CANADA

DEPARTMENT OF MINES

Hon. P. E. Blondin, Minister; R. G. McConnell, Deputy Minister

GEOLOGICAL SURVEY

MEMOIR 95

No. 77, Geological Series

Onaping Map-Area

BY

W. H. Collins

OTTAWA
Government Printing Bureau
1917

No. 1655

PLATE I.

Vermilion river near Gowganda Junction, Canadian Northern Ontario railway

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CHAPTER I.

INTRODUCTION.

Onaping map-area, with which this report deals, is one of the units into which the Geological Survey formerly subdivided Ontario for purposes of systematic geological exploration: hence its exact rectangular form and dimensions, 72 miles long from east to west, by 48 miles wide.

Until a few years ago this particular area could be reached and traversed only with the aid of canoes, the nearest railway point being 25 miles away. Even canoeing was not an easy means of access, for the area lies along the height of land between Hudson bay and the St. Lawrence, and the streams draining it are, consequently, small and full of rapids. Partly for this reason, it remained less known than the adjacent country. Neither had any valuable mineral deposits been discovered in it that would stimulate exploration. It is true, placer gold was found in Vermilion river and iron formation was discovered at Burwash lake, Shiningtree lake, and elsewhere, which induced the Ontario Bureau of Mines to investigate each of these localities; but none of the discoveries proved to be profitably workable and the geological investigations were soon abandoned.

Between 1906 and 1910, however, the prospecting boom that began in the Cobalt silver-mining district spread into Onaping area. A large number of prospectors were attracted there by the similarity of the diabase sills to those at Cobalt and the consequent chance of finding silver ores associated with them. At about the same time—between 1909 and 1912—the main line of the Canadian Northern Ontario railway was built across the area, making access to it much easier. The interest aroused by the vigorous prospecting for silver and the activity that accompanied and followed railway construction led the Geological Survey to undertake a systematic exploration of the map-area in 1909. This work, concluded in 1913, forms the basis of the present report.

There were no serviceable maps of the area when the work was begun, so geological work and the surveys of lakes and streams necessary to make a geographical base map had to be carried on together. For the latter purpose all navigable canoe routes were surveyed with Rochon micrometer and prismatic compass. Fortunately the country was at that time being subdivided into townships by the Ontario government, and these surveys kept pace with our work. The freshly run township boundaries made excellent controls for the less precise micrometer surveys, and facilitated traverses inland from the waterways.

Elevations of lakes were obtained by carrying series of hand-level measurements along canoe routes where most of the change in level is represented by rapids, falls, or short portages, and is, therefore, readily measurable. These measurements were connected to well established levels on the Canadian Northern Ontario and the Timiskaming and Northern Ontario railways.

There are no roads in the area; all travel is done in canoes along the streams and lakes. To a considerable extent these conditions determined the method of geological exploration. Preliminary geological observations were made along the navigable waterways with the aid of canoes; but the greater part of the geological information was obtained from traverses made on foot through the woods. Direction was measured with compasses and distances by pacing or rapid chaining. Traverses of this kind are slow and somewhat arduous, but these disadvantages were offset by the abundance of rock exposures.

During the three seasons spent in this area a large number of assistants were employed. Among these, credit must especially be given to H. C. Cooke, J. J. O'Neill, T. L. Tanton, and J. R. Marshall, each of whom worked more or less independently. Mr. O'Neill mapped 330 square miles in the southeast corner of the area, and 720 square miles along the western side were explored by Mr. Marshall.

POSITION AND MEANS OF ACCESS.

The situation of Onaping map-area, or Sheet No. 139 Ontario series, is indicated on Figure 1. It is 72 miles long and 48 miles wide; its centre lies 50 miles north of the town of Sud-

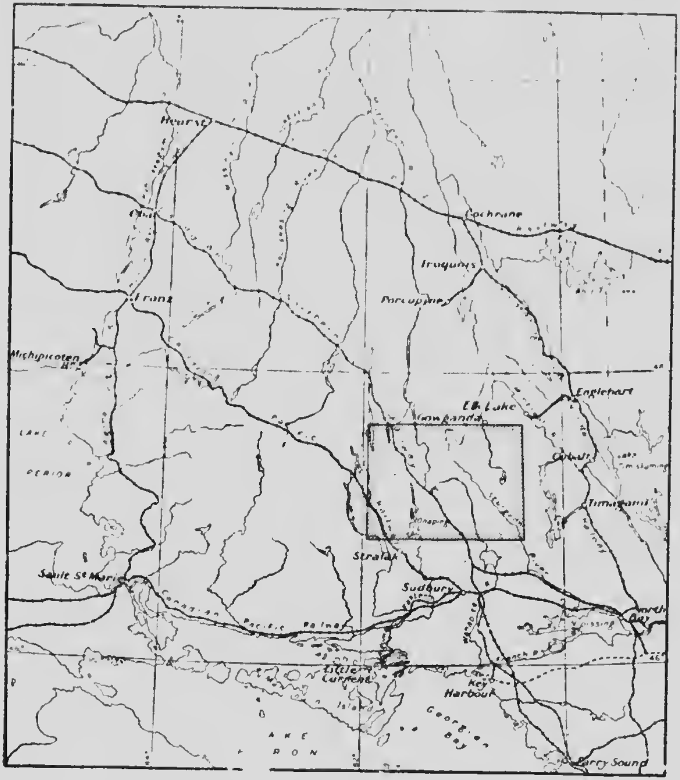

Figure 1. Location of Onaping map-area.

bury. The railway connexions are sufficiently well shown in Figure 1, but other subsidiary means of access deserve description. From Bannerman siding on the Canadian Pacific railway a 9-mile wagon road leads to Onaping lake, whence most points in the western part of the area are accessible by canoe. The eastern part of the area is best reached from Timagami st tion on the Timiskaming and Northern Ontario railway. Small power boats run from the station to all parts of lake Timagami, which reaches almost to the edge of Onaping map-area. Beyond the lake canoes have to be employed. A 27-mile wagon road connects Gowganda, at the northern edge of the area, with a branch line of the Timiskaming and Northern Ontario railway at Elk Lake. During the summer practically all points within the area can be reached by canoe.

PREVIOUS WORK.

Geographical. The first accurate geographical information about Onaping area was obtained during the location of a ronte for the Canadian Pacific railway. In 1880, W. A. Austin ran a trial line up Sturgeon river to Paul lake, thence northwest by way of Welcome lake to Wanapitei river, and thence past Opikinimika and Nebwagwissi lakes to Mattagami lake. The southwest corner of the sheet was also thoroughly explored in selecting a final location for this railway.

Subdivisional work in the region was commenced by the province of Ontario in 1888, when H. B. Proudfoot surveyed the first 18 miles of the Algoma-Nipissing boundary north to the northwest corner of Creelman township, and from that point ran a base line west for 42 miles. In 1896, Alexander Niven continued the boundary northward beyond the limits of the map-area. Creelman township was surveyed in 1898, but subdivision of the country into townships did not seriously begin for another 10 years. At present, all but the extreme western part of the map area is surveyed into townships 6 miles square.

The exploration and location surveys of the Canadian Northern Ontario railway have also added to the geographic knowledge of the area.

Geological. The first geological work in Onaping map-area was done by Robert Bell. In 1875, he traversed Wanapitei, Chiniguchi, and other lakes leading to Sturgeon river, ascended that stream, crossed by way of Stull and Scarecrow lakes to Smoothwater lake, and descended Montreal river. His account[1] of this journey contains a description of the rocks seen along the route, but is not accompanied by a map. While investigating the Sudbury map-area, during 1888-90, Bell extended his work at some places northward into Onaping area. His report[2] contains brief descriptions of the rocks seen along Onaping lake, and of the country north of Wanapitei lake. The eastern edge of the area was given a similar incidental examination by A. E. Barlow[3] during his exploration of Timiskaming map-area, which lies next to the east.

Since 1896 portions of the area have been examined for the Ontario Bureau of Mines. In that year, E. M. Burwash accompanied Niven's survey party as geologist and explored the country for several miles on either side of the Algoma-Nipissing line. His report[4] contains a geological map, on a scale of 2 miles to 1 inch, of the area studied by him. Placer gold was found in the sands of Vermilion river in the autumn of 1896 and the next year A. H. Gracey[5] was sent to examine the placers. His report includes some geological information regarding the region of the headwaters of Wanapitei and Vermilion rivers and Meteor lake.

In 1899, W. A. Parks[6] traversed the east branch of Spanish river and Minisinakwa lake, while on his way to work out the geology along the northern part of the Algoma-Nipissing boundary. He gives a description of this canoe route and of the rocks exposed along it.

Of the ten large parties sent out in 1900 by the Bureau of Mines to explore northern Ontario,[7] party No. 3, with J. R. L. Parsons as geologist, crossed parts of Onaping area. They followed the route taken by Bell in 1875 and that to Mattagami lake taken by Parks. The geological report adds little to the

[1] Geol. Surv., Can., Rept. of Prog., 1875-76, pp. 294-342.
[2] Geol. Surv., Can., Ann. Rept. 1890-91, part F.
[3] Geol. Surv., Can., Ann. Rept. 1897, part I.
[4] Rept. Ont. Bureau of Mines, 1896, pp. 167-184.
[5] Rept. Ont. Bureau of Mines, 1897, pt. III.
[6] Rept. Ont. Bureau of Mines, 1901.
[7] Report of the survey and exploration of northern Ontario.

descriptions of Bell and Parks, but it is supplemented by a geological map on an 8-mile to 1-inch scale.

The discovery of Moose Mountain iron range in Hutton township directed the attention of the Bureau of Mines to several other bodies of iron formation in this area. In 1901, A. P. Coleman[1] visited and described the iron range and other geological features near Shiningtree lake. The same year, W. G. Miller[2] visited Moose Mountain iron range and vicinity; his report calls attention to the probable alignment and original continuity of this iron range with a similar formation north of Wanapitei lake. The outlying extensions of Moose Mountain iron range in Roberts and Botha townships were reported on by Coleman in 1904.[3]

A systematic exploration of Onaping map-area was begun for the Geological Survey in 1906 by W. J. Wilson,[4] but was discontinued after one season's work.

In 1909 the townships of Charters, Leith, Nicol, and Milner were mapped in detail for the Ontario Bureau of Mines by A. G. Burrows.[5] The adjoining townships of Corkill, Wallis, Banks, Willet, Roadhouse, and Lawson were mapped in that year by the writer.[6] Finally, the present investigation of Onaping map-area was begun in 1908.

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[1] Rept. Ont. Bureau of Mines, 1901, pp. 181-212.
[2] Rept. Ont. Bureau of Mines, 1901, pp. 160-180.
[3] Rept. Ont. Bureau of Mines, 1904, pp. 216-220.
[4] Geol. Surv., Can., Sum. Rept. 1906, pp. 119-123.
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CHAPTER II.

SUMMARY.

Chapter III, General Character of the Area (pages 14-21). Onaping map-area lies in the southern part of the Pre-Cambrian shield. It is a hummocky, rocky plateau standing between 875 and 1,450 feet above the sea, though a few of its larger hills reach 1,900 feet. The Pre-Cambrian solid rocks are characteristically glaciated and covered by a thin, discontinuous soil-sheet of glacial debris averaging not more than 25 feet in thickness and presenting the topographic aspect of local terminal moraines fronted to the south by outwash plains. The planated character of the Pre-Cambrian rock-floor is a physiographic feature which long antedates glaciation, as do, likewise, the main river valleys and two intersecting series of notably parallel lake basins which occur in the southwest quarter of the map-area. The latter are most probably an expression of faults.

The drainage was disorganized by glaciation, so that now lakes are extraordinarily numerous and the smaller streams are irregularly graded. Since glaciation some of the rivers show signs of having diminished greatly in volume and the courses of some have been altered.

None of the present rivers are large, but they are capable of developing important water-powers, and will eventually be of great service in transporting timber when lumbering operations become general. The country is well forested in parts but has no agricultural value.

Chapter IV, General Geology (pages 21-108): The solid rocks beneath the thin cover of glacial and recent soils are all Pre-Cambrian. They are separable into an ancient, highly metamorphosed pre-Huronian division, and a much younger Huronian division, by an unconformity of major importance. The pre-Huronian consists of two main parts: a schistified complex, composed dominantly of volcanics and subordinately of water-deposited tuffs, iron-formation, and other sediments; and younger batholithic intrusions of granite-gneiss. The Huronian sediments form a single series (Cobalt series) of conglomerates, greywackes, quartzites, and a small amount of limestone. These sediments are intruded by diabase sills and dykes probably of Keweenawan age.

The pre-Huronian schist-complex, though schistified and closely folded wherever the folding is made apparent by its sedimentary components, is regarded as forming comparatively low synclinoria and anticlinoria; the erosion which exposed the granite-gneiss batholiths does not appear to have cut deeply into them. The axis of folding in the schists is northwest--southeast and thus nearly at right angles to the trend of pre-Huronian folding in the region as a whole.

Detailed lithological descriptions of the schist-complex are given on pages 33-49. Dynamic metamorphism due to deformational movements has partially converted the original volcanics and sediments into chlorite and sericite or paragonite schists. In general, the sediments, tuffs, and other mechanically weak formations have suffered to the greatest extent, though there is also a progressive decrease in intensity of the dynamic metamorphism away from the granite-gneiss batholiths. Contact metamorphism has been induced by these intrusives for distances up to half a mile back from the contacts. The net effect of contact action is loss of schistosity, increase in crystallinity, and the convergence of the originally diverse lithological components of the schist-complex into a black hornblende gneiss.

The schist-complex represents a period of dominant and varied vulcanism. Though ellipsoidal lavas are common, and conglomerate, greywacke, and other shallow-water sediments have been found in it, the complex is believed to be principally a land deposit.

The terms pre-Huronian schist-complex, and pre-Huronian granite-gneiss are applied to these rocks and to the batholithic intrusives in preference to the terms Keewatin and Laurentian or Algoman as defined by Lawson and by Miller and Knight, because they express more exactly our present knowledge of their sequential relations. No reliable classification of the pre-Huronian rocks can be made until a correlational datum plane has been established within the pre-Huronian by correlating the various pre-Huronian sedimentary series—Timiskaming series, Sudbury series, Pontiac series, etc.—which occur in northeastern Ontario and Quebec.

The intrusive batholithic rocks are dominantly granodiorites. These, however, vary considerably and have associated with them in smaller amounts a great variety of amphibolites, diorites, aplites, pegmatites, and related types. This petrological variety is concluded to be due to: (1) primary differences in the invading magma; (2) magmatic differentiation; (3) chiefly to magmatic assimilation of portions of the older schist-complex. Assimilation appears to have taken place on a grand scale, involving the absorption of cubic miles of pre-Huronian schists. A number of cases of magmatic assimilation are described to show that the products, especially where the process has not been thorough, are characterized by an irregular intergrowth of their constituent minerals, a feature which may have some value in diagnosing other less obvious cases of assimilation.

The Huronian consists of a single series of conglomerate, greywacke, quartzite, and limestone (Cobalt series) comprising the following formations:

White quartzite
Banded cherty quartzite 200+feet
Lorrain quartzite 2,000 to 3,000+feet
Gowganda formation (conglomerate greywacke, laminated greywacke, and limestone)....0 to 3,000 feet

In contrast with the pre-Huronian rocks, the Cobalt series is little metamorphosed and not greatly folded. The folding increases steadily in intensity in a southwesterly direction from gentle folding and doming in the northeast corner of the map-area to folds in the southwest dipping 70 to 90 degrees. Some locus of disturbance farther in that direction is indicated. Most of the folding has been along a northwest-southeast axis.

The Gowganda formation is a continental deposit laid down under glacial or at least cold-climate conditions. A considerable part of it, especially in the southeast part of the area, was deposited in water. A local unconformity between the Gowganda and Lorrain formations is regarded as due to overlap of this body of water, the time involved being brief. A portion of the base of the Lorrain quartzite is a terrestrial deposit, but the bulk of it and the quartzites above it represent subaqueous conditions of deposition.

The Cobalt series and pre-Huronian formations are intruded by diabasic sills and dykes, probably of Keweenawan age. With some of the sills are associated silver-cobalt ore deposits of the kind found at Cobalt. These sills show great petrological diversity due to three different causes. In the first place the magmas intruded in different parts of the area differed sufficiently to give rise to quartz diabase, quartz norite, and all gradations between these two rock species. The quartz diabases are confined mainly to the northeast corner of the map-area; toward the south and west they change to quartz norite. Consanguinity with the quartz norite of the Sudbury laccolith is implied. Secondly, during intrusion the magma absorbed a small amount of the older rocks into which it was intruded. Finally, following intrusion and during crystallization, the magma differentiated into two distinct rock products; a basic one of diabase or norite and an acid, aplitic one, differing slightly according to whether it was derived from a diabasic or a noritic magma. Both diabase (or norite) and aplite further differentiated within themselves into two gradational series ranging from basic to acid extremes. In each series the mineral constituents remain the same, but the proportions of each vary in a regular manner. The acid extreme of the diabase (or norite) series corresponds closely in chemical composition to the basic pole of the corresponding aplite series, although the mineral compositions are unlike. In addition to these two principal differentiates there are a number of subsidiary ones. Calcite is one, and the association of quartz, chalcopyrite, and silver-cobalt-nickel minerals, which constitute the silver-cobalt veins of the area, is believed to be another.

The quartz diabase and quartz norite, as well as the older Pre-Cambrian rocks of the area are intersected by dykes of a porphyritic olivine diabase. This diabase may represent a later expulsion of basic magma from the same subterranean reservoirs which gave off the quartz diabase and quartz norite.

The Pleistocene deposits overlying the Pre-Cambrian average about 20 feet in thickness, and appear to have been deposited chiefly during the final retreat of the ice-sheet. They consist in large part of a series of local terminal-moraine accumulations fronted to the south by flat outwash sand-plains. There is evidence that the course of Lady Evelyn river was different, and its volume greater in Glacial time. Similar changes in drainage were noted in some other streams.

Chapter V, Economic Geology (*pages* 109-127): Quartz veins carrying free gold occur in the pre-Huronian schist-complex near West Shiningtree lake, in the townships of Asquith, Churchill, and McMurchy. The first discovery was made in August 1911. Up to the present time gold has been found on eight or more mining locations. A considerable amount of surface development and test-pitting has been done on the more promising locations, but the result does not yet appear to warrant the inauguration of mining operations. The veins, though numerous and of satisfactory size, are irregularly mineralized; the average gold content is low.

A short geological description is given of the Crystal gold mine on the east side of Wanapitei lake. This mine is no longer operated, but it exemplifies a period of gold deposition in Ontario apparently not yet clearly appreciated. The veins worked intersect Cobalt-series sediments as well as a mass of younger, presumably Keweenawan, diabase with which they are suggested to be genetically related. Other gold-bearing deposits of the same general age and geological relationships—the Havilah mine north of Thessalon, the Sudbury copper-nickel deposits, the Mann mine at Gowganda, etc.—are cited to show that the post-Cobalt (Keweenawan ?) basic intrusives gave rise to a distinct series of auriferous vein deposits. A recognition of this epoch may have a beneficial directive influence upon prospecting for gold in northern Ontario.

The gold placers of Vermilion river and Meteor lake are also described. Attention is directed to the possible occurrences at two other places in Onaping map-area of similar placers.

The silver-cobalt ore deposits at Gowganda are in narrow veins similar in character to those at Cobalt, and like them genetically associated with sills of quartz diabase. Apparently the quartz norite sills in the central and southern part of the map-area are not accompanied by veins of this kind and the distinction of quartz diabase from quartz norite is suggested to be of prime importance in prospecting operations.

Though the quartz norite sills are similar petrologically to the Sudbury laccolith, they are so much smaller that basic segregations of copper-nickel sulphides like those in Sudbury district are not apt to occur in this map-area.

Several iron ranges are known in Onaping area, but none of them have been found high enough in iron to be minable. Even their future commercial importance is doubtful. They are all composed of banded iron formation belonging to the pre-Huronian schist-complex.

CHAPTER III.

GENERAL CHARACTER OF THE AREA.

TOPOGRAPHY.

General Statement.

Onaping map-area is part of the Pre-Cambrian shield, the ancient, rocky plain or low plateau of Pre-Cambrian rocks which occupies that half of Canada lying around Hudson bay and southward to the Great Lakes. It belongs more particularly to that part of the Pre-Cambrian shield which lies within northeastern Ontario. In northeastern Ontario the shield is a greatly eroded, low plateau between 700 and 1,500 feet above the sea and sloping northward to Hudson bay and southward to the St. Lawrence. The relief is only from 100 to 800 feet locally; nevertheless, the country is extremely rugged and hilly. Rocky hills, seldom over 300 feet high, alternate with irregular depressions filled with glacial drift, swamps, muskegs, or lakes. The drainage of this hummocky country, disorganized in Pleistocene time by glacial erosion and drift deposits, is very imperfect and in consequence lakes and ponds are extraordinarily numerous. The whole region is uncultivated and forested chiefly with evergreens.

A fairly precise idea of the elevation and general flatness of the portion of the Pre-Cambrian shield included in Onaping map-area can be gathered from the gradients of the railways and rivers that cross it. The height of land between Hudson bay and the St. Lawrence and the watershed between Montreal and Sturgeon rivers extend from east to west across the middle of the area. This apical portion, if a few exceptionally high hills are excepted, stands from 1,325 to 1,450 feet above sea-level. Some of the hills reach elevations of 1,700 to 1,800 feet. From the divide the country slopes northward and southward or southeastward very gently. The northward-flowing streams leave the area at elevations varying between 1,100 and 1,200 feet, indicating a mean northward slope of 7 feet per mile. Levels of lakes and the Canadian Pacific railway in the southwestern quarter of the area indicate the average elevation to be between 1,150 and 1,350 feet above the sea, with a gentle southward slope. In the southeastern quarter, the slope is to the southeast and much steeper. Vermilion, Wanapitei, Sturgeon, and Lady Evelyn rivers, which drain this part, are all exceptionally swift and are not more than 875 to 950 feet above sea-level where they cross the edge of the map-area. The mean slope southeasterly is not less than 12 feet per mile.

Detailed Statement.

The composition and structure of the rock formations have had an important influence upon the character of the surface. Those parts of the area which are underlain by Huronian quartzite present a relief notably greater than the rest. For instance, Maple mountain, situated at the extreme eastern edge of the map-area and the largest hill in it, is composed of quartzite. This ridge extends for 12 miles north and south through Rorke, Whitson, and Ba[illegible]ships, and at its highest point is 950 feet above Anvil lake, or about 1,900 feet above sea-level. Another prominent quartzite hill directly east of Bluesucker lake in Dundee township, is 600 feet high (1,700 feet above sea-level). Many others near Florence lake are over 400 feet high.

The diabase sills which intrude the Huronian and older formations, form smaller hills—not often over 200 feet high—but more characteristic in their arrangement. Sills that dip 15 degrees or more and outcrop along one edge frequently appear as a persistent ridge or row of elongated hills. The slender parallel arms of Gowganda lake lie on either side of such a high ridge; and the line of hills visible to the northwest from Esker lake or Wanapitei river represent the protruding edge of another inclined sill. These hills often have one precipitous face ending in a talus slope.

Areas of granite-gneiss and the older schists have an insignificant relief, except in the neighbourhood of Scotia and Onaping lakes, where the granite hills are up to 350 feet in height.

The topographic details of the area are essentially glacial in character. The rocky hills have subdued, rounded profiles. Polished and scratched rock surfaces and roches moutonnées are abundant. All the larger areas of drift exhibit esker ridges, the irregular pitted topography of terminal moraines, or flat outwash plains containing occasional kettle lakes.

These features date back only to the Glacial period. There are, however, certain other topographic features which, though modified by glacial erosion, appear to have originated much earlier. This is probably true of many of the lake basins in the western part of the area. These lakes are remarkably linear bodies, rarely over a mile wide and many miles in length. In some instances a number of them are aligned along the same straight valley, with intervals of low ground between them. They lie in parallel positions, constituting two intersecting parallel groups (Figure 2). The dominant group includes these lakes which extend about north 10 degrees west. A second, less conspicuous group, exemplified by the arm at the south end of Deschenes lake, and by parts of Onaping lake, extends at north 55 degrees west, intersecting the principal system at 45 degrees.

All these lakes occupy rock trenches, the origin of which is rather obscure. The granite-gneiss in which they are eroded has no well-defined or persistent gneissic foliation, so they cannot be ascribed to differential erosion along the strike of the gneiss. Even if this were the case it could account for only one of the two intersecting systems of depressions. Bell suggested[1] that Onaping lake coincided with a large diabase dyke which eroded more easily than the granite on either side; but Mr. Marshall, who examined this locality for the writer, found only a number of small dykes that extend in various directions and are not eroded more deeply than the granite-gneiss. This explanation is equally inadequate to explain the other linear lakes.

Signs of faulting were looked for as a more probable explanation of these linear troughs. The steep granite cliffs that occur

[1] Geol. Surv., Can., Ann. Rept. 1890-91, pt. F, pp. 37, 38.

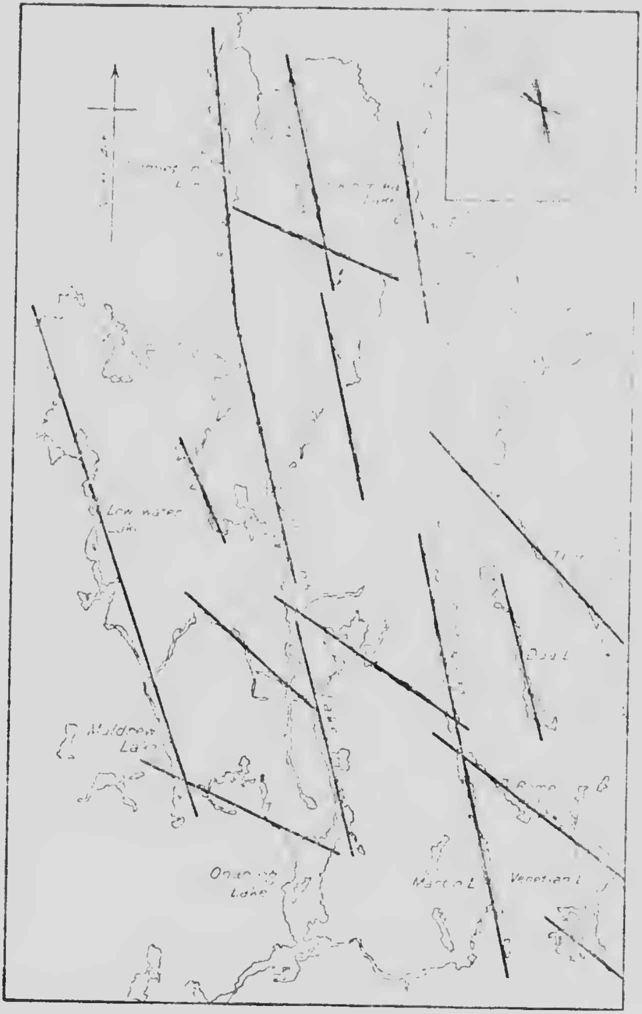

Figure 2. Lake-filled, intersecting, linear valleys unrelated to the geological structure of the rocks containing them. The courses of these valleys are plotted from a common centre in the inset diagram.

at many places along Scotia lake suggest fault scarps; but it is extremely difficult to recognize displacements within so monotonous a formation as granite-gneiss, where sedimentary rocks are not also present. Shear zones that would indicate such displacements were looked for at the ends of some of these lakes, but in all cases the ground proved to be swampy or soil covered. But, though no positive evidence of faulting was discovered, this explanation remains about the only adequate one. Whatever the cause may have been, it is likely that these depressions antedated glaciation. Ice movements would scarcely carve two intersecting series of valleys without the aid of some strong predisposing influence.

The principal river valleys also probably existed in pre-Glacial time. They are strongly developed, continuous topographic features. Wanapitei River valley in particular is scarcely explicable as a product of ice action. From Beulah to McLeod townships the river occupies a broad, even, rock-valley that extends from west to east directly across the course of the ice-sheet. Its entire course, in fact, bears no relation to the direction of ice movement. The Vermilion River valley does not run counter to the course of the ice, but, like the Wanapitei valley, it is deeply carved in the Pre-Cambrian rocks, and probably also greatly antedates the Glacial period.

The lower part of Lady Evelyn river appears to be an exception to this rule of well entrenched streams. From its source near Smoothwater lake as far downstream as the branch that empties into it from Florence lake, the river valley is broad, deep, and continuous. The stream which now occupies it is only a brook, yet portions of the channel a short distance from the source are paved with large, well-worn boulders that indicate the action of a much larger stream. Occasional pot-holes are also found along the channel. This well-defined valley continues only as far as the Florence Lake tributary. For the first few miles below the depression occupied by the river is soil-filled. Beyond that, it becomes rocky, ill-defined, and very poorly graded. The descent is accomplished mainly in falls, the largest of which is 81 feet high, and between these falls the channel is rocky and irregular. The tributary from Florence lake, on the contrary, although a feeble stream, traverses a broad soil-filled depression, and at the south end of the lake a rocky valley opens southward to a chain of lakes which drain southward into Sturgeon river. Parts of this valley are paved with smooth boulders, like the upper part of Lady Evelyn river; and even now in flood seasons, Florence lake partly discharges southward through this channel. Signs of a former large discharge toward Sturgeon river were found at a number of points in this now small stream. There is reason to believe, therefore, that Lady Evelyn river originally ran southward through Florence lake, to Sturgeon river, and that its present channel from Florence lake to the mouth was occupied only recently.

There is another deeply eroded valley extending from Scarecrow lake in Ellis township southward across Selkirk township, which appears to be too large for the tiny stream that now occupies it. In fact it contains two streams, flowing in opposite directions from a common headwaters pond a quarter mile southeast of Scarecrow lake. In many places the main southward-flowing rivulet is entirely hidden under a pavement of rounded boulders that suggest the former existence of a much more powerful stream. It crosses the south boundary of Ellis 25 chains west of mile-post 2.

It is probable that these changes in the drainage of the area are post-Glacial and consequent to diminution in the amount of run-off, and to the blocking of former channels with glacial debris.

DRAINAGE.

All the streams draining Onaping map-area have their sources in it, and are consequently small. At its ordinary summer volume Wanapitei river is 150 feet wide, about 3 feet deep, and flows between 2 and 3 miles an hour near where it leaves Onaping map-area. Sturgeon river is nearly as large. Vermilion (Plate I), Lady Evelyn, and Opikinimika rivers, and the branches of Montreal and Spanish rivers are from one-third to one-half the size of the Wanapitei. However, the small size of the streams is partly compensated for economic purposes by the large lakes connected with each of them. These lakes can be used for conserving the run-off and ensuring a steady flow through dry weather, when the rivers are eventually utilized. Water-power is available at Helen fall on Lady Evelyn river, where there is a total descent of 81 feet; and at Goose fall on Sturgeon river, where the fall is somewhat over 40 feet. A fall of 40 feet has been obtained on Opikinimika river by damming a rapid a few miles below the portages to West Shiningtree lake.

Lumbering promises to be the most important permanent industry in this area and in this connexion the rivers will be used for floating logs to the railways. Vermilion river is already harnessed for this purpose with log-chutes and conservation dams. Wanapitei and Sturgeon rivers are well adapted for carrying logs, being fairly free from large falls and lake expansions, and possessing numerous tributaries.

FORESTS AND AGRICULTURE.

