GUIDE BOOK No. 7

Excursions to Sudbury, Cobalt and Porcupine

Excursions A 3 and C 6

GEOLOGORUM CONVENTUS
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CANADA
MENTE ET MALLEO

ISSUED BY THE ONTARIO BUREAU OF MINES
TORONTO, CANADA

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TO

Sudbury, Cobalt and Porcupine

(EXCURSIONS A 3 and C 6)

ISSUED BY THE ONTARIO BUREAU OF MINES,
TORONTO

TORONTO:
Printed by L. K. CAMERON, Printer to the King's Most Excellent Majesty
1913

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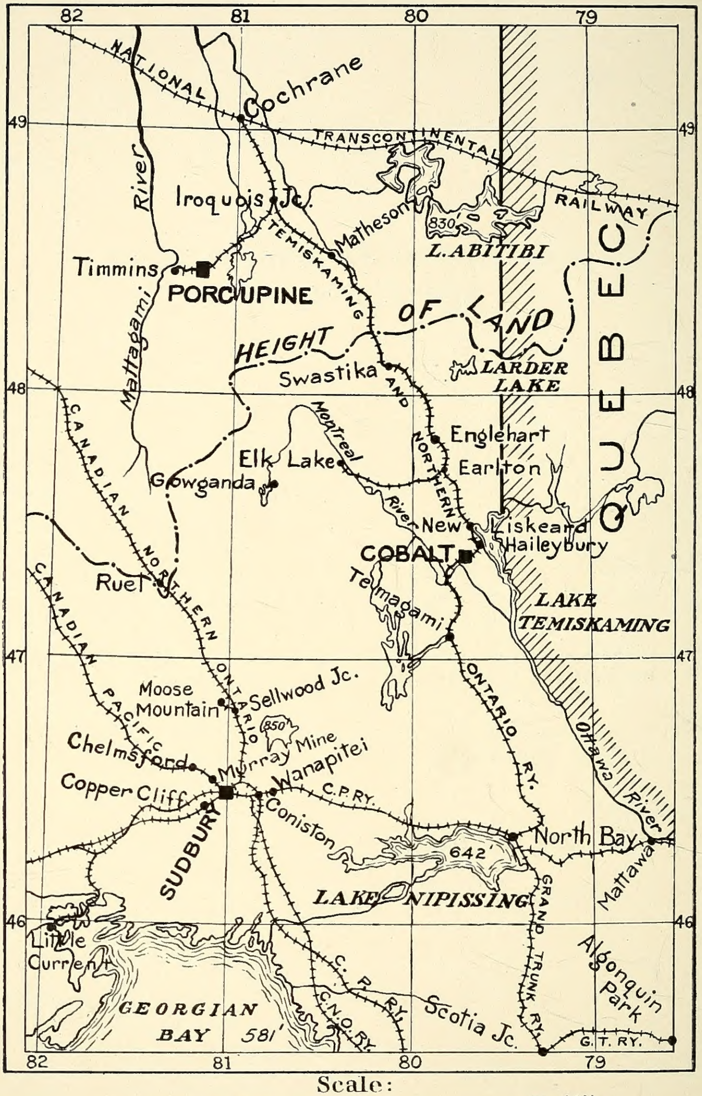
CONTENTS.



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The Sudbury-Cobalt-Porcupine region.

PREFACE.

The three mining areas, viz.: Sudbury, Cobalt, and Porcupine, that are described in this Guide Book, are the most important in the Province of Ontario. Sudbury is the world's greatest producer of nickel and is also an important producer of copper. Minor quantities of platinum, palladium and other metals have been obtained from its ores. Cobalt leads all other areas in the world in its output of silver and of cobalt, and arsenic and nickel occur in important quantities in its ores. Porcupine, the product of which is gold, is a comparatively new mining area and is only partly developed. The two chief mines, however, are splendidly equipped, and during the last year have been important producers. Other mines at Porcupine have recently begun milling operations.

As nearly as can be determined from Government reports, Sudbury had produced, in round numbers, 158,000 tons of nickel and 103,000 tons of copper by the end of 1912. Statistics of by-products—platinum, palladium, and other metals—are incomplete. At the same date, cobalt had produced approximately 156,000,000 ounces of silver. In 1912, owing to the Porcupine production, the gold output of Ontario had a value of $1,859,285, compared with $42,637 in 1911.

The ore deposits of all three of the areas are in rocks that are classified as of pre-Cambrian age, and are believed to owe their origin to igneous intrusions. At Sudbury the intrusive rock, described on following pages, is quartz-norite, at Cobalt quartz-diabase, and at Porcupine granite.

Sudbury is about 90 miles to the southwest of Cobalt, and it is believed that the norite of the one area and the quartz-diabase of the other are genetically connected. The close chemical relations of the two rocks are described in the following pages devoted to the Cobalt area.

The colored geological map, on a scale of eight miles to the inch, that accompanies this guide book, shows the geology of the three areas in so far as it is at present known. Larger scale maps have been published and are referred to in the text.

Relations of the Rocks.

Keewatin Series.

As the legend on the map shows, the oldest series known in the region is called the Keewatin. It consists for the greater part of basic volcanic rocks, now represented by schists and greenstones, together with more acid varieties such as quartz-porphyry. Associated with the Keewatin is considerable sedimentary material, consisting of schistose greywacké, jaspilyte, or iron formation, and crystalline limestone, which is, however, not seen in large exposures in any of the three mining areas. These sedimentary rocks are believed to represent the Grenville series of southeastern Ontario.

Laurentian Granite and Gneiss.

The rocks next younger than the Keewatin are grey granite and gneiss. They are well exposed along the railway north of North Bay, and are called Laurentian.

Temiskaming Series.

After the intrusion of the Laurentian into the Keewatin, there was a prolonged period of erosion, during which a thick series of sediments consisting of conglomerate, greywacké and other rocks was deposited. To this series in the Cobalt and Porcupine areas the name Temiskaming has been given. It is known in other areas to the north, south and west of Cobalt and appears to be represented at Sudbury by what Dr. Coleman has called the Sudbury series.

Lorrain Granite.

After the deposition of the Temiskaming sediments an intrusion of granite, characteristically pink in color, took place. This granite, which occupies large areas, is known as Lorrain. The relations of this granite to both the older and younger rocks are clearly shown at Cobalt. The granite which gave rise to the gold deposits at Porcupine appears to be of the same age.

Cobalt Series.

The period of erosion that succeeded the intrusion of the Lorrain granite gave rise to the conglomerate and other rocks known as the Cobalt series. Good exposures of these rocks are to be seen at Cobalt and along the railway to the south and to the north. At Porcupine only small exposures are found. The Ramsay Lake conglomerate of Sudbury appears to be of the same age.

In the Sudbury area there is also a series of sediments which has been mapped as of Animikie age. The age relation of this series to the Cobalt series and to the Ramsay Lake conglomerate is not definitely known.

Nipissing Diabase and Sudbury Norite.

Succeeding the deposition of the Cobalt series came the intrusion of the quartz-diabase which gave rise to the silver deposits of Cobalt. This intrusive is known as the Nipissing diabase. As stated above, the Sudbury norite, with which are genetically connected the nickel-copper deposits, is similar in chemical composition and appears to be of the same age.

Paleozoic Rocks.

To the north and east of Cobalt, limestone, with basal conglomerate and sandstone, of Silurian (Niagara) age, occurs as outliers on the pre-Cambrian.

With the exception of deposits of glacial and recent age, no rocks younger than the pre-Cambrian are found in the vicinity of Sudbury or Porcupine.

W. G. M.

Toronto, June, 1913.

THE SUDBURY AREA

BY

A. P. COLEMAN.

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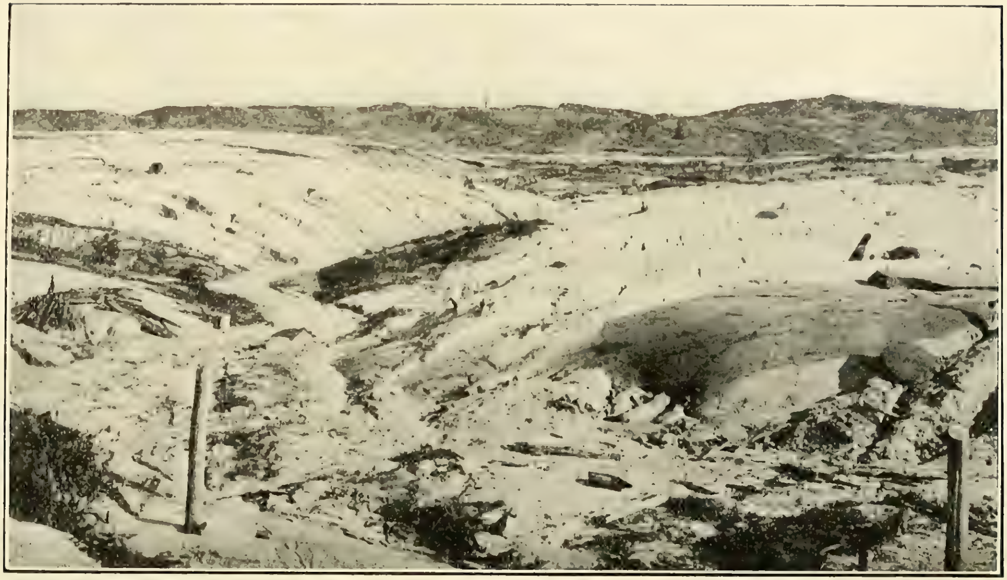
INTRODUCTION.

The Sudbury region is especially known for its nickel mines, the most important in the world; but the geologist finds an almost equal interest in its eruptive rocks, which include a remarkable basin-shaped laccolithic sill more than a mile thick and covering 400 square miles of territory, and its unusually complete set of pre-Cambrian formations, probably not surpassed by any other area of equal size in America. The region displays also striated rock surfaces and boulder clay, due to Pleistocene glaciers and shore and deeper water deposits of ancient Lake Algonquin.

The scenery of the region is mostly of the "rocky lake" character, but this is diversified with considerable stretches of fertile farm lands. In many parts the original forest has been destroyed by the lumberman and by fire, leaving the rock hills bare, so that the geological structures are admirably exposed; and in a few places sulphur fumes from roast beds and smelters have destroyed all vegetation, allowing rain to carve the drift materials and expose the glacier smoothed rock surfaces beneath.

The most striking physiographic features of the region are connected with the great basin-shaped sheet of the nickel eruptive. This consists of an easily-weathered outer side of norite blending into a resistant inner side of a granitic character, whch has metamorphosed and hardened the rocks above; so that after passing the irregular Archæan surface which surrounds the basin, there is everywhere a depression or trough, sometimes occupied by lakes, representing the basic portion of the eruptive, followed after a mile or two by rugged hills, made up of the acid portion and the metamorphosed sediments above.

After crossing this belt of rough hills the interior spreads out as a low plain covered with old lake deposits, often level as a prairie. From the farms of the interior one sees the rim of the basin rising on all sides as ridges or hills sometimes reaching 500 feet above the sheltered plain. The basin is drained by Vermilion river and its tributaries, which descend as fine cataracts and falls when their course leads over the acid edge, or meander with a gentle current



Rain erosion and striated surface of greywacké, Copper Cliff.

through the old lake deposits of the interior. The spreading out of the sheet of molten rock and its settling into a synclinal basin have given a regularity to the topographic forms not found in other pre-Cambrian regions, and rivers and lakes and farms and railway routes are all adjusted to the ancient rock structures.

Sudbury itself, the capital town of the region, lies some miles southeast of the edge of the basin and rests upon older rocks with a less orderly arrangement. They include near Wanup and Quartz on the Canadian Pacific and Canadian Northern railways, characteristc rocks of the Grenville Series, whose position with reference to the classification adopted by the International Committee is somewhat uncertain; and also a great series of other sediments older than the Laurentian, which have recently been proved to lie below the Huronian, and which have been named provisionally the Sudbury series.

The most recent classification of the pre-Cambrian in the Sudbury region is as follows:

Post Keweenawan(?)—Dikes of diabase and granite.

Keweenawan (?)—Nickel-bearing eruptive sheet.

Huronian—Upper Huronian (Animikie), conglomerate, tuff, slate and sandstone.

" —(Middle Huronian wanting.)

" —Lower Huronian, basal conglomerate.

Laurentian—Granite and gneiss eruptive through older rocks.

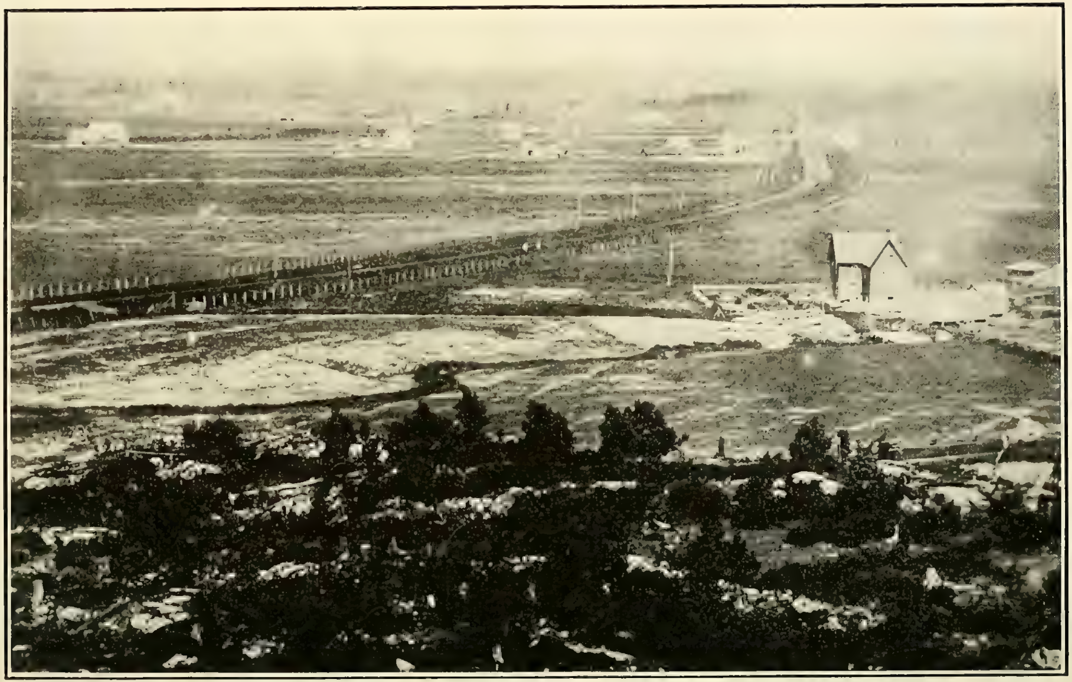
Sudbury Series—Copper Cliff arkose, McKim graywacké, and Ramsay Lake quartzite.

Keewatin—Iron Formation, greenstones and green schists.

Grenville Series—Quartzite, sillimanite schists and gneisses and crystalline limestone.

Whether the Keewatin and the Grenville series are of the same age or not is uncertain, since the two groups of rocks do not occur together.

As no fossil-bearing rocks have been found the position in time of the later eruptives is somewhat doubtful, as indicated in the table.



Interior plain of nickel basin from acid edge near Azilda.

THE GEOLOGY OF SUDBURY.

The town of Sudbury rests mainly on stratified clay underlain by quicksand formed in glacial Lake Algonquin, but hills of rock project above these lake beds, showing surfaces that have been smoothed and striated by Pleistocene glaciers. The chief rock within the town is McKim graywacké, which is well stratified with thin slaty layers the bedding showing distinctly on weathered surfaces. The beds are usually steeply tilted and are even vertical against a laccolithic mass of gabbro toward the east side of the town. The strike and dip vary considerably and in many places the greywacké is brecciated and recemented, the crushing having taken place, it is supposed, during the advent of the nickel eruptive. The graywacké is often crowded with small pseudomorphs after staurolite, suggesting contact metamorphism, which may be accounted for by the effects of the laccolithic gabbro and other eruptives in the region.

Toward the southeast on the shores and islands of Ramsay lake, the graywacké is followed by pale gray quartzite, well stratified in thick layers which are often cross bedded. They have usually a dip of about 45 deg. with a strike of northeast and southwest. The Ramsay lake quartzites form an extensive group of rocks, having a width of six miles, where widest, and an estimated thickness of 15,000 feet. They appear to overlie the graywacké, though well exposed contacts have not been found.

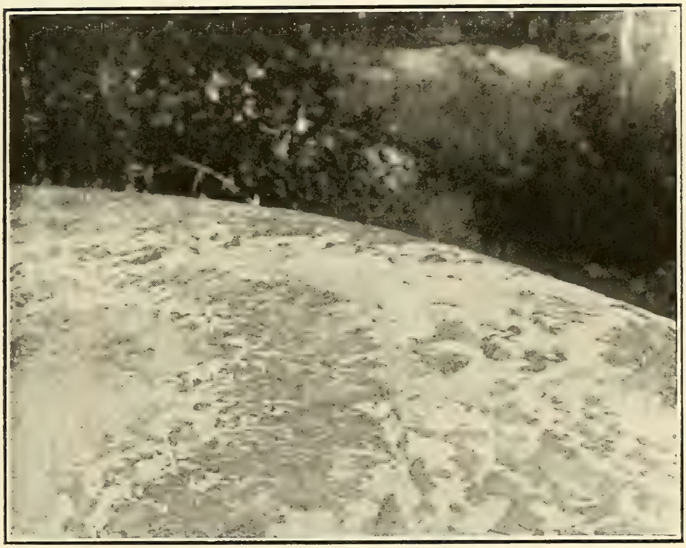
Areas of greenstone or greatly weathered gabbro penetrate the quartzite in various places, and granite or granitoid gneiss of a Laurentian type cuts them toward the south and southeast.

The quartzite, graywacké and a recrystallized arkose, rising as ridges somewhat to the west of the town, make up the Sudbury series, which is not less than 20,000 feet thick.

The most interesting of the eruptives penetrating the rocks just described forms a laccolithic range of hills in the eastern part of Sudbury, where gabbro has tipped up beds of graywacké and sometimes even overturned them slightly. The gabbro is gray-green and much weathered, consisting now mainly of hornblende and poorly preserved plagioclase; but at various points on the hills there are large patches of white rock, either "roof pendants" of quartzite partly digested, or segregations of a pegmatitic kind. These patches

Quartzite, showing cross-bedding, Ramsay Lake.

begin with a green band of hornblende on the outside, followed by an intergrowth of long blades of hornblende with white plagioclase. The latter on the inner side becomes coarse "graphic granite" with interleaved quartz, and the centre of the mass may consist of almost pure quartz. The largest example of the kind, a mile south of Copper Cliff, was worked as a quartz mine, and furnished thousands of tons of fairly pure quartz used as flux at the smelter. It seems most probable that the coarse textured rock surround-



Structure in Gabbro, Sudbury.

ing the quartz is a sort of "reaction rim" about a partially digested block of quartzite. A little pyrrhotite containing some nickel occurs with these masses of quartz suggesting a relationship to the nickel-bearing eruptive a few miles to the northwest.

The sedimentary rocks of the Sudbury series mentioned above were tilted and folded and penetrated by eruptives, and then carved down to an uneven plain before the Huronian began. On the upturned edges of the quartzite a coarse boulder conglomerate rests nearly horizontally. This has the characters of tillite, a matrix of graywacké enclosing angular, sub-angular and rounded stones of all sizes up to boulders several feet in diameter. Among these stones are many of quartzite and granite, the nearest outcrop of the latter rock occurring five miles to the southeast. No striated stones have yet been found in the tillite, perhaps because it is almost impossible to separate the stones from the matrix. Dr. Collins has traced this conglomerate northeast with

Structure in Gabbro, Sudbury.

scarcely a break to the basal conglomerate at Cobalt; and the present writer has followed it, with some intervals, to the lower Huronian conglomerate of the typical Huronian region toward the west.

The conglomerate, like the lower rocks, is often crushed into a breccia composed of large blocks cemented by more finely ground materials. This took place during the disturbances caused by the advent of the nickel eruptive. The tillite or conglomerate is the only lower Huronian rock found, and the middle Huronian is entirely absent.

INTERIOR OF THE NICKEL BASIN.

The next rock in position is the great laccolithic sheet of the nickel-bearing eruptive, which is bent into a boat-shaped syncline, 17 miles wide and 36 miles long, from southwest to northeast, with the square end of the boat at the latter end. As the sheet is really much later in age than the overlying beds, the sedimentary rocks enclosed in it will be described first. They were considered Cambrian by Dr. Robert Bell, but no fossils have been found in them, and

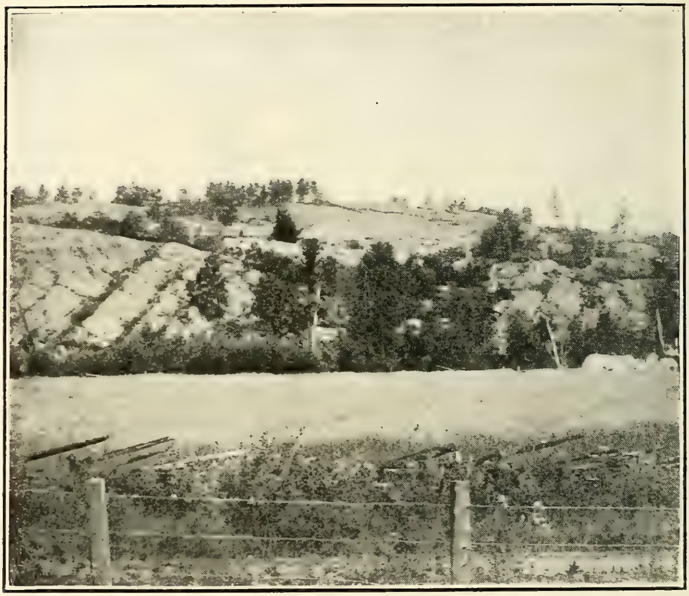
Onaping Falls over vitrophyre tuff.

petrographically they somewhat resemble the western Animikie (Upper Huronian), so that it seems better to class them with the Upper Huronian, though their age cannot be certainly fixed at present.

There are four subdivisions exposed in very regular succession in the interior of the basin, the Trout Lake conglomerate on the outside resting directly on the upper part of the eruptive sheet, followed by the Onaping tuff, which forms an inner and wider belt; and then by the Onwatin slate; while the Chelmsford sandstone runs down the centre of the basin.

The conglomerate is coarse textured and has generally been greatly metamorphosed by the underlying eruptive sheet so that its matrix is often changed to micropegmatite, and but for the vaguely edged boulders it would not be recognized as sedimentary. Often, too, there have been shearing motions giving a schistose structure to the conglomerate, which has even been mapped as Laurentian.

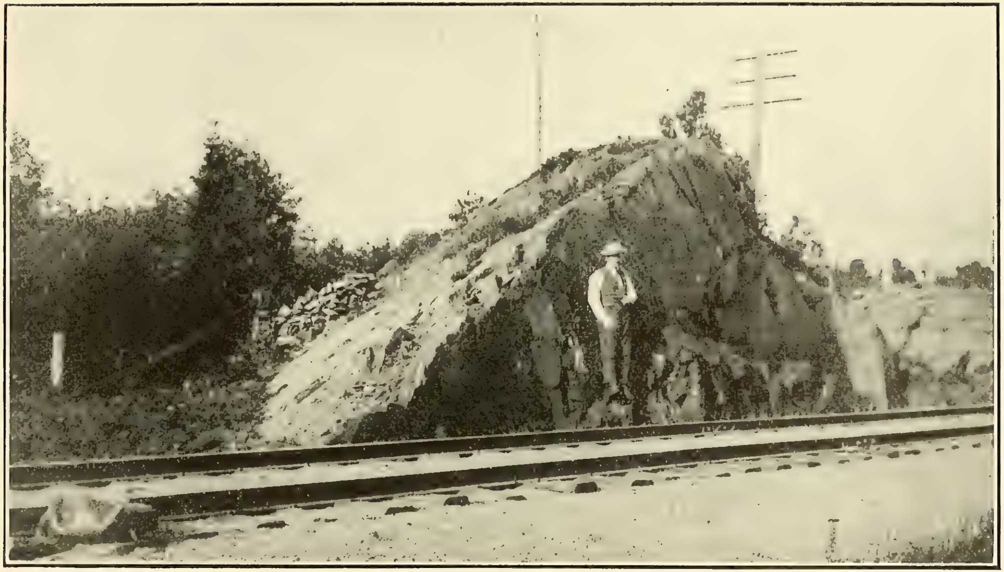
The conglomerate passes gradually into the Onaping tuff, which is well displayed at the beautiful falls of Onaping river, where there is a descent of one hundred feet over



Anticline of Chelmsford sandstone, near Chelmsford.

these rocks. The tuff is formed of sharp-angled glass fragments cemented by volcanic dust, and now transformed into chalcedony, serpentine, etc. It may be called a vitrophyre tuff, as suggested by Dr. Bonney, who first described it.

There is no distinct boundary between the tuff and the Onwatin slate, which is black and highly carbonaceous, sometimes containing ten per cent. of carbon. In it are found the curious veins of Anthraxolite (anthracitic carbon) which have aroused vain hopes of the discovery of coal. The anthraxolite, which when pure, contains 95 per cent.



Ruined anticline, Larchwood.

of carbon, as shown by Prof. Ellis, must have been fluid in the beginning, probably bitumen driven from the carbonaceous shale by the heat of the eruptive beneath. As the black slate is the softest rock in the region, it has suffered from erosion more than the rest, and is mostly covered by old lake deposits.

The Chelmsford sandstone is dark gray and might almost be called graywacké. It encloses numerous large oval concretions of impure limestone. When the Animikie beds were bent into the synclinal form the uppermost layers, especially the sandstones, were thrown into compression and rose as dome-shaped anticlinal ridges a few hundred feet high. There must have been a dozen or more of these elongated domes in the beginning, all stretching parallel to one another and to the longest axis of the basin. Now the domes are all more or less ruined, and some scarcely show above the drift deposits. One of the largest, at Chelmsford, is two miles long by a third of a mile wide, and rises about 150 feet above the plain. Several thick layers of sandstone have been removed from the top, and buttresslike remnants of beds rise from the fields on each side, so that its height must have been much greater in the beginning. A good example of a smaller anticline is crossed by the railway at Larchwood, six miles west, where the dip of the beds on each side is about 45 deg.

