already noted is a little south of E, and the dip is to the south or under the gneiss at an angle of 80°. Farther north on the shores of Furlonge Lake the schists are green rather than black, and altered traps more or less schistose are prevalent. From the exposure at the north end of Kaiarskons Lake, and on the shores of Furlonge Lake, Pipestone Lake, Sucker Lake and Manitou Lake, all of which are very satisfactory, it is inferred that this band of hornblende schists and other green schists, with their associated altered traps, has a breadth on the line of section of about two miles and a quarter. It is possible that the felsite schists which are represented on Pickerel Lake to the eastward by a broad band, and on Pipestone Lake to the west-

Thickness of hornblende schists.

ward by a very narrow band, may be continuous through the lower end of Furlonge Lake. If so, it must be very meagerly represented, and as I did not observe such rocks, I have mapped the band as discontinuous. A small boss of serpentine occurs in the green schists at the southwest end of Sucker Lake; it is associated with a mottled greyish-white saussurite gabbro. The actual contact of this serpentine and gabbro with the surrounding schists is concealed, but there is little doubt of its irruptive character. With relation to the other rocks of the belt, it occupies a position analogous to the other bosses or patches of serpentine, (and gabbro) already noted on Lake Despair, Clear-water Lake and Crow Lake. These bosses of altered basic, massive rocks have a coarse granular texture when not altered to serpentine, or when so felspathic as to alter to saussurite. They seem to have been irruptive through portions of the Keewatin series prior to their folding, and not improbably represent the cores of vents from which were extravasated the more basic portions of the Keewatin series.

Serpentine—analogous in position to other bosses of serpentine.

Felsite schists.

Following the green schists and altered traps on Sucker Lake is a narrow band of glossy or nacreous sericitic felsite schists with clear quartz grains (altered quartz-porphyries). This band is doubtless continuous with the more extensive development of the same rocks south of the mouth of Strawberry Creek on Pipestone Lake, and with the band that crops out on the west side of Pickerel Lake just to the south of the granite boss, which there interrupts the strata. The exposure on Sucker Lake is a small one, and from the known occurrence of other rocks on either side of it, the band must be a narrow one where it crosses the lake.

Soft grey fissile schists.

Following this is a band, a mile and a half in breadth, of soft, grey, fissile schists with which are intercalated at least two small subordinate bands of green-chloritic and hornblendic schists. This band is a rather persistent one, the rocks composing it being continuous with the similar rocks already alluded to on Schist Lake and the north part of Pipestone Lake. They are traceable also eastward on Pickerel and Manitou Lakes and on the west side of the latter lake, through to Grant Lake as far as the limits of the region mapped. The rocks composing it are probably mostly altered sediments, silts and clays derived from the erosion of volcanic rocks. The occasional occurrence of beds of pebble conglomerate proves their clastic origin, and other portions of them merge into schists, which are little more than slightly micaceous fissile clay-slates. On Strawberry Lake, these schists are, as near as possible, in a vertical attitude and strike E. and W,

Agglomerate schists.

They are followed, on the north side of Strawberry Lake, by a band of agglomerate schists. At the west end of the lake this band has a

width of half a mile, but apparently thins out before reaching the Yoke Lake portage from Pipestone Lake. To the eastward it is very probably continuous with the band of the same agglomerates so extensively developed on the south side of Harris and Missus Lakes.

At the mouth of the Bluff Lake Creek, and for a mile and a-half to the northward, the only rocks observable on the creek and on the shores of Bluff Lake are rather massive, whitish or yellowish-grey felsite, sometimes pinkish to greenish tinted. This felsite is a distinct agglomerate for a short space on the creek, and seems to constitute a band which is probably continuous with the more voluminous formation of the same agglomerates on the north-east arm of Yoke Lake. At the south end of Bluff Lake, as the contact with the Laurentian rocks is approached, these felsites become more schistose, and by the development of mica along the planes of schistosity assume a gneissic aspect. The Laurentian rocks near the contact are very basic and may, perhaps, be classed with the gabbros. The schists are cut by this gabbro in all directions. Away from the contact along the almost continuous exposures of the shore to the northward, the Laurentian rocks are observed to merge gradually from the basic or gabbro variety into the acid or granite. The gabbro passes first into a hornblende-syenite gneiss of coarse granitoid aspect with, besides the orthoclase, a good deal of triclinic felspar. The quartz appears gradually a little at first, and then more and more, till at the extreme north end of Bluff Lake the rock has the characters of a very quartzose-hornblende granite, very distinctly gneissic in some places, in others much less so, and properly a granite.

Character of Laurentian near contact.

The next section G-H is along a very satisfactory line of exposure extending from the south end of Pickerel Lake along the west side of that lake, across the lower end of Manitou Lake to Missus Lake. The first interesting feature observable on the line of section is the fault of 2000 feet at Cedar Narrows which has already been alluded to (*ante* p. 33).

Section G-H. From Pickerel Lake to Missus Lake.

At the contact with the Laurentian syenite gneiss, the base of the Keewatin is, as usual, represented by a band of black hornblende schists, with a strike nearly E. and W., and a dip to the north of 72° to 76°. The band has a width on the west side of the narrows of a-quarter of a mile transverse to the strike. The fault, with its northward trend on the east side, makes these schists abut squarely upon the Laurentian syenite gneiss which occupies the east side of the narrows. These hornblende schists are followed by a band, one mile in width, of felsite schists (altered quartz-porphyries). The effect of the Cedar Narrows dislocation is still distinctly perceptible since the lower portion of these felsitic schists on the west side of the lake abut directly upon the continuation of the basal hornblende schist band on

Fault.

the east side. This dislocation probably owes its origin to the same disturbance which resulted in the protrusion of the two granite masses on Pickerel Lake, and the larger one to the south of Bat Lake. The dislocation in its north-eastward continuation is probably represented in the present topography by the basin of Manitou Lake which is a long, narrow, deep trough.

Felsites or altered quartz-porphyries.

The band of felsites (altered quartz-porphyries) which occupy both sides of Pickerel Lake to the north of the narrows seems to have the form of a lens whose thickest part is on the line of section. Though having the width of a mile on Pickerel Lake, the rocks comprising it do not appear on Furlonge Lake, three miles to the west, nor on Three Island Lake about one mile to the east. On the west side of the lake the schists have a very uniform strike of 90° to 100°, and a northerly dip of from 75° to 80°. On the east side of the lake the strike is less constant, varying from 80° to 115° with the same northerly dip.

Hornblende schists.

The next rocks met with going north along the line of section are green hornblende schists. These form a narrow band about one-eighth of a mile across, observable on the west side of the lake. The schists strike E. and W. and dip N. $<70°$.

Second band of felsites.

These are followed by another band, half a mile wide, of felsite schists precisely similar to those of the first band described. This band also is apparently very lenticular. It does not appear on the shores of the lakes to the east of Pickerel Lake, and if it is continuous to the westward, as I suppose, as far as Sucker Lake, it has, at the latter place, a very limited breadth. This band is interrupted on both sides of Pickerel Lake by two distinct bosses of granite. That on the west side is shewn on the line of section G-H. Its exposed extent on the shore of the lake is about one mile. The boss of similar granite on the east side of the lake has its area better defined. Its greatest diameter is about one mile and a-quarter.

Granite bosses of Pickerel Lake.

Clastic rocks.

To the north of these granite bosses on Pickerel Lake is a broad band of clastic rocks, which occupy the shores of the north end of Pickerel Lake, and the lower end of Manitou Lake. This band has a known width of over a mile, and, according to estimates based on the disposition of the rocks on Strawberry Lake, Grant Lake and Missus Lake, its full breadth is placed at about two miles. At the north end of Pickerel Lake, the rocks are fine-grained grau-wackes or grits of dark color. Farther north, towards the rapids between Manitou Lake and Pickerel Lake, these become finer grained and pass into schists at the rapids, which are scarcely distinguishable from bluish clay-slates, though they are somewhat micaceous and distinctly schistose. The schists have a strike varying from 80° to 115°. The dip is either vertical or to the northward at high angles as far as the south shore of

Manitou Lake. On the north side of Manitou Lake, at the lower end, the dip is southward at angles varying from 70° to 90°, and the rocks here are less of the character of clay slates or grey-wackes and more of the character of greenish-grey ash beds with some thin beds of felsite schists, nacreous and glossy, and an abundance of soft, glossy, grey, fissile schists. The latter are, as has been shewn, abundantly represented to the westward on Strawberry Lake and Sucker Lake on the line of section E-F, and the same band appears to be persistent up through Grant Lake.

Agglomerate schists.

The next band of rocks which the line of section intersects is that of the felsitic agglomerate schists so voluminous on Lake Harris. At the north-east end of the latter lake, and at the middle part these agglomerates have a width transverse to the strike, of over a mile. They are well exposed on the south side of Missus Lake and appear, apparently much diminished in volume, at the east end of Strawberry Lake.

Felsitic schist.

Between these agglomerates and the Lake Harris Laurentian area is a band of felsitic schist which, on Manitou Lake, has a breadth of not more than a quarter of a mile. The section, as a whole, is remarkable for the comparatively small proportion of hornblende schists and altered traps which it reveals. In its general features, however, it is quite in harmony with the other sections already detailed.

Section I-J. from Smooth-rock Lake to Lake Harris.

The next section, that on the line I-J, crosses the Keewatin trough where it forms a wide belt, striking along the course of Manitou Lake, just before it bifurcates into two portions embracing the Stanjikoming area of Laurentian gneiss. That portion of the section which lies on the N.W. side of Manitou Lake is much better known than that on S.E. side.

Hornblende schists.

The eastern edge of the belt which strikes up Manitou Lake is intercepted at the points mapped on Windigons Lake and on Smooth-rock Lake. At the south end of the latter lake, the hornblende schists have a breadth westward across the strike from their contact with the Laurentian gneiss of over one mile, the rocks being, as usual, in a nearly vertical attitude. Here a mass of granite devoid of foliation projects through the schists. It presents a contrast to the Laurentian gneiss of the northern portion of Smooth-rock Lake in composition as well as in structure, it being a quartzose biotite-granite while the gneiss inclines more to the habitus of a syenite. The mapped area of this granite mass is inferred from its outcrop on Smooth-rock Lake. From the south end of Smooth-rock Lake across to Manitou Lake the rocks have not been actually traced on the line I-J, but their distribution is inferred from the exposures on the shore lines of the neighboring lakes. It is presumed that the hornblende schist surrounds the granite mass above mentioned on the west side as well as on the east.

Granite of Smooth-rock Lake.

Agglomerate schists.

The most interesting feature of the section on the S.E. side of Manitou Lake is the triangular area of agglomerate schists which occupies the middle portion of the trough just at the bifurcation of the belt. These agglomerates are prevailingly of a light yellowish-grey color, being mostly felsitic in composition. They are well exposed on Dog-fly and Vista lakes and on the canoe route between them. The area tapers off in three directions corresponding to the three branches of the Keewatin belt. The north-west corner of the area tapers off to a band which is traceable through to the south-end of Snare Lake to Mirror Bay of Pickerel Lake. The south-east corner tapers rapidly south of Vista Lake, and although exposed on the shores of Twist Lake the trough which it forms is pinched out between the latter and the north shore of Pickwick Lake where the Keewatin rocks are all hornblende schists. To the north-eastward it seems to thin out more gradually, traces of the agglomerates being observed at the north end of Windigons Lake, though not apparently in any well defined band.

Hornblende schists and altered traps of Manitou Lake.

West of the band which is formed by the north-eastward extension of these agglomerates is a band of hornblende schists and altered traps. Though there is little or none of the hard, black, glistening hornblende schist which characterises the Keewatin rocks at the base of the series when in contact with the Laurentian gneiss, this band, so well exposed on Manitou Lake, is very probably a repetition due to folding of the same rocks as those at the east end of the section, which are in contact with the Laurentian gneiss. The more schistose varieties of the rocks of this band are often quite soft and chloritic and there are not wanting local patches of small extent of fissile soft-grey schists. Many of the schists were observed to be charged with carbonate of lime or dolomite, and masses of the latter several yards in extent were observed which are probably segregations. A good deal of this dolomite occurs in the schists on the north-west side of Manitou Lake below Peep Bay, but none of it takes the form of distinct beds. The altered traps are nearly all somewhat schistose. The rocks are all in a nearly vertical attitude.

Felsite schists and agglomerates.

This band is followed to the north-west, on the west side of Manitou Lake, by a broad band which consists for the most part of alternations of grey felsites or glossy felsitic schists and felsitic agglomerates. Associated with these is a subordinate band of fissile, soft, glossy, grey schists and another of green hornblendic schists. The sequence from Paddle portage on the west side of Manitou Lake, to the north-west side of Lake Harris where the Keewatin rocks are in contact with the Lake Harris Laurentian area, is easily made out from the excellent exposures on Grant, Sairy Gamp, and Harris Lakes to be as follows, in a direction more nearly transverse to the strike than the

line of section I-J :—Agglomerate schists, ½ mile; soft, glossy, grey, fissile schists, ¼ mile; agglomerate schists, ⅛ mile; felsitic schists, ½ mile; green hornblende and chloritic schists, ¼ mile or less; agglomerate schists, 1¼ mile; felsitic schists, ¾ mile; Laurentian gneiss (or granite), indefinite extent. The measurements are, of course, approximate, but the sequence in about these proportions is undoubted; and, as the rocks are in a vertical attitude, or dipping at angles rarely less than 80°, the section appears to represent approximately the actual thickness of this part of the series, and indeed it is probably less than the original thickness by the deformation due to pressure. The rocks of the Lake Harris portion of the Keewatin trough are stratigraphically doubtless a repetition of the agglomerates of Dog-fly and Vista Lakes, since the felsites are so intimately associated with the agglomerates, and resemble them so much in composition, that they may be regarded for stratigraphical purposes as making up one geological formation. The structure of the trough is apparently that of a double fold, such as is suggested by the colored diagramatic section I-J., the basal portion of the series at the N. W. end of the section being wanting. The section thus interpreted gives a thickness for the series of probably five miles.

Further sequence of strata on section line I-J.

Thickness of Keewatin series

The line of section K-L crosses the Seine River belt of the Keewatin rocks at a peculiarily interesting locality. We meet here, for the first time, the rocks of the Coutchiching series between the Laurentian gneisses and the Keewatin rocks, forming the floor of the trough upon which the latter rest. From the south side of the Seine River, the whole of the country to the southward as far as Namakan Lake is occupied by the Coutchiching rocks. On the north side of the southeast part of Rainy Lake, these rocks dip at low angles to the northward under the Keewatin. As the Keewatin trough is approached, however, the underlying Coutchiching beds assume gradually a more vertical attitude, and close to the contact, plunge almost vertically under the basal beds of the geologically higher series. Those basal beds are on Grassy Lake, fissile, soft, green chloritic and hornblendic schists, the detrital origin of which is established by the fact that on the north side of the lake they constitute the paste of a pebble and boulder conglomerate. The structural planes of the rocks of both the Keewatin and Coutchiching series are parallel at the neighborhood of the contact and present an appearance of conformity. This appearance is, however, only what may be expected in formations that have been so squeezed together, and affords but little evidence as to the question of original conformity or unconformity. The very marked contrast in the lithological characters of the two series is indicative of an abrupt change in the conditions of formation; and the presence

Section K-L.

Coutchiching series.

Pebble conglomerate at base of Keewatin.

Indications of unconformity.

of a basal conglomerate in the upper series, in which the pebbles have very probably been derived from the underlying formation, is also indicative of a geological break, with a period of erosion which is one of the characters of an ordinary geological unconformity. There is an absence at the contact of those very black glistening hornblende schists which so commonly characterise the base of the Keewatin where it is in contact with the Laurentian gneiss. The conglomerate is a much more voluminous formation on the north side of Shoal Lake, a little to the east of the line of section, than on Grassy Lake. A similar conglomerate occurs in an analogous position on the opposite side of the same trough on the shores of Rat-root Bay, Rainy Lake.

Rocks on Bad Vermilion Lake and Little Turtle Lake.

Nearly all the bedded rocks across the belt on the line of section, so far as can be ascertained by the exposures on Bad Vermilion Lake, Little Turtle Lake and the portage between them, are more or less fissile, soft, green, chloritic and hornblendic schists, quite similar to the schists which form the paste of the pebble conglomerate on Grassy and Shoal lakes. Farther westward, altered traps are abundantly intercalated with these fissile schists on the shores of Seine Bay and Swell Bay. On the shores of Little Turtle Lake, at the narrows, where these schists are much mixed with Laurentian gneiss, they appear to have been altered to black, glistening, hard hornblende schists.

Boss of irruptive rocks.

The chief interest attached to the section is not, however, in the bedded formations of the series, but in the irruptive rocks which occupy a boss-like area in the middle of the belt, and cause it to bulge out on either side. In the middle of the belt on the S. W. side of Bad Vermilion Lake, there is exposed a distinct boss of very quartzose medium grained granite. This boss is roughly circular or heart-shaped, its greatest diameter being about three miles and a-quarter.

Very quartzose granite encircled by very basic gabbro.

It is surrounded on all sides by an encircling area or collar of very coarse-grained saussurite gabbro, in which the felspathic constitutent (anorthite) predominates greatly over the pyroxenic constituent (hypersthene?). This encircling area of gabbro is of varying width, and on the south-east side of Bad Vermilion Lake, or to the east of the granite boss, it forms a very considerable triangular area tapering to the eastward. The evidence establishing the relative distribution of the granite and gabbro is very clear, the continuous rock exposures on the shores of Bad Vermilion Lake and the scarcely less satisfactory out-crops on the river of the same name, and on its small lake-like expansions, permit the definition of the granite mass encompassed by gabbro with a more than usual degree of precision. A second much smaller area of granite occurs to the south of this collar of gabbro, between it and the green schists of Seine River. The mutual relations of these two rocks, the one of the extreme acid type and the

other of the extreme basic, and both of an eminently granular, massive, non-foliated structure, are most interesting and suggestive. They do not form an integral part of the Keewatin series, but in their present distribution seem to represent the truncation of an immense boss which protruded through the basal portion of the series. The simplest explanation that suggests itself, and that which is most in harmony with all the facts known in this field, is that this area of massive rocks represents the roots of an immense volcano, of the age of the Keewatin rocks, and that it indicates the vent through which have been extravasated a portion of the volcanic rocks which so largely enter into the composition of the Keewatin series. In this view two very distinct kinds of rock must have come from the same vent, the basic first and the acid last. The gabbro would represent the plutonic facies of the much less coarsely-grained altered traps (diabase and gabbro) which are so abundant in the lower portion of the Keewatin series. The granite would similarly represent the plutonic facies of the felsites, felsitic schists, and felsitic agglomerates (altered quartz-porphyries and their tuffs) which are so characteristic, in this region, of the upper portion of the same series. The extravasation of basic and acid rocks in this sequence is strikingly in harmony with the conceptions of the development of the Archaean crust to which all the other facts of the region point.

An Archæan volcano.

Sequence of extravasation.

## Petrography of the Keewatin Series.

### *Altered Diabase Trap.*

The most important of the rocks of the Keewatin, and those which give character to the greater part of the series, are in this region, as on the Lake of the Woods, the bedded traps or greenstones. These rocks are in all cases very much altered from the original condition in which they existed after solidification from their molten state. The influences which have been at work in bringing about this alteration are of two kinds, viz.: (1) those of paramorphic and metasomatic metamorphism, whereby the constituent minerals have their molecular particles re-arranged physically, or their atoms re-arranged chemically, so as to arrive at a state of maximum stability for present normal conditions; and (2) those of dynamic metamorphism, whereby the structure of the rock has been altered by an actual rending and sundering of its parts, associated with the development of new minerals which in part serve as a cement between the broken pieces. The first set of these metamorphic influences is found to have affected all these old traps. The second set, the result of pressure, is found to

Two processes of alteration.

have affected only part of them. Where the pressure metamorphism has been at work, we have, therefore, a combination of both sets of influences. The rending effects of pressure appear to afford the most favorable conditions for metasomatic changes, so that under such a combination of metamorphic agencies, the alteration from the original type is often so extreme that it is not possible to recognise it in the present form of the rock, and it can only be inferred by analogy. When the rock has undergone changes of a purely paramorphic or metasomatic character, scarcely, if at all, affected by pressure, it is usually not difficult, with a knowledge of fresher or younger rocks, and of the changes which their constituent minerals undergo, to arrive at a clear conception of its original form. Thus, among the altered traps of the Keewatin series it is possible to detect two closely allied types of rocks from which the present greenstones must have been derived. These are diabase and gabbro. In their fresh forms these two types are, as is well known, distinguished chiefly by their structural differences, together with an incidental foliated condition of the pyroxene of the gabbro which is not observable in the diabase. These differences are, in the nomenclature of Rosenbusch,* briefly, that in the gabbro both plagioclose and pyroxene are of synchronous generation, and consequently of allotriomorphic form, and the structure granular as in granites; while in the diabase, the plagioclase is of earlier generation than the pyroxene, and is of idiomorphic form, while the pyroxene is allotriomorphic, or at least hypidiomorphic; and the structure of the rock tends to the porphyritic. Now, when the rock has been subjected to simple paramorphic or metasomatic changes, even to an extreme degree, these structural differences are not obliterated, although the felspars may be entirely changed to saussurite, or replaced by calcite and quartz. In the one case, the characteristic idiomorphic form of the felspar still remains, and in the other the allotriomorphic. Again, although the pyroxene may be entirely re-placed by its paramorph hornblende, or even by chlorite, the relations in form of the secondary mineral to the plagioclase, depend upon the original conditions of crystallization, and are scarcely less distinct than in the case of the fresh minerals. So far as observation has gone on the bedded traps of the Keewatin series it seems to be a general rule that the foliated pyroxene of the rock of the gabbro type has been more resistant to paramorphic incroachment than has the augite of the diabase. A large number of slides have been examined, and in nearly every case where the ophitic or diabase structure was evident, there was no trace of augite remaining; while in the hornblende of rocks of granular structure, cores of diallage were not infrequently observed.

Diabase and gabbro. Distinction between.

To what extent distinctions are retained or obliterated by paramorphic or metasomatic alteration.

* Mikro. Phys. der Massig. Gestein. Stuttgart, 1886.

If we pass now to those rocks in which, in addition to paramorphic and metasomatic changes, there are evidences of crushing and stretching, where, besides the breaking and sundering of the crystals, those changes have proceeded much more actively than in less disturbed rocks, the difficulty of assigning a rock to a particular original massive type, or of asserting, with confidence, that it ever was a massive rock crystallized from a magma, becomes greater and increases proportionately to the violence of the crushing action. When the comminution of the rock has proceeded so far that the original structure is quite obliterated, the only grounds for asserting that the rock is an altered trap is that of analogy established by the study of gradations from rocks whose structure is intact. In extreme cases, however, the aspect of the rock under the microscope is undistinguishable from that of undoubted clastic rocks, such as the paste of certain pebble conglomerates and volcanic agglomerates. This paste would appear, in most cases, to have been originally made up of volcanic débris of the same material as that constituting the original diabase or gabbro rocks with which they are associated. This compacted débris or clastic rock, having been subjected to the same conditions of paramorphic, metasomatic and dynamic metamorphism as the massive rock, naturally presents much the same aspect as the massive rock whose structure has been crushed out of recognition.

Effect of dyamic metamorphism.

Difficulty of distinguishing between originally massive and originally clastic rocks when both have been much crushed.

From these considerations it will be apparent that when we have reached the limit of alteration, which still leaves us grounds for ascribing to a rock a once massive condition, we come upon a class of rocks between these and certain undoubtedly clastic rocks, of which it is impossible, at present, to determine the original condition. The altered traps which are altered only by paramorphic and metasomatic agencies, without the intervention of pressure sufficiently great to produce crushing effects, do not appear in the Keewatin series to be perceptibly schistose, but on the contrary, to have an eminently massive aspect. With the first evidence of crushing, however, as revealed by the microscope, in the sundering of minerals, etc., there is an accompanying development of a schistose structure, observable microscopically, which becomes more and more pronounced in proportion as the yielding of the rock to pressure has been great.

The green rocks of palpably clastic origin, other than agglomerates, appear to be the most fissile and schistose rocks of the series. Hence we have a gradation in schistosity from massive, practically uncrushed traps, through more and more crushed and stretched traps to the fissile condition of the chloritic schists of clastic origin; those of medium degree of schistosity, generally speaking, being those of which it is impossible to say that they were originally massive or clastic.

Degrees of schistosity.

The detailed results of the study under the microscope of the altered traps of the Keewatin series are given in more or less categorical form. The statement of observations, together with the localities, will serve as a record to which reference may be made conveniently in a more comprehensive treatment of the geology of the region. Those schistose rocks which resemble traps, but whose original characters as such, cannot, on account of their extreme alteration, be certainly determined, are considered by themselves.

Rocks on section from Bear's Passage to Seine River.

On the shores of Swell and Seine bays, the rocks of the Keewatin series lie in a sharply folded synclinal trough flanked on either side by the schists of the Coutchiching. A section from the Bear's Passage to the mouth of the Seine River shews this Keewatin trough to be made up very largely of altered traps, massive and schistose, and various kinds of green hornblende and chloritic schists.

A number of the traps crossed in such a section, as observed on the shores of Swell and Seine bays, have been examined, and the results are given first as representative of these rocks in an almost complete section across the Keewatin trough.

Gabbro one mile east of Bear's Passage.

Section No. 1604.—About one mile east of Bear's Passage, Swell Bay. Mottled green and white, massive, crystalline rock.

Under the microscope it presents the characters of a uralitic saussuritic gabbro, the structure being granular rather than ophitic. The felspar is almost entirely altered to zoisite and the pyroxenic constituent to a pale green hornblende, both fibrous and compact, the latter being frequently twinned according to the common law ($\infty P \bar{\infty}$). Leucoxene in irregular brownish-grey grains is the only other prominent mineral present.

Section No. 1606.—Half a mile north of last locality, Swell Bay. Greenish-grey massive rock of rather fine texture. It has a much smaller proportion of felspar than the last, and is made up chiefly of hornblende, in ragged, sheet-like or fibrous masses, with epidote in stout columnar, colorless crystals and in aggregates of grains. A little chlorite, leucoxene, magnetite and secondary quartz are also present.

Secondary enlargement of hornblende crystals.

The compact hornblende of this section occasionally appears in sharply defined crystals, with a fringe of fibrous hornblende of apparently the same optical orientation as the nuclear crystal, the appearance being much the same as that figured by Becke.* The sharp line between the compact hornblende and the fibrous margin of the same orientation sometimes observed recalls the secondary enlargment of hornblende as described by Van Hise.† The original augite of the rock appears to

* Eruptivgest. aus der Gneissformation des Niederösterreichischen, Waldviertels. Min. und Petrog. Mitt. von G. Tschermak, 1883, p. 159, fig. 6.

† Am. Jour. Sci. Sept., 1885.

have been changed within its own limits to compact hornblende which has become enlarged by a fibrous margin subsequently. The only indication of the original augite now remaining is the pale color of the central portions of the hornblende. The fibrous green hornblende is occasionally seen to be developed along the cleavage of the compact lighter colored mineral. The aspect of these enlarged hornblendes is shewn in Fig. 1 drawn with camera lucida from section of an altered diabase (734) from south side of Grassy Island, which is here not further described.

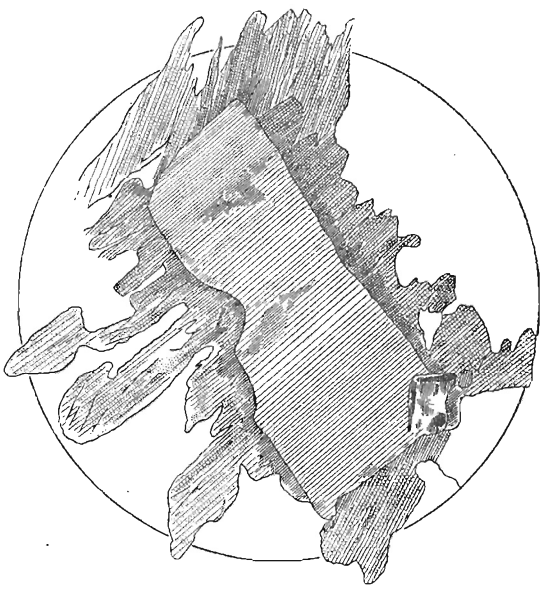


Fig. 1. — Crystal of compact hornblende with light colored central portion, secondarily enlarged by fringe of columnar or fibrous, deep colored hornblende of the same, or approximately the same, optical orientation as the central crystal. From altered diabase of south side of Grassy Island. × 18.

Section No. 1607.—One mile and three-quarters east of the Bear's Passage, Swell Bay. It is more chloritic than 1606, and contains much more magnetite. Epidote, zoisite and leucoxene are common throughout the section.

Section No. 1610.—Two miles and a-half east of the Bear's Passage. Light, mottled green, granular, uralitic, saussurite gabbro. The plagioclase is cloudy with decomposition products and is partly altered to saussurite. The twinning traces are not altogether obliterated, and twins of both the albite and baveno types are observable. A large part

Two and a-half miles E. of Bear's Passage.

of the hornblende is fibrous, though mostly compact, there being no pyroxenic mineral left unchanged. Pleochroic chlorite, in pale-green colors, colorless epidote, leucoxene with cleavage traces of the titanic iron still remaining, and magnetite are present, besides garnet in rounded colorless isotropic grains full of inclusions.

N. E. corner of Swell Bay.

Section No. 1614.—North-east corner of Swell Bay. Moderately coarse greenish-grey crystalline rock. Under the lens or low power of the microscope it exhibits a "flaser," or squeezed and pulled arrangement of the component minerals. The plagioclase is in long, lath-shaped crystals and is usually cloudy with decomposition products. The twinning structure is obliterated in some cases, but quite distinct in others. The hornblende is partially replaced by chlorite and calcite. Besides these, quartz and epidote are present in considerable quantities. Both quartz and calcite occur in mosaics of small interlocking grains, the mosaic areas having a parallel arrangement. The chlorite often appears as a base in which are imbedded grains of calcite and epidote. Leucoxene, with opaque nuclei of titanic iron is abundant. Associated with leucoxene, and apparently of the same secondary origin, are small double-wedge shaped crystals of titanite.

S. E. corner of Swell Bay.

Section No. 1618.—South-east corner of Swell Bay. Light greenish-grey, rather finely crystalline rock. Under the microscope it presents the characters of a uralitic diabase. The felspar is represented only by saussurite, of which zoisite is the most abundant constituent. The hornblende appears in section in ragged plates. Pleochroic chlorite, calcite in occasional large grains, quartz and leucoxene, with sometimes an opaque nucleus, are the less prominent minerals.

S. shore Swell Bay.

Section No. 1621.—South shore Swell Bay, near east end. Rudely schistose, green uralitic diabase. The plagioclase is in fresh crystals lath-shaped and twinned. The augite is still left in a fresh condition, and is seen in hypidiomorphic and allotriomorphic grains, occasionally shewing polysomatic structure. The felspar contains inclusions of acicular actinolite, besides a number of stout little bodies of high refractive index. The secondary minerals are: hornblende and chlorite as alteration products of the augite, which is often entirely replaced by them; quartz in mosaics, with an occasional grain of calcite; calcite in large single grains and in separate mosaics like the quartz; and leucoxene in large grains. Shreds of fibrous hornblende or actinolite derived from the augite are observed to have been developed within the substance of the fresh plagioclase, and along its line of contact with the augite.

Section No. 1622.—Half a mile west of last. Fine-grained green rock, made up of fresh plagioclase, in which both the albite and baveno twinning laws are observed, fibrous hornblende, epidote in large yellow

crystals, quartz in mosaics, large grains of leucoxene with cleavage traces, and a little calcite and iron oxide. The leucoxene is frequently faulted or crumpled by pressure, and chlorite has been developed along the cleavage lines. The felspar is also occasionally bent and broken, and the cracks filled with a cement of secondary hornblende and chlorite.

Section No. 1625.—South side of Swell Bay. A massive green schist. Under the microscope it has the structure of a porphyritic diabase, much altered. In a fine-grained ground mass of felspar, epidote and chlorite are imbedded large lath-shaped crystals of felspar which often S. shore Swell Bay.

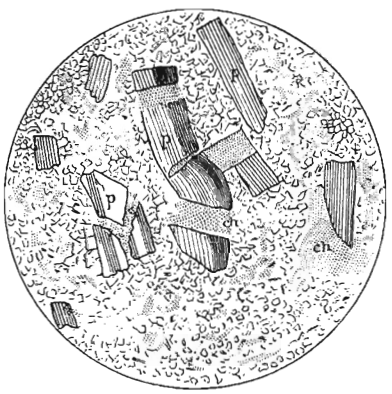



Fig. 2.—Section of altered diabase from Swell Bay, Rainy Lake, shewing bent, broken and sundered crystals of plagioclase (p), the cracks being filled with chlorite (ch). × 44.

shew pressure or rending effects very markedly, the crystals being torn apart and the cracks filled with chlorite (Fig. 2). Quartz occurs in mosaics with which are associated octahedra of secondary magnetite, some of which are surrounded by rims of hornblende. Calcite is present sometimes as a pseudomorph after the porphyritic felspar, but oftener in irregularly scattered grains. Leucoxene is abundant, often with chlorite deposited along the cleavage cracks of the original titanic iron, giving rise to a beautiful series of bars of alternating grey and bright green in ordinary light, or grey and black in polarized light between crossed nicols.

Section No. 57.—Four miles east of Little Rocky Narrows, north shore, Seine Bay. A uralitic diabase, composed of an aggregate of lath-shaped crystals of plagioclase and green uralitic hornblende, the latter greatly predominating. The felspar is largely decomposed and is replaced in part by epidote. Numerous isolated grains of clear quartz are scattered through the section. Seine Bay.

Section No. 59.—Six miles and a half east of Little Rocky Narrows, north shore of Seine Bay. A porphyritic uralitic diabase in which the ground mass is an aggregate of fresh lath-shaped plagioclase and hornblende. In this are imbedded large crystals of plagioclase, which are partially replaced by epidote and zoisite. Needles of apatite occur in the felspar. Numerous anastomosing veins of epidote traverse the section, throughout which are also scattered in sparing quantities calcite and chlorite.

Rock at mouth of Seine River.

Section No. 2101.—Seine River near the mouth. A medium textured massive green rock. Original character scarcely determinable but presents the aspect of a much altered porphyritic trap. It is made up of a rather non-descript aggregate of plagioclase, chlorite, epidote, quartz in lenses with granular margins, leucoxene with opaque nuclei and calcite. In this base are imbedded large cloudy crystals of felspar.

Porphyritic diabase at base of Keewatin series, Bleak Bay.

Section No. 60.—Base of Keewatin series, Bleak Bay, north side. A massive green rock of fine-grained texture with occasional porphyritic crystals of plagioclase. Under the microscope it presents the aspect of an altered diabase. The plagioclase is in large, rather stout, crystals, sometimes in idiomorphic development, but more frequently hypidiomorphic. The augite occurs in hypidiomorphic crystals almost entirely altered to hornblende and chlorite. Secondary hornblende chlorite and epidote have been developed very extensively along cleavages and cracks of the fresh plagioclase. The accessory minerals are apatite and magnetite, both well crystallized and the latter observed, in some cases, enclosing the former.

The belt of the Keewatin rocks, which may be seen in section between the Bear's Passage and the Seine River, continues westward across Rainy Lake. A few more characteristic specimens of the altered traps from this portion of the belt have been examined.

Berry Island.

Section No. 1537.—North side of Berry Island, Rainy Lake. A medium textured, green, altered diabase with roughly schistose structure, made up of cloudy, lath-shaped plagioclase and irregular but generally elongated crystals of hornblende of a rather pale-green color, quartz, with inclusions of small colorless microlites and epidote are plentiful, the latter most frequently occurring in the hornblende.

Section No. 1538.—North side of Berry Island, half a mile east of last locality. A fine-textured massive green uralitic diabase. The diabase structure is well preserved. Plagioclase in cloudy, slender, well defined, lath-shaped crystals is imbedded in broad plates of hornblende which is partly altered to chlorite. Considerable calcite, secondary quartz, in mosaics, and some leucoxene are present.

Section No. 1539.—Eastern extremity of Berry Island. Finely mottled green and white uralitic diabase, in which the characteristic

diabase structure is less perfectly preserved than in the last. The rock is made up of cloudy plagioclase in rather stout lath-shaped crystals; hornblende, in allotriomorphic development; leucoxene, with cleavage traces of original titanic iron; and a considerable amount of quartz.

Section No. 1549.—South side of Berry Island. A medium-grained dark-green altered trap which in structure partakes partly of the character of a diabase and partly that of a gabbro. The felspar appears in lath-shaped crystals, and in broad irregular tabular masses largely replaced by calcite, quartz, epidote and kaolin. The hornblende also occurs in elongated prisms and in broad masses of irregular shape, giving the section, on the whole, a granular aspect.

Section No. 709.—South side of Rat-root Bay, Rainy Lake. A greenish-grey crystalline rock of medium texture with a rude ill-defined schistose structure. Under the microscope, the structure is seen to have been much affected by pressure and stretching. The horn- Rock on south shore Rat-root Bay.

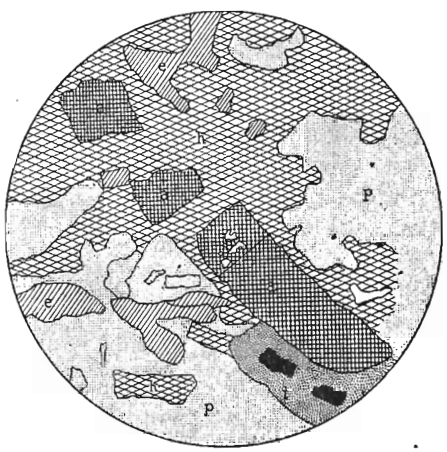



Fig. 3.—Section of altered diabase from Rat-root Bay, Rainy Lake, shewing stretching effects as evidenced by sundered crystal of apatite. × 120.
*a, a, a.* Apatite—same individual.
*h.* Secondary hornblende—various individuals.
*p.* Plagioclase.
*l.* Leucoxene.
*e.* Epidote.

blende mostly presents a very ragged aspect and is torn asunder with secondary hornblende developed in the cracks. In this torn and parted condition it seems to have been very liable to alter to biotite which accompanies it in considerable quantities. The plagioclase is occasionally seen in long lath-shaped crystals, but for the most part, the diabase

Effects of pressure.

structure of the rock has been obliterated by the crushing and stretching to which it has been subjected. The felspar is seen to have been broken, and the smaller fragments, together with decomposition products, such as calcite, epidote, quartz and albite, form a base in which

Fig. 4.—Stretched and sundered crystal of hornblende, with shreds of secondarily developed hornblende, some leucoxene and grains of titanic iron, in altered diabase from Rat-root Bay, Rainy Lake. × 44.

the larger felspars and the more resistant hornblendes appear to be imbedded. Apatite occurs as an original constituent, and shews very well the sundering process which the rock has undergone. Magnetite is present as an associate of the hornblende, and quartz in mosaics and titanic iron with leucoxene are abundant.

Another folded trough of the Keewatin rocks, flanked also on either side by the schists of the Coutchiching series, is well exposed in section on the shores of Rocky Islet Bay. The results of the examination of the altered traps of this belt is now given.

North of Back Point.