The forest covering Onaping map-area includes a fairly large variety of trees. White, red, and banksian pine, spruce, and balsam grow well in all parts of it. Cedar and tamarack grow to a good size but are confined to a few localities where soil and drainage conditions are favourable; they form a very small percentage of the total forest growth. Of the broad-leaved trees, poplar (*Populus grandifolium*) and white and yellow birch are common everywhere. Hard maple is fairly abundant in the dry rolling country underlain by Huronian quartzite, but does not grow to more than 12 or 15 inches in diameter. A few small elms are scattered through the clayey portions of Wanapitei, Sturgeon, and Vermilion River valleys. Black ash is always stunted and occurs only as fringes along marshy river banks. Hawthorn and choke-cherry occur rarely, serving merely to indicate the limits of tree growth.

The eastern two-thirds of the area lies within Timagami forest reserve, while the western third is being operated by various lumbering companies. At the border between these two portions the advantages resulting from the conservational policy of the Ontario government in effect in the northern part of the province are particularly evident. The lumbermen operating in the western part of the area, particularly in Creelman township, have left waste brushwood lying among what timber is left standing. Consequently, this part of the country has been scarred by forest fires (Plate II). Much of the timber left standing by the lumbermen has been killed by these fires. The fertile leaf mould gradually contributed to the soil by forest decay has been burned out and the residue of sand and gravel is left unprotected against denuding agents. Many of the hills, once forested, are now nearly bare of soil, and their reforestation is practically impossible.

The reserved part of the area is covered by a valuable forest almost untouched by fires. A force of rangers in the employ of the Ontario government guards it between May and October; but no effort has yet been made to utilize the timber, although there seems no reason why permanent lumbering and reforestation industries should not eventually be conducted within the reserve. One is struck in traversing it, by the excellent quality of the timber and even more by the possibility of increasing the yield of white pine and other valuable trees by judicious planting. White pines, 3 feet in diameter, are not uncommon. This tree grows thickly in some places, showing how great a crop the soil is capable of sustaining in equally favourable habitats where at present it is crowded out by birch and other less valuable species, a state of affairs which could be corrected by forest culture.

There are no large tracts of good agricultural land in the map-area. Lacustrine clays, which furnish the agricultural land in the "clay belt" along the National Transcontinental and Timiskaming and Northern Ontario railways, do not occur here. All the extensive soil-clad areas consist of glacially assorted sands and gravels, or bouldery morainic materials.

CHAPTER IV.

GENERAL GEOLOGY.

GENERAL OUTLINE.

The soil-sheet which covers the solid rock formations of Onaping map-area consists mainly of glacial drift and a certain amount of more recent accumulations in the form of muskegs and swamps. It does not average 25 feet in thickness for the whole area and is by no means continuous. The underlying rock floor is abundantly exposed. The solid rocks beneath the soil-sheet are entirely Pre-Cambrian, so the unconformity between them and the drift covering represents a time-interval reaching from late Pre-Cambrian to the Pleistocene.

The Pre-Cambrian is divided by a great unconformity into two main divisions widely different in age, lithological character, and degree of metamorphism. The younger, Huronian division consists in this area of a single thick series of conglomerate, greywacke, and quartzite (Cobalt series), and of younger basic intrusives. The Cobalt series is comparatively gently folded and has been metamorphosed very little. Originally several thousand feet thick and lying as a thick sedimentary blanket upon the older, pre-Huronian division, it has since been so greatly eroded that its vestiges cover less than half of the map-area. The rocks intrusive in the Cobalt series, probably Keweenawan in age, are sills and dykes of basic rocks ranging from quartz diabase to quartz norite in composition. Olivine diabase dykes cut the quartz diabase and quartz norite.

The older, pre-Huronian division that lies unconformably beneath the Huronian sedimentary mantle is, unlike the Huronian, composed of crystalline, greatly metamorphosed rocks. It is separable into two distinct subdivisions: an older, schistose, greatly disturbed complex composed of a great variety of extrusive and intrusive igneous rocks together with a small quantity of sediments (pre-Huronian schists); and a younger group of huge batholithic bodies of granite-gneiss (pre-Huronian batholithic intrusives) intrusive in the schists. The schist-complex represents a time of dominant and varied volcanic activity, the batholiths, a time of great earth movements and deep-seated intrusion.

The schists are folded and schistified to such a degree as to imply the operation of mountain-building forces. Yet the surface of the pre-Huronian upon which the Huronian sediments were laid down appears to be a maturely eroded one of somewhat the same planated character as the present surface of the region. It is evident, therefore, that an erosion interval occurred between pre-Huronian and Huronian time long enough for these pre-Huronian mountains to be levelled. Great areas of the batholiths, which are deep-seated intrusives, were exposed during this interval, while only irregular, downfolded remnants are left of the once much more continuous schist-complex.

TABLE OF FORMATIONS.

The succession described above may be tabulated as follows:

	Quaternary	....Pleistocene ...	Boulder clay, sand, gravel, and recent accumulations.
		Great unconformity	
Pre-Cambrian	Huronian	Keweenawan(?) basic intrusives	Olivine diabase Quartz diabase, quartz norite and intermediate varieties.
		Intrusvie contact	
		Cobalt series	Upper white quartzite, Banded cherty quartzite, Lorrain quartzite. Gowganda formation: conglomerate, greywacke, and limestone.
		Great unconformity	
	Pre-Huronian	Batholithic intrusives	Granite-gneiss and its differentiates.
		Schist-complex	Altered volcanic and intrusive rocks, iron formation, and other sediments

Pre-Huronian Schist-Complex.

DISTRIBUTION.

The pre-Huronian basement is continuously exposed only in the western third of the map-area. Elsewhere it is visible only in patches where holes have been eroded through the overlying mantle of Huronian sediments. The total amount of pre-Huronian visible, is slightly more than one-half of the map-area. There is little doubt, however, that it underlies the Huronian in the remainder of the area.

If the concealing Huronian mantle could be stripped off, the scattered patches of granite-gneiss and schists now visible would prove to be parts of a continuous pre-Huronian floor. And if the whole pre-Huronian surface could be so revealed the areal and structural relations of the schists and batholithic granite-gneiss would be clearer than they are now. These relations are important for the elucidation of pre-Huronian geological history, and any information regarding them, even if it is fragmentary, will sooner or later be of value. With this in mind an attempt has been made in Figure 3 to express, as accurately as can be inferred, the distribution of schist and granite-gneiss areas in the concealed as well as the visible parts of the pre-Huronian floor underlying the whole map-area. The eastern part is so completely hidden that its composition is quite conjectural, but the remainder can be mapped with some reliability. In projecting schist-granite boundaries beneath the Huronian mantle the prevalent strike of the schists, which agrees fairly closely in direction with the contact, has been found serviceable. The proximity of a schist-granite contact, though itself actually hidden by the Huronian, can also be inferred by strongly developed contact-metamorphic features in the schists; this means has served in some places to determine the distribution of schists and granite-gneiss beneath the Huronian.

Figure 3 shows two main bodies of schists, one on the north side, the other on the south, nearly separated by an up-arching batholith. There are traces in the middle of the map area of a former continuity between the two main schist areas. The schist area on the north is known to be just a lobe of a huge

Figure 3 Inferred distribution of schists and granite-gneiss in the pre-Huronian basement underlying Onaping map-area.
Scale: 1 inch = 12 miles

body that extends northward toward Porcupine. The tongues of schist along the southern margin of the area are known to be lobes of another large schist body whose main part lies farther south. The granite-gneiss areas in the east and west also extend far beyond the limits of the map-area.

Each main body of schists is bordered by numerous satellitic patches, that lie island-like in the granite-gneiss. There are also certain vague areas, neither granite-gneiss nor schists, but an intimate mixture of both. These are former areas of schist that were nearly completely assimilated by the invading batholithic magma. Some of them contain well-preserved remains of iron ranges. Apparently iron formation, a characteristic member of the schist-complex, resisted the assimilative action of the granite magma more effectually than the rest of the complex. The schist areas are fringed by a zone, half a mile or less wide, of this mixed "transition" material, which merges into ordinary granite-gneiss farther away from the schist contact. It is clear that the large and small schist areas and the scattered patches of "transition" material are all vestiges of a volcanic complex which may have extended over the whole map-area before it was folded and invaded by the granitic batholiths.

Something may even be determined regarding the fold-structure of the schist-complex. It is not possible, owing t low relief of the country, to see how steep the schist-gr contact is. But the schists themselves have a nearly verti schistosity, and such sediments as are included in them usually dip very steeply. It might be concluded that the schist areas are very deep-going synclinal remnants of a closely folded schist-complex and that the intervening granite-gneiss batholiths stood high above the present surface before they were cut down by erosion.

Other facts, however, do not bear out this idea. The occurrence of many "transition" patches scattered here and there in the granite-gneiss indicates the repeated synclinal dipping of an original cover of schist-complex; for these patches can only be regarded as the vestiges of roof-pendants, or downward-hanging parts of the cover into which the batholith was intruded. As such pendants are widespread, it must be assumed, that the cover of schist-complex was arched very little above the present surface. Again, the outlines of the schist areas in Figure 3 are gently curving and the areas are fairly equidimensional. There are few sharp salients and re-entrants such as characterize the eroded margins of areas that have been thrown into large and close folds. Iron formation, being a finely stratified, fairly thin sedimentary formation highly resistant to batholithic assimilation, affords the best medium for studying the folds in the schist-complex. All the iron ranges strike approximately northwest-southeast, so the axis of folding must lie in this direction. Since, also, there are traces of at least four parallel belts of iron formation, and the iron formation in each dips very steeply, there must have been not two main folds corresponding to the main schist areas, but a larger number of folds of correspondingly smaller amplitude.

These facts seem best explained by conceiving the schist-complex to have been folded into low synclinoria and anticlinoria with close minor folds, rather than into simple close folds of larger dimensions. According to this explanation the intrusive batholiths were not highly convex and have not been cut into deeply by subsequent erosion.

The northwest-southeast course of axial folding in the pre-Huronian schists of Onaping map-area is exceptional. In northwestern Ontario the prevailing strike is about 70 degrees east of north and seldom varies more than 20 degrees either way from that direction. The axis of folding in northeastern Quebec is practically the same. The persistence of this northeast-southwest trend has been repeatedly commented upon by geological workers in the Pre-Cambrian. There is a tendency among them to regard it as a constant regional feature, and to emphasize the parallelism of this Pre-Cambrian trend with similar regional trends in the Scottish and other Pre-Cambrian regions. It should be remembered, however, that a very small part of the Canadian Pre-Cambrian region has been explored in any detail. It is not improbable that, as geological work proceeds, many important irregularities like that in Onaping area will be discovered in the "regional trend."

GENERAL DESCRIPTION.

The schist-complex is made up of a great variety of extrusive and intrusive igneous rocks, not to speak of a minor proportion of sedimentary formations. These, subsequent to their deposition, have been greatly folded and schistified, and near the contacts with the intrusive granite-gneiss, they have also been intensely contact-metamorphosed. It is not possible, therefore, to separate this complex into its component formations by means of the reconnaissance methods of field work employed in mapping Onaping area. Most of the complex was explored only sufficiently to be mapped under one colour. But a number of small areas of some economic interest were studied in greater detail. Wherever an iron range was located by reconnaissance traverses it was mapped separately. A small gold-bearing area near West Shiningtree lake was examined somewhat carefully and part of the schist-complex was mapped into its component formations (Map No. 153A). An area of rhyolite and rhyolite-tuff in Leonard township was also mapped independently. The account which follows is correspondingly incomplete. A few general aspects of the group as a whole are treated first; then more complete descriptions are given of the above-mentioned localities where detailed work was done.

The schist-complex in Onaping map-area is dominantly igneous and dominantly volcanic. It includes tuffs and volcanic-ash rocks. Flows are recognizable by the presence of amygdules, flow lines, ellipsoidal and variolitic structures. In fact nearly all the phenomena connected with modern vulcanism are registered in this ancient Pre-Cambrian group. There are also intrusive rocks, though in what proportion it is difficult to estimate, because of the difficulty of distinguishing intrusives from extrusives in the present highly deformed state of the group. There is also present a small amount of sedimentary material, mostly iron formation or volcanic debris modified by the action of water. Normal sediments due to subaerial erosion and deposition in water are about nil. The igneous formations range from basalts and olivine-bearing varieties to rhyolites. Rocks of basic and intermediate composition, however, are commonest.

Consequently, the group as a whole, is characterized by dark colours, principally dark shades of green.

These lavas, intrusives, and sediments have since been metamorphosed to an important degree, locally by the contact-metamorphic influence of the intrusive granite-gneiss batholiths and throughout by the deformative movements which folded the complex into anticlinoria and synclinoria.

DYNAMIC METAMORPHISM.

The folding and faulting movements evolved schists—chlorite schists from diabases, andesites, and other basic or intermediate rocks, sericite and paragonite schists from acid varieties like porphyries and rhyolite. These schists are vertical or nearly so.

It seems clear that the whole complex has been closely folded, for wherever stratified deposits, such as iron formation, are found in it they are always steeply inclined. Yet the complex is by no means uniformly schistified: massive, well-preserved, igneous rocks are common, and especially in the interiors of the larger areas (Figure 5), massive and highly schistose formations often occur together; in fact the distribution of schistose and massive materials is highly irregular. An explanation for this is perhaps to be found in the heterogeneity of the schist-complex in respect to mechanical stability. Intrusives and thick flows capable of offering strong resistance to deformation are in association with weak materials, like volcanic ash, tuffs, and clastic sediments. Naturally the greater share of the adjustive movements that accompanied the folding of the whole complex would be accommodated by the weaker materials, rendering them more schistose than the stronger formations. This is well illustrated in the township of Churchill (Map No. 153A), where a thick flow of hornblende andesite and a series of conglomerate, arkose, and greywacke of pyroclastic origin occur together. The sediments are little younger than the flow and consequently must have been subjected to the same deformational forces. Nevertheless, the flow is massive and shows little evidence of folding, while the incompetent sediments, especially the greywacke, is intricately folded and crumpled and possesses a distinct secondary cleavage. A fuller description of these rocks is given on page 33.

Broadly speaking the schistifying effect of dynamic metamorphism grows more pronounced towards the margins of the schist-complex areas. Near the margins there is also a fairly distinct parallelism between the strike of the schists and the line of contact with the granite-gneiss. A relationship between batholithic invasion and the deformation of the schist-complex seems to be implied.

CONTACT METAMORPHISM.

Batholithic invasion has developed a broad, marginal, contact-metamorphic zone around the schist-complex areas. A conception of this zone, or aureole, may perhaps be most readily conveyed by a diagram (Figure 4), representing a typical section of the contact. The contact itself is extraordinarily ragged and uneven. In the course of batholithic invasion apophyses of granite penetrated the schist-complex, mostly along the planes of schistosity, wedging out tongues of schists. The interpenetration of invading and invaded materials is so complex that it is difficult to draw any precise line of contact. Close to the contact the schist-complex has been rendered massive and coarsely crystalline by the granite-gneiss. Farther away this effect gradually diminishes to imperceptibility. The distance to which it is perceptible varies from a few yards to half a mile. On the other (granite) side of the contact the contact aureole is represented by fragments of recrystallized schist-complex which were detached from the main body and floated out into the granitic magma while the latter was still plastic. Near the contact these crystalline fragments are more or less angular and occur in great numbers, the larger fragments splitting up into swarms of smaller pieces (Plate XI). The fragments and enclosing granite-gneiss, which is somewhat basified by assimilation of the fragments, together constitute the "transition" material referred to in preceding paragraphs. Farther out in the granite the inclusions become less abundant and rounded or drawn out into ribbons. While the "transition" material forms a border around areas of schist-complex, it is by no means restricted to such localities (Figure 3). Isolated patches of it are found in the granite-gneiss far away from any present schist area. In fact, comparatively little of the granite-gneiss in Onaping area is entirely free of these contact-metamorphosed vestiges of the schist complex.

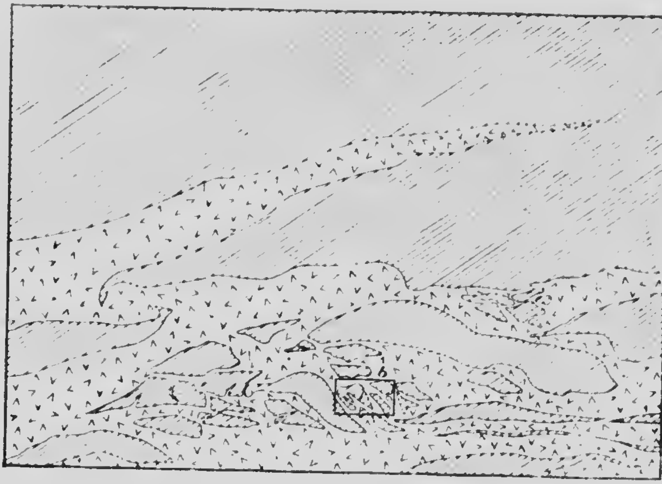

Figure 4. Brecciated character of contact between the pre-Huronian schist-complex (in oblique lines) and the intrusive granite-gneiss (in V pattern). See Plate XI for illustration of small rectangular area.

The schist-complex lying beyond the metamorphic influence of the granite is marked by an abundance of secondary minerals, chiefly chlorite, epidote, carbonates, and colourless micas. From this beginning to the final contact product found next the granite-gneiss the change appears to be essentially a convergence of originally diverse rocks to a common type. Siliceous rocks like quartz porphyry or iron formation are not readily affected and retain their mineral composition close up to the contact, but rocks rich in dark minerals are readily changed. The first observable change as the granite contact is approached is in the appearance of slender needles of black hornblende; these are frequently arranged with their long axes in the plane of schistosity. At about the same time the cloudy aggregates of decomposition minerals epidote, calcite, etc. begin to form into larger individuals, or to disappear. There eventually results a finely crystalline schist made up of irregular grains of feldspars, quartz, epidote, hornblende, titanite, pyrite, and magnetite. The feldspars include orthoclase, microcline, and soda-rich plagioclases. This association of minerals is surprisingly constant, though the proportions vary. Epidote is the last decomposition product to disappear, combining with the alkalic feldspars to form more calcic feldspar. After this there appear to be no further mineral reactions. The mineral individuals, particularly the hornblende prisms, continue to increase in size and to change from elongated to equidimensional forms with a consequent disappearance of the schistosity. The final product of contact action is a massive or gneissic, coarse-grained amphibolitic rock consisting essentially of glistening black hornblende, feldspars, and quartz, with accessory titanite, magnetite, pyrite, and apatite. Large grains of colourless garnet are found occasionally, also irregular areas of calcite. The hornblende is characterized by a strong blue-green pleochroism parallel to the optic axis c. The feldspars include orthoclase, microcline, and plagioclases ranging between andesine and oligoclase-albite. All these constituents are notably fresh.

This amphibolite is the predominant, virtually the only contact-metamorphic end-product of the schist-complex. Apparently all of the great variety of basic and intermediate materials in the complex, and perhaps even more siliceous ones, subjected to the same physical conditions, converged to this common type. From a mineralogical standpoint the convergence is complete, possibly because the conditions of temperature, etc., in the contact zone, were uniform and favourable for the development of hornblende, feldspars, etc. Considered quantitatively, either from a mineralogical or chemical point of view, the convergence is much less complete; for the proportions of hornblende, feldspar, etc., vary greatly in different samples of amphibolite.

In some, quartz is absent while in others it is relatively abundant. The proportion of hornblende and plagioclase to potash feldspar is likewise variable.

Mention may be made here of an interesting structure occasionally found in the contact zone, e.g. on the east shore of Venetian lake, Botha township. The amphibolite on the lake shore is traversed by a series of intersecting fissures and on either side of the fissures, for an inch or two, the rock has resisted erosion better than elsewhere, in consequence there is a raised network of ridges about 4 inches above the general surface, marking the surface off into depressed rhombic areas from 1 to 6 feet across. Some of the median fracture planes in the ridges are only thin cracks, but the majority are occupied by quartz veins an inch or less in width. They evidently were channels for silica-bearing solutions. The amphibolite adjacent to these fissures was probably silicified by the same solutions and owes its present ridged surface to the superior resistance to erosion of the silicified portions. As this raised mesh structure is found only near the granite-gneiss and as there is no evidence of like disturbance in the granite-gneiss itself, it seems likely that the fracturing and silica-impregnation are direct consequences of intrusion.

DESCRIPTION OF PARTICULAR AREAS.

WEST SHININGTREE AREA.

This area includes the townships of Churchill and Asquith (see Map No. 153A). The flatness of Onaping map-area finds its most pronounced expression in these townships. There are very few hills over 100 feet high and the highest point in the two townships is not more than 250 feet higher than the lowest point. There are a few morainic gravel hills near Stewart lake—in the eastern part of Asquith—but most of the area is scantily soil-clad. It is probably owing to this combination of flatness and scarcity of soil that so many lakes occur. No less than seventy-two were found in the 72 square miles examined, and three of these are each 5 miles long. The lakes differ very little in elevation and are connected by wide, sluggish creeks. The poor drainage also accounts for swamps of considerable size, such as that south of West Shiningtree lake. The whole area is thickly forested, except the portion east of West Shiningtree lake, which was fire-swept in 1911.

In spite of so many features apparently adverse to a geological study of the area, the Pre-Cambrian rocks are abundantly exposed in most parts of it. The southern part of Asquith is underlain by granite-gneiss. The remainder is occupied by a part of the great schist-complex area that extends northward from Onaping map-area toward Porcupine. These pre-Huronian rocks are intruded by dykes and larger masses—probably remnants of a sill—of diabase of post-Cobalt age, but Huronian sediments are entirely lacking. The succession may, therefore, be tabulated as follows:

Pre-Cambrian	Keweenawan (?) (quartz-diabase and olivine-diabase intrusives. Pre-Huronian batholithic intrusives (granite-gneiss). Pre-Huronian schist-complex.

A great deal of the schist-complex near the granite-gneiss is too disturbed and too much metamorphosed to be separable without great difficulty into its component formations. This undifferentiated part is mapped under one colour, although in the course of its exploration, a certain amount of information was obtained regarding it. It includes an altered diabase and diabase breccia. A quartz porphyry, now sheared to a sericite schist in which the quartz phenocrysts [illegible] as "eyes" of quartz, was found on the south side of West Shiningtree lake. A coarse amphibolite lies next to this schist. Chloritic schist, derived by the shearing of basic igneous rocks, is common throughout the complex.

A belt one mile in width and next to the intrusive granite-gneiss has been contact-metamorphosed. At this distance from the contact the basic, chloritic rocks begin to develop slender crystals of secondary hornblende. As the contact is approached the hornblende becomes more abundant, giving rise to fine-grained, black, hornblende schist. Within 600 feet of the contact the hornblende schist grows coarser, the hornblende individuals change in habit from slender needles to stout prisms, and the rock loses its pronounced schistosity, becoming a hornblende gneiss or amphibolite. The end product of contact-metamorphism at the contact is a massive amphibolite or hornblende gneiss of characteristic glistening appearance. A good example of it is seen at the south end of the portage leading away from West Shiningtree lake toward Allin lake.

Away from the granite contact, where there is less metamorphism to obscure the lithological character and relationships of the different formations, it is possible to distinguish some of these and to map them. An examination of parts of Connaught and Asquith townships yielded the following results:

The oldest rocks differentiated from the complex comprise flows and tuffs of hornblende andesite and trachyte which occur near Okawakenda lake; an attempt to map the andesite and trachyte independently was unsuccessful, the two types apparently grading into each other.

The trachyte tuff was found to grade into a stratified series comprising a conglomerate, an arkose-like formation, and a finely bedded slaty formation, all composed of volcanic materials, and mainly of the above-mentioned hornblende andesite and trachyte. It is necessary, therefore, to regard this series as younger than the andesite and trachyte.

The sediments are cut by dykes of a rock of intermediate composition and pale grey colour, which weathers to a characteristic bright red colour. Larger masses of rock having the same appearance and brillant colour on weathered surfaces, are found in other parts of the area.

This red weathering rock is overlain by a large flow of ellipsoidal andesite.

The ellipsoidal andesite is apparently older than certain dykes and larger masses of a nearly white rhyolite which occur with it.

Quartz veins, some of which carry gold, intersect the rhyolite, andesite, and other formations. These veins may represent more than one period of vein formation.

Both rhyolite and andesite are intersected by broad dykes of porphyritic granodiorite.

Everything, including the granodiorite, is cut by dykes of quartz diabase and olivine diabase, but as these dykes are similar in all respects to the diabases that intrude the Cobalt series in other parts of Onaping map-area, they are not regarded as members of the schist-complex.

Hornblende Andesite, Trachyte, and Associated Tuffs.

The hornblende andesite of this group varies greatly in composition. Its most basic variety is a dingy-green rock consisting of a dull-green, aphanitic groundmass crowded with prisms of black hornblende. Most of the hornblende crystals are slender in habit and less than 1 millimetres long, but there are a few larger, stout ones. There appears to be a complete gradation from this dark type to one of lighter colour in which hornblende phenocrysts occur only sparingly and are accompanied by phenocrysts of feldspar. The feldspar crystals are nearly square in section and only a little lighter in colour than the groundmass, consequently the porphyritic texture of feldspathic varieties is indistinct.

Plate III, A and B, represents thin sections of the basic and acid extremes. The hornblende is the common green variety. It contains inclusions, probably of crystallized glass, and is usually twinned. The feldspar crystals are too much decomposed for their composition to be more closely determined than as intermediate plagioclase. Hornblende phenocrysts form 15 to 20 per cent of the rock mass in basic varieties and diminish to 2 to 5 per cent in feldspathic phases; the feldspar phenocrysts increase from 0 to 10-15 per cent as hornblende diminishes. The groundmass is made up principally of a younger generation of lath-shaped feldspars, a few rods of hornblende, accessory apatite, and a few small areas of glass. Most of the glass is crystallized to a pale green substance resembling chlorite, but the interiors of some areas are still clear and amorphous, a somewhat rare occurrence in the Pre-Cambrian.

An ash-grey trachyte was found intimately associated with the andesite. This rock exhibits a porphyritic texture only in its coarser-grained phases (Plate III C). The phenocrysts are feldspars, much decomposed. The groundmass is formed mainly of feldspar laths, also considerably decomposed, with unimportant amounts of chlorite (after hornblende?), but no glass. Fine-grained varieties are without phenocrysts, the groundmass contains square sections of orthoclase, a much greater percentage of acid plagioclase in slenderer crystals, and a few crystals of hornblende more or less completely decomposed to calcite and chlorite.

The tuffs associated with the hornblende andesite and trachyte are composed of fragments of all the above described types. They range from a coarse tuff made up of angular fragments several inches in diameter down to one composed of particles a few millimetres in diameter.

It was suspected, in the course of the field work, that the andesite, trachyte, and tuffs might represent several volcanic extrusions, but this could not be ascertained. The andesite has so wide a range in composition and its most feldspathic phase is so little different from the trachyte that they seemed rather to be all phases of a single extruded mass. These rocks are surprisingly massive and free from signs of folding and shearing.

Conglomerate, Arkose, and Slate.

The tuff of the preceding volcanic group grades almost imperceptibly into a series of sediments of volcanic derivation. These sediments have been complexly folded and now stand on edge or at high angles, making it difficult in many places to determine their order of sequence. Along the north shore of Okawakenda lake, the volcanic tuff grades imperceptibly into an arkose-like formation composed of the same materials as the tuff, and plainly derived from it. This assorted tuff, or arkose, is not thick and gives place to a conglomerate of well rounded pebbles of volcanic materials. On the south shore the conglomerate and volcanic tuff are contiguous and apparently in conformity. No arkose intervenes. At all observed points the conglomerate passes conformably into a better stratified variety of the same arkose material as that which occurs beneath it. This in its turn grades into a finely stratified formation closely resembling slate, but in reality of volcanic derivation.

The conglomerate is best exposed on the large island near the east end of Okawakenda lake. At that place it consists of well rounded pebbles, up to 4 inches in diameter, crowded so closely together that they touch one another. These pebbles consist exclusively of volcanic materials derived very largely if not altogether from the andesite and trachyte just described. They are very similar in colour to one another and to the cementing material, hence the conglomeratic nature of the rock is not conspicuous. The conglomerate found near the south end of the 60-chain portage that leads south from Okawakenda lake differs from this in that its materials are imperfectly rounded, and even angular. One granitic fragment, fairly well rounded, was found in it at this point. Along the south shore of Okawakenda lake there appear to be gradations between volcanic tuff and the conglomerate.

The cement of the conglomerate (Plate III D) is a slate-coloured, greywacke-like material which, as observed under the microscope, resolves into angular to subangular fragments of quartz, feldspars, and composite grains of the same effusive materials as the pebbles are composed of. The composite particles are in greatest abundance, so that the cementing material closely resembles a fine tuff or volcanic ash. Occasional small grains of titanite, pyrite, and partly decomposed hornblende and biotite are also present. The recognizable fragments average 0·2 millimetres in diameter, and are cemented together by a pale greenish, somewhat fibrous substance, which probably consists largely of chlorite.

The arkose-like rock found above, and in places also beneath the conglomerate, ranges from a true volcanic tuff to a feldspathic quartzite. It also grades into the slate formation. It is, therefore, quite variable in character. A quartzitic type is represented in Plate III E. Like the conglomerate cement this also appears under the microscope as a mosaic of angular grains of quartz, feldspar, and fine-grained eruptive rock, with the interstices between these fragments filled with a green, chloritic paste. Pyrite and decomposed pieces of former ferromagnesian minerals are not uncommon.

The slaty formation is dark grey, finely-bedded, and resembles ordinary slate. On smoothly glaciated surfaces the laminæ, which are from a quarter to half an inch thick and differ slightly in colour, are conspicuous. On the islands in the eastern part of Okawakenda lake it passes into a more greywacke-like type, slaty layers 3 inches thick being interbedded with the latter. The formation is nearly always highly tilted and greatly crumpled. A slaty cleavage is everywhere distinctly developed. The clastic texture is perceptible without the aid of a lens, and microscopic study of thin sections shows it to be no true slate but a fine-grained, mud-like phase of the same volcanic material that makes up the arkose-like formation and the conglomerate cement. It consists of the same angular particles of quartz, feldspar, and composite rock matter embedded in a greenish chloritic paste. The particles average only 0·1 millimetre in diameter and for this reason, probably, recognizable fragments of lava are less common than in the coarser sediments of the series. The interstitial paste is also more abundant and shows a parallel arrangement of the secondary minerals—chiefly micas—in the plane of slaty cleavage (Plate III F).

The slaty formation contains a well-defined iron formation. Good exposures of this iron formation can be seen on both sides of Michiwakenda lake one mile below the point where the creek from Okawakenda enters; also on the smaller island in the eastern end of Okawakenda, and on the small lake to the south, which is reached by a 60-chain portage. The iron formation is a phase of the slaty formation in which layers rich in iron oxide alternate with ordinary slaty material. The ferriferous laminæ are from black to bright red in colour and are less than an inch thick. The resultant brilliant banding is made still more conspicuous by the complex way in which the formation has been crumpled. The total thickness of the iron formation varies considerably and does not exceed 100 feet.

The iron content, in the form of magnetite and hematite, is only about 10 per cent of the rock mass. Regarding the original source of the iron, it is interesting to note that T. L. Tanton[1] has found in northwestern Quebec a series of

[1] Geol. Surv., Can., Sum. Rept., 1914.

volcanics and related sediments that bears a striking similarity to the series under discussion. Parts of the slaty formation in his series contain a large percentage of pyrite in process of oxidation to limonite; other parts approximate to a lean iron formation.