This sedimentary series, resting upon the nickel eruptive, has an average dip inwards of 30 deg., and has been measured up with the following results:

Upper Huronian (Animikie)	Chelmsford Sandstone ..	800 to 1,500
	Onwatin Slate	3,800
	Onaping Tuff	3,700
	Trout Lake conglomerate	20 to 400
		9,400

The black slate resembles the Animikie slate at Thunder Bay, but the remarkable tuff of glass fragments has no equivalent in the western Animikie. It appears that these relatively soft sedimentary rocks, if they ever existed in other parts of the eastern pre-Cambrian, have been completely destroyed. Their preservation here is due to the protection of the upturned edges of the nickel eruptive basin, aided by the strengthening of the Trout lake conglomerate and of the lower part of the Onaping tuff by metamorphic action due to the eruptive sheet.

Crush conglomerate in granitoid gneiss, Creighton.

THE NICKEL ERUPTIVE.

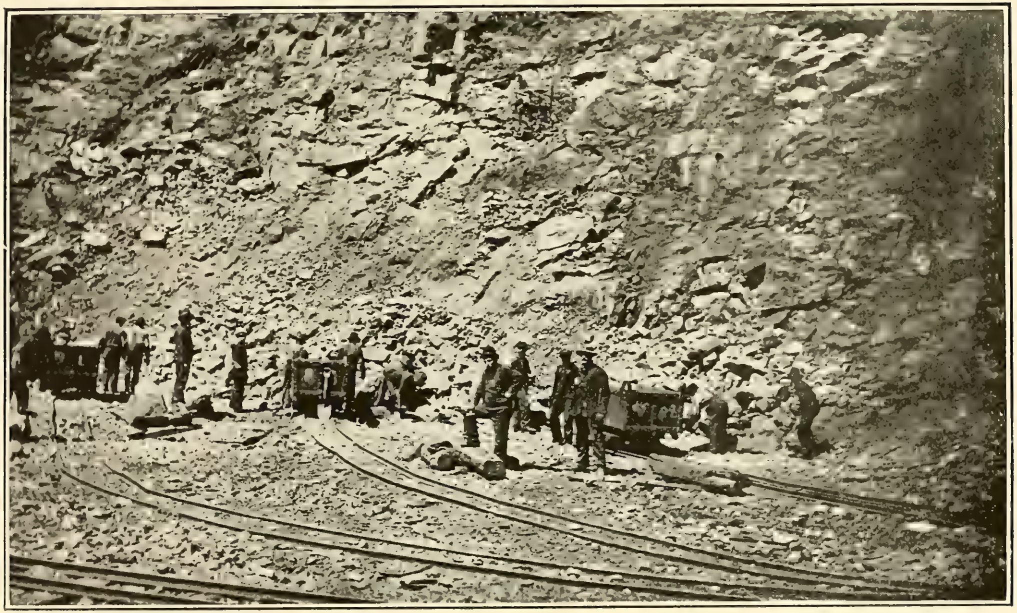
The most interesting and important feature of the region is the laccolithic sheet forming the synclinal basin and providing the great deposits of nickel and copper ore which have made the district famous. The sheet is 36 miles long and 17 miles broad with a thickness varying from half a mile to two miles and averaging a mile and a quarter. It is estimated to contain 500 cubic miles of rock, and it was once far larger, since it has lost much of its original dimensions by erosion.

The sheet consists of norite on its lower side, passing gradually into micropegmatite on the upper side. Blebs of ore are often scattered thickly through the lower part of the norite, and where there is a depression in the floor beneath this, pyrrhotite-norite merges without any break into ore bodies sometimes containing millions of tons of pyrrhotite and other sulphides. Unquestionably all three substances, ore, norite and micropegmatite, belonged originally to the great flood of molten rock which rose from some hearth beneath and spread out over the old eroded surface of ancient rocks, including the Sudbury series and the Laurentian gneisses; and under the flat-lying Animikie sediments just described. As the magma welled up from beneath, the floor of older rocks collapsed into large or small blocks which settled down allowing the sheet itself with the overlying sediments to assume the synclinal form.

Thus more than a mile's thickness of molten rock was blanketed by 9,400 feet of sediments, so that the cooling must have gone on extremely slowly, giving time for the heavier materials to settle to the bottom, and also for the upper, more acid part of the magma to metamorphose profoundly the conglomerate immediately over it and to silicify and harden the lower part of the Onaping tuff, as just mentioned.

The coming up and spreading out of the norite-micropegmatite sheet profoundly shattered all the adjoining rocks, and almost everywhere beneath the sheet there is a sort of breccia or conglomerate of fragments of the underlying rock sometimes cemented by norite or ore.

The freshest norite, which often occurs close to large ore bodies and may enclose portions of the ore, consists mainly of labradorite and hypersthene, with some ordinary



Face of ore, open pit, Creighton, early stage.

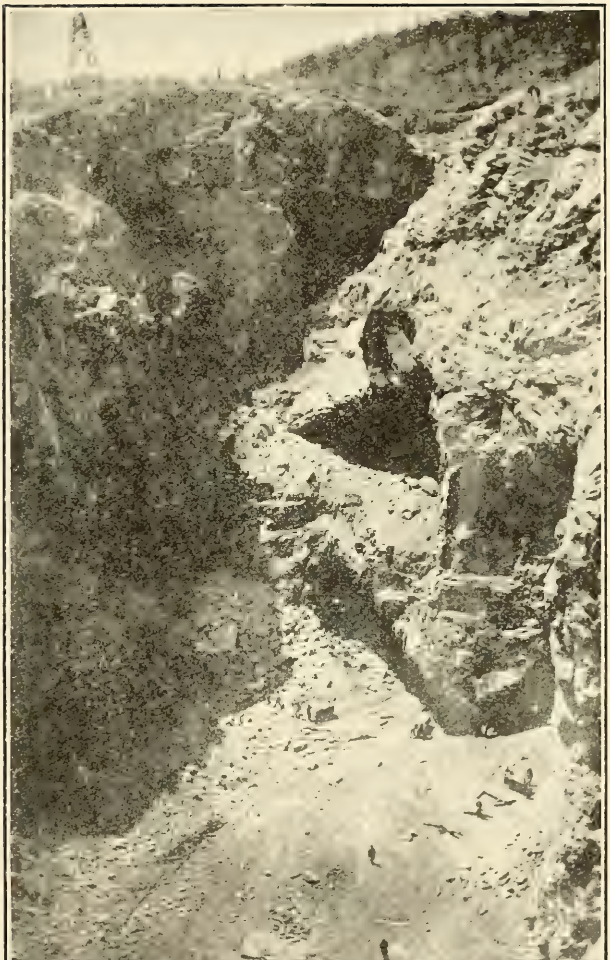
pyroxene and a few large bits of biotite. One finds also a little interstitial quartz and a few distinct blebs of bluish quartz. The most basic phase of the rock analysed contains about 50 per cent. of silica, and the most acid example of micropegmatite about 69 per cent., showing a considerable range from the bottom of the sheet to the top.

All the rocks of the district are cut by dikes of very fresh olivine diabase, some of which are 200 or 300 feet wide, and may be traced, as shown by Dr. Barlow, for seven miles, passing through norite, ore and country rocks impartially. This diabase and some dikes and irregular masses of granite are the youngest rocks of the region and may date from early Paleozoic times.

THE NICKEL DEPOSITS.

The nickel ores which give economic importance to the region are of a very uniform and monotonous character. In all the larger mines the ore consists of pyrrhotite in largest amount with subordinate quantities of pentlandite, (NiFe) S, and chalcopyrite. The pentlandite may be finely disseminated through the pyrrhotite and not apparent to the eye, but polished surfaces of the ore, as shown by Campbell and Knight, prove its presence under the microscope. The ore always contains small quantities of the norite minerals and sometimes fragments of norite or country rock. The country rock may be any of the older formations, sediments of the Sudbury series, acid or basic eruptives, or Laurentian gneiss, without in anyway affecting the ore deposit; but no ore deposit has yet been found without norite. "No norite, no ore," is the law of the district. There are, however, long stretches of the norite edge where no ore occurs, where the sheet is unusually narrow, or where the country rock bends inwards instead of outwards. There are cases where the norite edge is gossan covered continuously for more than a mile, as in the vicinity of the Murray mine.

The ore bodies may be divided into two principal kinds, marginal deposits, at low points or bays on the edge of the norite; and offset deposits, where channels lead out from such bays conveying the ore mixed with norite to various distances from the edge, sometimes even three or four miles



Creighton mine, recent condition of open pit.

The best example of a marginal deposit is at Creighton, where one of the largest bays of the norite edge has furnished the greatest nickel mine worked in the district or in the world up to the present. The Creighton mine began as an open pit, which is now nearly 300 feet deep, with lower levels worked by underground mining. The country rock is granitoid gneiss and the ore body which rests upon it dips 34 degrees inwards towards the central line of the nickel basin. The ore is unusually rich, containing about 6 per cent. of nickel and copper, the latter making up a quarter of the whole, and specimens showing pentlandite are often found. It may be distinguished from the enclosing pyrrhotite by its octahedral cleavage and brassy color as compared with the bronze of the more common mineral. The greenish yellow of the chalcopyrite is more easily recognised.

It is interesting to find that the dikes of fresh diabase cutting the rock and ore in various directions are glassy against the ore, which was a good conductor of heat, and only fine grained against norite or gneiss where the chilling was not so rapid.

The best examples of offset deposits are at Copper Cliff, where a large bay of norite narrows toward the southeast into a dike-like band of norite and ore which ends in the great columnar ore deposit of No. 2 mine. The open pit gives a good opportunity to see the shape of a characteristic offset deposit, which has been followed downwards for more than 600 feet.

A quarter of a mile to the south is the once renowned Copper Cliff mine, a still better example of this type, which reached nearly 1,300 feet in depth on an incline of 77 degrees to the east, and for years supplied the richest ore in the district, averaging nearly 9 per cent. Most offset mines are richer in copper than the marginal mines and the Copper Cliff ore contained more copper than nickel, justifying its name.

Two other deposits have been worked to the southwest and south at intervals of a quarter of a mile and of three quarters of a mile, but they were of minor importance. All of these ore bodies are associated with some norite spotted with blebs of ore, but they show no surface connections with one another or with the main mass of norite and must

Smelter, Copper Cliff.

have been supplied by devious channels between the shifting blocks of country rock. Whether these channels still exist beneath the surface or were above the present level is uncertain. Probably the present surface is thousands of feet below the original one, so that connections from above might have been eroded away.

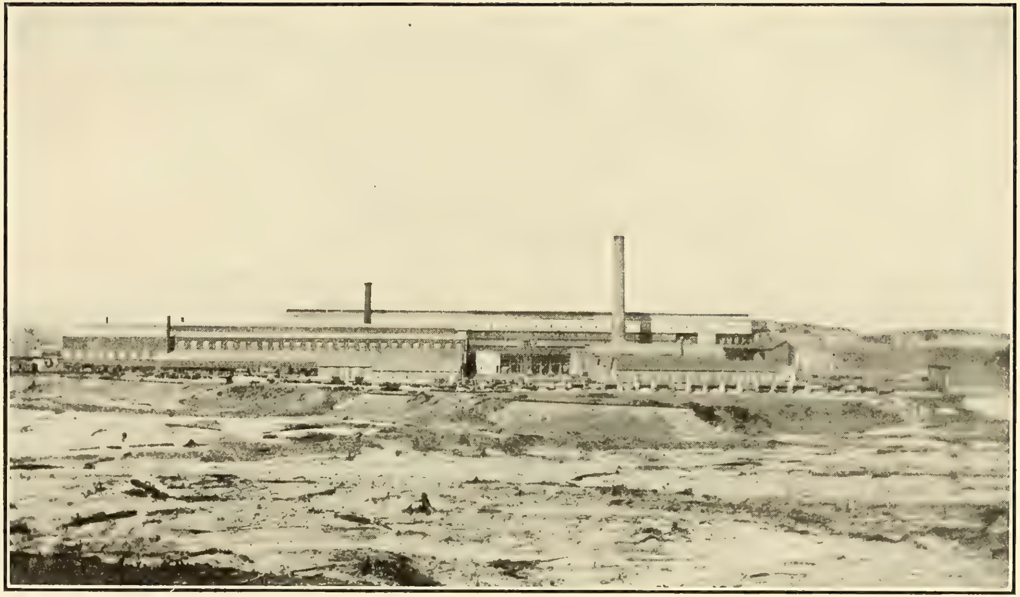
The columnar deposits at Copper Cliff and No. 2 mine are not the most extraordinary of their kind, since two still smaller columns have been followed downwards for 1,600 feet at Victoria mine.

The Copper Cliff offset deposits occur in contact with a variety of country rocks such as granitoid gneiss and greenstone among eruptives, and graywacké and pink quartzite of the Sudbury series among sediments, without any change in the character of the ore; and they are cut by dikes of granite and diabase which have likewise had no appreciable effect in changing the original ores.

In addition to typical offset deposits where the connection with the basic edge of the nickel eruptive is manifest there is one very important band of gossan and ore which runs nearly parallel to the edge of the norite with no suggestion on the surface of any connection. This is the Frood-Stobie offset north of Sudbury, the largest known body of ore in the district. There must have been subterranean channels through which the pyrrhotite-norite and ore reached their present position in this unique case. The Frood-Stobie offset runs as a narrow gossan covered ridge with one or two interruptions for nearly two miles from southwest to northeast, and touches several types of rock, such as graywacké and greenstone, but nowhere comes within three-fourths of a mile of the norite edge.

Diamond drill cores prove that the deposit dips at first with an angle of 60 degrees or 70 degrees toward the norite, while at a greater depth the inclination flattens decidedly suggesting a broad underground connection with the parent eruptive sheet.

The Frood-Stobie offset has been proved to contain more than 35,000,000 tons of average ore and far surpasses in magnitude any other known ore body in the Sudbury region. It has already furnished half a million tons of ore and shafts are now being sunk by both the Canadian Copper Company and the Mond Company, so that it will soon add greatly to the quantity mined in the district.



Smelter, Copper Cliff.

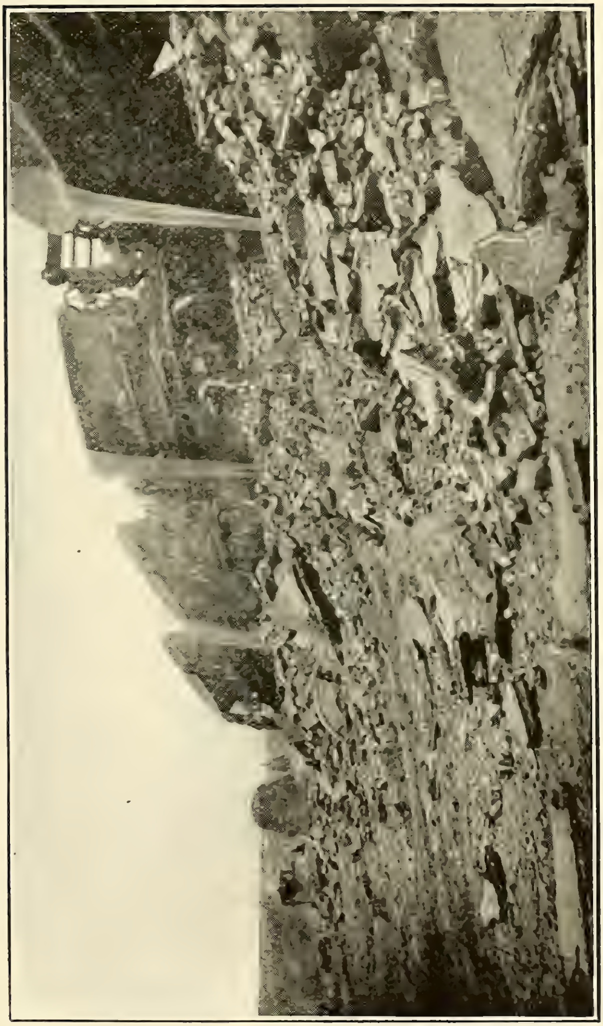
DEVELOPMENT OF THE NICKEL REGION.

The first discoveries leading to mining operations took place in 1884, when the Canadian Pacific railway was pushing westwards. Pyrrhotite and chalcopyrite were found in a cutting at what afterwards became the Murray mine. This property was acquired by the Vivians of Swansea and was worked in a small way for several years, since which it has lain idle. Soon after the rich Copper Cliff mine was opened, first for copper, as the name suggests, later the nickel was discovered. Within four years of the first find of ore all of the more important deposits had been discovered, though some of them were not worked for several years later. The most productive mine worked in the district is the Creighton, which was opened up in 1901 and has since produced more ore than all the other mines combined. Its ore is higher in grade than that of any other large mine except Copper Cliff, and its product has dominated the nickel markets of the world for the last few years.

The Canadian Copper Company, much the most important mining and smelting company in the Sudbury district, has been in operation without interruption since 1886, and has worked half a dozen mines each of which has produced from 100,000 to 2,000,000 tons of ore; while a number of smaller deposits have been drawn upon also.

It has gradually developed at Copper Cliff methods of mining, roasting and smelting the ores which have now reached high efficiency. Its smelter includes water jacket furnaces producing matte with about 35 per cent. of nickel and copper, basic converters bringing this standard matte up to 80 per cent. of the two metals, and reverberatory furnaces for treating materials which cannot be sent directly to the water jacket furnaces. There is probably no better equipped metallurgical plant in north America and few operate on a larger scale. Probably one-half of the nickel used in the world during recent years has come from this smelter.

The other company mining and smelting nickel copper ores in the district, the Mond Nickel Company, began work in 1899 at Victoria Mines 22 miles west of Sudbury on the Sault line of the Canadian Pacific. At present it obtains most of its ore from Garson mine, northeast of Sudbury, and it has recently erected a large and complete smelting plant at Coniston, 10 miles east of Sudbury.



Pouring slag, Copper Cliff.

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The Canadian Nickel Corporation owns some large deposits, such as the Whistle mine at the northeast corner of the nickel basin, and has recently bought the long unworked Murray mine, which has been shown by diamond drilling to contain 10,000,000 tons of ore.

None of the nickel-copper matte is refined in Canada, that produced by the Canadian Copper Company going to New Jersey for final treatment, and that of the Mond Company being shipped to Swansea in Wales.

In 1911, 612,511 tons of ore were raised, more than half of which came from the Creighton mine; and 17,049 tons of nickel and 8,966 tons of copper were contained in the matte produced. About 5,500,000 tons of ore have thus far been mined and diamond drilling shows that ten times as much remains in the different deposits. In 1912, the production was 22,421 tons of nickel and 11,116 tons of copper.

LITERATURE ON THE SUDBURY REGION.

A very extensive literature has grown up in regard to the Sudbury Nickel region, mostly devoted to the character of the ore deposits and their relationships to the norite and the country rocks. The first suggestion of the true relationships was by Dr. T. L. Walker in an Inaugural Thesis published in the Quarterly Journal of the Geological Society in 1897. The Geological Survey of Canada has naturally paid much attention to it, the most important publication being that of Dr. Barlow in Part H, Vol. XIV of the Annual Reports. Dr. Barlow takes up the petrographical features of the region in great detail. His work was published in 1904; and in the following year the Bureau of Mines of the Province of Ontario published the Sudbury Nickel Field as part III of their XIV Report. In this report, which was prepared by the present writer, the nickel eruptive was shown to be basin shaped and to form a continuous belt of norite-micropegmatite with which all the ore deposits are connected. In 1913 a later report by the present writer is to be published by the Mines Branch at Ottawa, and the most recent map of the region was prepared for the report just mentioned. The reader is referred to these three reports for detailed accounts of the region and for complete references to the literature.

THE MOOSE MOUNTAIN IRON RANGE.

At Moose Mountain about 7 miles beyond the northern side of the nickel basin and 33 miles from Sudbury by the Canadian Northern Railway, one of the largest iron ore deposits in Canada has been found. The iron formation here is separated from the northern nickel range by a band of

Banded iron formation, Sellwood.

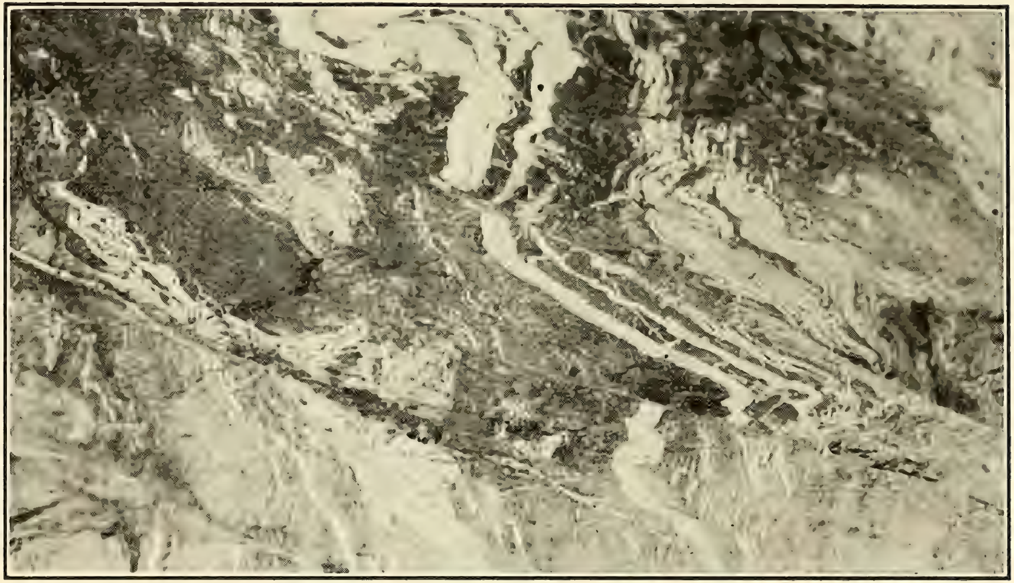
Laurentian consisting of granite, banded gneiss, greenstone and green schist, all more or less cut by pegmatite dikes. These rocks are far older than the nickel eruptive and underlie the deposits of the northern nickel range as country rock. The Sudbury series is lacking on this side of the nickel basin, so far as known, and nothing suggesting the Grenville series has been found, so that the geology to the north differs greatly from that to the south.

Moose Mountain, rising 280 feet above the plain and the railway, though one of the most important examples of the iron formation in the Keewatin of Ontario, presents less than the usual variety in the accompanying rocks, and the structural relations are more obscure than in some other regions, such as the Helen Iron Range.

In most cases the iron formation of Ontario consists of some form of silica interbanded with iron ore, either jasper with hematite or cherty or quartzitic silica with magnetite At Moose Mountain the latter material is found. Commonly the iron formation occurs as synclinal belts enclosed in green Keewatin schist; but a definite relation of this sort has not yet been proved at Moose Mountain, perhaps because the regularity has been disturbed by intrusions of greenstone and granite. The accompanying rock is a banded schist alternately light and dark gray. The iron formation here has the usual steeply tilted attitude. Often the banding is fairly straight and uniform for considerable distances, but in many cases there has been crumpling and sometimes crushing and faulting on a small scale. The ordinary banded ore contains 36 per cent. of iron, and from the results of stripping and diamond drilling, the manager of the mine, Mr. F. A. Jordan, estimates that there are 100,000,000 tons of ore of this grade. There are also 6,000,000 tons of higher grade magnetite in which there is much less silica and where the banding is less marked. Here some green hornblende is interbedded with the magnetite.

Laurentian-looking gneiss occurs just south of the iron formation but its relations to the ore bodies are not very certain; though dikes of granite and less often pegmatite cutting some of the outcrops of ore have probably come from it.

The richer parts of the ore have been greatly fissured and are penetrated in all directions by yellowish green bands or veins of epidote, evidently the last mineral formed. Beside these bands the magnetite is sometimes changed to hornblende which gradually passes into the usual ore within a few inches. The main ore body worked has been provisionally classified by Prof. Leith as belonging to the Pegmatitic type (Jour. Can. Min. Inst., Vol. XI, 1908, p. 93). He defines the type as including "ores which are



Contorted structures in iron range, Sellwood.

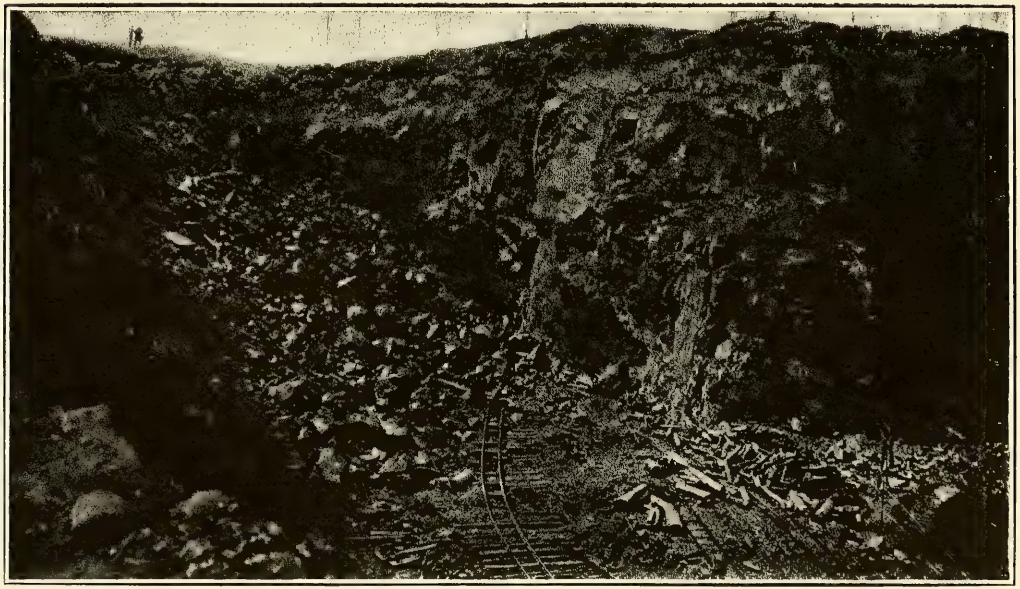
carried to or near the surface in magmas and are extended from them in the manner of pegmatite dikes, after the remainder of the magma has been partially cooled and crystallised. They are deposited from essentially aqueous solutions mixed in varying proportions with solutions of quartz and the silicates." He has evidently in mind the usual theory of the formation of the Kiruna and other magnetite deposits in northern Sweden. In his special reference to the Moose Mountain deposit he mentions that the ore shows " such intimate relations with greenstones as to suggest a direct derivation from them."