Section No. 1493.—Island three-eights of a mile north of Back Point. A coarse-grained, mottled, dark-green and yellowish-white, schistose altered trap. Under the microscope it is made up of large individuals of plagioclase in hypidiomorphic development, beautifully striated, and compact green hornblende, interstitial and enveloping the felspar.

Section No. 1494. Half a mile north of Back Point. Dark-green, fine-grained, altered diabase made up in thin sections of plagioclase in unusually long lath-shaped crystals, and hornblende in broad plates. The plagioclase is often broken; and fragments of plagioclase, original or secondary, quartz, epidote and calcite, make up a fine-grained secondary base.

Rock on island of Rocky Islet Bay.

Section No. 1499. Small island on west side of Rocky Islet Bay. A coarse-grained rock of granitic aspect, composed of lilac-colored felspar, yellow in patches from the presence of epidote, and a green pyroxenic mineral, largely changed to micaceous chlorite. Under the microscope the plagioclase appears in broad plates, sometimes quite fresh, but usually decomposed and altered to epidote and kaolin. The pyroxene is rhombic and slightly pleochroic. When it has escaped alteration to

chlorite, it must be regarded as bronzite or enstatite. Magnetite is present in sparing quantity.

Section No. 1500. West side of Rocky Islet Bay. A medium-grained, mottled, greenish-grey rock with foliated structure. Under the microscope it has the character of an altered gabbro, being made up of a granular aggregate of non-pleochroic foliated pyroxene, with an extinction of over 30° (diallage) and plagioclase. The fresh diallage is not abundant, and it is always partially altered to hornblende and chlorite, while there is an abundance of hornblende which, although it shews no cores of diallage, is doubtless paramorphic after that mineral. The felspar is very largely altered to zoisite, which appears in large patches with rounded areas of unchanged felspar included in it. Epidote is also an alteration product of the felspar, but it is very much less abundant than the zoisite. West side of Rocky Islet Bay.

The following three specimens were taken from the same mass of bedded trap at the north end of Rocky Islet Bay. No. 1503A is from the middle of the bed, 1503C from its contact with adjoining schists, and 1503B from a point intermediate between these. Bedded trap north end of Rocky Islet Bay

Section No. 1503A. A mottled green and white diorite-like rock of medium texture and granular structure. In this section it appears as an altered gabbro made up of a granular aggregate of diallage, with paramorphic hornblende and plagioclase, with a considerable amount of epidote. The diallage is in large plates of grey color, showing very distinctly the usual parting parallel to $\infty P\bar{\infty}$ upon which the extinction angle is 25° and upward. It is altered to green compact hornblende on its borders, and irregularly shaped plates occur, made up entirely of the hornblende which, however, is light-green to almost colorless in the centre, and deep green towards the periphery. In both diallage and hornblende, minute inclusions occur, arranged parallel to the parting of the one and the cleavage of the other. The plagioclase is cloudy with kaolin, epidote and zoisite. A little biotite, is also observable in the section. Middle of bed.

Section No. 1503B. Finer grained and darker colored than A. Under the microscope it resembles A, but there is no diallage left, that mineral having been entirely changed to hornblende, which is frequently dusty, with grains of magnetite, usually heaped together in the centre of the crystal, but occasionally in distinct octohedra. Some of the plagioclase is almost opaque with decomposition products, among which epidote is prominent; while other crystals are clear and glassy, and abound in inclusions of straight colorless microlites. Intermediate part of bed.

Section No. 1503C. A little finer grained than B, but more distinctly crystalline and glistening and of a darker color. The rock is a granular aggregate of hornblende and plagioclase, together with small quan- Edge of bed.

tities of quartz, epidote and magnetite. The hornblende, in some basal sections, is seen to have the outline of a perfect prism.

West side Rice Bay.

Section 1519B. Rice Bay Narrows, west side. Medium textured, mottled white and black altered gabbro, composed of a granular aggregate of plagioclase, hornblende and biotite, with some non-striated felspar. The plagioclase is for the most part fresh, being only occasionally cloudy with decomposition products. The hornblende is not so abundant as the plagioclase, and the biotite which accompanies it is apparently secondarily derived from it. In the case of some of the hornblende crystals, undoubted pyroxene can be detected, with brilliant polarization colors and high extinction angle. A few crystals of apatite occur in the hornblende.

Rock at north end of Bear's Passage, Redgut Bay.

Section No. 1561. Island at the north end of the Bear's Passage, Rainy Lake. A medium textured mottled black and white altered trap composed of a granular aggregate of plagioclase hornblende and titanic iron with rims of leucoxene. The felspar is rather decomposed, giving rise to quartz and epidote. It occasionally occurs in lath-shaped crystals, but for the most part, both the felspar and hornblende are allotriomorphic and the structure granular, inclining to the gabbro rather than to the diabase type. This trap rock holds included in it angular fragments of an older rock of finer texture and greener color. A section No. 1561A of one of these inclusions shews it to be made up of a felt work of hornblende, with considerable quartz, and a little plagioclase chlorite, epidote and leucoxene with opaque nuclei. The rock affords little indication of its original structure or mineral composition.

West side of Redgut Bay.

Section 1601A. West side of Redgut Bay, north of the Bear's Passage. A medium textured, black-green, massive, crystalline rock, made up of a granular aggregate of compact green hornblende in large irregular plates, with a little very cloudy interstitial felspar, some water-clear quartz, and fresh non-striated felspar. A little epidote is associated with the cloudy felspar.

Section No. 1601B. Same locality as last, and apparently only a different facies of the same rock, being greyer in color, and more quartzose and epidotic. The hornblende is largely altered to epidote, and the quartz occurs in mosaics of large grains. Grey leucoxene with opaque nuclei is the only other mineral.

Squall Point, Rainy Lake.

Section No. 763. Squall Point, Rainy Lake. A coarse textured uralitic diabase included in gneiss. Under the microscope, the hornblende is in large compact masses, with very frequently a pale green, almost colorless central portion, indicating the earlier form of the mineral as augite, and indeed in some cases traces of the augite itself appear still to remain. Epidote and magnetite are associated with the

hornblende. Plagioclase is in rather stout lath-shaped crystals, somewhat cloudy, but with twinning structure well defined; apatite and quartz are present in sparing quantities.

The following six specimens were taken from the Keewatin belt, as exposed on the shores of Manitou Lake:

Section No. 1139. West side of Manitou Lake, opposite Snare Bay. A mottled green and white, altered gabbro of medium texture. Seen under the microscope, to be made up of a granular aggregate of diallage and felspar, the latter being almost completely changed to a dense, cloudy, grey mass which, between crossed nicols appears as zoisite. The diallage is partially altered to hornblende. The only other mineral to be noted is leucoxene. Pressure effects are observable only to a very slight extent. Manitou Lake, opposite Snare Bay.

Section No. 1088.—Manitou Lake, east side, about a mile and one-half north-east of Snare Portage. A much altered diabase. The augite is represented now only by chlorite, having first probably passed through the uralitic stage. The plagioclase is nearly all replaced by calcite and chlorite, its long lath-shaped form being, in most cases, all that is left to determine the character of the original mineral. There is a good deal of quartz present, some of which holds needles of apatite as inclusions. Leucoxene occurs in large patches, with black opaque grains scattered through it, and shows pressure effects in being torn asunder. A little pyrite in cubes is also present. E. side Manitou Lake.

Section No. 1105.—West side of Peep Bay, Manitou Lake. A rudely schistose green rock, apparently a very much crushed and altered diabase. It is made up of fragments of plagioclase and quartz, imbedded in a base which is largely made up of chlorite and calcite, the former of which shews a tendency to a parallel linear arrangement which determines the schistosity. Both chlorite and calcite fill the interstices between the dislocated felspars, and many of the latter are wholly or partially replaced by secondary quartz, calcite and chlorite. Although the original structure of the rock is obliterated, it appears altogether probable, from the frequent idiomorphic lath-shaped character of the plagioclase or its pseudomorph, that the rock was originally a diabase. Peep Bay, Manitou Lake.

Section No. 1106. West side of Peep Bay, Manitou Lake, half a mile north of last. A light greenish-grey, somewhat mottled, finely crystalline altered diabase. Under the microscope the rock shews abundant evidence of crushing and stretching. The stout, lath-shaped crystals of plagioclase, which are quite fresh, are frequently broken and parted, the cracks being filled in with chlorite, calcite, epidote and quartz. Titanic iron, with associated leucoxene, is abundant, and is, like the felspar, frequently sundered. Irregular masses of chlorite appear to be

all that is left to represent the augite. The lath-shaped felspars are surrounded by the chlorite as they are by augite in fresh diabase. In between these masses of chlorite, crystals of felspar and grains of titanic iron, there is a base made up of a mixture of grains of chlorite, epidote, quartz, calcite and magnetite.

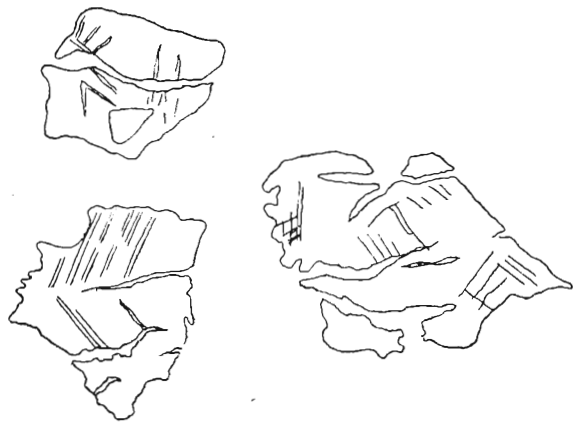


Fig. 5.—Stretched leucoxene in altered diabase from Peep Bay, Manitou Lake. × 44.

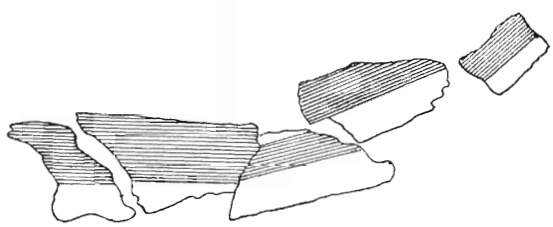


Fig. 6.—Shattered crystal of plagioclase in altered diabase from Peep Bay, Manitou Lake. × 44.

E. side Manitou Lake, opposite Peep Bay.

Section No. 1123.—Manitou Lake, east side, opposite Peep Bay. Greenish-grey, roughly schistose altered trap with an unctuous feel on cleavage surfaces. Under the microscope it presents the appearance of a very much crushed rock. The most prominent constituent is a comparatively fresh plagioclase, which is nearly always broken and appears, in some instances, to have been pulverized to a granular mass which probably, in a partially recrystallized form, mingles with chlorite and calcite, to form a secondary ground mass analogous to the "*Mörtel structur*" of Törnebohm. The augite is represented only by chlorite.

Apatite and titanic iron with leucoxene are present, but not abundant. The structure of the rock is almost obliterated, but it is probably only a cataclastic diabase. A section (1126) of a similar rock from near the same locality as last, which differs from it chiefly in the presence of biotite, is illustrated in Fig. 7, where the tearing apart of the felspars is well shewn.

Fig. 7.—Section of much altered rock from east side of Manitou Lake, shewing sundering of felspar crystals. × 44.

*f.* Felspar, mostly torn into several pieces.
*ch.* Chlorite.
*b.* Biotite.
*l.* Leucoxene.
*gr.* Ground-mass, crushed felspar, quartz, calcite, chlorite and muscovite.

Section No. 1117.—West side of Manitou Lake, two miles north-east of Paddle Portage. A fine textured, green, altered diabase, which shews under the microscope the typical diabase structure. Small lath-shaped crystals of quite fresh plagioclase, occasionally bent, but never broken, are surrounded by hornblende which is partially altered to chlorite. Associated with chlorite are epidote, calcite, and pyrite in cubes. W. side Manitou Lake.

The following five specimens are taken from exposures of the same belt as exposed much farther to the east on the shores of Crow Lake, Pipestone Lake and Kishkutena Lake.

Section No. 25.—Extremity of point on Crow Lake, half way between Crow and Wade portages. Uralitic diabase porphyrite (?) shewing a fine-grained ground mass of calcite, epidote, chlorite, hornblende, quartz and leucoxene, in which are imbedded large, rather

S. W. side Crow Lake.

stout, lath-shaped crystals of plagioclase which are often partially replaced by calcite. These felspars are often torn asunder, and the intervening cracks filled with chlorite. The felspars are also frequently surrounded by a deep fringe of chlorite, which is bright green and slightly pleochroic in ordinary light, and deep olive green to opaque between crossed nicols. The fibres or scales of the chlorite are observed to stand perpendicular to the contours of the felspar. Hornblende in large porphyritic crystals, frequently twinned, is as plentiful as the felspar.

S. shore Crow Lake.

Section No. 108.—South shore of Crow Lake opposite Patch Island. A coarse greenish-grey rock, with yellowish-white weathering, appears under the microscope as a uralitic saussurite gabbro, made up of a granular aggregate of hornblende and saussurite, the former predominating and frequently twinned. There is present also considerable grey leucoxene, with sometimes an opaque nucleus of titanic iron, secondary quartz enclosing needles of actinolite and chlorite in veinules. The saussurite is chiefly made up of bright blue polarizing zoisite.

Near Shanty Point, Crow Lake.

Section No. 145.—Bay west of Shanty Point, Crow Lake. A medium textured altered diabase of mottled aspect, due to intermixture of greenish-grey chloritic mineral and greenish-yellow felspar. Under the microscope, the plagioclase is in well defined lath-shaped crystals, very largely changed to saussurite, which renders it cloudy almost to opacity. Interstitial hornblende altered, for the most part, to chlorite, and grains of leucoxene make up the rest of the section.

N. W. side Pipestone Lake.

Section No. 306.—Island off the north-west side of Pipestone Lake. Mottled green and white uralitic saussurite diabase. Under the microscope the lath-shaped plagioclase appears as a cloudy aggregate, which the analyser resolves into albite, zoisite, epidote, muscovite and calcite, constituting the decomposition aggregate known as saussurite. The original pyroxenic constituent is represented now by elongated, often twinned, crystals of hornblende. A little quartz is present, also leucoxene with opaque nuclei.

S. side Kishkutena Lake.

Section No. 1892.—Kishkutena Lake, south side. An altered trap of eminently porphyritic facies. Macroscopically, it appears as a fine-grained ground mass, of green color, in which are imbedded large white sharply defined crystals of felspar, often as much as an inch in diameter. These crystals are sometimes observed to enclose portions of the ground mass. Under the microscope, the ground mass is made up of an aggregate of small grains of felspar, quartz and hornblende. The hornblende is in long prisms and short, more or less granulitic or rounded grains, with which are associated a little calcite. The porphyritic felspars are almost entirely replaced by zoisite, calcite, albite and muscovite, the first named mineral predominating, making up the

saussurite aggregate. A veinule of mosaic quartz and albite traverses the section. The section does not satisfactorily reveal its original character, but there is no doubt of its having been the porphyritic facies of a basic massive rock.

### *Hornblende Schists.*

Evidence of origin of hornblende schists.

In the rocks here considered there is no conclusive evidence as to their original character, whether they were massive or clastic. There is much presumptive evidence in favor of the view that they are partly altered massive rocks and partly altered volcanic ash beds (pyroclastic) but little or none that they are the alteration products of clays or other forms of detrital matter. The changes which these rocks have undergone have been so profound that only occasionally can a trace of their original character be discerned; and we have a new rock in which the constituent minerals have crystallized in situ, and have, since their crystallization, been practically undisturbed by pressure, except to this extent that the pressure was probably constant while secondary crystallization was in process. If dynamical influences were potent in the destruction of the original structure, as we must admit from the conditions of their occurrence, and their association with rocks that afford good evidence of crushing, chemical or metasomatic changes, have since been sufficiently active to have obliterated all or nearly all trace of crushing, and have replaced the crushed aggregate by an assemblage of minerals each of which has been formed under conditions implied by the contemporaneous crystallization of the others.

Diversity in microscopic aspect.

The rocks classed as hornblende schists exhibit within certain narrow limits a considerable diversity in their microscopic aspect. They are, however, for the most part, aggregates of hornblende and quartz, the common accessory minerals being epidote, zoisite and magnetite.

Two phases of first variety of hornblende schists.

In one variety a colorless base of quartz grains, which in section appear as a mosaic, forms a matrix in which are imbedded the hornblende individuals as the predominant constituent. Two fairly distinct phases of structure are observable in this variety, which are manifested particularly in the form and arrangement of the hornblende. In the first of these, the hornblende assumes sheaf-like forms, compact towards the middle, but frayed out into a radiating tuft of a more or less fibrous character at one or both ends of the somewhat elongated individuals, the elongation being, of course, in the direction of the *c* axis. These sheaf-like masses are thrown indiscriminately together so as to form a more or less intricate felt-work. In the second phase of structure the hornblende is uniformly compact, and assumes the form of

single prisms which are either short and oblong in shape, or have the shape of long slender needles or rods. These stout oblong prisms are in parallel alignment. The more slender rods or needles are less strictly so, and may cross each other at small angles and produce a felted aspect in section.

The structural features thus indicated are doubtless a function, both of the original character of the rock and of the conditions under which secondary crystallization has taken place, and although those conditions are not yet understood, it is altogether probable that a careful study of these schists will lead to as satisfactory a conception of the relations between structure and conditions of crystallization as has been established in the case of the massive rocks which have crystallized from magmas.

Two phases of second variety of hornblende schists.

2. In the other variety of these schists, plagioclase is a prominent constituent, and the rock approaches a diorite in composition, and in some cases even in structure. Two general phases of structure may also here be distinguished, viz.: that in which the disposition of the minerals is similar to that of the second phase of the first variety; and that in which the structure is more granular or dioritic.

Geological position of these schists.

The interesting feature of these rocks, when their petrographical characters are considered in connection with their field occurrence, is that they seem to be confined in the district under consideration mostly to the base of the Keewatin series, and then only when that base is in contact with the gneisses of the Laurentian, which shew abundant evidence of having existed beneath them in the state of a liquid or viscid magma, a condition of things which would amply account for their extreme alteration, especially if we consider the magma, which consolidated as the Laurentian gneiss, to have been one of hydrothermal and not necessarily of dry fusion.

Hornblende schist at contact with Laurentian gneiss.

At the contact of the Keewatin and Laurentian, at the south end of Crow Portage, the base of the former is represented by a compact, black glistening schist of freshly crystalline aspect. To the naked eye it appears to be made up of fine black needles of hornblende, all arranged approximately parallel, with an interstitial micro-crystalline greenish-grey material. Under the microscope (48A) the hornblende appears in elongated shreds and patches of bright green color. These hornblende crystals shew a distinct, though rough alignment or parallelism. The interstices between them are occupied by quartz and felspar (?) with some epidote and zoisite. The quartz is dusty with inclusions of colorless needles, liquid inclusions with and without bubbles, and gas inclusions. The epidote is rather abundant, and occurs in large, pale greenish-yellow masses, and in small oval grains which frequently have a nucleus of iron oxide.

Crow Portage.

Some of the rocks higher up in the series, but associated with schists such as that just described, are very similar to those at the contact, but are more felspathic, less evenly schistose, and of a more massive aspect. A specimen taken from Turtle Portage may be described as a type of these rocks. It is a dark-green to black rock, with a small amount of greyish-white mineral peppered through it, which comes out distinctly on the weathered surface, shewing a streaked or linear disposition. Under the microscope, the rock appears as a granular aggregate of hornblende and plagioclase, and may perhaps be designated as a diorite. It is not apparently, however, one of those rocks which are often called diorite, but which are clearly altered forms of diabase. There is no trace of diabase structure nor any evidence that the hornblende is a paramorph of any variety of pyroxene. Both plagioclase and hornblende are fresh. A little epidote and magnetite are scattered through the section. Turtle Portage.

On the north-west side of the lower end of Pipe-stone Lake, the rock is a dark green hornblende schist. In thin section (318) it is seen to be made up of an intimate felt work of tufts of hornblende, with a little chlorite and epidote, and considerable quartz in interlocking grains. Leucoxene is also present in long slender lenses arranged in parallel position, thus giving a decided banded appearance to the section. Lower end of PipestoneLake.

A somewhat similar rock occurs on the south-east side of this same lake. It is made up as seen in thin section (352) of a felt work of partially fibrous hornblende altered in places to chlorite. Considerable epidote is associated with the hornblende and magnetite in fine grains, generally disseminated. The colorless interstitial base of the rock is made of mosaic quartz.

A couple of miles along the same shore to the north-eastward in the same line of strike, the rock is a more massive, coarsely crystalline schist (355) in which the predominating mineral, hornblende, is present in the form of an intricate felt work of large hornblende individuals, and finer fibrous shreds, through which is distributed zoisite in short columnar crystals. Fresh plagioclase, probably albite, is present, as well as quartz and some leucoxene. The hornblende is in places partially altered to chlorite.

On the south-side of First-quill Lake, Kishkutena route, the hornblende schists are medium, grained, green, rather massive rocks. A specimen (1856) appears, under the microscope, to be made up of sheaf-like or double tufted masses of more or less fibrous hornblende, with a large amount of epidote and zoisite. Between these there is a fine ground-mass of felspathic material which polarizes in dull, bluish colors as an aggregate and partly shews an undulatory extinction. There are no sharply defined boundaries between the different grains. First-quill Lake

This ground mass shews a parallel or schistose arrangement, is in places decomposed to muscovite and epidote.

Lake Despair.

A specimen of the hornblende schists which occur on Lake Despair, taken from the south-west corner of South Bay of that lake, is a fine-grained dark-green to black, hard schist seen to be made up in thin section (1743) of green hornblende, in small oblong grains, all in parallel position, with quartz in rounded oblong grains, epidote and probably some felspar. Quartz also occurs in nests or mosaics of large grains.

Cedar Narrows of Pickerel Lake.

At the south end of Cedar Narrows of Pickerel Lake on the Manitou Route, the rock at the base of the Keewatin series is a compact black or dark-green, hard, slaty hornblende schist. A specimen from near the contact appears in thin section (988) to be made up chiefly of light-colored green hornblende in compact plates of irregular shape, but generally elongated parallel to the prism, and zoisite in colorless compact masses having the same orientation over wide fields, polarizing in soft blue colors and shewing parallel extinction and biaxial interference figure. A few sphenes are present in well formed crystals of the usual double-wedge shape, such as are common in the syenitic gneiss of the Laurentian immediately to the south of the narrows. Epidote and chlorite appear as decomposition products of the hornblende.

West side Pickerel Lake.

A specimen from the band of hornblende schists which crops out on the west side of Pickerel Lake, north of the Narrows, is a dark-green, medium-grained, rudely schistose rock (1003) made up of a felt work of compact sheaf-like hornblende imbedded in a colorless base of quartz grains in mosaic arrangement with a little epidote and leucoxene as the only other constituents.

Lake along the Hill.

On the south side of the Lake along the Hill, near its middle, the rock is a compact black-green finely crystalline hornblende schist which appears under the microscope (1208) as a close felt work of more or less sheaf-like hornblende imbedded in clear quartz, in mosaic grains. The only other constituent is titanic iron in aggregates of grains each surrounded by its margin of leucoxene. The quartz manifests a peculiar state of optical tension which causes different portions of the same grain to have slightly different orientations, so that the extinction is neither uniform nor undulatory, but jumps across the section from area to area between which there are no observable lines of demarkation.

Three Island Lake.

A specimen from the south-east corner of Three Island Lake, Little Canoe River route, is a fine-grained, green, hornblende schist, which is seen under the microscope (1230) to be made up of a fine felt work of shreds of hornblende imbedded in a colorless base which consists

chiefly of quartz, with some epidote, zoisite and leucoxene scattered through it. The hornblende, though matted together, shews a rough tendency to parallel arrangement.

Big Turtle River. Hornblende schists penetrated by Laurentian gneiss.

At the mouth of the Big Turtle River, the hornblende schists of the Keewatin series are much penetrated by, and included in, the underlying Laurentian gneiss. A specimen of the schist thus intersected by the gneiss appears on cleavage faces as a black glistening rock of medium texture. On transverse fracture it appears peppered with grey-white felspar in minute specks. Under the microscope (A) it resembles the specimen from Turtle Portage, and appears as a dioritic or granular aggregate of deep colored green hornblende and fresh plagioclase, with a very little quartz, the hornblende greatly predominating. A little epidote is also present, together with some cloudy or finely granular matter shewing aggregate polarization as of a fine micro-crystalline admixture of muscovite and calcite.

Rocky Islet Bay entrance.

The rock at the entrance to Rocky Islet Bay on the west side (1492) is a compact dark-green finely-crystalline schist made up of hornblende, quartz, and plagioclase. The hornblende is in compact, oblong grains with rounded corners all arranged in nearly parallel position. The quartz and fresh plagioclase are less abundant and are interstitial, also shewing a tendency to an arrangement in long parallel areas alternating with the hornblende.

North shore Rocky Islet Bay

On the north shore of Rocky Islet Bay the rock is a dark-green, fine-grained, glistening hornblende schist. Under the microscope (1502) the hornblende occurs in broad, irregularly shaped plates generally closely interlocking, but often with considerable quantities of epidote, zoisite and fresh plagioclase between the hornblende grains. A granular, nearly opaque, brownish aggregate of kaolin-like material is also present. The rock, to the naked eye, is seen to be banded with yellow areas, and a section through one of these shews it to be made up almost entirely of epidote in regular shaped oblong grains, together with a little zoisite and some hornblende, all the minerals having a more or less distinct parallel arrangement of their longer axes.

Another specimen from the north end of the same bay (1503 D) is a fine-grained, greenish-grey, glistening schist made up of a mosaic of hornblende, non-striated felspar and quartz. All three minerals occur in grains of oblong shape being usually two or three times longer than broad. The hornblende grains are larger than those of the quartz or felspar, both of which are about the same size and difficult to distinguish without reference to their action on converged polarized light.

Grassy Island.

A specimen from the south side of Grassy Island, Rainy Lake, is a dark-green fissile or slaty hornblende schist, shewing in thin section (735) a felted arrangement of sheaves of hornblende of a

more or less fibrous character, lying in a colorless matrix of quartz and calcite, throughout which are also scattered a little epidote, magnetite and chlorite.

Otukamamoan Lake.

The hornblende schists which form the middle of the three tongues into which the Keewatin belt splits up on Otukamamoan Lake are fine-grained and of an eminently crystalline, glistening, black aspect. A specimen from the west side of the lake appears, to the naked eye, to be made up of needles or prisms of black glistening hornblende, closely compacted and in parallel position, peppered with a greyish-white subordinate constituent. Under the microscope (1526) it is seen to be made up of hornblende, felspar and quartz, the first predominating in compact, deep colored, strongly pleochroic green prisms from two to four or five times longer than broad. This compact prismatic character of the crystals is very constant. The ends are sometimes sharp or jagged but more often somewhat rounded or square. These prisms are so closely packed sometimes that there is but little interstitial space between them, but for the most part there are irregular spaces which are occupied by fresh felspar and quartz, which have their contours determined by the shape of the interstices. None of the felspar was observed to be striated, and it is usually quite fresh. In both felspar and quartz there are numerous inclusions.

Memekwisi Lake.

A band of hornblende schists is exposed on Memekwisi Lake; these shew in hand specimens a black glistening surface on cleavage faces, while on transverse fracture it appears as an alternation of very thin laminæ of black glistening hornblende and greyish-white felspar and quartz. Under the microscope the hornblende appears in deep colored green patches or shreds of irregular shape, which are, however, usually elongated in the direction of the prismatic cleavage and arranged rudely parallel. The hornblende is in some portions of the section closely packed together, while in others it forms a more open felting, the interstices being occupied by plagioclase and quartz in mosaic, the former being quite fresh. The section appears to have been cut at only a small angle to the plane of foliation so that the lamination, which is so apparent in tranverse fracture, is not a marked feature of the thin section. Shreds of hornblende, together with numerous other inclusions, occasionally arranged in lines, occur in the felspar and quartz.

Longue Sault Rapid, Rainy River.

On Rainy River, at the head of the Longue Sault Rapid, the Keewatin series is represented by a dark-green, very fine textured, compact hornblende schist, somewhat glossy on cleavage faces. Under the microscope (1609) the base of the rock is seen to be made up of a felt-work of distinct, well defined needles of light green hornblende only slightly pleochroic. These needles shew a decided tendency to parallel arrangement, and the felted aspect is due to their crossing each other

at small angles, although occasionally needles may be seen transverse to the rest. The interstices between these needles are occupied by bluish felspar and a little quartz. Where the interstices are small, the grains of felspar have their shape moulded against the long needles of hornblende, but where they are more open, as is often the case, the felspar grains form mosaics, the constituent grains having a decided granulitic or rounded appearance. Grains of magnetite are commonly scattered through the section. In this base are imbedded large grains of plagioclase, both in lath-shaped crystals and in shorter tabular crystals. These are, for the most part, fresh, being only occasionally cloudy, and shew twinning lamellæ. Some of them have retained their crystallographic outline, but most of them shew a rending or granulation due to pressure and shearing; and, in some cases, the crystal has been apparently reduced to the cataclastic state (*mörtel structur* of Törnebohm). Some of these crystals of plagioclase have a broad border in which hornblende needles similar to those of the base have been developed along the cleavage partings of the felspar. The needles are abundant but are smaller and shorter than those of the base, which are often of great length. In other crystals, the development of hornblende needles is not confined to a peripheral border, but has taken place throughout the crystal, the needles always lying in the cleavage partings. The rock is doubtless an altered diabase-porphyrite in which the porphyritic plagioclase has suffered less alteration than the base. It is an interesting case where a rock having the characters of a hornblende schist still retains features which indicate clearly its derivation from a massive igneous rock. The base of the rock does not differ essentially from the sections of many of the hornblende schists above described, and the analogy is suggestive of the derivation of some of the latter from ordinary diabases free from large porphyritic crystals.

On the Pine River there are two exposures of the hornblende schists of the Keewatin. That at the first rapid is a very fine-grained, compact, hard, dark-green hornblende schist. In thin section (1617) it resembles the base of (1609). It is, however, finer-grained, and the needles more intricately felted. They show also a less regular shape. These microscopic characters seem to correspond with the fact that the rock is much less schistose than the rock at the Longue Sault. The interstitial base or matrix in which the hornblende is imbedded, is mostly bluish felspar, with probably some quartz, but too small to determine optically. Scattered through this base are attenuated linear areas lying in all directions, which are occupied chiefly by mosaics of felspar with some epidote and quartz (?). Some of these appear to be the granulated remains of lath-shaped plagioclase crystals, while others Pine River.

have rather the appearance of small cracks secondarily filled. Magnetite is sparsely distributed over the field.

The same description is applicable to the rock (1618) of the second rapids of the Pine River, except that the hornblende needles are larger and the texture, in consequence, appears coarser; and that remains of porphyritic felspar crystals are, perhaps, more distinct.

### *Soft Fissile Green Schists.*

Clastic origin.

These are schists closely resembling the paste of some of the conglomerates. They are usually distinctly bedded. Their clastic origin can scarcely be doubted, though, as in the paste of some of the conglomerates, their association with bedded traps and their mineralogical analogy with the altered phases of those traps, renders it extremely probable they were never ordinary clays, but were originally fine-grained, volcanic ash beds, the constituent minerals of which have suffered alteration and decomposition along the same lines as those observable in the traps. They are metamorphic rocks probably only in the sense that they exemplify in bedded volcanic ashes of a certain character, those paramorphic, metasomatic and dynamic changes which are now so well known in the corresponding massive rocks.

It is often difficult to draw the line between certain varieties of this class of rocks and those which have, in another section been spoken of, as hornblende schists. In this connection it is, as I have elsewhere pointed out, interesting to note that the darker, harder, more compact, and less chloritic hornblende schists are usually found at the base of the Keewatin series where the basal portion is in contact with the igneous granitoid gneiss of the Laurentian; while, when the base of the Keewatin rests upon the Coutchiching, the soft, fissile, light colored chloritic, green schists abound, and are also found in portions of the Keewatin removed from the contact with the Laurentian gneiss. The darker, harder, more compact, often glistening hornblende schists appear to be in part an altered phase of the fissile green schists, and the alteration further appears to be a function of their proximity to the Laurentian gneiss, which gneiss has all the characters of an igneous irruptive rock.

Swell Bay.

Only a few specimens of this class of rocks have been microscopically examined. On the shores of Swell Bay, these schists are found intercalated with the massive or slightly schistose altered traps. A specimen was taken from one of these beds about one mile east of the Bear's Passage. It is very fine-grained, greenish-grey schist, glossy on cleavage surfaces. In thin section (1604) it appears as an irregular aggregate of masses of fibrous hornblende, zoisite in colorless grains,

brownish-grey leucoxene in rounded grains, chlorite, quartz and calcite.

In another specimen (1605) taken at the same locality from another bed, the hornblende appears in needles and fibrous shred-like masses with a decided tendency to parallel arrangement. Chlorite is abundant. The other minerals are epidote, zoisite and leucoxene, none very abundant.

On an island in the north-east corner of Swell Bay the rock is a glossy, greenish-grey fissile schist made up in thin section (1616) of a fine-grained aggregate of quartz, fresh felspar, zoisite, decomposed biotite in parallel arrangement, and masses of chlorite in which are imbedded crystals of epidote. In contrast to this ground mass are large grains of calcite and leucoxene, with often opaque nuclei. Iron oxide stains the rock somewhat. The general aspect of the section is perhaps less like that of a volcanic ash than the other sections.

The fissile green schists of Grassy Lake on the Seine River are in thin section (49) seen to be comprised of chlorite, a few shreds of hornblende, an abundance of calcite and a little quartz, all in a more or less parallel arrangement. Grassy Lake.

On the north side of Bad Vermilion Lake a similar fissile schist occurs. It is composed (51) of an irregular mosaic of quartz, mixed with anastomosing areas of green, feebly pleochroic chlorite. Where the chlorite is in largest masses, it encloses crystals of colorless to yellowish epidote. The quartz contains liquid inclusions, often with a moving bubble and microlites of a highly refracting mineral, probably zircon. A little leucoxene with opaque nuclei, calcite and pyrite are the only other minerals. Veinules of epidote traverse the slide. Bad Vermilion Lake.

Another specimen of a similar schist from the N.E. end of the same lake (19) is a dark-green fissile rock, which, in thin section, appears to be made up mostly of quartz and chlorite. with large grains of calcite and some magnetite. All the constituents shew a parallel disposition.

A specimen of the dark-green fissile schists which are commonly interbedded with the altered traps on the north shore of Seine Bay, (17) is made up of quartz, felspar (in sparing quantity) hornblende and chlorite; with titanite, magnetite and epidote as accessory constituents. Some of the chlorite appears to be the result of the alteration of the hornblende, but for the most part its origin is indeterminate. The quartz and felspar form a mosaic ground-mass which, in places, is visible through the thin flocculent chlorite. The titanite is rather abundant in the usual double wedge-shaped crystals, and is disposed independently of the schistosity, which is evident in the arrangement of the other constituents. The crystals of titanite often have an opaque nucleus. The epidote is sparingly represented, and occurs in irregular grains. Seine Bay.

*Conglomerates.*

Interest attaching to these rocks.

These rocks are of extreme interest inasmuch as they not only give us a distinct criterion of the extent of the alteration which may be effected in strata of indisputably clastic origin, but also give us a clew as to the stratigraphical relations of the series of which they are members, to the underlying rocks. The nature of the pebbles, further affords us evidence as to the approximately original character of these latter rocks.

Rat-root Bay, Rainy Lake.

On the shores of Rat-root Bay, Rainy Lake, a formation of pebble conglomerate is well exposed and possesses strongly marked characters. The matrix is a rather soft, dark, glossy green, fissile chloritic schist. The pebbles are of a rather heterogeneous character and comprise smoothly rounded, distinctly water-worn pieces of glassy or saccharoidal quartz, pebbles of a somewhat foliated felspathic rock, and boulders of granite.

Granite boulder

A thin section (708) of a boulder of medium textured flesh-red granite imbedded in green schist on the south side of the bay appears under the microscope as a granular or allotriomorphic aggregate of orthoclase and plagioclase, with inclusions of apatite in the usual stout needles, quartz and biotite, with some accessory magnetite and secondary epidote. The felspars are cloudy, but the twinning lamellae of the plagioclase are quite distinct. The quartz has liquid inclusions arranged in streams. The biotite is frequently bleached or is altered to chlorite and epidote. Some fresh secondary biotite occurs as a rim around grains of magnetite. Leucoxene and limonite are present also in small quantities.

Granite boulder in schist, Swell Bay.

At the south-east corner of the end of Swell Bay, Rainy Lake, a granite boulder less than a foot in diameter was found imbedded in a fissile green schist which is interstratified with other green schists and with altered diabases. The granite is coarse-grained and of yellowish red color. Under the microscope (1618) it is remarkably fresh, and is made up of a granular aggregate of quartz, glassy orthoclase and plagioclase, with occasionally a micro-perthitic structure, and biotite. The accessory minerals are pleochroic titanite, apatite, magnetite and a little calcite. The orthoclase in exceptional spots is cloudy with muscovite. Radiating tufts of an actinolite-like mineral occur in the quartz. The plates of biotite are occasionally curved, and are often associated with and include crystals of titanite.

Seine River.

On the north side of Shoal Lake and Grassy Lake, on the Seine River, near the base of the Keewatin series where it rests on the Coutchiching, there is a formation of pebble and boulder conglomerate. The pebbles are mostly small, not exceeding, as a general rule, three

inches in longest diameter. Not infrequently, however, they are six inches or even a foot in diameter. They are distinctly water-worn and are oval or rounded in contour. They are imbedded in a fissile, glossy green, chloritic schist. The rocks have been evidently subjected to great pressure, to which must be ascribed the development of the schistosity in the matrix of the conglomerate; but owing to the great discrepency in resisting power between the pebbles and the matrix, the former have escaped deformation, while the latter has been much squeezed, as is shewn by the planes of schistosity bending around and conforming to the shape of the pebbles.

Pebbles.

A thin section (3003 a) of one of these smooth, oval pebbles appears, under the microscope, as that of an altered felsite, being made up of a compact micro-crystalline aggregate of quartz and felspar, both striated and unstriated, in which a large amount of sericite has been secondarily developed.

A section (3003 b) of another similar pebble from the same conglomerate appears somewhat coarser in texture than the last, and partakes of the nature of a porphyry. In a very fine-grained base of quartz and felspar, in which have been developed much sericite and epidote, there are imbedded crystals of microcline with sharp well formed boundaries.

Pickerel Lake.

On the west side of Pickerel Lake, Manitou Route, a band of felsitic agglomerate assumes locally the characters of a true conglomerate, in which a greenish schistose matrix holds rounded pebbles and angular fragments of quartz porphyry. A thin section (1044A) of one of these pebbles appears under the microscope, as a fine grained felsitic base in which are imbedded large porphyritic crystals of orthoclase, plagioclase and dihexahedral quartz, with a few tufts of fibrous hornblende. Veinules of secondary quartz in mosaics of large grains traverse the section.

Matrix of conglomerate.

The matrix in which pebbles of this character are imbedded, is a green hornblende schist (1044), made up under the microscope of an intimate felt work of sheaf-like tufts of fresh green hornblende which appear to be imbedded in a transparent medium or base of quartz in small interlocking grains, together with calcite in large separate grains, and in mosaics with the quartz. Associated with the hornblende there is considerable magnetite in small grains.