Owing to the intense folding to which the Churchill Township sediments have been subjected it is not possible to measure their thickness. They are, however, at least 300 or 400 feet thick, the slaty member making up about half of this amount.

The main axial direction of folding as indicated by the trend of the conglomerate and the iron formation is about south 60 degrees east. They must be younger than the andesite and trachyte volcanics adjacent to them since they are derived largely from the latter; and since these older volcanics lie on either side of the sediments the latter must constitute a down fold. The folding, however, is highly complex. There must be at least two main folds, for the conglomerate outcrops near the middle of the area as well as marginally. The principal folds are complicated by sharp deviations possibly of the nature of drag folds. Subordinate folds ranging down to microscopic dimensions are super-imposed upon the larger ones. The complexity and intensity of folding are indicated by the fact that the dip varies between 50 and 90 degrees, the strike varies through an angle of 90 degrees, and the slaty formation possesses a marked secondary cleavage. The extreme deformation of these weak, clastic rocks contrasts strongly with the massive character of the older but more resistant, andesitic flows with which they are associated.

The principal area of these sediments occupies 4 square miles near Okawakenda and Michiwakenda lakes. The same sediments occur on Michiwakenda lake at the northern boundary of Churchill township, but the extent of this area was not determined. Parks and Coleman both record a highly disturbed conglomerate at the south end of Mattagami lake, 7 miles west of Churchill township. Their descriptions are not detailed enough to establish the similarity of the Mattagami sediments with those in Churchill township; but, because the former locality is in the direction of folding of the Churchill sediments there is some probability that they may be the same. It is thus possible that the Churchill sediments have a fairly wide distribution.

Within Churc' " township, however, they do not give evidence of representing any important period of time. Their relations to the rest of the schist-complex in the c .stern part of the township were not determined, but in the northwestern part they grade conformably downward into the trachyte-andesite volcanics. There is a rather large porportion of quartz in the arkosic member of the series, as if it had been well assorted, and the conglomerate contains at least one granite boulder, but in the main the series is made up unmistakably of the subjacent volcanic materials. The constituent feldspars and volcanic fra nents are fresh enough to preclude any long period of weathering. It will also be shown in the succeeding paragraphs that the sediments are overlain by other volcanic rocks of the schist-complex. It must, therefore, be concluded for the present that the Churchill sediments are simply a series of assorted volcai :c debris laid down in water, that they represent one brief episode in a long period of volca ic activity, and that they do not represent a widespread or prolonged period of sedimentation.

Red-weathering Igneous Rock.

This rock is interesting mainly because it helps to fix the position of the sedimentary series in the schist-complex. Near the southernmost point of Okawakenda lake, slaty beds of the sedimentary series are cut by a narrow dyke of fine-grained rock, which is bluish-grey on freshly broken surfaces and evidently of fairly acid composition; yet on exposed surfaces it weathers to a brick-red colour. On the basis of this peculiarity the dyke rock was identified with a similar bluish-grey, red-weathering eruptive which occurs in Asquith township just east of West Shiningtree lake. The latter mass is of undetermined shape, is intimately associated with the more deformed part of the schist-complex and, on structual grounds, is believed to underlie the sheet of ellipsoidal andesite which is next to be described. So, while not important enough to be represented on the map, it serves to establish the relative ages of the sediments and ellipsoidal andesite.

Thin sections of this red-weathering rock, under the microscope, show that it is badly decomposed. Fairly clear rods of plagioclase, and a surprisingly large quantity of iron ore are distributed through a finely granular mass of decomposition products, chiefly carbonate. The iron ore, probably a titaniferous magnettite, is in small crystals of square, or diamond-shaped section. It is now altered to an opaque white substance (leucoxene ?) that constitutes about 5 per cent of the rock. No doubt it is the cause of the red colour on weathered surfaces.

Ellipsoidal Andesite.

West Shiningtree lake lies nearly altogether within an area of ellipsoidal andesite. Smaller areas of the same rock occur farther east in Asquith, Churchill, and the adjoining townships.

Being an extrusive rock it varies considerably in texture. From a dense bluish or greyish-green rock, too fine-grained for the constituent mineral grains to be seen with the unaided eye, it ranges to a medium-grained, darker green type in which feldspars and black hornblende crystals a millimetre long are easily distinguished. Movements subsequent to its extrusion have produced local shear zones of chlorite schist in the andesite, but most of it is still quite massive. Only in a few places can signs of flowage during solidification of the lava be found. Amygdules are equally uncommon. The most conspicuous and widespread extrusive characteristic is the ellipsoidal structure (Plate IV).

The ellipsoids are from 6 inches up to 5 feet in diameter and spherical to stoutly ellipsoidal, or irregular in shape. The periphery is finer-grained than the interior, but the centre even of large ellipsoids is quite fine-grained. Amygdules were not found in the ellipsoids, but in one of the infrequent instances where an ellipsoid had been broken open it contained a single flattened cavity a foot long and 4 inches wide. The interstices between the ellipsoids are filled partly with a crumbly, decomposed material which may have been andesite, and partly with quartz, calcite, and epidote. This interstitial matter weathers out rapidly, leaving the ellipsoids exposed as in Plate IV.

Although the andesite is massive and fresh-looking in hand specimens, it is really badly decomposed. Originally, the coarser holocrystalline phase was made up of about equal parts of feldspar and a ferromagnesian mineral ophitically intergrown. The feldspar is now too much saussuritized to be determined but it was probably all plagioclase since all the individuals have the same stout, lath-shaped outlines. The ferromagnesian mineral or minerals are now represented by a pale green hornblende. A darker green hornblende in the form of idiomorphic prisms and within the secondary variety may be a primary constituent. Grains of an opaque, white mineral with the triangular, skeletal structure (leucoxene?) are taken to represent a titanium-bearing magnetite. There are a few small areas of secondary quartz. The rock is probably to be regarded as a rather basic andesite.

Rhyolite.

This rock occurs only in small areas and exhibits no features of particular interest. When massive it is nearly white and cryptocrystalline, showing, under the microscope, small phenocrysts of quartz and feldspar in a finely crystalline groundmass of the same minerals. Sheared varieties contain a considerable percentage of sericite and are pale green in colour. The sericite shreds are oriented in the plane of schistosity. Tourmaline is a fairly common accessory constituent.

Quartz Veins.

The gold-bearing quartz veins of this area are discussed in the chapter dealing with the economic geology of the map-area.

Porphyritic Granodiorite.

Porphyritic granodiorite occurs in broad dykes intrusive in the schist-complex. It is granitic in appearance and much coarser-grained than the rest of the schist-complex; the feldspars reach one inch in diameter. Although intrusive the edges of these dykes show no signs of having been chilled.

Two generations of mineral constituents are prominently displayed in thin sections. The phenocrysts consist of oligoclase feldspars up to an inch in diameter, smaller quartz crystals, and a few crystals of mica. The quartz phenocrysts have pyramidal but no prismatic faces, and show either hexagonal or rhomboid outlines in thin sections. The mica is a colourless variety, probably a bleached biotite. The groundmass, consisting of the same minerals as the phenocrysts and in about the same proportions, is medium to fine-grained.

This rock bears a much closer resemblance to the batholithic granite than to any other of the formations in the schist-group.

RHYOLITE OF LEONARD AND TYRRELL TOWNSHIPS.

A considerable portion of Leonard and Tyrrell townships is underlain by a sheet of rhyolite and tufaceous deposits of the same composition. These rocks are best exposed on the shores of Spider and Black lakes. Fragmental matter was first ejected, forming a lower tuff bed. This was succeeded by a flow of lava and another shower of volcanic debris. A part of the upper tuff appears to have been assorted, probably in water, producing a rock resembling an arkose or feldspathic quartzite, and a slaty material which is interstratified with the arkosic type. The association of volcanic and water-assorted volcanic materials is much like that found in Churchill township, except that the water-assorted deposits are less varied in character and less abundant.

The total thickness of the series is probably some hundreds of feet. The slaty member, which is the only one showing distinct stratification, on Black lake dips 70 degrees west. On Spider lake it is nearly horizontal. But, judging from the form and extent of the area underlain by the series, and from the massive, unsheared character of the rock, it appears to be much less folded than most of the schist-complex. It rests upon schistose basic volcanics and iron formation that stands on edge. It may have been competent enough to resist the deformative forces which affected the iron formation, but it seems more likely that it is much younger and for that reason was never subjected to the same stresses.

Rhyolite.

Near the top and bottom of the flow, where it is finest grained, the rhyolite is a pale grey, greenish, or dark grey rock either without sign of crystalline texture or with a few glassy quartz crystals and dull white feldspars in a groundmass of this amorphous character. The middle of the flow is better crystallized. The coarsest phase consists of feldspar crystals a quarter of an inch long, and smaller ones of quartz and a ferromagnesian mineral abundantly distributed through a very fine-grained, grey groundmass. Amygdules filled with calcite and quartz occur only in the fine-grained portion near Spider lake, which is regarded as the top of the flow.

Fine and coarse-grained types are represented by Plate V A and B. The texture is always notably porphyritic. It seems that phenocrysts of feldspars and quartz began to crystallize about the same time during the cooling of the lava, for both are found in about equal abundance in the finest-grained phases of the rhyolite; but with progressive crystallization the feldspars grew much larger than did individuals of quartz. A ferromagnesian mineral is visible only in the coarser parts of the flow, and was, therefore, last to crystallize among the first generation of minerals. The feldspar includes a plagioclase of oligoclase-albite composition and, in lesser amount, orthoclase. Quartz individuals have a crystal form rather common in volcanic rocks (Plate V C). They yield rhomboid sections that extinguish diagonally, and triangular forms, sometimes with the angles bevelled off, when cut normal to the *c* axis. The ferromagnesian mineral is altered to epidote, etc., and cannot be identified. It forms a small percentage of the rock mass. Large and fairly numerous pyrite grains are present. Aggregates of pyrite also occur commonly in the rhyolite formation; in fact the abundance of this mineral is rather noteworthy.

Even where there are no phenocrysts (Plate V A) the groundmass is crystalline, consisting of a felty aggregate of minute feldspar needles; but this is probably due to the crystallization of an original volcanic glass after it solidified. The groundmass in the coarsest-grained phase is a holocrystalline mosiac of feldspar and quartz grains and a slightly altered dark mineral.

Tuff.

The tufaceous part of the series ranges from a coarse tuff, made up of angular fragments 6 inches or more in diameter, down to a coarse ash rock and also merges insensibly into water-sorted slaty and arkosic types. Plate V D represents a moderately fine sample. The fragments consist of rhyolite like that in the flow; some of them are of a more trachytic type containing no visible q artz and with the feldspar laths arranged in the manner characteristic of trachyte. A trachytic phase was not observed in the flow, but there is probably some range in its composition and such a rock type may well exist in it. The larger fragments in the tuff are more conspicuously amygdaloidal than the flow rock. The interstitial material is nearly always made up of finer fragments of quartz, feldspar, and rhyolite; but in one instance the fragments are enclosed in a glassy, ropy lava.

Stratified Materials.

There are conformable gradations from volcanic tuff into a whitish formation comparable in its composition to a feldspathic quartzite. The greater part of this formation is massive and without distinguishable bedding planes; but on Black lake and locally in Tyrrell township it alternates with thin beds of a dark grey, distinctly stratified formation of slaty appearance. At such points the stratified character of both is unmistakable.

The quartzitic type is composed of angular or poorly rounded quartz and feldspar grains, with an occasional composite one of the acid extrusive. The slaty type is made up of smaller angular grains of the same materials and a finer-grained paste in which the larger grains are embedded.

It is clear from the composition of these materials and from their gradational relations to the rhyolite tuff that they have been derived from the latter by assortment. No conglomeratic phase was seen, but in all other respects they closely resemble the volcanic sediments of Churchill township, and probably, like the latter, resulted from the deposition of volcanic debris in water.

VARIOLITIC, ELLIPSOIDAL LAVA.

Another member of the pre-Huronian complex that deserves independent description was found in the northern part of Tyrrell township. It lies just outside the limits of Onaping map-area but can be located on the map of Gowganda mining division.[1] It occurs in a prominent hill west of Mosher lake and at other points in that vicinity, notably along the north boundary of mining location H. R. 374.

Like most of the complex this formation has been so affected by geological disturbances that its precise extent and relations are now hard to determine. It can be said, however, that it is a volcanic flow of considerable thickness and of intermediate composition. It is characterized by an ellipsoidal structure particularly noticeable on weathered surfaces, where the material that fills the spaces between ellipsoids weathers into shallow grooves. The ellipsoids outlined by this net work of grooves are from 1 to 6 feet in diameter. They are not flattened to a noteworthy degree in any one direction and fit closely together. The interstitial grooves are not over an inch wide; and the angular spaces where three ellipsoids meet, unlike those in the ellipsoidal andesite of West Shiningtree area, are not large. Also, unlike the West Shiningtree andesite the interspaces between the ellipsoids are filled with lava, not with vein minerals.

Both ellipsoids and interspatial material are composed mainly of dark-green lava, so fine-grained that even with a hand lens it appears amorphous. The central parts of the ellipsoids consist of this lava alone; but around their margins the lava is thickly mottled with round spots of a much lighter, bluish-grey colour (Plate VI). These are the varioles. They consist of lava which does not weather so readily as the darker groundmass and so forms on weathered surfaces a peculiar pimply border around each ellipsoid. They are abundant and largest at the periphery of the ellipsoids; farther in they become smaller and fewer, and finally disappear. The variolitic border of the ellipsoids varies greatly in different parts of the flow. In some places it is scarcely noticeable; in others it is 6 inches wide and

[1] Geol. Surv., Can., Map No. 64 A, south half.

conspicuous. The individual varioles range from less than a millimetre to a centimetre in diameter. They are sharply defined from the darker groundmass and occur either as perfectly spherical individuals or joined together in strings parallel to the margin of the ellipsoid.

A thin section of the groundmass in which no varioles are present, taken from an ellipsoid having only a faint variolitic margin, consists, as observed under the microscope, of fan-shaped aggregates of colourless microlites embedded in pale green, devitrified glass. The microlites are about 0·4 millimetre long, slender, and are probably feldspars, though the colourless, unstriated, weakly refringent and birefringent substance now composing them cannot be positively identified. The matrix enclosing the microlites, no doubt formerly a glass, now consists of a felty aggregate of slender, slightly pleochroic needles (actinolite?), grains of epidote, and some indeterminable substances. There are a few phenocrystic areas, almost a millimetre in diameter, with outlines suggestive of stout feldspars in the section; but these areas are now occupied by the same secondary products as the groundmass and cannot, therefore, be positively identified. The rock is probably a fairly acid andesite.

Thin sections of the variolitic phase of the lava are so completely decomposed that none of the original constituents can be determined with any certainty; nor is it possible to ascertain the mineralogical difference between varioles and groundmass. The textural features of both remain. The groundmass has none of the fan-shaped spherulites noted in the non-variolitic lava; it consists of slender microlites, shot in all directions through what was probably once glass, but is now crystallized to a confused aggregate of secondary minerals: epidote, a colourless isotropic substance that may be a form of silica, and semi-opaque, granuler aggregates of some nighly refringent and highly birefringent substance. There are also occasional rectangular phenocrysts suggestive of feldspars; both these and the microlites now consist of a colourless indeterminate substance resembling chalcedony, and epidote.

The varioles consist of the same occasional, rectangular phenocrysts, needle-like microlites, and matrix of secondary minerals. There is no semblance of a radial arrangement. The microlites, however, unlike those in the groundmass, have a pronounced lateral skeletal development and resemble a feather in structure. Also the semi-opaque, highly refringent, secondary material that occurs in the groundmass is far more abundant in the varioles, rendering them grey and more opaque than the groundmass.

The needle-shaped microlites protrude from the varioles so as to give them a spiny appearance. Some of the rectangular phenocrysts also protrude into the groundmass, and in such cases the protruding portions are rounded, as if corroded by the groundmass. The impression conveyed is that after they had solidified the varioles were partly resorbed by the still fluid groundmass which enclosed them.

Varioles and groundmass alike are traversed by many microscopic fractures that are now filled chiefly with epidote.

Although this variolitic lava is too badly altered to throw additional light upon the peculiar differentiative process that gave rise to it, it is described at some length because it is the first, or one of the first, occurences to be recorded in Canada. An excellent historical account of the use of the term variolite is given by Cole and Gregory.[1] According to these authors, variolite is a product of rapid cooling at or near the margin of a basic igneous magma. It occurs occasionally as a selvage to dykes; but characteristically it is found in volcanic formations. Frequently, as in the present case, variolitic lava is also ellipsoidal, with the variolitic portion around the margin of the ellipsoids. The variolite of Mt. Génevre, they believe, consolidated while the groundmass was still plastic, because the variolite shell of the ellipsoids is in some instances infolded toward the interior of the ellipsoid; also because the varioles are sometimes corroded by the groundmass. From a comparison of available descriptions of variolitic lavas, they conclude that varioles may or may not have a radial structure.

[1] "The variolitic rocks of Mt. Génevre," Quart. Jour., Geol. Soc., vol. 46, p. 295.

CONDITIONS DURING THE FORMATION OF THE SCHIST-COMPLEX.

The schist-complex is predominantly igneous, and of the igneous rocks a large percentage by mass is extrusive. Sedimentary rocks are insignificant in amount and many of them are simply local deposits of pyroclastic materials that have been assorted and stratified by water action. The period was undoubtedly one of dominant, varied, and protracted vulcanism.

The presence of bodies of water during this time is implied by the sediments and by the ellipsoidal lavas. Evidence is steadily accumulating to show that an ellipsoidal structure in basic lavas is a characteristic very common and perhaps peculiar to subaqueous flows.[1] However, an ellipsoidal structure, though of frequent occurrence, is not common to all the basic extrusives of the complex. Sediments such as the conglomerate-arkose-slate series in Churchill townships, though evidently laid down in water, are shallow-water deposits, and of very limited extent so far as they are now known. There is also much volcanic debris in the schist-complex which shows no evidence of water action. The facts at hand suggest, therefore, that, while bodies of water did exist during this time, they were probably localized transient bodies, and that the surface as a whole was a land surface.

AGE RELATIONS.

The group of formations here designated the pre-Huronian schist-complex has been and is still frequently called the Keewatin; but there appears to be much uncertainty in the application of this term. The Keewatin, as understood in all recent rock classifications used in northeastern Ontario, is a mainly volcanic group older than the Laurentian granite-gneiss batholiths. The Laurentian in its turn applies to those batholithic intrusives older than the sediments variously termed the Sudbury series, Timiskaming series, etc. The identity of the Keewatin or the Laurentian depends upon their relation to these pre-Huronian sedimentary series. Now pre-Huronian sediments

[1] Wilson, M. E., Geol. Surv., Can., Mem. 39, p. 51.

are nowhere very abundant and are not recognizable at all in Onaping map-area. Consequently, it cannot be known whether the batholithic rocks of the map-area are pre-Sudbury, that is Laurentian, or post-Sudbury. They are more likely to prove to be the latter, for all the granite-gneisses in northeastern Ontario whose relationships have been determined, are intrusive into the pre-Huronian sediments. No Laurentian areas have yet been identified. Neither, then, can the schist-complex be proved to be pre-Laurentian, that is, Keewatin.

Even if the batholiths were Laurentian there would be some reason to doubt that the entire schist-complex was Keewatin. At all observed contacts of the complex with the granite-gneiss the latter is intrusive, and most of the members of the schist-complex are highly folded and schistose, a fact in harmony with the general opinion that batholithic invasion [illegible] an accompaniment, perhaps a consequence, of mountain-buil[illegible]. Some of its component formations, such as the rhyolite flow in Leonard township, are very gently folded. These gently folded formations have not been found in contact with the granite-gneiss so it cannot be decided positively whether they are older or younger than it; but it is possible that they were laid down near the end, or after the mountain-building and batholithic-invasion period, thus escaping extreme deformation. It is not advisable, therefore, to fix the date of these younger formations more definitely than as pre-Huronian.

The indiscriminate application of the terms Keewatin and Laurentian, in northeastern Ontario, to the schist-complex and granite-gneiss respectively is to be deprecated until their relationships to one another and to the pre-Huronian sedimentary series are established.

The sediments that are associated with the rhyolite-tuffs in Leonard township have been designated in one geological report[1] as Timiskaming series (an important pre-Huronian sedimentary horizon). This is evidently based upon a misconception of the nature and relationships of these sediments, which cannot be regarded as more than a local modification of volcanic

[1] Ann. Rept., Ont. Bureau of Mines, vol. XIX, part II, p. 189, and map of the S[illegible] Cobalt-Porcupine region, accompanying vol. XXII, pt. 1.

ejectamenta. Even if they did represent a sustained process of erosion and redeposition, such a correlation would rest upon the precarious basis of casual lithological and metamorphic resemblances. At the present time a precise correlation of the pre-Huronian sediments in Ontario is all-important for the elucidation of pre-Huronian history, for they alone can furnish a chronological datum-plane to which the preponderant igneous rocks can be referred; and because of its importance such a correlation should be especially well proven.

Pre-Huronian Batholithic Rocks.

DISTRIBUTION.

The whole western part of the map-area is underlain by granite-gneiss; elsewhere the crystalline basement is largely hidden beneath the Huronian sediments and only a few small areas of granite-gneiss are visible. It is practically certain, however, that much is concealed by the Huronian and that the small visible areas are part of a great batholithic mass (see Figure 2).

LITHOLOGICAL CHARACTER.

The batholithic rocks are all coarse-grained, dominantly light-coloured rocks of deep-seated origin. They vary from massive to imperfectly gneissic; a highly perfect foliation, so common in many parts of the Pre-Cambrian shield, does not obtain in this area. The common rock type passes in the field for a granite or granite-gneiss having hornblende, biotite, or both these minerals as its dark constituents. But the proportions of dark minerals, feldspars, and quartz vary greatly. Quartz may be subordinate or lacking, and the dark minerals abundant. The rock then becomes a syenite or even a diorite. Still more basic, highly amphibolitic types result from the recrystallization and partial absorption into the batholithic magma of basic fragments derived from the older schist-complex. Highly acid rocks are represented by dykes and irregular bodies of pegmatite and aplite that cut the rest of the batholith.

Microscopic study shows that plagioclase preponderates over potash feldspars in the batholithic rocks and that these are, therefore, granodiorites rather than granites. In quartz-bearing specimens plagioclase, ranging from oligoclase-ablite to andesine, is usually the principal constituent. It seldom forms less than 20 per cent of the rock mass, while potash feldspars fall considerably below this amount. It will be shown later, in dealing with the assimilation of schist-complex rocks by the granite-gneiss, that the abundance of plagioclase in the latter may be due to assimilation of basic materials by a normally granitic magma. In the aplites and pegmatites potash feldspars predominate.

It follows from the above general description that, in spite of a uniformity of colour, texture, and of the minerals composing them, the granite-gneisses have a considerable range in composition. This appears to be due to two, possibly three, independent causes.

CAUSES OF LITHOLOGICAL DIVERSITY.

In the first place, there are probably a number of distinct intrusive masses. It is likely that the invasion of so huge a volume of material as the pre-Huronian batholith was a slow, complex process involving repeated intrusions of magmas of slightly different composition. Positive, uncompromising field evidence of successive intrusions is hard to obtain. The contacts between lithologically unlike areas of granite-gneiss appear always to be gradational. Yet it is possible to distinguish several areas of quite unlike character in the same great batholithic area. Around Deschenes and Opikinimika lakes, for example, the granite-gneiss is dominantly a hornblende granodiorite rather rich in hornblende. This area is comparatively free of the fragments or ribbons of amphibolite that originate from included fragments of the schist-complex; hence it is unlikely that the original magma in this locality was much modified by assimilative processes. The granodiorite of this locality might well be taken to represent a normal batholithic magma. About Windy lake there is an area, also of considerable extent, underlain by a very light-coloured granitic rock almost devoid of ferromagnesian constituents. This also appears to represent a primary magma different from that at Opikinimika lake. Similarly, other parts of the batholith consist of fairly uniform biotite gneiss. These are possible instances of originally unlike intrusive bodies.

There is satisfactory evidence of differentiation having also contributed to the heterogeneity of the batholithic rocks. The ordinary granite-gneiss is cut by dykes of aplite and pegmatite of much more acid composition. The aplites are fine-grained rocks consisting essentially of quartz and feldspars, the latter either orthoclase or albite. The pegmatites differ from the aplites chiefly in being very coarse-grained. These rocks occur mostly as dykes that were intruded into the granite-gneiss after it had solidified; but some of the pegmatite masses are irregular, and merge into the granite-gneiss in so gradational a manner as to leave little doubt that they are parts of the same intrusive magma. Pegmatites and aplites, however, do not form any important part of the batholithic mass. It is also possible that some of the vaguely defined, exceptionally basic patches and schlieren that occur in the granite-gneiss are basic segregations; but these are difficult to distinguish conclusively from similar basic phases that originate by assimilation of xenoliths from the older schist-complex.

Without doubt, assimilation of pre-existing rocks has been a third cause of variation in the batholithic magma. The granite-gneiss is especially basic and rich in hornblende near its contact with the schist-complex. The constancy of this relation alone is strong evidence of interaction between the granitic magma and the basic schists. It is confirmed, however, by another circumstance. By the final freezing of the magma the assimilative process was interrupted in all its successive stages. Subsequent erosion has laid bare these originally deep-seated rocks so that it is now possible to view the unfinished stages of magmatic assimilation and deduce therefrom some idea of the process itself.

An early stage is well exemplified in the neighbourhood of Elephanthead lake, in Connaught township. The contact there is typically ragged and irregular, with spurs of the crystalline schist-complex projecting into the granite-gneiss and apophyses of granite penetrating into the crystalline schist. The granite-gneiss next to this ragged contact is full of angular blocks of the crystalline schist. Some of these blocks are many yards in length and have been moved so short a distance that the original positions from which they were moved are still recognizable. Others have been floated farther away, fractured, the fractures filled with the granitic magma, and in this manner broken up into a swarm of smaller fragments (See Plate XI). These in turn have been floated away from one another. The contact of the schist-complex and granite-gneiss and the swarms of xenoliths in the granite-gneiss near this contact resemble in miniature an irregular, deeply embayed coast-line fringed with a myriad of islands and islets (Figure 4).

The first stage in the assimilative process is thus one of intense fracturing and floating away of fragments of the schist-complex into the granitic magma. This is followed by melting and absorption by the granitic magma of the smaller blocks. The absorption stage is not well shown near Elephanthead lake, where the xenoliths are still angular or only subangular. It is better exemplified in the northwest part of McNamara township about 30 chains southeast of mile-post 4 on the west side. The rock there is for the greater part a medium-grained, biotite granite. Here and there in the granite are darker patches a few yards in diameter, which contain swarms of round, nodule-like inclusions. The inclusions vary from several inches to a fraction of an inch in diameter, and each is surrounded on the weathered rock surface by a tiny, moat-like depression, due to more rapid weathering of a narrow peripheral zone. They prove on microscopic examination to be highly altered iron formation. The dark patches enclosing the swarms of iron-formation inclusions are a diorite so rich in hornblende that it is nearly black. About 6 feet away from the swarm of inclusions it grows lighter in colour and in twice that distance merges into medium-grained, reddish, biotite granite, the prevailing rock in the immediate locality. The patches of dioritic rock containing the inclusions are evidently basified parts of this granite and the nodule-like inclusions are the vestiges of a body of iron formation, absorption of which produced the basic patches.

The details of this absorptive process as they appear under the microscope are shown in Figure 5. Owing to technical difficulty in securing good photomicrographs the microscopic features have been shown by camera-lucida drawings. The magnified diagrammatic vertical section (Figure 5a) shows an iron-formation inclusion and the main gradational phases from a highly hornblendic assimilation product next the inclusion to normal granite outside the zone of assimilative action. The camera-lucida micrographs (Figure 5 b, c, d) illustrate the actual mineralogical relationships that obtain at A,B, and C, Figure 5a).

The inclusions of recrystallized iron formation consist of a felty aggregate of blades of grünerite ($FeSiO_3$) and a smaller proportion of actinolite thickly peppered with small crystals of magnetite. Next to the contact with the intrusive rock (B, Figure 5 a and Figure 5 b) the grünerite blades are larger and radially oriented. There is no actinolite in this zone and magnetite is not so abundant. The line of contact is definite. Beyond the contact lies a zone about one-fourth inch wide (B, Figure 5 a and Figure 5 c) composed essentially of green actinolite in bladed aggregates and epidote. The epidote is in fairly good crystals embedded in the actinolite. This is the material which weathers into the tiny moat that surrounds each exposed xenolith. The actinolite-epidote phase passes gradationally into a third in which plagioclase and common hornblende gradually replace epidote and actinolite. The hornblende has the following pleochroism:

a—yellowish green, b—deep brownish green, c—blue-green. The plagioclase is an intermediate variety, though too much altered for the proportions of albite and anorthite to be precisely determined. Titanite and large rods of apatite are the chief accessories. As observed in thin section, the unbasified red granite, into which the above phase grades, consists of quartz, an acid plagioclase, orthoclase, and a small amount of biotite, altered to chlorite; magnetite, titanite, and pyrite are accessory. Quartz and plagioclase, probably oligoclase, are most abundant. The rock is, consequently, a granodiorite. The gradation from the third stage above into granite was not studied in detail, but its essential facts appear to be that the hornblende diminishes in

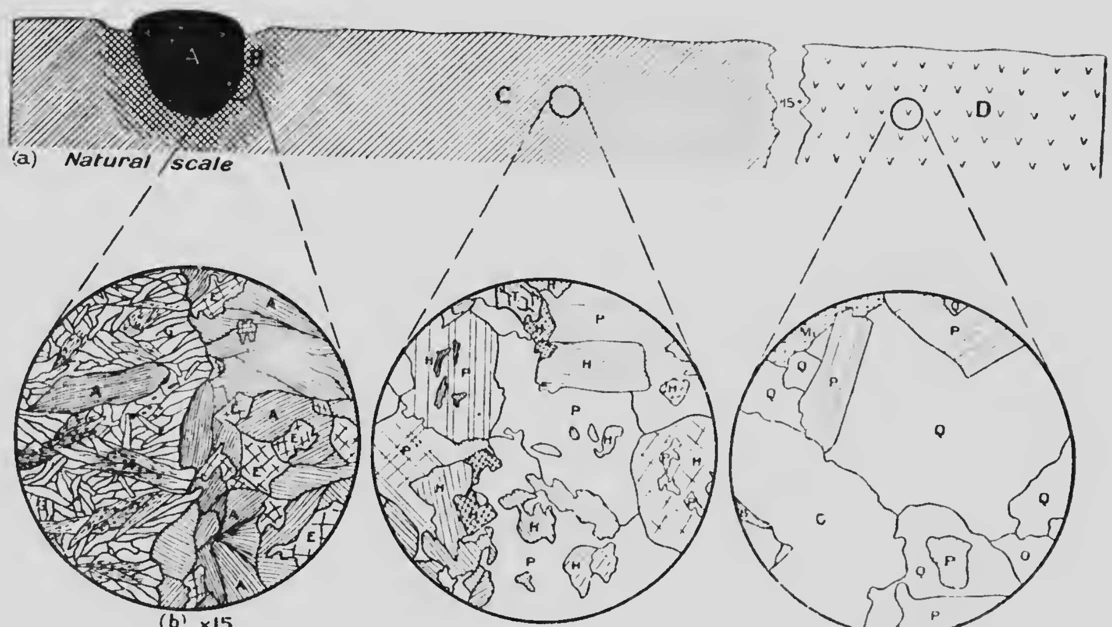

Figure 5. a. Vertical section showing a partly absorbed xenolith of iron formation (A), assimilation products resulting from the assimilation of iron formation by the granitic magma which enclosed it (B,C), and the same granite just outside the zone affected by assimilation (D). Natural scale. b, c, d. Camera-lucida drawings of thin sections taken from the zones A-B, C, and D for the purpose of showing the progressive mineral changes resulting from the assimilation of the iron formation by the granitic magma. Magnified 15 diameters. A = actinolite, B = biotite, E = epidote, G = grunerite, H = hornblende, M = magnetite, Mi = microcline, O = orthoclase, P = plagioclase, Q = quartz, T = titanite.

amount, the plagioclase becomes less and less basic, and orthoclase and free quartz appear and increase in amount.