It should be stated, however, that some of this richer ore is interbanded with belts of the poorer silicious type making up the majority of the whole series of deposits, and it is possible that the downward percolation of hot waters may have produced the enrichment. The latest effect of circulating fluids, the formation of epidote, is generally accompanied by an enrichment of the ore near the small veins of that mineral.

Moose Mountain has been the first iron mine in Canada to concentrate its ores magnetically on a commercial scale. The higher grade ore is crushed to about inch size and separated from the intermixed epidote and hornblende by magnetic means, raising its iron contents to a merchantable grade containing 55.50 per cent. of metallic iron. The plant in use, though small and experimental, has provided 155,000 tons of ore for shipment.

This method is not effective for the 36 per cent. ore in which the magnetite is intimately mixed with silica, and within the past two years a new concentrating mill, much larger and more elaborate, has been erected. Here the ore is crushed to 100 mesh and separated magnetically by the Gröndal method. The finely divided magnetite is then compressed to drive off most of the water, briquetted and finally treated in a furnace which sinters it slightly and transforms most of the magnetite into hematite.

Though not so large as the great magnetite deposits at Kiruna and elsewhere in northern Sweden, Moose Mountain promises to become a great producer of ore. The Keewatin iron deposits of Ontario, with the exception of the Helen and Magpie Iron Mines near lake Superior, are usually similar to the one just described at Moose Mountain.



Moose Mountain Iron Mine.

There is a good deal of dispute as to their origin, though the original materials of the iron ranges are admitted by all to have been sediments of some kind.

The map of the Moose Mountain iron deposits has been prepared by Mr. E. Lindeman of the Mines Branch at Ottawa, who recently carried out a detailed magnetometric survey of the property.

ANNOTATED GUIDE.

Toronto to Sudbury via Canadian Pacific Railway.

Miles and Kilometres.

0. Altitude 254 feet. (77.4 m.) Leaving Toronto (Union Station), by way of Parkdale and West Toronto, the train passes through a manufacturing district as far as Weston. The country is heavily covered with Pleistocene deposits, consisting of boulder clays, and stratified clays, sands and gravels, which conceal the underlying Paleozoic rocks. At Weston the clay is used for the manufacture of red brick.

The surface presents on the whole a rolling appearance, and is very suitable for farming purposes. Sometimes the surface is intersected by ravines, and sugar-loaf hills have been carved from the drift, as around Woodbridge and Humber.

About 70 miles (110 km.) north of Toronto old lake deposits become abundant. Half a mile south of Carley, stratified sand showing cross-bedding is splendidly shown in a ballast pit east of the track.

96. m.
154.5 km. One mile north of Coldwater Junction the first outcroppings of rock occur. These are of banded gneiss of Laurentian age projecting as rounded knobs through the drift.

99. m.
159.3 km. North of Lovering rock exposures become more frequent, and soon a typical Laurentian area is entered.

108.5 m. 174.1 km. North of the crossing of the Severn river farming land almost disappears occurring only in small scattered areas.

This Laurentian area stretches northward continuously along this route for 150 miles (240 km.). The Laurentian consists chiefly of dark grey micaceous and reddish granitic gneisses with dikes of red granite or pegmatite.

120. m. 193. km. Bala is the western gateway to the Muskoka lakes district, famous as a resort for tourists.

132. m. 212.4 km. Altitude 742 ft. (226. m.) Muskoka, a divisional point, is on Lake Joseph, one of the largest of the Muskoka lakes.

155. m. 249.4 km. At Parry Sound there is a splendid view of Georgian Bay from the train as it crosses the 1,700-foot (518 m.) steel viaduct which is 120 feet (36.6 m.) above the Seguin river. (518 m.)

181. m. 291.2 km. Another view of Georgian Bay is obtained from Point au Baril.

195. m. 313.7 km. Altitude 575 (175.3 m.). Byng Inlet is located on an arm of Georgian Bay. At this point there are extensive lumbering operations.

This region of Laurentian rocks is a striking peneplain with little soil and numerous clear-water lakes and swift running streams. The marks of glaciation are everywhere seen.

255. m. 410.3 km. Fragmental, pre-Cambrian, rocks are first observed two miles south of Romford Junction. They consist of layered quartzite. At Romford the quartzite strikes east and west and dips 45 degrees S.

On the north shore of Ramsay lake, three and a half miles west of Romford, a comglomerate, which rests unconformably on the quartzite, is exposed in the railway cuttings. It out-
262. m. crops along the lake and railway to the town of
421.5 km. Sudbury.

ITINERARY AT SUDBURY.

First Day.

8 a.m.—Sudbury to Ramsay Lake.

Sudbury, alt. 855 ft., (260.6 m.), chief town of the nickel region with a population of about 5,000, is situated on a flat plain of silt deposited in a bay of lake Algonquin. Above it rise hills of the Sudbury series of rocks.

A walk of two hours' duration will be taken through the town to Ramsay lake, crossing well stratified and steeply tilted greywacké (McKim greywacké), partly brecciated during the advent of the nickel eruptive. On the shore of the lake and on islands pale grey quartzite dips at an angle of 45 degrees southwest. It extends in that direction six miles (9.6 km.) and is estimated to have a thickness of 15,000 feet (4,500 m.). North of Ramsay lake the Basal Huronian tillite is seen resting unconformably on the quartzite. It contains pebbles and boulders of quartzite, greywacké and granite.

Northwest of the conglomerate a hill of laccolithic gabbro will be visited, halting first at a dike of fresh olivine diabase. Climbing the hill there are good views of the town and of Ramsay lake. On top of the hill one may study certain curious "roof pendants" (or acid segregations) having quartz in the centre, followed by pegmatite and by coarse-grained hornblende-albite rock, with a rim of hornblende in large bladed crystals.

From the laccolithic hill the party will return through the town to the special train. The total distance walked is two miles (3.2 km.).

10. a.m.—Sudbury to Levak.

Leave Sudbury by special train on the main line of the C.P.R. going northwest for 1½ miles (2.4 km.) through McKim greywacké, followed by pink arkose, (Copper Cliff arkose), following for some distance a great dike of diabase which may be seen in cuttings. After a steady ascent of four miles (6.4 km.), the latter part through greenstone and granite, the summit is reached at Murray mine, alt. 992 feet, (302.3 m.), where the railway crosses the gossan-covered edge of the nickel-bearing norite. Murray mine is one of the oldest of the nickel mines in the district but has not been regularly worked for many years.

The railway runs for two miles (3.2 km.) through a nearly flat plain formed of the dark grey, easily weathered norite, cut in one or two places by later granite. The norite then merges into reddish grey micropegmatite rising as rugged hills.

At Azilda, alt. 891 (271.8 m.), 7 miles (11.3 km.) from Sudbury, the railway enters the interior plain of the nickel basin, having come in by the easiest pass through the acid edge of the nickel eruptive. This plain of farmlands is formed of silt deposited in a bay of lake Algonquin, and Whitewater lake, a mile to the south, lies at the boundary of the interior sedimentary rocks against the eruptives. All round the basin, which is 35 miles (56.3 km.) long and 10 (16.1 km.) wide, may be seen hills of micropegmatite and of conglomerate which it has metamorphosed.

At Chelmsford, alt. 888 feet (270.6 m.), 12 miles (19.3 km.) northwest of Sudbury, in the middle of the basin, low anticlinal domes of sandstone begin, one of the largest lying southeast of the village.

At Larchwood, alt. 885 feet (269.7 m.), 18 miles (29 km.) from Sudbury the railway cuts through one end of a ruined dome just east of the Vermilion river, which crosses the upturned edges of sandstone as pretty rapids.

At Phelans, alt. 937 (285.6 m.), 21 miles (33.8 km.) from Sudbury, the railway ascends a gravel terrace, a delta deposit of the river where it entered lake Algonquin. and not far beyond is the beautiful falls of Onaping river, more than 100 feet (30.4 m.) in total height, over Onaping tuff, the third member of the Animikie as found in the nickel basin.

At Levak siding, alt. 1,020 feet (310.9 m.), 24 miles (38.6 km.) from Sudbury, the railway is in the midst of high and rugged hills of micropegmatite.

Three miles beyond, near Windy lake, alt. 1,221 feet, (373.7 m.), the basic edge of the nickel eruptive is found. A few hundred yards of drift, including an esker ridge, separate the last outcrop of norite from the Laurentian, which rises as the usual hummocky hills of gneiss.

After traversing the whole width of the nickel basin by train it is intended to halt for a study of various points of interest on the way back. A walk lasting two hours and covering about 3 miles will be made along the railway eastwards from Windy lake, giving an opportunity to examine Laurentian granitoid gneiss near Windy lake and outcrops of fresh norite to the east. Unfortunately the contact of the norite with the gneiss is hidden by fluvio-glacial deposits.

Continuing eastwards the gray norite passes into a reddish, syenitic-looking intermediate rock, and the valley narrows between precipitous hills at Levak siding, where the train will await the party and lunch will be taken.

After lunch the walk will continue for two miles to Onaping falls and Phelan. The micropegmatite phase (acid edge) of the nickel eruptive occurs as a rather pale gray rock when Onaping river is reached. Next is seen the basal conglomerate of the Animikie much metamorphosed by the underlying eruptive sheet; and this passes at the beautiful Onaping falls into vitrophyre tuff crowded with small glass fragments now turned to chalcedony or serpentine. The walk of about 2 miles ends at Phelan where there are good sections of the delta gravels formed by Onaping river in a bay of ancient lake Algonquin. Here the train will be taken to Larchwood.

At Larchwood a short walk will be made to a good example of the anticlinal hills of the interior basin. Vermilion river and the railway make their way across the ruined southeastern end of the anticline.

The train will then be taken to Murray, where a walk of about 2 miles will show the gossan covered basic edge of the norite resting on a complex of ancient lavas showing, in places, amygdaloidal and pillow structures. The lava when fresh has the composition of a norite, but is earlier than the nickel-bearing norite and more basic in character. Following a suggestion of Dr. Miller it is proposed to call this effusive variety of norite Sudburyite. Its relation to norite is similar to that of basalt to gabbro.

A hill of this rock just south of the old Elsie nickel mine affords a good view of the nickel range and the interior basin.

At Murray diamond drills will be seen at work determining the attitude and thickness of the nickel ore body, which is already known to reach a depth of 1,100 feet and to include more than 10,000,000 tons.

Return to Sudbury in the evening.

Second Day.

7 a.m.—Leave Sudbury by Algoma Eastern railway for Creighton, passing for 2 miles (3.2 km.) through greywacké, followed for a mile (1.6 km.) by arkose and then by greenstone. At 3½ miles (5.6 km.) west a branch runs south to Copper Cliff. Beyond this greenstone and granite extend to the norite of the Copper Cliff offset, here about a mile (1.6 km.) wide. For the rest of the journey the railway runs southwest near the contact of the norite with coarse granitoid gneiss.

Creighton, alt. 973 feet (296.5 m.) is 11 miles (17.7 km.) by rail west of Sudbury. The party will walk south through the village to a hilltop of granite and gneiss from which there is a broad outlook over the gossan edge of the nickel range and the mine with its surroundings. The hill displays interesting crush conglomerates as well as small faults caused by the arrival of the nickel eruptive. A walk will then be made past the east end of the mine to a characteristic contact of norite with the older gneiss; after which the gossan hill and the great open pit, 300 feet (91.4 m.) deep, will be visited. Those who wish may descend 60 feet (18.3 m.) to the first level of the mine, following the foot wall of the ore body.

Specimens of pyrrhotite, chalcopyrite and probably pentlandite may be obtained, as well as of pyrrhotite-norite, ordinary norite, and diabase, the latter cutting the ore.

10 a.m.—Return by the A.C.R. to Clarabelle junction, where the Canadian Copper Company's line will be taken south for 2 miles (3.2 km.) to Copper Cliff.

The line passes through the great roastyard where heaps of ore from the Creighton and other mines may be seen at every stage, some in process of building, others steaming with sulphur fumes, and others forming rusty heaps of well roasted ore.

Beyond this is the rockhouse of No. 2 mine, and then the large buildings and stacks of the smelter, followed by the town of Copper Cliff with its polyglot population of 2,500, mainly from Finland and southeastern Europe.

A walk will be taken to Lady Macdonald lake, where the edge of the norite narrows to a funnel leading to the long and important Copper Cliff offset, passing through granitoid gneiss, greenstone and greywacké.

No. 2 mine, with its open pit 300 feet (91.4 m.) deep, in a typical columnar offset deposit.

The Copper Cliff mine itself is not now working but will be visited as the richest and one of the most important of the early mines. The ore body formed an irregular chimney which has been followed for 1,300 feet (400 m.) on an incline of 70 degrees to the east.

After visiting Copper Cliff the party will be taken to the smelter, 2-3 of a mile (1.1 km.) northeast, where officers of the Canadian Copper Company will guide them through the various buildings and explain the processes. The plant is one of the largest and most complete in North America.

The destruction of all vegetation in earlier years by roast beds near the town has allowed rain erosion of a striking kind on the old lake deposits in and near Copper Cliff.

During the afternoon the party will return to Clarabelle junction and travel 4 miles (6.4 km.) northeast on the Canadian Copper Company's private railway to Frood or No. 3 mine, passing most of the way through greenstones.

At Frood the gossan-covered ridge will be ascended to give an idea of the largest known nickel deposit in the world, estimated to contain more than 35,000,000 tons of ore, perhaps even 100,000,000 tons. It extends almost unbroken for a mile to the southwest and almost as far to the northeast, where the Stobie mine once produced more than 400,000 tons of ore. After testing it with the diamond drill the Canadian Copper Company has sunk two shafts and begun work on the deposit, and the Mond Nickel Company, which owns the Frood Extension, taking in a part of the centre of the ridge, is sinking a third shaft.

The Frood-Stobie offset, unlike all others, shows no surface connection with the main nickel range, from which it is separated by about a mile (1.6 km.) of granite hills. The deposit may be described as a parallel offset. It doubtless has underground channels connecting it with the norite to the northwest, since drill holes show that the ore body dips that way.

Evening.—Return to Sudbury, where a complimentary banquet will be given by the Board of Trade for excursion A 3.

Third Day.

Leave Sudbury early in the morning by a branch of the Canadian Northern railway running 5 miles (8 km.) north and east to Sudbury junction, crossing a plain of old lake deposits (Algonquin) and rounding the hill of laccolithic gabbro in the eastern part of Sudbury. Near Sudbury junction quartzite may be seen to the south and east.

At Sudbury junction the Sudbury branch joins the main line 261.7 miles (421.1 km.) north of Toronto.

From the junction the line runs northwest through quartzite for two miles, followed by greywacké and greenstone, until the basic edge of the nickel eruptive is reached. Here the line turns north, passing Garson lake, which is in the micropegmatite phase of the eruptive. The whole width of the eruptive at this point is 2½ miles (4 m.), and the norite and micropegmatite are like those seen at Levak.

Passing the hilly acid edge of the eruptive and the Trout lake conglomerate, the flat interior plain of sand and silt deposited in a bay of lake Algonquin is entered. To the south, east and north can be seen the rugged inner rim of the nickel eruptive.

At Hanmer, 271.8 miles (347.4 km.) north of Toronto, a hill of Onaping tuff rises to the east, and a mile or two north black slate is seen near Onwatin lake.

The railway now follows the valley of the Vermilion river. To the west there is a high terrace of fluvio-glacial gravel, and at mile 273 the beach gravels of lake Algonquin are used for railway ballast.

Near mile 278 tuff may be seen passing into conglomerate at the northern side of the basin, and just beyond there are the usual hills of the "acid edge." The basic or norite edge of the nickel eruptive occurs at Nickelton junction, where the Nickel Range railway runs 4 miles (6.4 km.) east to Whistle mine.

To the north of the junction the railway enters the Laurentian, crossing coarse red granite and granitoid gneiss, with bands or larger areas of green schist or greenstone as far as Sellwood junction at mile 284.3.

From Sellwood junction a branch runs 5 miles (8 km.) northwest to Sellwood, where the Moose Mountain iron mines will be visited.

9 a.m.—No. 1 mine, near the brow of the hill, is worked largely as an open pit where magnetite more or less interbanded with hornblende and green epidote occurs, and a fault plane forms a slickensided wall on the west side. Granite occurs as dikes in greenstone and green schist near the ore, but does not actually touch it.

In a large stripping a quarter of a mile west granite dikes are seen penetrating the ore or running parallel to its banding.

A walk of a mile, mostly over drift deposits but passing some banded Keewatin schist, leads to the iron dam, or No. 2 mine, where the ore is very different, consisting of interbanded silica and magnetite without hornblende or epidote. This ore is leaner, containing only 36 per cent. of iron. Where the iron formation crosses the Vermilion river interesting crumplings and foldings of the banded ore may be seen.

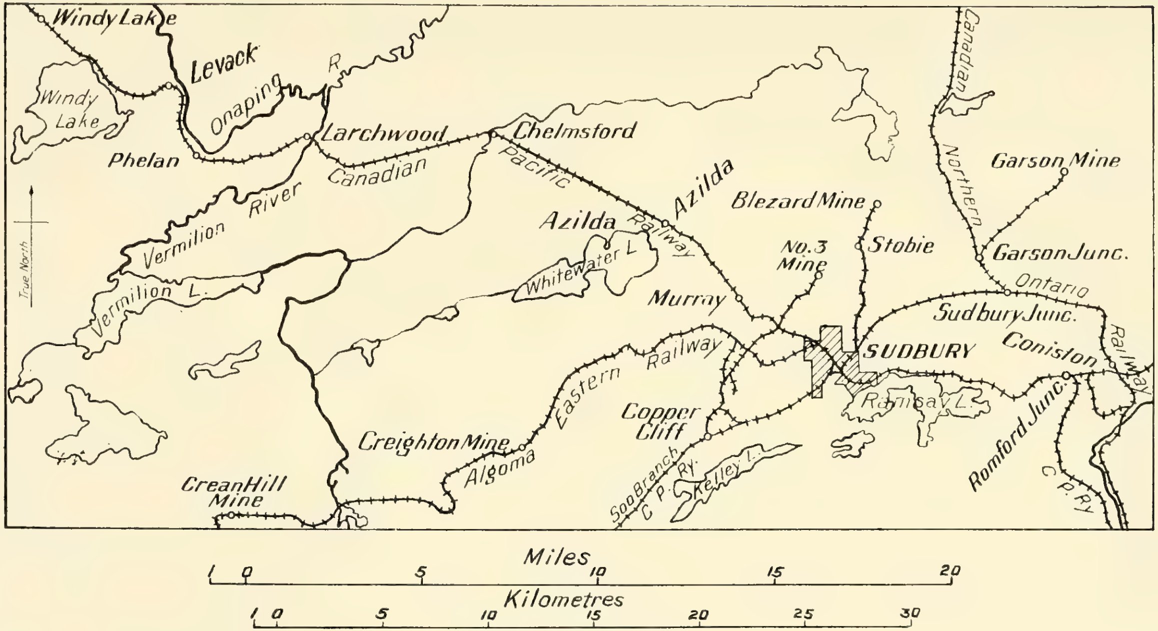
Half a mile farther north, near the new concentrator, a stripping shows banded ore cut by dikes of granite and by thin seams of epidote. A variety of interesting small scale structural features can be seen here, such as anticlines and synclines and faults of different dimensions.

Officers of the Moose Mountain iron mine will take the party through the mill and explain the methods of magnetic separation and briquetting, by which the 36 per cent. ore furnishes a high-grade product. Those who wish may visit a saw mill at work near the village.

Afternoon.—Leave for Sudbury. If time permits a stop may be made at mile 278 to observe a good contact of the micropegmatite with the Trout lake conglomerate.

Towards evening the smelter of the Mond Nickel Company at Coniston will be visited, giving an opportunity to see the latest and one of the most complete smelting plants in Canada.

Arrive at Sudbury in the evening.



Sudbury Nickel Area.

4–7

THE COBALT AREA

BY

WILLET G. MILLER.

CONTENTS.

INTRODUCTION.

In 1903, during the construction of the Temiskaming and Northern Ontario Railway, which is owned and operated by the Ontario Government, rich veins of cobalt-silver ore were discovered near what is now known as Cobalt station. The railway track runs almost over the top of one of the most important veins yet found.

At the time the discovery was made, the veins attracted little attention, the discoverers not being men whose vocation was that of prospecting or mining.

Niccolite is a characteristic mineral of the area, and, as its German name, kupfer-nickel, indicates, its color is somewhat like that of copper. Hence, it is not surprising that some of the first persons to see the deposits mistook the niccolite for copper ore, and, not having their attention drawn to the native silver, which occurred in profusion in parts of the veins, should have decided that the deposits were of the less precious metal. A sample of the niccolite, received at the Bureau of Mines toward the end of October of the year mentioned, aroused the writer's interest and he decided to visit the locality from which it came.

The great Sudbury nickel area lies 90 miles to the south-west of Cobalt, and in a report on a trip of exploration to the vicinity of what is now Cobalt, in 1901, the writer had said:

" It will be seen from what has been stated on preceding pages that the district examined contains as great a variety of rocks as probably any other part of the Province of equal area. . . .

" Although few discoveries of economic minerals have been made in this territory, it may reasonably be expected, judging from the character and the variety of the rocks, that deposits of value will be found when the district is more carefully prospected, as it will be in a short time, owing to the rapid settlement which is now taking place. . . . It would seem that at least some of the conditions of the Sudbury district are repeated in this more eastern field."*

*11th Report, Ontario Bureau of Mines, p. 229.

Cobalt station, June, 1905.

Naturally, on the receipt of the sample of niccolite, it appeared that this prediction might have been verified, and that deposits of nickel vastly richer than those of Sudbury might have been discovered.

On examining the veins then discovered, four in number, all near the shore of Cobalt lake, an unexpected and astonishing assemblage of minerals was seen, the most prominent being native silver, niccolite, smaltite and cobalt bloom. In the first paper he published on the area, describing one of the veins, the writer said:

"Here a perpendicular bare cliff, 60 or 70 feet high, faces west. The vein. . . . cuts this face at right angles, having an almost vertical dip. . . . When I saw it first it had not been disturbed. Thin leaves of silver up to two inches in diameter were lying on the ledges and the decomposed vein matter was cemented together by the metal, like fungus in rotten wood. It was a vein such as one reads of in text-books, but which is rarely seen, being so clearly defined and so rich in contents."*

The veins are narrow, averaging not more than 4 inches (10 cm.) in width. This feature discouraged certain of the first mining engineers who examined the outcrops, and caused them to doubt whether the veins were of economic importance. However, the large number of veins and their great richness has more than compensated for their narrowness.

It was soon proved by comparatively little work that Cobalt was really a "poor man's camp." One of the first operators, for instance, extracted ore having a value of approximately $250,000 at a total cost of $2,500. Statistics show that during the period of mining in the area dividends distributed have been equal to over fifty per cent. of the value of the output.

In the earlier years of mining there were no refining plants, in North America at least, that could economically treat the ores. Owing to the unusual and complex character of the ores there was waste of other constituents in extracting silver, there being present in addition to the precious metal, arsenic, cobalt and nickel in important quantities.

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*Eng. and Min. Jr., Dec. 10th, 1903.

The Cobalt area is not unique in Ontario in possessing an unusual ore, other representative economic minerals of the Province when discovered being without a market or requiring the development of a refining process. The Sudbury deposits, for example, were opened up for copper, nickel being afterwards found to be present. A considerable period elapsed before refineries were developed and a

Part of a map published in 1744, showing that the argentiferous galena deposit on the east side of lake Temiskaming (Ance à la mine), about nine miles from Cobalt, was known at that date.

market made for the nickel by proving to the nations of the world its value as a constituent of steel for armour plate. Again, in the earlier years of apatite mining in Ontario, the amber mica, which is now so highly prized, associated with this mineral, was thrown on the waste heaps. And when the corundum deposits were discovered, a process had to be developed for milling the rock and a market had to be made for the material. Other instances could be cited, but the examples given show that the characteristic of the minerals mined in Ontario's pre-Cambrian rocks is uniqueness.

It is gratifying to know that within the comparatively few years that mining has been prosecuted at Cobalt, plants capable of refining all of the constituents of the ore have been erected in Ontario, the processes employed being either improvements on those in use elsewhere or invented especially for these ores, such as that employed at the Nipissing mine for the extraction and refining of silver. This metal is refined at several other plants, and white arsenic and cobalt and nickel oxides are produced. The plants for refining cobalt oxide in Ontario are of capacity sufficient to supply the world's demand for the material. The white arsenic produced from Cobalt ores represents about 20 per cent of the world's output. Cobalt is the world's greatest producer of silver, its output representing about 13 per cent of the whole.

In 1904, the year in which the first shipments were made, there were produced 158 tons of ore. The average percentages of the four metals in this ore were:

Silver	5.34	per cent., or 1,309.33 ounces per ton.
Cobalt	10.21	" "
Nickel	8.86	" "
Arsenic	45.56	" "

In 1905 there were shipped 2,144 tons of ore of the following composition:

Silver	3.90	per cent., or 1,138.72 ounces per ton.
Cobalt	5.50	" "
Nickel	3.49	" "
Arsenic	25.60	" "

The ore shipped till near the end of 1907 was sorted by hand, or with crude mechanical appliances. Since then extensive concentrating plants have been erected.

Production of Cobalt Mines, 1904-1912

The following table summarizes the production of the Cobalt and adjacent areas.