Among the soft fissile glossy gray schists of the Keewatin series at the west end of Schist Lake, Pipe-stone route, there are several beds of conglomerate, the pebbles of which are mostly quartz rock, and the matrix a soft, more or less calcareous, decomposed schist, stained yellowish with oxide of iron.

Schist Lake conglomerate.

A thin section (217) was made across the line of contact of a pebble and its surrounding matrix. Under the microscope the matrix appears to be made up largely of calcite, muscovite in nests, quartz in aggregates of fine grains and in single fragments, and of irregular masses of brownish and red translucent iron oxide.

The pebble consists almost entirely of quartz in a very fine mosaic aggregate, partly chalcedonic. The line of contact of the pebble and matrix has been a channel of infiltration; for close to the contact there has been deposited in the quartz aggregate an abundance of minute scales of muscovite, which become less and less plentiful towards the centre of the pebble, and eventually disappear. Sharp little rhombs of calcite have, also, been deposited in the quartz rock pebble near the contact, and extend in stringers towards the centre of the pebble, but are entirely absent in its central portion. These rhombs of calcite are sometimes observed to have been developed around quartz grains, so as to quite include them, thus simulating on a microscopic scale the well-known phenomenon of the calcite of the Fontainbleau sandstone.

Discussion of conglomerates.

In considering these conglomerates with regard to the light they throw upon the mineralogical development of the rocks with which they are associated, upon the relations of the series of which they form a part to older series, and upon the original character of the older series from which the pebbles are presumably derived, the fact must be borne in mind, that they are intimately associated with rocks which are of undoubted volcanic origin, and are in fact but a subordinate portion of a voluminous volcanic series. Fissile green schists, such as usually form the matrix of these agglomerates are frequently found intercalated with the bedded traps of the series. They appear in these cases to be altered basic volcanic ash beds. And even where these rocks appear as the matrix of a true pebble conglomerate, it seems far more probable that these fissile green schists were originally volcanic débris composed of augitic and basic felspathic material, which has been subjected to the ordinary process of mineralogical alteration, giving rise to uralite, chlorite, epidote, calcite and quartz, than that they were ever clays which have by processes scarcely known to us, been crystallized into minerals which now compose the schists. The augite and plagioclase of the bedded diabases of the same series are very largely decomposed into the same minerals which make up the schistose matrix of the conglomerates.

Their presence in an overlying series, also, is evidence of an interval or geological break, during which the Coutchiching rocks suffered erosion; such break and erosion being indicative of unconformity between the Coutchiching and Keewatin.

The presence of granite boulders in these conglomerates is an interesting observation, but one which is susceptible of more than one explanation. Either the granites may have been torn from the shores of the trough in which the Keewatin rocks were being deposited by ordinary forces of rock disintegration, or they may have been brought up from beneath by volcanic forces. It is altogether probable, however, that they indicate the existence of subaërial granite at the time of the deposition of the Keewatin rocks; and although all the granites, of the region appear to be in some degree later than the Keewatin rocks, this does not necessarily conflict with the supposition of a granite shore for the basin in which the Keewatin rocks were deposited. A study of the region leaves no room for doubt in my own mind but that the original floor of the basin upon which the Keewatin and Coutchiching rocks were deposited, whether it were granite or any other rock, was fused in times of disturbance, and appears now to us as the foliated granite known as the Laurentian gneiss. Thus the granite boulders in the Keewatin agglomerates may have been derived from a granite basement now obliterated by subsequent plutonic fusion. Granite boulders in conglomerates.

The felsites and quartz-porphyries which, as smooth, well rounded or oval, waterworn pebbles, are so largely represented in the Keewatin conglomerates, have no known analogues within the district examined in the underlying Coutchiching or Laurentian rocks. But if the Laurentian were fused at a time subsequent to the deposition of either the Coutchiching or Keewatin, these pebbles may possibly represent the condition of a portion of these rocks as they existed prior to the fusion. Or, these felsites and quartz porphyry pebbles may have been derived from the underlying Coutchiching series, and represent the original character of part of the rocks of that series. The alteration of quartz-porphyries and felsites would readily yield, under the influence of great pressure, the fine grained, evenly laminated, grey gneiss which is now found interbedded with mica schists in the Coutchiching series. The alteration would be quite analogous to that worked out by Lehmann*, for the derivation of the granulitic gneisses of Saxony, from quartz-porphyries. No direct evidence has, however, been observed of volcanic agencies having had a part in the building up of the Coutchiching series.

### *Sericite Schists, Felsitic Schists—Altered Quartz-Porphyries.*

The rocks of the Keewatin series which, in field parlance, are referred to as felsitic schists, but which, in strict nomenclature, are for the greater part altered quartz-porphyries, occur sometimes as formations of enormous thickness, occupying extensive areas, and sometimes as Mode of occurrence.

* Ueber die Entstehung der Altkrystalliner schiefer gesteine. Bonn, 1884.

comparatively insignificant beds as little as a foot in thickness, intercalated with green schists. They are usually evenly stratiform in aspect, and by the development of secondary minerals as a concomitant of dynamic crushing and stretching, they pass on the one hand into the porphyroids and nacreous or glossy sericitic schists, and on the other, into granulitic biotite gneisses. They have very frequently associated with them acid volcanic tuffs and agglomerates, in which the paste appears to be simply the débris of the quartz-porphyry material, while the included fragments are, as a general rule, pieces of the massive rock. These quartz-porphyries are interesting geognostically in the fact that they represent a wide-spread extravasation of acid volcanic rocks, subsequent to the extravasation of the basic, volcanic rocks (diabases) which make up so large a part of the underlying or basal members of the Keewatin series in this region. From a petrographical standpoint they are interesting for the clear and unmistakable way in which they reveal the effects of rock-crushing and stretching, in the sundering of the felspars and quartzes, and the frequent reduction of the latter by granulation to lenses with tapering tails, as well as by the development of mica along the shearing planes, and its curvature around the porphyritic constitutents of the rock.

Sequence of acid after basic rocks.

Line Bay, Pipestone Lake.

No. 378.—On the east side of Line Bay, Pipestone Lake, in narrow bands, one to three feet wide, apparently imbedded with the green schists. The rock is a silver grey "porphyroid" sericite schist. Under the microscope it appears to be made up of a fine-grained ground mass of quartz and felspar, in which have been developed scattered scales of muscovite. In this are imbedded grains and crystals of varying size of quartz and felspar. These porphyritic constituents either retain the characteristic shape of felspar or the dihexahedral forms of quartz, or are in the form of lenses arranged with their long axes parallel. Besides the scattered scales of muscovite throughout the ground mass, there is a much more abundant development of that mineral along broad wavy parallel bands, which traverse the schists and flow around the porphyritic crystals. These lines, along which the muscovite has been so largely developed, would appear to have been shearing planes. These bands of muscovite, although flowing around the porphyritic crystals, rarely completely enclose them. For in the wake of the fragment or crystal there is usually congregated together a number of minute grains of felspar and quartz which, in some cases, appear to be a portion of the ground mass, which, in the shearing, has moved with the porphyritic grain in its shelter or shadow, and in others to be the result of the granulation of the larger mass. The muscovite in the wavy bands exists to the entire displacement of the ground mass; and would thus appear to have been developed during the

process of slipping and rending, the proof of which is seen in the dislocation and sundering of the porphyritic constituents, the cracks being filled with the ground mass and muscovite. The scales of the

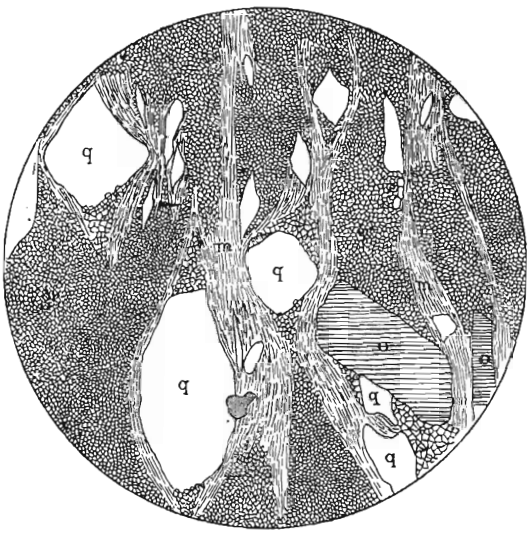



Fig. 8.—Section of porphyroid sericite schist (altered quartz-porphyry) from Line Bay, Pipestone Lake, showing more or less parallel bands of muscovite, (m) running through the rock and flowing around the porphyritic crystals of quartz, (q) and orthoclase, (o) some of which are reduced to lenses having their long axes approximately parallel. × 44.

muscovite of the wavy bands are, at any particular place, strictly parallel and closely compacted, so that the band extinguishes as a unit for as much of its length as may coincide with a section of the nicols. The relation of these bands of muscovite to the ground mass and to the porphyritic crystals is illustrated in Fig. 8 drawn with the camera lucida.

No. 1784.—South end of Clear-water Lake, Kishkutena route, west side. A flesh-tinted to purplish crypto-crystalline schist, with occasional porphyritic crystals of felspar, and with chlorite developed along the cleavage surfaces. Under the microscope, seen to be made up of a fine-grained ground mass of quartz and felspar, throughout which are disseminated the secondary minerals muscovite, chlorite, epidote and calcite. In this are imbedded large usually broken fragments of orthoclase and plagioclase, and areas of granulated quartz. Chlorite has been developed along the shearing planes. Clearwater Lake.

No. 1786.—Half a mile west of last locality at south end of Clear-water Lake. Light grey crypto-crystalline schist with rough, unctuous South end of lake.

cleavage surfaces, resembling the last in its microscopic character, particularly in the ground mass. The porphyritic constituents are crystals and broken fragments of felspar, and granulated lenses of quartz, indicative of intense crushing and stretching action. A large amount of muscovite has been developed in parallel position and frequently flows around the porphyritic grains. Small amounts of chlorite and calcite are scattered through the rock.

West side of lake.

No. 1788.—West side of Clearwater Lake, towards the south end. A greenish-grey to yellowish quartz-porphyry, carrying large masses of quartz and felspar, in which have been developed considerable muscovite and some chlorite, and in which are imbedded in porphyritic development, orthoclase, plagioclase and quartz. The felspars usually occur in well defined, crystalline forms, but are frequently dislocated and sundered. They are largely decomposed to kaolin, muscovite and epidote. The quartz occurs in irregular grains and in more or less dodecahedral forms, which are often seen to have corrosion bays of the ground mass running into them; or to be parted, the fissures being filled with the ground mass.

Hazy Point.

No. 1791.—South side of Hazy Point, Clear-water Lake. A flesh tinted to purplish quartz-porphyry, made up of a fine-grained ground mass of quartz and felspar, in which have been developed considerable muscovite in minute scales and a little chlorite, calcite and secondary quartz. In this are imbedded large porphyritic crystals of orthoclase, plagioclase, entire and in broken pieces, and quartz usually in lenses with granular margins. The long axis of the felspars and of the quartz lenses are parallel, and there is a flow structure of the muscovite and chlorite around them. There is present also a little epidote resulting from the decomposition of the plagioclase.

East side of lake.

No. 1829.—South end of Clear-water Lake, east side. Grey quartz-porphyry merging in the field into a gneiss by the development of biotite in parallel position. Under the microscope, it appears as a fine-ground mass of quartz and felspar, with considerable quantities of epidote, muscovite and a little calcite. In this are imbedded crystals of orthoclase, plagioclase, quartz, muscovite and biotite. The orthoclase is in Carlsbad twins, and the plagioclase in the usual polysynthetic twins of the albite type. They are usually rounded or sub-angular in outline, though they are occasionally met with in sharp, crystal forms. The quartz is in irregular grains, and in more or less rounded dodecahedral crystals. The muscovite and biotite are only sparingly present in rather thick plates.

S. of Burnt Narrows.

No. 1841.—South end of Clear-water Lake, east side, half a mile south of Burnt Narrows. This rock has the aspect of a micaceous granulitic gneiss, but is probably an altered form of the quartz por-

phyries with which it is associated. It is made up of a fine-ground mass of quartz and felspar, in grains. which, with high powers, are observed to be more or less rounded or granulitic, and the constituent grains appear to be larger than those of the ground mass of the quartz porphyries, above described. The porphyritic crystals are only observable in irregular and vague traces, with often a granular border. The porphyritic quartz is less abundant than the felspar. Biotite in irregular plates of varying size, but parallel in position, is scattered throughout the rock, together with a smaller number of rather large plates of muscovite.

No. 2023.—South side of Off Lake. In association with the acid clastic tuffs, 2019, 2021 and 2022. Macroscopically, a purplish, cryptocrystalline sericitic schist. Under the microscope, it presents a fine ground-mass of quartz and felspar, throughout which an abundance of muscovite has been developed, and epidote in lenticular nests. In this are imbedded crystals of orthoclase in Carlsbad twins, plagioclase, and Off Lake.

Fig. 9.—Sundered crystal of tourmaline in quartz-porphyry from south side of Off Lake. × 11.

quartz generally in lenses with granulated margins. A crystal of tourmaline was observed in a long prism, showing the sundering or stretching effects manifested elsewhere in this rock. The sundered aspect of the tourmaline is shewn in Fig. 9. It does not appear to have been a completely developed crystal, but the separation of the once continuous parts is nevertheless quite apparent. The crystal is strongly pleochroic, $\omega$ very dark-green to greenish blue, $\varepsilon$ very light brown.

No. 997.—West side of Pickerel Lake, north of Cedar Narrows, Manitou route. A light bluish-grey, quartzose schist of fine sugary texture, with large porphyritic blebs of quartz. Under the microscope, it appears as a fine-grained ground mass of quartz and felspar, throughout which shreds of muscovite are plentifully scattered, together with irregular aggregates of grains of epidote and a little calcite. In this ground mass are imbedded large grains of quartz, some of which have distinct dodecahedral outlines which give the rock the characters of a quartz porphyry. Pickerel Lake.

No. 1001.—West side of Pickerel Lake, one mile north of Cedar Narrows. A grey aphanitic rock in which are imbedded grains of quartz One mile N. of Cedar Narrows.

and crystals of felspar. Under the microscope, constituents of three generations are represented by three grades of fineness. The predominant of these are the grains of the second generation which consist of quartz and non-striated felspar in uniform-sized grains from ·1 to ·2 mm. in diameter. These are sometimes so closely packed as to leave no interstitial space, more frequently, however, there is an interstitial space between the grains, which is filled by the material of the third generation, which comprises grains of felspar and quartz from ·01 to ·04 mm. in size. The constituents of the second and third generations together with grains of epidote, shreds of muscovite, and a little leucoxene, make up a ground mass in which are imbedded large grains of quartz, crystals of orthoclase twinned on the Carlsbad law and filled with sharp little scales of muscovite and crystals of plagioclase twinned on the albite law, and largely altered to epidote. There is throughout a well marked flow structure manifested, seen in the bending of streams or bands of muscovite around the porphyritic grains which are further sometimes torn asunder.

Swell Bay. No. 54.—South shore, Swell Bay, one mile N. E. of Little Rocky Narrows. A dark grey crypto-crystalline schist made up of a fine-grained base of quartz and felspar grains of varying size, in which has been developed considerable muscovite. Coarser mosaic linear areas alternate roughly with finer or more sericitic areas, giving the rock a schistose or banded structure. In this base are imbedded grains of quartz, some of which are rounded or crushed into granulated lenses while others retain their dihexahedral form quite distinctly. Fresh biotite is observed to have been developed along shearing planes in the wake of the crushed or granulated quartzes. A good deal of calcite is interspersed throughout the base, and occasionally replaces the felspar.

No. 1619.—South shore, Swell Bay, near east end. A yellowish grey, feebly banded aphanitic schist, with sericitic gloss on cleavage surfaces. A very much squeezed and drawn out rock made up of a fine ground mass of quartz and felspar, with considerable muscovite arranged in streams or flowing bands along shearing lines. In this are imbedded grains of magnetite and lenses of granulated quartz, with liquid and dirty inclusions, so altered that it might possibly have been a quartz porphyry tuff rather than the massive rock itself.

Sturgeon Falls. No. 52.—Sturgeon Falls, Seine River. A glossy, grey, porphyroid schist made up of a very fine felsitic ground mass, in which has been developed an abundance of muscovite, and porphyritic crystals of orthoclase and plagioclase, both very cloudy, with irregular or pear shaped grains of quartz with undulatory extinction. There is a good deal of calcite in large individuals present as well as a considerable amount of fresh biotite, developed along parallel lines which probably represent shearing planes.

*Fragmental Rocks—Grauwackes—Volcanic Tuffs, etc.*

Besides the conglomerates and those fissile green schists which appear to be altered augitic volcanic ash beds, there are voluminous formations of other fragmental rocks which form prominent members of the Keewatin series in the region under consideration. These fall into two main types which, however, both in their conditions of occurence and in their petrographical characters are closely associated (1) grits or grauwackes, generally very distinctly bedded, varying in color from light-yellowish grey to very dark grey and presenting varying degrees of texture. These have sometimes the characters of quartzites, and occur generally on the same horizons with felsitic schists, from which they cannot be separated for purposes of mapping. (2) Volcanic agglomerates or tuffs, generally extremely felspathic, and having a paste quite similar, in many cases, to the grauwackes. The included fragments are, for the most part, either sharply angular or lenticular, and composed of a very felspathic rock, often a quartz-porphyry, which is usually of lighter color than the paste. The lenticular aspect of the fragments appears to be intimately associated with a pronounced schistosity of the rock, and is doubtless the result of deformation due to pressure. There is throughout the region a notable paucity of those greener or more hornblendic varieties of the agglomerates which were observed on the Lake of the Woods. Micaceous varieties are also not well represented. The agglomerates of the Rainy Lake region are remarkably uniform in their highly felspathic character, but are quite the same as the more felspathic varieties observed on the Lake of the Woods. A somewhat detailed account of the characters of a few specimens of these fragmental rocks will be of more immediate interest than any general statements that may be made concerning them.

Two types of these rocks.

First type.

Second type.

On the south side of Crow Lake there is an extensive development of bedded fragmental rocks, most of which being felspathic rather than quartzose, and having their constituent grains angular, rather than rounded, may be termed grauwackes. Some of them are, however, very quartzose, and of the character of indurated sandstones. The finer grained of these are probably partially of volcanic origin, i.e., the direct débris of volcanic material, and partially of sedimentary origin. A specimen (109) from the south side of Patch Island is a very fine-grained, dark grey, evenly banded, hard rock, with a brittle, conchoidal fracture. Under the microscope, it has a well marked clastic structure, being made up chiefly of angular broken fragments of quartz of varying size. Occasionally, the grains are rounded or pear-shaped. The rock shews the banding or bedding in the thin section, the demarkation between the different layers being an irregular wavy

South side Crow Lake.

line, along which has been deposited a finely granular, almost opaque material, probably iron oxide. Minute grains of epidote, pale green flakes of chlorite, and shreds of muscovite, are present, with a little leucoxene.

Patch Island. Half a mile west of Patch Island a little grey massive rock with blades of chlorite occurs. Under the microscope (98) it appears to be made up chiefly of angular, sub-angular and occasionally rounded grains of plagioclase containing needles of apatite, and quite fresh save for the presence of a few grains of epidote and shreds of muscovite. Larger grains of epidote and calcite are generally distributed through the section, together with a little leucoxene. Micaceous chlorite occurs in large patches as if pseudomorphic, after some pyroxenic mineral and pyrite with decomposition rims of limonite.

S.E. of Chase Point. Two miles south-east of Chase Point, on the south shore of Crow Lake, the rock is a grey to a yellowish white grauwacke, evenly bedded. Under the microscope (125) it is made up of a fine-grained ground-mass of more or less rounded grains of quartz and felspar, in which are imbedded large fragments of plagioclase, orthoclase and quartz. The section is cloudy with aggregations of kaolin and epidote. Well defined individuals of epidote also occur. Other secondary minerals are: quartz in mosaics, calcite in occasional grains, sometimes replacing the felspar, muscovite in minute scales, a little limonite and some elongated shreds of fibrous hornblende.

Shanty Point. On the shores of the bay east of Shanty Point, an agglomerate or tuff occurs, the finer-grained base which, under the microscope (146) is made up of a paste of minute particles of quartz and felspar, in which are imbedded angular fragments of the same minerals which have sometimes a jagged outline with sharp re-entrant angles. The plagioclase is spotted with small quantities of muscovite, epidote and zoisite. Shreds of hornblende with epidote are generally disseminated, as well as an abundance of epidote, unassociated with the hornblende, in single grains and in nests of grains.

Pipestone Lake Unde Rapids. At the south end Unde Rapids between Schist Lake and Pipestone Lake, a grey to yellowish compact rock occurs with whitish weathering. Under the microscope (234) it appears as a fine-grained ground mass of felspar and quartz, with interspersed scales of muscovite and grains of epidote, in which are imbedded rounded and angular fragments of plagioclase and quartz. The most prominent mineral in the rock, however, is calcite, which has been developed *in situ* in beautifully sharp rhombs. The calcite is also seen partially replacing the plagioclase fragments, and occasionally a well defined rhomb of that mineral occurs in the heart of a felspar grain. The calcite has occasionally a nucleus of almost opaque granular material.

On Pipestone Lake, half a mile west of Pivot Point, north side, a specimen was taken of a greenish grey clastic rock, which in thin section (286) is seen to be made up of a fine-grained paste of quartz grains, shreds of muscovite and chlorite and grains of epidote. In this are imbedded rounded and angular grains of quartz and some leucoxene. Pyrite and calcite are prominent secondary minerals. That the rock has yielded to pressure is indicated not only macroscopically by its schistosity, but also microscopically by the breaking and sundering of the quartz grains and the drawing out of the leucoxene into long stringers. W. of Pivot Point.

A quarter of a mile west of the last locality, a dark green, rudely schistose chloritic rock, spotted with fragments of quartz, occupies the shore. Under the microscope (266) it is made up of a matrix of

Fig. 10.—Fragmental rock from from near Pivot Point, Pipestone Lake, shewing sundering of individual of quartz, (q, q, q) into several pieces. Rending effects also seen in leucoxene (l), (q) quartz grains other than the sundered individual. The base of the rock is chlorite, (ch) in which, subsequent to pressure, have been developed sharp rhombs of calcite or dolomite. × 18.

chlorite and quartz in fine grains. In this are imbedded large rounded and angular fragments of quartz, felspar and leucoxene. The rock shews pressure effects to a remarkable degree, the quartz grains frequently being torn asunder into numerous fragments shewing the same, or approximately the same, extinction. The spaces between these sundered fragments are filled with chlorite, the scales of which are in Pressure effects

definite parallel position corresponding to the schist planes. The leucoxene shows the same sundering, though in a less degree. Felspar grains are abundant. Beautifully sharp calcites have been developed in the chloritic base of the rock, apparently at a period subsequent to the action of the pressure. The various features here described are illustrated in Fig. 10.

Three-quarters of a mile west of Pivot Point, on the south side, the rock (277) is a grey schist made up of a fine-grained ground mass of quartz grains and shreds of muscovite in parallel position with patches of chlorite and grains of epidote. In this are imbedded larger, rounded and pear-shaped grains of quartz, with occasionally more angular pieces. Aggregates of muscovite are massed together in parallel position, in areas having an oblong shape, apparently constituting a pseudomorph, after felspar. Scattered through the section are rhombs and irregular masses of calcite and magnetite in grains or loose lenticular aggregates of grains.

S.E. side of lake.

On the south-east side of Pipestone Lake there occur some subordinate beds of a grey-green, fine grained, though not uniformly textured rock, having a well marked schistose structure. It (356) is made up chiefly of small angular and sub-angular grains of quartz, shreds of partially bleached biotite in parallel arrangement, large and small grains and aggregates of grains of epidote, with areas of mosaic quartz and calcite of large grain, and a few crystals of pyrite.

Pickerel Lake, north end.

At the north end of Pickerel Lake, Manitou route, there is a large volume of compact, dark-grey quartzose, clastic slates, passing across the strike into fine grained clay slates. A thin section of this rock (1011) from the west side of the lake, shews it to be distinctly banded and made up chiefly of quartz in more or less rounded grains, with generally a black rim around the periphery where in contact with other grains. Over this are scattered cloud-like patches of yellowish-green isotropic chloritic material, and an abundance of opaque (carbonaceous) matter in irregular grains and ragged shreds. Grains of leucoxene with opaque nuclei and small plates of muscovite are also present. Microlites of apatite and zircon are included in the quartz.

East side of lake.

On the east side of the lake, another specimen of the same rock formation presents in thin section (1022) to the naked eye, or with a low power, a spotted appearance, due to the presence of round or pear-shaped areas, in rough parallel arrangement, which are clearer and more transparent than the rest of the rock. The base of the rock is an aggregate of minute quartz grains, intermixed with which is a considerable amount of finely divided opaque matter, probably carbonaceous. The rounded and pear-shaped clear spots are areas where there is a much less amount of carbonaceous matter, and where mus-

covite has been developed in little nests to its exclusion. The border of these clear areas is a comparatively sharp one. Muscovite in large plates and a little flocculent chlorite are also scattered throughout the section. The differentiation in the distribution of the carbonaceous matter recalls that in the Steiger Schiefer of the Barr-Andlau contact zone described by Rosenbusch,* although the process appears to be the reverse of that there observed; being an elimination of the carbon from certain areas, not its condensation into "Knötchen." The specimen described is from the proximity of the most easterly of the two granite bosses on Pickerel Lake.

Another specimen (1023) from the same formation near the same granite boss is a fine grained compact rock, made up of a fine quartzose base, through which are scattered small plates and ragged shreds of biotite of pale, greenish-brown color, and colorless muscovite, with occasional crystals of pyrite, the decomposition of which has stained the rock yellowish.

On the south side of the lower end of Manitou Lake, the rock is a much finer grained and more slaty or fissile phase of the same formation as that from which the specimens just described were taken. It (1077) resembles the last in microscopic structure. Under low powers of the microscope it shews a distinctly marked lenticular structure identical in miniature aspect with that shewn by glaciated sections of squeezed agglomerates on the large scale. The lenticular areas are more transparent than the base of the rock. This base is made up of an irregular aggregate of quartz, actinolite (almost colorless), muscovite and calcite. Scattered through it and rendering it cloudy is a large amount of a grey, granular, semi-translucent substance resembling the product of the kaolinization of felspar. With high powers these grains in ordinary light are transparent, but almost opaque between crossed nicols. It is the absence of this cloudy granular material in the lenticular areas of the section that render them so transparent and prominent, since they do not appear to otherwise differ greatly from the rest of the rock. Manitou Lake.

On the west side of Clearwater Lake, Kishkutena route there is an extensive formation of felsitic (quartz-porphyry) agglomerate. A specimen taken from the shore one mile north of Hazy Point, appears as a greenish, clastic rock, or quartz-porphyry tuff, in which are included large angular and lens-shaped masses of flesh-tinted quartz-porphyry. Under the microscope, a section of one of these inclusions (1796) is that of a typical quartz-porphyry, shewing a fine grained, ground mass of quartz and felspar, in which have been developed secondary muscovite and a little epidote. The porphyritic minerals are orthoclase, plagioclase Clearwater Lake.

* Mikr. Phys. der mass. Gestein. Stuttgart, 1886, p. 47.

and a few grains of quartz. The felspars are in well defined crystal forms, although some are broken.

The matrix of the agglomerate shews also a fine grained ground mass of quartz and felspar, but the grains are not of such uniform size, nor the structure of the rock so compact, as in the case of the porphyry. There is much more epidote, muscovite, calcite and chlorite; and in the porphyritic or pseudo-porphyritic grains, the felspar is much more fragmental or broken in character, and there is an abundance of irregularly shaped grains of quartz. It also shews a foliated structure, and might be mistaken for a much crushed quartz-porphyry, were it not for its association and known clastic origin.

Off Lake.

On the west shores of Off Lake, on the west side of the Kishkutena route, there occurs a coarse fragmental rock of a yellowish to greenish color, which under the microscope, (2019) is made up of an indiscriminate aggregate of quartz and felspar in angular fragments, with irregular shaped nests of epidote and chlorite, apparently the results of decomposition of included chips of a basic rock.

Pseudo-gneissic structure.

Farther along the shore to the southward, the rock passes into a more uniformly textured rock of yellow color, which has developed in it a well marked pseudo-gneissic structure. Under the microscope (2021) the rock appears to be much the same as that last described, but shews pressure and pulling effects to a remarkable degree. The quartz grains are reduced to long lenses surrounded by a granular border which runs out into a tapering tail at each end. The lenses all shew a decided undulatory extinction due to unequal tension. The granules surrounding these lenses closely interlock, and are freer of inclusions than the lens itself, indicating a re-crystallization of the grains as part of the process of granulation. These quartz lenses, with their granulated borders, tapering tails, and undulatory extinction correspond exactly with those described by Lehmann in some of the rocks of Saxony, as a result of pressure.* The felspars are shattered and torn apart. A considerable amount of muscovite, chlorite and epidote has been developed in the rock, and these minerals, together with the quartz lenses are all in parallel arrangement, giving rise to its gneissic aspect.

Resemblance to rocks of Saxony described by Lehmann.

On the south side of the lake the rock is still more gneissic in aspect, and under the microscope (2022) appears much more altered. It is made up of orthoclase, plagioclase and quartz. The felspars are in grains of usually crushed or lenticular appearance, with some broken fragments of less regular contours. The quartz is in mosaics, arranged in parallel stripes which appear to represent the granulation of large grains of quartz carried to an extreme. Larger lenses of quartz, with

* Cf. Intersuch. über die Entstehung der altkrystallinischen Schiefergesteine, p. 250.

granulated margins and tails are also observable. Muscovite and epidote are abundant and are generally arranged in long, narrow areas or in stripes in parallel position.

On the south shore of Rainy Lake, and on the off-lying islands in the neighborhood of Grind-stone Narrows, there occur rocks of clastic origin which appear, in some places, to be simply altered sandstones, while at others they are very felspathic, schistose and glossy, and are associated with occasional beds of agglomerate and true conglomerate. A specimen (743) from the shore of the lake one mile west of Grind-stone Narrows, appears, under the microscope, as a fine grained matrix of quartz, epidote, muscovite and felspar, in which are imbedded large and small broken fragments of quartz and plagioclase, which are usually quite sharply angular, though sometimes rounded. These fragments of quartz are full of fluid inclusions which are, for the most part, arranged in rows or streams. The other minerals present are magnetite, limonite and leucoxene in sporadic grains. Grind-stone Narrows.

At Grind-stone Narrows the rock is a yellowish, quartzose schist made up, as seen in thin section (749), of a clastic aggregate of quartz and felspar grains of a generally angular or sub-angular shape, imbedded in a paste made up of the same minerals in a more finely divided state, and cemented by secondary minerals such as quartz, calcite, muscovite, chlorite, limonite and epidote.

### *Peridotites and Gabbros.*

Peridotite rocks are very poorly represented in the Rainy Lake region. They have been observed at only a few localities, and in these they occur in the extremely altered forms known as serpentine. They occur only in the Keewatin series, but their relations to the rocks adjoining them are ill defined, and have not been altogether satisfactorily determined. They appear, however, to be the alteration products of igneous masses which are of the same geological age as the traps and other volcanic rocks of the Keewatin series; and although their common boss-like character suggests that they are intrusive through the Keewatin rocks, such intrusion has probably taken place coeval with the bedded formations, volcanic and sedimentary, of the Keewatin. Peridotites not abundant. Their geological relations.

One of these bosses of serpentine, apparently of quite small extent, occurs on the N. E. extremity of the point of land that projects into Crow Lake from the west side midway between Crow Portage and Wade Portage. The rock is of a fine, compact texture, and has a mottled, light and dark green aspect and shows a yellow weathered surface. It is associated with green altered traps and green schists. Crow Lake serpentine.

Little can be determined from the microscopic examination of the rock (24) as to its original character. It is seen to be made up of rounded or sub-angular grains, now composed entirely of serpentine of a pale green color, but probably originally composed of olivine. Between these grains there is considerable interstitial calcite and a little chlorite, while granular or dusty magnetite is disseminated throughout the section.

Clear-water Lake.

On Clear-water Lake, Kishkutena route, the west shore of the lake, for a distance of about a mile south from the 49th parallel is occupied by a similar rock, which was observed to be traversed by small veins of coarsely fibrous serpentine or picrolite.

Serpentine of Lake Despair

Another locality at which this class of rock was observed is at the bottom of the South Bay of Lake Despair, to the west of the North-west Bay of Rainy Lake. Here it occupies the shore for the space of between a quarter and half a mile, with black hornblende schists on either side. Its relations to these schists could not be studied at the time the locality was visited, from the fact that the woods were on fire close down to the water's edge, and it was with difficulty that a few specimens could be secured. Two varieties of somewhat different aspect were observed in the same mass. One of these (1741) is a purplish, green, compact serpentine, speckled with glistening facets of mica. It weathers on exposed surfaces to a dull red color. Under the microscope, the only minerals that can be detected now are serpentine, magnetite and white mica. It is probably an extremely altered form of an olivine-enstatite rock of coarse-grained texture. The only traces of these minerals, however, that are now observable are the rounded or double-domed outlines of the one with fine dusty magnetite, heaped together in the middle, and the oblong nearly rectangular forms of the other with the cleavage lines still remaining. The magnetite is occasionally in distinct octahedra, but generally it occurs in irregular granules, and is nearly always associated with a mica which is either colorless, or pale green and pleochroic; some of it polarizes brilliantly and some in quieter colors, such as brown and grey. It all, however, gives a biaxial interference figure in converged polarized light, a fact which determines it as muscovite, and not bleached biotite, as might be suspected from its association with the iron oxide. The less brilliantly polarizing varieties shew between crossed nicols, the peculiar bird's-eye-maple mottling so characteristic of the micas.

First variety.

Second variety.

The second variety (1742) of serpentine taken from this occurrence on Lake Despair, has a mottled aspect of a greenish, black base and silvery grey spots. Its microscopic aspect resembles that of the specimen just described, in all respects, except that there is an abundance of grey leucoxene. This often shews opaque nuclei of magnetite or titanic iron, but is more commonly without such nuclei.

On the north side of the south-east arm of Crow Lake there is boss-like area of gabbro which, in places, appears to be entirely altered to serpentine although retaining, for the most part, its granular character. A specimen of the less altered part of this mass appears in thin section (46 A) to be an olivine, hypersthene gabbro. It is composed of hypersthene, olivine, diallage and plagioclase. The hypersthene is the most abundant, the diallage and plagioclase are the least abundant, and occur in about equal proportions. The hypersthene is quite fresh and shews its characteristic pleochroism very strongly. Neither it nor the diallage are bounded by crystallographic contours, but are allotriomorphic. The olivine is in more or less well defined crystals, with characteristic dome faces, but is more than half altered to serpentine, anastomosing veins of which traverse the olivine in all directions. The plagioclase is in cloudy, lath-shaped, polysynthetically twinned crystals, and in small oval bodies included in the hypersthene. There is associated with the hypersthene a considerable proportion of magnetite. Crow Lake olivine gabbro

The area of gabbro which is exposed on the shores of Bad Vermilion Lake and River, differs from that just described from Crow Lake in the fact that plagioclase was, in the original rock, the dominant mineral, while the olivine and pyroxenic minerals were very sparingly represented. Thus, under process of decay and alteration, the rock has assumed, not the form of serpentine but that of saussurite, the condition determining the difference being doubtless the proportion of magnesia and iron in the original magma. The gabbro on Bad Vermilion Lake is, in many places, a fine white rock resembling at first sight a coarsely crystalline marble. It is, however, much harder, and is for the most part mottled, with the pyroxenic constituent. Under the microscope (47) there is little to be noted, save that the anorthite is almost entirely changed to the aggregate of zoisite and albite, known as saussurite, and that the pyroxene is non-pleochroic and rhombic, though much decomposed, and difficult to determine accurately. Saussurite gabbro of Bad Vermilion Lake.

In another section (2154) calcite is a prominent constituent of the saussurite, besides the zoisite and albite, and the pyroxenic constituent is altered entirely into serpentine in nests or aggregates of small grains.

## THE COUTCHICHING SERIES.

Around the east arm of Rainy Lake there is an enormously thick series of schists of remarkably uniform character underlying the Keewatin series. They are composed chiefly of quartz and biotite, with or without felspar, and are distinctly bedded in layers of varying Geological position of series—its bedded character.

thickness, and in such a manner that it is difficult to resist the conclusion that the layers are the result of original deposition.

Section on shores of Rainy Lake and Nameukan Lake.

The series is best studied in its stratigraphical aspects in the excellent natural section afforded by the shores of the lake, on the Canadian side, from Bleak Bay to Kettle Falls and thence across Nameukan Lake to Sand Point Lake. Throughout this distance, about twenty-four miles in a direction more or less obliquely transverse to the strike, only the upturned edges of the beds of the Coutchiching series are seen, the dip varying from almost horizontal to quite vertical. The only interruptions are a few small intrusions of gneiss or granite which traverse the rocks in the neighborhood of the axes of folding.

Breadth of belt.

The breadth of the belt from Bleak Bay to Sand Point Lake, in a direction directly transverse to the strike is about eighteen miles. The limit of the belt on the north is its contact with the Keewatin rocks along the edge of the trough which runs down the Seine River and across Rainy Lake to the bottom of Rat-root Bay. Its southern limit is its contact with an area of gneiss and granite of which the full extent is not yet known, but which has been traced on the shores of the International Boundary canoe route as far as the east side of Basswood Lake. Within these limits this belt of the Coutchiching rocks comprises a three-fold repetition of the full volume of the series; and two axes of folding, one an anticlinal and the other a synclinal are clearly indicated.

Three-fold repetition of volume.

For six miles and a half southward from the northern limit of the belt of the Coutchiching series the dips are continuously to the north or under the above mentioned Keewatin trough, at angles which range from 15° to 85°. Then we come upon a line along which the rocks are in a perfectly vertical attitude, and to the south of which they dip southward. This line is taken to be the axis of a great anticlinal fold. It intersects the shore at a point midway between the mouth of the Rat River and Vague Point.

Anticlinal axis.

Similar disposition of rocks on United States side of the Lake.

A precisely similar disposition is observed in the section afforded by the shores of the lake on the United States side. From their contact with the Keewatin rocks, near the mouth of Black Bay, to the Brulé Narrows, the Coutchiching rocks run in continuous exposure, striking with the general trend of the shore and with a prevailing northerly dip at angles varying from 50° or 55° to 90°. At Cranberry Bay it is about vertical. After rounding Point Observe at Brulé Narrows and entering Saginaw Bay, it becomes lower and lower, the direction, however, of both dip and strike remaining constant. With the exception of an unimportant local or intermediate fold observable at the southwest corner of Saginaw Bay, this northerly dip at low angles is constant on all the shores and islands of the bay. South of Pine Islands, the dip

gradually becomes steeper, and at the Narrows between Big Island and the south shore, a line is reached along which the dip is vertical. This is the same axis as that observed between the mouth of Rat River and Vague Point. It is again found on the line of section afforded by the Pipestone River, about one mile up stream, the dip on the north side being distinctly northward, and on the south, southward. The total distance through which this axis is thus traceable is sixteen miles, and judging from the uniformity of structure it probably extends very much further. In the vicinity of this axis and to the south of it, on the islands and especially the south shore of the lake, there are numerous intrusions of granitoid gneiss and of a very coarse muscovite granite, in which the constituent crystals are often several inches in diameter. These are most prominent on the islands to the south and south-west of Vague Point and in the neighborhood of Big Island, as well as on the south shore east of Big Island.