In the above instance of magmatic assimilation all the rocks are unfoliated. There appears to have been no flow movements in the magma. Assimilation took place by diffusion of the basic assimilated material into the granitic magma; and the complex series of mineralogical reactions that took place was no doubt due to the varying concentration of the original reacting materials—iron formation and granodiorite. More commonly there has been fluidal movement during assimilation, and the xenoliths are drawn out into ribbons of glistening hornblende gneiss. In such cases practically no gradation in composition is perceptible between these ribbons and the adjacent granite-gneiss. Magmatic movements, no doubt, prevented concentration of basic materials around the xenoliths that were being absorbed. This streaky banded gneiss is well developed south of Burwash lake.

Magmatic assimilation has long been accepted as an operative geological process. The above example is only one more added to an already long list, and is described chiefly because the details of the mineralogical reactions involved are so clearly preserved. At present, investigators of the problem are more concerned with its quantitative aspect. To what extent has magmatic assimilation ever been effective?

Some information relative to this question was obtained in the vicinity of Burwash lake where assimilation appears to have taken place on a large scale. The granite-gneiss in Cotton township, in which Burwash lake lies, and in the adjoining townships is full of ribbons and subangular masses of the glistening variety of hornblende gneiss which characterizes the contact-metamorphic aureole around schist areas. There are also many small bodies of iron formation enclosed in the gneiss. So it may reasonably be concluded that a large body of schist-complex once existed there. Except for the vestiges mentioned, this body is now gone, either eroded or absorbed by the granite magma. Wherever iron formation has been found within an area of schist-complex it is underlain as well as overlain by an apparently great thickness of other members of the complex, so it may be assumed that the iron formation near Burwash lake was once underlain in the same manner. Erosion could not remove this thick underlying part without also removing the iron formation, whether the complex were folded or not. The uprising batholithic magma must have itself removed it in order to reach and enclose bodies of iron formation as it does. In fact, it probably also destroyed some of the complex superior to the iron formation, for the iron formation now rests on edge with granite-gneiss on both sides of it. The iron formation survived by virtue of being the most refractory material in the schist-complex, encountered by the granitic magma. That the part which disappeared was actually assimilated is implied by the swarms of partly absorbed xenoliths that remain, and by the unusual basicity of this part of the batholith. The granite-gneiss underlying an area of 50 or more square miles in this neighbourhood is unusually variable in composition from point to point, and, on the whole, unusually rich in hornblende. Frequently it merges into a hornblende diorite possessing a texture which, as shown later, is rather characteristic of rocks formed by assimilation.

If the view expressed above is correct, over an area of many square miles—at least 50—in this locality, the batholithic magma absorbed a thickness of schists measurable in hundreds if not thousands of feet. This is the only place where, owing to the presence of the iron-formation remnants, an approximation to a quantitative estimate is obtainable. But the results of assimilation are not more striking here than at most points around the edges of the schist areas. It is not unreasonable, then, to regard the amount of assimilation registered at Burwash lake as representative of other parts of the region.

TEXTURE OF ASSIMILATED PRODUCTS.

Plate VII A represents a thin section of a syenitic portion of the granite-gneiss on the west shore of Burwash lake. The gneiss near where the specimen was obtained contains many partly assimilated inclusions of glistening amphibolite, and there is additional evidence to indicate that the specimen itself is ordinary granite-gneiss rendered especially basic by assimilation of amphibolite.

The specimen is peculiarized by the complicated intergrowth of its constituent minerals. Even in the hand specimen the hornblende and feldspar can be seen to interlock and to be intergrown, and under the microscope this textural peculiarity is pronounced. The feldspars form a continuous background or matrix in which is embedded a swarm of small hornblendes. Some of the hornblendes have good crystal forms, but the majority are irregular in shape and they are irregularly oriented. The background of feldspars consists of large irregular oligoclase individuals separated from one another by canal-like areas of microcline. Microcline and oligoclase have crenulated interlocking contacts, recalling cranial sutures in aspect.

The rock just described may be a magmatic assimilation product. In the course of field work in this and other map-areas in northern Ontario, a series of undoubted cases of magmatic assimilation have been studied, and in each case the product of assimilation was characterized by the same complex interlocking of mineral individuals and the same irregular intergrowth of the mineral constituents. These are described below.

At mile-post 298 on the Canadian Northern Ontario railway, the Huronian sediments are invaded by a dyke of coarse diabase, in the middle of which are a number of "ghosts," or vaguely defined light-coloured areas 30 inches or less in diameter. These represent inclusions that were partly fused and digested by the diabase magma. They were either feldspathic quartzite or granite but they have been so recrystallized that their original nature cannot be more precisely recognized. For a few inches marginally they have reacted with the diabase magma to form an assimilation product, a photomicrograph of which is shown in Plate VII B. At least 90 per cent of the assimilation product consists of quartz and feldspar, principally orthoclase, with finely striated acid plagioclase less abundant. Biotite is the only other essential constituent. Crenulated, suture-like contacts between the feldspars and quartz are conspicuous. In fact the quartz and feldspars are intergrown to such an extent that, under crossed nicols, the feldspars have a worm-eaten appearance approximating in regularity to a micrographic intergrowth. In some cases all the quartz within one feldspar individual extinguishes at the same time, but quite as often it extinguishes irregularly. The proportion of quartz and feldspar thus intergrown is highly variable. The biotite occurs in small irregular individuals enclosed within the quartz and feldspar.

The next example was observed outside Onaping map-area. At the village of Blind River, on the north shore of lake Huron, a mass of diabase has intruded quartzite, fragments of which it has enclosed and more or less completely absorbed (Plate VIII A). The product of interaction between the diabase and the quartzite (Plate VIII B) is intermediate between these rocks in composition and is slightly coarser than the adjacent diabase. It is composed essentially of common hornblende, plagioclase of intermediate composition, and a micrographic intergrowth of quartz and oligoclase. There is also some epidote. The hornblende is in small irregular patches mingled indiscriminately in the plagioclase and quartz. The contacts between quartz and plagioclase are again complexly interlocking, or these minerals are intergrown micrographically.

A third example of the same complex, suture-like contacts between feldspars and quartz, a rudely micrographic intergrowth of these minerals, and the poicilitic enclosure within them of hornblende was observed some years ago in Gowganda Mining Division, in rocks developed at the contact of diabase sills with greywacke.

Referring to the contact facies between an acid granophyre and an older basic gabbro in the north of England, Harker states[1] that "there are not wanting indications of a micrographic intergrowth on a small scale between augite and the other constituents, including magnetite........So far as I have observed, this structure is found only in the remarkable basic modification of the granophyre near its junction with the gabbro"; of the basic modification he says further "the curious modification of the Carrock Fell granophyre is due to a reaction between the acid (granophyre) magma and the highly basic margin of the previously consolidated but still hot gabbro."

[1] "The Carrock Fell granophyre", Q.J.G.S., vol. LI, p. 129.

In all the first-hand instances just given the rock resulting from assimil. on of solid rock matter by a magma is characterized by:

(1) Irregular intergrowth of the various constituent minerals, usually without parallel orientation; quartz and feldspar, however, tend to become intergrown micrographically. All these minerals are, of course, products of anamorphic conditions and, consequently, similar to the primary constituents of igneous rocks. Their irregular intergrowth is easily distinguishable, therefore, from the somewhat similar, confused arrangement of minerals that have resulted in rocks from decomposition.

(2) A crenulated, interlocking contact between the larger mineral individuals.

How important these textural features may prove to be in diagnosing cases of magmatic assimilation is something that will appear as a multiplicity of examples are compared. It is probable, however, that their value will be a limited one. In each of the examples given above assimilation has been imperfect; so imperfect, in fact, that from field observations alone no doubt could exist as to the nature of the process. On the other hand, a great deal of assimilation must have taken place along the contacts between the granite-gneiss batholiths and the schist-complex, yet the textural peculiarities described above are not very common. An irregular vermicular mineral intergrowth does occur in the glistening hornblende gneiss of this contact zone, but not invariably. It is possible, therefore, that the textures in question are due to imperfect fluidity and will, consequently, be found to be restricted to cases of imperfect assimilation.

This texture must be distinguished from somewhat similar ones that are produced under different conditions, e.g. the graphic and micrographic intergrowths in purely igneous rocks or by the formation of decomposition products. Nevertheless, if it proves to be even a supplementary means of identifying assimilation products it will be a useful instrument in this at present obscure corner of metamorphic geology.

Cobalt Series.

LITHOLOGICAL CHARACTER.

The mantle of Huronian sediments that overlies the pre-Huronian crystalline basement consists, in Onaping map-area, of a single series, the Cobalt series. It is composed almost altogether of clastic sediments—conglomerate, greywacke, and feldspathic quartzite; it includes, in addition, one thin formation of siliceous limestone. But in respect to mode of origin and lithological character it is separable into two quite distinct parts.

The lower part is made up dominantly of dark grey conglomerates and greywackes characterized by imperfect weathering and imperfect assortment, and regarded by the majority of geologists who have studied them as probably of glacial origin. These materials mingle so complexly and their order of succession varies so much from place to place that no attempt has yet been made to map them separately. This lower division has no suitable name, as yet, though one is needed. Logan's term, Upper slate conglomerate,[1] is hardly adequate, for it includes greywacke, laminated greywacke, and limestone as well as conglomerate. The name Gowganda formation is suggested for it, as the rocks in question are exceptionally well developed in Gowganda district. The term formation may seem unsuitable for what is really an association of formations rather than a single one; but the conglomerate, greywacke, laminated greywacke, and limestone are too intricately and variably associated to be resolved by the field methods which served to differentiate the other formations in the Cobalt series. They have to be represented on geological maps by one colour. Moreover, these rocks are, it is believed, bound naturally together by a common mode of origin. So, for practical purposes the term formation is serviceable.

The upper part of the series is very thick and consists altogether of quartzites, evidently laid down under water. It is separable into a thick lower quartzite called the Lorrain

[1] Geol. Surv., Can., Mus. Bull. No. 8, p. 23.

quartzite, a banded cherty quartzite as yet unnamed, and another white quartzite above, also unnamed. On the accompanying map, however, these three formations are included under one colour. They are all white or pale coloured.

In spite of their diversity of appearance, composition, and genesis these two parts of the Cobalt series are, for the most part, in conformable relation to each other. An unconformity exists in a few places.

GOWGANDA FORMATION.

Except in a few places the basal member of the Gowganda formation is conglomerate, usually a boulder conglomerate and ordinarily several hundred feet thick. The basal conglomerate is succeeded by greywacke, laminated greywacke, and other conglomerates, of variable thicknesses and arranged in no constant order of succession. The upper part consists of greywacke, more or less quartzitic and well stratified. Considerable interest attaches to the lithological characters of these rocks because of the growing opinion that they are continental deposits of glacial origin.

Conglomerates.

Most of the basal conglomerate is a boulder conglomerate distinguished by the preponderance of cement over pebbles and boulders, and by the extreme diversity in size, shape, and composition of the latter. There are pebbles of all the characteristic igneous materials found in the pre-Huronian basement and occasional ones of pre-Huronian conglomerate, quartzite, and greywacke. A crystal of quartz $1\frac{1}{2}$ inches long, with well preserved edges and angles, was found in it at one point, and at another place on the west shore of Shiningtree lake a well rounded pebble of fresh pyrite. Pebbles of soft, easily destroyed materials such as chloritic schists are indiscriminately mingled with others of resistant granites, iron formation, etc. They range from small pebbles up to boulders 3 feet in diameter or occasionally larger. The largest observed in the map-area measured 5 feet 4 inches across the exposed surface. They vary in shape from subangular to smoothly rounded. Boulders with several flattened faces are common. Scratched boulders were not found within Onaping map-area, but a number have been found at various places in northeastern Ontario.[1]

The pebbles and boulders make up less than half of the rock-mass. They are seldom in contact with one another and in some parts of the conglomerate only one or two are found in a square yard of surface. The cement is unstratified. It is ordinarily a dark grey greywacke. Microscopic examination shows it to consist of quartz and feldspar grains, composite rock fragments, scales of chlorite, etc., ranging in size from fine sand grains to ultramicroscopic dust. There is little evidence of assortment. Neither is there much evidence of weathering, for the feldspars are still clear and fresh. The unweathered character is indicated in the following analysis of boulder-conglomerate matrix by the high ratio of soaa to potash, of magnesia to lime, and of ferrous oxide to ferric oxide.

SiO_2	61·96
Al_2O_3..	17·20
Fe_2O_3	1·42
FeO	4·49
MgO .	3·27
CaO	1·00
Na_2O.	5·27
K_2O .	2·01
H_2O (110°)....	0·10
H_2O (above 110°).	2·70
TiO_2	0·60
MnO	0·10
Total	100·15

Matrix of boulder conglomerate, [illegible] formation, from lot 4, Thompson township, Ontario. M. F. C[illegible], analyst.

Locally this boulder conglomerate merges into a more nearly normal beach deposit. On the south shore of Burwash lake, for example, and on Bobs lake in Tyrrell township, the conglomerate consists of medium-sized, well rounded pebbles so closely packed together that each touches its neighbours at several points. The cement, which is correspondingly scanty, is well washed sand or coarse grit.

[1] Coleman, A. P., Jour. Geol., vol. XVI.
Wilson, M. E., Geol. Surv., Can., Mem. 39, p. 94.
Collins, W. H., Geol. Surv., Can., Mus. Bull. No. 8, Plate I.

The conglomerates found higher up in the Gowganda formation are either of the boulder type or a peculiar variety apparently not found in other horizons of the Pre-Cambrian. They consist of a delicately stratified greywacke or argillite through which are sparingly distributed a few pebbles or small boulders rarely over 6 inches in diameter. The pebbles are in many cases so few that the formation scarcely merits the name conglomerate; but in other places they are fairly abundant, though never constituting more than 10 or 15 per cent of the rock mass. This remarkable type is really a conglomeratic phase of the laminated greywacke, which is discussed more fully in a later paragraph.

Greywacke.

The boulder conglomerate usually grades by a loss of pebbles and slight fining of the cement into greywacke; otherwise in such cases where the latter is poorly stratified, the conglomerate cement and greywacke are alike. But, especially near the top of the Gowganda formation, where it is distinctly stratified, there are gradations between ordinary greywacke and feldspathic quartzite. Presumably this material, originally a greywacke in composition, was sufficiently worked over by water to remove more or less of the finer particles and thereby concentrate the larger quartz and feldspar grains.

Laminated Greywacke.

There are all gradations between ordinary massive greywacke and the delicately stratified variety which has been termed banded slate, banded greywacke, argillite, and laminated greywacke, by the various geologists who have described the Cobalt series. It appears to be a fine-grained phase of the greywacke which has been segregated and delicately stratified by water action. Because the name laminated greywacke signalizes these two salient characteristics it is given preference in these pages. It is a dark-grey, slate-like rock made up of layers that range in thickness from one-fourth to one-fortieth of an inch. This lamination is brought out conspicuously on weathered surfaces. The lower part of each layer resists weathering better than the upper part. It also bleaches to a lighter colour than the upper part. The result is a faintly corrugated surface striped in alternating light grey and dark grey or brown colours. The nature of the banding is shown clearly under the microscope (Plate IX A). Each lamina, it may be seen, consists near the bottom of a fine, sandy greywacke which grows progressively finer toward the top. The laminated appearance is, thus, not due to differences in successive laminæ, but to a variation in texture within each lamina. The structure is comparable with the grain of wood. In most cases the laminæ are remarkably uniform and continuous; less commonly they are irregular in thickness and taper out.

The lower, coarse part of each layer is apt to be poorly assorted. It usually carries a few particles much coarser than their neighbours. These range from sand grains to small pebbles or even boulders 10 inches in diameter. Where such large ones occur, they have embedded themselves with sufficient force to cause the laminæ for an inch or two beneath to sag downward and pinch out (Plate IX B). The succeeding layers pass over them with little diminution in thickness. These boulders are nearly all well rounded and include a variety of rock materials. Only an occasional one may be present or they may be sown thickly enough through the laminated greywacke to form a conglomerate.

In a few localities the laminated greywacke has been brecciated and reconsolidated in a manner not readily explicable. So many such cases have been observed that the same causative agency, whatever it was, must have been operative for the whole region. Breccia of this sort is rather well exemplified on the west shore of a small lake lying just north of mile-post 4 on the eastern boundary of Frechette township. The banded greywacke at most points along the shore is very little disturbed and it dips only 20 degrees; but locally it is made up of angular to sub-angular fragments of the greywacke, closely packed together with a trifling amount of the same material acting as a matrix. In places the fragments still retain their regular banding undisturbed; but in other places they have been distorted and mashed together as if they had been plastic at the time. The breccia is now thoroughly reconsolidated. The boundary between the brecciated and the unbrecciated parts of the laminated greywacke is vague, with no sign of disturbance in the latter other than gentle folding.

The best exposed example of this breccia was observed on a small island at the south end of Duncan lake, a few miles north of Onaping map-area.[1] The breccia there is confined to a band less than 2 feet wide, which is conformably overlain and underlain by unbrecciated laminated greywacke dipping 20 degrees. It seems clearly a case of deformation contemporaneous with deposition. Yet the breccia fragments are sharply angular and were not distorted or mashed, the fine stratification lines in each fragment remaining quite straight, as if the deformed material had even then been a rigid brittle rock.

The laminated greywacke is evidently a water-laid deposit. The regularity of its lamination indicates that. The uniformity in thickness and texture of successive laminæ further implies a recurrent process of deposition, perhaps annual as in the case of the post-Glacial stratified lake-clays, which they resemble in most respects. The progression from coarse to fine materials in each lamina must have corresponded with a diminution in the currents which transported these materials; this in its turn perhaps corresponding with annual climatic changes; and the extraordinary delicacy of the laminæ—in some places only one-fortieth of an inch thick—calls for tranquil deposition. Yet under the same conditions boulders up to a foot in diameter were laid down with this finely stratified mud, forming the conglomeratic phases of the laminated greywacke which have already been described. The conclusion seems unavoidable that these boulders were carried not by water currents alone but by the additional agency of floating and melting ice.

The local contemporaneous brecciation of this greywacke is most readily explained by assuming the climatic conditions indicated above. It is difficult to conceive how, in a brief time and in a moist climate, the greywacke could become hard and

[1] See map of Gowganda Mining Division, Geol. Surv., Can., No. 1244a.

brittle enough to be brecciated, except by being frozen. The most readily conceived brecciating agency is, likewise, moving ice. Local crumpling in the post-Glacial lake-clays similar to those in the Huronian greywacke is believed to be caused in this way.

Limestone.

Only one thin limestone formation was found in the Cobalt series within Onaping map-area. It is exposed at a number of places in Demorest and Clary townships. The most accessible of these localities is on Sturgeon river. Beneath the limestone at this place is a rather quartzose, stratified greywacke. This grades into [illegible] by the appearance of calcareous layers a fraction of [illegible] interbedded with greywacke layers several [illegible]. The base of the limestone is thus a very thin-bedded calcareous greywacke about 2 feet thick. In the next 5 or 6 feet the [illegible] layers increase to a maximum thickness of 10 inches while the alternating sandy greywacke layers diminish in importance. At the middle of the formation about three [illegible] of it is limestone. From the middle upward this transition is reversed, the limestone grading into a material somewhat more quartzose than that which lies beneath. Including about 3 feet of calcareous greywacke at top and bottom, the total thickness is 15 to 20 feet. On weathered surfaces the limestone layers weather down more rapidly than the alternating sandy ones, producing a very characteristic corrugation. The limestone, being weak and not so competent to resist deformational stresses as the greywacke above and beneath, has been extraordinarily crumpled. The crumpling is brought out conspicuously on weathered surfaces.

Succession and Thickness.

There appears to be little uniformity in the thickness of the Gowganda formation or in the order of succession of the various materials comprised by it.

In the southeast quarter of the map-area, e.g. in Dundee, McConnell, Clary, and Beaumont townships there is a thick boulder conglomerate at the base. Partial sections show about

200 feet of this conglomerate, and its real thickness in places is perhaps twice as much. It appears, however, to vary a good deal in thickness and even to be lacking, for in Selkirk township west of Solace lake, a greywacke rests against the pre-Huronian granite-gneiss. The basal conglomerate passes gradationally up into poorly stratified greywacke. Higher up, the greywacke becomes better stratified, and usually includes a considerable development of delicately laminated greywacke, laminated greywacke-conglomerate, and locally some boulder conglomerate. The total thickness of greywacke, etc., is measurable in hundreds of feet; in Selkirk township, where the series dips 50 degrees east, there is an apparent thickness of 2,800 feet of greywacke. The thin limestone formation exposed in Clary and Demorest townships lies within the greywacke, at a considerable distance from the top. The total thickness of the Gowganda formation was estimated only at Solace lake in Selkirk, where the basal conglomerate is absent. It is likely, therefore, that the value obtained—2,800 feet—is several hundred feet below the maximum.

Westward from Wanapitei river, roughly speaking, the Gowganda formation thins out. On Burwash lake there is a distinct basal conglomerate and a greywacke above it, but the latter does not appear to be very thick. In Roberts township, there is also a basal conglomerate but no greywacke was seen, the conglomerate being succeeded by Lorrain quartzite. In Sweeny township, on the third lake of the chain forming the canoe route to Venetian lake, the Lorrain quartzite, with a thin conglomerate at its base, was found within a few feet of the pre-Huronian granite; so the Gowganda group appears to be entirely lacking at this point. The small Huronian outlier on Venetian lake consists of a basal conglomerate, massive greywacke, laminated greywacke, and quartzite in conformable succession; but the total thickness up to the quartzite appears to be only 500 feet, and as the quartzite is conformable above, 500 feet is evidently the original total thickness of the Gowganda formation. The small outlier of Lorrain quartzite in Rhodes township seems to rest directly upon the pre-Huronian granite-gneiss.

In the northern part of the map-area, near Shiningtree and Gowganda lakes, for instance, the Gowganda formation is very thick. It apparently includes a second conglomerate well up in the succession but separated from the Lorrain quartzite by stratified greywacke.

The succession and thickness of the Gowganda formation in Onaping map-area may be summarized approximately as follows:

Stratified and finely laminated greywacke and an upper conglomerate		0 — 2,800 feet
Limestone (locally)	10 — 15 feet	
Massive, stratified, and finely laminated greywacke		
Boulder conglomerate		0 — several hundred feet.
Total thickness		0 — 3,000 + feet

LORRAIN QUARTZITE.

The Lorrain quartzite, overlying the Gowganda formation, is a thick formation of somewhat variable character. White and pale greenish-white are the prevalent colours. The lower part of the formation is highly feldspathic, consisting of quartz and feldspar grains—orthoclase, microcline, and acid plagioclase—and occasional shreds of mica either bleached or still coloured and strongly pleochroic. The feldspars are notably fresh and both quartz and feldspar grains are poorly rounded or even angular. The rock is usually medium or rather fine-grained, though in places, as on Chiniguchi lake, the constituent grains of feldspar reach one-half an inch in diameter. In general, the material composing the lower part of the Lorrain quartzite has the appearance of having been accumulated under conditions of vigorous disintegration, relatively little decomposition, and brief transportation.

Higher up, approximately in the middle of the Lorrain, the quartzite is less feldspathic and is characterized by thin beds of conglomerate. The proportion of conglomerate to quartzite is small, possibly 5 per cent. Individual conglomerate beds are not over 3 feet thick and apparently not of great horizontal extent. This conglomerate is peculiar in composition, and would seem to indicate a more thorough process of assortment than obtained in the earlier stages of the Lorrain. The matrix is a somewhat feldspathic quartzite in which the original sand grains were more or less well rounded, but otherwise not remarkable. The enclosed pebbles are thoroughly worn, and uniform in size, not exceeding 2 inches in diameter. They consist exclusively of white quartz, or, in places, mainly quartz pebbles with a few of grey chert and of fine-grained igneous materials. Red jasper pebbles, so characteristic of the Lorrain quartzite on the north shore of lake Huron, were not seen.

The limits of the conglomeratic part of the Lorrain are rather indefinite. Above it, however, there is quartzite without conglomerate. This upper part extends to the top of the Lorrain, that is, to the banded cherty quartzite. It is whiter and less feldspathic, and the sand grains constituting it are better rounded than those in the lower part of the formation. Ripple-marks are common.

The thickness of the Lorrain quartzite in Onaping map-area can be estimated only approximately. Judging from the area it covers and the dip of the beds it would seem to be at least 2,000 feet, and more probably 3,000 feet thick. There are hills of this quartzite near Florence lake 600 feet high, whose bases are evidently high up in the formation. This estimate is probably conservative, for the Lorrain quartzites near Sault Ste. Marie have recently been estimated, on comparatively reliable field data, to be 6,000 feet thick.[1]

BANDED CHERTY QUARTZITE AND WHITE QUARTZITE ABOVE THE LORRAIN.

In the course of exploring the Lorrain quartzite in Onaping map-area a peculiar variety of quartzite was observed, first on Lady Evelyn river 3 miles above McPherson lake, and later on Smoothwater lake and numerous other places. This variety is an ultrafine-grained quartzite closely resembling chert. It is thinly and regularly stratified. The individual layers are from ½ to 3 or 4 inches thick and vary in colour through various shades of grey and green, giving the rock a banded appearance.

[1] Geol. Surv. Can. Mus. Bull. No. 8

In fact, its general aspect recalls the more dully coloured varieties of iron formation found in the pre-Huronian schist-complex. Its normal sedimentary character, however, is not in doubt, for ripple-marks are abundant in it and the chert-like layers are often associated with coarser-grained beds of distinctly quartzitic character.

Under the microscope the cherty quartzite proves to consist of extremely small, sharply angular quartz and feldspar fragments cemented by shreds of colourless secondary mica and quartz dust. The cement forms slightly less than half the rock mass. The fragments of quartz and feldspar are notably uniform in size, about 0·1 millimetre diameter. Feldspar particles are much fewer than those of quartz and are usually fresh.

At the time Onaping area was explored, the banded cherty quartzite was regarded only as a phase of the Lorrain quartzite and not of sufficient importance to be differentiated from it. It had not been found in the neighbouring Gowganda area, nor had any reference been made to it in geological reports dealing with Timagami, Cobalt, and other areas in the same part of northeastern Ontario. Subsequently, however, the writer found the same cherty quartzite on the north shore of Lake Huron[1] so distinctly developed and in such thickness that it seemed desirable to separate it from the Lorrain quartzite. Owing to this circumstance the cherty quartzite is not distinguished on the accompanying map from the Lorrain quartzite, nor from the white quartzite that overlies it. A partial thickness of about 100 feet is exposed on Lady Evelyn river above McPherson lake. The total thickness is perhaps twice as great.

The quartzite overlying the banded cherty quartzite is measurable in hundreds of feet, and is the highest member of the Cobalt series found in the map-area. It is a white, ripple-marked, nearly pure quartzite composed of well-worn quartz grains.

[1] Geol. Surv., Can., Mus. Bull. No. 8.

STRUCTURAL RELATIONS OF THE COBALT SERIES.

RELATION TO PRE-HURONIAN.

The unconformity between the Cobalt series and the pre-Huronian is conspicuous. The conglomerate at the base of the Cobalt series contains pebbles of all the characteristic pre-Huronian rocks. The Cobalt series is gently folded and not much metamorphosed, while the pre-Huronian granite-gneisses and schists are all highly crystalline and foliated by deformational stresses. The very superposition of Cobalt conglomerate upon great areas of batholithic granite-gneiss implies an enormous amount of erosion necessary to uncover these deep-seated intrusives.

Ever since Coleman, in 1905, suggested a glacial origin for the lower part of the Cobalt series considerable attention has been paid to the character of the pre-Huronian surface upon which it lies. The opinion has already been expressed, as a result of observations made in neighbouring map-areas, that "the Huronian was deposited upon a surface never far below the present one and of the same peneplanated type."[1] This is not so obvious in the present map-area: placing the thickness of the Cobalt series near Florence lake at the conservative figure of 3,000 feet, the pre-Huronian floor must be more than that depth below the present surface. In the western part of the area, where only remnants of the Cobalt series persist, the pre-Huronian surface upon which the Cobalt series was laid down must have stood above the present surface of the country. This would imply a pre-Huronian topographic relief of over 3,000 feet if no distortion had taken place since. It must be recalled, however, that the Cobalt series has been considerably folded by deformational stresses which would also warp the pre-Huronian.

It was possible at a number of points in the map-area to observe some of the details of this pre-Huronian surface. On the northeast shore of Shiningtree lake, pre-Huronian schists are overlain by a few inches of Cobalt conglomerate, worn through in places. The surface of the schists is irregularly

[1] Geol. Surv., Can., Mem. 33, p. 51; also Mem. 39, p. 20.

jagged and the line of contact knife-sharp. The conglomerate also includes pebbles of granite and a variety of other materials not found just beneath, so it was evidently not derived in situ. Another harsh surface, of granite in this case, was observed in Unwin township a mile northeast of the portage on Wanapitei river. The rough and undecomposed granite is overlain by slate-like greywacke. On Wapus creek just where it crosses the northern edge of the map-area the basal conglomerate rests upon smooth, well-worn granite-gneiss.[1] The granite-gneiss at this pre-Huronian surface is quite as fresh as that exposed at the present surface. Contacts between the basal conglomerate and granite-gneiss are also well exposed on Venetian lake, Botha township. The contact surface is not observable, but the knife-sharp, wavy line of contact implies it to be smooth and gently undulating. No contacts were found beneath which the pre-Huronian is disintegrated as it is near lake Timiskaming.[2]

RELATION OF LORRAIN QUARTZITE TO GOWGANDA FORMATION.

In the eastern third of Onaping map-area, in Gowganda area and much of the adjacent region, the Lorrain quartzite is conformable upon a stratified greywacke representing the top of the Gowganda formation. The passage from greywacke to quartzite takes place through a thickness of 20 to 30 feet of well stratified, presumably water-deposited greywacke and quartzite. In some places the rock merges insensibly from greywacke to quartzite. In others, quartzite beds, at first very thin, begin to alternate the greywacke, growing progressively thicker until they entirely take the place of the greywacke. The beds forming this 20 to 30 feet are moderately thick and the materials in them fairly coarse, so that the time required to deposit them may be assumed to have been fairly brief. This part of the region seems to have been continuously submerged from some time during the deposition of the Gowganda formation, through Lorrain time.