Year.	Ore shipped	Nickel		Cobalt		Arsenic		Silver		Total value
	Tons	Tons	Value	Tons	Value	Tons	Value	Ounces	Value	
			$		$		$		$	$
1904.............	158	14	3,467	16	19,960	72	903	206,875	111,887	136,217
1905.............	2,144	75	10,000	118	100,000	549	2,693	2,451,356	1,360,503	1,473,196
1906.............	5,335	160	....	321	80,701	1,440	15,858	5,401,766	3,667,551	3,764,113
1907.............	14,788	370	1,174	739	104,426	2,958	40,104	10,023,311	6,155,391	6,301.095
1908.............	25,624	612	....	1,224	111,118	3,672	40,373	19,437,875	9,133,378	9,284,869
1909.............	30,677	766	....	1,533	94,965	4,294	61,039	25,897,825	12,461,576	12,617,580
1910.............	34,282	504	....	1,098	54,699	4,897	70,709	30,615,181	15,478,047	15,603,455
1911.............	26,653	392	....	852	170,890	3,806	74,609	31,507,791	15,953,847	16,199,346
1912.............	21,933*	....	....	515	317,165**	1,964***	79.297	30.243,859	17,408.935	17,805,397
Total	....	....	....	....	....	....	....	155,815,839	81,731,115	83,184,268

*Does not include ore refined at Cobalt. **Cobalt oxide, etc. ***Refined.

For some time after mining began at Cobalt, the ore was shipped to the sampling works of Ledoux and Company, New York. The richest shipment contained 7,402 ounces of silver to the ton, the next in order being 6,909; 6,413; 6,163 and 5,948 ounces to the ton. The average percentages of other metals in the 366 carload lots sampled by this firm were: cobalt, 5.99; nickel, 3.66; arsenic, 27.12.

Concerning the high-grade ore at Cobalt, Mr. R. B. Watson recently has said: "A typical ore carries 10 per cent. silver, 9 per cent. cobalt, 6 per cent. nickel, and 39 per cent. arsenic; the rest is lime, silica and smaller amounts of antimony, iron, sulphur, tellurium, etc."*

The most productive vein in the area is that known as the Carson, on the Crown Reserve property. It has been estimated that this vein, with its extension on the Kerr Lake property, will have produced before being exhausted 20,000,000 ounces or more of silver from that part of it above the 200-foot level.

The richness of the ore in various mines is well shown by what it has cost, on the average, to produce an ounce of silver. In 1911, for example, the cost per ounce, including mining and all other expenses, given in the annual reports of certain companies, was: at the Crown Reserve, 10.761 cents per ounce; at the Coniagas, 8.8; at the Nipissing, 13.95; and at the Kerr Lake, 14.69.

The chief object in building the Temiskaming and Northern Ontario railway was the development of the agricultural areas at the head of Lake Temiskaming, to the north of Cobalt. It was also felt that the railway would increase the value of the timber lands through which it passed, but, it is safe to say, the most sanguine supporters of the policy of railway building little dreamed of the mining development to which the construction of the road would lead. It is true that mining at Sudbury had been pursued for some years before it was decided to build the railway into the Temiskaming country, but Sudbury had never excited much interest among the people of Ontario. Those who were inclined to invest in mines had little faith in the mineral resources of their own Province. The discovery of Cobalt, however, has given confidence in the Pro-

*Eng. and Min. Jr., Dec. 7th, 1912

vince's mineral industry and has led to the development of Porcupine and other areas tributary to the railway. The value of the ore produced at Cobalt, in less than ten years, is equal to about five times the cost of constructing and equipping the 252 miles of railway from North Bay to Cochrane, together with branch lines, and the dividends alone are equal to two and a half times the total cost of the railway.

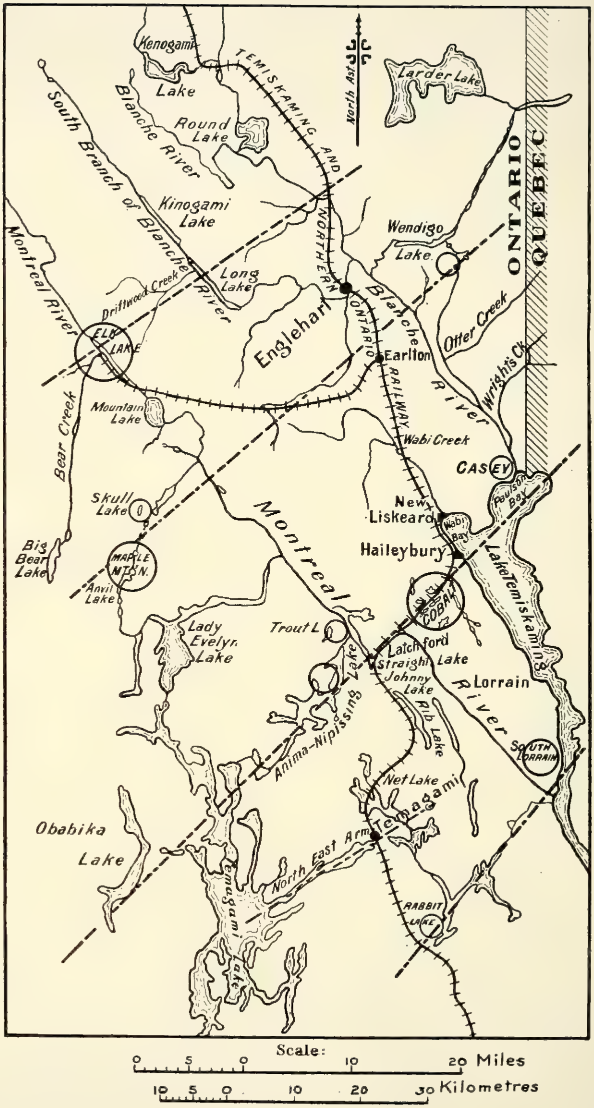
Moreover, the discovery of Cobalt, which lies near the southern edge of the great pre-Cambrian regions that occupy nearly one-half the surface of Canada's 3,750,000 square miles of territory, has given confidence in these regions as storehouses of economic minerals and ores that future prospecting will bring to light.

THE ROCKS AND THEIR RELATIONSHIPS.

At first, owing to the surface being covered with green timber and to the presence of much drift material, contacts and good exposures were difficult to find. Now, that the timber has been removed parts of the area have almost the appearance of a large model, e.g. between the northwestern face of Mount Diabase and Peterson and Cart lakes, or on the Nipissing property to the west of Peterson lake, where the loose deposits have been removed from the surface by hydraulicing.

From the maps of the area that have been published, it will be seen that there is considerable variety in the pre-Cambrian series. On the shores and islands of Lake Temiskaming, a few miles to the north or northeast of Cobalt station, the Clinton and Niagara of the Silurian system also show prominent outcrops. Between the Niagara and the Pleistocene or Glacial there are no formations represented in the district.

The following table shows the subdivisions, based on age relations, that have been made among the rocks of the Cobalt area proper. Representatives of most of these subdivisions of the pre-Cambrian are found in other areas that have been carefully mapped in the surrounding region.



N.W.-S.E. and N.E.-S.W. lines of regional disturbance in the district of Temiskaming and the cobalt-silver areas.

In the Porcupine gold area, one hundred miles to the northwest of Cobalt, the Keewatin and Temiskaming series are prominent. The Cobalt series is also present in this area, and certain dikes are believed to represent the Nipissing diabase of Cobalt.

In the Gowganda silver-cobalt area, which lies fifty or sixty miles to the west of Cobalt, the Nipissing diabase and Cobalt series occupy much of the surface. The Temiskaming series is found in good exposures in part of the area. The latter series has also been found at Swastika and Larder lake, at Abitibi lake, 75 miles north of Cobalt, and eastward across the boundary in Quebec. It is thus known to occur at various points over a large region.

It is possible that unconformities that have not been discovered exist in the pre-Cambrian of the Cobalt and adjacent areas. Moreover, the relationship which the Cobalt and Temiskaming series have to the fragmental rocks of the classic Huronian area of the north shore of Lake Huron is not known. Hence, in the following table the name Huronian is not employed. If the Huronian is considered to include all the post-Laurentian and pre-Keweenawan fragmental rocks of the region, then both the Cobalt and Temiskaming series come under this heading.

The dual subdivision of the pre-Cambrian into Algonkian and Archean, or Proterozoic and Archeozoic, employed by many authors, is not adopted by the writer, since he believes that the Grenville series, which includes limestones and other sediments of great thickness, is of pre-Laurentian age. Thus a dual subdivision of pre-Cambrian rocks, based on arguments that have been employed in its behalf, fails. If a name is desired for the pre-Cambrian rocks, to correspond with Paleozoic and Mesozoic, the well-known name Eozoic may be used.

Age Relations of Rocks of Cobalt and Adjacent Areas.

PALEOZOIC	
SILURIAN **Niagara**	Prominent outcrops of Niagara limestone, with basal conglomerate and sandstone, occur on some of the islands and the shores of the north end of lake Temiskaming.
(*Great unconformity.*)	
EOZOIC OR PRE-CAMBRIAN	
LATER DIKES	Aplite, diabase, basalt.
NIPISSING DIABASE (*Intrusive contact.*)	This diabase, which is of such great interest in connection with the cobalt-silver veins, is believed to be of Keweenawan age. Certain aplite dikes are genetically connected with the diabase.
COBALT SERIES (*Unconformity.*)	The Cobalt series includes conglomerate, greywacké and other fragmental rocks.
LORRAIN GRANITE (*Intrusive contact.*)	This granite occupies a considerable part of the township of Lorrain and has large exposures elsewhere in the vicinity of lake Temiskaming.
LAMPROPHYRE DIKES (*Intrusive contact.*)	Lamprophyre dikes are to be seen near some of the mines at Cobalt.
TEMISKAMING SERIES (*Unconformity.*)	Like the Cobalt series, the Temiskaming consists of conglomerate and other fragmental rocks.
KEEWATIN COMPLEX	The Laurentian, gneiss and granite, which in age lies between the Keewatin and Temiskaming, is absent in the Cobalt area proper, but is found in the surrounding region. Under the heading Keewatin are grouped the most ancient rocks of the region. They consist essentially of basic volcanic types, now represented by schists and greenstones, together with more acidic types, such as quartz-porphyry. With the Keewatin are included certain sediments, such as iron formation or jaspilyte, dark slates and greywackés, which probably represent the Grenville series of southeastern Ontario. Certain dike rocks that are grouped with the Keewatin may be of post-Temiskaming age, but since they have not been found in contact with the Temiskaming series their age relationships are unknown.

NOTES ON THE ROCKS.

KEEWATIN

The Keewatin rocks, of the Cobalt area proper, fall into four groups: (1) Basalts, (2) Diabases and other basic rocks, (3) Acid intrusives, (4) Sediments. Of these the basalts are the most common. The diabases are also of common occurrence, although they are not so

Torsion cracks in Keewatin greenstone, Cobalt.

widely distributed as the basalts. The acid intrusives are of infrequent occurrence in the Cobalt area. They include felsite, feldspar-porphyry and quartz-porphyry. The sediments grouped with the Keewatin include iron formation (jaspilyte, chert and greywacké), graphite schists and slates.

Many of the basic, igneous rocks of the Keewatin have been rendered schistose and their original character cannot now be definitely determined.

The acid intrusives of the Keewatin are on the whole younger than those of more basic composition. Certain diabases are intrusive into the basalts and iron formation.

No granite, or granite gneiss, older than the Lorrain granite, occurs in the immediate vicinity of Cobalt, but certain pebbles and boulders in the conglomerates of the silver area have been derived from the Laurentian.

The name Laurentian is applied to granite or granite gneiss, typically of grey color, the gneiss frequently possessing alternate dark and light colored bands. The well-banded gneiss owes its composition and structure to the inclusion of fragments and masses of Keewatin in the intrusive granite, which have been squeezed or drawn out.

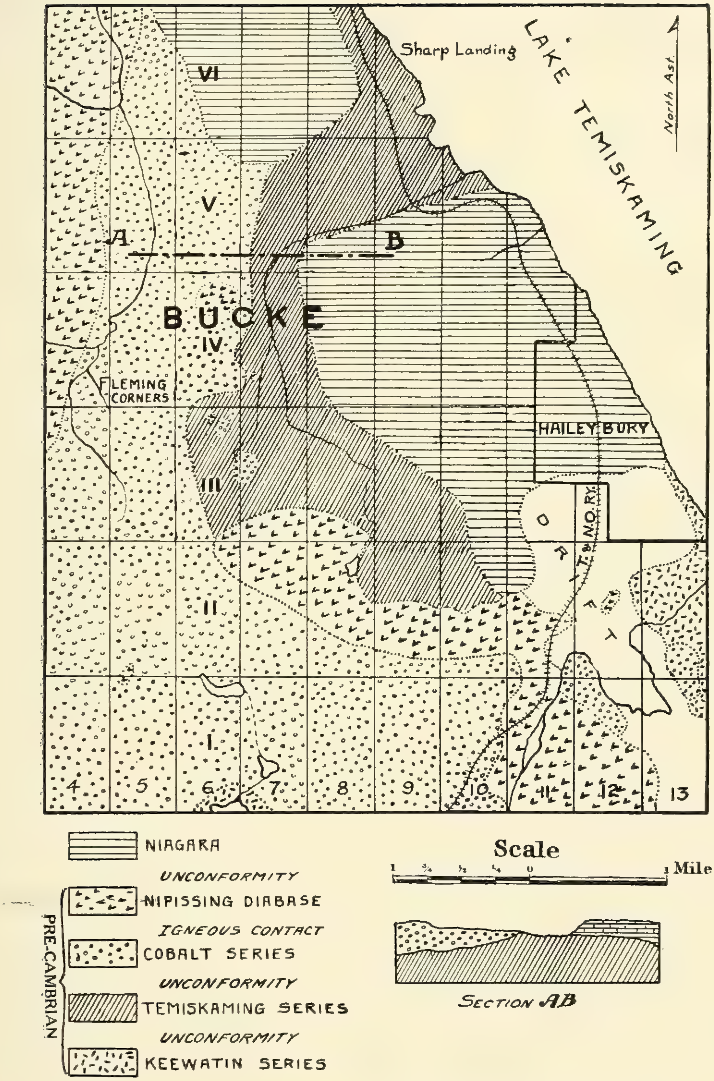
The Laurentian intrudes both the Keewatin and the Grenville series. The Temiskaming is the oldest fragmental series known in the region that is of post-Laurentian age.

THE TEMISKAMING SERIES

The Temiskaming series is composed of conglomerates, greywackés and slates. The conglomerates show a great variety of pebbles, including the following: basalt, diabase, green schist, pyroxene or hornblende-porphyry, quartz-porphyry, feldspar-porphyry, felsite, jaspilyte, grey, white and red cherts, grey granite, granite gneiss and coarse porphyritic syenite with crystals of feldspar one-half to one inch in length.

The Temiskaming series is generally distinctly bedded, and the strata are everywhere seen to have been tilted up until they now rest in a vertical, or almost vertical, attitude. Cross-bedding has been noted in some of the greywackés. Along the shores of lake Temiskaming, between Haileybury and New Liskeard, the strike is easterly, observations giving strikes of N. 60 degrees to 70 degrees E., and steep dips to the south. At the northwest corner of lot 8, in the second concession of Bucke, the strike is N. 20 degrees W., with steep dips to the east. In various places the series is intersected by quartz stringers a few inches in width and a foot or more in length.

An unconformity is inferred to exist between the Laurentian granites and gneisses and the Temiskaming sediments, because granite, syenite and granite gneiss pebbles are found in these sediments.



Geological map of area a few miles north of Cobalt.

The Temiskaming series was invaded, first by lamprophyre dikes, and later by the great mass of Lorrain granite. Good contacts of the Lorrian granite and Temiskaming series are to be seen immediately south of the Temiskaming mine, and at Kirk lake.

West of Haileybury about three miles, an unconformity is exposed between the Temiskaming and Cobalt series. Here, at the southwest corner of lot 7, in the fourth concession of Bucke, the Cobalt conglomerate rests on the upturned edges of the Temiskaming greywacké, the latter showing distinct bedding. Nearby, the older series is cut by lamprophyre dikes, which do not, however, invade the Cobalt sediments. In the same neighborhood there are several places where the two series are separated only by a few feet of drift, but the discordance of the dips is so striking that there can be little doubt about the existence of the unconformity. At Fleming Corners the flat lying, slate-like greywackés of the Cobalt series are in marked contrast to the disturbed Temiskaming sediments one-half mile to the east.

Boulders of conglomerate of the Temiskaming series are found in the conglomerate of the Cobalt series, as shown in the accompanying illustration.

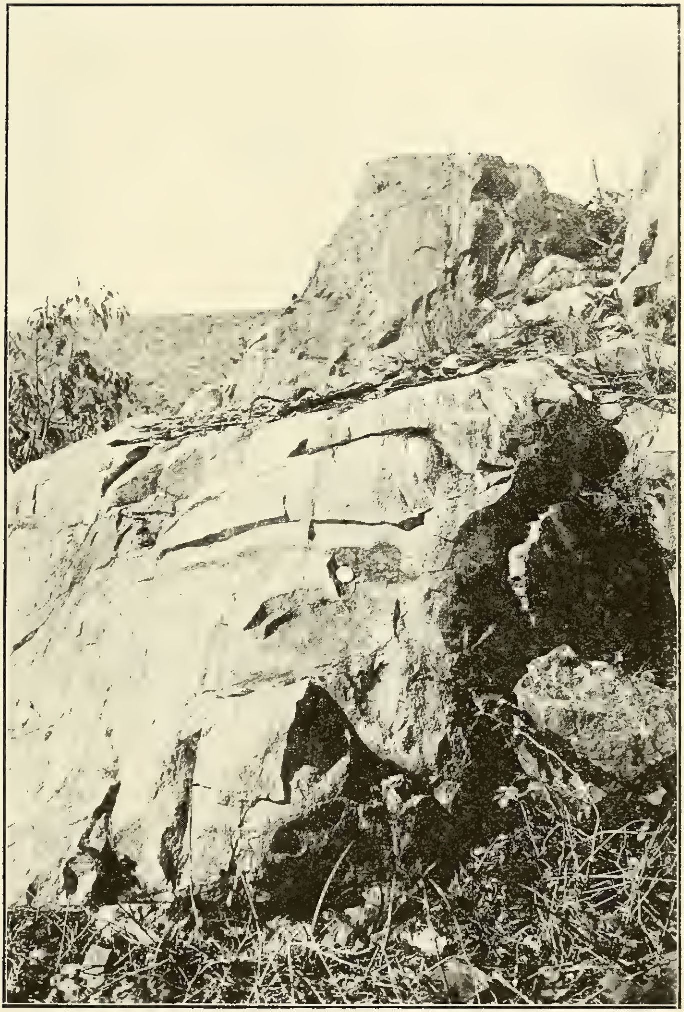
The thickness of the Temiskaming series cannot now be determined with certainty. In one locality it is known to be at least 7,000 feet.

LAMPROPHYRE DIKES AND LORRAIN GRANITE

Near Kirk lake, both lamprophyre and granite intrude the Temiskaming series, and the lamprophyre is seen to be older than the granite.

Lamprophyre dikes are numerous in the area. They are, for the most part, characterized by the prominence of hornblende, biotite or augite. The following types are probably present, viz.: minette, kersantite, vogesite and camptonite. The rocks vary in grain from fine to coarse, and in width from a foot to twenty feet or more. While they are somewhat disturbed, and in some cases much decomposed, they are usually massive rather than schistose, and frequently preserve their original textures.

The distribution of the Lorrain granite is shown on the map of Cobalt, scale one mile to an inch. The rock is a



Temiskaming series, tilted into vertical position, between Haileybury and New Liskeard.

coarse-grained, biotite granite, with a characteristic pink color. At Kirk lake it invades the Keewatin greenstone, the Keewatin iron formation (Grenville series), the Temiskaming sediments and the lamprophyre dikes. Whether some of the quartz and feldspar prophyries, described under the Keewatin series, are genetically connected with the Lorrain granite is not as yet known. The granite is overlain unconformably by the Cobalt series. Its relative age is therefore accurately known. Where it invades the adjacent formations it sends out in every direction many fine-to-medium-grained aplite dikes. In hand specimens these dikes are similar to some of the aplites which are the end phase of the Nipissing diabase. The latter dikes, however, contain only small quantities of potash, while the granite aplites at Kirk lake have normal percentages of soda and potash, as will be seen from the analyses given below. The intrusion of the Lorrain granite was probably the means whereby the Temiskaming sediments were tilted up into their present more or less vertical position. Near the contact the intrusion has sometimes developed garnets in the adjacent rocks.

Analysis No. 1, given below, is from the coarse-grained parts of the granite, while No. 2 is from the aplite dikes a few inches in diameter. In each case about a dozen specimens were taken in order to arrive at average results.

	1	2
SiO_2	71.86	76.03
FeO	2.34	1.29
Fe_2O_3	1.73	1.44
Al_2O_3	15.11	13.02
CaO	.51	.15
MgO	.43	.16
Na_2O	3.70	3.68
K_2O	3.48	3.74
H_2O	1.22	.96
	100.38	100.47

While the Lorrain granite has been intruded by the Nipissing diabase, silver-cobalt deposits of importance have not been found in it. That silver is rapidly deposited on the surfaces of or in cracks in the granite is shown by the occurrence of this metal in veinlets which penetrate granite boulders in the Cobalt series, in the vicinity of the veins at the Coniagas and Trethewey mines. Certain dikes from the granite penetrate the Keewatin in the lower workings of the Temiskaming mine and are cut through by the vein. The granite is here coated with silver.

In the township of Lorrain, to the east of Cobalt, much of the granite presents a weathered surface, there being a gradual transition from the undecomposed rock to the overlying sediments of the Cobalt series.

THE COBALT SERIES

The age relations of this series of fragmental rocks are shown in the table on a preceding page.

Since eighty per cent. or more of the ore mined at Cobalt has come from veins, or parts of veins, that are found in this series, it is the most important, from an economic point of view, of the rock groups of the area. Hence the name given to it is appropriate. The series also presents many other interesting features.

Erosion has left but remnants of this series, which in a past age covered practically all the surface in a vast region in Northern Ontario.

The series is wholly of fragmental origin, and contains rocks varying from those that are uniformly fine in grain to those that contain boulders several feet in diameter. The kinds of fragments composing these rocks are almost innumerable, representing as they do the erosive products from all the older pre-Cambrian series of the region—Keewatin, Laurentian, Temiskaming, Lorrain granite and intrusives of various ages. Naturally, fragments of the harder rocks and minerals have withstood better the destructive agencies to which they have been subjected, and the Cobalt series, especially the members of it that are coarser in grain, contain grains of feldspar and quartz, and pebbles and boulders of granite and other igneous representatives, in greater numbers than they do of minerals or rocks that weather or are abraded more readily. But representatives, as has already been said, of all the older rocks in the region are to be found in the form of pebbles or boulders as components of the Cobalt series.

Boulders Composed of Conglomerate.

From the description of the Temiskaming series, on a preceding page, it will be seen that it, like the Cobalt series, consists of fragmental rocks, ranging from greywackés fine in grain to coarse conglomerates. Probably the most re-

Conglomerate of Cobalt series, containing a conglomerate boulder from the Temiskaming series.

markable boulders in the conglomerate of the Cobalt series are those of conglomerate from the Temiskaming series. If the latter series has furnished conglomerate boulders to the former, undoubtedly it has supplied pebbles or boulders of quartz and other minerals and rocks which once were constituents of its conglomerates.

Order of Deposition.

The surface of the region, in the period immediately preceding the deposition of the Cobalt series, was uneven, and possessed in all probability higher hills and deeper valleys than those of the present surface. Having been laid down on such an uneven floor, the series cannot be expected to show the same thickness of sediments everywhere, even had a great period of erosion not elapsed between the deposition of the sediments and the present time. Moreover, it would be expected that there would be a considerable variation in the order of succession of the sediments from those that lie at the base to those that form the upper members. While such variation in the thickness of the members of the series, and in their order of deposition, has been observed, as is shown in the following table, still, there is a pronounced definite order of deposition in the areas which have been studied by various workers throughout a wide region.

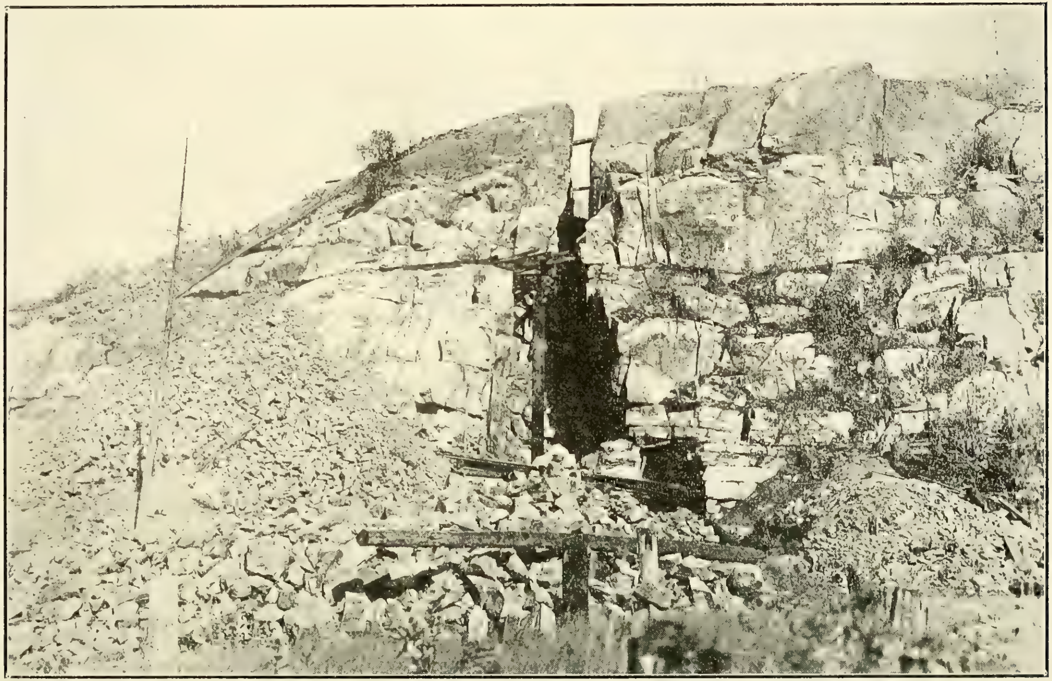
The following table shows the thickness of the Cobalt series at several characteristic localities, and the nature of the sediments, together with the order of deposition:

Wendigo Lake	Little Silver Cliff (Cobalt)	Mt. Chemaniss	Mt. Sinclair	Maple Mountain
Conglomerate*	Conglomerate (30 to 40 ft.)	Conglomerate (100 ft.)	Conglomerate*	Arkose and quartzite (900 ft.)
Greywacké and quartzite (26 ft.)	Quartzite (15 ft.)	Quartzite (135 ft.)		* * *
Quartzite (10 ft.)				* * *
Greywacké (54 ft.)	Greywacké (20 ft.)	Greywacké (315 ft.)	Greywacké (300 ft.)**	* * *
* * *	* * *	* * *	Conglomerate*	* * *
Total 90 ft.	70 ft.	550 ft.	300 ft.	900 ft.