Pipestone River section.

South of the axis the strata continue to dip south, to a line drawn parallel to the strike through Kettle Falls. This latter line constitutes a synclinal axis, the rocks to the south of it all having a southerly dip. The distance between the anticlinal and synclinal axis is about four miles and three-quarters. The distance between the Kettle Falls syncline and the southern limit of this belt of Coutchiching rocks where it comes against the granite and gneiss of Sand Point Lake is about six miles and three-quarters. In this three-fold repetition of the volume of the Coutchiching series an unusually good opportunity of forming an estimate of the thickness of the series is afforded, owing to the simplicity of the folding. In the first six miles and a half of the belt, from its northern limit southward to the anticlinal axis it is difficult to form an estimate of the average dip. The whole distance may, however, be divided into five portions, in each of which the average dip may be estimated with comparative accuracy, and the total thickness thus deduced be taken as that of the series. At the contact with the base of the Keewatin series on Bleak Bay and on the Seine River, the Coutchiching schists plunge under the higher rocks in an almost vertical attitude. A little away from the line of contact, however, they become more inclined and the average dip for the first mile may be taken as about 75°; the average dip for the next mile and a half is about 45°; for the next mile and three-quarters, 30°; for the next mile and a quarter, 45°, and for the last three-quarters of a mile up to the line of the anticlinal axis, 75°. The total volume estimated from these angles is 23,760 feet, or 4·50 miles.

Synclinal axis.

Estimation of thickness.

First measurement.

The second or southerly dipping portion of the belt between the anticlinal and synclinal axes, or between Rat River and Kettle Falls is four miles and three-quarters in breadth, and presents a greater uniformity

Second measurement

of dip, the general average of which may be taken at about 75°; giving a thickness of 24,224 feet or 4·588 miles.

In the third portion, or that between the synclinal axis at Kettle Falls to the southern limit of the belt against the gneiss and granite of Sand Point Lake, the dip again varies considerably. For the first two miles the average dip to the north is about 75°; for the next half mile, 50°; for the next mile and a half, 30°, and for the last two miles and three-quarters, 60°. Calculating in the same manner as before we find a thickness of 28,754 feet or 5·44 miles.

Third measurement.

Thus the three independent measurements of the series shew a fairly satisfactory agreement, and they seem to be sufficient to establish its enormous thickness. So far as the figures are to be relied upon, they indicate that the series is thickest towards the south, and diminishes in volume northward.

Diminution of thickness to the northward.

Two other belts of Coutchiching.

Two other distinct, but stratigraphically connected, areas or belts of the Coutchiching series are known. Both of these have an anticlinal structure and dip under the Keewatin formations on either side of the axis.

Bear's Passage belt.

The first of these comprises the belt of mica schists (occasionally gneissic by addition of felspar) which extends from the neighborhood of the Bear's Passage across Rainy Lake in a W.S.W. direction to Coutchiching and thence down Rainy River. In the direction of its strike, the belt is traceable continuously for twenty-four miles, and it probably continues to the westward, under the post-glacial formations of the Rainy River, for a distance of at least sixteen miles. The breadth of the belt at the Bear's Passage and from that point to Open-water Narrows is about two miles and a quarter. Westward of Open-water Narrows the belt bifurcates around an area of gneiss, the more northerly spur running out to Gash Point, while the southerly or main spur keeps the general trend of the belt, and near Coutchiching is a little more than two miles wide.

Bosses of Laurentian gneiss in anticlinal axis.

The anticlinal axis of the belt is marked by a line, or series, of three distinct and well defined oval or elliptically shaped bosses of Laurentian gneiss. The Coutchiching schists dip away from these bosses in all directions, so that the general anticlinal structure of the belt is made up of three anticlinal domes. These three bosses of Laurentian gneiss cut the Coutchiching schists in the same manner as an irruptive granite and displace a very considerable proportion of the series in the middle of the belt. The first of these, which is well exposed at the Bear's Passage and the shore to the south-west of it, is three miles long and one mile and a quarter wide. The second, in the neighborhood of Open-water Narrows, is three and a quarter miles long, and one and a quarter miles wide. The third is over eight miles long, and two

miles and a half wide. In each case the long diameter of the boss coincides with the general trend of the schists composing the belt.

At the north end of the Bear's Passage the Coutchiching schists dip away from the Laurentian gneiss (or granite, for here it is very indistinctly foliated) at an angle of 40°. Across the strike, for a distance of a little over half a mile to the north-west, the angles of dip diminish and the rocks finally pass under the altered traps of the Keewatin inclined at an angle of 20°. All around the north-east end of the boss of gneiss, whose limit in this direction is the Bear's Passage, the schists dip away from it at comparatively low angles. At the south-east corner of Redgut Bay, east of the Bear's Passage, they gradually assume a constant N.N.E. strike and dip E.S.E. at angles varying from 60° to 75°; at which angles, both at the extreme south-east of Redgut Bay and on Swell Bay, one mile east of Bear's Passage, the Coutchiching rocks may be observed to pass under the Keewatin. The southern edge of the belt along the line of its contact with the Keewatin has already been sketched in the description of the distribution of the latter series. The Coutchiching rocks along this line appear to be the return of those which, on the south side of the lake, dip northward under the Seine River Keewatin belt, the two being continuous stratigraphically, and forming a synclinal trough in which that belt of the Keewatin lies sharply folded. The northern edge of the belt, between the north end of the Bear's Passage and the bay north of Open-water Narrows is only partially determined to be as mapped, the mapping being inferred from the known disposition of the mica schists inland on the north side of the Bear's Passage boss of Laurentian gneiss, and between the latter and the Open-water Narrows boss, where they constantly dip away from the gneiss and towards or under the Keewatin at angles nowhere greater than 60°. At the entrance to Rocky Islet Bay on the west side, the Coutchiching schists dip under the Keewatin at an angle of 60°, but along the shore from Back Point to Gash Point the dip is vertical or somewhat inverted. The rocks forming the belt have not been observed on the shore of the lake opposite Gash Point, north of Coutchiching, and the spur of the belt which terminates at Gash Point appears to have been cut off either by a fault or by an analogous displacement of the rocks by the Laurentian gneiss.

Coutchiching rocks passing under Keewatin.

Limits of Bear's Passage belt.

Perhaps the most remarkable feature of this belt is the smallness of the revealed thickness, as compared with the great thickness determined for the same series in the south part of the lake only a few miles distant. It is difficult to find sections across the belt where a satisfactory estimate of the thickness can be formed, on account of the interruption of the bosses of gneiss which occupy its central part along the anticlinal axis. The volume is, how-

Comparative smallness of volume.

ever, evidently small compared with that already described. The maximum measurable thickness is that revealed along the south shore from Rat-root Bay to near Coutchiching, where it is probably between 8000 and 9000 feet. This diminution in volume agrees with the fact already stated, as observed elsewhere, that the thickness diminished regularly towards the north. This thinning out may, however, be due to absorption in the magma from which crystallized the Laurentian gneisses and granites.

Excessive metamorphism at Contact with Laurentian.

Those portions of the Coutchiching series which are in immediate contact with the bosses of Laurentian gneiss, are the most altered, and exhibit the strongly marked characters of contact metamorphism, being studded with nodule-like crystals of andalusite or staurolite. The rocks are, however, very much decomposed, and the metamorphic minerals have been much altered and removed by subsequent decay. The least altered portion of the series appears to be that which is seen on the south shore of the lake between Coutchiching and Rat-root Bay, where in places the schists have the character of bluish, somewhat micaceous quartzose slates.

Rice Bay area of Coutchiching.

The third area occupied by the Coutchiching series is that on the shores of Rice Bay. Here again the structure is that of a beautifully distinct anticline, the rocks dipping away at angles of 45° from the axis, and passing beneath the Keewatin rocks on either flank at the somewhat steeper angles of from 60° to 75°. The axis passes through the centre of the peninsula which separates the two arms of Rice Bay, but at the extremity of the peninsula, where it can be closely located, the base of the series is not revealed, and no estimate can be formed as to its full thickness at this place. A minimum thickness may be calculated from a revealed breadth across the strike of about one mile, the average dip being taken at about 60°. This gives a thickness of about 4,600 feet. The Laurentian gneiss appears in the axis of the anticline at the north-east end of the north arm of the bay. But the irruptive character of the gneiss precludes the assumption that the beds in contact with it are the proper base of the Coutchiching. The south-eastern flank of this anticline appears to form with the northern flank of the anticline of the second belt above described, a synclinal trough in which lie the Keewatin rocks exposed on the shores of Redgut Bay to the north of the Bear's Passage and on the shores of Grassy Portage and Rocky Islet bays. The connection of the two areas and their stratigraphical relationship is further seen in the band of Coutchiching rocks which surrounds the north-east end of the area of Keewatin rocks, and forms the rim in that direction of the basin or trough in which the latter lie.

Minimum thickness.

Stratigraphical relationship of different areas of Coutchiching rocks.

## Relations of the Coutchiching Series to the Keewatin and Laurentian.

Without being able to conclusively prove it, there appears to be much presumptive evidence in the facts cited to shew that the present eminently crystalline state of the Coutchiching series is the result of the metamorphism of strata which were originally in large part ordinary quartzose sediment, although part may possibly have been acid volcanic rocks, such as quartz-porphyries or felsites. In many parts of the series garnets abound, and if the rocks were carefully examined other metamorphic minerals would doubtless be found. That percolating siliceous solutions were active agencies in effecting the metamorphism of these strata, is proved by the fact that in many places, particularly on the north side of Saginaw Bay and east of Brulé Narrows, the partings between the beds have served as fissures for the deposition of vein quartz. This vein quartz is very abundant in lenses or lens-like sheets, and is clearly a secondary product in the rock. The same watery solutions which deposited the quartz in these lenses in the more open portions of the formation, must have saturated the rock throughout, and given rise, probably, to much of the quartz and felspar in it. Only in one instance has hornblende been observed throughout the whole series. There are no intercalations of basic volcanic rocks, and none that can now be distinctly recognized as acid volcanic rocks. There are no limestones or dolomites in the series, nor have any conglomerates been observed.

The Coutchiching metamorphic series.

Vein quartz between strata.

The advent of the time of the formation of the Keewatin rocks was the inauguration of a period of intense volcanic activity. Prior to that there is no certain record of volcanic action; while a very large proportion of the total volume of the Keewatin is made up of volcanic rocks, such as diabase and quartz-porphyry, with their tuffs and agglomerates.

Period of volcanic activity following quiescence of Coutchiching.

Such a change in the conditions of rock formation does not in itself necessarily imply any great lapse of time between the cessation of the accumulation of the Coutchiching and the deposition of the first rocks of the Keewatin. That there has been a certain interval, however, during which erosion has taken place is indicated by the conglomerate at the base of the Keewatin on Seine River and Rat-root Bay. If the question of the conformity of the two series is to be decided merely by the parallelism of the structural planes in the vicinity of the contact, the two series should be described as conformable. But if the question is considered more broadly, and the term unconformity is to be regarded as expressive of a geological break, or profound change in the conditions of rock formation, then the two series are unquestionably unconformable.

Nature of break between Coutchiching and Keewatin.

A. C. LAWSON, PHOTO, 1886. G. E. DESBARATS & SON, ENGRAVERS & PRINTERS, MONTREAL.

Angular inclusions of schist of Coutchiching series, inclosed in Laurentian gneiss, a few yards from the contact of the two, on island off south shore of Rainy Lake, three miles east of Coutchiching.

Relations of Coutchiching to Laurentian.

With regard to the relationship of the Coutchiching series to the underlying Laurentian, little need be added to what has already been said. Wherever the contact of the two is observable that contact is igneous and more or less brecciated, the conditions being precisely the same as those which prevail at the contact of the Keewatin and Laurentian at places where the Coutchiching rocks do not intervene. The contact is well seen on a small island just three miles east of Coutchiching. The north half of the island is occupied by Laurentian gneiss, which is presumably continuous with the area of the rock so well exposed on the islands between Open-water Narrows and the vicinity of Gash Point. The south half of the island is occupied by the schists of the Coutchiching series. The line of contact runs across the island in a direction parallel to the strike of the schists. Apophyses from the gneiss cut the Coutchiching schists transversely, and these are distinctly foliated; while fragments of the schists of irregular angular contour, which have very evidently been detached from the main mass of the Coutchiching, are found imbedded in the gneiss at a few yards from the contact. Plate I. shews the nature of these inclusions, as well as the distinct foliation of the gneiss in which they are imbedded, close to the contact. The same phenomena are very apparent at many places on the islands where the contact of the Coutchiching is mapped between Open-water Narrows and Gash Point, and at many places where the contact is not seen, large masses and bands of the Coutchiching schists may be seen imbedded in the gneiss, the schist, where in large bands, being more or less shattered and penetrated in all its fissures by the gneiss which retains its foliation usually parallel to the walls of the fissure as shewn in Plate II. representing a contact on one of the islands between Back Point and Gash Point. The exposures in the vicinity of Open-water Narrows and Bear's Passage afford good instances of the intrusion of the gneiss through the schists, although here the former is more granitoid than it is farther west on the islands in the neighborhood of Gash Point. Plate III. shews the contact of the Laurentian gneiss and the Coutchiching mica schists at the south-east part of Redgut Bay, where the gneiss cuts the schists sharply and the latter abut upon it obliquely.

Irruptive character of contact.

Penetration of schists by gneiss.

Contact on Redgut Bay.

The rocks of granitic composition, which cut the Coutchiching series on the shores and islands of Rainy Lake between Brulé Narrows and Kettle Falls, are in some places distinctly foliated and gneissic, while in others they are quite undifferentiated or granitoid in structure. The same is true of the Laurentian rocks which break through the same series on Nameukan Lake. In both cases the gneiss or granite cuts the schists in the most irregular fashion and numerous detached portions of the latter are imbedded in it. The same conditions prevail at the contact across the north end of Sand Point Lake.

Sporadic intrusions of granite and gneiss.

A C LAWSON, PHOTO., 1886. G. E. DESBARATS & SON, ENGRAVERS & PRINTERS, MONTREAL.

Contact of Laurentian gneiss and schists of Coutchiching series, Redgut Bay, two miles and a half east of Grassy Portage, Rainy Lake. The schists (on the right) abut obliquely upon the gneiss, which appears to cut them as an irruptive mass.

## COUTCHICHING SERIES.

The rocks of the Coutchiching series deserve a much more thorough microscopic investigation than I have had an opportunity of giving them. A close comparison of their detailed structure with that of the Laurentian gneisses, which in this region appear to the writer to be beyond question irruptive, would, he is convinced from a consideration of their field conditions, throw much light upon the vexed question of the distinction between gneisses (?) which are truly altered sediments, and gneisses which are nothing more than foliated granites. Need of more extensive study

The leading macroscopic characters of the rocks of the series have already been given, and it only remains to add a description of the microscopic character of the few typical specimens which have been examined, in order to put on record all that is up to the present known of these rocks.

### *Mica Schists and Granulitic Gneisses.*

Near the Coutchiching Rapids the rocks are typical mica schists of the series. They are dark, fine-grained slaty rocks made up essentially of quartz and biotite. A thin section (690) of a specimen from the shore of the lake to the east of the rapids shows it to be an aggregate or mosaic of rounded or sub-angular grains of quartz of a generally uniform size. The quartz is characterized by a more or less undulatory extinction, suggestive of unequal tension. Biotite is in irregularly shaped plates lying in parallel position, determining the schistosity of the rock. A little muscovite accompanies the biotite, and epidote in yellowish to colorless crystals, and in aggregates of such crystals, is sparingly present. Limonite is generally distributed in large and small grains. Apatite also is an accessory constituent. Coutchiching rapids.

On the south side of Knuckle Island, about a mile and a half east of Open-water Narrows, the mica schist is observable in immediate contact with the southern margin of the Open-water Narrows area or boss of Laurentian gneiss. The line of contact of the gneiss and mica schists is parallel to the shore of the island, and close to the waters edge, so that the accessible contact zone of schists is a narrow one. The schist is a fine-grained, light grey, fissile rock, with lumpy or nodular cleavage surface, due to the presence in the schist of large rounded or stoutly spindle-shaped bodies, (occasionally square or rectangular in outline) which give it a gnarled or knotted appearance. The rock is rather soft and fissile, due to decomposition under weathering influences. Under the microscope, (1560) the mass of the rock is seen to be a fine-grained aggregate of granulitic quartz and brown biotite in small plates all arranged parallel. In this, as base, are imbedded large, oblong Contact zone.

plates of muscovite with parallel basal boundaries, but ragged and shred-like at the ends. These plates of muscovite are congregated together in nests with some of the base of the schist, in a modified form, as interstitial cement. This cement differs from the rest of the schist in having more biotite and less quartz in its composition. Besides these nests of large plates of muscovite, there are larger, light-colored areas of oval outline, but of irregular boundaries, which appear to have been probably occupied by crystals of andalusite, or some allied mineral as a product of contact metamorphism. In the present altered condition of the rock the original mineral is replaced by a grey mass of minute particles of muscovite and kaolin, which polarize as an aggregate. The quartz of the schists is seen occasionally to enclose minute shreds of biotite. The total absence of felspar in a rock which has undergone contact metamorphism at the contact with a granitic mass is an interesting fact. It is in harmony with Rosenbusch's observations on the contact zone of Barr-Andlau.*

Absence of felspar in altered rock at contact.

Rock from top of series.

A specimen from the top of the series near the contact with the Keewatin at the west end of Red-pine island is a dark, grey, fine-grained, micaceous schist. Under the microscope, (1436) it appears as a fine-grained quartzite, made up mostly of grains of quartz with a little felspar and a good deal of brown biotite. The quartz grains appear in section as a mosaic, but present a distinctly rounded or granulitic aspect. There are, however, areas in which mosaics of coarser texture appear with the grains more interlocking. These are probably secondary. There are also occasional larger broken pieces of plagioclase and quartz, which shew a partial rounding of the contour, as if by abrasion. Calcite and a little muscovite are also present as secondary minerals.

South shore Rainy Lake.

On the south shore of Rainy Lake near Coutchiching Rapids there is in association with the mica schists an iron grey, micaceous gneiss differing from the former only in the possession of a felspathic constituent. It might perhaps be rather called a felspathic mica schist than a gneiss. In thin section (690 b) it is seen to be composed of quartz, orthoclase, plagioclase, biotite and muscovite. A more or less distinct rounded or granulitic appearance is presented by the orthoclase, though not by the plagioclase. The quartz contains inclusions of apatite in characteristic jointed needles, besides opaque minutely granular bodies.

Bleak Bay.

The rocks on the south side of Bleak Bay are fine-grained, grey gneisses or felspathic mica schists. A specimen (53) in thin section, cut parallel to the schist planes, appears as a more or less granulitic

* Die Steiger Schiefer und ihre Contactzone and en Graniten von Barr-Andlau, Strassburg, 1877.

mosaic of quartz, orthoclase and plagioclase, with an abundance of fresh biotite, mostly arranged in parallel position. Both quartz and felspar contain numerous liquid inclusions, some with bubbles, together with minute microlites. A number of opaque grains of uncertain character are also present. A similar rock, from one of the islands in this part of the lake, in which the section (55) is cut perpendicular to the schist planes, resembles the last closely. The orthoclase is cloudy, while the plagioclase is quite fresh. The quartz contains liquid inclusions with moving bubbles, and hair-like needles of rutile, besides oval grains of apatite. There is a well marked tendency to granulitic structure in the quartz and orthoclase, while the plagioclase is usually in irregular shaped grains. The biotite is in plates of various thickness lying in parallel position.

Another specimen from the south side of Bleak Bay resembles (53). It is very quartzose, and the disposition of the biotite is such as to give it a spangled appearance. Under the microscope, the rock has a strongly marked granulitic aspect, the grains of quartz and felspar having a prevailingly rounded shape. The grains are of varying size. The quartz preponderates very much over the felspar and is full of liquid inclusions arranged mostly in streams. Fresh, brown biotite is distributed throughout the section in small shreds and large plates all in parallel position.

Rocks near Cranberry Bay.

A specimen from the south shore of the lake between Cranberry Bay and Brulé Narrows, resembles the last in general appearance. In thin section (1239) it is seen to be made up of quartz, plagioclase, biotite, muscovite and garnet. The granulitic or rounded character of the constituent grains is confined to the quartz, part of which, however, is also in elongated, irregular lenses. The plagioclase occurs in grains of quite irregular shape, adapted to the contours of adjoining grains, in other words, is granular in the sense in which Rosenbusch defines the word. The biotite is much more abundant than the muscovite and occurs in large plates. Both micas are in parallel position throughout the section. A few garnets of a purplish grey color occur, some of which are the largest individuals of all the minerals in the rock. These are of irregularly rounded shape, and sometimes enclose portions of the base of the rock.

Lob-stick Island.

On the east side of Lobstick Island the series is represented by a dark, pepper-and-salt grey, glistening schist of very fine-grain. Under the microscope (680) it is seen to be composed of quartz, orthoclase, plagioclase and biotite, with a little hornblende. The biotite is very abundant in irregular shaped plates, lying in parallel position. The orthoclase exhibits a zonal structure, the outer portion being of different optical orientation from the inner perfectly shaped crystal which

forms the nucleus of the irregularly shaped grain. The same structure is less commonly exhibited by the plagioclase. In many of the felspars, ocherous or dusty matter, together with minutely granular or granulitic matter, is congregated in more or less spherical bunches in the centre of the grain. Otherwise, the felspars are fresh and glassy. The hornblende is usually in elongated, but irregularly shaped grains. The structure is for the most part granular.

Rocks of Rice Bay area of Coutchiching.

The rocks of the Rice Bay area of the Coutchiching series differ somewhat from those of the same series farther south. They are as before all very quartzose and fall into two varieties, those containing felspar and those free from it. In the latter, which are probably the more prevalent, the rock is either made up of a very schistose interleaving of thick layers of quartz and thin films of dark green scaly chlorite, apparently an alteration production of biotite; or is composed of a similar but less even interleaving of quartz and muscovite, the latter being more abundant than the chlorite in the first case. In the felspathic variety, both biotite and muscovite are usually present, the biotite predominating, and the rock assumes the form of a gneiss of peculiar character, in which the quartz is disposed in lenses usually from one-eighth to one-quarter of an inch in diameter, and from one thirty-second to one sixteenth of an inch thick at the middle. If not in lenses the quartz is in very distinct sheets often one or two inches across, and one sixteenth to one eighth of an inch thick. These sheets taper towards their periphery and are, indeed, also much flattened lenses of great diameter. In these rocks orthoclase occurs sometimes in large crystals from half an inch to an inch across, with their greatest diameter parallel to the schist plane, and the plane of composition of the Carlsbad twins inclined at an angle of about 45° to the same. These crystals of orthoclase usually have long tails as in the felspars of augen gneiss. Whether the habitus of the quartz and orthoclase are the result of pressure analogous to that described in the Saxon granulites by Lehmann, or whether they partake of the nature of vein minerals due to the percolation of heated solutions, is a question which can only be decided by a much more careful microscopic study of the rocks than I have had an opportunity of giving them. Apart from these augen-like orthoclases, which are only of occasional occurrence along certain lines, particularly in the rocks on the west side of the narrows of the north arm of Rice Bay, there is a considerable proportion of felspar associated with the quartz throughout the rock. The schists, or gneisses, in which the augen-like felspars were observed, are in proximity to the very coarse mica-syenite or syenite gneiss on the south-east side of Hopkins Bay which appears to be of irruptive origin. Only a few characteristic specimens of these rocks have been examined microscopically.

Macroscopic characters.

At the entrance to Rice Bay, on the west side, the series is represented by a fine-grained, evenly laminated grey gneiss. Microscopically (1506) it appears as a granulitic aggregate of quartz, orthoclase, plagioclase and biotite, with some muscovite and epidote. As a rule, the granulitic or rounded character of the quartz and felspar is very marked. The quartz contains liquid inclusions. All the mica plates are in parallel position. Entrance to Rice Bay.

On the west side of the Narrows of the north arm of Rice Bay, a rock occurs whose macroscopic characters have been described on the last page. Under the microscope, (1519 A) it appears as an eminently granulitic aggregate of quartz, orthoclase, microcline, plagioclase and biotite, with some muscovite and epidote. The granulitic or rounded character of the grains is, however, characteristic only of the quartz and orthoclase, while the plagioclase often presents irregular or granular shapes. The felspars are all quite fresh. Rice Bay narrows.

A specimen from the north shore of the east arm of Rice Bay, is a schist made up of muscovite and quartz. In thin section (67) the quartz appears in areas of granulitic grains surrounded by muscovite which is very abundant, both in broad plates and in compact aggregates. The quartz is full of colorless microlites. The plates of muscovite are in parallel position. East arm of Rice Bay.

A specimen from the north end of the north arm of Rice Bay is a schist composed of alternate thick layers of quartz and thin films of green biotite or biotite altered to chlorite. Under the microscope (66) the quartz is granulitic, and contains liquid inclusions and microlites. North arm of Rice Bay.

On an island in Rainy River, a little over four miles above Manitou Rapid, there is an outcrop of a rock which has provisionally been classed with the Coutchiching, although its isolated character renders its stratigraphical relations a matter of conjecture. It has the aspect of a very fine-grained, grey gneiss of even lamination, but microscopically (1604) it appears to be little more than a micaceous sandstone or quartzite. It is made up mostly of quartz, with a little plagioclase in grains of varying size, partly rounded and partly angular. It is evidently a clastic rock, the chief alteration which it has undergone being the development of secondary quartz in mosaics and of muscovite and brown biotite in small irregular plates lying in parallel position. The rock is scarcely schistose. The rounded shape of the constituent grains of quartz appears to be due to water-wearing action in an original sand. There is a good deal of cloudy, kaolin-like material scattered through the section. Coutchiching on Rainy River.

## A.—Laurentian.

It will be convenient in describing the Laurentian of the region under consideration, to deal with each area separately, dwelling particularly only on that which has been most closely studied, viz.: the Stanjikoming area.

Stanjikoming area

The limits of this Laurentian area have been already described and are shewn on the map of the region which is being prepared. It has a north and south diameter of thirty-two miles, and its greatest diameter is an east and west direction, from Clear-water Lake to the east end of Redgut Bay, is about forty-six miles.

Dimensions

Area separable into two parts.

The area is naturally separable into two distinct parts, according to the character of the rocks which compose them, viz., (1) an inner nucleus, and (2) a broad peripheral zone. The distinction between these is very clearly and sharply defined in the northern half of the area, but much less so in the southern half. The inner nucleus is composed essentially of a biotite-granite gneiss of medium texture and grey color, which is very quartzose and distinctly foliated. The rocks of the peripheral zone are more basic than those of the inner nucleus. The prevailing habitus is that of a syenite, or hornblende-granite, quartz being either absent or only sparingly present. The color is either grey or reddish; the texture is coarse-grained and the gneissic foliation very much less pronounced than it is in the biotite gneisses of the inner nucleus.

Line of demarkation between peripheral zone and inner nucleus.

From the west end of the North-west Bay the line of demarkation between the inner nucleus and the outer zone of hornblende-syenite gneiss, with its local facies of hornblende-granite, and even biotite-granite, gneiss, has been traced very satisfactorily as mapped, around in an irregular crescent, concave to the south, to Redgut Bay. From Lake Despair, across the Despair River and the various arms of Jackfish Lake, through Loon Lake, across the Manitou River above the Devil's Cascade, and thence across Vane Lake and Capt. Cuttle Lake to Black Sturgeon Lake and Crow Rock Inlet, the line is very sharp, and can be located at all of these various points of intersection very closely, there being a sudden change from one rock to the other. This line is rudely parallel to the line of contact previously sketched between the Keewatin and Laurentian. Between these two roughly parallel lines the zone of syenitic gneisses has a breadth which varies from three to to six or seven miles. That the whole of this breadth is occupied by the same kind of rocks is established by the examination of the well bared shores of the half dozen or more canoe routes, which traverse it at intervals sufficiently close to afford the necessary data for mapping.

At the two ends or horns of this crescent-like zone it appears to become confused with the biotite gneisses of the inner nucleus, and to blend with them in a manner which seems only explicable on the supposition that the two rocks were both in a more or less plastic or fused state at the same time. This lack of sharp distinction between the two kinds of rock begins on the west side on Lake Despair and becomes more and more apparent as we endeavor to trace the syenite gneiss across the end of North-west Bay to Half-way Inlet. A band of these syenite gneisses certainly crosses the North-west Bay in the direction indicated, such direction being coincident with the strike of the evenly foliated biotite gneisses. But in this band are portions which are scarcely distinguishable from the ordinary biotite gneisses, except, perhaps, that they are rather coarse-textured, and which do not appear to be inclusions, but pass into the syenitic phase of the rock by gradations. In the adjacent biotite gneiss, also, which occupies the greater portion of the shores of North-west Bay, there are local developments of a syenitic facies. These are intimately associated with what appear to be included masses and bands of hornblende schist, or massive dioritic rock, in the more acid biotite gneiss, and it would appear in these cases that the coarse syenite gneiss, whether it be mica-syenite or hornblende-syenite, has resulted from the fusion and intermixture of the more acid with the more basic rock. The first occurrence of this coarse syenite gneiss observed in going up the bay is on the south shore opposite Shelter Island, where it has the facies of a porphyritic mica-syenite with frequently a little quartz. At all the available exposures on the shores of Half-way Inlet, this gneiss appears to be the prevailing rock, from a point a quarter of a mile north of Cliff Narrows to the bottom of the inlet. It also appears on the S.E. shores of the terminal expansion of the North-west Bay and occupies probably a mile and a half of the shore. It occurs also on the north, or north-west shore of this same expansion of the bay, opposite Gusty Point. Here, however, as at other places, it is much mixed with the ordinary biotite gneiss, so that the relationship that exists between the two is difficult to make out. In some places it appears to cut the latter as an intrusion through it, but this appearance only extends to the sudden and boss-like presence of the syenite in the midst of biotite gneiss, and contacts where the relationship can be satisfactorily studied, are difficult to find.

Breadth of zone.

Local blending of two kinds of rock.

Gneisses on shores of North-west Bay.

In its continuation to the S.E. the band appears to thin out to a narrow width between Half-way Inlet and the west shore of Rainy Lake, where nothing but biotite gneisses are found, except at a point three-quarters of a mile N.W. of Standing-stone Point, where a small patch of syenite was observed; and some on the latter point itself.

Continuation of zone of syenite gneiss on Rainy River.

It seems probable that the zone of syenite gneiss which thus begins, at the west end of the North-west Bay, to become confused and mixed with the biotite gneiss, is continued in the area of hornblende syenite gneiss, which is exposed on Rainy River between six and seven miles above the Manitou Rapid, and also in the area of coarse mica-syenite gneiss which is exposed on Rainy River at Fort Frances and thence northward for about six miles on the west side of the lake to Stanjikoming Bay. The small area of hornblende and mica-syenite gneiss observable on the south-east side of Hopkins Bay seems to serve as a link of connection between the last and the first described crescent-like zone at its eastern extremity on Redgut Bay. On the Big Canoe River route, the syenite gneiss occupies the whole of the breadth between the inner nucleus of biotite gneiss and the base of the Keewatin. South-eastward of this, however, the zone of these rocks appears to diminish rapidly in breadth, and on Black Sturgeon Lake and Crow Rock Inlet is little more than a mile wide. In this interval, moreover, the rocks composing it are no longer in direct contact with the Keewatin, for the exposures on Big and Little Saw-bill lakes, Porter Inlet, and the north end of Redgut Bay, shew that an area of ordinary quartzose, biotite gneiss lies between the Keewatin and the zone of syenitic gneiss. The latter seems to taper to a point on Redgut Bay, and where it does so, it appears in places to be intimately mixed with the biotite gneiss and appears further, in certain cases which have been examined carefully, on the north side of the bay opposite the Indian village, to result from the fusion of the biotite gneiss with certain included bands or masses of hornblende schist and diorite, which will be alluded to more particularly in the discussion of inclusions in gneisses.

On Big Canoe River route.

Distribution of two gneisses north of Redgut Bay.

Relationship of structural planes of two gneisses at contact.

Above the Devil's Cascade, on the Manitou route, the biotite gneiss may be seen very clearly dipping under the syenite gneiss at an angle of about 60°. On the south-east side of Loon Lake the two rocks are in the same relative attitude, the angle of dip varying from 45° to 60°. At the lower end of Loon Lake, and across Jack-fish Lake, the dip of the biotite gneiss is much less regular, being sometimes away from and sometimes towards the syenite gneiss, the former being the prevailing dip on Jack-fish Lake and on Reserve River. On Vane Lake the planes of foliation of the gneiss are not sufficiently regular to afford an indication of the dip. At the contact here of the biotite gneiss with the hornblende-syenite gneiss, the former is traversed by dykes of granite, while the latter is not. At the contact on Captain Cuttle Lake, no very exact line of demarkation could be detected, but rather a passage from the biotite-granite gneiss, through hornblende-granite gneiss to the syenite gneiss.

The only portion of the zone where the rocks vary so much from their general character as to pass completely from the syenitic facies, and become prominently quartzose and granitic, is at its extreme east end. On the shores of the west arm of Jack-fish Lake, the rocks are somewhat quartzose, and the quartz becomes more abundant on Clear-water Lake, where the rock is a coarse-granite, foliated in some places, and scarcely at all, in others. Variation from normal character.

The biotite gneisses of the inner nucleus of the Stanjikoming area of Laurentian rocks, are, as regards their field characters, chiefly remarkable for the constancy of their composition and general aspect, the uniform regularity of their foliation, the regular dip of such planes of foliation, generally at angles of from 45° to 60°, and the ease with which the strike of their edges can be traced in curves which, in one notable instance at least, close upon themselves in concentric circles. The gneiss is characterized, too, by holding included fragments of foreign rock, which resemble the rocks of the Keewatin and Coutchiching series. These inclusions will be considered more in detail in the next section. The contact with the geologically higher series of Coutchiching and Keewatin rocks is always of a more or less distinctly brecciated character, the gneiss sending apophyses into the schists, and holding imbedded in it detached angular fragments of them. The geologically colored map, taken with the detailed descriptions of typical specimens of the rocks, renders a lengthy account of the geological features unnecessary. Attention may, however, be directed particularly to the structure of the rocks of this portion of the area. The plotting of the observed strikes and dips shows that if we follow the strike of the planes of foliation from the Devil's Cascade southward, it curves gradually to the south-west and west on the shores and islands of Manitou Sound and the bays to the west of it; then north-west along the shores of the North-west Bay and Foot Print Lake, north to north-east through Jack-fish and Loon Lakes, and finally south-east at the south-east part of Loon Lake where the rocks trend directly towards the starting point at the Devil's Cascade, joining in a complete circle. This circular trend of the strike of the planes of foliation of the gneiss is constant in a zone which has a considerable breadth measured on the radii of the circles or in a direction transverse to the strike. The breadth of the zone bears no relationship to the angle of dip, being no greater where the dip is low than where it is high. Thus from the north side of Ash Bay to Ami Point, the rocks have a constant dip to the south-eastward of from 30° to 45°, and the breadth of the zone is much the same as at the opposite side of the circuit where, on Loon Lake and Jack-fish Lake, the dip is at a much higher angle. The angle of dip is also high along the North-west Bay. The concentric circles thus formed by the inter-

Biotite gneisses of inner nucleus.

Concentric structure of foliation.

section of the planes of foliation with the horizontal plane of the present surface have their centre in a point which appears to lie in the north arm of Ash Bay, the rocks in that vicinity being at extremely low angles, almost flat in some cases, and the strike consequently difficult to trace. The dip is away from this centre all the way around, so that the structure is the same as that which would be revealed by a section across a low cone or dome laminated concentrically to its surface. The simplest explanation that suggests itself to account for the structure, is that of an upheaving force acting on a plastic mass, such force acting with greatest intensity in the vertical line which would correspond to the axis of the cone or dome. This would correspond to an anticlinal dome in ordinary bedded formations. With this difference, however, that in the latter the structural planes existed as planes of bedding prior to the application of the force which bulged it into a dome, whereas in the case of this Laurentian gneiss, all the evidence goes to show that the structural planes are the result of such upheaval and a differentiation, from the homogeneous character of the rock, produced by the deformation incident to it.

Focus of concentric structure.

Synclinal and anticlinal structure.

South of a line drawn from Ami Point to the entrance to the Northwest Bay, between Hay-marsh and Woodchuck Islands, the dip is very suddenly reversed and we have what appears to be a synclinal axis, the strike on either side of the line diverging to the eastward. A parallel line four miles to the southward, drawn from Frog Portage to the neighborhood of Standing-stone Point, appears to be the corresponding anticlinal axis, for on the south side of this, the dip is again to the south or south-east.

Sporadic intrusions of granite.

Between these two lines, the dip is constantly to the north, and the rocks lying within them are much traversed by local or sporadic intrusions of red granite accompanied by pegmatitic veins. Along the line of the anticlinal axis just mentioned, the biotite gneisses are observed locally to give way to hornblende granite and syenite gneisses. To the south of the line a considerable number of observations have been made as to the strike and dip, but no general statement as to the structure can be deduced from them beyond the fact that the dip is prevailingly south-eastward or eastward on the west side of the lake where the strike curves around to a north and south direction. In this part of the area, inclusions of rock fragments resembling the formations of the Coutchiching series are more abundant in the gneiss than farther north. Indeed in some places, notably between Blaze Point and Frog Portage, the gneiss appears to be quite composite in character, as if made up of shattered fragments of such rocks as occur in the Coutchiching series which had become immersed in a felspathic magma, partially fused and drawn out into lenticular bands. Some

Composite character of gneiss locally.

phases of this variety of the gneiss present a remarkably evenly rib-banded aspect due to alternations of sheets of dark, fine-grained, very micaceous rock, with others of light grey color, of coarser grain and mostly felspathic, with little or no mica.

Bosses of Laurentian gneiss between Bear's Passage and Coutchiching.

The three small bosses of biotite gneiss that lie in the axis of the anticlinal fold of Coutchiching rocks which stretches from the Bear's Passage to Coutchiching have already been alluded to at sufficient length (p. 102). It only remains to be noticed that the gneiss of the most westerly of the three exhibits the most pronounced, and that of the most easterly the least pronounced foliation, or is most granitoid. In all three the evidence of their protrusion through the Coutchiching rocks is most clear, and also that the protrusion has been one of slow upheaval of a magma which must have been very thickly viscid, or tough and coherent, rather than fluid. For the gneiss has not simply filled a dyke-like fissure in the Coutchiching schists, but has displaced the latter in such a way that the strata have everywhere accommodated themselves to the shape of the protruded boss, i.e., the strike conforms to the shape of the boss, and runs around it, while the dip is constantly away from it. The dykes that emanated from the gneiss and penetrate the schists at the contact are of a local character, and do not extend far within the schists, being originally rather of the nature of a plastic mass forced into fissures and crevices by great pressure, than fluids filling cracks in the crust like regular dykes.

Sabaskong Laurentian area.