[1] Geol. Surv., Can., Mem. 33, p. 51.
[2] Rept. Ont. Bur. of Mines 1907, p. 46.

At a number of points in the south of Lampman township stratified Lorrain quartzite rests upon an uneven surface of greywacke representing the top of the Gowganda formation. There is no gradation from one formation to the other. The contact is slightly uneven and discordant with the nearly horizontal bedding planes of the greywacke so that the greywacke appears to have been subjected to erosion before the quartzite was deposited upon it. It appears also to have been somewhat plastic at that time, for contorted pieces of greywacke project into the quartzite or occur in the quartzite for an inch or so up in it. The evidence points to a brief interruption in the deposition process.

Not far west of this locality the Lorrain quartzite rests directly upon pre-Huronian granite. An occurrence of this relation in Sweeny township has already been described; there the base of the quartzite contains worn pebbles of granite. Lorrain quartzite was also found lying directly upon granite on the Canadian Northern Ontario railway north of Gowganda Junction and again in Rhodes township. In Ogilvie and Lawson townships, likewise, there appears to be no Gowganda formation, or only a small thickness of it, between the Lorrain quartzite and the granite-gneiss, though the heavy drift covering in both localities hides the actual contact everywhere.

Somewhat different conditions are recorded from near Lake Timiskaming. At one place near Cobalt the Lorrain quartzite rests upon a jagged surface of greywacke, angular blocks of which form a breccia at the base of the quartzite.[1] On the east side of lake Timiskaming, Barlow found quartzite presumably Lorrain, grading transitionally downward into disintegrated granite[2]; and not far from that exposure in Fabre township, Harvie found at the base of the same quartzite a thick breccia derived from immediately subjacent pre-Huronian greenstone. In all three cases the base of the Lorrain quartzite is made up altogether or in part of the disintegration products of the pre-Huronian rocks beneath. It must be concluded that the older rocks were subjected to subaerial weathering previous to the

[1] Ann. Rept. Ont. Bur. Mines, 1907, part II, p. 46. In the report for 1913 (part II, page 83) this breccia is regarded as probably of secondary, dynamic origin.

[2] Geol. Surv., Can. Ann. Rept., vol. X, part J., p. 103.

deposition of the Lorrain quartzite; also that the base of the Lorrain is itself a land formation, for the angular fragments in the breccia and the granite quartzite transition described by Barlow, show no sign of water action.

In Onaping map-area and the adjoining neighbourhood of Lake Timiskaming, therefore, the base of the Lorrain quartzite exhibits three quite different aspects: it is in some places water-deposited conformably upon the Gowganda group; in other places it is apparently also water-laid, but unconformably upon an eroded surface either of the Gowganda formation or the pre-Huronian; and near Timiskaming it is basally a land formation resting upon a disintegrated surface of Huronian and pre-Huronian. Apparently a large share, but not all, of the region was submerged before the close of Gowganda deposition. Portions of it, e.g. in the neighbourhood of Lake Timiskaming, remained unsubmerged and subject to erosion until an early stage of Lorrain time; but eventually the whole region became covered by the body of water in which the Lorrain sands were deposited, for the main part of the Lorrain has the appearance of a water-laid formation.

The local unconformity at the base of the Lorrain must be, according to this explanation, the result of overlap. In Onaping map-area it is discontinuous, perhaps incipient. When the geology of north Ontario and Quebec becomes better known, places may be found where it is persistent and more important.

The evaluation of the time represented by this local unconformity offers some difficulty. On the east shore of Lake Timiskaming, it is equal to the time necessary to remove the Gowganda formation and disintegrate to a considerable depth the underlying pre-Huronian granite, because the Lorrain lies directly upon disintegrated granite. If the thickness of the Gowganda formation be taken as 3,000 + feet, the time would be great. On the other hand, where the Lorrain is conformable upon the Gowganda greywacke, the change from one type of deposit to the other takes place in a thickness of 20 to 30 feet, implying a very brief period of time. If both these conclusions were correct it would be necessary to conclude that overlap of the Lorrain sea or lake, or whatever body of water it was, had been

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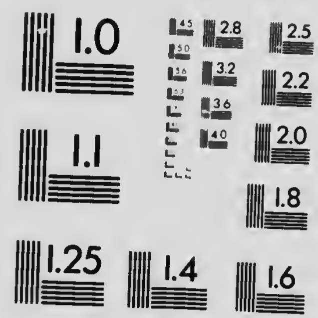

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exceedingly slow, especially as the surface of the country at that time appears to have had rather a low relief. But the existence at the base of the Lorrain, on both sides of lake Timiskaming, of unassorted disintegration products, is scarcely compatible with a slow submergence; they would have become water-worn and well assorted during such a process. The extremely local occurrence of the unconformity, the certainly brief transition in all cases of conformity, and the evidence of hasty submergence afforded at lake Timiskaming all argue powerfully for a brief time-gap. The contradiction in this argument is probably due to attributing a uniform thickness of 3,000 + feet to the Gowganda formation east of lake Timiskaming. It has been remarked already that its original thickness on Venetian lake is only 500 feet. It is entirely possible, therefore, that no important thickness of Gowganda formation ever existed on the east side of lake Timiskaming, and that, as originally laid down, its thickness varied greatly in different parts of the region.

FOLDING AND FAULTING.

If a few localities where deformational movements were unusually intense are excepted, a general increase in the degree of folding in the Cobalt series is observable toward the southwest. In the northeastern part of the area, in Corkill, Parker, and Dufferin townships for instance, the strata are irregularly domed. They dip only 0 to 30 degrees. Commencing near Sturgeon river, the dips rise to 15 to 60 or 75 degrees and the strike assumes a fairly uniform direction, ranging from northwest-southeast to north-south. Along Vermilion river the northwest-southeast strike is persistent and the dip ranges from 30 to 90 degrees. This progressive increase of folding towards the southwest apparently holds for most of the adjacent country. As far toward Sudbury as Huronian rocks continue, they are quite highly folded, while in the opposite direction, toward Lake Timiskaming, they are gently domed, or almost horizontal. The locus of this disturbance would thus appear to lie southwest of Onaping map-area.[1]

[1]Compare Mus. Bull. No. 22, which was written subsequent to this report.

Locally the deformation is more intense than the foregoing general statement would indicate. This is strikingly true at the head of McPherson lake, in McGiffin township, where Lady Evelyn river falls over fissile, grey-green schist that stands on edge and strikes somewhat west of north. This schist has the highly metamorphosed aspect of a pre-Huronian schist; nevertheless, it is only a schistose phase of the Lorrain quartzite. It is only 150 feet wide and grades on either side into normal quartzite. Apparently, deformational movements were so severe in this narrow zone that the ordinary feldspathic quartzite was altered to a fissile sericitic schist. No very careful effort was made to trace it across country, but it was met at a sufficient number of points to indicate that it extends northwestward to Smoothwater lake, broadening out from a narrow zone of dislocation to a series of close folds about a mile across. Where it crosses Gamble township the quartzite stands on edge and is more or less sheared. Near the middle of Smoothwater lake the quartzite dips from 70 to 85 degrees. Beyond Smoothwater lake it appears to die out.

The base of the Cobalt series seems to have been especially subject to deformation. At numerous places the basal conglomerate is schistose for a few feet, or even yards, away from the pre-Huronian basement. Occasionally the pebbles in it are flattened. Good examples of this schistified base of the conglomerate occur east of the railway in Beaumont township. The underlying granite-gneiss is not deformed.

The thin limestone formation has also been deformed to an exceptional degree. Where it is exposed on Sturgeon river, just above the portage to Parsons lake, it is overlain and underlain by thick beds of quartzitic greywacke. These beds and the limestone lie in folds that dip 10 degrees. The greywacke shows no other deformation; but the intercalated limestone, which consists of thin alternating calcareous and sandy layers, is complexly crumpled. The crumpling is made conspicuous by the limestone layers weathering more quickly than the sandy layers, producing a strongly corrugated surface. All the minor folds are represented by the sandy layers; the limestone between them adapted itself by flowage. The limestone clearly acted as a weak incompetent formation between stronger formations below and above, and accommodated itself to most of the differential movements consequent to the main folding. The effect is precisely analogous to that observed in the pre-Huronian schist-complex of Churchill township,[1] where a weak slaty formation was contorted and schistified, while the adjacent more competent volcanic flows, enduring the same stresses, remained massive.

CONDITIONS OF DEPOSITION OF THE COBALT SERIES.

The origin of the Cobalt series is a problem which has already been carried far towards solution by Coleman, Miller, Wilson, and other geological workers in northeastern Ontario. Investigations like the present one contribute to its solution as much by corroborating in new fields the evidence already accumulated as by discovering new evidence. To a large extent, therefore, the present discussion must be a repetition of earlier writings.

There appears to be no dissent from the opinion that the Gowganda formation is a continental and in part a terrestrial deposit. This conclusion is based on the following evidence: (1) The conglomerate and greywacke composing it are too poorly assorted to be marine, and the individual fragments in these rocks are poorly rounded or angular. (2) The conglomerate, greywacke, etc., alternate repeatedly, implying unstable conditions of deposition. Moreover, the sequence of formations found in different parts of the region varies considerably, indicating that the depositional conditions were not uniform for the region. (3) Local unconformities, ripple-marks, cross-bedding, and breccias formed in the course of deposition are common. These indicate shallow-water and occasional subaerial conditions. (4) Limestone, a characteristic marine sediment, is almost entirely lacking. (5) An old soil, formed by the decomposition of the pre-Huronian floor, occurs at the base of the Gowganda formation in some places, also at the base of the Lorrain quartzite immediately above. (6) The basal conglomerate is too thick to have been deposited in the sea.

[1] Page 40.

One further piece of evidence in favour of this opinion can be added. The original thickness of the Gowganda formation in Onaping area varies from 3,000 + feet down to 500 feet—possibly to 0 (page 78). This is all the more remarkable because the underlying pre-Huronian surface seems to have possessed no great topographic relief. So great a range in thickness is, therefore, highly improbable in a marine deposit, though entirely possible in a continental one.

The observations made in Onaping map-area are confirmative of the evidence cited of continental deposition. There appears, however, to be a greater portion of water-deposited materials in the Gowganda formation within Onaping map-area than there is near Lake Timiskaming. Especially is this the case in the southern part of the area, where there is a great thickness of well-stratified greywacke, limestone is also present, and the succession is comparatively simple and uniform over a large area. This part of the area was evidently submerged, probably as a lake, while the upper part of the Gowganda formation was being deposited.

Coleman first expressed the opinion in 1905[1] that the Gowganda formation was of glacial origin. Since then, he has reiterated this belief and advanced a substantial mass of evidence for the existence at that time of a continental ice-sheet.[2] Miller recognized the same possibility in 1905,[3] but did not regard the evidence then at hand to be sufficient. Subsequently, he has exerted a stimulative influence upon the investigation by pointing out the various inadequacies of the glacial explanation.[4] Lately, the available evidence has been weighed impartially by Wilson,[5] who concludes that it preponderates in favour of a glacial origin. The arguments for and against the glacial origin are so succinctly stated in these reports and papers[6] that the briefest comment upon them suffices for this discussion.

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[1] Rept. Ont. Bur. Mines, vol. XIV, part 3, p. 129.

[2] See especially, Am. Jour. Sc., vol. XXIII, 1907, pp. 187-192; Bull. G.S.A., vol. XIX, pp. 347-366; Jour. Geol., vol. XVI, 1908, pp. 149-158.

[3] Rept. Ont. Bur. Mines, vol. XIV, part 2, p. 41.

[4] Rept. Ont. Bur. Mines, vol. XVI, pt. 2, pp. 57-58; vol. XIX, part 2, pp. 86-87.

[5] Geol. Surv., Can., Mem. 39, 1913, pp. 88-98.

[6] Esepcially Coleman, Jour. Geol., vol. XVI, pp. 149-158; Miller, Rept. Ont. Bureau of Mines, vol. XVI, pt. 2, pp. 57-58; and Wilson, op. cit.

(1) The boulder conglomerate is strikingly similar in appearance and composition to other boulder conglomerates, or tillites of admittedly glacial derivation, e.g., Dwyka conglomerate of South Africa.[1] But H. E. Gregory has recently concluded with respect to a boulder conglomerate occurring in Arizona, that "materials resembling glacial deposits in the Navajo reservation occur as strata interbedded with Mesozoic sediments and also as superficial drift. Their position in the stratigraphic column is believed to be due to igneous agencies."[2] The present writer[3] has also found in the Bruce (Lower Huronian) series on the north shore of lake Huron a boulder conglomerate (Bruce conglomerate) of wide extent underlain by stratified quartzite (Mississagi quartzite) and overlain by limestone (Bruce limestone). This conglomerate closely resembles the Gowganda boulder conglomerate, but its thickness (20 to 150 feet), great extent, and conformable position between well stratified formations are hard to reconcile with a glacial derivation. It may be, therefore, that boulder conglomerates not readily distinguishable from tillite may originate in other ways than by glaciation, which, if true reduces the importance of the Cobalt conglomerate as evidence in favour of glacial deposition.

(2) Striated and soled boulders have been found in the boulder conglomerate. The striations not infrequently cross one another and clearly are not due to deformational movements after deposition.[4]

(3) Boulders of large size have been found in the conglomerate miles from the nearest source of supply, implying a powerful transportation agent.[5] It has been suggested that torrential streams in a semi-arid, mountainous district might perform this work as well as an ice-sheet.[6] But the pre-Huronian surface beneath the Cobalt series, so far as its character has been determined, appears to be one of mature erosion and gentle

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[1] Especially, Coleman, Jour. Geol., vol. XVI, pp. 149-158.
[2] Am. Jour. Sc., 1915, p. 115.
[3] Geol. Surv., Can., Mus. Bull. No. 8.
[4] Jour. Geol., vol. XVI, pp. 149-158.
[5] Geol. Surv., Can., Mem. 33, p. 57.
[6] Rept. Ont. Bur. of Mines, 1907, pt. II, p. 56.

topography.[1] This, together with the evidence in section 5 excludes the argument for the torrential stream agency.

(4) Smooth, though unstriated surfaces of fresh pre-Huronian rocks have been found beneath the Cobalt series in some places;[2] in others the pre-Huronian surface is disintegrated.[3] The smooth surfaces are regarded by adherents of a glacial origin as due to glaciation, and the disintegrated surfaces as those which obtain "near the edge of a glaciated area, where the thickness of the ice is not great."[4] Opponents of this opinion regard the existence of an old soil beneath part of the Cobalt series, and the absence of striæ in the few small areas of smooth surface yet observed as contradictory or at least unconfirmatory of Huronian glaciation.[5]

(5) The laminated greywacke and laminated greywacke conglomerate of the Gowganda formation are similar in most respects to the Pleistocene stratified clays found in the same region. The latter are glacial lake deposits, and a like interpretation for their Huronian analogues seems unavoidable.[6]

Regarded as a brief for a glacial derivation of the Gowganda formation very few items of this budget of evidence have escaped serious challenge. Collectively, however, they cannot be rejected; for, as Wilson has shown, no other conceived process except a glacial one is capable of accounting so well for all the available facts.

The additional observations made in Onaping map-area are mainly confirmatory of what has already been presented. A large part of the Gowganda formation is well stratified and apparently was laid down in water, so the climate of the time could scarcely have been arid. The delicate stratification of the laminated greywacke is evidently the result of deposition in quiet water. Yet the occasional boulders found in it were certainly not carried there by gentle currents alone. Their presence is explicable only on the assumption that they were

[1] Geol. Surv. Can., Mem. 33, p. 51.
[2] Ibid, p. 52.
[3] Rept. Ont. Bur. of Mines, 1907, pt. II, pp. 48, 58.
[4] Jour. Geol., vol. XVI, p. 155.
[5] Rept. Ont. Bur. of Mines, 1907, pt. II, p. 58.
[6] This memoir, page 66.

dropped from melting blocks of floating ice. This would indicate a cold as well as a moist climate. Beyond this the evidence is not so positive. The pre-Huronian rocks, wherever they were found immediately beneath the basal conglomerate, are as fresh as where they have been more recently glaciated. They present both jagged and smoothly worn surfaces. No opportunity was found to look for glacial striæ on this floor nor was any persistent search made for scratched boulders.

Judging from the well stratified character of the upper part of the Gowganda formation most of Onaping area was under water before the close of Gowganda time, though parts of it and of the adjoining region remained exposed to erosion. During Lorrain time the region became wholly submerged. It is possible that the cold, moist conditions prevailing in Gowganda time persisted well into the Lorrain; for the amount of feldspar and mica in the lower part of the Lorrain and the coarse, angular character of the sand grains constituting it imply rock disintegration to have been much more energetic than chemical decay, a condition favoured by a cold climate.

Post-Cobalt Basic Intrusives.

QUARTZ DIABASE AND QUARTZ NORITE.

Distribution.

The intrusive bodies of quartz diabase and quartz norite which cut the Huronian and older rocks occur either as dykes—approximately vertical tabular bodies injected without regard to the structure of the intruded formations—and as sills—thicker, more nearly horizontal, tabular bodies that tend to follow the structural planes of the older formations. Dykes are most abundant in the pre-Huronian formations, though by no means absent from the Huronian. All the sills, on the contrary, lie within or immediately beneath the Huronian, and are, therefore, confined to the eastern half of the map-area.

This selective distribution of dykes and sills may have been determined by mechanical factors in the invaded formations. The pre-Huronian schists and granite-gneiss are either vertically foliated or are without regular planes of weakness. Fractures, through which the diabase magma rose, would, therefore, be liable to form at not less than 45 degrees to the horizontal. Different conditions would be encountered in the Huronian. These sediments separate most readily along their bedding planes, which for a large part of the area are not inclined more than 30 degrees. Their load was also less than that on the pre-Huronian. The diabase magma upon reaching the Huronian would, consequently, spread out either along the contact between it and the pre-Huronian or along bedding planes within it, forming sills.

There is abundant evidence that the large masses are sills. Many contacts were observed between the bottom of the diabase and Huronian sediments and in most cases the contact conforms with the stratification. Upper contacts are not so often seen, the diabase usually presenting an eroded upper surface. But no vesicular lava, indicating the diabase to be a flow, was found; and a cover of sediments was observed in a sufficient number of cases to indicate that the majority of the larger bodies are intrusive and sill-shaped. A good example of an upper contact can be seen in Milner township between Gowganda and Elkhorn lakes. There the diabase is directly overlain by gently dipping, stratified greywacke bleached and spotted (adinolized) for several yards next to the contact.

The thinnest sill, that south of Smoothwater lake, is 100 to 200 feet thick. Other sills reach a thickness of 500 to 600 feet, possibly more. Their horizontal extent is hard to determine for parts of them are still covered by the Huronian and other parts have been completely destroyed by erosion. It is difficult to say how continuous were formerly the remnants now visible. Some of the remnants are themselves large. The sill east of Gowganda lake is continuously exposed northward for 13 miles. That in Whitson and Banks townships is nearly horizontal where it appears on Little Bear and Great Bear lakes. It probably once extended in this horizontal attitude continuously over most of Tretheway, Brewster, and Corkill, for all the higher hills in these townships are capped by masses of diabase resting horizontally on the Lorrain quartzite. Apparently this sill had an area of at least 150 square miles.

The dykes are not economically important and consequently have not been mapped carefully. A very small percentage of them is shown on the map. They range in width from a few inches up to 150 feet, but little is known about their lengths. A few of them have been traced for distances of 1 to 3 miles without signs of terminations. Those which appear on hillsides and cliffs are vertical or nearly so.

Lithological Character.

The diabase varies greatly in appearance according to the thickness of the sill or dyke in which it occurs, or, in other words, according to the rapidity with which it solidified. In dykes a foot or less wide, which were quickly chilled, it is a dark green aphanitic rock consisting mainly of glass, with minute crystals of plagioclase and pyroxene distributed through it. In larger dykes it ranges up to a medium-grained diabase, the individual crystals in which are about half a millimetre long. Sill diabase is still coarser, ranging up to 2 millimetres.

Sill diabase is also distinguished from that in dykes by much greater variability, due as explained later to the more protracted operation of assimilative and differentiative processes in the cooling magma. Thus there are found in sills, though not in dykes, occasional patches of exceptionally coarse grain, which are believed to have resulted from the assimilation of fragments of older rocks. These patches are seldom more than a yard or two across, and merge gradually into the surrounding diabase, from which they differ in being considerably lighter in colour, richer in feldspar, and much coarser. The pyroxene individuals are often from 1 to $1\frac{1}{2}$ inches long. The sill diabase is also intersected infrequently by dykes, seldom more than 4 feet wide, of an acid aplitic differentiate. The aplite is a fine-grained rock, varying from deep red to white and consisting principally of feldspar and quartz. Thirdly, some of the sill rock is distinctly lighter in colour and more feldspathic than that in other sills or even, occasionally, in other portions of the same sill.

Primary Differences. Each of these three variable features has a distinct significance. The variability in colour of the diabase, which deserves first consideration, seems due to primary differences in the intruded magma.

Thin sections of the darker, less feldspathic variety of sill rock prove it to be quartz diabase (Plate X A). It consists, when fresh, of approximately equal parts of plagioclase and augite, with a few per cent of black iron ore—a titaniferous magnetite—and 0 to 10 per cent of a micrographic intergrowth of plagioclase and quartz. Crystals of hypersthene and flakes of brown biotite are found only rarely. The plagioclase and augite are ophitically intergrown, while the micrographic intergrowth always occupies interspaces, being evidently the last constituent to crystallize. The first-generation plagioclase varies from basic labradorite to basic andesine; the plagioclase of the intergrowth is always andesine, or more acid. Comparisons of many sections show that these constituents are always present, though in varying proportions. The quantity of micrographic intergrowth is especially variable; it may be practically lacking in some specimens and make up 10 or even 15 per cent of others.

Examination of thin sections of the light-coloured sill rock proves it to be a quartz norite. In texture it is quite like quartz diabase and the constituents are the same except that slightly more than half of the pyroxene is hypersthene, the remainder being an augite like that in the quartz diabase. The hypersthene individuals are distinctly larger than the augites. Plagioclase of the first generation is also somewhat in excess of pyroxene, as is apparent from the pale colour of the hand specimen.

Between the quartz norite and quartz diabase all intermediate gradations were observed.

Their areal distribution throws further light upon the relationships of these rocks. They were first carefully studied in Cobalt, Gowganda, and other areas, in connexion with the silver-cobalt ore deposits, and were invariably found to be quartz-diabase. It may be said therefore, that in the northern part of Onaping area and northeastward all these intrusives are quartz diabase. A noritic variation was first noticed in the sill at Florence lake. Most of this sill consists of quartz diabase, but south of the lake about 2 miles it grades over into a lighter-coloured rock containing from 5 to 10 per cent of hypersthene. The noritic and diabasic rocks in this sill appear to be phases of a single magmatic body, and not distinct intrusions. The sill in

North Williams and Leonard townships is quartz diabase; that in Dufferin, which is probably part of the same sill originally, is noritic. The sill in Lechette and McNamara townships is a quartz norite in which the hypersthene is slightly more abundant than augite. Most of the sill rock in Clary and adjacent townships in the southeastern corner of the area is noritic, though quartz diabase specimens were also obtained. Farther southward and westward to Sudbury the noritic type predominates, and the great nickel-bearing laccolith in Sudbury is itself a quartz norite.

It is apparent that between lake Timiskaming and Sudbury there is a gradual change in the post-Cobalt, basic intrusives from a quartz diabase type to a quartz norite type; that, as indicated by the gradational character of the change, and more specifically by the Florence Lake sill, these types represent not two distinct magmatic sources but, rather, one which varied regionally; and that since some of the sills are entirely quartz diabase and others entirely quartz norite the two types cannot be the result of differentiation in the magma after intrusion, but rather represent differences that existed in the magma before its intrusion. The relationships give support to a growing opinion that the basic intrusives of Sudbury and Cobalt districts and their respective associated ore deposits are closely related in time and source.

The chemical differences between the quartz diabase and quartz norite are brought out by the analyses below. Analysis No. 1 is of a rather fine-grained quartz diabase dyke in which no differentiation has taken place since intrusion, and which is believed, therefore, to approximate the average composition of the quartz diabase. Analysis No. 2 is of a coarse-grained basic variety of quartz diabase. Analysis No. 3 is a phase of quartz norite corresponding in grain and basicity to No. 2. No. 4 is of a sample from the "basic edge" of the Sudbury quartz norite laccolith and No. 5 is Coleman's average for the "basic edge." A comparison of these analyses shows only two respects in which the Sudbury quartz norite differs notably from the quartz diabase of Cobalt and Gowganda: it is several per cent higher in silica; and it is also distinctly higher in potassa, and the ratio of potassa to soda is higher. This difference in the potassa-soda ratio persists even in the respective aplitic differentiates, being much higher throughout the "acid edge" rocks at Sudbury than in the quartz diabase aplite, in the acid extreme of which potassa disappears and soda rises to over 8 per cent.[1] In all chemical respects, the quartz norite of Onaping area, as represented by analysis No. 3, is intermediate between the quartz diabase and the Sudbury norite, thus confirming the idea of consanguinity conveyed by the petrological study of these rocks.

Analyses of Quartz Diabase and Quartz Norite

	I	II	III	IV	V
SiO_2	50·76	48·06	51·46	49·90	51·615
Al_2O_3	13·90	18·23	11·21	16·32	18·137
Fe_2O_3	4·13		2·07		0·590
		9·57		13·51	
FeO	10·28		6·60		8·365
MgO	4·73	7·80	8·14	6·22	4·510
CaO	8·11	11·55	8·84	6·58	6·715
Na_2O	2·82	1·87	2·53	1·82	2·267
K_2O	6·85	0·27	2·09	2·25	1·117
H_2O at 110°)	0·23	0·12	0·09		
				9·76	1·085
H_2O (above 110°)	1·57	1·98	3·25		
TiO_2	1·50	1·20	0·71	1·17	1·157
MnO	0·34	0·70	0·4	tr.	0·122
CO_2	—	—	0·35	—	
Other constituents	0·07	6		0·17	0·472
Totals	99·3	99·	99·76	99·03	99·752

I. Fine-grained dyke of quartz diabase, Rankin township, Ontario M. F. Connor, analyst. Cf. Geol. Surv., Can., Mem. 33, p. 76.
II. Gabbroid phase of quartz diabase, Cobalt, Ontario. J. O. Handy, analyst. Cf. Rept. Ont. Bur. of Mines, 1905, pt. II.
III. Coarse-grained, basic phase of quartz norite sill, Frechette township, Ontario. M. F. Connor, analyst.
IV. Basic phase of "basic edge" Sudbury quartz norite laccolith. T. L. Walker, analyst. Cf. Quart. Jour., Geol. Soc., London, vol. LIII, p. 56.
V. Average of "basic edge," Sudbury laccolith. Cf. Rept. Ont. Bur. of Mines, 1905, pt. III, p. 116.

To a certain extent, then, the petrological diversity of the post-Cobalt intrusives is due to primary differences in the

[1] Cf. pages 95, 99

intruding magma. Following intrusion this diversity was increased by two distinct processes: assimilation into the still molten magma of quantities of the formations invaded, and differentiation of the magma into a basic and an acid series of rocks.

Assimilation. There is not much positive evidence that the diabases in this map-area assimilated any considerable quantity of the older rocks. Partly fused fragments of quartzite were found in the bottom of a sill at a point on Lady Evelyn river just north of Florence lake, also at a number of places in the thin sill that lies south of Smoothwater lake; but the diabase around these inclusions was not perceptibly more siliceous than usual. Fragments of greywacke are fairly common in the edge of the sill at Gowganda, but they are angular and do not seem to have been attacked by the diabase. Nevertheless, the sill-rock exhibits one peculiarity which is likely the result of assimilation of older rock fragments. Attention has already been directed to occasional light-coloured, coarse-grained patches that occur in the diabase, which are usually a few feet in diameter and imperfectly defined from the enclosing diabase. The significance of these patches was not ascertained at the time; but since then the origin of similar patches that occur in diabase at Blind River on the north shore of lake Huron, has been made clear (compare page 61). At that place the diabase contains a series of inclusions ranging from blocks of quartzite, through others in which a core of quartzite is surrounded by a rim of silicified diabase, to light-coloured patches of diabase containing no trace of the original quartzite fragments. The patches observed in the diabase of Onaping map-area are so like those at Blind River that they also are thought to represent assimilated rock fragments. They are not abundant enough, however, to indicate any extensive operation of this process.

Differentiation. Still a third process of change is represented by the narrow aplitic dykes, referred to above, which intersect the sill-diabase. After the magma was intruded and while it was crystallizing, it began to split into several distinct rock types. For various reasons this differentiative process is not easy to interpret. In the first place the magma injected in different parts of the region was not of exactly the same composition and consequently the products of differentiation differ somewhat from place to place. The quartz diabase magma in the northern part of Onaping map-area did not give rise to precisely the same differentiates as did the quartz norite magma farther south. Also, the magma, being intruded as dykes and sills ranging from a few inches to hundreds of feet in thickness, solidified at very different rates and the differentiative process was stopped in various stages of incompletion. In no case is it complete. The rocks which resulted are, therefore, nearly all hybrid mixtures of the two principal differentiates and are not satisfactory material for analysis. This disadvantage is offset, however, by the fact that, with the freezing of small and large intruded masses, the differentiative process was suspended in various stages between its inception and completion. By arranging these in their order of sequence and comparing them a very fair idea of the whole process is obtainable.

Whether the original magma was diabasic or noritic, the differentiative process varies only in detail; hence a description of the quartz diabase intrusives that occur in the northern part of Onaping area will serve, with some local modifications, for the whole map-area. The quartz diabase in this and the adjacent Gowganda area was studied in some detail by the writer several years ago and the results published in full.[1] What follows is a summarized repetition of that account.

The field-work led early to the conclusion that the diabase magma had risen to its present position through fissures in the pre-Huronian floor that are now occupied by diabase dykes. It undoubtedly did rise, and these dyke-filled fissures are the only available vents that have been found. The rapidity with which they finally solidified, as shown by the fineness of grain, gave reason to suppose that the differentiative process, so obvious in the sills, had proceeded to no important extent in these small bodies. In confirmation of this the diabase in a good many dykes was examined and found, megascopically and microscopically, to be practically alike. Two chemical analyses of dyke

[1] Geol. Surv., Can., Mem. 33, pp. 59-94.

material were also found to correspond closely (page 89). It was concluded that all the diabase magma injected into that part of the region had been nearly uniform in composition and that the dyke-rock represented more nearly than any other part of the intrusives the original magmatic composition. A kind of fixed point, or datum plane, was thus obtained from which could be estimated the amount of variation experienced by the slowly-cooled sill rock.

Compared with the dyke rocks the diabase in the sill showed distinct variability, even upon casual qualitative study. Samples from different parts of the same sill were found to differ notably in the relative amounts present of augite, feldspars and, more particularly, quartz. Chemical analyses, of which a considerable number had been made by various investigators, corroborated the evidence of the microscope. Field work also showed that the sills were traversed by dykes, up to 4 feet wide, of the fine-grained, pink to dull red, aplitic rock already mentioned. These dykes were found only within the sills. The same light-coloured rock was also found in irregular masses within the sills, grading imperceptibly into the diabase. Such relations pointed strongly to the conclusion that the aplitic material had been derived from the diabase magma. Taken in conjuction with the variability of the diabase it indicated some differentiative process in the sills.