*Thickness not given. **Greywacké contains occasional beds of slate and quartzite. ***Base of section is not exposed.

The arkose and quartzite of Maple mountain are considered to represent the Lorrain or upper part of the Cobalt series. This mountain contains the greatest thickness of sediments known in the region.

The exposure on the shore of the bay, on the east side of Lake Temiskaming, just south of Fabre wharf, may be cited as an example of a section where members of the series are absent. Here the upper conglomerate lies on the surface of the well-banded greywacké.



The Little Silver Vein, Nipissing mine. The cliff is about 70 feet in height, and is composed of almost horizontally lying rocks of the Cobalt series. At the bottom are probably several feet of coarse conglomerate, which is succeeded by about 15 or 20 feet of well banded slate-like greywacké. This is followed by about the same thickness of feldspathic quartzite, overlying which, at the top of the cliff, is a coarse conglomerate. The greatest thickness of the vein, as originally exposed, was about 8 inches. The strike is east and west, and the dip, as the photograph shows, is almost vertical. About $300,000 worth of ore was extracted from this vein.

Underlying Surface.

In the vicinity of Cobalt, the Cobalt series rests, characteristically, on a weathered surface of one or other of the older series of rocks. Most commonly the underlying series is the Keewatin, as rocks of this age are more widespread in the productive part of the area than are the other pre-Cobalt series. No surface that has the appearance of having been produced by glaciation is known beneath the Cobalt series in the vicinity of Cobalt.

Where the rocks of the Cobalt series rest on the greenstones or other easily decomposed members of the Keewatin there is a gradual transition from the non-disintegrated rock upward into the distinctly fragmental member of the Cobalt series. The disintegrated material on the surface of the Keewatin has been recemented and consolidated, or, in other words, recomposed. It is impossible at certain contacts, without the examination of thin sections under the microscope, to distinguish the recomposed material from the underlying massive igneous rock.

Something the same may be said of the contact between the upper members of the Cobalt series, the Lorrain arkose, and the Lorrain granite. In the township from which the name of these rocks is derived, arkose lies on the weathered surface of the granite, there being a gradual passage from the undecomposed rock upward into the arkose.

At the base of the Cobalt series there is the recomposed material described in the preceding paragraphs with, typically, conglomerate or breccia, many of the fragments of which can be seen to have originated in place. A striking example of the origination *in situ* of such material is to be seen on the shore of lake Temiskaming, on the extreme north end of lot 15 in the first concession of the township of Bucke, a couple of miles south of Haileybury. Here, as the geological map, scale 1 mile to 1 inch, shows, the Cobalt series forms a contact with the Keewatin. At the contact the Keewatin consists of greenstone, or basalt, and a dike of feldspar-porphyry. That the conglomerate and breccia of the Cobalt series, here resting on the Keewatin, has, for the most part at least, originated *in situ* is shown by the fact that it contains fragments of various sizes of the porphyry dike. These fragments range in form from angular to sub-angular and rounded. Both the greenstone and the porphyry, but more especially the latter, show characteristic torsion cracks.

This contact and others in the district, between the Cobalt series and the older rocks, have a striking resemblance to those which have been described as existing between members of the pre-Cambrian, Torridonian and the older Lewisian, of the Northwest Highlands of Scotland. "The observer may climb one of these Archæan hills, following the boundary line between the Lewisian rocks and the younger formation, and note, step by step, how the subangular fragments of hornblende-schist that fell from the pre-Torridonian crags are intercalated in the grits and sandstones, thus indicating the slow submergence of the old landsurface beneath the waters of Torridonian time."*

" The basal breccias which often flank the buried mountains are, as already explained, of the nature of scree material. They consist of fragments of the local rocks embedded in a sandstone matrix. The conglomerates, on the other hand, are probably torrential deposits brought down from a district very different in geological structure from that of the area in which the Lewisian gneiss occurs."†

Slate-like Greywacké.

Normally, the basal conglomerate and breccia pass gradually upward into fine-grained, delicately banded, slate-like greywacké. The components of the graywacké are so fine in grain that they cannot be distinguished except by examination of thin sections under the microscope. When thus examined, they are found to consist, for the most part, of angular fragments of quartz and feldspar, which is usually quite fresh and undecomposed. The feldspar consists of orthoclase, microcline and the more acidic soda-lime varieties. Grains of glassy volcanic rocks, and of iron ore and other material, have also been observed. Chlorite and

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*The Geological Structure of the North-West Highlands of Scotland, p. 4. Memoir of the Geological Survey of Great Britain.

†Idem, pp. 286-7.

other decomposition products are present. Under the microscope certain thin sections of the greywacké resemble volcanic ash. It has not been proved, however, that there was contemporaneous volcanic activity.

Typically, the slate-like greywacké has a greenish or greyish color, but in certain localities the color of the rock is distinctly reddish. The latter color is not found in the greywacké of the productive part of the Cobalt area proper, but reddish greywacké lies both to the west and to the east, outcropping in the western half of Coleman township, near Latchford on the Montreal river, and at two or three points near the shores of lake Temiskaming.

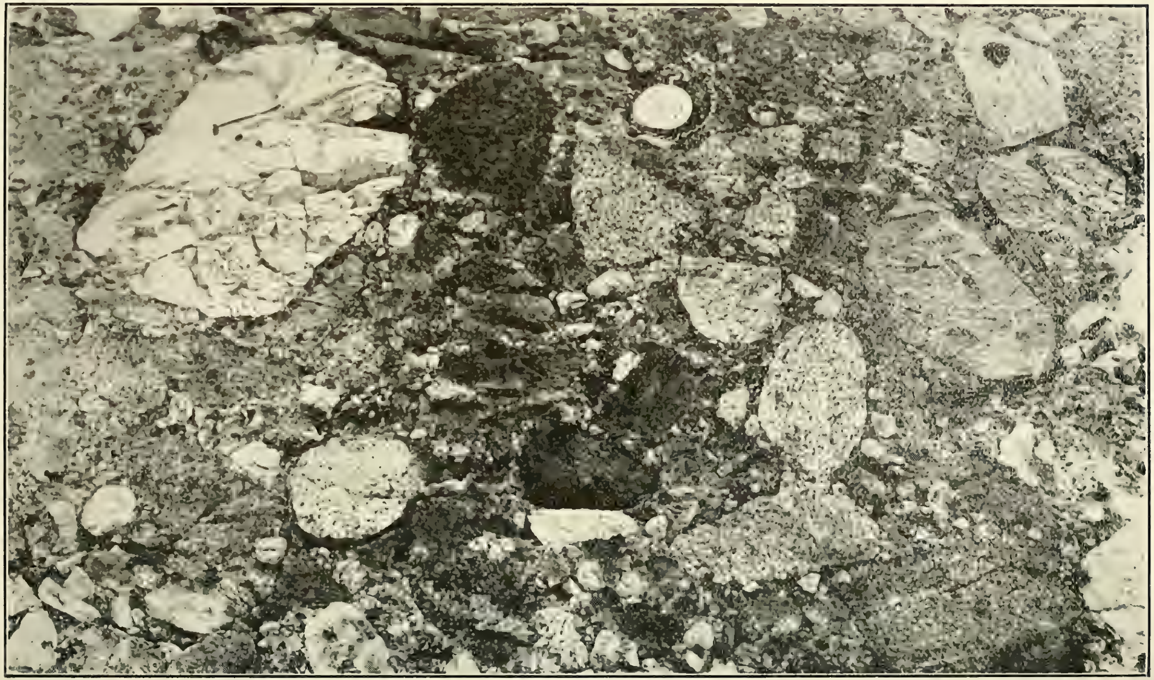
The greywacké, like the other members of the Cobalt series, lies usually in an almost horizontal position. Ripple or wave marks are frequently seen on the surface of its beds, *e.g.*, in the cliff at the Little Silver mine on the Nipissing property. Mud cracks have also been observed. While usually showing little evidence of disturbance, the greywacké is quite compact and does not split readily along the junction of many of the beds.

Normally, the greywacké passes upwards into quartzite, more or less impure, and the latter into conglomerate, but at times the quartzite is lacking and the greywacké is succeeded by conglomerate. Where the members of the series are complete, as at some points along the eastern shores of lake Temiskaming, the conglomerate appears to be succeeded without unconformity by what has been called the Lorrain arkose and quartzite, the latter of which is frequently interbanded with pebbly material.

At two or three places, however, where the upper members of the series, conglomerate or arkose, lie directly on the greywacké, without the quartzite or other intermediate member being present, the greywacké is seen to have been eroded before the deposition of the overlying rock.

Quartzite.

The quartzite usually has no great thickness, frequently being only twenty or thirty feet, but in certain localities impure quartzite or greywacké that overlies the delicately



Coarse boulder conglomerate, Cobalt series. Trethewey mine, Cobalt.

banded greywacké has a much greater thickness, as shown in the table on a preceding page.

At the Little Silver cliff, on the Nipissing property, the base of the Cobalt series is not exposed. Here there are fifteen or twenty feet of well-banded greywacké, overlying which there is about the same thickness of feldspathic quartzite. Above the latter is twenty or thirty feet of conglomerate.

At times the quartzite is interbanded with greywacké

Conglomerate.

What may be called the second conglomerate, to distinguish it from the conglomerate and breccia that lie at the base of the well-banded greywacké, or in other words the conglomerate that overlies the quartzite, is one of the most interesting members of the Cobalt series. The great variety of pebbles and boulders that are found in this rock give to it an appearance that attracts attention. It contains boulders representing practically all of the numerous older rocks of the region. Whether it represents a glacial deposit, or whether it is of torrential or other origin, in the opinion of many observers, is undecided.

The conglomerate of the Cobalt series is distinguished from that of the Temiskaming series chiefly by the fact that pebbles and boulders of pink granite, rather coarse in grain, are characteristic of the former and not of the latter. This is owing to the fact that the granites of the region, that antedate the Temiskaming series, are typically grey in color, while the pebbles and boulders in the conglomerate of the Cobalt series have been derived from the pink-colored Lorrain granite, which intruded the Temiskaming, but is older than the Cobalt series. Moreover, the members of the Temiskaming series dip at high angles while those of the Cobalt series are usually but slightly inclined.

Origin of the Conglomerate.

In the first edition of his report on the Cobalt area, concerning the origin of the conglomerate the writer said: "It is difficult to understand, for example, how certain large boulders of granite in the conglomerate, which forms part of the highest outcrops of the Lower Huronian (Cobalt series), have been carried so far from their parent masses. These large boulders are found over much of the district, and there are now no outcrops of granite in the neighborhood of many of them. . . . In the present state of our knowledge we have little warrant for claiming that the granite boulders, often two or three feet or more in diameter and distant a couple of miles from exposures of the rock, indicate glacial conditions during Lower Huronian times, although we have no proof to the contrary."*

A couple of years after this report was published Dr. A. P. Coleman, while on a visit to the Trethewey mine, discovered striated boulders in the conglomerate in an outcrop on this property† that have all the characteristics of those which are found in glacial deposits. Hence, Dr. Coleman and other writers have decided that a certain part, at least, of the conglomerate of the Cobalt series is of glacial origin.

In the opinion of the present writer more evidence is required before the glacial origin can be accepted. Although for many years conglomerates similar to those of Cobalt have been studied over a vast extent of territory in northern Ontario, no glaciated surface on the rocks underlying this conglomerate has been discovered. During the last few years several workers in the Cobalt and surrounding areas have diligently searched for such a surface, but without success. The underlying rocks present, characteristically, a weathered surface, there being no sharp line of division between the underlying, undecomposed, or non-disintegrated, rock and the overlying fragmental rock. The glacial origin of the Cobalt conglomerate cannot therefore be proved so clearly as it can for similar rocks in other parts of the world. The Dwyka of South Africa, for example, rests on rocks that frequently show undoubted evidence of having been smoothed by glaciers. Opportunities for observing contacts at Cobalt are, however, being constantly enlarged

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*Fourteenth Report, Bureau of Mines, Ontario, Part II., page 43.

†Am. Jr. Science, March, 1907. Journal of Geology, February-March, 1908.

by stripping the surface in prospecting, and it is possible that the Cobalt series may be found to rest on a surface of a different character from those at present known.

A glacial origin was at one time suggested for certain breccias or conglomerates in the Torridonian of the North-western Highlands of Scotland. In the report on that region, published a few years ago, this suggested theory of origin has been discarded.* "From the nature of the rocks it may be inferred that the conditions of deposit were probably those of a rapid accumulation in shallow water near a shore line, subject to violent currents and the influx of flood or stream-borne materials, with occasional intervals of quiescence during which the finer sediments were laid down. . . . In one instance, on the north side of Loch Maree, it has been observed that the blocks in the conglomerate have come from the hornblende-schist ridge of Ben Lair, and may have travelled a distance of three miles."

That surfaces on rocks resembling closely those produced by glaciers can be formed by other means is shown by the observations of Dr. E. O. Hovey.* In speaking of the accumulation of volcanic material on the side of Mt. Pelée, he says: "From time to time the coat of new material became water-soaked from the heavy tropical rains and slid down the mountain in more or less of a sheet avalanche. On the collecting ground of the steep upper cone, planation and grooving were not prominent, but on the middle ground of the Morne Saint Martin, where the force of the avalanches spent itself, planation and grooving were pronounced. In June, 1902, the striated surface of the old agglomerate, with here and there a heap of unassorted ash upon it, suggested closely the appearance of a regularly glaciated surface with its overburden of till."

Dr. Hovey says further: "Where the crevicing of the rock-mass has been favorable, the impact of stones hurtling down the stream bed has broken off chips from the bed rock, producing a good imitation of the 'chatter' marks made by a glacier."

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*The Geological Structure of the North-West Highlands of Scotland, pp. 23 and 273. Memoirs of the Geological Survey of Great Britain, 1907.

*Striations, U-shaped valleys, and hanging valleys produced by other than glacial action. Geol. Soc. Am., Vol. 20.

If such surfaces are thus produced, undoubtedly the faces of pebbles and boulders in moving masses of rock are also grooved and striated in such a way as to be undistinguishable from those of glacial origin.

Lorrain Arkose and Quartzite.

As explained on a preceding page the arkose and quartzite, to which the name Lorrain has been applied, are here grouped with the Cobalt series, and are considered to represent the upper members of the series. In two or three localities, the arkose and quartzite have been found to be unconformable to the slate-like greywacké or other lower members of the series, but in other places there is no evidence of an erosion interval. Since, however, the arkose and quartzite in most of the areas that have been mapped tend to occur distinct from the lower members of the series they are distinguished on the maps, by a different color, from the latter.

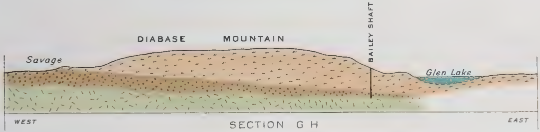
Frequently the arkose is found on the surface of granite, e.g., in the township of Lorrain, and is the decomposition product of the latter rock, there being a gradual passage from the undecomposed rock into the arkose. There is, moreover, a gradual passage upward from the arkose, first into impure quartzite, then into a purer quartzite and conglomerate, composed chiefly of quartz pebbles.

THE NIPISSING DIABASE

The diabase, to which the name Nipissing has been given, occurs characteristically as a sill. At Cobalt much of the hanging wall of the sill has been removed by erosion, and the diabase occupies about one-half of the surface of the productive area, the sill dipping on the whole at a low angle to the southeast. From following descriptions, however, it will be seen that the dip of the sill is much steeper at certain points.

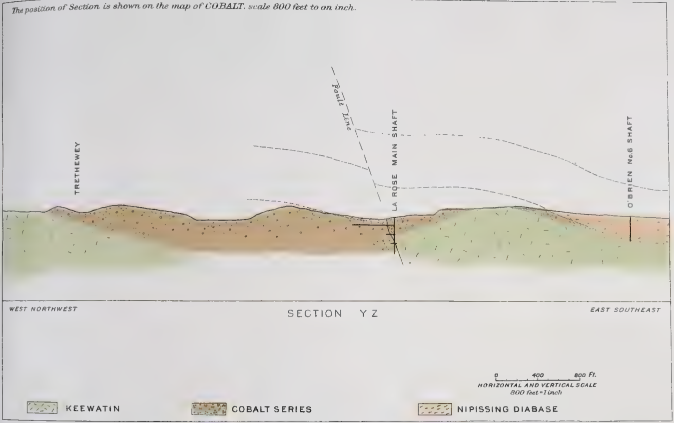
In the region 5,000 square miles or more in extent, that surrounds Cobalt, the diabase occupies a considerable percentage of the area, and is seen in many cases to be in sill-like form. Owing to the association of cobalt ores with

The position of Sections is shown on the map of COBALT, scale 800 feet to an inch



SECTION G H

PLATE V



To accompany Fourth Edition of Report by **WILLET G. MILLER**, *Provincial Geologist, on the Cobalt-Nickel Arsenides and Silver Deposits of Temiskaming In Part II. of the Nineteenth Report of the Bureau of Mines, Ontario.*

this diabase in numerous localities throughout this region, the diabase and the ores are believed to have come from the same magma.

Nearly all varieties of the rocks forming the sill at Cobalt, when examined in thin sections, are found to have an ophitic texture, and primary quartz is almost always present. The rock is, therefore, a quartz-diabase. Most of the quartz is associated with feldspar in micrographic intergrowth.

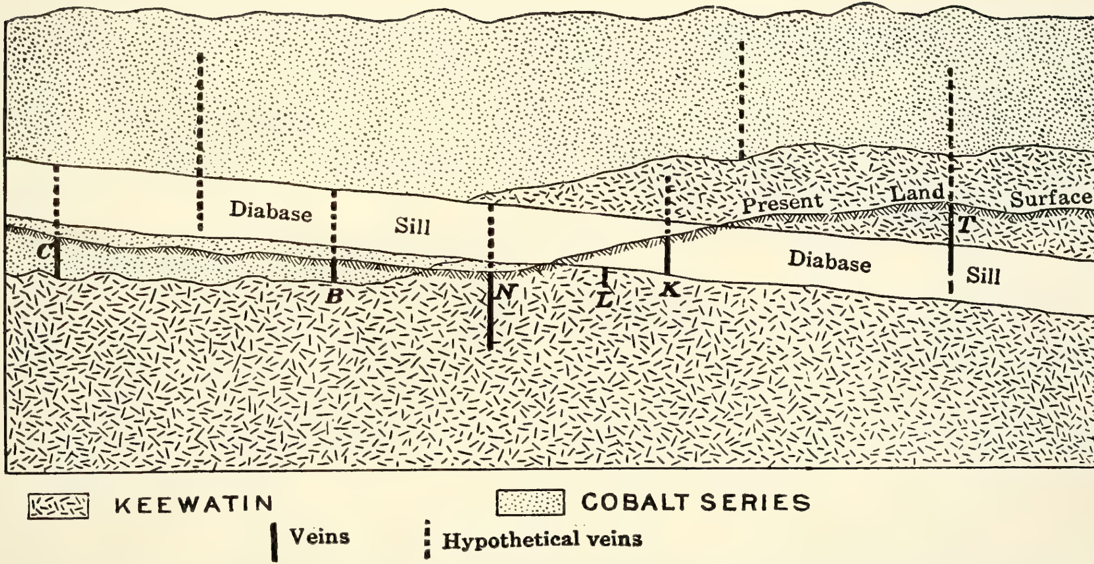
The chemical composition of certain typical specimens of the quartz-diabase of the Cobalt area, and its relation to the quartz-norite of Sudbury are shown in a following table.

The thickness of the diabase sill at Cobalt is five or six hundred feet or more. In diamond drilling, at one point near the shore of Cross lake, the thickness was found to be nearly twice as great, but this is believed to be due to faulting. Cross lake lies in line with Kirk, Chown and Goodwin lakes, the chain of lakes probably indicating the direction followed by a fault.

The accompanying generalized section shows the relation of the diabase sill to the Keewatin and the Cobalt series, and to the veins, in the Cobalt area. Cross-sections of the area published by the Ontario Bureau of Mines give more details, as the following notes on the general section of the area show. The "Map of Cobalt Area," scale 800 feet to 1 inch, that accompanies this guide book, shows the location of the sections.

General Section, Upper Half of Plate IV.

The section incorporates much of the information contained in other sections, together with additional data. Its total length is about 4½ miles, and it may be added that the bottom line represents sea level. The cross-section begins at the southeast corner of Sasaginaga lake, and shows the important area of conglomerate, greywacké, etc., of the Cobalt series, resting in an ancient valley of the Keewatin series, between Cobalt and Sasaginaga lakes. A reverse fault—normal to the line of section—occurs parallel to the longer axis of Cobalt lake, and it is also found at the McKinley-Darragh about one-quarter of a mile to the southwest, and at La Rose at the north end of the lake.



GENERALIZED VERTICAL SECTION THROUGH THE PRODUCTIVE PART OF THE COBALT AREA.

The section shows the relations of the Nipissing diabase sill to the Keewatin and the Cobalt series, and to the veins. The eroded surface is restored in the section. The sill is less regular than the illustration shows it to be.

B and C represent a large number of veins that are in the fragmental rocks, Cobalt series, in the lower or foot wall of the eroded sill. N represents a type of vein, such as No. 26 on the Nipissing, in the Keewatin below the eroded sill, and L a type such as one under Peterson lake, in the Keewatin foot wall, but not extending upward into the sill; K, a vein in the sill itself, such as No. 3 on the Kerr lake property; T, a vein such as that on the Temiskaming or Beaver properties, in the Keewatin hanging wall and extending downward into the sill.

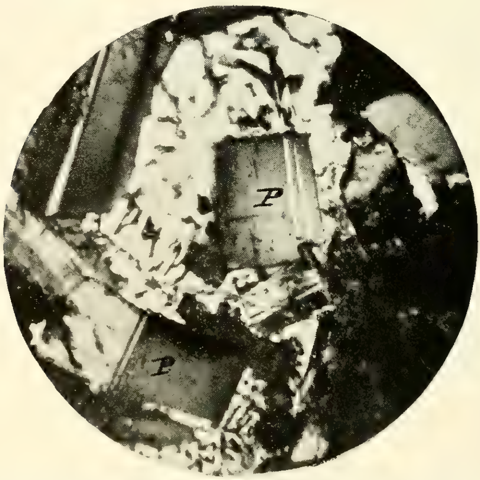
At La Rose mine the rocks on the west side of the fault have been carried down a vertical distance of 210 or 220 feet, and at the McKinley-Darragh a vertical distance of at least 250 feet.

The diabase at the Little Nipissing dips S. E. at an angle of 16 degrees, while at the Crown Reserve it has been proved to dip more steeply at angles varying from 17 to 45 or 50 degrees to the N.W., from which it appears that the sill occupies a basin-like depression in the underlying rocks between these two properties.

If the Kerr lake area be now studied it will be found that the diabase inclines steeply to the N.W. and to the S.E. of the axis of the lake, forming a saddle-like structure. It may be seen dipping to the N.W. at the following points: the southwest shore of Cross lake; the northeast corner of the north Drummond lot; about 200 yards east of Kerr lake and 25 yards north of the road (a diamond drill hole near here has also proved the dip to be northerly); a trench on the Silver Leaf has exposed the contact of the diabase for about fifty yards or more. On the south flank of this saddle-like structure the diabase has been proved to dip S.E. at the following points: the Valentine shaft; a vertical diamond drill hole on the south part of the south Drummond lot; shaft No. 5 of the Drummond mine; shaft No. 1 of the Hargrave; two drifts from the No. 3 shaft of the Kerr lake; a drift from the 369-foot level of the No. 3 shaft of the Hargrave. From the above data it is thus seen that the saddle-like structure of the diabase at Kerr lake has been proved at several points. But it may be added that some of the steep inclinations of the sill may be partly due to faulting. There is, for example, a well defined fault in the diabase at the Crown Reserve, 540 feet north of the shaft in the drift at the first level, dipping 15 or 20 degrees to the north. Again on the south side of the saddle-like structure a fault, dipping to the southeast, was encountered at the Hargraves and Drummond.

At the Lumsden a shaft was sunk in the Keewatin to a depth of 290 feet, where it passed into the Nipissing diabase, proving that the sill here dips beneath the Keewatin greenstones at an angle of about 26 degrees. Similar relations are known to obtain at other points along the same contact to the southwest as far as Mount Greywacké

Coming, finally, to the Temiskaming mine it is found that the diabase has been encountered on the fourth and fifth levels, and at a depth of 575 feet in the main shaft. The surveys show that the sill dips at angles varying from 17 to 30 or 40 degrees in different parts of the mine, but it is probable that faulting may have caused some of the steeper inclinations, because a vertical fault between the diabase and Keewatin is known to occur on the fourth level. There are, however, no data at present to determine the throw of this fault.



Quartz-diabase, Cobalt, showing labradorite, P, embedded in a micrographic intergrowth of quartz and feldspar.

Facies of the Diabase.