The rocks of the Sabaskong Laurentian area, so far as they are known, on the Kishkutena route, Sabaskong Bay, and the shores and islands of the south part of the lake, are mostly quartzose gneisses. An exception to this general rule is found in a mass of hornblende-syenite gneiss, of very coarse texture and very indistinct foliation, which occupies about two miles of the south-east shore of Lake of the Woods, beginning at a point one mile north of the 49th parallel. A patch of the same rock also occurs on the extremity of Pork Point. All the other rocks are either biotite-granite gneiss or hornblende-granite gneiss, the latter being usually only a local facies of the former. Thus the rocks of Sabaskong Bay, as a whole, resemble very closely those of the inner nucleus of biotite gneiss of the Stanjikoming area, but on the islands at the mouth of the bay, on the south shore where it opens out to the lake, the proportion of the quartz is less, hornblende replaces a part of the biotite, and finally the rock passes into a hornblende-granite gneiss in which there is no mica. At the east end of the bay, the proportion of mica becomes less, and that of quartz increases, and the whole aspect of the rock is more granitoid and perhaps coarser grained. This increases along the Kishkutena route, till on Kishkutena Lake the rock is a very quartzose, coarse-grained,

Variation in character of rocks.

reddish granite, with a foliation only occasionally developed, but still geologically the same as the evenly foliated gneisses of the western and middle portions of Sabaskong Bay. The strike of the planes of foliation of these gneisses exhibits a marked tendency to a disposition in concentric circles similar to that observed on Rainy Lake. The gneisses both here and on the south-east shore of the lake towards the mouth of Rainy River are often charged with inclusions of hornblende schist and dioritic or amphibolitic rock. In Sabaskong Bay their foreign and included character is much more apparent than in the gneiss south of the mouth of Little Grassy River, where the schist and gneiss are either confusedly mixed, or appear in remarkably even inter-bandings, due, doubtless, to pressure deformation, such as that discussed by Teall,* with this difference, that, whereas, Teall regards the more basic bands as the squeezing or pulling out into sheets of the more basic early secretions from the magma, the evidence here points to their having been fragments detached from the once overlying Keewatin series, or pipes of volcanic rocks that filled vents in the floor upon which the Keewatin was deposited, and which by fusion and recrystallization gave rise to the Laurentian gneiss. Even where they are most evenly banded, there is occasional evidence of the gneiss having been the matrix, since it traverses the schists locally transversely to the strike. Many of these inter-bandings appear, too, as I have before stated, to have been produced by the penetration of the gneiss in a plastic condition along fissures which are coincident with the cleavage planes of the schist, the latter having been parted on the large scale in a manner similar to that shewn in Plate VI for a comparatively small inclusion.

Inclusions of foreign fragments.

Turtle Lake Laurentian area.

In the Turtle Lake Laurentian area, so far as it comes within the limits of the region examined, the greater part of the gneisses are quartzose, biotite gneisses, similar to those of Rainy Lake and Sabaskong Bay. Going northward from Rainy Lake to Manitou Lake, by way of the Otukamamoan route, all the shores of the lakes as far as the outlet of Kinojé Lake are composed of this rock. Between this point and the Manitou Lake, however, we come upon rocks of the character of hornblende-granite and syenite gneiss of much less distinct foliation and coarser texture. These are very similar in character to those of the peripheral zone of the Stanjikoming area, and occupy a similar position relatively to the biotite gneisses and to the Keewatin series. These hornblende-granite and syenite gneisses are well exposed on all the shores of Kionjé, Kahwawiagamak, Memekwesi (west end), Downgrade, Smooth-rock, and Windigons Lakes. All the Laurentian rocks observed on the shores of lakes and rivers between the Otukamamoan

Zone of syenitic gneiss similar to that of Stanjikoming area.

* On the origin of certain banded gneisses, Geol. Mag., Nov., 1887.

route and Big Turtle River, and on Big Turtle River itself, to a point one mile north of Jones Lake, are quartzose, biotite gneisses. At the point above Jones Lake just mentioned, however, we come upon coarse, reddish, hornblende-syenite gneiss. This is probably geologically the same with the hornblende-syenite and granite gneiss observed at the north end of the Otukamamoan route, and if so, they would appear to form a zone quite as extensive as the peripheral zone of the Stanjikoming area.

Lake Harris Laurentian area.

The Lake Harris Laurentian area on the northern limits of the region mapped, has only been partially examined. The small portion of it which comes within the limits of the Rainy Lake sheet appears to be continuous with the Laurentian known to occupy the shores of the middle and eastern parts of Deer Lake and which, according to Bell,* also occupies the shores of Hugh Osbourne's Lake, and of lakes Rowan, Hill and Lawrence. If this be so, then the Lake Harris area is an immense pear-shaped area of Laurentian rocks completely encircled by the rocks of the Keewatin series, and so quite analogous to the Obabicon, Sabaskong, and Stanjikoming areas. From Dr. Bell's account of the distribution of the (Huronian ?) Keewatin on Wabigoon and Eagle Lakes, and our own knowledge of the distribution of the Keewatin on the Manitou route and thence continuously by way of Pipe-stone Lake, Crow Lake and White-fish Lake to the west end of Deer Lake, there appears to be no doubt but that the area is completely encircled, as stated, by these rocks. The interior of the area has not yet, however, been examined and all that can be said at present is that it is very probably entirely occupied by Laurentian gneiss. The greatest length of the area in a N.E. and S.W. direction is forty-five miles, and its greatest width, from Lake Harris across to near the outlet of Deer Lake, is about twenty-five miles.

Encircled by Keewatin schists.

Lake Harris.

On Lake Harris the gneiss is coarse and granitoid with very indistinct foliation, or none at all. Hornblende-granite and biotite-granite both prevail, the former, however, being probably more abundant than the latter. Both kinds are simply different facies of the same geological mass. No varieties were here observed which are entirely devoid of quartz.

Bluff Lake.

On Bluff Lake, however, the Laurentian rocks in the vicinity of the contact with the Keewatin are very basic, and have the facies of a uralitic gabbro. Towards the north this passes into a hornblende-syenite gneiss and then into a hornblende-granite gneiss, the rocks at the north end of the lake being distinctly quartzose.

* Geological map of the Lake of the Woods and adjacent country, 1881.

## PETROGRAPHY OF THE LAURENTIAN ROCKS.

### *Hornblende-Granite and Hornblende-Syenite Gneiss.*

Different facies of same rock mass.

The hornblende-granites, foliated and non-foliated, are not separable, geologically, in the Rainy Lake region, from the hornblende-syenites. In the former, the quartz is never, as a rule, very abundant; and in the same geological mass, specimens may be taken which, regarded in themselves, would be classed as hornblende-granites, while others, not far distant, may be taken in which it is difficult to find a trace of quartz, and which would, therefore, be placed with the syenites. In view of the sparing amount of quartz, when present, and of the geological identity of the quartzose varieties with the quartz-free, it has been found convenient to refer generally to these rocks as syenite, particularly those of the peripheral zone of the Stanjikoming area. When foliated they are called syenite gneiss. It is, however, just as difficult to draw a hard line between the foliated and non-foliated varieties of those rocks as between the quartzose and quartz-free. The one grades into the other, and rocks which are non-foliated may sometimes be referred to as gneisses, because of their being a mere local facies of a mass which is prevailingly foliated or gneissic. Although distinctly foliated, the rocks here considered rarely, if ever, assume that evenly parallel lamination or banding which is commonly observed in the biotite gneiss.

Stone-dam Lake.

The Laurentian formation with which the Keewatin rocks are in contact at the north end of Stone-dam Lake is a coarse-textured, hornblende-granite gneiss. In thin section (375) it is seen to be made up of a granular aggregate of orthoclase, plagioclase, hornblende and quartz, with some rounded prisms of apatite, a few grains of magnetite and a little secondary biotite and epidote. The quartz is in large water-clear grains, including apatite and other less determinate microlites. The orthoclase is partially altered to kaolin and muscovite. The plagioclase is usually fresher, but is occasionally cloudy. There are included in it long, perfectly straight, extremely fine rods which are sometimes in perfect continuity for great lengths and sometimes disjointed. Part of the hornblende is somewhat fibrous, and has associated with it epidote as an alteration product. On its margin it is in places altered, also, to biotite, which in turn has epidote developed in it.

North shore Loon Lake.

Another specimen from this part of the zone, taken from the north shore of Loon Lake, is a coarse, foliated, mottled, black-green and white granite. Under the microscope (525) the structure is granular. The orthoclase and plagioclase are usually quite fresh, with exceptional small patches of decomposition products. The hornblende is in

deep green colored, compact grains, with sometimes a nuclear, light yellowish colored portion, which shews brilliant polarization colors and large extinction angle, evidently the remains of an original pyroxene of which the hornblende is a paramorph. The cleavage of the pyroxene is coincident; and the latter, although not at all fibrous, appears to be developed along the cleavage of the pyroxene well within the nuclear area occupied by it. Biotite is sparingly present associated with the hornblende, from which it is probably derived. Epidote occurs in large, yellowish masses with well defined cleavage ( $\infty P\bar{\infty}$ ) to which the extinction is parallel. It is sometimes associated with the hornblende, but is often quite apart from it. Apatite is of rather frequent occurrence in small oval and stout columnar crystals shewing pyramidal terminations.

Jack-fish Lake north-west arm

On the shores of the north-west arm of Jack-fish Lake, the same geological mass or zone is represented by a coarse-textured, flesh-tinted rock made up, so far as can be determined, macroscopically, of felspar and black hornblende. Under the microscope (562) the hornblende is compact and of a deep color, with the usual pleochroism, and is frequently observed to have a core of foliated pyroxene. The pyroxene (diallage) polarizes in brilliant colors and shews a high extinction angle, it is colorless and not perceptibly pleochroic. The encroachment of the paramorphic hornblende upon the pyroxene along the cleavage traces is shewn very beautifully. The felspars are cloudy orthoclase, microcline and fresh plagioclase, with inclusions of apatite. Larger crystals of apatite and sphene in idiomorphic development are sparingly distributed. Small quantities of brown mica and a very little quartz are also present. Epidote occurs in separate, well-formed, pleochroic crystals of greenish-yellow color, often with an opaque nucleus of iron oxide. It also occurs in the plagioclase. Besides this, chlorite is present as an alteration product of the hornblende.

Cores of pyroxene in hornblende.

Another specimen from the south-west side of the same bay is a coarse-grained, pepper-and-salt, grey, hornblende and felspar rock. Under the microscope (560½) the structure is granular. The hornblende possesses distinct cores of foliated pyroxene (diallage) which demonstrate very perfectly the secondary origin of the former, and point to the paramorphic derivation of all the hornblende in these rocks from pyroxene of some form or another. The diallage appears to pass into a pale, green colored variety of the hornblende first, and then into deeper colored varieties, the pyroxene itself being of a light grey to lavender color, and very slightly pleochroic. The angle of extinction is about 40°, and the polarization colors are the brilliant ones common the pyroxenes. Plagioclase and orthoclase are present in abundance, but the former predominates very much over the latter.

Apatite is fairly abundant as an inclusion in the other minerals, and biotite is present but is probably an alteration product of the hornblende with which, together with epidote, it is closely associated. The remains of foliated pyroxene and the preponderance of plagioclase taken together with the granular structure, suggest that this rock perhaps belongs with the gabbros rather than the syenites.

Foot-print Lake S. W. side.

On the south-west side of Foot-print Lake, the biotite gneiss is interrupted by a rather ill-defined area of hornblende syenite. The rock is a coarse-textured aggregate of flesh-tinted to red felspar and greenish, black hornblende. Under the microscope, the structure is granular, and the section (642) is made up of fresh microcline, inter-grown with albite, giving regular perthitic structure; plagioclase, slightly cloudy, in patches; compact, green hornblende, with occasionally a core of the original pyroxenic mineral to suggest the secondary origin of all the hornblende. Sphene and apatite are generally distributed, though not abundant, the latter in stout, rounded or pyramidally terminated prisms, and the former in its characteristic double-wedge shaped forms. Epidote is plentiful and has, in some instances, apparently been formed around a grain of magnetite or other iron oxide, but is generally associated with the hornblende from which, and from the felspar it is derived. A small proportion of the hornblende or of the pyroxene of which it is a paramorph, has been changed to nearly isotropic chlorite.

Foot-print Lake lower end.

At the lower end of the same lake, the rock, evidently the same geologically as the last, is a coarse-textured, salmon-tinted gneiss, made up of felspar with a small proportion of epidote and chlorite in rough but distinct gneissic arrangement. Under the microscope (646) the felspars are seen to be fresh orthoclase, microcline and plagioclase (albite). The lamellæ of the latter are frequently bowed and the twinning of which they are indicative is, in some instances, probably secondary and due to pressure. Other pressure effects are observable, such as the minute faulting and dislocation of crystals, and the abrupt termination of twinning traces upon cracks.* The pyroxenic or hornblendic constituents of the rock have been so decomposed that they are represented now only by intermingled aggregates of epidote and chlorite. The only other minerals observed are a little limonite and some secondary quartz.

North-west Bay Rainy Lake.

At the west end of the North-west Bay of Rainy Lake a decomposed syenite rock interrupts the biotite gneiss much as it does on Foot-print Lake. It is a coarse-grained, granular aggregate of flesh-red felspar, faded-green hornblende and yellow-green epidote. Under the microscope (918) the felspars comprise orthoclase, microcline and

* Cf. Judd. Tertiary and Older Peridotites of Scotland, Q. J. G. S., 1885.

plagioclase with inclusions of apatite. The hornblende is very largely altered to epidote, which is closely associated with it. Besides this there is an abundance of epidote, in large masses and in aggregates of grains, whose origin is less apparent. Quartz is only sparingly present, and is dusty, with liquid and granular inclusions.

Above Devil's Cascade.

On the Manitou Canoe route from the Devil's Cascade to Cedar Narrows, on Pickerel Lake, the whole breadth of the peripheral zone of the Stanjikoming Laurentian area, is well exposed. The rocks are gneissic, hornblende-granites and syenites, of which a number of typical specimens have been critically examined. Half a mile above the Devil's Cascade, the rock is a grey, distinctly foliated gneiss, which in thin section (951) is seen to be a granular aggregate of orthoclase, plagioclase, hornblende and quartz, with some idiomorphic apatite included in all these, and epidote in considerable abundance associated with the hornblende. The felspars are all fresh and the hornblende is compact, but of rather pale shades of green, and not so strongly pleochroic as it is usually; it is in irregularly shaped grains, which, however, are generally elongated in the direction of the prism. The quartz contains, as inclusions, long, straight, extremely fine, rod-like bodies.

Sphene Lake.

About a mile W.N.W. of the last locality, on the shores of Sphene Lake, the rock is of the same microscopic characters. Microscopically (959) it is a granular aggregate of orthoclase, microcline, plagioclase, hornblende and quartz, the last in sparing quantity. The accessory idiomorphic constituents are brown, pleochroic sphene, apatite in jointed needles and oval bodies, a few zircons, and a slender, pink-tinted, limpid, pleochroic prism, with parallel extinction, and low refractive index, probably tourmaline. The latter is included in the orthoclase. The felspars are fresh, and there is probably more than one variety of plagioclase, some of the crystals shewing broad twinning lamellæ, while in others these are excessively fine. The hornblende is compact, deeply colored and stoutly pleochroic. It is usually full of inclusions of apatite, sphene, and grains of magnetite. The quartz plays a very subordinate rôle, and may be regarded as an accessory.

A mile and a half north of the Devil's Cascade, on Sphene Lake, the rock is very much the same as that last described, a distinctly gneissic, coarse-grained, hornblende-syenite, with accessory quartz, apatite and sphene, together with a little secondary biotite associated with the hornblende. The quartz is dusty, with inclusions of an indeterminate character, together with microlites of apatite, small, stout, brown bodies and long, straight, excessively thin rods, probably rutile, many of which have a parallel arrangement, but which, taken altogether, have no apparent regularity. The most interesting point to be observed in the

Twinned sphene.

section (961) of the specimen from this locality is the beautiful instance of the twinning of sphene according to the law first described by Dr. G. H. Williams,* as explanatory of the apparently perfect cleavage in

Fig. 11. Section of hornblende-syenite gneiss from west side of Sphene Lake shewing a crystal of titanite polysynthetically twinned parallel to—4 P (Dana), probably as a result of pressure. Nicols +. × 44.

| | |
|---|---|
| *t.* Titanite | *a.* Apatite |
| *o.* Orthoclase | *b.* Biotite |
| *h.* Hornblende | *q.* Quartz |
| *p.* Plagioclase | *p′.* Plagioclase, dislocated, and shewing pressure twinning. |

American varieties of this mineral. The sphene is rather abundant in brown, slightly pleochroic crystals of the usual double-wedge shape, and the crystal shewing the twinning parallel to —4 P (Dana) is cut approximately perpendicular to the prismatic zone. The aspect of the crystal between crossed nicols will be gathered from a glance at (Fig. 11). There is a well pronounced set of lamellæ of varying width, inclined at a small angle to one of the prismatic faces; and feeble traces of another set of polysynthetic lamellæ are also observed as nearly parallel to the other prism, or inclined to the first set of lamellæ at an angle of 113°. This twinning law, which gives rise to the parting commonly regarded as cleavage in the largest sphenes found in many crystalline limestones does not seem to have hitherto been observed in the sphenes occurring in massive rocks. Dr. Williams in his paper, suggests that this twinning is probably due to pressure, and its occurrence, in the present instance, is under such conditions as lend interesting confirmation to this view. Faulted and secondarily

Probable pressure effects.

* Cause of the apparently perfect cleavage in American sphene, Am. Jour., Sci. XXIX, June, 1885.

twinned plagioclase occurs in such relation to it as to shew that there must have been pressure exerted at right angles to the best developed twinning lamellæ, while at right angles to the feebly developed lamellæ, there is no such evidence of pressure.

At Cedar Narrows, Pickerel Lake, the gneissic hornblende-syenite is in contact to the north with dark green, hornblende schists. Near the contact the syenite gneiss loses its foliated aspect, and becomes very much darker in color, the hornblende greatly predominating, and at the contact, the appearance is such as might be produced by a partial fusion of the green schists and their absorption into the magma which solidified as the syenite. There is a transition of several yards between the schists and the coarse-textured, foliated, black and white syenite, whose general character may be described as that of an aggregate of hornblende crystals in which are included reddish crystals of orthoclase. Under the microscope (1054 A) this transition rock is seen to be made up, besides orthoclase and hornblende, of large quantities of epidote and zoisite, with muscovite, derived from the decomposition of the felspar in scattered shreds. In another section (1054 B) of the same rock, where it is coarser-grained and farther from the contact, the structure is that of a hornblende syenite. The hornblende sometimes shews a pale colored central area, suggestive of its derivation from pyroxene, and carries numerous inclusions of apatite, besides which there are larger oval apatite crystals scattered through the slide. The felspar is cloudy and is sometimes stained red with oxide of iron. Epidote occurs in large individuals and in aggregates of grains.

Cedar Narrows.

Transition rock at contact.

Among these hornblende-syenite and granite gneisses the most interesting point, is, perhaps, the frequent detection of either a pyroxene core, or evidence of the former presence of one, in the middle of the hornblende crystals, demonstrating the secondary origin of a portion at least of the hornblende of these rocks. This, of course, raises the question of the extent to which the hornblende is secondary; and it seems not improbable that all the hornblende of the hornblende-syenite and granite of this region is of secondary origin. Such a view appears to be quite in harmony with the growing conviction of petrographers and geologists as to the general paramorphic origin of hornblende in cases where it is not distinctly basaltic. Irving* sums up his conclusions, at the end of a valuable paper on this question, in these words: "Thus, after an examination of about a thousand thin sections, representing the crystalline schists, acid eruptives and basic eruptives of a region some 400 miles in length by 300 in width, and of three distinct geological systems, I have found no hornblende that is

Secondary character of hornblende.

Irving's conclusions.

* On the Paramorphic Origin of Hornblende of the Crystalline rocks of the North-western States. Am. Jour. Sci., 1883. Vol. XXVI, p. 27.

Wadsworth.

not either clearly, or very probably secondary to augite." Wadsworth had previously expressed a similar opinion with reference to the greenstones of the Marquette district.* The development of the idea of the secondary origin of hornblende is succinctly sketched by Dr. Williams and a number of instances are described by him shewing the passage of augite into compact hornblende.† In view of these and many other observations, and of the fact that the hornblende of the syenite and granites of this region frequently has a remnant of the original pyroxene clearly discernable in its centre, I feel warranted in stating that these rocks, hornblende-syenites and granites, foliated and non-foliated, seem to bear the same relation to pyroxene-syenites and pyroxene-granites as do many of the old greenstones, commonly called diorites, to original diabases and gabbros.

Williams.

*Mica-Syenite Gneiss and Biotite-Granite Gneiss poor in Quartz.*

Texture and structure.

These rocks resemble closely the foliated, hornblende syenites and granites in their conditions of occurrence, but are sometimes in geographically separate masses. Their texture is coarse to very coarse, and they are usually of gneissic habit, although they can be traced into varieties in which it is difficult to detect any sign of foliation. They are usually characterized by the porphyritic development of orthoclase in large crystals twinned according to the Carlsbad law, and, when the rock is gneissic, the long axes of these porphyritic crystals are in parallel alignment. The planes of foliation are, however, in their detail undulatory, owing to their flowing around the large felspars as in the case of augen gneiss. It occasionally contains rounded or ovoid secretions of finer grain, or more rapidly cooled portions of the rock which are of identical composition with the bulk of the rock mass.

Falls of Fort Frances.

The rock at the Falls of Fort Frances on Rainy River belongs to this class. On the islands below the fort and on the shores of Sand Bay, the same rock is more distinctly foliated than it is at the falls. A section (65) of this rock shews it to be a granular aggregate of orthoclase, plagioclase and biotite, with a little accessory hornblende and quartz, in which are imbedded porphyritic crystals of orthoclase. Other accessory constituents are sphene, apatite and magnetite. The twinning lamellæ of the plagioclase are very fine and the extinction determined on a cleavage slice parallel to $\infty P\bar{\infty}$ is about 1°, so that it is very probably oligoclase.

Sand Bay, Rainy Lake.

At the bottom of Sand Bay, near the Half-breed village, the rock is much the same as that at the falls, but it is distinctly gneissic and

* Bull. Mus. Comp. Zool., 1880, pp. 37, 39, 42, 46.

† On the Paramorphosis of Pyroxene to Hornblende in Rocks. Am. Jour. Sci., 1884, Vol. XXVIII, p. 259.

shews areas of finer grain enclosed in the coarser, probably as earlier secretions. The composition and structure of these, as revealed by the microscope, present no marked difference from the rest of the rock except in the texture. The thin section (662) is that of a granular aggregate of fresh plagioclase, orthoclase, biotite, hornblende and quartz, with some epidote.

Stanjikoming Bay.

Another specimen of this same gneiss was taken from the east side of Stanjikoming Bay near the channel leading into it from the lake. The rock is here a coarse, grey gneiss with porphyritic crystals of orthoclase in Carlsbad twins. Under the microscope (793) it is a granular aggregate of orthoclase, microcline, plagioclase, biotite and quartz. Apatite and sphene are accessory original constituents and limonite and epidote secondary products. None of these are very abundant. The quartz is in sparing quantity and is intergrown with orthoclase in micro-pegmatitic structure. Only an occasional crystal of hornblende is observable. The epidote is derived apparently from the biotite with which it is associated as large, well-formed crystals of yellowish color.

Near Standing-stone Point.

Farther north, on the west side of Rainy Lake, three-quarters of a mile N.N.W. of Standing-stone Point, a decomposed, flesh-red, porphyritic gneiss of coarse-texture interrupts the biotite gneiss of that part of the lake. It is made up of large crystals of felspar around which the micaceous constituents flow. Under the microscope (833) the felspars are seen to be orthoclase, microcline and plagioclase with some included zircons. The mica is altogether changed to epidote and chlorite, there being none of the fresh mineral left. A little leucoxene is also present.

### *Biotite Gneiss.*

Comparison of foliated and non-foliated varieties.

The biotite gneisses of the region have not been made the subject of extensive microscopic study, such an investigation being unnecessary for ordinary determinative purposes. A few typical specimens from different parts of the region have, however, been examined, chiefly with the object of instituting a comparison between the minute structure of the more distinctly foliated and the less or non-foliated varieties. Such a comparison failed to establish any essential distinction between the two varieties beyond that observable with the naked eye in the parallelism of arrangement of the constituent minerals in the gneiss as contrasted with their indiscriminate disposition in granite. In both the structure is granular.

Crow Portage.

At the south end of Crow Portage, Sabaskong Bay, the gneiss which has been described as forming a brecciated contact with the basal, hornblende schists of the Keewatin series, is a medium grained, flesh-

tinted to grey rock of unusually even foliation. In microscopic section (48 B) it is seen to have a well-defined granular structure, all the minerals being allotriomorphic, except a few large porphyritic felspars of an earlier generation than the mass of the rock. The constituents are quartz, orthoclase, plagioclase, and biotite. The last mentioned mineral always lies in definite parallel planes, while the quartz and felspar grains exhibit a corresponding but much ruder tendency to a similar arrangement. The felspars are usually quite fresh. When decomposed to kaolin or muscovite, the decomposition is nuclear or central rather than marginal, and shews itself in sporadic flakes or cloudy aggregates sometimes along cleavage lines. The orthoclase is occasionally seen in Carlsbad twins, and the plagioclase is as usual twinned on the albite law, or a combination of this and the pericline law. The felspars are occasionally observed to be broken and parted with a shear, the intervening fissure being filled with secondary quartz or muscovite. The quartz carries inclusions of apatite, liquid inclusions with dancing bubbles, and darker bordered round inclusions, probably of gas, besides dusty or granular indeterminate matter.

Loon Lake.

On the south side of Loon Lake, on the Pipestone canoe route, there is an extensive exposure of the biotite gneiss of the inner nucleus of the Stanjikoming Laurentian area. A specimen taken from the west side of the lake, about a mile north of Speak-no-bad-language Portage is an evenly, foliated, flesh-tinted to grey, fine-grained rock. Microscopically (476) it is built up of allotriomorphic grains of quartz, orthoclase, plagioclase, biotite and epidote, the structure of the rock being granular. Quartz is the most abundant mineral. It contains fluid inclusions with moving bubbles, fine straight, rod-like bodies, probably rutile, and besides these a number of small yellowish, highly refracting, oval or oblong bodies. The orthoclase is perfectly fresh, and is only distinguished from the quartz by the bluish color between crossed nicols and its biaxial interference figure in converged polarized light. The plagioclase is also quite fresh and is as usual recognized by its polysynthetic twinning. The biotite is of a greenish, brown color. Stout, oblong crystals of apatite and epidote in aggregates of grains are also present.

Stanjikoming Bay.

The medium grained, biotite gneiss on the west shore of Stanjikoming Bay, towards its north end, differs but little from that last described, except that it is much less distinctly foliated and looks more like an ordinary grey granite. In thin section (776) the structure is granular. The felspars are usually fresh and the plagioclase is probably more abundant than the orthoclase, although the rock is decidedly quartzose. Apatite and sphene are sparingly present. The biotite is in places altered to chlorite.

From the west coast of Rainy Lake, about two miles north of the entrance to Stanjikoming Bay, a specimen was taken which may be regarded as typical for a very large proportion of the gneiss of the inner nucleus of this Laurentian area. It is a medium-textured, evenly foliated, biotite gneiss, which, in thin section (801), appears as a granular aggregate of quartz, orthoclase, plagioclase and biotite, with sphene and apatite as accessory constituents in their usual idiomorphic forms, included in the first named minerals. Besides these there are a few small, stout, highly refracting, brilliantly polarizing bodies which are probably zircons. Some epidote, derived from the mica and a few grains of magnetite complete the list of constituents. The quartz is water-clear and shows streams or rows of liquid inclusions with moving bubbles. This mineral shews in all its sections a strongly marked undulatory extinction. The undulatory character manifests itself in two ways, (1) the extinction passes across the quartz section like a wave, as is ordinarily the case when a crystal is subject to unequally distributed tension, and, (2) a somewhat abrupt break in the optical orientation in different parts of the crystal without any apparent break in its individuality. The angle, however, through which the stage of the microscope must be revolved to make these diversely orientated portions of the same individual coincide in intensity of extinction, is very slight. West coast Rainy Lake.

Of the more granitoid or less foliated varieties of this gneiss, a specimen from the north side of the Open-water Narrows is a good example. Under the microscope (1464) it appears as an aggregate of orthoclase, microcline, plagioclase, quartz, biotite, muscovite and some epidote. The rock has a granular structure and is a true granite according to Rosenbusch's classification since it contains the two micas. The foliation is only observable on the large scale. Open-water Narrows.

On the north-west side of Pipestone Lake a mass of granite breaks through the Keewatin schists, which appears to be identical geologically with the Laurentian granite and granitoid gneiss of Kishkutena Lake which pass into distinctly foliated gneisses along the route to Sabaskong Bay. A thin section (326) of this rock is seen under the microscope to consist of hypidiomorphic orthoclase and allotriomorphic quartz and plagioclase with bleached biotite. The accessory minerals are apatite, sphene, magnetite, and leucoxene. The orthoclase is usually quite decomposed, the kaolin and muscovite having often a very distinct zonal arrangement. The sphenes are in sharply defined crystals, often surrounded by a rim of varying width of grey or brownish leucoxene. The biotite is often of a green color, and has epidote associated with it. Pipestone Lake.

Clear-water Lake, east side.

On the east side of Clear-water Lake, Kishkutena route, the peripheral zone of syenite gneisses of the Stanjikoming Laurentian area, presents the local facies of a medium-grained, flesh colored granite of porphyritic aspect which, in places, is distinctly foliated. In thin section it consists of large idiomorphic or hypidiomorphic crystals of felspar (orthoclase, microcline and plagioclase) and allotriomorphic quartz, felspar and biotite, the latter mostly altered to chlorite and epidote. The felspars, even when quite allotriomorphic, shew a distinct zonal structure, the different zones having a different optical orientation, indicating difference of composition. The decomposition in some zones is much greater than in others, so that the alteration products have a zonal arrangement. The quartz is water-clear and comparatively free of inclusions. A few small sphenes are present.

Laurentian gneiss at contact with Coutchiching.

The Laurentian gneiss at the contact of that formation with the schists of the Coutchiching series on a small island three miles east of Coutchiching, is a grey, medium grained, distinctly but not evenly foliated rock. It forms the matrix in which are imbedded the detached fragments of Coutchiching schist shewn in Plate I. Under the microscope (693) it is an eminently granular aggregate of grains of orthoclase, plagioclase, quartz and biotite. The felspars are partially decomposed, the cloudy, grey kaolin exhibiting a definite zonal arrangement, though occasionaly confined to the central portion of the crystal. Shreds of muscovite are generally distributed as an alteration product of the felspar. The biotite is only sparingly represented. It is often bleached green, and is then usually associated with epidote into which it has partially altered. Apatite occurs included in the biotite. Pyrite is also present in small quantity and limonite in various brown grains.

## Inclusions in Laurentian Gneiss.

Shape of inclusions.

The Laurentian gneisses of the region, both of the granite and the syenite type of composition, frequently form a matrix in which are imbedded portions of foreign rock either as sharply angular, sub-angular, or somewhat rounded blocks, or as more or less attenuated bands drawn out parallel to the foliation of the gneiss and confused with it. This phenomenon is perhaps more commonly observed in the granite gneisses than in the syenite gneisses. As in the Lake of the Woods region these inclusions are most abundant in the vicinity of lines of contact with over-lying rocks. They are, for the most part, indistinguishable from the basal portions of either the Keewatin or the Coutchiching series. Where they present points of difference, the difference is such as is readily

explicable as a result of the conditions to which the inclusions must be conceived to have been subjected. Near the contact with the Coutchiching series the Laurentian gneiss holds as inclusions generally only fragments which are identical with Coutchiching rocks where examined *in situ;* whereas near the contact of the Laurentian with the Keewatin fragments resembling the Coutchiching rocks are very rarely met with, and those resembling the basal formation of the Keewatin abound. These facts, taken in connection with the prevailingly shattered character of both the Coutchiching and Keewatin strata at the contact with the Laurentian gneiss, which allows apophyses or dykes from the main area of gneiss to ramify through the schists both parallel and transverse to their planes of schistosity, leave no room for doubt but that these inclusions are detached portions of overlying formations, which, in a firm and brittle condition, have become immersed in the underlying viscid magma which subsequently crystallized out as the Laurentian gneiss and granite. It seems probable, too, that such shattering and detachment of fragments took place at the last stages of crumpling of the crust in this region. This opinion is based on the fact that while both the Coutchiching and Keewatin rocks afford ample evidence of having yielded to pressures and earth stresses, the Laurentian gneisses do not, except very locally, and to an insignificent extent. This fact proves that after the solidification of the Laurentian gneisses there was no farther very violent deformation of the crust and no shattering subsequent to the time at which those gneisses were solid, hard rocks as they are now. All the violent disturbance of the region, and the folding and crumpling of the strata of the Coutchiching and Keewatin series appears to have transpired antecedent to the final solidification of the Laurentian rocks, and while the latter were yet in the form of probably a thick, viscid magma upon which floated the slowly shrinking and crumpling strata of the Coutchiching and Keewatin series. The scattered fragments of the overlying series which we now find imbedded in the Laurentian gneiss do not, of course, represent the whole of the shattering and decrepitation, as it were, of the overlying rocks. Large portions of these rocks have very probably been absorbed by fusion with the magma, for the Laurentian rocks appear to have resulted from the fusion not simply of the floor upon which the Coutchiching and Keewatin rock first rested, whatever such floor may have been, but, also, with it, of portions of those series. The inclusions which we now see are probably only those fragments which were detached, as I have stated, at the later stages of the development of the Laurentian gneiss, when the heat was less intense and the temperature of the magma was approaching the fusion point or the point of solidification, for the pressure and other modifying influences to which it was subjected.

Comparison with Keewatin and Coutchiching rocks.

Shattered character of strata at contact with Laurentian.

Period of shattering.

Probable absorption.

Meaning of contact of upper and lower Archæan.

This conception of the development of the Laurentian gneiss, which seems necessary in order to give a consistent explanation of all the phenomena of this field, involves the belief that the present line of demarkation between the lower and upper Archæan, or the contact of the Laurentian with either the Coutchiching or Keewatin, represents what was once the contact of the lower surface of the crust, in this region at least, with the magma upon which it rested.

Inclusions in gneiss remote from contact.

While these inclusions are, as a rule, most abundant near the contact of the Laurentian with the Keewatin and Coutchiching series, they are by no means wanting in the gneisses many miles remote from such contact. On the shores and islands of Sabaskong Bay there are revealed the most unequivocal evidence of the brecciated contact of Laurentian and Keewatin rocks, the penetration of the latter by the former, and the inclusion of angular broken pieces of the Keewatin schists within the gneiss. Scores of the the most beautiful instances of fragments and groups of fragments of rocks indistinguishable from those which form the base of the Keewatin, may be seen in a day's paddle among the well bared rocky islands of this intricate labyrinthine portion of the lake. They occur here almost as abundantly away from the contact as close to it. So long as these inclusions retain their broken augular shapes, there is never any confusion of their boundaries with the enclosing gneiss. The contrast of matrix and inclusion is as sharp and distinct as it possibly could be, and indeed much more so than one would naturally expect. The size of the fragments varies usually from the dimensions of one's fist to those of a house. Many are much larger than a house, but these are not always traceable around their entire contour. Some are acres in extent, and some take the form of bands one or several miles in length, by hundreds of feet in breadth, which, in single sections, might easily be mistaken for inter-stratifications with the gneiss. When groups of these fragments are found in the gneiss together, they are arranged more or less distinctly in lines corresponding with the foliation of the gneiss, and the whole appearance of the horizontal section, presented by the glaciated surface of the rocks, is suggestive of the thick, crystallizing magma, in which they were once immersed, having been subject to a fluxion or flowing, to which is due both the foliation of the gneiss and the alignment of its included fragments of foreign rock.

Conditions observed on Sabaskong Bay.

Microscopic characters of inclusion.

A specimen of one of these angular inclusions in biotite gneiss taken from an island south-east of Rabbit Point, Sabaskong Bay, is a glistening black to iron grey schist made up of glistening hornblende in minute needles, and a greyish-white mineral, which modifies the color of the schist, but which is too minute to show crystal faces to the naked eye. In thin section (1709) the rock is seen to be banded, owing to the dis-

tribution of the hornblende. All of the latter mineral occurs in compact, stout prisms or needles arranged parallel. In certain parallel linear areas, however, these hornblende prisms are much larger than in the rest of the section, and are much more closely crowded together, with but little interstitial space. In the broader areas lying between these, the hornblende prisms are much smaller and much less crowded, the interspace being occupied by felspar in small irregular grains with some quartz. In exceptional areas the felspar predominates, and the hornblende prisms stand out very sharply in direct light from the colorless base, and present an appearance analogous in miniature to a bird's eye view of a run of saw-logs in a broad stream. Grains of magnetite are scattered throughout the section.

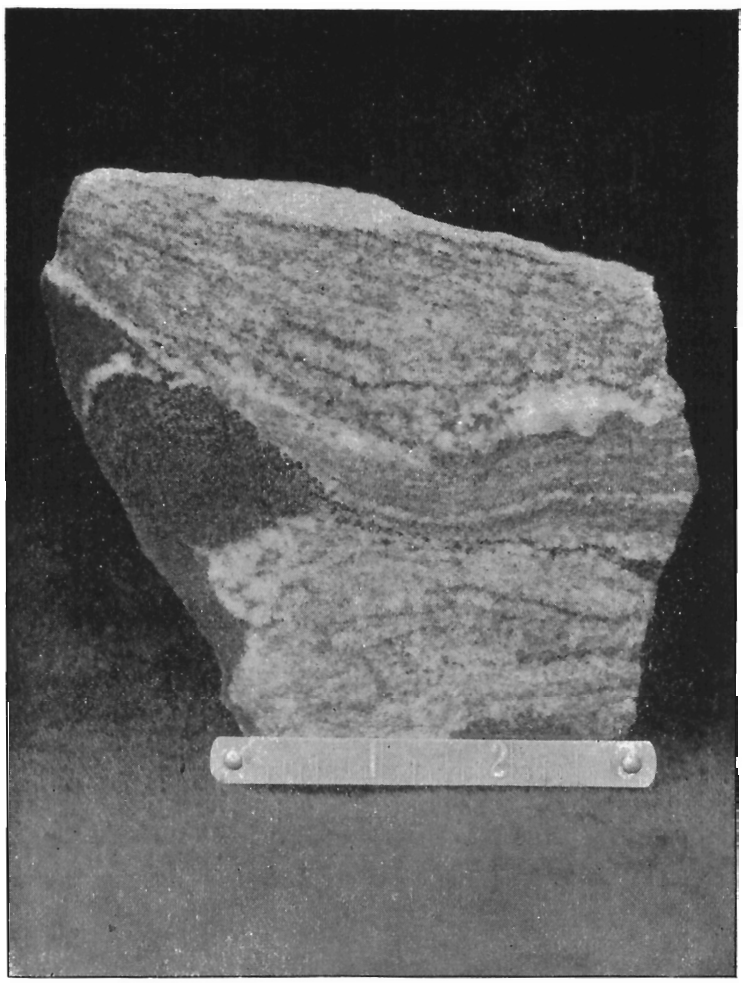
The description of the microscopic characters of this specimen shews that it differs in no essential feature from those rocks of the Keewatin series which have been classed as hornblende schists, and described in a previous part of this report.