It was equally evident that the nature of this process could not be more definitely determined without the aid of some precise data. Accordingly an extensive suite of aplite specimens taken from a number of places was next investigated quantitatively by Rosiwal microscopic analysis and by chemical analysis. It was found that the aplite always consists of four minerals: quartz, plagioclase ranging from Ab_{65} An_{35} to Ab_{100} An_0, mica possessing unusual golden yellow to dark greyish-brown pleochroic tints, and titanite. Also that the amount of each mineral present varies in such a way as to constitute an aplite series. The most basic form of the aplite consists of 33 per cent mica, 66 per cent andesine (Ab_{65} An_{35}), and 1 per cent titanite, quartz being virtually absent. The most acid form consists of 58 per cent albite (Ab_{100} An_0), 40 per cent quartz, and 1 per cent titanite, mica being reduced to a trace. Intermediate between these extremes is a regular series, the mineralogical and chemical composition of which is shown in Figures 6 and 7. Calcite and magnetite are sporadic constituents of the aplite whose significance is discussed later. All the aplites have a texture like that of a fine-grained granite (Plate X B).

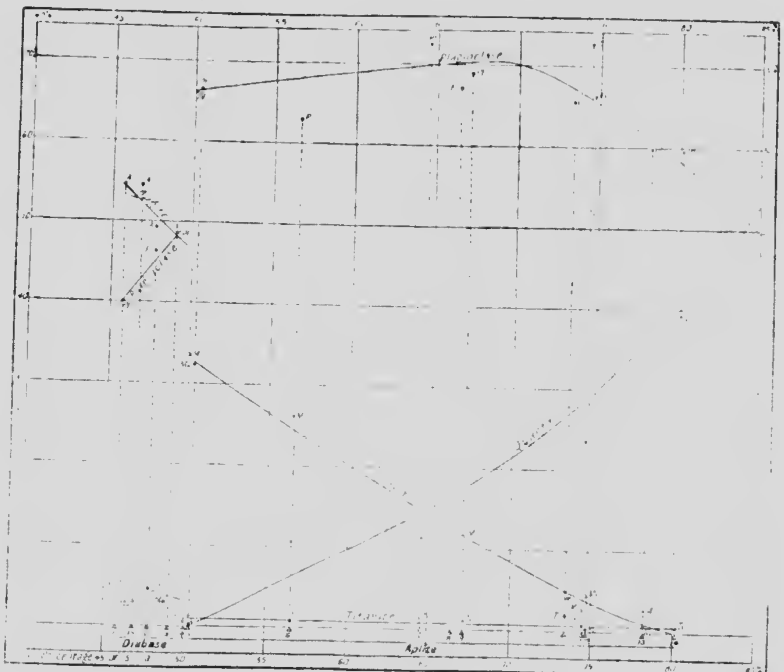

Figure 6. Mineralogical differentiation of quartz diabase magma, Gowganda district, Ontario.

The sill diabase was next inspected to see whether a similar serial arrangement between basic and acid extremes was perceptible. Only confused signs of it were found at first: the plagioclase of the first generation varied from labradorite, some-

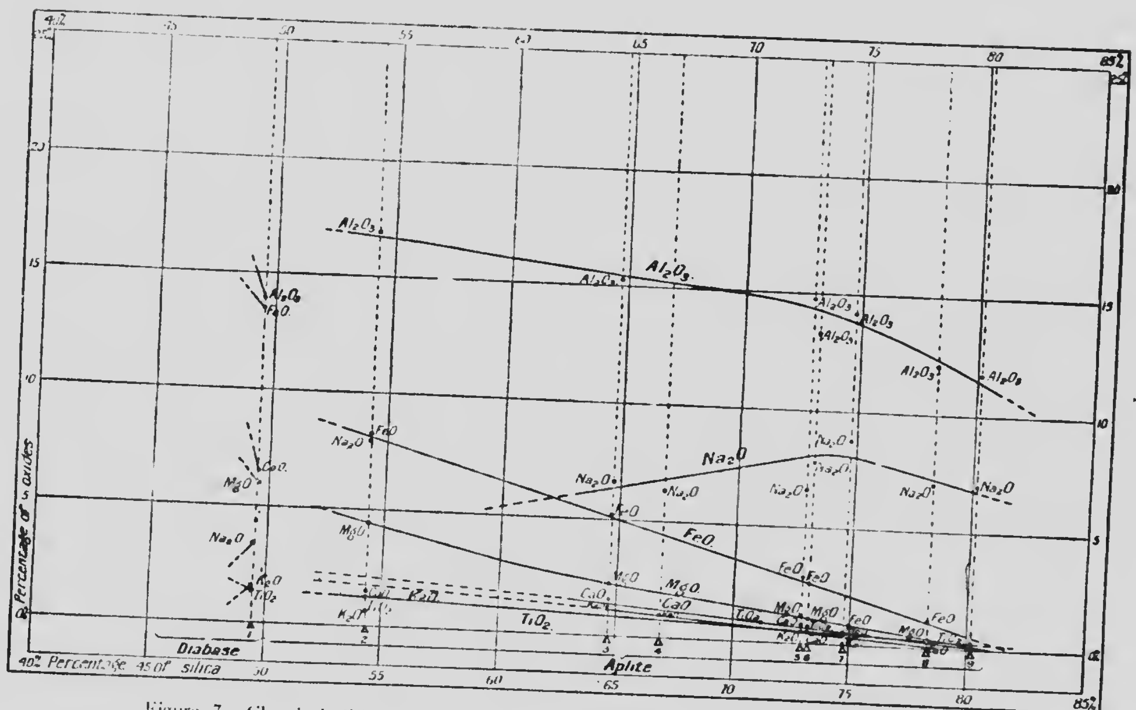

Figure 7. Chemical differentiation of quartz diabase magma, Gowganda district, Ontario.

times as low as $Ab_{25}An_{75}$, up to andesine Ab_{65} An_{35} and the amount of plagioclase also increased with the percentage of albite in it, and coincidentally the amount of augite diminished; but the percentages of iron ore and of micrographic intergrowth, particularly the latter, were in no ratio to those of augite or plagioclase. Neither was any regularity discoverable in comparing chemical analyses of sill diabase.

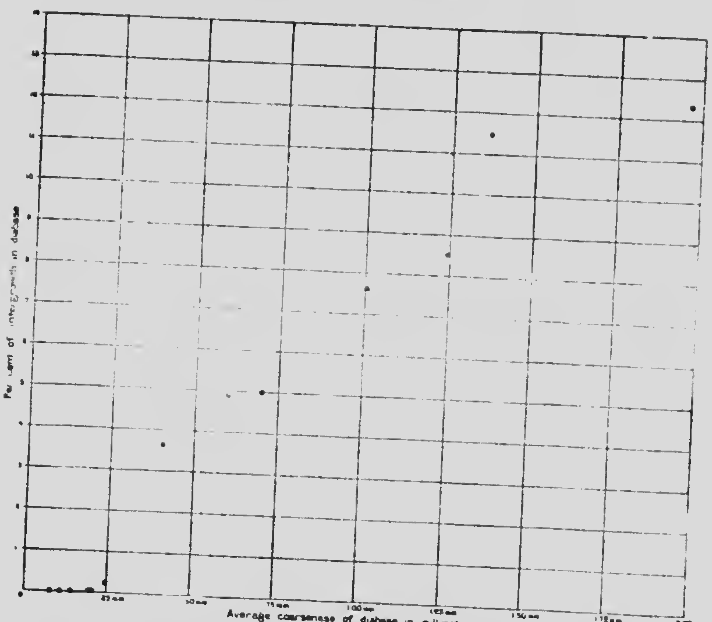

Figure 8. Relationship between quantity of micrographic intergrowth of quartz and plagioclase in quartz diabase and the coarseness of the diabase.

Incidentally, however, certain suggestive relationships of the micrographic intergrowth were discovered. Micrographic intergrowth does not occur at all in diabase, the average coarseness of which is less than 0·25 millimetre; and in coarser diabase the amount present is in nearly direct ratio to the coarseness (Figure 8). This is equivalent to saying that the amount of micrographic intergrowth is directly proportional to the time allowed for crystallization, since coarseness of grain, other factors being constant, is proportional to the rate of cooling. Cases were also observed where the micrographic intergrowth included small grains of titanite and flakes of the peculiar yellow mica that characterizes the aplitic mineral association. In fact a fairly complete gradation from ordinary micrographic intergrowth to aplite was found. The quantitative relationship implies the micrographic intergrowth to be a segregation from the diabase rather than an essential constituent of it; its mineralogical connexion with the aplite indicates further, a close relationship with that material. Altogether the micrographic intergrowth seems best accounted for as an incipient form of aplite that had not sufficient time to segregate from the diabase before the latter congealed.

According to this conclusion all diabase containing micrographic intergrowth is a mixture of diabase and incipient aplite. It is possible to test this opinion. If the content of aplitic matter (micrographic intergrowth) in a sample of diabase were subtracted, the remainder should be a normal diabase composed of augite, plagioclase, and titaniferous magnetite. If this were done for a series of samples in which the plagioclase ranged from basic labradorite in some to andesine in others, the normal types so restored should constitute a basic to acid series if such a series exists. This operation was performed with a small suite of specimens. It was found that the proportions of augite and plagioclase (anorthite + albite), in relation to the total silica content, were representable by smooth curves (Figure 6). The titaniferous magnetite does not show the same regularity as the augite, albite, and anorthite. Freed of micrographic intergrowth, there appears to be, however, a normal diabase series just as there is an aplite series.

The most basic specimen of diabase so examined consisted of augite 55 per cent and plagioclase (Ab_{35} An_{65}) 40 per cent, with about 5 per cent magnetite, and a total silica content of about 46 per cent. Toward the acid extreme, the plagioclase changes to andesine ($Ab_{65}An_{35}$) and augite diminishes. The acid limit is sharply defined; it is a rock composed of augite 48 per cent and andesine ($Ab_{65}An_{35}$) 48 per cent, magnetite making up the remainder, and the total silica amounting to about 48 per cent. Apparently when this composition is exceeded the diabase by a series of mineralogical changes becomes aplite; for it was invariably found in samples of this composition that yellow mica and titanite began to appear, apparently replacing augite and titaniferous magnetite. The sporadic appearance of titaniferous magnetite (a diabase-association mineral) in aplite is suspected to be due to lag in the process of inversion.

It appears from the foregoing that the principal ultimate differentiation products of the quartz diabase magma are:

(1) A diabase series consisting of augite, basic plagioclase, and titaniferous magnetite.

(2) An aplite series consisting of yellow mica, acid plagioclase, quartz, and titanite. The proportion of aplite to diabase as seen in the field is insignificant, probably less than 1 per cent. This, however, does not include the micrographic intergrowth included in the diabase, which makes up from 0 to 15 per cent. An equation, $M \times$ average composition of aplite series $+ (1\text{-}M) \times$ average composition of diabase series = average composition of undifferentiated diabase as represented by analyses of fine-grained dyke material, gives for M, that is, the proportion of aplite, an approximate value of one-seventh.

In addition to these two main differentiates the magma gave off small amounts of several other independent products. One of these is calcite. Occasional areas of calcite are found in sill diabase in which the other constituents are so fresh that it cannot be regarded as a secondary constituent. It must have crystallized from the diabase magma. It is still more abundant in aplite. There may be anywhere from a trace up to 15 per cent of it, and in one case an aplite dyke was found which graded from a practically calcite-free aplite to a rock consisting of fresh albite, quartz, a little mica, and about 50 per cent of calcite. This calcite is a primary constituent of the diabase and aplite in the sense of having been crystallized from the magma along with the other minerals composing these rocks. Its sporadic appearance in both rocks, in quantities bearing no definite relation to the other constituents, gives it the aspect of a third independent differentiate of the diabase magma. Like the micrographic intergrowth in sill diabase, it was probably trapped in the cooling diabase and aplite before segregation could be completed.

The quartz-calcite veins carrying silver, cobalt, and other ores that occur along with the diabase sills are also regarded as late differentiates of the diabase magma. Ground for this opinion is offered in the chapter dealing with the ore deposits of the area.

No such detailed study of the above has been made of the quartz norite sills that occur in the southern part of the map-area; but their general petrographic features are quite analogous to those of the quartz diabase. The quartz norite carries a micrographic intergrowth of quartz and acid plagioclase, and is intersected by narrow aplite dykes. It may safely be concluded that a corresponding incomplete differentiation into a norite and an aplite series took place. It is likely, however, that just as the norite differs somewhat from diabase, so the aplite series associated with it, differs from that which is associated with the diabase.

Although the quartz norite in Onaping map-area has not been studied quantitatively, that in Sudbury district, which is much like it, has been so investigated by Walker[1] and others. Walker found that the Sudbury laccolith had differentiated into a lower, basic portion of noritic character (basic edge) and an upper acid portion of aplitic character (acid edge). Both portions were found by chemical analyses to cover a wide range in composition, really constituting a noritic and an aplitic series like that here described for the quartz diabase and its aplitic offshoot. But the course of differentiation in the Sudbury norite differs from that of the Gowganda diabase in at least one respect. While the feldspar in the aplite associated with quartz diabase is wholly acid plagioclase, the "acid edge" at Sudbury contains both acid plagioclase and orthoclase. This difference is expressed quite definitely by the proportions of soda and potash in the two series. Soda and potash occur in nearly the same ratio at

[1] Quart. Jour. Geol. Soc., vol. LVIII, 1897.

the basic poles of the aplite associated with quartz diabase and of the "acid edge" associated with the Sudbury quartz norite. But as the acid pole of the aplite series is approached potash diminishes and finally disappears, while the soda increases greatly (see Figure 7 and analyses I and III below). As the acid pole of the "acid edge" series is approached the proportions of soda and potash remain nearly constant though the amount of each increases somewhat (see analyses II and IV below). Otherwise, the behaviours of the two aplitic differentiates are closely alike.

Analyses of Aplite and Acid Edge Rock from Gowganda and Sudbury Districts.

	I	II	III	IV
SiO_2	54·34	61·93	78·28	69·27
TiO_2	1·24	0·84	——	0·78
Al_2O_3	16·90	13·03	12·00	12·56
FeO	6·76	8·00	1·19	4·51
Fe_2O_3	1·65	0·56	——	2·89
CaO	1·29	4·02	0·29	1·44
MgO	4·51	1·76	0·37	0·91
Na_2O	8·02	3·18	6·89	3·12
K_2O	0·55	2·80	tr.	3·05
H_2O	4·40	1·95	0·61	0·76
CO_2	——	0·32	——	——
P_2O_5	0·12	0·18	——	0·06
MnO	——	0·19	——	——
S	——	——	——	——
	99·78	98·76	99·97	99·35

I. Aplite from quartz diabase sill, Gowganda district. See Geol. Surv., Can., Mem. 33, p. 76.
II. Acid edge rock, from near Whitson lake, Sudbury district. See Rept. Ont. Bur. of Mines, 1905, pt. III, p. 116.
III. Aplite from quartz diabase sill, Gowganda district. See Geol. Surv., Can., Mem. 33, p. 76.
IV. Acid edge rock from near Whitson lake, Sudbury district. See Rept. Ont. Bur. of Mines, 1905, pt. III, p. 116.

It is entirely likely, since the sills in the central and southern part of Onaping area are intermediate between the quartz diabase of Gowganda district and the quartz norite of Sudbury district, that the aplitic material associated with them is likewise intermediate mineralogically and chemically between the aplite found in Gowganda and the acid edge at Sudbury.

Metamorphism. The post-Cobalt, basic intrusives are a little decomposed, in part at least by ordinary weathering agents. The augite changes to hornblende characterized by a blue-green pleochroism ‖ c; rhombic pyroxene alters to bastite; and the plagioclase, particularly the basic plagioclase not intergrown with quartz, is more or less saussuritized. But in other respects these rocks have been affected very little since they solidified. There has been no deformational movement capable of altering their original massive character. Shear zones are narrow and infrequent; but contraction joints formed during cooling are marked near the edges of some of the sills, as for example, on Great Bear lake, where the diabase next to the quartzite separates parallel to the contact into thin plates, so that at a little distance it looks like a stratified rock. The quartzite near this contact is jointed in the same manner. Farther away from the contact the jointing is rudely columnar and at right angles to the plane of contact. This contraction jointing is probably responsible in part for the erosion trenches that mark the edges of diabase sills.

Even the thick sills have metamorphosed the adjacent older rocks for a very short distance away from their contacts, seldom more than 2 or 3 feet. The upper contacts are more metamorphosed than those at the bottoms of the sills. Granite and green-schist are not noticeably affected, but the effect upon Huronian sediments is quite distinct. Greywacke for 2 or 3 feet from the diabase becomes bleached to a dull grey colour and flecked with dark green spots about a millimetre in diameter. A thin section of this adinolized material is more crystalline than ordinary greywacke. It is a mosaic of anhedral quartz and feldspar grains with a few shreds of chlorite, the feldspar being largely albite, while the dark green spots are aggregates of chlorite. The change is essentially one of crystal enlargement, aggregation of chlorite, and increase in the albite content. In a few instances observed, the crystalline texture is quite evident in the hand specimen and thin sections show a marked similarity in texture and mineral composition to aplite. Chemical analyses of this contact metamorphic product[1] are chiefly distinguished from ordinary greywacke by a much higher content of soda.

[1] Geol. Surv., Can., Mem. 33, p. 79.

The Huronian quartzite near diabase contacts is rendered glassy by secondary enlargement of its constituent grains. Within 6 inches of the diabase it is apt to be incompletely fused to a dense black material in which a few unfused pieces of quartzite persist. In some places, as on Smith lake, Corley township, these unfused pieces are rounded and up to 1 or 2 inches in size, so that the product of partial fusion resembles a conglomerate. The line of contact between the fused quartzite and the diabase is distinct; in fact occasional globules of diabase occur within the fused quartzite and quite as distinct from it as particles of oil in water. The unfused remnants of quartzite can be seen to be contorted and flow lines also appear in the dark fused portion. There is also present a quantity of calcite considerably greater than that usually present as a secondary mineral in feldspathic quartzite. It appears to replace quartz and may possibly have been introduced from the diabase magma.

OLIVINE DIABASE.

Distribution.

Olivine diabase has been found in this area only in the form of dykes. Those shown on the map are probably a small percentage of the number actually present, for no serious effort was made to find and map dykes; moreover, a good many of olivine diabase were no doubt mistaken for quartz diabase, from which they are not readily distinguishable; but in any case the total number of olivine-diabase dykes is not great. It is all the more remarkable, therefore, in the absence of larger parent masses, to find them throughout not only Onaping map-area, but the entire region between lake Superior and Quebec. They are intrusive into all the other Pre-Cambrian formations, including the quartz diabase.[1]

Lithological Character.

The olivine diabase has nearly the same texture and colour as quartz diabase and, especially in narrow dykes, is not easily

[1] See A. P. Coleman, Rept. Ont. Bur. of Mines, 1905, pt. III; also Geol. Surv., Can., Mem 33.

distinguished from the latter. The feldspars are slenderer and more conspicuously ophitic toward the dark constituents. In wide dykes the rock becomes conspicuously porphyritic, stout plagioclase crystals up to 3 or 4 inches in length occurring thickly in a fine or medium-grained diabase matrix. These phenocrysts evidently grew after intrusion of the magma into the dyke, for they do not occur in narrow dykes, nor at the chilled edges of wider ones. Only in a few of the largest dykes, where no chilling effects are perceptible, do they occur from edge to edge.

The olivine-diabase is notably fresh—much fresher than quartz diabase. The groundmass is holocrystalline. Two-thirds of the rock is made up of laths of labradorite showing a persistent zonary banding, while olivine and an augite, reddish in transmitted light, are in about equal amounts and form most of the remainder. Black iron ore numerous rods of apatite, and rare zircons are the accessory constituents The plagioclase crystals penetrate the augite ophitically. The large plagioclase phenocrysts are of nearly the same composition as the second-generation feldspar. They exhibit a broad margin of zonary lamellation, varying from intermediate labradorite in the interior to basic andesine. The zoned margin includes many small individuals of augite and olivine, but the centres are free of such inclusions. Probably the phenocrysts had grown to about one-fourth their full size before the dark minerals began to crystallize.

The chemical character of the olivine diabase is indicated in the following analyses of samples from Sudbury and Cobalt districts respectively. For purposes of comparison an analysis of quartz diabase is also given.

Analyses of Olivine Diabase from Sudbury and Cobalt Districts

	I	II	III
SiO_2	47·22	45·20	50·76
TiO_2	3·62	——	1·50
Al_2O_3	16·52	19·08	13·90
FeO	12·40	14·64	10·28
Fe_2O_3	3·32	3·64	4·13
CaO	9·61	7·80	8·14
MgO	3·33	4·98	4·73
Na_2O	3·40	3·32	2·82
K_2O	0·67	1·08	0·85
H_2O	0·30	——	1·80
P_2O_5	0·33	——	0·07
MnO	0·04		0·34
BaO	0·01		
CuO ..	tr.		
NiO	0·0275		none
CoO ..	0·0055		none
	100·803	99·83	99·32

I. Analysis of olivine diabase, Murray mine, Sudbury district. From Rept. Ont. Bur. of Mines, 1905, pt. III, p. 126.
II. Analysis of olivine basalt, Cross lake, Cobalt district. From Rept. Ont. Bur. of Mines, 1907, pt. II, p. 64.
III. Fine-grained quartz diabase dyke without micrographic intergrowth, Rankin township, Gowganda district. From Geol. Surv., Can., Mem. 33, p. 76.

Relationships.

These olivine diabase dykes occur over a very wide area; at many points in Onaping map-area and the neighbouring Gowganda area; at Cobalt and in Sudbury district; and a considerable number of them along the north shore of Lake Huron were observed by the writer in 1914.

Ordinarily, dykes are intimately related to some larger parent intrusive, but in this case no such source can be identified. The quartz diabase and quartz norite sills are the only rocks in the region that the olivine diabase resembles. It is possible, even probable, that some genetic relation does exist between these rocks. It cannot be, however, the same as that which exists between the aplite dykes and the quartz diabase; for, while aplite dykes are never found outside the diabase sills the olivine diabase dykes are more frequently intrusive into the older

Pre-Cambrian formations than into these sills. If the olivine diabase is related to the quartz diabase and quartz norite, it is not as a differentiate that resulted after intrusion, but as a later, more basic product from the same magmatic source.

Pleistoc e.

The soil-sheet overlying the Pre-Cambrian rocks consists mainly of glacial debris deposited, in large part if not entirely, during the northward retreat of the last ice-sheet. Boulder clay forms a rather inconspicuous part of it. Outwash plains of sand, esker-like ridges of rudely stratified gravel, and other products of glacial melting and stream action are more in evidence; but post-glacial stratified lake clays like those forming the clay belt of northern Ontario, do not occur in this area.

There are extremely few places in this forested region where the glacial deposits can be seen in section. There are, however, several fairly extensive areas where its topographic aspect indicates the soil-sheet to be a glacial deposit laid down at the edge of a retreating ice-sheet. One of these areas includes most of Marshay, Blewett, Beulah, and adjoining townships. The soil-sheet in this area must be thick, for, although it possesses a relief of about 75 feet, the rock floor beneath is exposed in very few places. The northern part of it, in the northeast of Beulah and the contiguous part of Moffat township, is very hilly. The hillsides are steep, some of them only a little less than the angle of repose of the gravelly soil composing them. Kettle-hole depressions are abundant, some of them being dry and others occupied by small lakes or marshes. Southwestward, the country becomes level and sandy. The Canadian Northern Ontario railway is built across this sand-plain and has exposed sections in which the sand can be seen to be irregularly, often convexly, stratified. The plain is also characterized by a great number of kettle lakes, many of these having no visible outlet. Others probably feed large springs, for example, the spring which emerges from the base of a gravel ridge separating Shoofly and Oshawong lakes and flows into the latter. These two lakes, likewise Meteor and Opikinimika lakes, and a number of other small ones are separated by extraordinarily narrow gravel ridges, although the difference of water-level is as much as 20 feet. It is clear that the original form of the sand-plain has not been appreciably changed by stream-action; otherwise such feeble barriers would have been removed.

The hilly, pitted drift area in northern Beulah and in Moffat resembles, in its topography and in the gravelly material composing it, a terminal moraine; the sand-plain to the south, which covers most of Beulah, Blewett, and Marshay townships, has the appearance of an outwash deposit. Apparently the ice-sheet halted long enough at the northern edge of this area to deposit a small terminal moraine, during which time the outwash plain to the south was constructed by streams fed by the melting ice-sheet. Vermilion river was evidently the main drainage channel for this outwash plain the southern part of which it still drains. The outwash deposits at Meteor lake and other points carry gold in fine particles, and placer gold in the same fine state has been found at various points along Vermilion river, above the present water-level, indicating that transportation has been in that direction.

A second drift-covered area of the same character occurs in Fawcett, Ogilvie, Browning, and adjacent townships. The central and northern part of Fawcett is extremely hilly and dotted with kettle lakes. Some of the longer ridges may be eskers. The drift is coarse and gravelly. Southward through Ogilvie and Browning this grades into a sand-plain marked by many shallow kettle lakes, presumably an outwash deposit. Wanapitei river may have received the drainage from this outwash plain. Its valley in Unwin and Stull townships contains low terraces of stratified sand and clay which indicate its volume to have been greater formerly than it is at present.

Much of the same topographic conditions exist in Miramichi township and southwestward therefrom. The country along the north of Miramichi is heavily drift-covered, hilly, and full of kettle-holes. The southern part of the township and considerable of Londonderry, Garvey, and Garibaldi constitute a sand-plain.

Large sand-plains were also observed in the western part of the map-area by Mr. Marshall, but descriptive details of these are lacking.

The only large drift-covered area of this kind in the eastern part of the area extends over most of the townships of Lawson and Corkill and parts of Charters and Brewster. In Lawson and northern Corkill, the surface is unusually hilly and kettle-holes are abundant, though mostly dry. Distinct esker-like ridges of coarse gravel occur in the northwestern part of Corkill. The southern part of the area is a flat, sand-plain containing numerous shallow lakes.

As far as can be determined the above-mentioned areas of terminal moraine and outwash thin out in the intervals between them and lose their identity. They seem to represent local accumulations along the margin of a retreating and comparatively thin ice-sheet.

It is probable that a thin ground moraine of boulder clay is distributed over parts of the area where terminal moraines and outwash deposits do not occur, but owing to the forest growth this was seldom actually seen. Over a very considerable part of the map-area, the Pre-Cambrian rock-floor is practically bare. Where it is most deeply buried the drift is at least 75 feet but, judging from the general relief of the rock-floor and the frequency of rock outcrop, not over 150 feet deep. The average thickness of the drift-sheet for the whole map-area is, by approximation, not more than 20 feet.

The existence of broad outwash plains implies an abundance of water in late Glacial time, a condition which is also manifested by numerous differences between the drainage of that time and now. In the valley of Vermilion river there are terraces of stratified gravel and sand, apparently built by the river, which stand well above the present water-level. The highest and most important of these lie south of Onaping map-area, but a low one about 10 feet above present water-level occurs near Graveyard lake. Low terraces of stratified sand and fine silt also occur along Wanapitei river in Unwin and Stull townships. These stand about 12 feet above present low-water level.

In the case of Lady Evelyn river the course as well as the volume of the river appears to have been different (cf. page 18). At its present source, just south of Smoothwater lake, there is a prominent gravel ridge resembling an esker in form and probably to be regarded as such. From there down to its Florence Lake tributary it occupies a broad, well graded rock-valley no doubt of great age. The channel it occupies must once have contained a far more powerful stream than the present shrunken one; for between Apex and Mud lakes this channel is broad and paved with smooth boulders among which the present flow is quite concealed. Similar boulder pavements occur at intervals downstream. At Florence lake the Lady Evelyn of Glacial time appears to have flowed southward through Florence lake, for the remainder of the channel it now occupies shows no more boulder pavements or other signs of having accommodated a large river. On the other hand at the south end of Florence lake there is a capacious rocky channel floored with worn boulders, although no water flows through it now, except in time of high water, when a small share of the lake drains that way. From Florence lake the old channel, paved in places with boulders, is easily traced through Bluesucker and the chain of lakes in Turner and Seagram townships to Sturgeon river.

A similar boulder-paved channel, now almost dry, was traced by Scarecrow lake in Ellis township, in a southeasterly direction across Selkirk, Dundee, and Turner townships.

No important geological changes have taken place in this region since the last ice-sheet disappeared. Talus slopes have accumulated at the foot of cliffs, notably those composed of diabase. Forest fires have caused the rock surface to scale off thinly, forming a scanty angular debris; but a considerable part of the surface still bears the striations made by the ice-sheet. Rock decomposition due to atmospheric agents has been negligible. In the case of the amygdaloidal rhyolite in Leonard township, for example, the rock is comparatively fresh half an inch beneath a glacially smoothed surface, and the amygdules are still full of calcite at a depth of one inch.

The glacial drift has, no doubt, been carried down from the hills and either deposited at lower levels or carried off by the streams. The gradual silting-up of lakes, which act as catch-basins for the sediment carried in by affluent streams, is exemplified at the head of Opikinimika lake and in many of the smaller ponds. Also a considerable thickness of vegetable mould has accumulated in the lower, wet parts of the country, forming muskegs and swamps. In the higher, dry parts this soil is destroyed from time to time by forest fires and never attains any considerable depth.

CHAPTER V.

ECONOMIC GEOLOGY.

GOLD.

WEST SHININGTREE AREA.

History.

Quartz veins carrying gold were found near West Shiningtree lake, in Asquith and Churchill townships, during the summer of 1911. A party of prospectors from Sudbury visited the lake in the autumn of 1910 and, although no gold was then found, they were so favourably impressed by the numerous quartz veins that they returned early the next spring to examine tl[illegible] more carefully. At that time the favourable developr[illegible] Porcupine district had directed attention more particularly to gold prospects in northern Ontario. Early in August a good showing of free gold was found on what is now known as the Gosselin property near mile-post 3 on the north boundary of Asquith township. On August 19 Mr. L. Jefferson made a similar discovery on the east side of Wasapika lake, McMurchy township. These two discoveries became nuclei for careful prospecting which resulted, during that and the following summer, in the location of five other gold-bearing properties.

The means of access to the area was improved during 1911, the district being now reached most conveniently from Ruel station on the Canadian Northern Ontario railway. The trip in or back can be made by wagon and motor boat down Opikinimika river in one day during summer. A sleigh road is used in winter. The post-office of Tungsten was established on West Shiningtree lake early in 1912.

Serious efforts to investigate the commercial possibilities of the district were begun in 1912. Under option of purchase the Gosselin property was explored by stripping the veins of overburden, test pitting to depths up to 42 feet, and collecting samples for assay. At the conclusion of this examination the option was allowed to lapse. Surface exploration and sampling were also done upon the Jefferson and Bennett claims during 1912, a shaft having been sunk 40 feet on the main vein of the latter property on July 31. Since then the writer has not had opportunity to follow in detail the progress made in the district. Exploration, however, has not yet led to commercial mining operations and there has been no output of gold.

Geology.

The main geological features of the gold-bearing area are indicated upon Map No. 179A accompanying this report. Map No. 153A gives the geology of part of it in greater detail.