While, as will be seen from the preceding descriptions, the diabase in the productive part of the Cobalt area is fairly uniform in character, differentiation is found in the outlying areas. Thus, a few miles to the west and also to the south of Cobalt pink spots, areas of micropegmatite, appear in the diabase. In certain localities these pink spots increase until the rock becomes pink or reddish, and is then more correctly described as granophyre than as diabase. A similar, but more complete, change, from a basic, darker rock to a lighter colored, more acidic variety, is found in the norite of Sudbury.

At times the typical diabase passes into a rock much coarser in grain, that has been described as gabbro, but many of these coarser varieties, when examined closely, are found to have the ophitic texture.

DIKES OF APLITE OR GRANOPHYRE YOUNGER THAN NIPISSING DIABASE

Especially in the Elk lake and Gowganda areas the Nipissing diabase is frequently cut by narrow dikes of aplite or granophyre. The material in these dikes is believed to represent residual, more acid material of the diabase magma. On the cooling of the diabase, cracks were formed in it, and material from the residual magma, rising through the cracks and fissures, formed the dikes of aplite or granophyre. Chemical and microscopical examinations of these dike rocks show that they are genetically connected with the diabase rather than with granite. Compared with the fine-grained granite or felsite dikes in the region, such as those connected with the Lorrain granite, the aplite dikes associated with the Nipissing diabase are found to be characteristically high in soda and low in potash, as following analyses show.

At Cobalt there is a dike of granite on the property of the University mine that cuts the Nipissing diabase and from its chemical composition is seen to be related to the aplites of Gowganda and Elk Lake. Having a much greater width than have the characteristic dikes elsewhere in the region, it is naturally coarser in grain. An analysis of samples from this dike is given below.

Examined in thin sections under the microscope, the dike rock at the University mine is found to be made up of feldspar, quartz and a colored constituent. The feldspar predominates, and consists of microcline and an acid plagioclase showing fine albite twinning lamellæ. The quartz and feldspar occur in allotriomorphic grains, but in two instances show distinct micrographic intergrowths. The colored constituent is not abundant; it was apparently originally a mica, but is now represented by chloritic material.

This dike averages fifty feet in width, while the dikes of the Montreal river area and Gowganda are usually under eighteen inches.

Analyses of the Acid or Granophyric Facies of the Eruptives

—	I	II.	III	IV	V
SiO_2	72.33	62.54	61.93	67.76	76.03
Al_2O_3	12.99	14.79	13.03	14.00	13.02
Fe_2O_3	0.00	0.00	0.56	0.00	1.44
FeO	2.50	8.49	8.00	5.18	1.29
MgO	0.97	2.08	1.76	1.00	0.16
CaO	1.73	1.49	4.02	4.28	0.15
Na_2O	7.60	6.27	3.18	5.22	3.68
K_2O	0.00	1.12	2.80	1.19	3.74
H_2O	1.09	3.51	1.95	1.01	0.96
TiO_2	0.74	0.00	0.84	0.46	0.00
P_2O_5	0.00	0.00	0.32	0.19	0.00
MnO	0.00	0.00	0.18	trace	0.00
CO_2	1.00				
S	0.00	0.00	0.19	0.00	0.00
	100.95	100.29	98.76	100.29	100.47

I. University mine dike, Cobalt, N. L. Bowen, analyst (Journal Can. Min. Ist., Vol XII).

II. Lost Lake granophyre, Gowganda Cobalt-Silver area, N. L. Bowen, analyst,

III. Acid edge of nickel eruptive Onaping section, Sudbury, E. G. R. Ardagh, analyst.

IV. Near acid edge of the Blezard-Whitson lake section. Sudbury, T. L. Walker analyst.

V. Lorrain granite dikes, fine in grain or aplitic, Cobalt. About a dozen specimens were taken to get an average.

Analysis No. V is added to the table to show the difference in composition between the dikes of Lorrain granite and the acid facies of the Nipissing diabase and Sudbury norite. In all the analyses of the latter the proportion of soda to potash is high while in the case of the Lorrain granite dikes it is more nearly equal.

BASIC DIKES YOUNGER THAN NIPISSING DIABASE

In the region one hundred miles in width, between Sudbury on the southwest and Quinze lake, which lies to the east of the head of Lake Temiskaming, on the northeast, basic dikes have been found at many points. These dikes are younger than the Sudbury norite and the Nipissing diabase, which, of the basic igneous rocks, immediately precede them in age.

The age relation of these dikes to those of aplite or granophyre, described in a preceding paragraph, which are believed to represent acidic, residual material of the Nipissing diabase magma, is not known. The basic dikes in all probability also came from this magma. In the Sudbury area these dikes are cut by greyish, fine-grained granite, the youngest intrusive of that area.*

*14th Report, Ontario Bureau of Mines, Part III., pp. 14, 126.

At Sudbury the basic dikes are composed of olivine diabase which on weathering shows the characteristic spheroidal forms. In thin sections under the microscope the rock is one of the most beautiful of its class. Similar dikes of olivine diabase on the Quinze river, a hundred miles to the northeast of Sudbury, have been described by the writer*

In the region between Sudbury and the Quinze many dikes of olivine diabase have been found as well as those of olivine-free diabase.

In the vicinity of Cobalt these dikes are rare, the only one studied by the writer being the basalt-diabase of Cross lake.

Analyses.

The following table shows the chemical composition of two typical samples of the Nipissing diabase at Cobalt, and that of a rather basic type of the Sudbury norite, together with analyses of two later basic dikes.

——	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
SiO_2	45.20	47.22	49.84	48.06	49.90
TiO_2	....	3.62	....	....	1.47
Al_2O_3	19.08	16.52	18.94	18.23	16.32
Fe_2O_3	3.64	3.32	1.51	9.57	....
FeO	14.64	12.40	6.40		13.54
CaO	7.89	9.61	10.32	11.55	6.58
MgO	4.98	3.33	7.39	7.80	6.22
BaO	....	.01	....	....	....
Na_2O	3.32	3.40	1.99	1.87	1.82
K_2O	1.08	.67	1.28	.27	2.25
MnO	....	.04	....	....	trace
CuO	....	trace	....	....	....
NiO	....	.0275	....	....	....
CoO	....	.0055	....	....	....
P_2O_5	....	.33	....	....	.17
H_2O	....	.30	....	....	.76
Loss on ignition	....	....	2.57	3.54	....
Total	99.83	100.803	100.24	100.89	99.03
Sp. Gravity	....	3.01	....	....	....

No. 1, basalt-diabase dike, Cross lake, Cobalt. No 2, olivine diabase dike, Sudbury. No. 3, Nipissing diabase cut by basalt-diabase dike at Cross lake. No. 4, Nipissing diabase, on the Violet property near Cross lake. No. 5, norite, more basic than the average, at Sudbury.†

*11th Report, Ontario Bureau of Mines, pp. 227, 229.

†Analyses Nos. 2 and 5 are taken from Dr. A. P. Coleman's paper in the Fourteenth Report, Ontario Bureau of Mines, Part III.

PALEOZOIC

It will be seen from the map, scale 1 mile to the inch, that the Niagara and Clinton limestone forms some large outcrops on the islands and in the vicinity of the shore near the northwest corner of lake Temiskaming. This limestone affords stone suitable for building and for the production of lime, and on this account should be of considerable value in the years to come, since the rock is a somewhat rare material in most of this northern part of Ontario. The district to the west and north is being rapidly settled and will soon contain a large population which will need much material for building purposes. The following is an analysis of a sample of limestone taken from Farr's quarry, Haileybury:

	Per cent.
Insoluble residue	1.60
Ferric oxide and alumina	.66
Lime	29.50
Magnesia	21.59
Carbon dioxide	46.84
Sulphur trioxide	.70
	100.89

This limestone formation extends northward, although overlain by clay and similar deposits in many places, and has been observed by the writer along the south branch of the Blanche river below what is known as the Mountain portage.

Considerable attention has been paid to the limestone area, Sir William Logan having first described it years ago. It has been shown that the series here is more closely related to the Niagara of Southern Ontario than it is to the Niagara areas to the north and west.

The cobalt-silver deposits being of pre-Cambrian age, the Paleozoic limestone is of little interest in connection with the ores. It is of course possible that ore-bearing rocks underlie the limestone.

Along the wagon road, in lots 5 and 6 in the third concession of the township of Dymond, to the northwest of the town of New Liskeard, the limestone cliff presents a striking face, indicating faulting. The fault line is continuous with the western shore of lake Temiskaming, and furnishes still further evidence confirmatory of the theory that the lake lies along a great northwest-southeast fault.

In places these limestones are rich in fossils.*

PLEISTOCENE

Immediately preceding the Glacial period, doubtless the surface of what is now the productive cobalt-silver area was in a highly weathered or decomposed condition. The glaciers scraped off the loose material from the surface and carried it southward, intermingled with other material. In all probability much more cobalt-silver ore was carried away by the ice sheet than has been mined. Nuggets or boulders of rich silver ore have been found in prospecting trenches at numerous points to the south of the mines. A glacial boulder, worth about five thousand dollars, is now in the Bureau of Mines collection.

Everywhere throughout the region the surfaces of the rocks give evidence of glacial action. The underlying loose deposits, on the surface of the glaciated rocks, consist typically of boulder clay. This is succeeded upward, north of Cobalt, by a considerable thickness of strikingly well laminated clay. Above this clay, on some of the hills, to the north of lake Temiskaming are sand and gravel deposits. The glacial deposits in this part of Ontario have been well described by Dr. A. P. Coleman.**

A couple of miles northward of Cobalt station the agricultural region of this part of northern Ontario is met with. The soil is essentially a well banded clay. Between this point and the height of land, or watershed, between the Hudson bay and Ottawa river waters, the clay does not form a continuous mantle, but there are large areas of tillable land which is being rapidly settled. Outcrops of solid rock, in many cases representing hill tops, which project through the clays, are seen. North of the height of land, however, is a large agricultural area, estimated at 16,000,000

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*Geol. Sur. Canada, Vol. X, 1897.

**Lake Ojibway; Last of the Great Glacial Lakes. Eighteenth Report, Ontario Bureau of Mines, p. 284 *et seq.*

acres, now traversed by the National Transcontinental Railway, and known as the "great clay belt," in which exposures of solid rock are few in number. The clay on both sides of the height of land is pretty uniform in character.

Following is an analysis of the clay in a cut on the railway between Haileybury and New Liskeard. It will be seen that the lime and magnesia are rather high. This is owing to alternate bands containing considerable marl. The clay effervesces strongly in acid.

	Per cent.
Silica	52.00
Alumina	16.11
Ferric oxide	4.69
Lime	8.26
Magnesia	4.10
Potash	1.74
Soda	2.76
Sulphur trioxide	.09
Loss on ignition	9.64
Total	99.39

THE COBALT-SILVER VEINS.

The cobalt-silver veins occupy narrow, practically vertical fissures or joint-like cracks in rocks of three ages, viz.: Cobalt series, Keewatin series and Nipissing diabase. The relations of the veins to each of these three groups of rocks are shown in the accompanying generalized cross-section of the Cobalt area and in the larger scale, colored cross-section, (plate IV), published by the Ontario Bureau of Mines. The veins are much more numerous in the rocks of the Cobalt series than in the Keewatin or Nipissing diabase.

It was estimated that up to July 1st, 1911, the yield from the Nipissing diabase had been approximately 7.55 million ounces from 12 veins, or 629,000 per vein, or 7 per cent. of the total production. The Keewatin with 13 veins had produced 11.7 million ounces, or nearly 1 million per vein, or 10.85 per cent. of the total. From 86 veins in the Cobalt series there had been obtained 88.55 million ounces, or a little over 1 million ounces per vein, representing 82 per cent. of the total production. It is difficult to determine the exact number of productive veins owing to the fact that, being very narrow, parts of one vein may be mistaken for two or more distinct veins. At the present time there are 115 or more productive veins, and the relative productivity of those in the three series of rocks is about the same as it was in 1911.

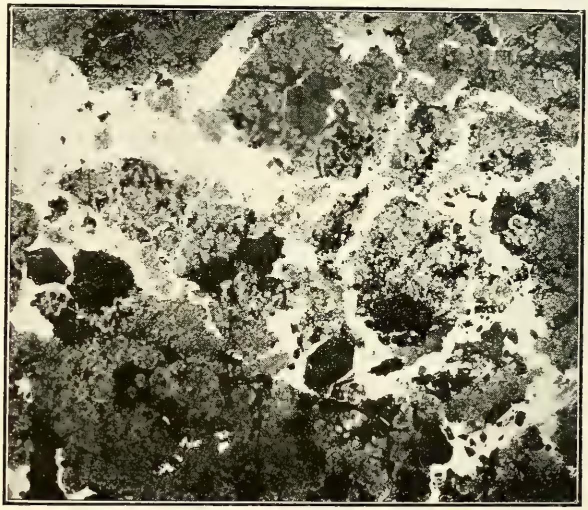
A typical silver-cobalt vein, outcrop on Coniagas, Cobalt. The head of the hammer shows the width.

ORIGIN OF THE VEINS.

After the intrusion of the Nipissing diabase sill, which, on the whole, dips at a low angle from the horizontal, and pentrates both the Cobalt series and the Keewatin, disturbance, probably due chiefly to the contraction of the sill on cooling, caused fissures and joint-like cracks to be formed. These openings were made in the rocks of the hanging-wall of the sill, in those of the foot-wall, and in the sill itself.

Ore-bearing waters working through or along the zone of weakness produced by the sill deposited their burden in the fissures and cracks. The minerals first to be deposited were essentially cobalt-nickel arsenides, and related compounds, and dolomite or pink spar. The fissures and cracks were ultimately filled with these minerals. Then there was a slight disturbance of the veins, reopening the ore-filled fissures and cracks, or facturing the material deposited in them.

In the interval, between the filling of the fissures and cracks with cobalt-nickel ores and the fracturing of the veins thus formed by a secondary disturbance, the character of the material carried by the circulating waters had changed. Silver was then the characteristic metal in solution and it was deposited, along with calcite, in the



Polished surface of silver ore, slightly magnified, from La Rose mine, Cobalt. The native silver, S, is the white material in the illustration. The large black patches are calcite, the small black spots niccolite, and the grey is smaltite.

cracks and openings in the fractured veins. There may have been some silver deposited in the earlier period of vein filling and doubtless cobalt-nickel minerals were deposited after the secondary disturbance, but the latter minerals belong characteristically to the first generation and the silver minerals to the second.

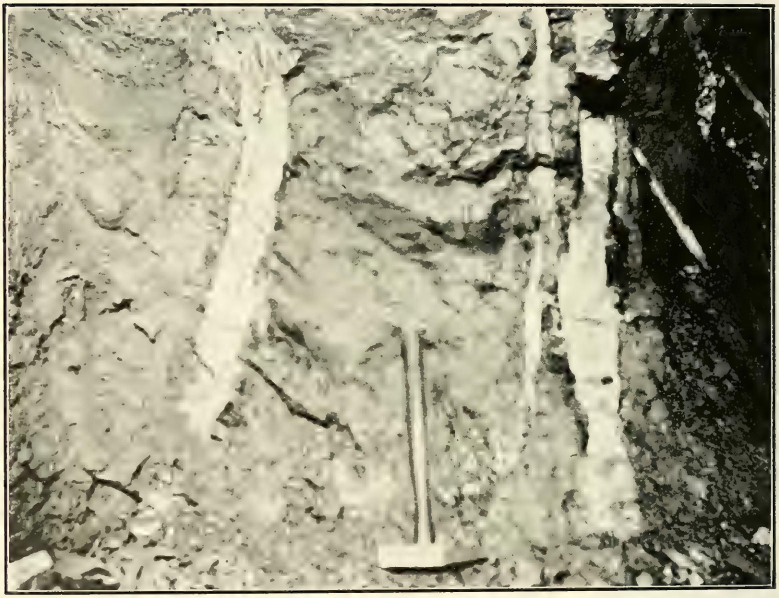
Certain writers on the Cobalt ores have expressed the opinion that the silver represents "secondary enrichment," meaning that it has come from the decomposition of compounds of the metal in the veins that were deposited at approximately the same time as the cobalt-nickel minerals. The present writer believes that at least by far the greater part of the native silver is of primary origin. The recent interesting experiments of Messrs. Chase Palmer and Edson S. Bastin,* on the precipitation of silver from solutions by cobalt-nickel minerals, appear to confirm the opinion that the native silver is a primary deposit, and did not come from the decomposition of silver compounds in the veins. The work of these gentlemen shows that where silver solutions come in contact with cobalt-nickel minerals the silver is deposited rapidly and essentially as native silver. Since there is much calcite in the veins with the native silver, it would appear that the metal was carried in solution as a carbonate, or double carbonate. Under ordinary conditions of temperature and pressure, silver carbonate is slightly soluble in water. For example, sufficient of the carbonate can be dissolved in an ordinary beaker of water to make a distinct precipitate of metallic silver when cobalt-nickel minerals are placed in the beaker.

It has been proved, by the experience gained in mining at Cobalt, that the presence of rich silver ore is dependent on proximity to the diabase sill. Over much of the productive area, not only the upper wall of the sill but the sill itself and more or less of its foot-wall have been removed by erosive agencies. Owing to little of the upper or hanging wall remaining in the productive area, most of the ore has come from the foot-wall of the sill, or from what was the foot-wall before erosion took place. In these veins, in the foot-wall of the sill, it is the exception to find rich silver ore extending more than two or three hundred feet below the surface. Most veins are productive to a lesser depth. After rich silver ore disappears, with increase in depth, cobalt-nickel ore frequently continues downward in the veins. This seems to be due chiefly to the strong precipitating effects that the cobalt-nickel minerals had on the silver in the waters that worked downward beneath or along the sill. The silver was deposited before it reached a great depth. In certain cases, where veins with cobalt-nickel minerals contain no rich silver ore, or in which the silver extends to

*Ec. Geology, March, 1913.

a comparatively shallow depth, the absence of the precious metal is to be accounted for by the fact that such veins, or parts of veins, escaped fracturing during the secondary disturbance, thus not affording openings for deposition from the silver-bearing solutions.

Frequently, below the rich silver-bearing parts of veins well crystallized argentite and hair silver are found in vugs. These minerals may represent secondary deposition



An underground view in La Rose mine, Cobalt, showing parallel veins.

of a little of the silver that has been dissolved from the upper part of the veins and carried downward.

Characteristically, the native silver of the area is impure, chiefly from the presence of antimony and mercury. Samples of well crystallized silver and certain veinlets of the mineral that have been examined are free from these impurities. Such silver is probably of secondary origin.

When native silver is precipitated by its solutions coming in contact with cobalt-nickel minerals, compounds of nickel and other metals go into solution. Hence, it is not surprising to find in the Cobalt veins minerals or compounds of the baser metals that appear to have been deposited during the later period of vein filling.

FORMER VERTICAL EXTENSION OF VEINS.

Certain writers have expressed the opinion that veins of the Cobalt area, that outcrop at the surface or occur immediately below the drift covering, represent the narrower, lower parts of wider veins that extended to or towards the original surface. There is no justification for the holding of such an opinion. The few veins that have been worked to a depth of a few hundred feet in rock of one series give no indication of becoming narrower below, although, when the veins are in the foot wall of the sill, the ore tends to become less rich as the vertical distance below the sill or the eroded part of it becomes greater. Moreover, "blind" veins, or those which do not reach the present surface of the rock, have been found. These veins have the same character, as regards width and mineral content, as those which are exposed at the surface.

Briefly, it appears that after the intrusion of the diabase, fissures and cracks were formed in the rocks of the hanging wall and in those of its foot-wall, and in the sill itself. The openings in the upper wall probably extended a considerable distance upward beyond the sill, but there is no evidence that they reached the surface or that they were wider in the parts that have been eroded.

Some of these fissures in the upper wall extended downward into the sill itself, e.g., veins on the Temiskaming, Beaver, and Nova Scotia. The veins on these properties, worked at the surface in the Keewatin hanging-wall, and in the diabase sill below, are the deepest mines in the area. No foot-wall vein has been found to be productive to such a depth.

Then there are veins, e.g., that on the Cobalt Central property, which have been worked at the surface in the diabase and followed downward into conglomerate and greywacké which at times lie beneath the sill.

Again, blind veins are found in the Cobalt series and in the Keewatin where the sill has been eroded.

There are also blind veins, e.g., one that was worked two or three years ago under Peterson lake and one on the Silver Leaf property, that lie in Keewatin beneath the sill. These veins run upward to the lower face of the sill but not into it.

The types of veins mentioned in the preceding paragraphs are shown in the accompanying, generalized cross-section of the area.

RELATION OF WALL ROCK TO ORE.

The productive veins, as the maps and cross-sections show, are found in three series of rocks, viz.: the conglomerate and other sediments of the Cobalt series, the Nipissing diabase sill, and the Keewatin complex. But eighty per cent. or more of the ore has come from the Cobalt series. The chief reason for this greater productiveness is due to the fact that these rocks fractured more readily than did the diabase or the Keewatin.

There appears to have been no difference in the precipitation of ores due to physical-chemical influences of the country rocks. Precipitation seems to have taken place as readily in rocks of any one of the three series mentioned in the preceding paragraph as in the others.

Judging from the way in which silver is found in the minutest cracks in granite boulders of some of the conglomerate near the veins, this ore, at least, was precipitated no less readily in acidic rocks than in basic ones. With the exception of these boulders, there are few opportunities afforded of observing the relations of the ore to granite. But in the Temiskaming mine, a few hundred feet below the surface, narrow dikes of Lorrain granite intrude the Keewatin and are cut across by a vein. The surface of the granite is plated with native silver.

The occurrence of rich silver ore depends on the character of the openings in the rocks now occupied by the veins, on whether the veins have been affected by secondary disturbances, and on the proximity of the openings to the diabase sill. Naturally it would be expected that solutions would work upward through the openings in the hanging wall above the sill more readily than downward into the foot wall. Unfortunately owing to the excessive erosions to which the district has been subjected, there is little of the hanging wall of the sill left in the productive area at Cobalt. But of the veins thus far worked the two or three that occur in the hanging wall are productive to the greatest depth reached in the area.

In the foot wall of the sill, or what was the foot wall before erosion took place, the rich or merchantable ore is limited as to the depth to which it extends. This depth below the sill is variable, depending on the character and strength of the fissures, and other factors already mentioned. Rich ore descends to a less depth in narrow more irregular fissures than in wide ones.

As has been said previously, much the greater part of the ore has come from veins in the fragmental rocks of the Cobalt series in the foot-wall of the sill. These veins, on reaching the contact of the Cobalt series with the underlying Keewatin, either end at the contact, or split into stringers, or continue down into the Keewatin. In many cases the rich ore disappears when the veins penetrate the Keewatin. On the other hand, a few veins in stronger fissures have been found to be productive in the Keewatin, that, before erosion, lay beneath the sill.

In the veins both in the diabase and Keewatin rocks, ore is found to occur more irregularly distributed than in those of the Cobalt series. In other words, it tends to occur in bunches.

The best veins that have been worked in the diabase are one on the Kerr lake property and one on the O'Brien. Of those in the foot-wall of the sill, the best vein in the Keewatin has been No. 26 on the Nipissing.

ORES AND MINERALS.

The more important ores in the veins under consideration are native silver—associated with which is usually some dyscrasite, argentite, pyrargyrite and other compounds of the metal—smaltite, niccolite and related minerals. Many of the minerals occur mixed in the ores, and for this reason some of them have not been clearly identified. Another character of the minerals, which renders their identification difficult, is the fact that most of them occur in the massive form. Crystals when present are small, being frequently almost microscopic in size. The following minerals have been identified and can be conveniently classed under the headings:

I.—Native Elements:

Native silver, native bismuth, graphite.

II.—Arsenides:

Niccolite, or arsenide of nickel, $NiAs$; chloanthite, or diarsenide of nickel, $NiAs_2$; smaltite, or diarsenide of cobalt, $CoAs_2$.

III.—Arsenates:

Erythrite, or cobalt bloom, $Co_3As_2O_8+8H_2O$; and annabergite, or nickel bloom, $Ni_3As_2O_8+8H_2O$; scorodite, $FeAsO_4+2H_2O$.

IV.—Sulphides:

Argentite, or silver sulphide, Ag_2S; millerite, or nickel sulphide, NiS; argyropyrite? stromeyerite? $(Ag, Cu)_2S$; bornite, Cu_5FeS_4; chalcopyrite, $CuFeS_2$; sphalerite, ZnS; galena, PbS; pyrite, FeS_2.

V.—Sulpharsenides:

Mispickel, or sulph-arsenide of iron, $FeAsS$; cobaltite, or sulph-arsenide of cobalt, $CoAsS$.

VI.—Sulpharsenites:

Proustite, or light red silver ore, Ag_3AsS_3; xanthoconite? Ag_3AsS_4.

VII.—Antimonides:

Dyscrasite, or silver antimonide, Ag_6Sb; breithauptite, $NiSb$.

VIII.—Sulphantimonites:

Pyrargyrite, or dark red silver ore, $Ag_3\ SbS_3$; stephanite, $Ag_5\ SbS_4$; polybasite? $Ag_9\ SbS_6$; tetrahedrite, or sulph-antimonite of copper, $Cu_8Sb_2S_7$; freibergite? (silver-bearing tetrahedrite).

IX.—Sulphobismuthites:

Matildite, $AgBiS_2$; emplectite, $CuBiS_2$.

X.—Mercury:

Amalgam?

XI.—Phosphate:

Apatite.

XII.—Oxides:

Asbolite; heubachite?; heterogenite?; arsenolite; roselite?

XIII.—Veinstones:

Calcite, dolomite, aragonite, quartz, barite, fluorite.

The table contains a few minerals that have been found in only one or two veins and cannot be considered characteristic. Millerite, for instance, is of rare occurrence, and emplectite has been found only in the Floyd mine, near Sharp lake, in the western part of the Cobalt area. Bornite, chalcopyrite, zinc blende, galena and pyrite are not characteristic of most of the ore, these minerals occurring more frequently in the wall rock or in non-silver bearing ore of the Keewatin, but one or two mines have produced copper with cobalt-silver ore. Apatite in recognizable crystals has been found in the ore of only one mine. Mercury appears to occur in the ore of all the mines that contain high values in silver, but whether it occurs only as amalgam or in other forms has not been determined. Among the veinstones, aragonite is found but rarely, at least in easily recognizable form, while barite and fluorite have not been observed in the veins at Cobalt proper.