Cases of apparent fusion of inclusions with matrix.

In many instances, however, these inclusions, as observed on Sabaskong Bay and elsewhere, have lost their sharply angular contours and have rounded, oval, or more or less attenuated, lenticular shapes. In these cases the line of demarkation between matrix and inclusion becomes less sharply defined, and in many cases there is evidence of the included fragment having been reduced by total or partial fusion to a condition admitting of its deformation and drawing out into lenses. In these cases the condition of fusion must have been one of thick viscidity which did not permit of the complete mingling of the magma of the inclusion with that of the matrix or gneiss. In those cases where magmas had by higher temperatures been sufficiently liquid to mix, the inclusions have probably been entirely absorbed by the gneiss leaving no trace of their existence, except a more basic local facies of the gneiss. When the inclusions have been so deformed and drawn out by partial fusion and recrystallization, there is a partial admixture of the two at the contact, and a transitional rock exists which is midway in character between the matrix and the inclusion. The inclusion in these cases, too, has lost its schistose character, and has become more felspathic in composition and more granular in structure, having the facies of a diorite. The felspar seems to have been absorbed from the inclosing magma probably rather by the agency of the penetrating watery solutions from the granite magma, than by a direct addition of a portion of the latter in the dry state.

Inclusions on Jackfish Lake

A good example of this kind of inclusion is one taken from the west side of Jackfish Lake, Pipestone route. Here the biotite gneiss assumes locally the aspect of a breccia, in which a very quartzose, biotite gneiss forms the matrix for angular blocks of foreign rock of an essen-



G. E. DESBARATS & SON, ENGRAVERS & PRINTERS, MONTREAL.

Polished surface of specimen of biotite gneiss, with included fragment of amphibolite partially drawn out into a "tail." West side of Jackfish Lake, Pipestone route.

tially hornblendic or dioritic character. The specimen taken is from the shore about two miles north of Foot-print Portage. It is of interest as shewing on the small scale in a hand specimen a condition of things which is very common on the large scale, and yet difficult to describe clearly without specimens. In the field the foreign and included character of the angular blocks of amphibolite or diorite is very apparent and can be examined critically in numerous well-exposed examples on the glaciated surfaces of the country rock. The specimen in question was cut through the middle and polished. Plate IV is a reproduction of a photograph of the polished surface, and shews the sharp well-defined character of the inclusion. The foliation of the gneiss flows around the inclusion, and the longest diameter of the irregularly shaped fragment lies parallel to the general trend of the foliation. A portion of the fragment has been drawn out into a "tail" analogous to those which may be observed in the porphyritic crystals of quartz-porphyries, and other rocks that have been subjected to excessive pressure. The two cases are, however, not entirely analogous, for the "tail" of the lenses in squeezed porphyries seems to be due to actual rupture of the solid brittle crystal, with probably a certain amount of recrystallization, while the "tail" of the dioritic inclusion in the biotite gneiss would seem to be due to a partial fusion and recrystallization of the hornblendic material, while the matrix was in a plastic condition and in process of solidification. On the large scale, by a similar process, blocks seem to have been, under the combined influence of pressure and partial fusion, drawn out into flat sheets which have all the aspect of intercalated beds, so even and sharp is the banding, and yet so unmistakably due to a simple stretching of the viscid and crystallizing magma with its included blocks of foreign material. The rock composing the matrix of the specimen figured is an evenly foliated grey, biotite gneiss of medium texture. Under the microscope (568 A) it is seen to be made up of a granular aggregate of orthoclase, plagioclase, quartz and biotite, with a few crystals of apatite and some secondary epidote. The felspars are fresh and glassy. The quartz is very abundant in water-clear grains with minute inclusions arranged usually in rows. The biotite is in the form of greenish-brown shreds. The epidote is in greenish-yellow crystals, and in aggregates of grains.

Stretched appearance of inclusion.

Microscopic characters of matrix.

Another thin section (568 B) from the same hand specimen was made across the line of contact of the inclusion and matrix. The line of contact was observed even in thin section to be quite sharp and decided, though not a simple straight line. The gneiss is identical with that last described. The included block is made up of a medium-grained, granular aggregate of compact, deep colored green hornblende, fresh plagioclase and quartz. Hornblende is the predominating

Microscopic characters of inclusion.

mineral. There is no biotite. On the other side of the line of contact biotite is abundant, and there is no trace of hornblende to be found. The ragged character of the contact is such as would be presented by a section of the surface of a broken rock fragment of medium grain. There are traces of fusion and inter-penetration, but within very narrow limits, at the place where the section was cut. The inter-penetration is much more apparent, where the block is drawn out into a "tail."

S.E. side of Lake of the Woods.

The biotite gneiss of the south-east side of the Lake of the Woods, between the mouth of Big Grassy River and that of Rainy River is characterized by an abundance of these inclusions, in sharply angular blocks, in more or less attenuated lenses, and even in sheets which simulate strata.

Inclusions in gneiss near 49th parallel.

Plate V is the reproduction of a photograph of a horizontal glaciated surface of the rock on an island off this shore about three-quarters of a mile north of the 49th parallel. It illustrates very beautifully what is common on a scale usually much too large for photography, and shews in one small horizontal section a representative variety of the shapes of these inclusions, and their relationship to the gneiss in which they are imbedded. Some, it will be observed, have rectilinear boundaries and sharply angular contours, others are oblong in shape, but more or less rounded, and some are distinctly lenticular. The foliation of the gneiss is well shewn, as is also its flow around the inclusions. The sundering of the included fragments, the penetration of the gneiss into the crevices, the drawn out or tapering ends of some of the fragments and the alignment of all of them parallel to the foliation of the gneiss, also are features which come out very clearly in the photograph and which are full of suggestion and instruction.

Inclusions in Stanjikoming area.

The biotite gneisses of the inner nucleus of the Stanjikoming area of Laurentian rocks is, in some places, charged with these inclusions, while in others it is remarkably free from them. Here they do not always resemble the rocks of the overlying series, but are frequently very coarse-textured and massive, and would be classed as massive amphibolites or diorites rather than hornblende schists. In this connection it should be observed that on the supposition that the Laurentian gneiss is the result of the fusion and recrystallization of the floor or basement upon which the Keewatin rocks were deposited, we should expect to find other inclusions than those of rocks such as occur in the Keewatin. The Keewatin series being largely made up of volcanic rocks, the vents from which these volcanic rocks emanated must have existed in the acid crust or floor at the time the latter succumbed to the process of fusion, whatever the exact nature of that process may have been. These pipes or vents would be filled with the

A. C. LAWSON, PHOTO., 1887

G. E. DESBARATS & SON, ENGRAVERS & PRINTERS, MONTREAL.

Angular and lenticular fragments of hornblende schist similar to that of the Keewatin series, included in Laurentian gneiss, on island off S.E. shore of Lake of the Woods, three-quarters of a mile north of 49th parallel. The flow or "pulled" structure is in the field very pronounced, the fragments being arranged in streams.

deep seated, coarser, granular phases of the rocks, which, as flows and loose ejectamenta, formed the Keewatin strata at the surface. When these vents were filled with basic rock, they would, in a fusion which only reduced the rocks to a thickly viscid magma, and did not permit of their mingling, or the complete absorption of the one by the other, still retain their distinctive characters, and on solidification present a strong contrast to the general gneissic matrix. Such appears to be the probable origin of some of the more massive coarse-textured amphibolitic or dioritic inclusions in the biotite gneiss of Rainy Lake. They are usually very much more irregular in shape, and their relations to the gneiss much more confused, than in the case of those inclusions which are recognizable as identical with the schists at the base of the Keewatin. Their size varies very much, and some are so large that their character as inclusions is not directly determinable, but is inferred from their analogy with the smaller inclusions adjacent to them. They are often traversed by irregular veins or dykes emanating from the main area of gneiss. As an example of this class of inclusion, a specimen was taken from an island in Rainy Lake opposite the mouth of the North-west Bay. The inclusion is a large block of irregular outline, the greatest diameter of the exposed surface being twelve or fifteen feet. A microscopic examination of a section (3000 B) of the rock shews that it is made up of a granular aggregate of deep colored green hornblende, with a little felspar, both cloudy and glassy, striated and non-striated. A small amount of epidote is associated with the cloudy felspar. No biotite is present. The hornblende is greatly in excess of the felspar, so that the rock may be classed as an amphibolite rather than a diorite, particularly as light colored central areas occur in the hornblende occasionally, which suggest the probability of its derivation from pyroxene.

Origin of certain inclusions.

Example of a class of inclusions.

The matrix in which this block is imbedded is a medium-grained, grey, distinctly foliated gneiss. Under the microscope (3000 A) it is made up, like the other similar gneisses of the region, of a granular aggregate of quartz with liquid inclusions having dancing bubbles, fresh orthoclase, microcline, plagioclase and biotite, partially altered to epidote. There is no hornblende present.

Matrix in which inclusion is imbedded.

The biotite gneiss of Redgut Bay, opposite the Indian village, is much like that already described from other localities. It is medium grained, light grey in color and distinctly foliated. Under the microscope (1600 A) it appears as a granular aggregate of orthoclase, plagioclase and biotite, the latter largely altered to epidote, together with a sparing number of apatite crystals in slender, round-ended prisms and in oval bodies.

Gneiss of Redgut Bay.

Included in this gneiss is a dark green, medium grained amphibolite rock. The inclusions do not here retain their angular forms, but are drawn out into attenuated lenses or sheets, which have the appearance of being intercalated with beds of gneiss, and give the rock a pronounced laminated or banded structure. The appearance is, however, deceptive, and it is far more satisfactory and more consistent with all the facts observed to ascribe the banded structure not to any intercalation or stratification, for it is very local, but to the attenuation of inclusions by the combined action of pressure and a process of slow fusion and recrystallization. The amphibolite in thin section (1600 B) appears as a granular aggregate of hornblende and cloudy felspar, the former greatly predominating. Some of the felspar is striated, but for the most part the twin structure, if present, is obscured by the decomposition. Attenuated lenses.

The rock along the line of contact of the attenuated inclusion and the matrix of biotite gneiss is not of a simple nature, but is made up of a fused mixture of the two. This mixed character of the margin of the inclusion was observed in the field, and the conclusions there arrived at as to the relations of the amphibolitic lenses and the gneiss, and as to the conditions to which the rocks must have been subject, to produce the appearance presented, have been sustained by a microscopic study of the normal gneiss, the core of the lens and the marginal or transitional rock. This transitional rock is a mica, hornblende and felspar rock with some quartz. Microscopically, the additional constituents, apatite, leucoxene and epidote, are observable. The structure is granular, with porphyritic crystals of orthoclase, which are somewhat cloudy. Some of the biotite seems to be an alteration product of the hornblende, and much of it is observed to have altered very largely to epidote. In some of these lenses, the interfusion of matrix and inclusion has been so complete that they are entirely made up of this transitional rock, which has the facies of a syenite, while in other cases, probably where the imbedded mass has been larger, the inter-mixture has been only marginal. Transition between inclusion and matrix.

The syenite gneiss which crops out on Rainy River on Mr. Geo. Singleton's farm about six miles and a half above the Manitou Rapid exhibits some very beautiful and instructive instances of inclusions of fragments of h ornende schist. One of these is represented in Plate VI from a photograph of the bare rock surface close to the water's edge. The gneiss is distinctly foliated, as appears in the photograph. The figure illustrates, in a very forcible manner, the drawing out and sundering of the included fragments. The large, central, pear-shaped piece of schist appears to be only the remnant of a much larger block which has been reduced in size by the tearing off of fragments which Inclusions in gneiss on Rainy River.

are still in its immediate vicinity, and whose relationship to the central mass is quite apparent. All these detached pieces, as well as the central pear-shaped mass, have their longest diameter parallel to the foliation of the gneiss, and there seems little room for doubt but that the foliation of the gneiss and the alignment of these fragments of schist, are due to the same unequal pressures upon the mass as a whole, and to a general flow in the rock at a time when the matrix was plastic, and not yet completely crystallized. To have produced these effects, the matrix in which the inclusions are imbedded, although yielding to pressure and flowing like a liquid, must have been very nearly solid, or at all events a very thickly viscid and tough magma, such perhaps as some laboratory preparations of soluble silica, or molten glass at low temperature near the point of solidification. That the matrix could not, at the time it yielded to pressure and exercised such rending effects upon the included blocks of schist, have had the form of a crystalline aggregate such as it now is (a syenite), is shown by the fact that there is every evidence of the constituent minerals of the present rock, in all the minute crevices and corners into which it penetrates, having crystallized *in situ*, and no evidence of such minerals having been subjected to excessive pressure since the rock solidified and assumed its present form of a hornblende-syenite. The effect of the same pressure on a solid crystalline rock is seen in the shattering and sundering of the inclusion of the hornblende schist, which here seems not to have been fused to any extent, even on its edges. Had the matrix, at the time that it yielded to pressure, been a solid crystalline rock, we cannot conceive of the deformation, such as it indicated by its flow, its penetration of the schists, and its accommodation to the most intimate parts of the schist, taking place without a similar shattering of the rock, or of its constituent crystals, and without their granulation and reduction to the cataclastic state.

Conditions affecting the sundering of included fragments.

Inclusions of fragments of rocks of Coutchiching series.

In the Laurentian gneiss of the southern part of Rainy Lake there are numerous inclusions of fragments of rock which are indistinguishable from the rocks of the Coutchiching series, which is largely developed in that part of the lake. These inclusions occur both in the regular biotite gneiss and in the coarser gneiss of the syenitic type. As an instance of these inclusions in the latter rock, may be mentioned those which are observable at the north end of the island which lies opposite the entrance to Stanjikoming Bay. The inclusions are most plentiful in the gneiss in the vicinity of the contact with the Coutchiching series. Plate I. will serve as an illustration of these. It is reproduced from a photograph of a rock surface a few yards distant from the contact on an island off the south shore of Rainy Lake, three miles east of Coutchiching. The distinct character of the inclusions,

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Fragments of hornblende schist, similar to that of the Keewatin series, enclosed in Laurentian gneiss. The fragments are arranged in a stream, and there is a distinct pulled or stretched appearance. The large, pear-shaped inclusion in the centre appears to be the remains of a larger mass, the sundering of which has given rise to the more attenuated lateral fragments. The gneiss is distinctly foliated, although it does not appear so in the illustration. Geo. Singleton's farm, Rainy River. R. XXVIII., Tp. 5 S., Sec. 8.

the foliation of the gneiss and the penetration of the latter within the fissures of the inclusions is very clearly shewn in the photograph. There is not the remotest doubt of the derivation of the included fragments from the edge of the Coutchiching formation a few yards to the south. That edge is ragged and shattered, and the schists are traversed by apophyses, from the main mass of gneiss, which retain their foliation distinctly. Shattered edge of Coutchiching schists.

## Summary of Archæan Geology.

The broad results which have been arrived at by my study of the Archæan geology of the Rainy Lake region may be briefly summarized. They are :—

1. The primary separation of the Archæan complex of this region into two great natural sub-divisions, viz. : A lower division, Laurentian, and an upper division, composed of at least two distinct geological series, the Coutchiching and the Keewatin. Primary division of Archæan.

2. The Laurentian is composed entirely of rocks, which are of the nature of granites and syenites in mineralogical composition and granular structure, but which, by reason of their more or less distinct foliation, are known as gneisses. Laurentian.

3. Abundant evidence has been adduced to shew that these gneisses behave in all essential particulars precisely as irruptive granites do; and that they are plutonic rocks which have crystallized slowly, probably under an extremely gradual diminution of temperature from a thickly viscid, coherent or tough, hydrothermal magma. Irruptive and plutonic character of Laurentian.

4. There is evidence that such magma, up to the time of its final solidification, when it became approximately rigid, was subjected to differential pressures, which, by causing a yielding or deformation, induced a flow in the mass. To this flow is ascribable, with great probability, both the foliation of the gneiss, and the parallel alignment of certain inclusions of foreign rock imbedded in in it, presently to be mentioned. Differential pressures on magma.

5. Whatever may have been the more remote history of the Laurentian rocks of this region, it appears clear that the magma from which they crystallized as foliated granites and syenites, was immediately or proximately produced by the fusion of the basement or floor upon which the formations of the upper division of the Archæan were originally deposited. With the fusion of this floor it seems probable that portions of the superincumbent strata, which once formed integral parts of either the Coutchiching series or the Keewatin, have also been absorbed into the general magma, and reappeared on crystallization as Laurentian gneiss. Origin of magma.

Extent of fusion.

6. This fusion, however, only extended up to a certain uneven surface, which surface constitutes the demarkation between the present upper and lower Archæan.

Relation of crust to magma

7. Above this surface, or upper limit of fusion, the formations of the Coutchiching and Keewatin series retained their stratiform or bedded disposition, and rested as a crust of hard and brittle rocks upon the magma, subject to its metamorphosing influences.

Disturbance of crust.

8. There is abundant evidence that while resting on this plastic magma the crust was violently disturbed, folded, crumpled and in places shattered. This disturbance probably served to accentuate the sharpness of the line of demarkation between the fused and unfused rocks, and accounts for the sharp contrast to-day visible along the line of contact of upper and lower Archæan.

Relative age of rocks of upper and lower Archæan

9. The normal condition of things along this line of contact proves very clearly that the schists of the upper Archæan, while in a hard and brittle state, were shattered; and that detached fragments became immersed in a magma which at the same time penetrated within the main mass of schists and filled their fissures and crevices. This magma which thus permitted fragments of foreign rock to sink into it, often to great distances from the contact, and which filled the cracks of the overlying schists, crystallized eventually as the Laurentian gneisses; which, therefore, as rocks, must be considered of later age and newer formation than the overlying schists.

Period of yielding to pressure.

10. After such crystallization and final solidification, there appears to have been no further violent disturbance; for while the rocks of the upper Archæan afford abundant evidence in their folded and crumpled condition, in their prevailingly schistose character, and in their microscopic structure, of their having yielded to excessive differential pressure, there is no such evidence in the Laurentian, except locally and to an unimportant extent. The Laurentian gneiss formation, regarded generally, does not appear to have been affected to any notable extent by pressure deformation after it had assumed its present crystalline form of foliated granite or syenite; the foliation being regarded, as above stated, as due to a flow in the magma prior to crystallization, and while crystallization was in progress, but not after the rock was wholly crystalline.

Bedded character of upper Archæan

11. The rocks of the upper Archæan occur in bedded formations, and afford no evidence of having ever been reduced to a fused or plastic state after their deposition.

Coutchiching series.

12. The lower of the two series of the upper Archæan or Coutchiching series is a very voluminous formation of mica schists and felspathic mica schists, or fine grained, grey, evenly laminated gneisses. The latter differ very much in their field appearance and in microscopic

structure from the granite and syenite gneisses of the Laurentian, the constituent grains having a prevailingly rounded or granulitic aspect in thin section. All the rocks of the series are very quartzose, and no other rocks than those mentioned occur in its entire volume, which, in measured sections where the series is at its maximum development, varies from 22,000 to 28,000 feet.

13. It seems entirely probable that this series is of metamorphic derivation from sedimentary strata, deposited in a quiescent epoch, with little or no volcanic disturbance; and that such metamorphism has been largely effected by the upward percolation of heated, watery solutions from the underlying magma upon which the series rested after the fusion of the floor upon which it was deposited. Evidence of the percolation of such waters is seen in the numerous lenses of vein quartz which occupy the partings between the strata in many parts of the series. Origin of Coutchiching series.

14. The Keewatin series is also largely metamorphic, but the rocks composing it are mostly of volcanic origin, either as flows or in the pyroclastic state. With these are associated rocks of undoubted erosive sedimentary origin, and others, such as some of the hornblende schists, which, from the extreme metamorphism to which they have been subjected, do not reveal with certainty their original characters; such extreme metamorphism being displayed most prominently at the contact with the irruptive Laurentian gneiss and granite. Origin of Keewatin series

15. In a general way, the Keewatin series in the Rainy Lake region is naturally divided into two parts, an upper and lower. The lower part is prevailingly made up of the more basic rocks, such as bedded diabase and hornblende schists, while the upper part is composed rather of acid rocks such as quartz-porphyries and their tuffs and agglomerates with felspathic greywackes and other rocks of distinctly clastic origin. There is, however, no hard and fast line between these two upper and lower parts of the Keewatin, and they are of interest chiefly in shewing the change in the character of volcanic ejectamenta or the sequence of volcanic rocks in the earliest epoch of which we have any record. This sequence of acid after basic rocks accords with the evidence of the sequence of extravasation from the Archæan volcano whose roots are exposed on Bad Vermilion Lake. Division of Keewatin series. Archæan volcano.

16. The break between the Coutchiching and Keewatin is important, geologically, as indicating a profound change in the conditions of rock formation, the advent of the Keewatin epoch being the beginning of a wide-spread and intense volcanic activity. There is evidence also in the pebble conglomerates at the base of the Keewatin on Rainy Lake and Seine River of an interval of erosion such as is required by the definition of a stratigraphical unconformity. Break between Coutchiching and Keewatin.

Relative distribution of upper and lower Archæan.

17. An important discovery has been made in the mapping of the relative distribution of the upper and lower Archæan, whereby it appears that the latter, consisting of Laurentian gneiss and granite, occurs in large, isolated, central areas more or less completely surrounded by the schists of the upper Archæan, the encircling belts anastomosing and forming a continuous mesh work.

## THE GRANITES.

Character of granites.

The rocks here considered are of an eminently granitic, non-foliated aspect, usually of a reddish color and a texture that varies from medium to fine grained, although some of them are extremely coarse and partake of the characters of pegmatite. They occur in various parts of the region, irruptive through Laurentian, Keewatin and Coutchiching rocks. Where they have broken through the Laurentian gneisses their age is determinable at once as post-Laurentian and post-Archæan. When, however, they break through the formations of the Keewatin or Coutchiching series, it is a matter of considerable doubt as to whether they are of later age than the Laurentian gneiss, or whether they are portions of the gneiss that have broken through the schist under such conditions that there was developed in them no gneissic foliation. That some of these masses are of such a character is extremely probable, as will be shewn farther on. On account of this difficulty of identifying the age of those granites which cut the Laurentian gneiss with that of those cutting the Keewatin or Coutchiching, and of discriminating between the latter and certain facies of the Laurentian rocks, the granites of the region will be considered under two heads, viz.: (1) Those cutting the Laurentian gneiss, and (2) those cutting the formations of the Keewatin or Coutchiching series.

Age of granites

Classification.

### *Granites cutting Laurentian Gneiss.*

Distribution.

These granites may be studied under their least equivocal and most characteristic conditions of occurrence in an area twenty miles long and five miles in maximum width, at its middle part, which extends across Rainy Lake in an east and west direction from the end of the North-west Bay on the west side, to Macdonald's Inlet on the east. The Laurentian biotite gneisses of this area are intersected by innumerable sporadic masses and irregular ramifying dykes of granite. The largest of these masses do not extend a mile in diameter, so far as observed, while the dykes may have apophyses only a few inches in width. The granite is most plentiful and occurs in largest masses on the shores of the eastern half of North-west Bay. Its characters are very uniform.

It is a reddish, usually fine-grained, biotite granite and has, commonly associated with it, veins of very coarse pegmatite of the character of the so called "contemporary veins."

Relation of granite to Laurentian gneiss.

Although there is the clearest evidence that these granites have cut the gneiss, after the gneiss was in approximately its present condition, yet it seems not improbable that they are more or less intimately associated in age and in origin with the Laurentian gneiss itself, and that they represent simply the up-welling through fissures, of the same magma as that, which, in its more superficial portions, under the influence of fluidal motion had solidified earlier as Laurentian gneiss. But however probable this conjecture may be, the evidence of their having broken through the gneiss after the latter had assumed its present form, is so clear, that we have no option but to classify them as post-Laurentian and post-Archæan. They are always perfectly devoid of foliation, a fact which would seem to indicate that they had solidified in fissures or vents in a comparatively quiescent condition.

Granite of Hanging-stone Point.

One of the largest of these granite masses is that which occupies Hanging-stone Point at the entrance to the North-west Bay. In thin section (840) it appears as a granular aggregate of quartz, orthoclase, microcline, plagioclase and biotite, the last very largely altered to epidote and chlorite. Apatite in long needles is included in all of these minerals. The felspars are in some instances quite fresh, while in others they are charged with kaolin, epidote and muscovite. The quartz is full of liquid inclusions with dancing bubbles. Another specimen (922) from a similar but smaller mass at the west end of the bay, near Hope Portage, is almost identical with the one from Hanging-stone Point. The only difference to be noted is that the biotite, as a rule, is fresher, shewing very beautifully between crossed nicols its characteristic bird's-eye-maple shimmer, though sometimes it is bleached colorless. Both quartz and felspar shew undulatory extinctions.

Hope Portage granite.

Granite near Squall Point.

Of the granites associated with the Laurentian gneisses in other portions of the region, only one has been microscopically examined. It is a fine-grained, purplish, hornblende granite, which interrupts the gneiss on one of the islands off the S.E. corner of Squall Point. Only a small patch of it was seen, and the actual contact with the gneiss was not observed. A thin section (665) shews it to be made up of a granular aggregate of orthoclase, plagioclase, quartz and hornblende, with some accessory biotite, magnetite and leucoxene. A little apatite is also, as usual, present. The quartz and felspar shew a crude granophyre structure, and the quartz is besides observed to occur commonly in spherical blebs included in the felspar. The quartz contains numerous inclusions of rod-like microlites. The most prominent constituent after the felspar is the hornblende. This has sometimes a

roughly radiating, fibrous structure, though usually quite compact, and in basal sections shews the usual prismatic cleavage. An occasional plate of biotite, probably original, is observable, while there is a good deal more that has been formed as an alteration product of the hornblende with which it is closely associated, and a little that has been secondarily developed around grains of magnetite.

Bat Lake granite.

On the Little Canoe River route from Rainy Lake to Manitou Lake a boss of red, medium textured granite is crossed, the north and south diameter of which is about seven miles. The boss is apparently irruptive through the more or less syenitic, coarse-grained, Laurentian gneisses, and extends from the northern portion of Bat Lake to the south end of Respite Lake. The contact of the granite with the gneiss is more closely observable on its southern confines than on its northern, and at the south end of Respite Lake the gneiss is traversed by dykes of the granite. The rock is composed of a red orthoclase, quartz and biotite, the latter being often replaced by hornblende, so as to give rise to a hornblende-granite. On Bat Lake the line of contact can be traced approximately, as mapped, without, however, affording any satisfactory exposures of the actual juxtaposition of the two rocks. The granite is well exposed on Bat Lake and Bat Creek, the latter being a sluggish stream in a gorge, flanked on either side by precipitous granite hills. On the shores of Bend Lake the facies of the rock is that of a hornblende granite. No specimens from these granites have been examined microscopically. A similar mass of red granite projecting through an area of Laurentian gneisses is observable on the shores of Spawn Inlet, and has a length in a north and south direction of at least three miles and a half.

Other granites cutting Laurentian.

The only other granitic masses cutting the Laurentian gneisses in the region mapped are small and unimportant, and are usually rather of the character of a plexus of dykes than simple irruptive bosses. A few of these are, however, deserving of brief mention. The gneiss on the shores Blue-beard Lake is interrupted by a mass of red granite, which occupies the west shore of the lake for three-quarters of a mile at the north end, and the east shore for about one-eighth of a mile as mapped.

At the north end of Heron Lake, a number of dykes cut the gneiss in different directions.

On the south-east shores of Big Turtle Lake the gneiss is similarily traversed by dykes, and small, irregular masses of red granite, so much so that in some places of limited extent the granite predominates over the gneiss.

*Granites cutting the Keewatin and Coutchiching.*

On Pickerel Lake, Manitou route, two apparently distinct bosses of granite occur, one on either side of the lake, cutting the Keewatin rocks. Two granite bosses on Pickerel Lake.

That on the west side is a flesh-red, coarse-textured granite, which under the microscope (1008) is seen to be made up of orthoclase, microcline and plagioclase, with epidote and chlorite in nests replacing the biotite, a little of which, however, still remains. Some of the orthoclase is idiomorphic, being of earlier generation than the rest of constituents, though it does not differ from them in size sufficiently to present a marked porphyritic aspect. The felspars are full of inclusions of microlites and needles of apatite. Beautiful, double-wedged sphenes are common, often in close association with an opaque substance, brownish in reflected light, as if secondarily derived from it.

The extent of this mass of granite is only known from its exposure on the shores of Pickerel Lake. The rocks through which it is intrusive are partly volcanic and partly clastic rocks, those on the south side of the boss being felsitic schists (schistose quartz-porphyries) and on the north side, greenish-gray, schistose, clastic rocks. The actual contact on either side was not observed, although it could be located very closely. Extent of boss on W. side.

The granite from the east side of Pickerel Lake presents on its margin the facies of a porphyry, which, under the microscope (1032) is seen to consist of a fine-grained, ground mass of quartz and felspar in which are imbedded large crystals of orthoclase, twinned according to the Carlsbad law, and finely laminated plagioclase, both comparatively fresh. Biotite generally much decomposed occurs in ragged patches and pyrite partially changed to limonite is occasionally observed. Boss on E. side.

The limits of this boss have been fairly well determined, from the fact that it occupies a portion of a peninsula on the greater part of whose shores the rocks are well exposed. It is apparently an oval mass whose long diameter, one and one-eight miles, has a N.E. and S.W. trend and the short one, three-quarters of a mile, a N.W. and S.E. The rocks through which it protrudes are mostly felsitic grauwacke, and conglomerate on the south and west side, and finer schistose or slaty clastic rocks on the north. Its limits.

On the shores of the south-west side of Bad Vermilion Lake and on Bad Vermilion River there occurs, as is represented on the map, a boss of granite between three and four miles in diameter. This granite is peculiarily interesting from the fact of its intimate association with a still larger mass of saussurite gabbro. The granite is, for the most part, unusually acid or quartzose, while the gabbro, being made up Granite of Bad Vermilion Lake

mostly of an altered lime felspar, anorthite, with but a small proportion of the foliated pyroxenic constituent, is among the most basic rocks with which we have to deal. This granite and gabbro are intimately associated, the latter surrounding the main mass of the former as a zone or collar. A smaller area of granite lies to the south beyond the zone of gabbro which encircles the main granite mass. Portions of this, in places, exhibit an indistinct sort of foliation, and hornblende occasionally replaces the biotite. The geological relations of this granite and gabbro have already been discussed in the account of the section K-L across this part of the Keewatin belt.

Bad Vermilion River.

A few specimens of the granite have been examined microscopically. One from the second falls of the Bad Vermilion River, appears under the microscope (2150) as a simple granular aggregate of quartz, cloudy orthoclase and plagioclase. The biotite is never abundant, and is almost all changed to chlorite and epidote. The quartz contains fine dusty inclusions and liquid inclusions with bubbles.

Specimens.

Another specimen (48), from the larger of the two masses into which the granite is divided by a band of gabbro, taken from the extreme south of Bad Vermilion Lake, differs from this in having quartz in large, rounded blebs, imbedded in the granular aggregate of quartz, felspar and biotite, which forms the base of the rock. These blebs of quartz shew a well marked ecto-peripheral rim, composed mostly of small, brightly polarizing needles, sometimes arranged perpendicularly to the outline of the quartz, and sometimes arranged parallel to it or interwoven in a felt work. The quartz includes microlites of apatite, rutile and zircon; and rutile is common as an inclusion in the biotite which is sometimes bleached, or altered to chlorite; calcite is present as an alteration product of the felspars which are more or less cloudy.

At the S.W. end of Bad Vermilion Lake this granite is in thin section (50) a granular aggregate of quartz, orthoclase, microcline and plagioclase, with idiomorphic apatite, zircon and sphene. The quartz is full of liquid inclusions with moving bubbles. The felspars are somewhat cloudy with kaolin, muscovite, etc.

Boss of granite on Pipestone Lake.

On the north-west side of Pipestone Lake, near its lower end, a boss of granite breaks through the Keewatin schists and is entirely surrounded by them. The granite is exposed for three-quarters of a mile on the shore of the Pipestone Lake, but the greatest diameter of the boss is probably a mile or over. Although detached from the great area of Laurentian gneiss and granite which extends to the westward of Kishkutena ridge by the Keewatin schists which constitute the ridge, it is probably in geological continuity with the gneiss and granite. It is quite devoid of foliation, but not more so than many portions of the Laurentian gneiss on Kishkutena Lake. It is, therefore,

regarded as Laurentian and is described petrographically with the Laurentian gneisses.

Granites cutting the Coutchiching.

A large number of sporadic masses of granite and gneiss cut the rocks of the Coutchiching series in the south-east arm of Rainy Lake. Some of these are distinctly gneissic and are indistinguishable from the ordinary Laurentian gneiss of the region. Others are of the character of very coarse non-foliated granites or pegmatites. These masses are usually of small extent and break through the schists in the most irregular manner. On the United States side of the lake, however, the peninsula between Rainy Lake and Nemeukan Lake appears to be largely occupied by the coarser variety of these granites. Most of them from their analogy with the Laurentian gneisses should probably be placed with the latter, although it is possible that some of them may be correlated in age with the post-Laurentian granites. Their distribution is shown on the map. None have been microscopically examined.

## Post-Archæan Diabase Traps.

Questions of interest.

These are the youngest of the crystalline rocks with which we have to deal. Their occurrence is one of the most interesting of the geological features of the field we are considering. The chief questions of interest arising from a consideration of these rocks may be stated to be :—1. Their relations *in space* to other rocks—mode of occurrence. 2. Their relations in time of formation to that of other rocks, as inferred from such mode of occurrence. 3. The physical conditions under which they finally solidified as rocks. 4. Their geographical distribution. 5. Their petrographical character, comprising their mineralogical composition, structure and metamorphism. Upon these various heads, which include most of the interest attached to any formation, we have more precise and definite information than can be cited with respect to perhaps any other geological formation in this region.

Mode of occurrence of dykes.

By far the greater number of the occurrences of these post-Archæan traps are of the nature of dykes with sharply defined, approximately parallel, confining walls. Occasionally they are found in more diffuse masses with less regular boundaries, without, however, losing their dyke-like characters, if we consider, as the essential feature of a dyke-rock, the fact of its having solidified from a magma within a fissure in pre-existing rocks, whether the walls of such fissure be comparatively close and parallel, or widely separated and of irregular contour. These traps may then, for the most part, be referred to as occurring in dykes.

Strike of dykes

The strike of these dykes is commonly transverse to the strike of the gneisses, schists and other rocks of the region. And they are always, when bounded by parallel walls, in a more or less vertical attitude. The fissure walls are remarkably sharp and are brecciated only to a very limited extent. It is only occasionally that fragments of the country rock are found imbedded in the dyke, and when this is the case it is often possible to trace the fragment to the place from which it has been detached, as has been noted in the case of the dyke crossing Thompson Island, Lake of the Woods.* Even rarer than inclusions of country rock in the dyke is the occurrence of lateral apophyses penetrating the country rock. In the few instances where these have been noted, they usually run out obliquely from the main dyke at a small angle, and are very insignificant in size compared with the parent dyke. An inspection of the occurrence of any of these dykes leaves no room for doubt, but that the fissures that have been filled with dyke matter were made after the rocks of the region had been tilted into their present attitude or had solidified in approximately their present form. They traverse indifferently all the other rock formations of the region, and pass from one to another transverse to the line of their contact. The few inclusions that have been caught up by the dykes are identical, in every respect, with the adjacent country rock. Local metamorphism along the line of contact has not been developed so as to be macroscopically apparent, a fact probably due to the generally highly crystalline state in which the rocks were before the molten dyke matter came in contact with them. It is very probable, however, that a microscopic study of the country rock near the contact would shew that chemical and physical changes had been induced. There is no evidence whatever in the dykes themselves or in their relations to the rocks they cut, of their having been subjected to those forces of upheaval, folding and deformation that have so profoundly affected the other rocks. They have been practically undisturbed since the time of their solidification. The dykes which are contained by parallel walls have a generally uniform width of from about 60 to 150 feet. Their strike is, for the most part, in a remarkably constant direction, being N.W. and S.E. There are, however, some exceptions to this rule as will be noted below. Their continuity along the same straight line for great distances across country, not as the same dyke, perhaps, but as a prevailing line of fissure, is one of the most interesting features of these dykes, as will appear in the discussion of their geographical distribution.

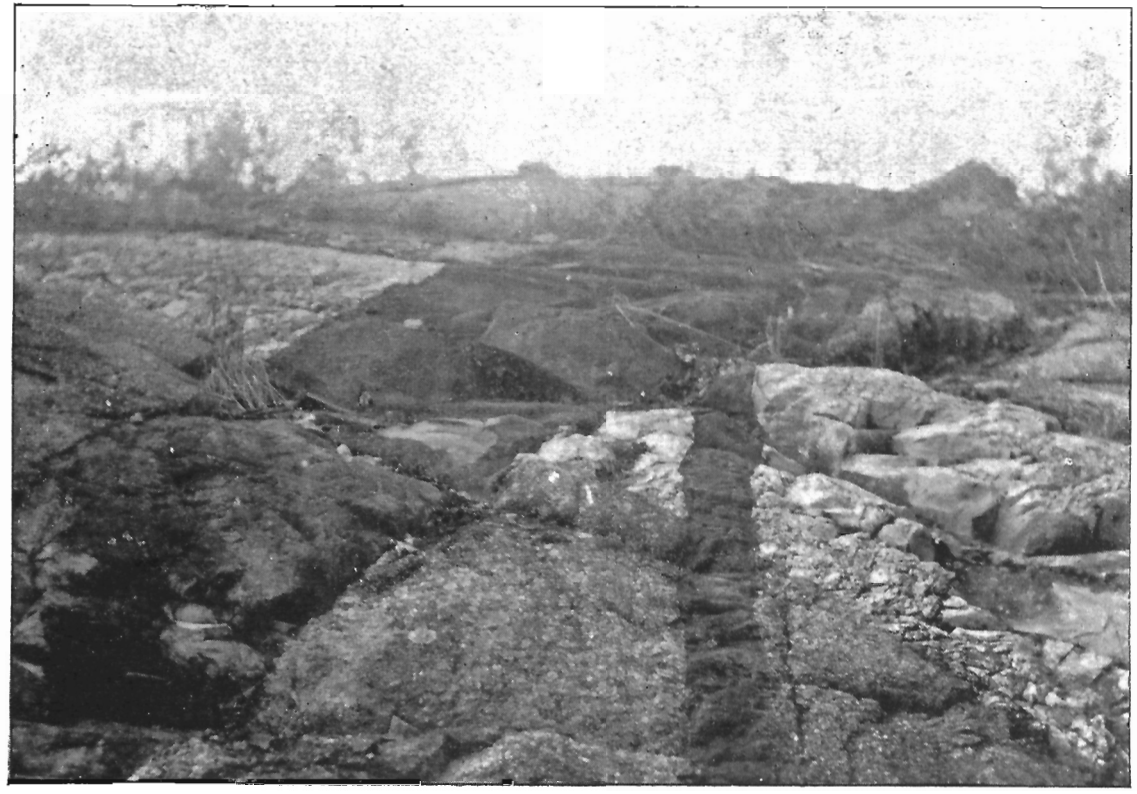
Lateral apophyses.

Age of dykes.

Width of dykes

A constant character of all these dykes is the very marked differentiation observable in the texture of the rock as one passes from the

* v. Annual Report, 1885, p. 121 G G.