Three main geological divisions are represented: the pre-Huronian schist-complex, the batholithic granite-gneisses intrusive in these schists, and dykes and remnants of sills of quartz diabase similar in character, and presumably in age, to the post-Cobalt diabases found throughout Onaping map-area. The gold-bearing veins are found only in the schist-complex, which is, therefore, of chief interest. The schist-complex consists of an extraordinary variety of igneous, mainly volcanic, rocks. The lavas range from basalt to rhyolite and with these are associated volcanic tuffs and one sedimentary series derived from pyroclastic materials. A detailed description of these rocks is given on pages 33 to 44, but for convenience the main facts may be repeated here.

The older part of the complex, which was not differentiated into its component formations, includes diabases, amphibolite, quartz porphyry, etc. The oldest rocks differentiated from it consist of flows and tuffs of hornblende andesite and trachyte not separable one from the other. These tuffs grade upward into a well stratified series several hundred feet thick, consisting, in ascending order, of conglomerate, an arkose-like member, and finely bedded greywacke which locally becomes a lean iron formation. This series is composed of the same materials as the underlying tuffs and appears to be only a water-assorted phase of them. The sediments are cut by dykes of a pale-grey rock of intermediate composition, characterized by its bright red colour when decomposed. A large flow of ellipsoidal andesite around West Shiningtree lake appears to be younger than the red-weathering rock and still younger are small bodies of nearly white rhyolite. All these rocks are traversed by wide dyke-like bodies of a coarse porphyritic granodiorite which may represent apophyses from the granite-gneiss batholith. These rocks have been greatly disturbed; nevertheless schistification has been confined mainly to the tuffs and sediments and to local zones in the non-clastic formations. Most of the intrusives and flows are remarkably well preserved and massive. Besides the metamorphism due to deformation, all the schist-complex in a zone about half a mile wide next to the granite-gneiss batholith has been contact metamorphosed chiefly to chloritic schist and amphibolite.

The overburden of sand and gravel is, fortunately for prospecting, not thick nor continuous. Rock outcrops are abundant and none of the exploration trenches seen were more than 10 feet deep. Recent forest fires have also overrun a large part of the district, facilitating its exploration.

Ore Deposits.

The gold-bearing quartz veins intersect all the rocks of the schist-complex with the possible exception of the granodiorite dykes. Their relation to these dykes has not been observed. They are cut, however, by dykes of the post-Cobalt diabase. It has not been possible to fix the age of the vein formation within narrower limits. The veins have been found in greatest abundance in the ellipsoidal andesite. It is also noteworthy that the interspaces between the ellipsoids are filled with quartz, calcite, and epidote, a sample of which, collected by the writer and assayed by Mr. H. Leverin of the Mines Branch, was found to carry a small amount of gold. The abundance of veins in the ellipsoidal andesite and the presence of gold in the interellipsoidal filling suggest some relationship with the andesite flow. It is not to be overlooked, however, that the interellipsoidal spaces may have been filled by agencies quite unconnected with the andesite flow, and that the abundance of veins in that formation may be a purely fortuitous circumstance. The genesis of the West Shiningtree veins remains, therefore, an open question.

There are two somewhat different types of deposit. In most cases the gold is found in distinct veins from a few inches to 6 feet wide, the widths varying greatly from place to place. Some have apparent widths at the surface of 20 feet or even more, but this is due, in a number of cases at least, to the veins being folded, so that the surface exposed is oblique instead of a normal cross-section of the vein. Ordinarily they are nearly vertical. A number of veins had been traced for a distance of 200 feet when the district was last visited by the writer, so it is probable that they attain considerably greater lengths. They are filled with white quartz. Occasionally the quartz is accompanied by patches of white carbonate, which weathers to a rusty, limonitic powder. Minute aggregates of tourmaline were found locally in the quartz. Pyrite in scattered grains occurs both in the vein matter and in the wall rock. Gold occurs as small flakes and irregular particles in the quartz and also in small cavities in the quartz which are filled with limonitic powder, probably the weathering product of pyrite.

In fewer cases mineralization has occurred in a shear zone in the schist-complex. The schist is filled with small veins and stringers of quartz and both schist and quartz are sprinkled with pyrite. These mineralized shear zones have no definite boundaries separating them from the less sheared, unmineralized country rock. They are larger than the quartz veins but their gold content is too low for profitable mining.

Descriptions of Properties.

The following brief descriptions of the properties on which gold had been found in 1912 refer to what was known about them at that time.

Gosselin. Mining locations W.D. 1151-52, 1155-59. The first discovery in the district was made on W.D. 1151. At least six different veins were exposed in 1912. One of these in the southwest corner of W.D. 1157, had been uncovered for over

100 feet and for a width of 20 feet, but this was afterwards reported to have proved to be a folded vein whose true thickness was much less. The other veins range from 1 to 4 feet in width and have been traced for distances up to 150 feet, and in one case, 450 feet. The veins are of satisfactory size for mining and their horizontal extent encourages the opinion that they may extend to important depths; but the average values obtained by sampling near the surface indicate that very economical mining operations would be necessary to be profitable.

Moore and MacDonald. Mining locations W.D. 1165-1164, 1171. A mineralized shear zone from a few feet to 100 feet in width extends east and west across W.D. 1164 and 1163, into W.D. 1427, known as the Thompson claim. This zone consists of schist and small veins of quartz fairly well mineralized with pyrites. An assay of this material by the Mines Branch yielded 40 cents per ton in gold.

A quartz vein on W.D. 1171 about 2 feet wide and reported to contain gold had been traced by trenching for 200 feet.

Holding. Just south of W. D. 1176. This discovery of gold in quartz vein was made in September 1912 and was not seen by the writer. It is reported by Mr. R. B. Stewart[1] to be promising.

McGuire. Near the southwest corner of West Shiningtree lake. Very rich samples of gold in quartz have been taken from this property. The veins, however, are less than 1 foot wide and had been uncovered for only short distances in 1912.

Jefferson. One mining location immediately east of W.D. 1417. Three veins, two of which extend east and west and the other north and south, have been uncovered for distances of 200 feet or less. The greatest width observed is 4 feet. Very rich specimens of gold-bearing quartz have been obtained from one of these veins, but the values seem to be concentrated in pockets.

Saville. W. D. 1417. Several veins have been found on this claim, but they had not been exposed by trenching for very considerable distances when seen in 1912. An open-cut was

[1] Rept. Ont. Bureau of Mines, 1913, pt. 1, p. 237

being made in the largest vein at a point where it traversed the face of a low cliff. At this point the vein was 6 feet wide and carried some visible gold.

Caswell. W. D. 1418-1421. Fine specimens of gold have been taken from a vein about a foot wide which extends east and west from W. D. 1418 into W. D. 1420. The veins on this property, however, are all narrow.

Bennett. W D. 1406. One vein of more than ordinary promise, for this district, was being carefully explored in 1912. This vein, striking nearly northwest, had been traced for 275 feet. Its greatest width in that distance is 4 feet. Free gold had been found along the surface for 70 feet and to the bottom of a 40-foot shaft, which was being continued to greater depth. Some other smaller veins on this claim have been folded so as to give an exaggerated impression of their widths, a feature also observed on the Gosselin and Jefferson properties.

Since August 1912 the Knox, MacDonald, and McIntyre and Ripple properties have been taken up. Comparatively little is known by the writer of these properties.

WANAPITEI AREA.

The gold-bearing deposits to be described under this head do not strictly come within the scope of the present report since they lie outside Onaping map-area. Moreover, none of them have been operated for a number of years and they may never again be operated. Yet, from a brief examination made during the course of the work in Onaping map-area enough was learned about them to indicate that they differ widely in age and genesis from most of the other gold occurrences of northern Ontario.[1] For this reason the present account is given.

The deposits to be discussed occur in the immediate vicinity of Wanapitei lake. Of these, the Crystal mine, situated on the east side of the lake on the portage leading to Mattagamishing lake, is the most important. It was operated for a period of years following 1892, but has been inactive for the last six years.

[1] Cf. Tyrrell, J. B., Trans. Roy. Soc. Can., vol. IX, 1915, p. 117.

The mine is located on a contact between banded greywacke and greenish arkose, belonging to the Cobalt series, and an intrusive mass, probably a sill, of diabase similar in outward appearance to the other post-Cobalt diabases of the region. The normal dip of the Huronian beds is 25 degrees or less, but near the diabase they are more steeply inclined and the contact itself is often marked by a crush-breccia of both intruded and intruding rocks. In the small hill which contains the mine-workings both diabase and sediments are intersected by numerous quartz veins, usually less than a foot wide. These veins consist of quartz and a pink or pale brown carbonate of magnesium and iron (breunerite), the breunerite weathering when exposed on the ore-dump to a characteristic deep bronze colour. The gangue of quartz and breunerite carries pyrite and native gold. The pyrite is evidently copper-bearing because it takes on brassy and purple weathering discolorations. The gold occurs in visible form, often in pieces of considerable size. The Huronian wall rock for about 6 inches away from the veins is bleached and strongly impregnated with crystals or breunerite and with pyrite.

The veins are clearly younger than either the Huronian sediments or the diabase, since they intersect both. It is also possible that they are genetically related to the diabase since they occur in proximity to it, and because there is no other geological agent known in the area to which the mineralization can be ascribed. A number of other occurrences of gold near Wanapitei lake are described by Coleman[1] and others, and as far as these accounts go the character and relationships of the deposits are essentially like those at the Crystal mine.

Certain occurrences of gold in other parts of northern Ontario appear to corroborate this opinion that the post-Cobalt diabases have given rise to gold deposits. Baker[2] records auriferous quartz veins in quartz diabase near lake Abitibi, and gold is reported to have been found in assay material taken from the Mann mine at Gowganda. Mr. George Bennett of Sudbury also stated to the writer that samples taken from veins on his

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[1] Rept. Ont. Bureau of Mines, vol. V, p. 262; ibid, vol. VII, p. 86.
[2] Rept. Ont. Bureau of Mines, vol. XVIII, pt. I, pp. 263-283.

claims in North Williams township yielded a small amount of gold when assayed. These veins occur in quartz diabase. The Ophir, or Havilah, gold mine in the township of Galbraith 15 miles north of Bruce Mines, is also located at the edge of a mass of diabase intrusive in the Huronian, the veins intersecting the diabase. The gangue minerals at this mine are, like those of the Crystal mine, quartz and a brown-weathering carbonate, presumably breunerite. It is even noteworthy that a small quantity of gold is recovered from the Sudbury nickel ores which are associated with a quartz norite laccolith. All the basic intrusives mentioned are regarded as belonging to the same great period of intrusion, the Keweenawan. In addition, therefore, to the copper deposits of lake Superior and on the north shore of lakes Huron and Superior, to the copper-nickel deposits of Sudbury, and to the silver-cobalt deposits of Cobalt, it is probable that the Keweenawan diabases have given rise to deposits of native gold. As some of the gold deposits already found have proved to be quite rich, e.g. the Crystal and Havilah mines, a knowledge of this relationship may prove useful to prospectors in northern Ontario.

METEOR LAKE PLACER.

In the autumn of 1896 placer gold was found in the northeast corner of Hanmer township, in a gravel bed elevated somewhat above Vermilion river. From that point gold was traced at intervals up Vermilion river to the upper waters of Wanapitei river and eventually to Meteor lake. On December 10, 1898, the Onaping Gold Mining Company, with an authorized capital of $490,000, was incorporated to wash gold from the gravel and sand on Meteor lake. A small steam plant was erected on a gravel point in the northeastern part of Meteor lake. The gravels were sluiced with water pumped from the lake by this plant and the gold left behind was caught by amalgamation with mercury.

This venture was not successful. Reasons for its failure have been suggested by Coleman[1] and by A. H. Gracey.[2] They

[1] Rept. Ont. Bur. of Mines, 1901, pp. 151-159.
[2] Ibid, 1897, pp. 256-259.

found the gold content of the gravel to run from 12 to 15 cents per ton, occasionally rising to 50 cents or $1; but the gold is in such a fine state of subdivision that a good separation is difficult. Bedrock, where a better concentration might be expected, is too deeply buried to be easily reached. The cost of sluicing is also high because of the lack of a natural head of water and the consequent necessity of pumping. It is true that Meteor lake is 35 feet higher than Opikinimika lake, and an attempt was actually made to trench through the intervening sand barrier to secure a flow, but for some reason the attempt was given up. Mr. Gracey was of the opinion, however, that if carefully handled placer operations might be profitably conducted.

The placer deposit at Meteor lake and its exploitation, although unsuccessful, is worthy of mention because of the possibility of finding similar deposits in other parts of Onaping map-area. In discussing the Pleistocene geology the opinion was advanced that Meteor lake lies within a glacial outwash plain, which drained southward into Vermilion river. The placer deposits in Vermilion River valley are then ascribable directly to this drainage. Quite similar outwash plains occur in the general neighbourhood of Ogilvie township, of Corkill township, and probably along the east branch of Spanish river. Gold is so widespread in the Pleistocene sands of northern Ontario that in all likelihood these other sand-plains also have a low gold content. Given suitable conditions of drainage the gold may have become concentrated as it has apparently been in Vermilion river. In the case of the Corkill township sand-plain, the drainage was probably southward through the north branch of Lady Evelyn river, while that about Ogilvie township was drained in part by the present Rosie creek. It is not unlikely, then, that the sands and gravels in these stream-channels may carry gold. There is no reason, however, to believe that they would prove richer or even as rich as the Vermilion River gravels.

SILVER.

HISTORY.

That part of northeastern Ontario around and including Onaping map-area was actively explored for silver-ore deposits from 1906 until about 1911. The search was a deliberate one, with expectations of success based upon two fairly well established geological opinions. The rich silver-cobalt ores then being mined at Cobalt had been shown fairly conclusively to be genetically connected with a sill of post-Cobalt diabase, and other sills of the same sort were known to occur in the adjoining region. The inference was that these sills might also contain veins of silver-cobalt ore and this expectation was verified by a succession of discoveries that lasted from 1906 until 1910.

The first silver-bearing vein in Onaping map-area was found east of Gowganda lake in the spring of 1908. Later in the season others were found on the west side of the lake. These early finds were so rich that hundreds of prospectors hurried to Gowganda immediately after the breakup of the ice in 1909 and during that season prospecting spread far south into Onaping map-area. Silver was found at Flanagan lake in Leith township, on the east side of Lady Dufferin lake in Donovan township, east of Shiningtree lake in Leonard township, and near Rosie creek in Browning township (see Map No. 179A).

The climax of the boom was passed before the end of that year. None of the new discoveries were so promising as those near Gowganda. Vigorous development work had also been started at Gowganda which demonstrated within a year that the camp did not compare in richness with Cobalt. Consequently, much less exploration was done in 1910. No new silver-bearing areas were found, but much surface development work was carried on in the areas already known and a number of additional discoveries were made in these areas. Exploration further declined in 1911 and may be said to have ceased by 1912.

Since 1909 Gowganda has become a producing camp. Up to the end of 1914 the total shipment of ore has been 1,412 tons.[1]

[1] Report of the Timiskaming and Northern Ontario Railway Commission, by A. A. Cole, 1914, p. 38.

The production, in tons of 2,000 pounds, by individual mines is as follows:

Silver Production of Gowganda.

	1909	1910	1911	1912	1913	1914
Bartlett	2·00	——	6·75			
Bonsall	....	6·78	——			
Boyd-Gordon	....	30·00	1·25			
Burke-Remey	....	2·00	——			
Calcite Lake	....	——	——	8·50		
Canadian Gowganda	....	——	——	8·00		
Everett	....	8·35	——			
Mann	....	——	——	16·00	20·00	20·00
Milleret	....	346·30	128·00	188·00	——	——
Miller Lake—O'Brien	....	31·00	116·50	112·60	172·90	118·8
Powerful	....	1·00	——	——	——	——
Reeves-Dobie	....	61·00	5·00	——	——	——
Welsh	....	1·25	——	——	——	——

None of the other areas have shipped ore, though an exploration shaft was sunk 92 feet on a vein of the Caswell property at Shiningtree lake.

DESCRIPTION OF ORE DEPOSITS.

The silver-bearing veins at Cobalt and Gowganda have been so frequently and fully described[1] that only a few of their salient characteristics need be summarized here.

The veins at Gowganda occur nearly altogether within the sills of post-Cobalt quartz diabase. Only two or three veins have been traced into the Huronian sediments. They are sharply defined fissure veins rarely 2 feet wide and usually less than 1 foot. They are not often traceable for more than 300 or 400 feet. They are vertical or nearly so. A distinct tendency for as many as seven veins to occur in parallel arrangement at intervals of 25 to 75 feet has been observed on the Mann property at Gowganda and on the Neelands claim at Shiningtree. But beyond this there does not appear to be any common trend to the veins in any one area or in the region as a whole.

[1] See especially, Rept. Ont. Bureau of Mines, vol. XVI, pt. I; vol. XVIII, pt. II; and vol. XIX, pt. II; Geol. Surv., Can., Mem. 33.

The veins contain native silver, smaltite, niccolite, and chalcopyrite in a gangue of calcite and quartz. Native bismuth, pyrite, specular hematite, stibnite, and galena are less constant constituents. Cobalt bloom, annabergite, azurite, and limonite are the chief oxidation minerals. The carmine stain of the cobalt bloom is one of the most conspicuous signs whereby the veins may be recognized. Quartz was deposited first, as it encrusts the vein walls. Chalcopyrite, galena, and specularite crystallized at about the same time, since they occur within the quartz. Campbell and Knight[1] conclude that smaltite and niccolite were deposited next. Calcite came next and then a period of slight fracturing of the vein matter, these fractures being filled with native silver. Bismuth crystallized after the silver.

This association of vein minerals, gangue as well as ore minerals, is believed to be a late differentiation product from the quartz diabase magma. The course of differentiation as far as it has been actually traced (cf. pages 90-99) points to some such end product. The earliest product to solidify was a diabase containing less than 50 per cent of silica. This was followed by an aplite the silica content of which rises to 80 per cent. Certain facts suggest that the aplite was followed by still other differentiation products. A small amount of chalcopyrite, or pyrite containing copper, is distributed through the diabase, while in the aplite this constituent is in distinctly greater amount, both disseminated through the aplite and as veins traversing that rock, e.g., at the United States mine near Elk Lake. Primary calcite, likewise, occurs sparingly in the diabase and in greater amounts in aplite. In two cases aplite dykes were found to merge into calcite veins. On the whole, there seems to have been a decided tendency for silica, calcite, and chalcopyrite, three of the principal vein constituents, to concentrate in the residual aplitic portion of the differentiated magma. With differentiation carried somewhat further these residues might well be expected to form veins like those which actually do occur in the diabase sills. Traces of silver, cobalt, nickel, or bismuth, the other vein constituents, however, could not be found in the aplite nor the diabase.

[1] Econ. Geol., 1905-06, p. 767.

The concentration of silica, calcite, and chalcopyrite in the aplite foreshadow the later appearance of veins composed of the same materials. A direct connexion of the silver-cobalt veins with the diabase is further supported by the fact that these veins are invariably found within diabase sills or in their immediate neighbourhood. This association holds for the entire silver-producing region.

FUTURE.

What the writer knows about the various silver mines and prospects in Onaping map area has already been published in detail,[1] and it is unnecessary to repeat that information. Neither is it within the scope of a reconnaissance of so large an area as that under discussion to investigate the future of mining operations in the working mines; that is for detailed geological study. But certain observations and inferences have been made regarding the possible extent of the silver-bearing area which may have some value in directing the course of future prospecting which belong more properly in this report.

The silver deposits at Cobalt, Gowganda, Shiningtree lake, in fact wherever appreciable amounts of silver have been found, are associated with sills of quartz diabase. The veins on Florence lake, which carry no silver and only traces of cobalt, but considerable chalcopyrite and quartz rather than calcite, are associated with a sill which is partly a quartz norite. The atypical veins occurring in North Williams, Dufferin, and Browning townships, containing little smaltite, cobalt bloom, stibnite, galena, etc., and little or no silver, are also associated with a sill intermediate between a quartz diabase and a quartz norite. The sills in the southeastern quarter of the map-area, which have yielded no silver-bearing veins, are all quartz norite or intermediate between quartz norite and quartz diabase. If veins occurred in these sills some of them would probably have been discovered, for they have been examined attentively by many prospectors. It is, therefore, more probable that veins are lacking or scarce.

[1] Geol. Surv., Can., Mem. 33, pp. 99-113; Sum. Repts., Geol. Surv., Can., 1909-1911.

As far, then, as present experience in northern Ontario goes, typical silver-cobalt veins are to be expected in association with sills of quartz diabase and not with sills of quartz norite. The distinction between these two rock types (pages 86-89) is, accordingly, a matter of economic importance. So far as Onaping map-area is concerned true quartz diabase is confined to its northern part. The sill remnants in Leonard township, those near Gowganda and extending southward past Smoothwater lake, and the various patches east and northeast of Smoothwater lake are quartz diabase. The remainder are either quartz norite or intermediate between quartz norite and quartz diabase, and, consequently, according to the facts presented, not promising ground for silver-cobalt veins.

Since the copper-nickel ores at Sudbury are genetically associated with a great intrusive mass of quartz norite, it might be concluded that similar deposits should occur with the quartz norite sills in Onaping map-area. The latter intrusives, however, are comparatively small masses with thicknesses measurable in hundreds of feet, while, according to Coleman, the Sudbury laccolith is $1\frac{1}{4}$ miles thick. If, therefore, nickel ore-bodies have segregated from the Onaping sills, they are probably very small compared with those at Sudbury. No such deposits have yet been found.

ZINC.

During the field season of 1912 information was received that a deposit of nickel ore had been found just east of Onaping lake and close to the south boundary of Shelly township. According to Mr. J. R. Marshall, who was instructed to visit the discovery, little development work had been done and the deposit did not appear to be a particularly promising one. The opinion that it carried nickel appeared to be based solely upon the occurrence of pyrrhotite disseminated through a coarse diabase, the principal formation in that locality.

Since then the discovery has been visited and examined by W. L. Uglow, who found it to be a lead-zinc deposit rather than one of nickel. "The country rock is a massive greenstone or altered gabbro, associated with a lean, greenish, carbonate phase of the iron formation. The latter strikes about east and west. The ore is a very fine-grained intimate mixture of galena and sphalerite, occurring in at least two zones parallel to the strike of the country rock. Pyrrhotite occurs in places, as well as pyrite and traces of chalcopyrite. The ore minerals appear to be in the nature of an impregnation in the greenstone and the iron formation. The galena occurs generally in very narrow vein-like stringers cutting through the blende. The ore is not usually clean, but contains bunches of barren rock scattered through it. It is reported that pyrrhotite was the original discovery and that on sinking, zinc blende was encountered. The bottom of the shaft is reported to be in high-grade sphalerite.

"A shaft reported to be 60 feet deep, but full of water at the time of the writer's examination, and six surface trenches, constitute the total development on the property. Traces of the ore may be seen in a general east-west direction across three claims, but continuous development has not proved more than 250 feet of ore deposit."[1]

IRON.

All the iron ore deposits in Onaping map-area are of the type known as banded iron formation. They all belong to the pre-Huronian schist-complex. None of them has any present commercial value, but as efforts have been made in the past to develop them, it seems advisable to discuss briefly their geological character and economic possibilities.

All the bodies of iron formation in the map-area that are known to the writer are represented in Figure 2. They include:

A narrow, discontinuous range east of Shiningtree lake.

A group of small, highly metamorphosed bodies near Burwash lake. The small mass in Blewett township is of this type and, although 20 miles away, may conveniently be included here.

Outliers of Moose Mountain iron-range that occur in Roberts and Botha townships.

A small body at the east end of Okawakenda lake, Churchill township (see Map No. 153A).

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[1] Uglow, W. L., "Lead and zinc deposits in Ontario and in eastern Canada" Ann. Rept. Bureau of Mines, Ontario, vol. XXV, Part II, 1916.

SHININGTREE RANGE.

The Shiningtree iron-range is best developed on the east side of Fournier lake, where it forms a ridge 350 feet wide and 1¼ miles long from north to south. This ridge consists of several parallel bands of iron formation alternating with chloritic and sericitic schists, the schists and iron formation striking slightly west of north and dipping 85 degrees west. Some small outlying bodies of iron formation occur on the west side of Fournier lake and at a few other places away from the main range. North of Fournier lake the main range disappears beneath a younger and less folded flow of rhyolite which covers the northern part of Leonard township; but iron formation in alignment with this range is again exposed near the southwest corner of Tyrrell township. It shows in the northeast corner of mining location H.S. 750 as a brilliant red and black banded jaspilite. At that place it strikes north 10 degrees west, but the locality is so swampy that it can be followed for only 200 feet. A third body in line with the second begins 53 chains north of mile-post 61 of the Algoma-Nipissing boundary line, and just west of the line. According to Burwash[1] it is traceable for half a mile northwestward. It has a maximum width of 100 yards and is associated with green schists. The range probably continues northwestward in this intermittent manner, for iron formation occurs on Houghton lake, an expansion of Montreal river, which lies a few miles beyond the northern edge of the map area and in line with the trend of the range.

The iron formation is a thinly stratified rock consisting of alternating siliceous and iron-bearing layers from ¼ to 1 inch thick. The iron-rich layers, composed of minute magnetite octahedra embedded in silica, are dark grey or black; the lean layers vary from different shades of grey to bright red. The formation near mining location H.S. 750 is brilliantly coloured, but that near Fournier lake is dull grey. Under the microscope the rock is seen to consist mainly of finely granular quartz, in alternate layers of which small octahedral crystals of magnetite are concentrated. Shreds of colourless secondary mica arranged

[1] Rept. Ont. Bureau of Mines, 1896.

along the stratification plane are fairly abundant. No clastic texture is apparent. The total amount of magnetite present does not usually exceed 15 per cent.

Practically the whole range was taken up by MacKenzie and Mann, Limited. Under the direction of Mr. A. Fournier, surface exploration was begun in 1910 on the east side of Fournier lake. Trenches were made across the range at intervals of 50 feet, exposing a main ore-body from 10 to 50 feet wide, and some much smaller parallel ones. Ore was found in this manner for 4,000 feet along the strike. It is a somewhat concentrated phase of the iron formation consisting of a highly siliceous mixture of magnetite and some hematite. Selected samples were said by Mr. Fournier to contain 52 per cent iron. The average iron content, however, is considerably lower and could not be successfully marketed without concentration. It was planned to do diamond drilling on the property in order to determine the character of the ore-body in depth; but this was never carried out and in 1911 exploratory work was abandoned.

BURWASH LAKE RANGE.

The iron formation east and southeast of Burwash lake comprises a large number of distinct masses, all of small size, embedded in granite-gneiss. The granite-gneiss also contains a multitude of angular fragments and ribbons of glistening black hornblende gneiss such as characterize its contacts with pre-Huronian schist areas. It is quite evident, in fact, that in this neighbourhood the granite-gneiss batholith invaded a roof of pre-Huronian schists and that the patches of iron formation and hornblende gneiss that now occur in the granite-gneiss are the only remaining vestiges of that roof. Apparently iron formation resisted assimilation by the granitic magma better than the remainder of the schist-complex since its original characteristics have not been obliterated by metamorphism and it occurs in relatively large amount.

In consequence, however, of the intense effect of the granite-gneiss the iron formation differs considerably from that at Shiningtree. The banded character is retained; but in addition to silica and magnetite a bright green, fibrous amphibole (grünerite) has been developed in large amount. Limonite and hematite fail completely. It is quite obvious that a rock so highly anamorphosed would afford little opportunity for the concentration of its iron content, especially since it occurs in small scattered bodies. Unless the iron ore had been concentrated before batholithic invasion there is little likelihood of finding an ore-body; and no evidence of such early concentration has been found. The best ore seen would not yield more than 30 per cent of iron, and the probability of the Burwash Lake range ever producing iron ore in paying quantities is very remote. The small body of iron formation in Blewett township has not been visited by the writer, but, as its geological relationships are closely similar to those of the iron formation at Burwash lake, it is unlikely that it will ever prove useful.

The Burwash Lake deposits have been examined for MacKenzie and Mann, Limited, by means of surface exploration and diamond drilling, as a result of which they were abandoned.

OUTLIERS OF MOOSE MOUNTAIN RANGE.

Moose Mountain iron range lies just south of Onaping map-area, chiefly in the townships of Hutton and Kitchener.[1] The occurrences of iron formation described here are small outliers of the main range, occurring in Roberts and Botha townships. The principal one lies in Roberts township about one mile west of the railway and consists of ordinary banded formation lying within pre-Huronian schists. The body appears to be about 200 feet wide; its length was not ascertained, but cannot be more than half a mile. No evidence was seen of iron ore concentration.

Much smaller bodies occur near the south end of Morin lake in the same township, and on the western boundary of Botha township. These are associated with glistening horn-

[1] For descriptions of this range see especially A. P. Coleman, Rept. Ont. Bureau of Mines, vol. XIII; Leith, C. K., Ibid, vol. XII; Miller, W. G., Ibid, vol. X; Lindeman, E., "Moose Mountain Iron-bearing districts, Ontario." Mines Branch, Dept. of Mines, Canada; Collins, W. H., Sum. Rept., Geol. Surv., Can., 1912, pp. 312-314.

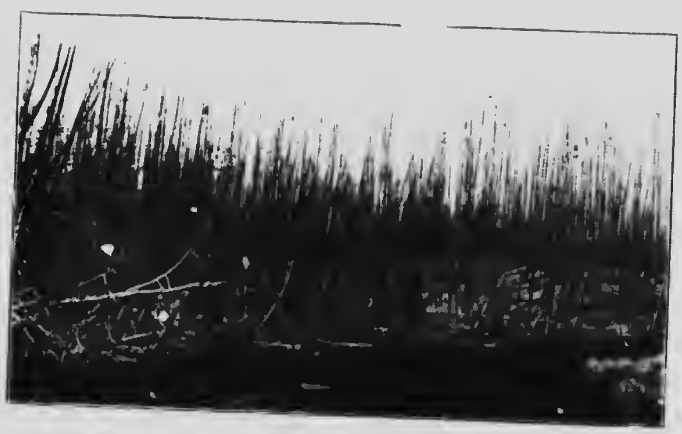
blende gneiss near the intrusive granite-gneiss and are, consequently, of the same unpromising character as the Burwash Lake formation.

WEST SHININGTREE RANGE.

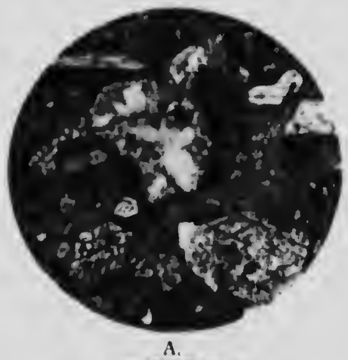
This body of iron formation differs from all the others described in being part of a true clastic sedimentary formation. Its geological character has already been described (page 39). It is too poor in iron to be of commercial interest.

Plate II

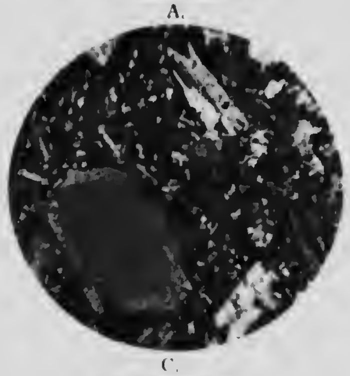
A. Fire-protected pine forest, Frechette township, within Timagami forest reserve. (Page 21.)



B. Fire-swept cedar and spruce forest, West Shiningtree district. (Page 21.)


A.


B.


C.


D.


E.


F.