A question mark has been placed after the names of several minerals in the table which have been reported to occur in the veins but the identification of which has not been made complete by chemical analyses or crystallographic measurements.

Gold in small quantity has been found in a number of veins, especially in those in which cobaltite or mispickel are characteristic minerals.

A characteristic of the group is the subordinate part which sulphur plays in comparison with arsenic. Antimony, which is not abundant, is found in some compounds where one would expect to find arsenic, since the latter is so much more abundant. For instance, while both native silver and arsenides occur in abundance, the compounds of arsenic and silver are found only in small quantity. Then one would also expect to find more compounds of bismuth since this metal occurs in the free state in considerable quantities in some parts of the deposits. It might also be expected that native arsenic would occur at times.

Nearly all the chemical groups of minerals found in the celebrated Joachimsthal deposits of Bohemia are present in the Temiskaming ores. The most important exception is uraninite or pitchblende, which came into prominence a few years ago on account of its being the chief source of the element radium.

ORDER OF DEPOSITION OF MINERALS.

The following table shows, in descending order from the youngest to the oldest, the general succession in the order of deposition of the principal minerals of the Cobalt area proper. There appear to be, however, minor exceptions to this order.

III. Decomposition products, e.g., erythrite or cobalt bloom, annabergite and asbolite.

II. Rich silver ores and calcite.

I. Smaltite, niccolite and dolomite or pink spar.

After the minerals of group I. were deposited the veins were subjected to a slight movement. In the cracks thus formed the minerals of group II. were deposited. A few veins that escaped the disturbance do not contain silver in economic quantity.

This order of deposition appears to be the same as that of the minerals in the Annaberg deposits of Germany and in those of Joachimsthal, Austria.* At Annaberg the uranium ore or pitchblende is said to have been deposited earlier than the rich silver ores and later than the cobalt-nickel minerals, while barite, fluorite and quartz were deposited prior to the latter. At Annaberg there are thus considered to have been broadly five periods of deposition, while at Cobalt there have been but three, minerals representing the first and third periods being absent.

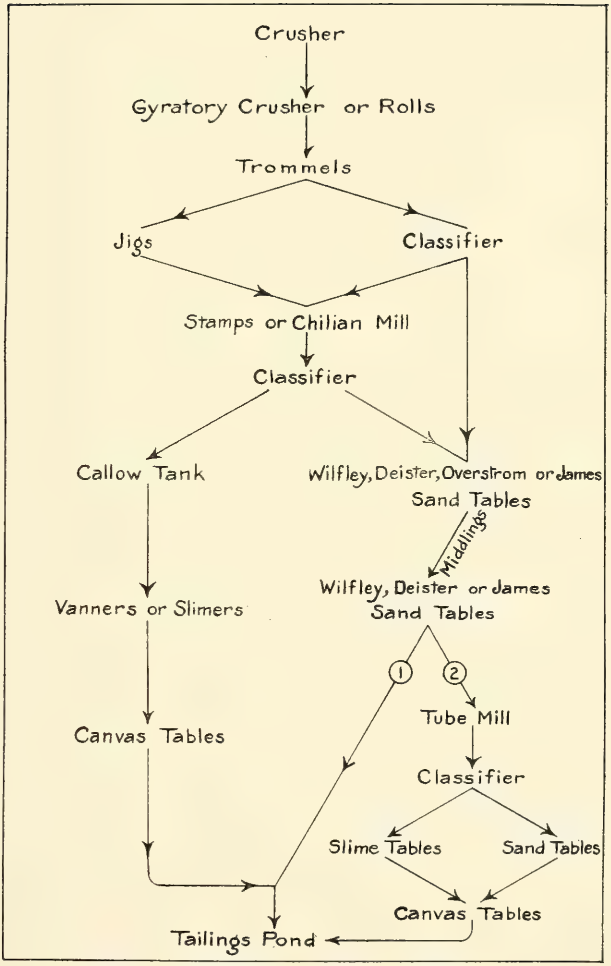
MINING AND MILLING.

Descriptions of the working mines, and of the methods employed in mining and milling, in the Cobalt area, are given in part I of the Annual Reports of the Ontario Bureau of Mines, and in the Annual Reports of Mr. A. A. Cole to the Temiskaming and Northern Ontario Railway Commission.

BIBLIOGRAPHY.

References to most of the literature on the Cobalt and adjacent areas are given in the report on the "Cobalt-Nickel-Arsenides and Silver Deposits of Temiskaming," fourth edition, published by the Ontario Bureau of Mines, Toronto, 1913.

*Beck, "The Nature of Ore Deposits," Weed's translation, pages 285, 289.

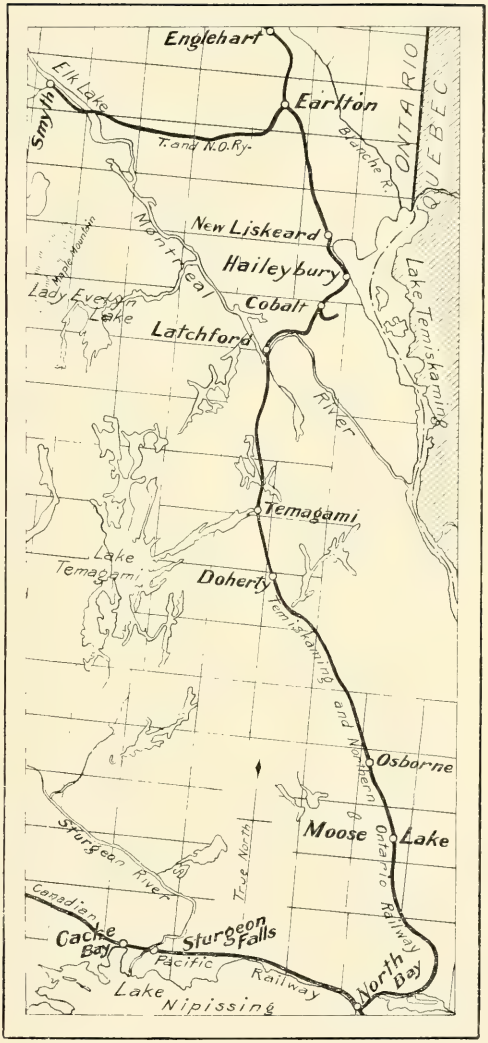


General flow sheet, Cobalt concentrators.

ANNOTATED GUIDE.

SUDBURY TO NORTH BAY.

Miles and Kilometres.	
439.2 m. 708 km.	Just east of the station at Sudbury there is a hill of gabbro. Beyond this a conglomerate, called the Ramsay lake conglomerate, outcrops all along the north shore of the lake for two miles. This conglomerate overlies a quartzite which occurs toward the easterly end of the lake.
432.2 m. 697 km.	(Altitude 841 feet). The quartzite is well exposed around Romford junction, showing the beds of the stratified rock dipping about 45 degrees S.
431. m. 695. km.	The Mond Nickel Company have erected a copper-nickel smelter about one mile south of Coniston to treat the nickeliferous pyrrhotite ores from Victoria mines and other properties. Just east of Coniston a tongue of greenstone crosses the track.
427.1 m. 689. km.	(Altitude 799 feet). Near Wanapitei station there is a contact of the quartzite and Laurentian gneiss to the east. This contact follows for some distance the northeast-southwest course of the Wanapitei river. Between Wanapitei and Sturgeon Falls the railway follows a series of valleys in the Laurentian. In these valleys are several towns about which there are small areas of good agricultural land. All the rock exposed along the railway east of Wanapitei is Laurentian gneiss.
383.3 m. 618. km.	(Altitude 687 feet). At Sturgeon Falls the water power is utilized by a mill in the manufacture of pulp from spruce wood which is floated down the Sturgeon river. Reddish Laurentian gneiss is well exposed about the dam at the pulp mills.
360. m. 580. km.	(Altitude 654 feet). For a few miles west of North Bay the railway skirts the north shore of Lake Nipissing, which is 90 miles long and 20 miles wide. Immediately west of North Bay the Laurentian is concealed by a covering of drift.



Route map between **North Bay** *and* **Englehart**

Miles
10 0 10 20 30

Kilometres
10 0 10 20 30 40 50

The town of North Bay (population about 8,000) is a divisional point on the Canadian Pacific railway, and also the southern terminus of the Temiskaming and Northern Ontario railway. Both the Grand Trunk and Canadian Northern railways have lines into the town.

ANNOTATED GUIDE.

NORTH BAY TO TEMAGAMI, COBALT AND HAILEYBURY.

Miles and Kilometres.

For 64 miles (103 km.) north of North Bay, as far as the station of Doherty, the railway crosses a monotonous succession of Laurentian gneisses, which in many areas are characterized by a strikingly banded structure. Generally speaking these gneisses may be said to consist dominantly of pink or light grey bands, and subordinately of dark-colored or black bands, all having the composition of granite, save some of the darker types. Regarding the age relation of the light-colored and dark-colored bands, it may be said that the former are seen in some cases to be intrusive into the dark bands, but that more often it is difficult or impossible to determine what the relation is. The dark bands are certainly in part elongated fragments of Keewatin greenstones. Both dark and light bands are injected by pink granite and pegmatite, either parallel with or cutting across the schistosity.

0.0 m. 0.0 km. Leaving North Bay the elevation of which is 654 ft. (199.4 m.) the railway climbs a heavy grade for 21.5 miles (34.7 km.) reaching an elevation of 1,290 ft. (393.3 m.) above sea level, that being the highest point on the track in the 479 miles (772.5 km.) which separate Toronto from Cochrane. For about a mile (1.6 km.) from North Bay the banding of the gneisses is very striking. The darker bands contain biotite or hornblende. To the east of the railway for a few miles the gneisses become in places thickly studded with garnets and they may then be referred to as garnet schists. These schists are often intricately contorted, and are similar to certain schists in Eastern Ontario which are commonly classed with the Grenville series.

10.1 m. Between mileage 1 (1.6 km.) and mileage
16.3 km. 10.1 (16.3 km.) the gneisses are much covered with superficial deposits, but pink, grey and brown types were noted, holding few dark bands.

What may be referred to as the Mulock gneiss occurs in the area about Mulock station,
18.0 m. altitude 1,222 ft. (372.6 m.). It is a coarse-
29.1 km. grained, pink biotite variety in places having a marked "augen" texture. This gneiss lacks the striking banding of the rocks at North Bay. Pink, light-colored gneisses with subordinate areas of the dark banded types occur between
27. m. mileage 21.5 and Tomiko, altitude 1,167 ft.
43.6 km. (355.9 m.). On the other hand the country between Tomiko and mileage 35 is underlain
35. m. by a banded, dark, glistening biotite gneiss, in
56.5 km. which pink gneiss is subordinate in amount.

47. m. For the next twelve miles, as far as the
75.6 km. station of Bushnell, altitude 996 ft. (303.5 m.), the rocks are poorly exposed, the last seven miles being covered by "muskeg."

56. m. Between Bushnell and Redwater, altitude
90. km. 1,015 (309.3 m.), a dark biotite gneiss first predominates; as Redwater is approached the dark bands become hornblendic and chloritic, one small lense held by the pink gneiss consisting largely of chlorite. This latter resembles a fragment of Keewatin greenstone schist. Both pink and dark gneisses are injected by granite pegmatites, cutting across or parallel with the bands.

A variety of granitic rocks occurs between
64. m. Redwater and Doherty, altitude 1,063 ft. (324
103. km. m.). Thus, for the first three miles north of Redwater pink gneisses predominate holding

subordinate areas of grey or dark gneiss. Between mileage 59 and 60 the rock is a massive red granite, gneissoid in part and not often banded. The next two and a half miles disclose banded gneisses, many of the dark bands of which are as basic as certain Keewatin hornblende schists. Between mileage 62.5 and 64 a coarse, massive, hornblende granite is well exposed. Dikes of fresh diabase, resembling the olivine diabase dikes of the Sudbury nickel area, are to be seen between mileage 56 and 64.

At Doherty, mileage 64, the first exposures of pre-Cambrian sediments make their appearance. A series of conglomerate, greywacké, and slate-like greywacké, resting in horizontal position, lie unconformably on the massive, hornblende granite last mentioned. This series of sediments, which is known as the Cobalt series, holds numerous pebbles and boulders of the underlying granite. Contacts of the conglomerate and granite occur at the railway station.

65.5 m.
105.3 km. About one and one-half miles north of Doherty fine-grained hornblende schists of the Keewatin series are well exposed. These are cut by light-grey dikes of quartz or granite-porphyry. On the east side of the track the conglomerate of the Cobalt series rests on the upturned edges of the hornblende schists.

66. m.
106.1 km. One-half mile farther north, outcrops of Nipissing diabase occur. This rock is widely distributed in Northern Ontario, and is of importance because of the fact that it is closely connected, genetically, with the phenomenally rich silver-cobalt veins which occur near the town of Cobalt, 36 miles (57.8 km.) to the north.

72. m.
115.8 km. Between mileage 66 and Temagami, altitude. 989 ft. (301.3 m.), good outcrops of Keewatin schists and conglomerate of the Cobalt series are seen. South of Temagami grey sericite schists of the Keewatin series have resulted from the metamorphism of quartz-porphyries.

Temagami lake is one of the most beautiful sheets of water in Northern Ontario, a fact which caused the building of three summer hotels on its shores. The railway station lies at the east end of what is known as the North-east Arm of the lake. A few hundred yards north of the station conglomerate of the Cobalt series may be seen resting on the jagged edges of Keewatin greenstone schists. While to the west of the track about two hundred yards splendid outcrops of the Keewatin iron formation (jaspilyte) occur. The latter, which is 1,000 ft. wide in places, is easily reached by a foot-path, and consists of silicious magnetite inter-banded with variously colored jaspers and cherts, with in some instances a small proportion of hematite.

94. m.
151.2 km. Between Temagami and Latchford, altitude 922 ft. (281 m.), the railway passes successively over granite, conglomerate, slate-like greywacké, quartzite, diabase, and red, banded greywacké. The latter is well exposed on the cliffs bordering the railway south of Latchford.

98. m.
157.6. km. For the next four miles, as far as Gillies, altitude 934 ft. (284.6 m.), the railway closely follows the Montreal river, which empties into lake Temiskaming 21 miles to the southeast. At Latchford the river, which for the most part pursues a steady southeasterly course, bends sharply to the northeast until Gillies station is reached when it takes its normal direction again to the southeast. Below Gillies several miles, at Hound and Ragged chutes, important falls on the Montreal river have been utilized to supply compressed air and electric energy for the silver mines at Cobalt. At Ragged chute the air is compressed by a simple and ingenious hydraulic method, and is conveyed directly to Cobalt in a 24-inch pipe.

Leaving Gillies station the railway passes over Nipissing diabase, Keewatin greenstones, and conglomerate and greywacké of the Cobalt
103. m. series, to the town of Cobalt, altitude 973 ft.
165.7 km. (296.5 m.). The town is built on the west side of Cobalt lake, a small, narrow body of water about a mile in length. The population of the town, according to the census of 1911, is 5,638.

107. m. There is a steady descent of the railway for
172.1 km. about four miles to the town of Haileybury, altitude 766 ft. (233.4 m.), on lake Temiskaming. The rock-cuts and cliffs along the way show exposures of conglomerate and greywacké of the Cobalt series, and also of the Nipissing diabase.

THE PORCUPINE AREA

BY

A. G. Burrows.

CONTENTS.

INTRODUCTION.

The Porcupine gold area, which for the past four years has attracted much attention, is situated on the Hudson Bay slope of northern Ontario. The latitude of Niven's First Base Line of 1899, which runs through the centre, forming the south boundary of Tisdale and Whitney, is 48° 27′ 54″; consequently the area is somewhat farther south than the Canada-United States boundary in Manitoba and other western provinces. The camp is in the Temiskaming judicial district. Lying along the southern fringe of the great clay belt of Northern Ontario, it adjoins a prospective farming country. In this belt many townships have been laid out in six or nine-mile squares and subdivided into concessions and lots; in the gold area itself and in the adjoining country to the north, many half lots containing 160 acres each have been granted to veterans as homesteads.

During the last two years there has been little extension of the gold-bearing area beyond what was known in 1910. The discoveries of Hollinger and Wilson of 1909, now the Hollinger and Dome mines respectively, still remain the most important that have been made, while Tisdale is by far the most important township.

Ingress to the Area.

A branch line of the Temiskaming and Northern Ontario railway has been constructed from Iroquois Falls (on the main line), in a southwesterly direction to the town of Timmins, a distance of 33½ miles.* Timmins by railway is 485 miles distant from Toronto.

A number of townsites have been established in the area. The most important of these are: Porcupine, South Porcupine and Lakeview, situated on Porcupine lake; Schumacher, on Pearl lake; Timmins, west of Miller lake; and Mattagami, on the Mattagami river.

Elevation of the Area.

In elevation the area averages about 1,000 feet† above mean sea level. In this respect it is similar to Cobalt, which

* 0.621 mile = 1 kilometre. † 3.28 feet = 1 metre.

Street in South Porcupine, March, 1912.

lies 100 miles to the southeast, south of the height of land. The divide between the Hudson Bay and the St. Lawrence waters is not pronounced, being only about 1,300 feet above sea level.

The highest elevation near Porcupine is along the south boundary of Jamieson, where a felsitic ridge has an altitude of 1,350 feet above sea level.

The country from Night Hawk lake to the Mattagami river is one of low relief. Occasional ranges of hills reach an elevation of 150 feet, but generally abrupt changes in elevation are less than 50 feet. Often in a low area rocks outcrop only a few feet above the surrounding drift and are only a fraction of an acre in extent. Northwest, south, southwest and southeast of Porcupine lake the country is somewhat elevated, and rock exposures are more frequent than in most of the area.

The First Prospecting.

Previous to the building of the Temiskaming and Northern Ontario railway, the area was difficult of access and little prospecting was done in it until 1909.

In 1906 some work was done by prospectors on a vein near Miller lake and a few hundred feet from the present Hollinger vein. Evidently seeing no gold, and having no assays made, they abandoned the property. In the same year claims were staked in Shaw township on what is described in the application as a " vein of sugar quartz and hematite iron." This is of interest since the so-called vein is simply the upturned edges of the Keewatin iron-formation.

In 1908 claims were staked by Mr. H. F. Hunter on the east shore of Porcupine lake in Keewatin formation. Gold was found disseminated through quartz and schist in a sheared zone.

It was not, however, until the following year that the spectacular discoveries of J. S. Wilson, on what is now the Dome property, caused a rush to the district, and in a few weeks practically all of Tisdale and a great part of the adjoining townships and unsurveyed territory were staked out in mining claims.

Superficial Deposits.

The area is for a considerable part drift-covered. These drift deposits consist largely of stratified clays, sands and gravels of post-Glacial age; and in addition there are patches of morainic material. Sections of stratified clay, overlain by sand, are well exposed on the Mattagami river, north of Pigeon rapids, and along the shores of Night Hawk lake. Most of the islands in this lake have a rocky shore line, but are capped by stratified material. Where the soil has been removed the rocks are seen to have been intensely glaciated. The fine-grained greenstones have well preserved the scratches and grooves produced by glaciation. On several islands were noted two sets of striations, S. 15° W. mag., and S. mag., the latter representing the later ice movement. Owing to the lack of drainage, much of the country, though higher than the rivers and lakes, is very wet, but would be suitable for agricultural purposes if properly drained. For a description of the agricultural possibilities of the country the reader is referred to reports by Mr. A. Henderson.*

Forest Fires.

During the past two years forest fires have greatly ravaged the area around Porcupine. About the middle of May, 1911, a fire completely destroyed the surface workings and buildings of the Hollinger mine. From that time forest fires were burning in the area until the middle of July. On July 2nd, the buildings of the Dome Extension and part of the townsite of Pottsville were destroyed.

The greatest fire of the year occurred on July 11th, when, after a prolonged dry season, a hurricane from the southwest brought up a fire which did the greatest damage. The surface workings and buildings of the Dome, West Dome, Vipond, Standard, Preston East Dome, North Dome and several other properties were entirely destroyed. The town of South Porcupine was completely wiped out, and almost all that part of Pottsville which escaped the fire of July 2nd. The north part of Porcupine (Golden City) was also destroyed. This

* Agricultural Resources of Abitibi, Bur. Min., Vol. XIV. (1905); *Idem* Vol. XV. (1906).

Stratified clay at Sandy Falls, Porcupine area.

fire was attended by a great loss of human life, 71 in all having lost their lives either by being burned, suffocated or drowned.

Timber.

In the parts which have escaped the fires there is a dense growth of timber, including white and black spruce, jackpine, birch and poplar. It is interesting to note that a growth of young tamarac is replacing the old tamarac trees, which have all been destroyed in recent years by the larch saw-fly.

GEOLOGY.

The compact rocks of the area may all be referred to the pre-Cambrian, and are similar to those of the Cobalt area, described on preceding pages. However, only the Keewatin and Temiskaming series are of importance in the part of the area that is productive at present. The following table shows the age relations.

Pleistocene.

Post-Glacial.—Stratified clay, sand, and peat.
Glacial.—Boulder clay.

Pre-Cambrian.

Later Intrusives.—Quartz-diabase, olivine-diabase, etc.

Igneous contact.

Cobalt Series.—Conglomerate.

Unconformity.

Temiskaming Series.—Conglomerate, quartzite, greywacké, slate or delicately banded greywacké.

Unconformity.

Laurentian.—A complex of granites older than the Cobalt series. It intrudes the Keewatin, but its relationship to the Temiskaming is not definitely known; it may be in part older and in part younger than the Temiskaming series.

Igneous contact.

Keewatin.—The series consists chiefly of basic to acid volcanics, much decomposed, and generally schistose; amygdaloidal basalts, serpentine, diabase, quartz or feldspar porphyry, felsite, iron-formation and rusty weathering carbonates, and other rocks have been recognized.

Keewatin.

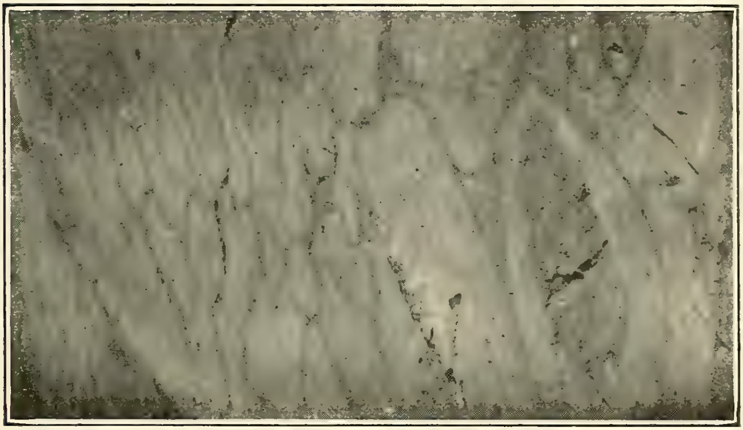
The Keewatin has a much greater distribution in the Porcupine area than the other members of the pre-Cambrian, and it is also of more importance economically, since it contains the greater number of the gold-bearing veins which have so far been discovered.

As in other parts of Ontario, the series is highly metamorphosed, and many rocks are so much altered as to give little evidence of their original character. However, much of the series can be seen to consist of basic and acid volcanics such as basalts and porphyries, with intermediate types, although these are often altered to schists. Where schistose, the general strike over a considerable area is found to vary from east and west to northeast and southwest, while the dip is generally steep to the north.

Basic Rocks. Among the more massive rocks are greenstones (basalts, etc.), which frequently show a striking ellipsoidal or pillow structure. Amygdules often accompany this structure and occur most abundantly along the rims of the ellipses. The centres of the ellipses are often bleached to a light greenish or whitish color, whereas the margins are considerably darker. This structure is frequently seen in the northwest part of Whitney township. It is very pronounced in the greenstone along the shores of Night Hawk lake and on the islands in this lake. On the main land, opposite Callinan's island in Night Hawk lake, the ellipsoidal greenstone has been rendered quite schistose, so that the structure appears as alternate light and dark bands. Some of the greenstones have been brecciated and resemble conglomerate.

Serpentine occurs in parts of the area in large volume. The range of hills immediately southeast of Porcupine lake are largely composed of this rock, which is impregnated with much carbonate. Occasional veinlets of fibrous asbestos are seen. A section of a sample of serpentine rock from the southeast shore of Porcupine lake is made up largely of fibrous serpentine, together with residual iron oxides which in arrangement suggest original crystals like olivine. The remainder of the rock is dolomite. A chemical test showed the absence of chromium oxide in this rock.

A spotted rock, from the northeast part of the West Dome in lot 5 in the first concession of Tisdale, is probably an altered amygdaloidal lava. The schistose matrix consists of secondary material, dolomite, sericite, etc., and the amygdules, whose margins are stained with limonite, are filled with calcite, sericite, and quartz. Some of the amygdules are an inch in length.



Ellipsoidal, Keewatin, greenstone, Night Hawk lake.

An amygdaloidal rock from the 100-foot level of the Vipond mine is entirely decomposed. The amygdules are now stained with red iron oxide and show much clear calcite. Rims of chlorite surround the amygdules, along which are scattered grains of magnetite. There are also some minute grains of a secondary mineral, quartz or feldspar.

A sample from the main shaft at the Dome Extension is quite schistose in thin section. Rods of plagioclase can still be recognized, while the ferro-magnesian mineral is entirely altered to chlorite. Quartz is present in small grains, and calcite is abundant. Secondary feldspar is present in the form of clear grains. The rock may have been a diabase or basalt, but is now much altered.

Acidic Rocks. The light-colored, more massive rocks are principally quartz-porphyries and felsite, which in places intrude the more basic rocks. When the porphyry occurs in some volume, as around the Hollinger mine, the name rhyolite has been applied to it. Much of the porphyry has been altered to a sericitic schist, and frequently a rather massive rock can be traced into a very schistose one. This change can be well seen in the porphyry to the southwest of the Dome mine workings. A porphyry from the south half of lot 4 in the first concession of Tisdale, examined in thin section, shows the phenocrysts to be largely plagioclase feldspar, while quartz in rounded grains is also present. The groundmass is made up principally of plagioclase feldspar and quartz. Laths of tourmaline are scattered through the rock.