A. C. LAWSON, PHOTO., 1887. G. E. DESBARATS & SON, ENGRAVERS & PRINTERS, MONTREAL.

Diabase dyke, with lateral off-shoot, cutting Laurentian gneiss through which runs an earlier dyke (lightest colored portion) of felsite or microgranite. Rainy River, opposite the east end of the town of Fort Frances or Alberton.

contact with the country rock on either side towards the central portion of the dyke. At the immediate contact with the fissure walls, the dyke rock is, in every case observed, a very compact, greenish, black rock, either entirely aphanitic, or made up of an aphanitic base in which are imbedded minute, glistening, porphyritic crystals. A little distance away from the contact, often only a few inches, the rock rapidly, but by insensible gradations, assumes a granular aspect, being made up entirely of minerals which appear to the unaided eye to be distinct crystals, although very minute. This fine-grained rock passes gradually into a coarse-grained, mottled, dark grey rock in the middle of the dyke where the greenish-white felspar, the lustrous black augite, and the metallic-grey magnetite may be distinguished at a glance. This transition in the texture of the rock appears to be practically the same in all the dykes; and a specimen from the middle of a large dyke does not appear to be of coarser texture than that from the middle of a small dyke. Hence the transition in a small dyke must be more rapid than in a large dyke.

Differentiation in texture.

The texture of the rock being a function of its distance from the containing walls, it is inferred that it is also a function of the rate of cooling and solidification. If this inference be just, and it is of wide acceptance among geologists in analogous cases, it has its bearing upon the general question of the relation of rock structure and rock texture to conditions of solidification. Important investigations have of recent years been made upon this subject, particularly by Stelzner,* Judd,† Hague and Iddings,‡ and Lotti§. The general tendency of these investigations has been to establish the intimate relationships existing between the structure of igneous rocks and the *pressure* under which they have cooled. In the case of the dykes which we have been considering, however, the differentiation in texture and structure is not a function of pressure. For, in the horizontal plane, which the present surface affords us, we must conceive the pressure in the liquid mass, now represented by the dyke, to have been practically uniform and the same near the walls of the fissure as in the middle of the mass. We have the same magma cooling at the same depth and under the same pressure, presenting a very rapid differentiation in structure and texture, in a comparatively short space, so that we are forced to admit that the structure and texture of these rocks is a function of the rate of cooling quite independent of the pressure. This conclusion does not, of course, preclude the possibility that, under a *varying* pressure, a

Differentiation due to variation in rate of cooling.

Variation in pressure *vs.* variation in rate of cooling.

* Beiträge zur Geolog. u. Palæont. der Argentinisshen Rebublik. 1885.

† Gabbros, Dolerites and Basalts of Tertiary age in Scotland and Ireland. Q. J. G. S., Vol. XLII., 1886.

‡ Development of crystallization in the igneous rocks of Washoe. Bull. U. S. Geol. Survey, No. 17, 1885.

§ Paragone fra la roccie ofiolitiche italiane e le roccie basiche pure terziare della Scozia e dell' Irlanda (Boll. d. Com. geol. ital., 1886, 93).

differentiation in structure might be induced of an entirely different order to that which is a function of the rate of cooling simply. It would appear that no attempt has yet been made to discriminate between that differentiation of structure which is due to difference in rate of cooling, and that which may be due to varying pressure simply, or that which may result from a combination of these two varying influences.

Prominence of dykes.

These dykes stand out more or less prominently from the rocks they cut, their steeply rounded or domed glaciated surfaces contrasting strongly with the more gently inclined *roches moutonnées* of the schists and gneisses. On the smooth glaciated surfaces of the dykes there is sometimes observed a peculiar pitting arranged in remarkably even and straight, uniformly spaced lines which run across the dyke transverse to its strike. These lines seemed to correspond to the surface limits of vertical structural planes of some sort, though what the real nature of these planes is, I have not been able to discover.

Weathering.

The aërially weathered surfaces of the dykes assume usually brownish tints, and are rougher than those surfaces below high-water mark, which are of a black color, and retain a smooth, fresh aspect.

Dykes on Lake of the Woods.

On the Lake of the Woods it has been observed that a line of dyke filled fissures extends in a N.W. and S.E. direction from the vicinity of Rat Portage to the E. side of White-fish Bay near the S.E. corner of the area embraced in the Lake of the Woods sheet. The intervals at which these dykes have been observed on the northern part of the Lake of the Woods are probably much greater than the actual occurrences of them warrant, as, at the time of the geological examination of these shores, they were not particularly looked for, and their characters were less familiar than they are now, and less easily distinguished from those of the more massive altered diabases of the Keewatin series. However, there is enough evidence to indicate a well marked line of fissure. The dyke which cuts the S.W. end of Scotty Island is very probably identical with that which traverses Thomson Island from N.N.W. to S.S.E.; and this, together with the dyke which cuts the Keewatin schists on the main shore S.S.E. of Yellow-girl Point appears to be in the north-westward projection of the remarkable line of dykes which my assistant, Mr. A. E. Barlow, traced across White-fish Bay in 1885, at intervals, for sixteen miles, with a strike of 140°. If we follow this line south-eastward we find these dyke-filled fissures continued at intervals, as far as our explorations have gone, to the south side of Rainy Lake on the International Boundary. The first of this linear series of dykes is one which cuts the green schists of the south side of Crow Lake a little over a mile to the N.E. of Crow portage. The next observed crops out on Clear-water Lake just where the 49th

Line of dyke-filled fissures for 100 miles.

parallel intersects the N.W. shore of the lake. In nearly the same line a large dyke crosses Jack-fish Lake less than a mile east of Totem Point. Still further to the S.E. on the shores of the North-west Bay of Rainy Lake there is another at the west side of the entrance to Brown Inlet. At the north-east corner of Stanjikoming Bay and on the north shore of the adjoining Shoe Bay, there is a group of three parallel dykes not far separated, all having a common strike of N.W. and S.E. The most easterly of these appears to be the strongest and probably represents the dominant fissure. On the north shore of Shoe Bay it is between 60 and 70 feet wide, and occupies two small islands which lie off shore in the mouth of the bay. It is probably identical with the dyke which cuts the gneiss on the N.E. side of Home-stretch Island, and occupies the southern extremity of Risky Island. About a mile and a-quarter to the south-east of the latter, in almost the same line, we have a large dyke occupying the east half of Memento Island, crossing Gash Point, and appearing again on Lobstick Island and the adjacent small islands. On the south side of Rainy Lake in the line of the strike of the dykes of Shoe Bay and Gash Point, two large well defined dykes have been observed which have a N.W. and S.E. strike but which are not quite parallel, being convergent at a small angle towards the south. The more easterly of these is more nearly in a line with the Gash Point dyke than the other. It traverses Stop and Grassy Islands, and some of the adjacent smaller islands, and has been traced for one mile and three-quarters from its most northern exposure to where it cuts the rocks of the south main shore. The other more westerly dyke traverses Medouganak Point and crosses the mouth of Rat-root Bay, being observable on both shores.

Dykes between Shoe Bay and S. shore.

I have thus sketched briefly the distribution of a series of dykes which, in a very remarkable linear arrangement, and all with a common strike, extend from the north end of the Lake of the Woods to the south shore of Rainy Lake, a distance of 100 miles. The line of their occurrence has a bearing of 140° to 145°. The fissures of which they are *prima facie* evidence, whether they be absolutely continuous or be made up of a series of ruptures with intervening planes of strain, have probably played an important part in the post-Archæan earth movements which have affected the region. It is difficult to positively assert that any profound faulting has occurred along this line, since there is little direct evidence to warrant such an assertion. That it is a line of fault, however, seems extremely probable, and it is worthy of note that the whole rocky surface of the country to the S.W. of this line of dykes and to the south of the 49th parallel, is on a level distinctly lower than that of the country to the N.E. of that line, being covered with the flat-bedded, low-lying, post-glacial deposits through

Line of fissure, and probable faulting.

which Rainy River has cut its way. Although the linear arrangement of these dykes is very marked, it does not follow that the fissure was confined to any single line. Indeed, as has been noted, the dykes occur in triplicate and duplicate; but, in these instances, the dykes have been so near together as to leave no doubt as to their close relationship, all being in the same linear area. There are a few dykes, however, which have been observed to lie a little out of the line of fissure, as above sketched, and although they have the same strike, are to be regarded rather as belonging to parallel but subordinate and less pronounced fissure lines than the main line. One of these dykes occurs on the east side of Clear-water Lake, three miles and a-half south of the 49th parallel. Another crosses the south shore of Pipestone Lake one mile west of Stone-dam Portage. In this category also may be classed the dyke which crops out on the United States side of Rainy River opposite the east end of the town plot of Fort Frances. (*v.* Plate VII.)

**Parallel fissures.**

**Line of dykes from Shoal Lake to Little Grassy River.**

The dykes enumerated do not comprise all that have been observed. In the south part of the Lake of the Woods a line of post-Archæan irruption has been noted and mapped on a string of small islands extending some eight miles N.W. from the N.W. point of Big Island. This irruption does not appear to be a simple parallel-walled dyke, but seems in places to have a very considerable width, and its exact distribution cannot be determined on account of its occurrence on a number of small islands. The arrangement of these islands in a line which runs N.W. and S.E. is eminently suggestive of the strike of the longitudinal axis of the irruption. The contact of the irrupted trap has, moreover, been observed on two of the islands, viz., on Massacre Island and on a small island two miles W.N.W. of the north end of Bear Island, and in each of these cases the strike of the fissure wall is N.W. and S.E., and all the conditions of contact are identical with those observed in dykes of more limited dimensions and contained within observable parallel walls. The north-westward projection of the line in which these trap islands lie, passes through a small boss of trap that projects through the sand at the south end of Shoal Lake. And with this is probably associated a mass of trap which cuts the schists on a small island off the west shore of Shoal Lake between Berry Point and Calm Bay.

The south-eastward projection takes in a dyke which cuts the gneiss on the west side of Bigsby Island near its south end, and another which occupies part of a small island opposite the mouth of Little Grassy River. Thus we have again sketched for us by the occurrence of a line of dykes, another line of fissure extending for over forty-five miles in a general N.W. and S.E. direction, and again the surface of the country is lower to the south-west of this line than it is

to the north-east. This line is not strictly parallel to the White-fish Bay line of fissure, but varies from parallelism only by a very small angle, the two lines being convergent towards the south-east at an angle of between 5° and 10°. Assuming their continuity across the state of Minnesota, they would meet near the head of Lake Superior. The line of fissure indicated above as extending from the bottom of Shoal Lake to the mouth of Little Grassy River appears to be distinctly traceable for the distance of forty-five miles. There is evidence, however, of its much greater extension to the S.E. The country to the S.E. of the mouth of Little Grassy River is covered with post-glacial formations, and no occurrence of dykes has been noted along this line for thirty-five miles. After this interval, however, we again meet with them in great strength on Rainy River. The Manitou Rapid on Rainy River flows over a large dyke, whose strike appears to be N.W. and S.E. The actual contact with the enclosing rocks is not exposed, but a distinct gradation from a fine to a coarse texture can be observed, indicating that the containing walls of the dyke cannot be far distant from the part with the finest texture; and the dyke presents a distinct ridge at right angles to the stream which is taken to be its strike. For three miles north from the river this trap can be traced through the bush at intervals on the Indian Reserve. It seems to lose its dyke-like characters to the northward, and to merge into a rather extensive boss of uniformly coarse gabbro. About six miles further up Rainy River, above Manitou Rapid, there are two other dykes which may perhaps be classed with that at the rapid, and so be considered as belonging to the same line of fissure. They both have a strike of from N.W. and S.E. to N. and S. One of these occurs on the American shore projecting through the post-glacial formations as a prominent bluff, and cuts through green hornblende schists. The other occurs on the Canadian side, about one mile and a-half from the river at the back of Mr. Lutterel's farm. Like the first it projects boldly through the post-glacial deposits with a width of about 150 feet without, however, shewing the rock which it traverses. On either side of the middle part of the exposure the rock becomes finer-grained towards the sides, so that it may safely be inferred that the exposure represents very nearly the width of the dyke, although the contact is concealed. The coarser portions of the dyke shew, in places, a very distinctly foliated, possibly a "flowed" structure. Thus if these dykes on Rainy River be assumed to be part of the same system of fissuring as that traced from Shoal Lake to Little Grassy River, and they are approximately in the same line, that system will have a linear extent of over eighty miles, and is then comparable, in its minimum length,*

Convergence of two lines of dykes.

Dykes on Rainy River.

Foliated structure in dyke.

* Of course either of these lines of fissure may extend to the N.W. and S.E. beyond the limits of the field of exploration.

with that of the White-fish Bay system of fissuring. Two other trap dykes have been observed on the river which do not fall into line with any others. One of these crops out on the south side of the river one mile below the foot of the Longue Sault. The other crosses the river in a N.W. and S.E. direction, and causes a slight rapid in the stream, about half a mile above the mouth of Rapid River. Neither of these is sufficiently exposed to afford positive evidence of their being dykes, and that they are so, is inferred chiefly from the similarity of the rock to that of the other dykes of the region. One other dyke remains to be noticed and that is unique in having a strike of N.E. and S. W. It occurs on a small island two miles and three quarters W.N.W. of Halleluiah Point near the mouth of Seine Bay, with a width of sixty feet cutting the Bad Vermilion Lake saussurite-gabbro formation.

Other dykes.

Petrographical characters.

The petrographical characters of these dykes have only received a preliminary study so that no exhaustive statement regarding them can be made. A few notes on the microscopic features of some of them which have already been published elsewhere,* are, however, incorporated here, so that taken with the foregoing description of their field occurrence they may make the general account of these dykes as complete as possible to date.

Jack-fish Lake dyke.

One of the most characteristic of these dykes traverses the coarse granitoid gneiss of the west arm of Jack-fish Lake, which lies to the north-west of Rainy Lake. Its width is 135 feet and its contact with the country rock is well exposed as a sharp line. From a macroscopic examination, the gneiss does not appear to have been altered perceptibly towards the contact. Specimens for microscopic examination were taken from different parts of the dyke, viz., at sixty feet, twenty feet, and six feet from the contact, and at the contact. At sixty feet from the contact, the rock is a coarse-grained, mottled grey rock, in which dirty white felspar and black pyroxene are the prominent constituents. Under the microscope it presents the characters of a coarse-grained, comparatively fresh diabase. Augite of a pale mauve tinted grey color is abundant, and often occurs in masses that fill the field of the microscope when low powers are used. Sometimes these plates of augite are individual crystals. For the most part, however, they are not single individuals. When examined between crossed nicols the plate of augite is seen at once to be resolved into an intimately interlocking mosaic of irregularly shaped grains of diverse optical orientation. In ordinary light the boundaries between the different members of these "polysomatic"† masses of augite are traceable only with difficulty and uncertainty. There is no interstitial

Rock at 60′ from contact.

"Polysomatic" augite.

* Proceedings Canadian Institute, 1887.

† Adapted from Tschermak's use of this word as applied to a similar structure in the olivine of certain meteorites.—v. Die Mikr. Beschaff. der Meteor. Stuttgart, 1885.

matter whatever, the different grains being as intimately associated as in the case of interpenetration twins of felspar. That they are not twins is shown by the fact that there are often as many as half a dozen grains all of different orientation thus combined in the same mass. The cleavage, by its lack of continuity over the field, of course, indicates a difference of orientation in different parts of it, but the cleavage traces are not strongly marked, and attention is only directed to the discordance of the cleavage after the polysomatic character of the mass has been rendered prominent by the analyser of the microscope. This polysomatic structure of augite does not appear to be common. Rosenbusch does not mention it in his last comprehensive summary of the present state of petrographical knowledge.* The nearest approach to this structure that is at all well known is the polysomatic character of some chondri of olivine in certain meteorites such as are figured by Tschermak† and Wadsworth.‡ Olivine in a similar condition in terrestrial rocks has recently been described and figured by Renard in specimens from Kerguelen Island in the Indian Ocean.§ The polysomatic structure in augite is not so well known. Renard notes that the augites of the felspathic basalt of Heard Island, Indian Ocean, are grouped together at certain points,‖ and again in the same rocks at Marion Island that the augite is characterised by a tendency to form groups of individuals having their vertical axes parallel.** Teall mentions "Granular Aggregates" of augite in the Hett and the High Green dykes in the north of England.†† Some of these appear from the figures given to be aggregates of grains of augite not in close juxtaposition with an interstitial base, although that figured in Plate xii, Fig 5, would seem to be a polysomatic augite, and if so is the only strictly parallel instance that I can find of this structure so common in this dyke and in others of the region. Analogies.

The augite is generally altered to hornblende at its periphery and occasionally the latter mineral entirely replaces the former. The process of alteration does not appear to proceed along the almost or quite imperceptible lines of demarkation between the different individuals of the polysomatic augite, but extends from the periphery of the mass as a whole in towards its centre. Alteration of augite.

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* Mikr. Phys. der Mineralien und Gesteine Stuttgart, 1886.

† Die Mikr. Beschaff. der Meteor. Stuttgart. 1885, Taf. xv. Fig. 1 and 2.

‡ Lithological Studies, Mem. Mus. Comp. Zool. Harvard, Vol. x., pl. 1.

§ Notice sur la geologie de l'ile de Kerguelen, Bul. Mus. Roy. Hist. Nat. Belgique, Tome IV. No. 4., p. 233, fig. 1, pl. v.

‖ Notice sur les roches de l'ile Heard. Bull. Mus. Roy. Hist. Nat. Belgique, 1885, 8 p. 26[illegible].

** Notice sur les roches de l'ile Marion. Ibid. p. 250.

†† Petrographical Notes on some north of England Dykes, Q. J. G. S., 1884, 158. p. 2[illegible]9 and 242.

Plagioclase.

The plagioclase appears in two general forms: a rather stout or tabular form, which is the larger and usually the more cloudy with decomposition products, and a small long lath-shaped felspar which appears quite fresh, and in which the polysynthetic lamellæ are much more distinct than in the former.

Accessory minerals.

Magnetite occurs in irregularly bounded masses or is disseminated, often quite thickly, through the augite as inclusions of dusty or finely granular aspect. Pyrite also occurs and is discernable macroscopically. Apatite is seen in occasionally colorless hexagonal sections and in slender prisms with rounded terminations. Water-clear quartz, with inclusions of apatite microlites and liquid inclusions with dancing bubbles, forms a considerable proportion of the mineral constituents of the rock and is characterized by having a common orientation for isolated sections over a wide area of the microscopic field, as in the micropegmatite structure. A few colorless garnets are also present. The rock, such being its characters, may be classed as a uralitic quartz-diabase.

Rock at 20′ from contact.

At twenty feet from the contact the rock is very similar to that at sixty feet, but is much less coarse in texture. It differs from the latter in mineralogical composition in the fact that there is present a number of white or colorless garnets, all perfectly isotropic. They have a well defined border, indicative of a high index of refraction and perceptibly rough surface. Their shape is for the most part rounded, or, when rectilinear outlines are observable, they are hexagonal sections of the rhombic dodechedron. The larger grains have a curved parting which may be demarkation lines between different individuals. The treatment of the slide with hydrochloric acid, cold or hot, leaves them unaffected. The occurrence of garnets in basic dykes is by no means unique. They are, however, regarded as a product of contact metamorphism within the dyke. Speaking of the "Iron District of Lake Superior," Wadsworth says: "Most of the 'diorites' (uralitic diabases) here (at Republic Mt) contain garnets, this mineral being found principally along the edge of the intrusion while the centre was nearly if not entirely free from it. The schist in like manner near the 'diorite' frequently contains garnets, both rocks appearing to have mutually reacted upon each other."* The garnets in the Jack-fish Lake dyke do not appear to be a product of contact metamorphism, since they are found in the middle of the dyke and very much more abundantly at twenty feet from the contact than at six feet from it, or immediately at the contact, where their presence has not been detected. Beyond the abundance of garnets, the dyke at twenty feet has the same characters as at sixty feet. The polysomatic structure of the augite is pronounced.

Garnets in dykes.

* Notes on the Geol. of the Iron and Copper Districts of Lake Superior. Bull. Mus. Comp. Zool. Harvard, 1880, pp. 45, 46, 47.

At six feet from the contact the rock is fine-grained and the ophitic structure of typical diabase is much more characteristically developed than in the coarser grained parts of the dyke. In this part of the dyke there is first observed a differentiation of the rock into constituents of different periods of crystallization, the order being first plagioclase in more or less idiomorphic,* lath-shaped individuals lying in all positions, then augite generally allotriomorphic,* sometimes hypidiomorphic,* and finally a base or matrix of both these minerals in a very much more finely crystalline state, together with magnetite. The structure of the base is rather obscure, the chloritic substance usually present in diabase rocks being more prominent here than in the coarser grained part of the dyke where it is almost, or perhaps entirely, wanting. Quartz is present but in smaller quantities than in the coarser grained portions of the dyke. The augite occurs both in simple individuals and in polysomatic masses. The uralitization of the augite, which is generally observable, is much more pronounced in the irregularly bounded polysomatic masses than in the simple allotriomorphic development of the same mineral. A few garnets are present as inclusions in the felspar, but were not identified with certainty. In this respect this portion of the dyke differs markedly from the more central portions examined. The most interesting constituent of this portion of the dyke remains, however, to be mentioned. It is the non-pleochroic, colorless, rhombic pyroxene, enstatite; it occurs in idiomorphic development showing the characteristic obtuse domes in some of the sections. It shows regular cleavage parallel to ∞ P (110), upon which the angle of extinction is zero, and characteristic cross parting, along which partial alteration of the mineral to bastite or serpentine is apparent. This enstatite is not abundant, and plays the rôle of an accessory mineral. Its occurrence in a rock of well marked diabase structure is interesting. Rosenbusch remarks that it is present in only a few diabases which have a gabbro-like structure,† and Teall has recorded the occurrence of the allied rhombic pyroxene bronzite in the Whin-Sill of the north of England as an accessory.‡ Enstatite also occurs in a variety of the allied rock, diabase porphyrite, from Schaumberge, which has been described by Laspeyres and Streng under the name of Palatinite. This enstatite was not observed in the coarser parts of the dyke but occurs, as will be noted, in the still finer grained diabase at the contact.

Rock at 6′ from contact.

Enstatite.

At the immediate contact the dyke assumes macroscopically the characters of a very compact, greyish-black, aphanitic rock in which

Rock at contact.

* Terms introduced by Rosenbusch. Cf. op. cit. p. 11.
† Mik. Phys. der Massigen Gestine, 2nd Ed., 1886, p. 188.
‡ Q. J. G. S., 1884, p. 652.

can be occasionally detected minute glistening facets of porphyritic crystals. With low powers of the microscope the matrix is not resolvable, but appears as a uniformly yellowish to greenish-grey ground thickly dotted with grains of magnetite. Under the higher powers this is seen to be made up, in addition to magnetite, of a fine felt-work of lath-shaped crystals of plagioclase imbedded in hazy, somewhat yellowish green flocculent chloritic substance derived presumably from the alteration of the augite, since that mineral cannot, with certainty, be identified in the base. The porphyritic character of this part of the dyke is well marked, though the imbedded crystals are small. These are augite in small irregular polysomatic masses, with a hazy margin or fringe of greenish decomposition products, long lath-shaped plagioclase and occasionally stouter broken fragments. Besides these are porphyritic crystals of enstatite much more altered and less plentiful than at six feet from the contact. Neither quartz nor garnet are observable in the contact rock.

Porphyritic character.

Points of interest.

Considering then the dyke with reference to its variation in structure and mineral composition, the points of interest to be noted are: the passage of the coarse grained central portions of the dyke to the compact aphanitic rock at the contact; the absence of porphyritic structure in the middle of the dyke as contrasted with the well marked development of the same as the rock becomes finer grained towards the dyke walls; the absence of the characteristic chloritic substance of diabase in the centre of the dyke, and its abundance towards the contact; the presence of quartz in greater quantity in the coarse grained middle portions than at the sides; the presence of garnets in the coarsest parts of the dyke, their abundance in the medium grained parts, and their rarity or total absence in the neighborhood of the contact; the presence of the rhombic pyroxene enstatite in typical idiomorphic porphyritic crystals in the fine grained parts near the contact, and its absence in the coarser central parts; the diminution in size of the porphyritic crystals near the contact in co-extension with the increasing fineness of the ground mass; and finally the "polysomatic" structure common to the augite throughout the dyke.

Continuation of dyke.

Three-quarters of a mile from where the specimens whose characters have just been given were collected, there occurs, on the opposite side of the bay in the line of the strike of the dyke, another exposure of the same dyke. On the islands of the bay which lie intermediate between these two localities, the outcrop of the dyke is observable, so that there is no doubt of their both being exposures of the same dyke. The rock here was not studied in so great detail as at the last exposure. The specimens taken were of the same grade of coarseness as those taken at twenty feet from the contact on the north side of the

bay. The felspars are more decomposed, and the twinning lamellæ often obscure, and the small quantity of quartz which is associated with them appears to be of secondary origin; whereas the origin of the quartz noted in the same dyke on the north side of the bay seemed much more problematic. In the latter case the common micropegmatic character of the quartz and the occurrence in it of needles of apatite, which in no way differ from those in the felspar, together with the not infrequent occurrence of one individual of apatite partially included in quartz and partially in an adjacent felspar, would argue for the primary character of the quartz. The augite in the dyke on the south side of the bay resembles that already described, occurring both in simple individuals and in polysomatic masses. It is largely altered to uralite. Titanic iron with its alteration product leucoxene shows characteristic barred structure of the cleavage traces parallel to the planes of the rhombohedron. The leucoxene is frequently accompanied by a margin more or less extensive, of secondary brown mica. Apatite is present in comparative abundance. Chlorite occurs in vaguely defined masses and the garnets which, as before, are present, are associated with it.

Characters of other specimens.

On the south-east shore of Pipestone Lake, about a mile west of Stone-dam Portage, there is another of these dykes cutting transversely schists which have a strike of N.E. to E.N.E. The specimen taken

Pipestone Lake dyke.

Fig. 12. Section of diabase, from Pipestone Lake dyke, showing large polysomatic grain of augite in three granules of diverse orientation *a b c*; *d*, uralitic-hornblende; *e*, magnetite. × 28.

from the middle of the dyke has the characters of an uralitic quartz diabase. The felspar, as a rule, is remarkably fresh, and occurs in the usual lath-shaped twinned crystals of plagioclase. The crystals are commonly observed to be cracked transversely and the cracks filled with a brownish-yellow material which shows aggregate polarization. The augite occurs more commonly in polysomatic masses than in simple individuals. The magnetite is often surrounded by rims of secondary

brown mica. The quartz is apparently original and has numerous inclusions of an opaque granular character, together with fluid inclusions with dancing bubbles, gas pores with black borders and glass (?) inclusions oval and circular.

Dyke on S. shore of North-west Bay.

On the south shore of the North-west Bay of Rainy Lake, a similar dyke cuts both the biotite gneiss of the region and the red granite which is intrusive through it. It is an uralitic quartz diabase. The felspar is in rather stout crystals in the coarser grained part of the dyke, though usually lath-shaped. It is much decomposed and is partially replaced by quartz and chlorite. The polysomatic character of the augite is not prominent, but this may be due to the fact that it is about half altered to hornblende and to chlorite. The augite individuals are often twinned and the cleavage traces are usually well defined. The magnetite shows a tendency to peripheral arrangement around the altered augite indicative of its secondary origin. Quartz is present which is probably original besides that which is clearly secondary. Apatite in long slender needles and leucoxene in irregular masses, are the accessory constituents.

In the same dyke, nearer the contact where the texture is fine-grained, the rock is much more uralitized, traces of augite being observable only in the cores of the green compact hornblende, which has almost entirely replaced it. Apatite appears more abundant, as do also the secondary quartz and chlorite. Garnet of a pale yellowish color occurs sparingly.

Fig. 13. Plagioclase from diabase dyke, North-west Bay, Rainy Lake, showing effect of pressure of one crystal against another.

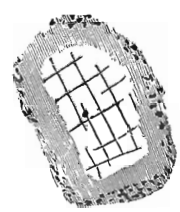

Fig. 14. Augite from diabase dyke, North-west Bay, Rainy Lake, showing marginal alteration to green compact hornblende with an encircling wreath of secondary magnetite.

At the contact the dyke rock is a compact aphanitic base in which can be detected minute porphyritic crystals. Under the microscope the base is seen to be made up of minute lath-shaped crystals of fresh plagioclase, augite grains, magnetite and chloritic substance. The porphyritic crystals are lath-shaped felspars occasionally broken and showing the lamellæ in some instances bent, as the result of pressure of

one individual against an angular part of another, and augite generally surrounded with an irregular border of secondary hornblende, which, in turn, has an outer girdle or wreath of granules of magnetite that have separated out in the process of uralitization as in Fig. 14.

On the lake, near the extremity of Gash Point, one of these dykes cuts the schists with a strike of N.W. and S.E. across the whole breadth of the point and traverses the islands on both sides of it. Here it is traceable on the point and on the islands for the distance of a mile. Three miles to the south-east in the line of the strike of the dyke, a dyke occurs cutting the schists on the islands off the south shore of the lake which is probably a continuation of that of Gash Point. From this point it is traceable for two miles across the islands to the main shore on the south side of Grassy Narrows. Thus, this dyke has a length of at least six miles and has an extension to the north-west and south-east of the points observed, for a distance that is probably very much greater. A specimen from the central part of this dyke, proved, on examination, to have the characters of a uralitic quartz-diabase. The plagioclase occurs in long, rather stout, lath-shaped crystals, which are generally so cloudy as to obliterate the twinning in most cases. The augite occurs both in simple individuals and in polysomatic masses. It exhibits the usual marginal alteration to hornblende, and there is besides a certain amount of chlorite. Original magnetite is frequently surrounded by a margin of secondary biotite. Micro-pegmatitic quartz is abundant. It is often intimately intergrown with the felspar, and, as the latter is much decomposed, would seem to replace it as a partial pseudomorph, but apatite needles of the same aspect as those which occur as inclusions in felspar, augite, and quartz, are often seen to be inclosed

Gash Point dyke

Grassy Narrows dyke.

Fig. 15. Polysomatic grain of augite—Grassy Narrows Dyke, Rainy Lake, *a* and *b* are twins—the other granules are of diverse optical orientation. × 28.

partly in a felspar and partly in quartz grain. The primary origin of the quartz, in spite of its micro-pegmatic character, is however, not beyond doubt. It is to be noted that were the quartz original we would hardly expect to find it in such close association with the felspar. The plagioclase of these rocks affords unmistakable evidence

Origin of quartz

in its idiomorphic character of its having first crystallized from the magma. The augite crystallized next, enclosing the lath-shaped plagioclase; and the quartz, which would be last to crystallize, we would expect to find separated from the plagioclase by the augite, *i.e.*, to fill in the interstices between the augite. Again, although single apatites are often found extending from a quartz grain to a felspar grain, a condition of things favoring the notion of a common primary origin of both the latter minerals, yet such a phenomenon is not incompatible with a secondary origin for the quartz, since the replacement of felspar by quartz must necessarily be a slow operation and proceed particle by particle. Further, if the quartz were original we should hardly expect to find in it inclusions of crystals of the first generation like apatite, which would be liable to be enclosed, for the most part, in the earlier secretions like felspar and augite, rather than in the residual silica of the magma. The non-existence, however, of quartz in some diabases which are very much decomposed and its presence in fresh ones, militates against the theory of the secondary origin of the quartz in these rocks, so that the question of how much of the quartz is primary and how much secondary in an old diabase is a question that as yet does not appear to be susceptible of definite settlement.

Rat-root Bay dyke.

About a mile to the west of this dyke where it crosses Grassy Island is another nearly parallel dyke converging on the former at a small angle towards the south. The rock is an uralitic quartz diabase and in its coarser portion, near the middle, the texture is more granular than that of typical diabase. The plagioclase is cloudy with decomposition products, and quartz is abundant. The augite is entirely replaced by compact green hornblende the only indication of the augite that remains being the light colored character of the central portion of the hornblende and the abundance of magnetite granules that have separated out in the process of alteration. Apatite occurs in slender hexagonal needles, mostly in the quartz, but also in the felspar and hornblende; and a number were observed which were common to both felspar and quartz. A few zircons showing parallel extinction, deep black border and brilliant polarization colors, also occur. A few colorless, rounded, isotropic grains, probably garnets, were observed. Nearer the contact where the rock is much finer grained the typical diabase structure is much better developed, the felspar having its usual lath-shaped character, with augite in allotriomorphic structure around it, although the character of the latter is obscured by its extensive alteration into hornblende. The augite so far as revealed in the cores of the hornblende occurs both in simple individuals and in polysomatic masses, and it is interesting to note that the hornblende derived from a polysomatic aggregate of augite is of

Microscopic characters.

uniform orientation throughout. Magnetite or titanic iron with associated leucoxene is generally distributed. The quartz is in small grains proportioned to the finer grained texture of the rock. In the central part of the dyke the quartz is in large grains commensurate with the increased size of the felspar and augite. In neither case does it occur in the mosaics which are so characteristic of the secondary or vein quartz. In addition to the minerals enumerated in this part of the dyke, there is in prominent porphyritic development an altered rhombic pyroxene. The alteration has proceeded very far and the mineral is now represented only a mass of yellowish green serpentine with perhaps some of the intermediate alteration product bastite. The cleavage is, however, well defined and the extinction in the several cases noted is sharply parallel to it. These characters together with the traces of the obtuse dome so characteristic of sections of enstatite are sufficient to identify it as that mineral in an altered state. The occurrence of the enstatite in this dyke in its finer grained parts towards the contact is analogous to, and an interesting confirmation of, the similar occurrence of the mineral noted in the Jack-fish Lake dyke also in the vicinity of contact. Rhombic pyroxene.

To summarise, the main points of interest are, briefly: 1. Post Archæan age of dykes. 2. Their problematic relationship to traps of Animikie and Keweenawan. 3. Their uniform strike and arrangement in lines indicative of great lines of fissure. 4. Sharp contact. 5. Passage from coarse texture at centre to aphanitic at sides. 6. Granular character towards centre, porphyritic at sides. 7. Prevalence of quartz and garnets towards centre and absence near contact. 8. Presence of enstatite at sides, absence towards centre. 9. "Chloritic substance" abundant at sides, absent towards centre. 10. Polysomatic character of augite thoughout. 11. Uralitization of augite. 12. Very marked contrast of texture of two different parts of a rock which solidified under practically the *same pressure* but at *different rates of cooling*. Summary.

## Glacial Phenomena.

What was said of the glaciation of the Lake of the Woods in my report of 1885 is generally true of the Rainy Lake region. The whole country has been swept, grooved and polished by glacier ice. Towards the south, the surface has been covered by a great sheet of post-glacial fresh-water deposits, but north of the area over which these are distributed, wherever the glaciated rocks are exposed, the surface is hummocky, being made up of *roches moutonnées* and long rounded ridges Aspect of rock surfaces.

which follow the strike of the rocks of the country. In spite of this hummocky character, the surface of the country is essentially that of a flat plateau with a gentle slope to the south-west. The most prominent features resulting from the glaciation are the grooves and striæ which so constantly mark the surface of the *roches moutonnées*, and the heaps of boulders which are so abundantly strewn upon portions of their slopes. These boulders are all of Archæan and northern origin, and are all that remains of the glacial drift. All the finer kinds of drift, such as till, sand, pebbles, &c., appear with the exception of occasional remnants to have been swept down into glacial or post-glacial lakes and spread out into strata by the action of their waters. As on Lake of the Woods, those slopes which have been in the lee of the glacial current or flow have a greater accumulation of these boulders resting upon them than have those slopes exposed to its impact. Subjoined is a list of the observed direction of the ice grooving and striation at various localities. The list may seem somewhat lengthy, but it only represents an average of one observation to about every 16 square miles of the area mapped on the Rainy Lake sheet. The direction of the glacial grooves and striæ is very constantly south-westerly. The direction of the ridges and valleys of the country is quite independent of the direction of the ice flow as indicated by the grooving, and is dependent almost entirely upon the strike of the rocks as above stated. Where the strike of the rocks and the consequent trend of the ridge has been transverse to the general flow of the glacier there appears to have been little or no deflection from its mean course; but where the ridges have made a small angle with the mean course of the glacier movement, the lower portion of the glacier seems in some instances to have suffered deflection to the extent of this angle, and to have flowed in the direction of the ridges and their accompanying valleys till a change in the strike permitted its falling into line with the general flow. The average direction of the glacier movement over the Rainy Lake region as indicated by the grooving is about 40°, as compared with 45° on the Lake of the Woods, a deflection towards the meridian as we pass south-eastwardly which is probably associated with the more easterly trend of the height of land to the eastward of Lake of the Woods.

Grooves and striæ.

Distribution of boulders.

Direction of ridges and valleys independent of glaciation.

Average direction of glacier movement.

LIST OF DIRECTIONS OF GLACIAL GROOVES AND STRIÆ.

*Kishkutena Route.*

| | | | | |
|---|---|---|---|---|
| Kahtimi-agamak Lake | S. shore, | 1 m. | E. S. E. of outlet | 53° |
| " | " | 1½ m. | E. " | 58° |
| " | W. " | ½ m. | N. " | 46° |

| | | |
|---|---|---|
| Clear-water Lake, 1 m. S. W. of north end | 33° | Bearings of glacial grooves and striæ. |
| " S. E. shore opposite Hazy Point | 53° | |
| Minomin River, ½ m. W. of entrance to Lake Despair | 33° | |
| Hope Lake, N. side, ¾ m. W. N. W. of North-west Bay Portage | 36° | |

*Pipestone Route.*

| | |
|---|---|
| Crow Lake, 1 m. N. W. of Crow Portage | 39° |
| " 1¾ m. N. E. of " | 44° |
| " 1¾ m. S. E. of Chase Point | 36° |
| " west side of Shanty Point | 42° |
| " north side of " | 49° |
| Schist Lake, 1 m. N. W. of outlet | 23° |
| Yoke Lake, north end | 48° |
| Pipestone Lake, ½ m. N. W. of Unde Rapids | 20° |
| " ¼ m. W. N. W. of Fisher Island | 29° |
| " ¾ m. west of " | 20° |
| " bottom of James Bay | 37° |
| " Gates-ajar Narrows | 27° |
| " ¾ m. E. of north end of Corner Island | 44° |
| " N. W. side of Line Bay | 41° |
| " 1 m. N. E. of Stone-dam Portage | 44° |
| " 1 m. S. W. of " " | 44° |
| Loon Lake, mouth of Whistle Bay | 44° |
| Jack-fish Lake, ½ m. S. of Two Lake Narrows | 24° |
| Foot-print Lake, 1 m. N. W. of outlet | 25° |

*Kaiarskons Route.*

| | |
|---|---|
| Bluff Lake, 1¼ m. S. S. W. of north end | 28° |
| Strawberry Lake, S. side ¾ m. from E. end | 38° |
| " " 1¼ m. " E. " | 48° |
| " at outlet | 39° |
| Strawberry Creek | 53° |
| Sucker Lake, E. side, ¼ m. S. of outlet | 33° |

*Manitou Route*

| | |
|---|---|
| Grant Lake, N. E. end | 38° |
| Missus Lake, S. shore, 1 m. E. N. E. of west end | 48° |
| " " ¼ m. " " | 43° |
| Manitou Lake, W. side, 1¾ m. N. E. of Paddle Portage | 48° |
| " " 1½ m. S. S. W. " | 28° |
| " S. E. side, 1½ m. N. E. of Snare Portage | 53° |
| " " 2¼ m. E. of Pickerel Rapids | 44° |
| " S. W. end | 44° |
| Pickerel Lake, entrance to Mirror Bay | 34° |
| " ½ m. N. N. E. of entrance to Mirror Bay | 36° |
| Manitou River, ¼ m. S. W. of Porcupine Rapids | 33° |
| Famine Point, Sphene Lake | 33° |

Bearings of glacial grooves and striæ.