Photomicrographs of lavas and sedimentary materials (pre-Huronian schist-complex) derived from the tuffs associated with these lavas, by imperfect water assortment of the latter. Okawakenda lake, Churchill township.

A. Hornblendic phase of hornblende porphyrite, showing a vesicular cavity filled witth quartz. Magnified 15 diameters. (Page 36.)

B. Feldspathic phase of hornblende porphyrite, showing about equal numbers of phenocrysts of hornblende and of plagioclase. Magnified 20 diameters. (Page 36.)

C. Trachytic variety of lava intimately associated with A and B. Magnified 18 diameters. (Page 36.)

D. Cement of conglomerate derived by water assortment of tufaceous phases of A, B, and C. Magnified 15 diameters. (Page 38.)

E. Arkose-like stratified rock derived in the same manner as D. Magnified 12 diameters. (Page 38.)

F. Slate-like, stratified rock derived in the same manner as D and E. Magnified 20 diameters. (Page 39.)

PLATE IV.

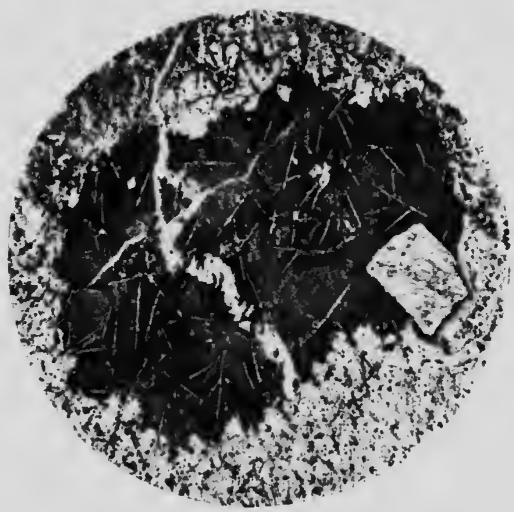
Ellipsoidal andesite formation belonging to the pre-Huronian schist-complex, West Shiningtree lake, Churchill township. (Page 42.)

PLATE V.

Photomicrographs of rhyolite from volcanic flow in the pre-Huronian schist-complex, Leonard township.

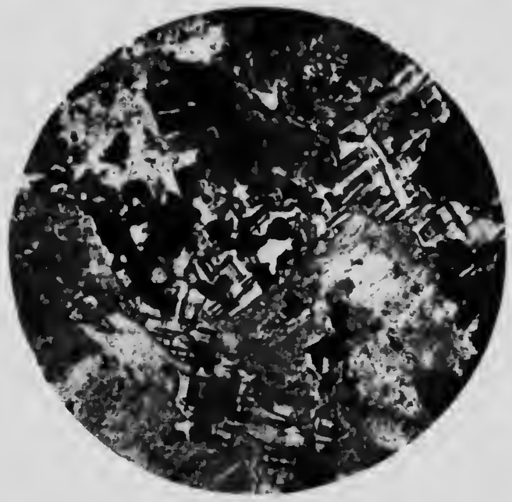
A. Fine-grained amygdaloidal phase containing small amygdule filled with calcite and quartz. Magnified 20 diameters. (Page 45.)
B. Coarse-grained phase, showing phenocrysts of feldspar (large) and quartz (small). Magnified 20 diameters. (Page 45.)
C. Sample showing characteristic crystal habit of the quartz phenocrysts. Magnified 18 diameters. (Page 45.)
D. Tufaceous phase; the three segments represent portions of three fragments and the central triangular part some of the matrix. Magnified 7 diameters. (Page 46.)

Plate VI.



Photomicrograph of thin-section of variolitic lava from pre-Huronian schist-complex, Tyrrell township. The dark patch in the middle represents a variole, and the lighter peripheral part the groundmass of the lava. (Page 47.)

PLATE VII.



A.

B.

Photomicrographs of products of magmatic assimilation showing their characteristic irregular mineral intergrowth.

A. Product of interaction between pre-Huronian schist and granite. West shore of Burwash lake, Cotton township. Magnified 12 diameters. Note canal-like arrangement of secondary microcline around the primary plagioclase. (Page 59.)

B. Product of interaction between diabase and (probably) quartzite. Near mile-post 298, Canadian Northern Ontario railway. A single individual of orthoclase forms the background of the section. Magnified 20 diameters. (Page 60.)

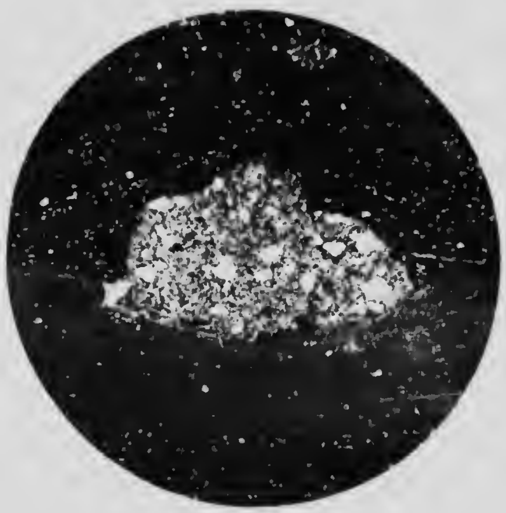
PLATE VIII.

A. Fragment of quartzite enclosed in and partly assimilated by diabase, Blind River, Ont. One-fifth natural size. The unassimilated vestige of the quartzite xenolith and the product of interaction between it and the diabase lie within the black line. Note the dark, hornblende-rich rim next to the diabase. (Page 61.)

B. Photomicrograph representing the interaction product. An irregular mineral intergrowth is its textural characteristic. Magnified 15 diameters. (Page 61.)

PLATE IX.

A. Laminated greywacke from the Gowganda formation carrying occasional boulders. (Page 67.)

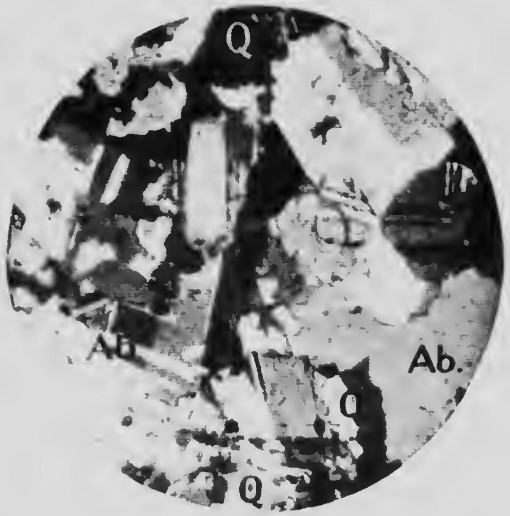


B

B. Photomicrograph of A showing cross-section of two complete laminæ and a pebble of quartzite belonging to the upper lamina. Magnified 7 diameters. (Page 67.)

PLATE X.

A.



B.

A. Photomicrograph of medium grained quartz diabase, Gowganda district, Ont. Magnified 30 diameters. The black area is titaniferous magnetite. Page 87.

B. Photomicrograph of aplitic derivative of A. Magnified 20 diameters. A small amount of mica is present in the aplite. Page 87.

L = labradorite. Ab = albite. Au = augite. Mg = micrographic intergrowth of quartz and andesite, Q = quartz.

Plate XI.

Contact between pre-Huronian schist-complex and intrusive granite-gneiss. See Figure 4. (Page 31.)

INDEX.

A.

B.

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R.

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Z.

PUBLICATIONS OF THE GEOLOGICAL SURVEY.

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

Memoir 41, *Geological Series 38.*
Memoir 54, *Biological Series 2.*
Museum Bulletin 5, *Geological [illegible]*
Museum Bulletin 6, *Anthropological [illegible]*

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

Publications Issued Since 1909.

MEMOIRS.

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

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

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

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

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

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

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

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

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

MEMOIR 10. *Geological Series 10.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in south-western Ontario, 1911—by J. W. Goldthwait.

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

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

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

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

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

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

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

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

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

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

MEMOIR 21. *Geological Series 15.* The geology and ore deposits of Phoenix Boundary district, British Columbia, 1912—by O. E. LeRoy.
MEMOIR 22. *Geological Series 27.* Preliminary report on the serpentines and associated rocks in southern Quebec, 1914—by J. A. Dresser.
MEMOIR 23. *Geological Series 23.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C., 1914—by J. Austen Bancroft.
MEMOIR 24. *Geological Series 16.* Preliminary report on the clay and shale deposits of the western provinces, 1912—by Heinrich Ries and Joseph Keele.
MEMOIR 25. *Geological Series 21.* Report on the clay and shale deposits of the western provinces, Part II, 1914—by Heinrich Ries and Joseph Keele.
MEMOIR 26. *Geological Series 34.* Geology and mineral deposits of the Tulameen district, B.C., 1913—by C. Camsell.
MEMOIR 27. *Geological Series 17.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911, issued 1912.
MEMOIR 28. *Geological Series 18.* The Geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario, 1912—by Charles D. Walcott.
MEMOIR 29. *Geological Series 32.* Oil and gas prospects of the northwest provinces of Canada, 1913—by W. Malcolm.
MEMOIR 30. *Geological Series 40.* The basins of Nelson and Churchill rivers, 1914—by William McInnes.
MEMOIR 31. *Geological Series 20.* Wheaton district, Yukon Territory, 1913—by D. D. Cairnes.
MEMOIR 32. *Geological Series 25.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C., 1914—by R. G. McConnell.
MEMOIR 33. *Geological Series 30.* The geology of Gowganda Mining Division, 1913—by W. H. Collins.
MEMOIR 34. *Geological Series 63.* The Devonian of southwestern Ontario, 1915—by C. R. Stauffer.
MEMOIR 35. *Geological Series 29.* Reconnaissance along the National Transcontinental railway in southern Quebec, 1913—John A. Dresser.
MEMOIR 36. *Geological Series 33.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C., 1914—by C. H. Clapp.
MEMOIR 37. *Geological Series 22.* Portions of Atlin district, B.C., 1913—by D. D. Cairnes.
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MEMOIR 82. *Geological* [illegible] River district, Ontario—Surficial [illegible] W. A. Johnston.

MEMOIR [illegible] [illegible] formations in Ontario [illegible]

MEMOIR [illegible] [illegible] of the Lazin and Edson [illegible] by Charles Camsell

[illegible] surveys in 1914, 1916—by [illegible]

MEMOIR [illegible] [illegible] foods and food prepar- [illegible]

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MEMOIR [illegible] [illegible] Graham island, British [illegible] MacKenzie.

MEMOIR [illegible] [illegible] Mountain—Willowbunch Coal [illegible] Bruce Rose.

MEMOIR 90. *Anthropological Series 13.* Time perspective in aboriginal A[illegible] study in method, 1916—by E. Sapir.

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MEMOIR 95. *Geological Series 77.* Onaping map-area—by W. H. Collins.

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

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

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

Mus. Bull. 5. *Geological Series 21.* A Beatricea-like organism from the middle Ordovician, 1914—by P. E. Raymond.

Mus. Bull. 6. *Anthropological Serie 3.* Prehistoric and present commerce among the Arctic Coast Eskimo, 1915—by V. Stefansson.

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

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

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

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Mus. Bull. 12. *Geological Series 24.* On Eoceratops Canadensis, gen nov, with remarks on other genera of Cretaceous horned dinosaurs, 1915—by L. M. Lambe.

Mus. Bull. 13. *Biological Series 5.* The double-crested Cormorant (Phalacrocorax Auritus) and its relation to the salmon industries on the Gulf of St. Lawrence, 1915—by P. A. Taverner.

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A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories, 1910—by Joseph Keele

Summary Report for the calendar year 1909, issued 1910.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902, issued 1911—by Alfred W. G. Wilson.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers, 1911—by W. McInnes.

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Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario, 1913.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa, 1913.

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Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island, 1913.

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Guide Book No. 10. Excursions in northern British Columbia and Yukon Territory and along the north Pacific coast, 1913.

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Summary Report for the calendar year 1915, issued 1916.

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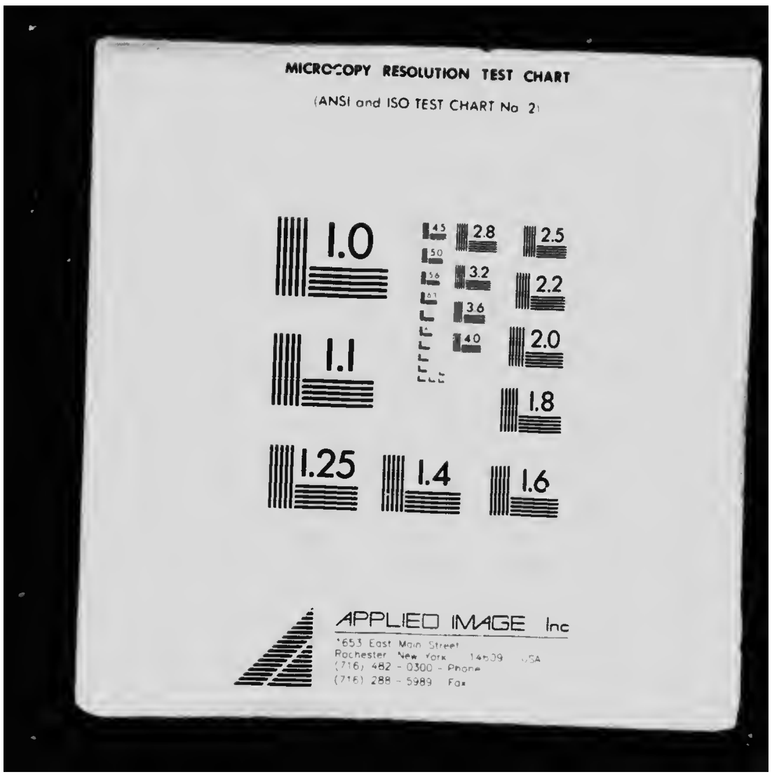
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(ANSI and ISO TEST CHART No. 2)
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LEGEND

HURONIAN

PLEISTOCENE AND RECENT

Q

KEWEENAWAN

olivine diabase

quartz diabase quartz nor... and intermediate varieties ... and their aplitic derivati...

COBALT SERIES

A4

Lorrain quartzite et...

white quartzite and quartz... conglomerate Lorrain ... by banded cherts quartzi... white quartzite

Gowganda formatio...

conglomerate greywacke ... laminated greywacke ... quartzite and siliceous ...

PRE-HURONIAN

Batholithic intrusive...

granite gneiss principally ... related aplite and pegmatite

Transition rocks

granite gneiss containing ... recrystallized fragments from ... the pre-Huronian schist comp...

A2

Iron formation

differentiated from the schist co...

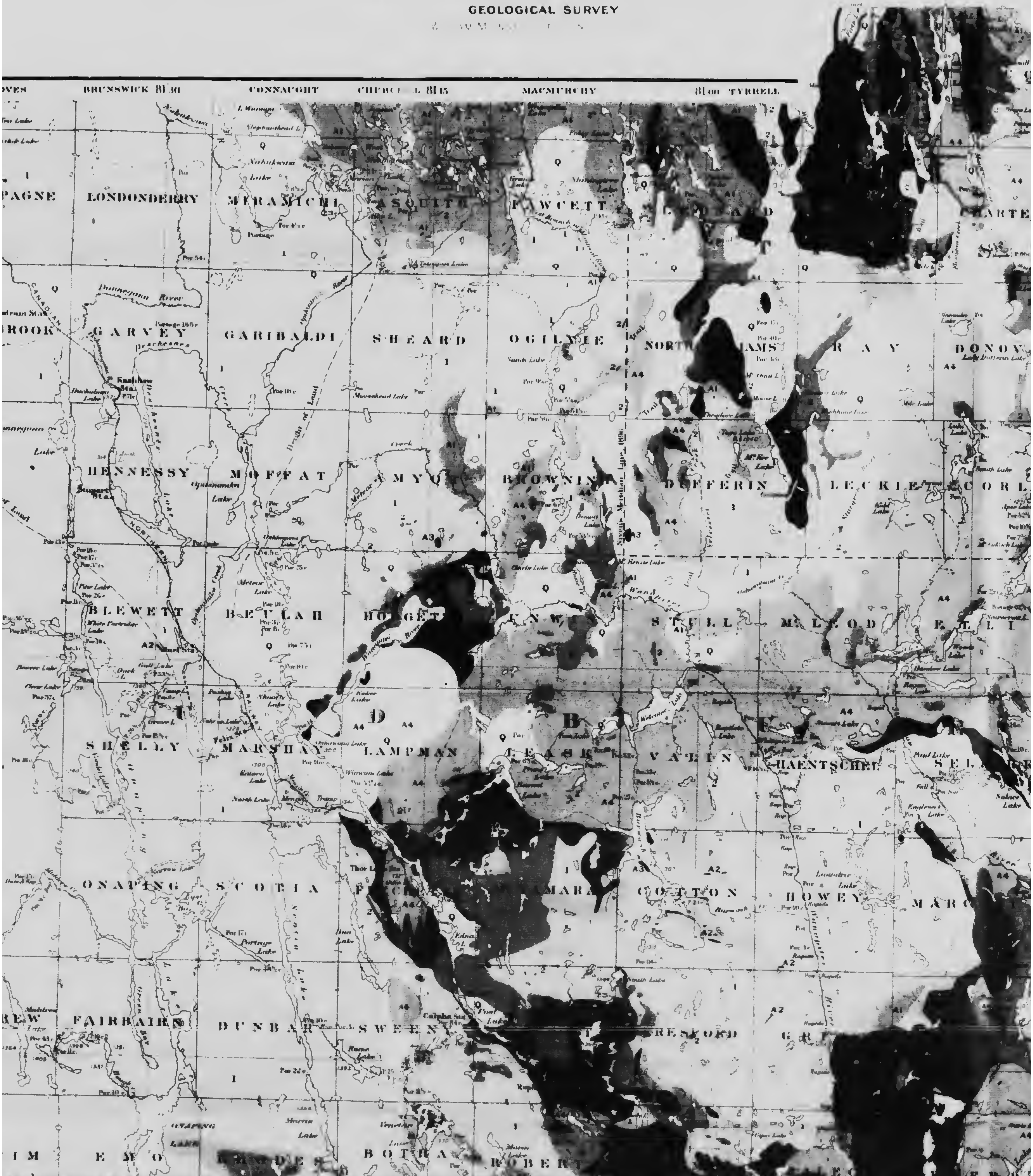
Schist complex

Symbols

Canada

Department of Mines

GEOLOGICAL SURVEY



PRE-HURONIAN

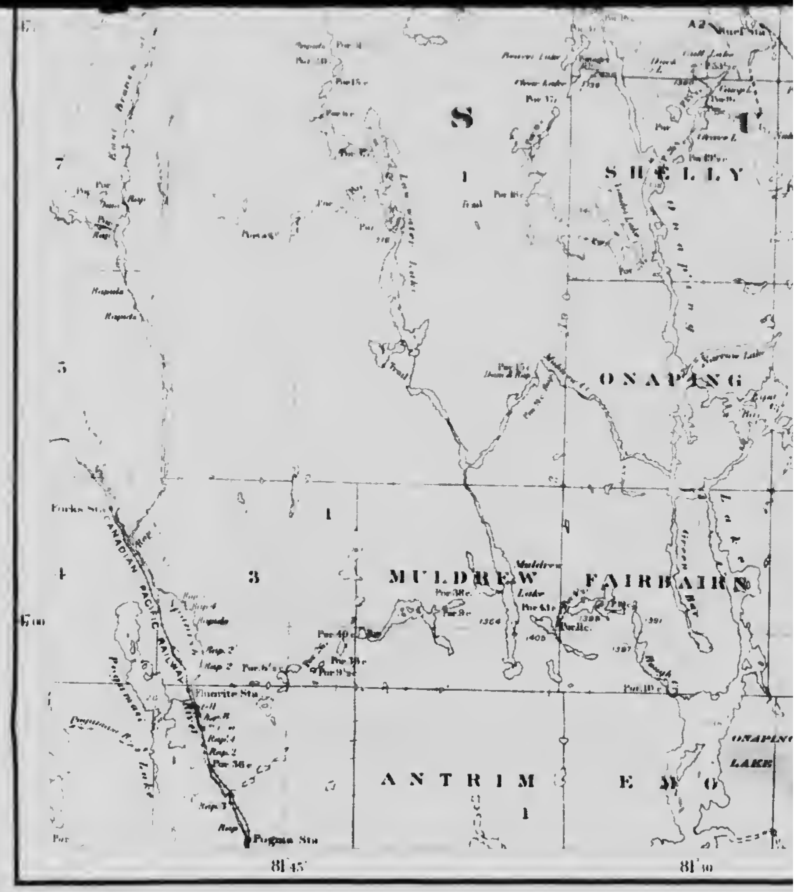
Symbols

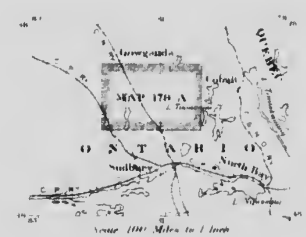
Geological boundary

Geological boundary

Elevations

Magnetic declination 5° to 7° West





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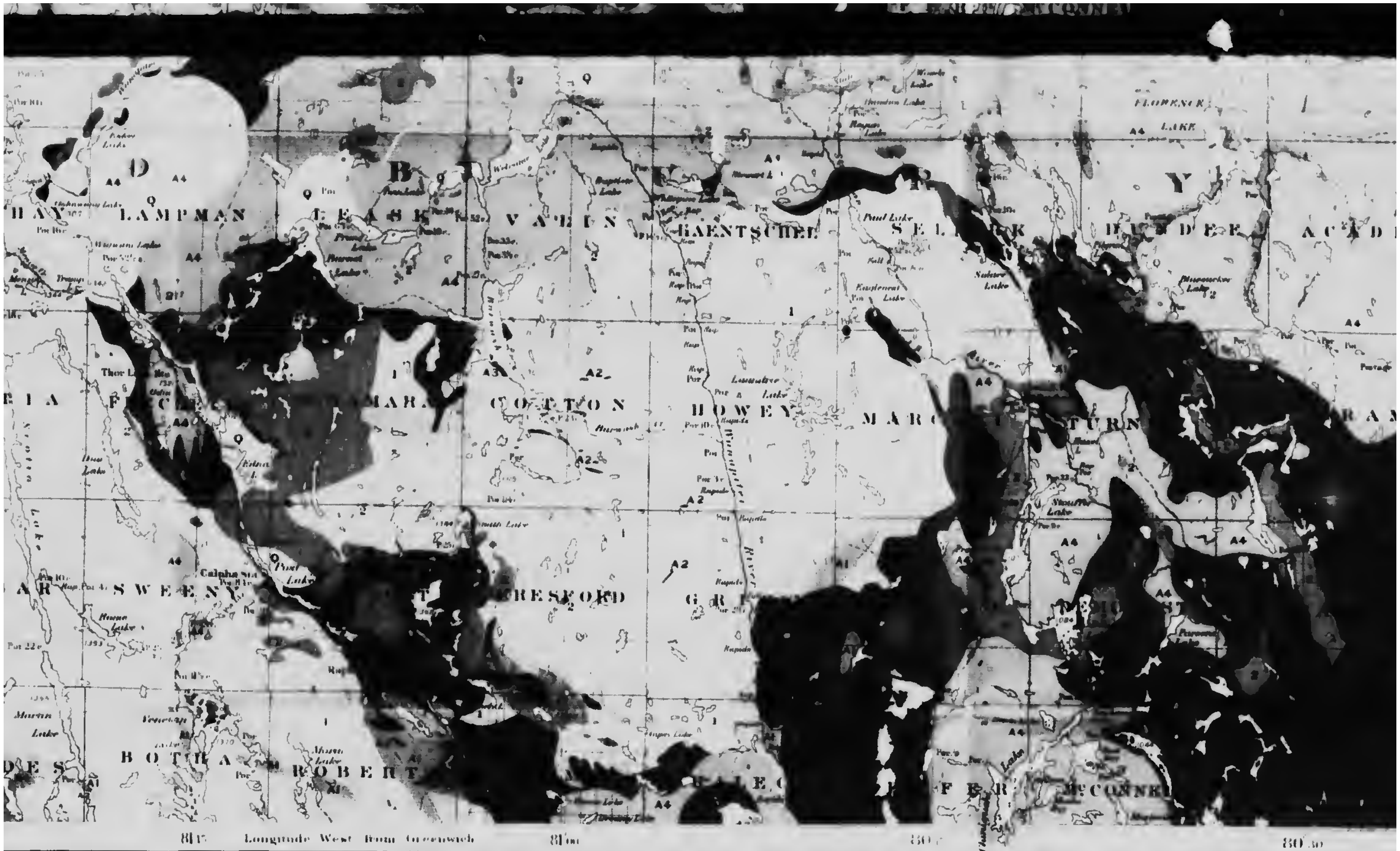

Inks sheet 130

MAP 179 A
Issued 1917

ONAPING

SUDBURY AND TIMISKAMING DISTRICTS

ONTARIO

Scale, $\frac{1}{253{,}440}$

Miles

Kilometres

4 MILES TO 1 INCH

SOURCES OF INFORMATION

Geology ... surveys by

...B Collins 1909-1911 and assistants ... Cooke
...1909-1910 ... E L O'Neill 1912, and ... R Marshall 1912-1913
... J Wilson 1913
...reau of Mines Ontario 1909

Surveys by

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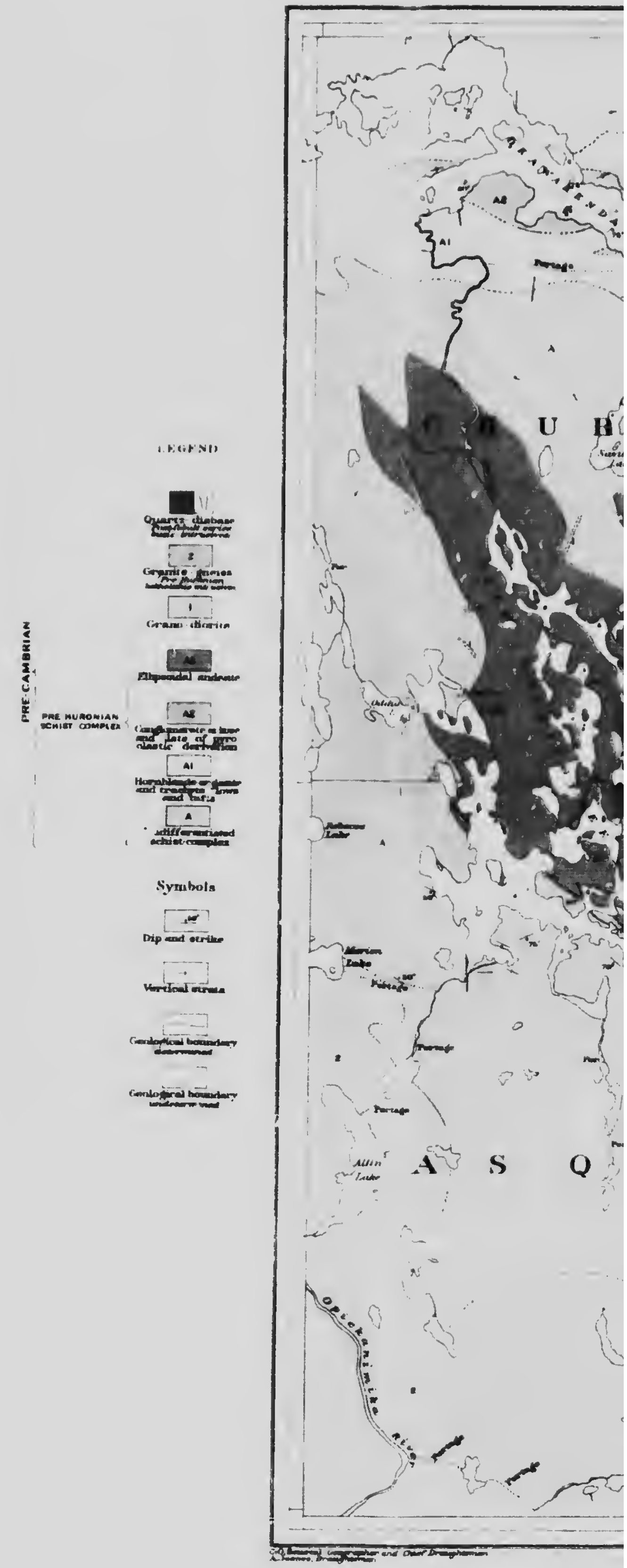
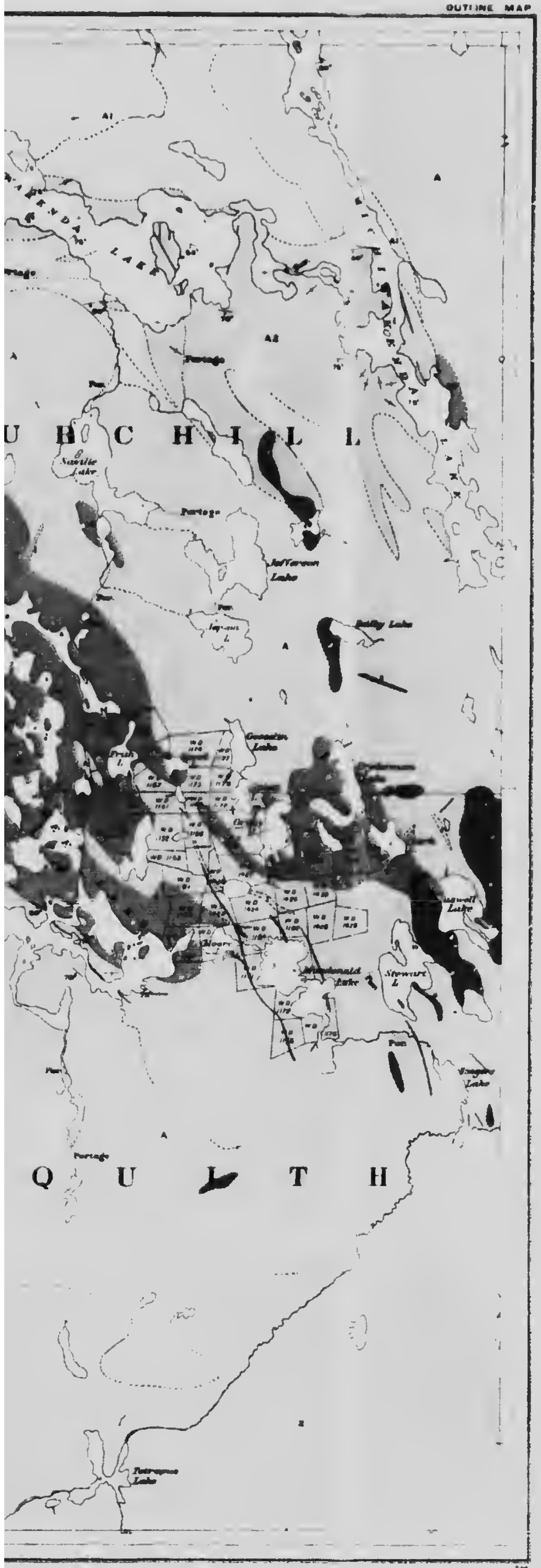


ASQUITH AND C
SUDBURY D

GEOLOGICAL SURVEY

OUTLINE MAP



MAP 153 A
Issued 1916

ND CHURCHILL TOWNSHIPS,
URY DISTRICT, ONTARIO.

Scale of Miles

Geology by W H Collins 1912