*Little Canoe River Route.*

| | |
|---|---|
| Bat Lake, 1¾ m. S. E. of portage to Three Island Lake | 26° |
| Respite Lake, S. end | 28° |
| " W. side | 31° |
| Vane Lake, E. side, ¼ m. N. N. E. of outlet | 33° |
| Little Canoe River, 1 m. N. of mouth | 40° |

*Big Canoe River Route.*

| | |
|---|---|
| Dog-fly Portage | 43° |
| Vista Lake, N. end, W. side | 30° |
| Pickwick Lake, ¾ m. from N. end | 23° |
| Sam Weller Lake, 1½ m. N. E. of outlet | 38° |
| Obikoba Lake | 33° |

*North-west Bay of Rainy Lake.*

| | |
|---|---|
| Two miles S. of Gusty Point | 50° |
| Rocky islet, ¾ m. E. of Indian Falls | 33° |
| S. shore, 1 m. E. of Gusty Point | 37° |
| N. shore, 1¾ m. N. E. " | 48° |
| S. shore, ½ m. W. of Camp Narrows | 48° |
| " ¼ m. N. of Cliff Narrows | 38 & 48° |
| " ¾ m. N. E. " | 45° |
| " entrance to Brown Inlet, E. side | 38° |
| Brown Inlet, E. side | 44° |
| N. shore, opposite Brown Inlet | 50° |
| Hanging-stone Point | 46° |

*North Arm of Rainy Lake.*

| | |
|---|---|
| Island, 1¼ m. N. E. of Hanging-stone Point | 53° |
| West side, 1¾ m. W. N. W. of Standing-stone Point | 28° |
| Alfred Point | 23° |
| West side, 1 m. W. N. W. of Standing-stone Point | 38° |
| " 1 m. " Hook Island | 28° |
| " 1¼ m. S. W. of Alfred Point | 28° |
| " 1 m. " " | 28° |
| Island, ½ m. N. N. W. of Hook Island | 25° |
| Entrance to Grassy Narrows Bay | 36 & 45° |
| East end of Hook Island | 23° |
| Shoe Bay, north side | 38° |
| Island, opposite Shoe Bay | 38° |
| West shore, ¾ m. N. of entrance to Stanji-koming Bay | 30° |
| East shore, Ami Point | 43° |
| Macdonald Inlet, north side, E. of Big Canoe River | 33° |
| " " 1½ m. E. " | 38° |
| Blaze Point | 40° |

| | |
|---|---|
| Hopkins Bay, 1 m. E. of Blaze Point | 46° Bearings of glacial grooves and striæ. |
| " 1½ m. " " | 35° |
| " 2 m. E. " | 48° |
| " 3 m. E. " | 32° |
| " bottom of bay | 45° |
| " S. E. shore at 3 diff. points | 44° |
| Reef Point | 28° |
| Point, 1 m. E. S. E. of Reef Point | 38° |
| Shore, 1½ m. S. E. of Reef Point | 36° |
| Entrance to Stanji-koming Bay, north side | 40° |
| " " " south side | 28° |
| Stanji-koming Bay, E. shore | 31° |
| " " W. shore, 2¼ m. from S. end | 30° |
| " " " 1¼ m. " N. " | 18° |
| " " island, 1½ m. from N. end | 35° |
| Hay-marsh Bay, N. side | 48° |
| Island, ½ m. E. of Squall Point | 31° |
| Squall Point | 43° |
| Sand Bay, small island | 36 & 43° |
| " 1½ m. N. of Pither's Point | 43° |

*Turtle River Route.*

| | |
|---|---|
| Turtle River, 1¾ m. N. N. W. of Jones Lake | 44° |
| Big Turtle Lake, N. E. end of large island | 35° |
| Robinson Lake, W. side, near N. end | 42° |
| " " ¾ m. N. N. W. of outlet | 43° |
| Heron River, half-way from mouth to Heron Lake | 46° |
| Heron Lake, W. side, 1¼ m. N. N. W. of outlet | 53° |
| Little Turtle Lake, at mouth of Little Turtle River | 53° |
| Little Turtle Lake, S. shore, ¾ m. E. of Portage to Bad Vermilion Lake | 63° |
| " " " 3 m. from S. W. end | 63° |
| " " " 1 m. " | 61° |
| Sand Island River, Otter Falls | 33° |
| Redgut Bay, 2½ m. S. W. of mouth of Otukamamoan River | 48° |
| " 3¼ m. " " " " | 42° |
| " Porter Inlet, 2¼ m. N. E. of entrance | 23° |
| " " 2½ m. E. N. E. " | 43° |
| " W. shore, ½ m. N. of Pine Narrows | 33° |
| " west side Pine Narrows | 43° |
| Black Sturgeon Lake, S. side | 23° |
| Redgut Bay, 3 m. N. of Bear's Passage | 28° |
| Bear's Passage | 50° |

*Seine River Route.*

| | |
|---|---|
| Seine River 1 m E. of Partridge-crop Lake | 56° |
| Wild Potatoe Lake E. end | 36° |
| " " " S. shore 1¼ m from E. end | 48° |
| " " " S. shore at narrows | 50° |
| " " " N. shore at " | 40° |
| " " " S. " 1¼ m W.S.W. of narrows | 48° |
| " " " S. " at outlet | 58° |

Bearings of glacial grooves and striæ.

| | |
|---|---|
| Shoal Lake N. side 1 m from E. end | 45° |
| " " S. side 1½ m " W. " | 53° |
| " " N. " near outlet | 53 & 63° |
| Seine River opp. Kettle Pt. | 46 & 60° |
| " " ¾ m from mouth | 53° |
| Bad Vermilion Lake, Island Bay | 40° |
| " " " N. shore 3 m from S. W. end | 48° |
| " " " S. " 2 m " " " | 53° |

*East Arm of Rainy Lake—Pither's Point to Seine River.*

| | |
|---|---|
| South shore 1 m E. of Pither's Point | 48° |
| " " 2 " " " | 48° |
| Island 3 " " " | 33° |
| Island ¾ m N. of Medouganak Point | 33° |
| Medouganak Point | 46° |
| Entrance to Black Bay W. side | 48° |
| Lobstick Island | 53 & 28° |
| Island S. of Gash Point | 38° |
| Main shore N. of Lobstick Island | 41° |
| Cross Island | 43° |
| Main shore W. of Lichen Island | 48° |
| Rocky Islet Bay, W. side 1½ m N. of entrance | 36° |
| Rice Bay, at entrance S. E. side | 53° |
| " " N. W. side 1 m. S.W. of narrows | 48° |
| " " near bottom | 48° |
| " " 1 m. E.S.E. of narrows | 57° |
| Grassy Portage Bay, 1¾ m W. of Grassy Portage | 53° |
| Island 1¼ m. E. of Last Island | 40° |
| " 1 m. E.N.E. of Last Island | 43° |
| Pukamo Island E. end | 53° |
| Island ½ m E. of Cross Island | 41° |
| Nowhere Island N. side | 43° |
| Island 1 m. N. of Red Sucker Island | 38° |
| Red Pine Island S. side | 48° |
| Sand Point Island S.W. end | 43° |
| Dryweed Island E. end | 48° |
| Sand Point Island at Open-water Narrows | 48° |
| Goose Island S.E. point | 48° |
| Rest Island S. end | 38° |
| Goose Island W. end | 48° |
| Berry Island S. side | 43° |
| Little Rocky Narrows | 43° |
| Swell Bay S. side 1½ m N.W. of Little Rocky Narrows | 48° |
| Swell Bay E. end | 51° |
| Island 3 m W. Halleluiah Point | 48° |
| South shore, 2½ m W. of Brûlé Narrows | 53° |
| Bleak Bay, E. end | 56° |
| Seine Bay, N. side opposite mouth of Seine River | 53° |
| Seine Bay, bottom of bay | 58° |
| Halleluiah Point | 61° |

*Rainy Lake—Brûlé Narrows to Kettle Falls.*

| | | |
|---|---|---|
| Island ½ m S.W. of Point Observe | 73° | Bearings of glacial grooves and striæ. |
| " 2½ m S.W. of " " | 63° | |
| " at bottom of Saginaw Bay | 63° | |
| Shore ½ m S.W. of Pine Islands | 60° | |
| Lobstick Point | 33° | |
| W. shore opposite Oak Point Island | 28° | |
| Kettle Falls | 38° | |
| S. shore 1 m W. of Soldiers' Portage | 33° | |
| Soldiers' Portage | 33° | |
| W. shore opposite Oak Point Island | 33° | |
| W. shore ½ m N.E. of Oak Point Island | 36° | |
| Stokes Bay, south side | 58° | |
| Mouth of Pipestone River | 33° | |
| Pipestone River, 5 miles up stream | 53° | |
| " " 6 " " " | 43° | |
| N. shore 2 m N.N.W. of entrance to Stokes Bay | 43° | |
| Breezy Island | 40° | |
| N. shore 1 m N. of Breezy Island | 43° | |
| Vague Point | 48° | |
| Shore, ¾ m N.W. of Vague Point | 55° | |
| Mouth of Rat River | 58° | |
| Shore 1 m W. of mouth of Rat River | 59° | |
| Shore 3 m N.W. of Deer's Horn Point | 60° | |
| Brûlé Narrows E. side 1 m N.E. of Pt. Observe | 53° | |

*Rainy River.*

| | |
|---|---|
| Island 4 m above Manitou Rapid | 38° |
| S. side 1 m below Longue Sault Rapids | 24° |
| Pine River, first rapid | 24° |
| " " second rapid | 24° |
| South side ½ m above mouth of Rapid River | 38° |

## Post-Glacial Formations.

Rainy River, from its source at Rainy Lake to its mouth on the Lake of the Woods, flows through a country which is thickly covered by post-glacial formations. The earliest notice of scientific value, which I have been able to find of these post-glacial deposits, is that by J. J. Bigsby, M.D.,* who remarks that "throughout the whole length of the river La Pluie, its banks expose a grey clayey and loamy soil, full of small angular fragments of the yellow limestone of the Lake of the Woods, intermixed occasionally with round lumps of gneiss from the size of the fist to that of the head. I saw no marks of stratification, nor any marine or fresh water shells." J. E. Norwood, M. D.,† in run-

Previous notices.

Bigsby.

Norwood.

* Geol. Jour., Vol. VIII., 1851, p. 217.

† Report of Geol. Survey, Wisconsin, Iowa and Minnesota, by D. D. Owen, 1852, p. 319.

ning down the river from Rainy Lake to the Big Fork, noted that "while descending Rainy River, a bed of blue clay was observed similar to that seen and described on St. Louis and Embarras rivers. It is full of gravel and overlaid by a bed of yellow sand." S. J. Dawson* also has noted that "the land immediately bordering on Rainy River, on the British side, is of an alluvial description, and almost as uniformly level as the prairie at Red River."

Dawson.

Dr. Bell † states that "the banks of the Rainy River, except in approaching the Lake of the Woods, are generally from fifteen to twenty feet high, and are composed of clay and drift materials in which pebbles and boulders of a yellowish grey limestone are plentiful."

Bell.

These brief notes by earlier observers of the formations through which Rainy River cuts its way, do not give a sufficiently clear or comprehensive account of their character, their distribution or their geological history. I shall, therefore, attempt to supplement them by observations I have been enabled to make in the field myself, as well as to point out the connection of the facts adduced with those that have been observed by others in the study of post-glacial phenomena in adjoining regions. I am at a loss to understand Dr. Bigsby's statement that he saw no marks of stratification in the banks of the river. There are abundant and distinct evidences of the deposition of the greater part of the formations in stratiform layers or beds. They are first observed on Rainy Lake on the west shore of Sand Bay, as bedded clays. Between Rainy Lake and Fort Frances, the banks of the river are composed of light colored, more or less, sandy and calcareous clays with numerous pebbles of yellow or cream-colored limestone. The banks rise about ten or twelve feet above the surface of the river at its mean height, and the country back from the river is flat. Below the Falls of Fort Frances the river sinks in level, between 22′ and 25′. And as the surface of the country remains flat, the height of the river banks below the falls is increased by this amount. The banks here present a more or less steeply scarped aspect, a character which they retain almost continuously to the mouth of the river, although there are occasionally short stretches of sloping banks or low shores which are wet or dry, according to the height of the water in the river. For a long distance down the river from the falls, evidences of stratification are not very prominent in the banks. The clay is very calcareous or marly, and crumbles readily when dry, forming a steep talus. The bedding can, however, be seen occasionally in the short scarp which rises above this talus quite distinctly. In these cases, thicker beds of a calcareous

Evidence of stratification.

Character of beds.

Steeply scarped banks.

* Report on the exploration of the country between Lake Superior and the Red River settlement. Appendix to Vol. XVII. of the Journals of the Legislative Assembly. Session 1859.

† Report on the country between Red River and the South Saskatchewan, with Notes on the Geology of the Region between Lake Superior and Red River, 1873.

or sandy clay, with numerous small pebbles, are generally separated by thin partings of purer unctuous clay. The thicker beds usually vary from 2″ to 6″ in thickness, and are often much more sandy than clayey. For the first three miles below the falls, the underlying glaciated rocks upon which the formation rests crop out occasionally on both sides of the river. From these exposures I should judge that the mean level of the rocky surface of the country along this part of the river would be but little below the surface of the river, and that we have in the height of the banks a vertical section nearly equal to the mean thickness of the formation which would, therefore, be between 30′ and 40′. After turning the bend three miles below Fort Frances, no rocks crop out along the river for over twelve miles. Throughout this distance, the character of the banks varies but little and presents only a few points of special interest. On the Indian Reserve opposite the mouth of Little American or Little Fork River there is a peculiar terrace-like ridge running parallel with the river a few hundred feet from the water's edge. It is observable only for a short distance where the Indians have cleared away the bush. Between the Little and Big American Rivers on the Canadian side there can be seen an extensive, apparently unstratified mass of clean, unctuous, blue clay underlying the bedded marly clays and sands of the upper portion of the bank. Below the Big American River the bedded clays, sandy and marly clays and sands prevail, and the lower unstratified blue clay was not again observed for a considerable distance. On Mr. George Singleton's farm, (Sec. 9, Tp. 5 S. R., XXVIII,) the glaciated surfaces of the old rocks outcrop from beneath these post-glacial deposits, not only on the river banks, but over a considerable area in the rear of his farm, the rock being a hornblende-syenite gneiss. Rock exposures are more common from this point on to the bottom of the Longue Sault than anywhere else along the river, and some of the more prominent points appear to have been islands in the fresh water lake, in which the post-glacial formations were deposited. The latter cannot be on the average much more than 25′ or 30′ thick along this part of the river. The surface of the country rises gently, however, on the north side of the river, and at the back of Mr. Lutterel's farm, Sec. 22, Tp. 5, S. R. XXVIII, a low flat gravel ridge was observed which probably lies on top of the beds exposed at the river bank. Between this point and Manitou Rapid many more boulders of Archæan rocks were observed imbedded in the strata of the river banks than had been noticed higher up the stream, although they are not prominent near the rapid itself, the formation, as observed by Dr. Bigsby,* being unusually clayey there. Near the eastern limit of the Indian

Thickness of formation.

Terrace-like ridge.

Blue clay.

Rock exposures.

Gravel ridge.

Unbedded clay.

*Loc. cit.

Reserve at Manitou Rapid there may be seen on the north side of the river a mass of unbedded clay with pebbles to a thickness of 10′ to 15′ above the surface of the river, and resting upon this 4′ of evenly bedded sandy clay in which the pebbles are mostly yellow colored limestone. Down near the rapid these upper beds are wanting just at the water's edge and the lower clay only is seen. This lower clay is probably the same formation as that noted between the Big and Little American rivers.

Beds below Longue Sault.

Below the Longue Sault Rapids for some miles the banks of the river on either side, wherever the scarped faces permit of close observation, shew only bedded marly clays, and clayey sands with pebbles. If the unstratified lower clay underlies these beds, as appears quite probable, it is concealed by the soft talus that has fallen from the scarp. Mr. Cameron informed me that he had sunk a well four miles back from the river on a logging road, Sec. 21, Tp. 4, S. R. XXV., for 22′, and had bored a further 40′ through formations similar to those on the bank of the river before he struck solid rock. He obtained water at this depth of 62′, but found it extremely hard, a fact due to the abundance of calcareous matter in the loose strata through which water must percolate before reaching the comparatively impermeable surface of the underlying hard rocks. The formations up the Pine River, as far as the second rapid, are, as on Rainy River, bedded marly clays and clayey sands together with gravel made up very largely of limestone debris. At the first rapid on Pine River a gravel ridge which lies on the glaciated surface of the rock has been cut into by workmen engaged in the construction of a dam across the rapid. The gravel is rather fine, mostly calcareous, and much mixed with clayey matter. In it were found large numbers of fresh water-shells together with some fragments of bones of the buffalo (*Bos Americanus*, Gmelin.) Fresh-water shells were also found in the beds on Rainy River, at the confluence of Pine River, and at various points below this, particularly, however, in the bedded sands and clays at the mouth of Beaudette River. Although the shells at these points are numerous, the species are few. The following have been identified by Mr. Whiteaves, *Sphærium sulcatum*, Lamark; *Sphærium striatinum?* Lamark; *Planorbis* (*Helisoma*) *bicarinatus*, Say; *Limnœa* (*Limnophysa*) *desidiosa?* Say (one, broken). Near the confluence of Beaudette River and from that point on to the mouth of Rainy River, the banks still retain their abruptly scarped aspect rising from 10′ to 20′ above the river, but the formations composing them gradually change in character, and the clay gives place to a fine light-yellow muddy sand, bedded often with very thin partings of clay. A third of the way from Beaudette River to the mouth of Rainy River, this yellow sand is

Well.

Pine River.

Remains of Buffalo.

Freshwater shells.

observed to rest upon a pebble conglomerate made up of limestone and Archæan pebbles imbedded in a partially hardened mud matrix. Conglomerate.

At the south-east corner of the Lake of the Woods these post-glacial deposits of sand have been much modified and altogether re-arranged by the currents incident to the discharge of a large river, by the waves of a large open expanse of water exposed to the full force of the west wind, and by the wind itself wherever they are exposed above the surface of the water and unprotected by vegetation. About three miles west of Rainy River there runs out from the south shore of the lake, in a direction 65°, a sand spit three miles and a-half in length. The sand on this spit has been blown by the wind into dunes and ridges which are now partially protected by vegetation. At the extremity of this spit, on Oak Point, the main current from the river discharges into the open lake. On the other side of this gap of half a mile, through which the current sweeps, the sand spit is continued in a long barrier running parallel with the shore, or in a direction 40°, as far as Burton's Island, a distance of six miles and a-half from the gap above mentioned. Portions of this barrier are only revealed above the surface of the lake in seasons of low water, and its breadth varies according to the height of the water. It is, however, very narrow compared with its length, and is for the most part a prominent ridge standing out boldly against the sky in a series of wind-blown dunes which rise from 10′ to 40′ above the level of the lake. The sand is of a light yellowish color, and of varying degrees of coarseness. It is composed chiefly of quartz and felspar grains. In the dunes may sometimes be detected a bedding due to the action of the wind, and the process of sorting out the different sands in layers according to their coarseness and the strength of the wind, may be observed in actual operation. The channel or open lagoon, which lies between the shore and this barrier, varies in width from half a mile to a mile and is silting up on the shore side, there being, apparently, a weak side current from the river along the inside of the barrier which keeps it free of the grassy vegetation which prevails closer to shore, and which catches the fine silt in seasons of high water. Sand-spit. Sand-barrier. Dunes. Bedding due to wind.

The shore of the lake from Burton's Island north-eastward to the Indian Reserve north of the mouth of Little Grassy River is mostly sand of the same character as that of the barrier, and has been much modified by wave action. Windy Point is a long sand-spit and the island to the north-east of it partakes of the nature of a delta. The water for considerable distances off shore along this stretch of coast is very shallow. On the Indian Reserve 35 E., bedded clays similar to those on Rainy River are again observed in low scarped banks. The shore of the bay on the north side of this reserve was the most northerly point along this coast at which these deposits were observed. S.E. shore of lake. Bedded clays on Indian Reserve 35 E.

Further distribution of bedded clays.

Here they consist of clayey limestone gravel and marly clay in beds. The same formations occur together with much sand on Bigsby Island, and in places on the south and west side of Big Island. Their occurrence on Cornfield Island was noted in my report of 1885. West of Cornfield Island, the northern limit of the distribution of these post-glacial beds bends more to the north, for they are found on the shores of the North-west Angle Inlet, and probably underlie the extensive flat country to the south-west of the inlet and west of the Lake of the Woods. At the south end of Shoal Lake great sandy stretches occur and at the north-west corner of Shoal Lake, in the neighborhood of Indian Bay, the bedded clays are again observable. The northern limit of the flat country underlaid by these post-glacial deposits appears, from such information as I can gather from those familiar with the country, to cross the C. P. railway in the neighborhood of Whitemouth, and such deposits appear thereafter to be in direct continuity with the prairie country of Manitoba.

Country north of Rainy River.

In the country north of Rainy River it appears, from information supplied by the reports of Mr. S. J. Dawson,* Mr. T. O. Bolger,† and from the plots of the township surveys as well as from my own observations, that these post-glacial formations, through which the river cuts its way, extend back to an average distance of about twenty miles, or to a line connecting the N.W. corner of Sand Bay on Rainy Lake with the northern limit of Indian Reserve 35 E. on the Lake of the Woods.

Northern limit of post glacial formations.

Thus it appears to be possible to trace approximately the northern limit of a great sheet of post-glacial deposits from Rainy Lake to Whitemouth, a distance of 150 miles. The line defining this limit is more or less sinuous, so far as can be made out, but its general direction is remarkably straight and *has a course which is approximately at right angles to the direction of the glacial grooving* in the exposed rocky region immediately to the north of the line. This sheet of post-glacial deposits appears to extend indefinitely to the south, and from various sources of information‡ the flat country underlaid by them appears to be in direct continuity with the prairie country of western Minnesota, Dakota and Manitoba. The body of water in which these formations were deposited appears to be the same, as stated in my report of 1885 with Mr. Upham's Lake Agassiz.§ According to

Lake Agassiz.

* Exploration of country between Lake Superior and Red River Settlement, 1859.

† Report of Commissioner of Crown Lands of the Province of Ontario, 1886, p. 48 et seq.

‡ Reports of Progress together with a Preliminary and General Report on the Assiniboine and Saskatchewan Exploring Expedition, by H. Y. Hind, M.A., 1859. Report VII.

Geol. and Resources of 49th Parallel, G. M. Dawson, 1875, p. 212.

Information received from Mr. Thompson, who was engaged upon a preliminary survey of a railway from the mouth of Rainy River to Red River across northern Minnesota.

§ Eighth Annual Report, Geol. and Nat. Hist. Survey of Minn. 1879, p. 84, et seq.; Eleventh Report 1882, p. 137-153; also Bulletin 39, U.S. Geol. Survey.

Mr. Upham's determination of a northerly upward slope of the surface of Lake Agassiz as it approached its northern ice barrier* there would be by his estimate 150 feet of water above the present level of Rainy Lake and much more above the present level of the Lake of the Woods. This being the case, the waters of Lake Agassiz ought to have extended far to the north of Rainy Lake and Lake of the Woods, and the fresh water deposits, which I have sketched as stretching to the south of a line drawn from Rainy Lake to Whitemouth, should also extend far to the north of that line, since there is no sufficient rise of the land along the line against which the waters of Lake Agassiz could form a shore. As a matter of fact, no old beaches have been observed along the northern limit of the fresh-water formations. Hence, if Lake Agassiz stood at this elevation, the only explanation that will account for the non-continuance of the lake deposits to the north, is the supposition that the line which defines the northern limit of those formations is approximately also *the line of the ice-barrier which dammed back the waters.* Against the base of such a barrier there would be no beaches formed, since it would be in deep water, but a gradual overlapping of strata in flat layers as the ice receded. There are, however, some facts which have yet to be reconciled with this hypothesis. These are the occurrence of areas of post-glacial deposits in the country to the north, and numerous gravel ridges and other deposits which are known to exist, but have not yet been studied. In valleys tributary to Rainy Lake, such as the basin of the Seine River and that of the Turtle River, there are local deposits similar to those on Rainy River which may perhaps be regarded as having been formed in arms or bays of Lake Agassiz. These deposits appear to lack a feature which is very characteristic of the deposits along Rainy River, viz., the presence of pebbles of cream colored or yellow Silurian limestones. The northern limit of the distribution of this limestone drift has been noted by Bigsby, Dawson and myself, and it appears to be coincident with the line that has been sketched as limiting the northern extension of the post-glacial formations. The limestone pebbles and boulders, while doubtless derived in the first instance from the Silurian rocks of the Red River basin, appear on the Lake of the Woods to come immediately from the post-glacial strata in which they are imbedded. Their glacial origin is attested by the very common and distinct striation observable upon them; which fact also attests that they have been very little water-worn since their escape from the foot of the glacier, the inference being that the clayey strata in which they are imbedded were derived largely from the same glaciers. With regard to other isolated patches of post-glacial formations, it is to be noted

Northern barrier of Lake Agassiz.

Other local deposits.

Source of limestone pebbles.

* Bulletin cit. p. 15.

that those of any considerable extent that are known, such as that near Lake Wabigoon, appear to lie on the north side of the height of land, and may have been formed at a somewhat later stage of the recession of the ice barrier, after Lake Agassiz had shrunken to a fraction of its maximum size. On this assumption the lake in which the deposits around Wabigoon were deposited would have had the height of land for its southern barrier and probably the ice for its northern. There are few facts, however, as yet to support such speculations, and they are only suggested by the analogies which the results of Mr. Upham's work naturally lead us to look for.

## Economic Geology.

Prospective development.

The country mapped on the Rainy Lake and Rainy River sheets, accompanying this report, presents, in the geological features which have been described, conditions which are favorable to its development both as an agricultural and mining district of considerable importance. The lumbering industry is already fairly well established there, the greater part of the timber which is sawn at the numerous mills near Rat Portage and Keewatin being brought down the Rainy River. The fur-trade, also is an active industry, trapping being the chief occupation during the winter months of the numerous bands of Indians who inhabit the country, while in the summer they support themselves by fishing, shooting and rice-making.

Agriculture.

Agriculture is perhaps the most promising of the economic prospects of the region. Rainy River, from its source at Coutchiching to Hungry Hall, flows for eighty miles through a rich alluvial plain, which, so far as can be judged from the banks of the river, is eminently adapted to support a large agricultural population. Travellers and explorers vie with one another in praising the beauties of the river and its capabilities for settlement. Mr. S. J. Dawson in his "Report on the Exploration of the Country between Lake Superior and the Red River settlement" says of it, "The distance from Rainy Lake to the Lake of the Woods, following the windings of the stream, is about eighty miles, and throughout the whole of this extent the land fronting on the river is fit for settlement without, I may say, a single break; indeed, I have never seen anything to equal it in my experience, except at Swan River and on the Assiniboine. Farther inland, although the ground becomes in many places swampy and broken, there must be a fair proportion also fit for settlement, but to ascertain anything like the precise area that is so, would require a closer examination than we have as yet been able to bestow." Prof. H. Y. Hind in his account of the country examined by the same expedition says of the land along

Mr. S. J. Dawson's opinion.

Rainy River: "The average breadth of superior land for a distance of seventy miles might perhaps, with propriety, be assumed to be not less than six miles, giving an area of available soil of high fertility, exceeding two hundred and sixty thousand acres; and there can be little doubt, that with the progress of clearing, much that is now included in the area occupied by swamp, would, without difficulty or expense, be reclaimed." In another paragraph the same authority says: "No part of the country through which we have passed from Lake Superior northwards can bear comparison with the rich banks of the Rainy River thus far. The river has preserved a very uniform breadth, varying only from about 200 to 300 yards. The soil is a sandy loam at the surface, much mixed with vegetable matter. Occasionally, where the bank has recently fallen away, the clay is seen stratified in layers of about two inches in thickness, following in all respects the contour of what seems to be unstratified drift clay below. Basswood is not uncommon, and sturdy oaks, whose trunks are from eighteen inches to two feet in diameter, are seen in open groves, with luxuriant grasses and climbing plants growing beneath them." Prof. Hind's opinion.

A more recent authority is Mr. T. O. Bolger, P.L.S., who explored the region in the summer of 1886, for the Department of Crown Lands of Ontario, with the special object of ascertaining its fitness for settlement. His description and opinions are more valuable than the preceding, and they are even more optimistic. He says: "I first encountered good land at the point where the forty-ninth parallel or the first base strikes the Lake of the Woods, and following up Little Grassy River, which empties into the lake, a couple of miles south of this point, I found, from travelling in every direction, that the block of four townships composed of townships one and two south, ranges twenty-three and twenty-four east, contains a large percentage of the finest land I have ever seen, and the same description applies to the block of land lying westward between these townships and the Lake of the Woods. Little Grassy River is navigable for canoes for a distance of about eight miles from its mouth, and the land on the shore is all good, being composed of a rich calcareous drift formation, equal to any soil in the best agricultural districts of Ontario. Mr. Bolger's description of soil of Rainy River country. Little Grassy River.

"The timber along the river is chiefly large thrifty poplar, mixed with some scattering oak and swamp elm, and some evergreens such as balsam and spruce; inland, the timber changes in character somewhat from that along the river shore, as large balm of Gilead, spruce, balsam and tamarac are met with more frequently, and the nice open bush which prevails along the river banks is changed for a tangled brushy undergrowth; but the character of the soil remains the same. Tamarac and spruce swamps occur frequently in this section of the country, as Timber on Little Grassy River.

is the case all throug is large level area of good land which lies along the banks of Rainy River. These swamps were all perfectly dry this summer, and are nearly all capable of being made into excellent land by drainage, as they lie nearly as high as the surrounding dry lands, and only require proper ditching to take the surface water off in wet seasons. The extreme levelness of the country causes the presence of so much swamp land here, as the surface water has no means of escaping from the low-lying portions, and consequently the growth of moss and swamp timber is engendered. I noticed that in most cases the beds of the little streams are deep enough to form outlets for ditches and drains, and these creek beds are usually so numerous that to drain any swamp no very long ditches would be required; in nearly all the swamps through which I passed I observed the soil to be a black vegetable mould, varying in depth from one to three feet, and always underlaid by the same calcareous clay above alluded to. I seldom met the muskeg proper, that is to say, the wet shaky bog in which water is present at all seasons of the year, and which grows nothing but dwarf spruce and moss. I then paddled up Rainy River, and on both shores I found the same kind of country as I have described as being in the vicinity of Grassy River, and as there are a good number of settlers along the river on the Canadian side, I had an opportunity to observe the soil while under cultivation, and to see the kind of crops it is capable of raising.

Swamps drainable.

Soil.

"The soil I found to be most excellent in character, calcareous clay overlaid by a thin streak of whitish fine earth about six inches in thickness, and this again covered with a coating of vegetable mould, and these three mixed up together in the working of the land form a soil which cannot be excelled in any part of the Dominion. I saw along the river crops of potatoes, turnips, hay, oats, wheat, corn, tomatoes and cabbage, all grown to perfection this season, which shows that the climate, as well as the soil, is suitable to successful farming, especially when tomatoes ripen as they certainly did this year as well as I ever saw them ripen in the vicinity of Lake Ontario.

Crops.

"As I went up the river I frequently travelled inland several miles, and at the easterly side of township three, range twenty-four, I penetrated northward to the section I had explored from Grassy River, and found that the calcareous clay formation extends at this point clear from the Lake of the Woods to Rainy River, a distance of over twenty miles in a straight line; I found a tremendous bush fire raging along the first correction line south, which was destroying everything before it; in fact bush fires were very frequent in this part of the country this season, owing to the extremely dry weather. There is an area of pine land in here a little north of the first correction line south, where

Pine.

the soil is inclined to be sandy, but the exten[illegible] this tract is not very large.

"Along the line dividing ranges twenty-six and twenty-seven the good land extends back some twelve miles from the river, but towards the north-east corner of township three the rough regions begin to appear, and away to the northward the country is broken and rocky, and the good land disappears. Broken country.

"Township three and the north part of township four, range twenty-seven, have been burnt over some years ago, and are now grown up with small second growth of poplar.

"Townships four in ranges twenty-eight, twenty-nine and thirty, are mostly all good land; while townships three in the same ranges are generally broken with rocky ridges, but contain some excellent land in the valleys among the hills; townships two, ranges twenty-seven and twenty-eight, also contain some good land, although broken by rocky hills.

"A straight line drawn from the south-west corner of the large Indian Reserve on Big Grassy River to Fort Frances would approximately form the north boundary of the good belt of land, while almost all the country lying between this line and Rainy River and the Lake of the Woods is good agricultural land. This tract of country is over sixty miles long, and averages over fifteen miles wide, and contains over nine hundred square miles, or something like six hundred thousand acres, and has a water frontage on the Lake of the Woods and Rainy River of over one hundred miles. Of this area, perhaps thirty per cent. is swamp, most of which can be drained and made tillable land, rocky ridges occur very rarely, and the soil is all a limestone clay such as I have described. No limestone rock in place has been observed, but loose limestones containing fossils are frequently to be met along the rivers, and the settlers along Rainy River pick them up and burn them into excellent lime; in fact this whole district is a glacial drift. Extent of good agricultural land.

"The timber is chiefly poplar which grows to a great size; I have seen trees over eighteen inches across the stump and sixty feet long clear of the limbs. Balm of Gilead, too, prevails in some sections, while spruce, tamarac and balsam of thrifty growth are everywhere met with. In some places magnificent cedar abounds large enough for telegraph poles, shingle bolts, or any other use to which cedar is applied; there are some groves of pine through this section, but it cannot be called a pine country, that is, on this drift formation." Timber on Rainy River.

Such testimony as to the character and value of the land through which Rainy River flows leaves little for me to say beyond expressing my entire concurrence in the opinions quoted as to the great suitability of the country for settlement and agriculture. Settlers are

going in gradually, and there are some excellent farms along the river front, the chief market for produce being the town of Rat Portage and the milling population between it and Keewatin. With the settlement of the question of civil jurisdiction, and the prospect of the railway which is projected to run through the valley, a more decided influx of settlers may be expected, and all the lots along the river front will doubtless soon be occupied and cleared. The river affords an easy means of access, and the levelness of the country renders roads easy to build.

Settlement.

Other patches of good land.

Other small isolated patches of flat-lying land, probably old post-glacial lake bottoms, which would be suitable for agricultural purposes occur to the north and east of Rainy Lake. One of these is on Big Turtle River, and another smaller one, now occupied by Indians, is on Seine River.

Mineral resources.

The economic value of the Rainy Lake region, as regards its mineral resources, is entirely prospective. There are no mines in the region, and extremely little search has been as yet made for mineral deposits. It is, however, quite probable that when such search is made, the various minerals will be found which are more or less common elsewhere under the same conditions as those which obtain here. The Keewatin rocks of the Rainy Lake region are the same as those in which the gold of the Lake of the Woods occurs. In them deposits of iron may confidently be looked for. Indeed on Seine River, good indications of iron ore have already been discovered, and farther up the river, beyond the limits of the region mapped, valuable deposits have been found on the Atic-okan. Iron pyrites, copper pyrites and arsenical pyrites are very common in small quantities in the Keewatin rocks and will doubtless some day be found in valuable deposits in some portion of the belt. Lead and zinc ores may also possibly be discovered. The occurrence of bosses of serpentine suggests the possibility of diamonds, and some enterprising prospector may yet be rewarded for a close examination of the vicinity of the serpentine rocks indicated on the map, or of others that may be discovered, particularly if they be found near the carbonaceous schists that sometimes occur in the Keewatin. Asbestus should also be carefully searched for in these serpentine rocks. Poor varieties were observed in veins in the serpentine of Clear-water Lake. Closer examination may reveal the finer and more valuable varieties. Good soapstone is not uncommon in the Keewatin rocks and will some day be of value. Limestone in small quantities has been observed on Manitou Lake, associated with the green schists. Good roofing-slate has not been observed, but occurs in the Keewatin series on the Lake of the Woods. Some of the more siliceous schists would make good whetstones, and the finer-textured

felsite schists good hones. The development of these various resources will, however, only come with the gradual settlement of the country, as it is only the discovery of the more valuable metals in large quantities that will create a sudden influx of prospectors and mining population.

In the dykes and irregular masses of pegmatite which break through the rocks of the Coutchiching series on the south-east arm of Rainy Lake and on Nemeukan Lake, white mica occurs abundantly, but unfortunately not often in sheets over two inches in diameter. If these pegmatites were carefully prospected, local developments of large and valuable sheets of white mica would very probably be found in paying quantities. Mica.

The Laurentian rocks of the region are, so far as they are known, perfectly destitute of metalliferous deposits, except in one instance, where, at the immediate contact of these rocks with the schists of the Coutchiching at the Bear's Passage, a quartz vein occurs in which flakes of molybdenite are common. Even in this instance it is difficult to say whether the vein is not as much in the Coutchiching as in the Laurentian, the contact of the two being a brecciated one. This remarkable barrenness of the Laurentian rocks, as contrasted with those of the upper Archæan, is a fact of great interest as well as of practical importance to the prospector. On the map accompanying this report, the distribution of the Keewatin rocks is mapped distinctly, so that prospectors for gold, or iron, or any other of the metalliferous ores, need not waste time examining the Laurentian country. Barrenness of Laurentian rocks.

The reason why the Keewatin series should be metalliferous and the Laurentian barren of metals is a theoretical question which need not be gone into at all fully here. It may, however, be briefly indicated that the fact is quite in harmony with the interpretation of the geology of the region which has been given in the earlier pages of this report. It has there been shewn that the Keewatin series is largely made up of volcanic rocks, while neither the rocks of the Coutchiching nor of the Laurentian are volcanic. From this it is inferred, as has been established in many parts of the world, that the presence of metalliferous deposits is intimately associated with the volcanic rocks. It has also been shewn that the Laurentian or lower Archæan rocks have very probably resulted from the plutonic fusion and recrystallization of the floor upon which the upper Archæan was deposited, and that such fusion has included portions of the upper Archæan formations. Such fusion would effect the dissemination throughout the magma of whatever metalliferous deposits existed, so that on recrystallization, the ores would only be found in the minutest traces, while the existence of an extensive magma underlying the unfused rocks of the upper Archæan may have Theoretical considerations.

been an important factor in the production of the numerous veins found in them.

Value of post-glacial formations.

In the post-glacial formations of Rainy River, the clays, sands, and limestone boulders are all of economic value. Some of the lower blue clay seen on the banks of the river appeared to be very pure and capable of being worked for pottery. Other clays would make good bricks. Much of the sand intercalated with the clays would be serviceable for building purposes, and some of that at the mouth of Rainy River would be good for glass making. The limestone boulders are occasionally burned for lime by the settlers.