The schist at the surface, and at 50 feet in No. 1 shaft of the Hollinger mine, is fine in grain and of a light grey color when fresh. The groundmass consists essentially of sericite (or talc), dolomite, quartz and feldspar. In this occur round and irregular eyes of quartz which may represent phenocrysts in the original rhyolite or quartz-porphyry from which the schist has probably been derived. Cubes of iron pyrites are commonly set in the rock. Other thin sections from the grey schists on the Timmins properties have about the same group of minerals, and most of them effervesce with hydrochloric acid.

The somewhat massive rhyolite exposed just southeast of Miller lake is made up of a fine-grained matrix of quartz, feldspar and sericite, in which are set small phenocrysts of quartz and feldspar. The rock is much impregnated with dolomite.

A sample of schistose rock from the 140-foot level of the Bewick-Moreing shaft, east of Pearl lake, shows an abundance of sericite, chlorite and calcite, with numerous quartz grains. The rock is entirely altered, but some of the quartz grains may be remnants of phenocrysts.

A sample of schistose quartz-porphyry from south of the Dome mine workings shows phenocrysts of quartz and feldspar in a fine-grained groundmass of these minerals.

Narrow quartz veins in Keewatin carbonate schist at Dome property, Nov., 1910.

The extinction angle of some of the feldspar phenocrysts is near that of oligoclase-albite. Sericite scales are often grouped around the crushed feldspar crystals and have penetrated them. Cubes of iron pyrites are abundant.

In addition to the quartz-porphyry there are numerous dikes of a grey feldspar-porphyry. These are generally less than 100 feet in width, and south of Porcupine lake on the Edwards claim intrude the schistose quartz-porphyry. One such dike of feldspar-porphyry, on H. R. 1,043 in Deloro townhip, has been prospected for gold. The dike is intersected with minute stringers of quartz in which most of the gold occurs. A thin section of the rock shows the phenocrysts to be an acid plagioclase which is fairly fresh, but is partly invaded by scales of sericite. Plagioclase is also prominent in the groundmass.

At times the Keewatin has been much crushed and broken, so that the rock has the appearance of a conglomerate; so much so that in the vicinity of the Dome mine, where greywacké and conglomerate occur, it is impossible to draw a close line of distinction between the autoclastic rock and the true conglomerate.

Iron-Formation. Banded iron-formation, grouped with the Keewatin, has an extensive development in parts of the area. It outcrops frequently in the southwest part of Whitney township, in the first and second concessions. The disturbance in the formation here has not been so great as in other areas. Often the bands are lying almost horizontally. In places they have been somewhat brecciated, but are otherwise little disturbed. The bands are alternate reddish or greyish sugary quartz and magnetite or hematite. Sometimes the narrow bands of magnetite, one-eighth inch thick, carry a merchantable percentage of iron, but these are relatively subordinate in comparison with the main mass of rock. It is unlikely that merchantable iron ore will be found in quantity. In parts of the formation iron pyrites replaces the magnetite. Almost horizontal, interbanded iron pyrites and silica are seen on the south half of lot 5 in the second concession of Whitney. A sample of banded quartz and iron pyrites gave 40 cents in gold per ton. Iron pyrites occurs in considerable quantity with a sugary quartz on lot 9 in the second concession, and might be worthy of investigation as a source of sulphur.

Carbonate Rocks. In various parts of the area, associated with Keewatin rocks, are carbonates to which various terms have been applied, such as dolomite, ferro-dolomite, ferruginous carbonate and ankerite.

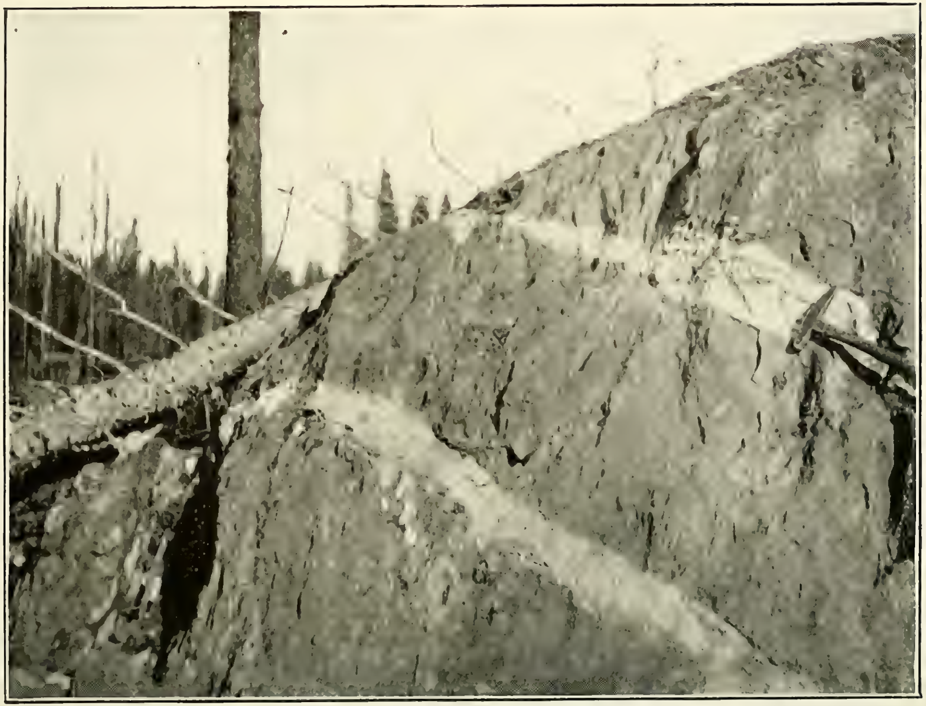
There is much uncertainty as to the origin of this rusty carbonate rock in different parts of the area. The carbonate may occur in at least four different forms, namely, as original bedded material, as a replacement, as vein filling, and as a decomposition product of basic, igneous or other rocks.

That there has been considerable migration of carbonate solutions is shown by the manner in which almost all the rocks of this area are more or less impregnated with it. Sections of quartz-porphyry schist show the presence of much calcite as a secondary mineral. Veins and veinlets of ankerite occur frequently, not only in basic rocks, but in the quartz-porphyry.

Laurentian.

A few outcrops of granite occur in the township of Whitney. This granite is a medium-grained biotite variety, and not typical of that occurring in large volume to the north and south of the area. In south Whitney it intrudes light-colored porphyry of Keewatin age, but its relation to the Temiskaming is not known.

While typical granites do not outcrop in the immediate vicinity of Porcupine, they occur in large volume to the north, west and south of the area, and are known to intrude the Keewatin. Where the granites are exposed over large areas they are medium to coarse in grain, and have been exposed at depth by extensive erosion. It is considered that some of the granophyre, porphyry and felsite rocks are dike representatives of the granites, which very likely underlie the Keewatin and Temiskaming formations at Porcupine. The predominant feldspar of the acid dikes is a plagioclase (near albite), which is also prominent in many of the granites.



Narrow quartz veins (auriferous) cutting conglomerate at Three Nations Mining Co.'s property. Sept., 1911.

The Temiskaming Series.

This series of rocks has been described in preceding pages in connection with the Cobalt area.

At Porcupine the series is of much greater economic interest than at Cobalt, since important gold deposits have been found in it.

The largest area of these rocks at Porcupine stretches from the Dome mine in a northeast direction for about ten miles. It consists of slate, quartzite and conglomerate which have generally been greatly disturbed. The beds have been highly tilted, dipping at angles of 70° to vertical. A secondary cleavage has frequently been developed, and the rocks have been rendered quite schistose. The general direction of the strike is from N.E.-S.W. to E.-W. In this respect the series is related to the Keewatin which has a corresponding strike. It is evident that much of the deformation of the Keewatin was post-Temiskaming.

The sediments at the Dome have been greatly altered to schists. Similar rocks around Three Nations lake have been less altered, and, except for a high dip, greatly resemble the Cobalt series.

The succession of Temiskaming strata is well shown at the property of the Three Nations Mining Company on lot 5 in the fifth concession of Whitney. Along the line between the fifth and sixth concessions very much altered Keewatin rocks, now largely serpentine and rusty carbonate, are exposed. The contact with the Temiskaming conglomerate practically follows this line. Here, at the base of the conglomerate, are numerous fragments of rusty-weathering Keewatin rocks; while farther to the south there are numerous pebbles of acid rocks, including quartz-porphyry, felsite, etc. The conglomerate is overlain by a narrow band of fine-grained black slate, which splits in very thin layers. Overlying the slate is a greywacké which becomes coarser towards the south. About half a mile south of the concession line the rock is quite coarse-grained, and may be called an arkose-like quartzite. Throughout the Temiskaming series there is considerable carbonate, and many samples effervesce briskly with acid.

It should be noted that no granite pebbles were found in the conglomerate. It is believed that the series was laid down when the surface rocks were largely volcanics, and that the intrusion of at least part of the granite came after the deposition of the Temiskaming, but prior to the Cobalt series.

At the North Dome there is a strikingly banded rock which was originally a succession of fine clay and rather coarse sand layers. A secondary cleavage is developed at a low angle with the upturned edges of the strata.

On the Foley-O'Brian the sediments in addition to being highly tilted show a wavy structure along the strike.

At the Dome property, in contact with large quartz masses, is a conglomerate which is likely basal. On the weathered surface the included fragments of porphyry, greenstone, schist, etc., are conspicuous, but in freshly broken pieces the conglomeratic character is easily overlooked, since the rock breaks in prismatic blocks resembling schist. The included pebbles are frequently drawn out in the direction of the schistosity.

The Cobalt Series.

The younger series of pre-Cambrian sediments has been observed only in small volume on the south boundary of Langmuir township, about 15 miles to the southeast of Porcupine lake.

Later Intrusives.

In all parts of the area are basic dikes which generally are less than 100 feet in width. These dikes appear to here represent the Nipissing diabase of Cobalt and the later intrusives of that area. At Porcupine they are believed to be much younger than the gold deposits.

Contact of quartz and schist on the N. W. wall of No. 4 vein, Hollinger mine, where vein was intersected in the first cross-cut from No. 1 vein on the 100-foot level. Width of exposure, 6 feet.

THE GOLD DEPOSITS.

Origin.

It has been suggested, in the notes accompanying the editions of the Porcupine map, that the quartz veins of the area are the result of a granitic intrusion, the immense quantity of quartz present in the veins having been supplied by the acid magma as a differentiation product. The primary quartz of the veins shows evidence of having been deposited under pressure, as it contains numerous cavities of gas and liquid inclusions. The quartz has filled the fissures rapidly, as there is generally an absence of well-defined walls, except where there has been secondary movements. Quartz and rock are often cemented, forming a contact like that of an intrusive.

Mr. C. W. Knight noted the occurence of feldspar in a quartz vein on the Miller-Middleton, one of the Timmins locations, and suggested the relationship of the deposit to granite or pegmatite dikes. The feldspar which is an acid plagioclase has also been noted in other veins, including the No. 1 vein of the Hollinger, the Rea vein, and in many of the narrow veins in the vicinity of Three Nations lake. The feldspar is most abundant near the margins of the veins. The extinction angle of the feldspar in the veins on the Three Nations Lake Mining Company's claim shows it to be very near albite. A chemical analysis of this feldspar gave: Soda, 10.37 per cent.; potash, 0.90 per cent.

The mineral scheelite, calcium tungstate, occurs in some of the veins around Pearl lake as one of the earliest constituents. It has been found in the Jupiter, Plenaurum, McIntyre and Hollinger, but only in very minor quantity. It is interesting to note that scheelite generally occurs with minerals like topaz, cassiterite, tourmaline, and arsenopyrite in pegmatitic veins, which are considered to have a genetic relationship with granites. The presence of scheelite in the Porcupine veins may point to the pegmatitic origin of the veins in this area.

Tourmaline occurs quite frequently, not only as a later mineral in the veins but with the original quartz, as at the Dome Extension, West Dome and other properties.

Arsenical pyrites is abundant in the quartz veinlets on the McAuley-Brydges claim in Bristol township.

Quartz masses in contact with schistose-conglomerate, Dome mine, Nov., 1910.

The following sulphides have been recognized in veins at Porcupine: iron pyrites, copper pyrites, pyrrhotite, arsenical pyrites, galena and zinc blende. Of these the most abundant is iron pyrites, which occurs in some quantity in all the gold-bearing veins. Copper pyrites, galena and zinc blende, although also widely distributed, occur in minor quantity. Pyrrhotite is the chief sulphide in the veins which are being developed in No. 4 shaft of the Dome Extension.

Only one telluride has been recognized, occurring in the quartz-carbonate deposit at the Powell claim, M.E. 20, in Deloro township. A chemical analysis of the mineral gave the following results, silver 61.88 per cent, gold 0.10 per cent., with strong reactions for tellurium, indicating the mineral hessite. Native gold occurs as a later constituent in minute seams in the hessite.

In support of the theory of the relation of the quartz veins of Porcupine to granite intrusions, may be mentioned the following:

1. The irregular occurrence of the quartz in many of the deposits, in lenticular masses, resembling pegmatite dikes.

2. The occurrence of feldspar, scheelite, and tourmaline in the quartz in several deposits.

3. The great pressure at which the quartz has been deposited, indicated by the presence of liquid inclusions and gas bubbles. These are frequently seen in quartz in granites.

4. The frozen contacts of quartz and enclosing country rock. The free walls seen at some properties indicate a secondary movement in the quartz, since these walls are slickensided. Where free walls exist they may be either the hanging or foot wall, while the other wall is indistinct—grading into the country rock.

5. The occurrence of narrow felsitic dikes, frequently cut by minute veinlets of quartz, which represent the final solidification of the felsitic magma, and which frequently carry gold values as on Night Hawk lake.

Character of the Gold-Bearing Deposits.

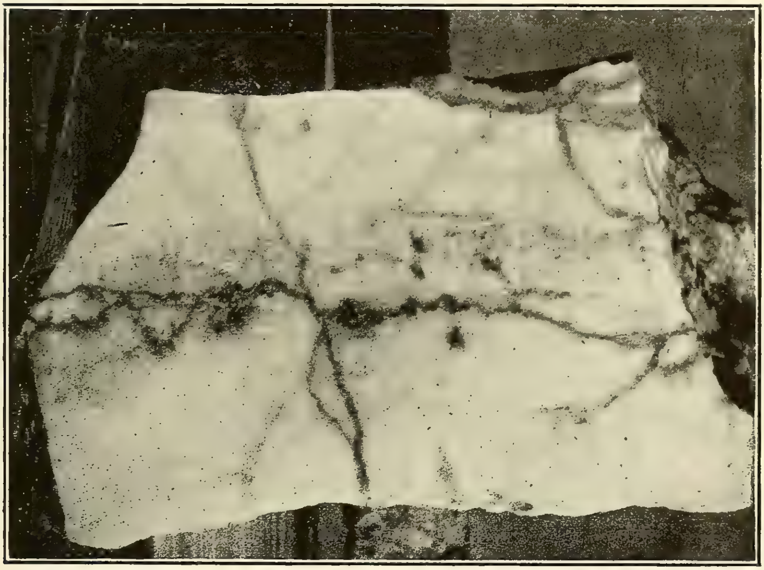
The occurrence of gold at Porcupine is associated with the quartz solutions which circulated through the fissures in the Keewatin and Temiskaming series. The irregular fissuring has produced a great variety of quartz structures,

Part of "Golden Stairway" vein containing spectacular gold showings, Dome mine. The lenticular character of the deposit is shown; the rock enclosing quartz is slate, Oct., 1911.

varying from the tabular, though often irregular or lenticular, vein which may be traced several hundred feet, to mere veinlets, often only a fraction of an inch in width and a few feet in length, which ramify through a rock that has been subjected to small irregular fissuring. This latter variety is well illustrated in the fissuring of ankerite bands, so characterictic of some of the gold deposits of Porcupine. Irregular and lenticular bodies of quartz often occur which may have a width of ten or twenty feet, but which die away in a distance of fifty feet. Again, there are dome-like masses of quartz which are elliptical or oval in surface outline. In some parts at least these masses can be seen in contact with underlying rocks at a low angle, which would suggest that they are broad lenticular masses which have filled lateral fissures in the country rock. The most conspicuous dome masses are those of the Dome property, where the two largest are about 125 feet by 100 ft. A fissure may be vertical and regular at some points. At others it may incline at a lower angle to the horizontal or take on a more or less lenticular form.

The term "vein" as here used is not confined to the filling of a single fissure with well-defined walls, for this type of vein is rather the exception in the Porcupine area. The fissuring has been so irregular that a "vein" in one part may consist largely of quartz, and in another part of numerous veinlets of quartz and intervening schist, resembling a stockwerk; again, the main part of a vein may be almost vertical in attitude, but many veinlets, branches from the main vein, may extend laterally into the country rock. It is often found that the values are obtained in parts of the vertical vein which have been subjected to a later movement and enrichment, whereas the lateral veins have little or no value. This is illustrated in the No. 1 vein at the Rea mine.

The relationship of the strike of the veins to that of the enclosing rock is often difficult to determine, since generally along the veins there has been shearing of the country rock which may conform to the general direction of the strike of the veins. However, by determining numerous strikes in the schist away from the veins, it is seen that the majority of them are inclined to the strike of the enclosing rocks. In dip the veins vary from vertical to nearly horizontal. In No. 1 shaft of the Hollinger the vein is practically vertical, while a series of narrow quartz veins, 6 to 18 inches wide on the Lindburg claim, have a dip at the surface of only 20°. The prevailing dip of the schist in the Porcupine area is to the north at a high angle, and frequently the veins dip distinctly to the south across the cleavage of the schist. While it is apparent that most of the deformation of the country antedates the vein formation, nevertheless there is a decided tendency in many cases for the fissuring to be influenced by the direction of schistosity, which is also a direction of



Photograph of quartz from the Swastika mine. The quartz shows dark streaks in crushed areas. Iron pyrites is abundant along the dark lines, together with visible gold. Length of sample, 3½ inches.

weakness; hence we find veins having a more or less lenticular structure, the strike of which closely corresponds to that of the country rock.

Lenticular veins occur chiefly where the country rocks have been intensely sheared or rendered schistose, as around Pearl lake. Usually when there has been less disturbance, the veins are more likely to have a marked difference in strike from the enclosing rock—as around Three Nations lake and the porphyry area south of Simpson lake. It may be stated that the larger and usually lenticular veins of the area occur where the rocks are extremely schistose, while the narrower, better defined veins occur as stringers from these main lenticular veins, or in less disturbed areas.

Distribution of Veins.

While gold-bearing veins occur over a wide area and are often isolated, it is seen, from a number of those already discovered, that they occur in groups along certain lines. For instance, in Tisdale township there are at least three distinct areas where the fissuring has been most pronounced. One such area extends from the southeast end of Miller lake, on lot 11, in the second concession, in a northeasterly direction for three miles, and includes such veins as the McEnaney, Miller-Middleton, Hollinger, Dixon, McIntyre, Jupiter, Rea, and others with visible gold. The average strike of the veins here is northeast and southwest. An exception is a vein on the McEnaney, which strikes northwest and southeast.

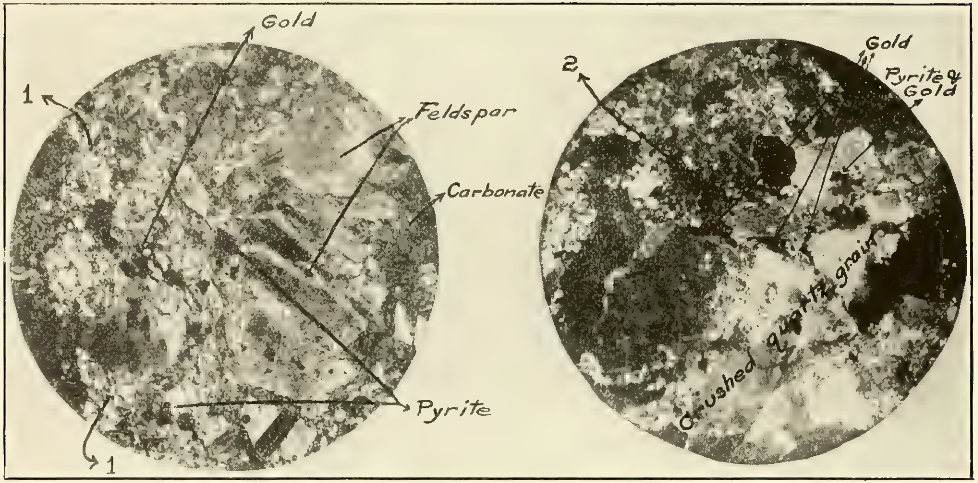
Another series, including the Smith, Davidson, Crown Chartered and Dobie, occurs in the northeast part of the township. To these should be added the Scottish-Ontario, Mullholland, Hughes and Gold Reef, which are in the northwest part of Whitney township. The general direction of these veins is east and west.

Again, in the southeast part of the township is a group including the Dome Lake, West Dome, Dome, and Dome Extension, with a general strike north of east.

Similar groupings occur in other parts of the area in which gold-bearing veins have been found.

Occurrence of the Gold.

A field examination shows that there is an irregular distribution of the gold in the quartz veins. Very often it occurs along dark streaks in the quartz, along the contacts of quartz and schist, or around patches of dark colored mineral in the quartz. At the surface, rich portions of veins are often indicated by rusty streaks or patches, while at depth the rusty character gives place to dark grey, black or greenish colors.



GOLD ORE.

1. Microphotograph, McEnaney. 2. Microphotograph, Vipond.

1. Fine grained carbonate, tourmaline, quartz, feldspar, and sericite.
2. Brecciated quartz with later corbonate.

MICROSCOPICAL AND OTHER CHARACTERISTICS.

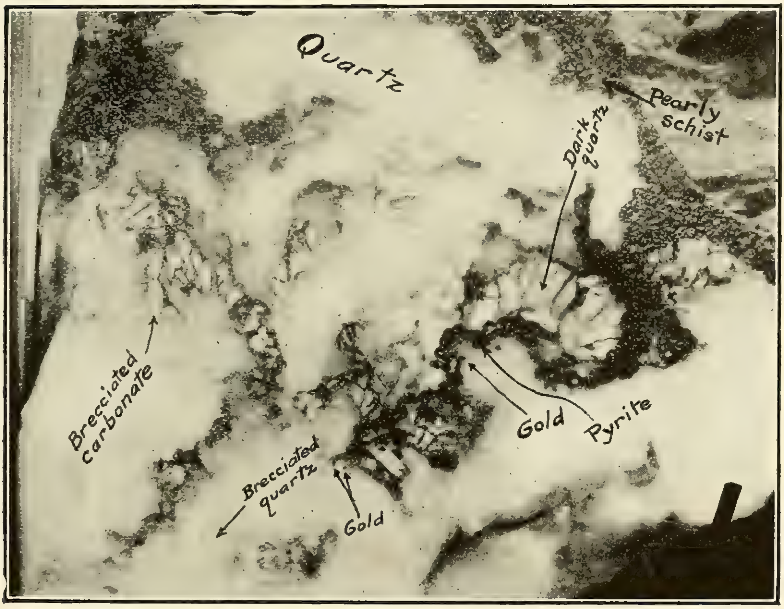
Under the microscope the gold is generally found in areas which have been greatly crushed or in the quartz or schist bordering on these areas.

The prominent minerals which occur in the crushed areas are pyrite, calcite, dolomite, sericite, chlorite, tourmaline and quartz. It is thought that most of the gold has

Streaked ore from the Jupiter mine, Porcupine. The dark lines are tourmaline; the quartz is much crushed and contains visible gold.

been deposited along with pyrite from the solutions which circulated in the minute fissures and crushed areas of the primary quartz of the veins. The quartz of No. 1 vein of the Hollinger mine shows numerous dark streaks in parts of it and often across the width of the vein. These are generally short and irregular in distribution. Iron pyrites and often galena occur with the gold. Examined microscopically, the quartz is seen to occur in fairly large grains, to contain liquid and gas inclusions, and to have been subjected to secondary pressure and granulation along the margins of the grains. The iron pyrites often occurs in well shaped crystals which have been formed subsequently to the crushing.

The fine dark streaks may have resulted from a shrinkage of the quartz, forming filmy cracks which may have become slip or crushing planes along which the richer gold-bearing solutions were deposited at a later period.



Brecciated structure of quartz from McIntyre main vein (natural size).

The minute dark streaks in the quartz are frequently slickensided, and this character may often be seen in hand specimens, as in those from the Rea or Vipond mines.

It should be noted that where cracks or fracture planes have been produced in a quartz vein and subsequently filled by minerals from solution, secondary quartz can be distinguished with difficulty, if at all, from the original quartz. Hence it is not always possible to say whether visible gold in such a vein occurs in the original or in secondary quartz.

Often a vein may show a width of ten feet but the fractured portion may be only a few feet, or even inches, wide along either wall. In this portion there may be many streaks of dark mineral which are often parallel, giving a banded character to the ore, as in many of the veins in the north part of Whitney and Tisdale, namely, at the Mullholland, Scottish Ontario, Davidson and adjoining properties. A similar banded structure is seen at the Rea mine. At these properties tourmaline is the principal mineral of the streaks. The gold may occur along these lines or in the intervening quartz, which is often much crushed and filled with later minerals.

Several sections were examined, which showed grains of gold apparently enclosed in the primary quartz, but the occurrence is much less prominent than where gold occurs in the crushed areas.

It is important to note that practically all the veins which are gold-bearing contain considerable carbonate of varied composition. Wherever the enclosing rocks are schistose they always carry carbonate and frequently effervesce with cold hydrochloric acid. Much of the carbonate of the veins has been absorbed from the wall rock, while portions have been formed from ascending solutions which circulated through the veins. Pyrite and grains of gold frequently occur in the carbonate.

Carbonate in the form of ankerite constitutes the main portion of veins at the West Dome, Apex, and in parts of Deloro township. This carbonate is distinctly earlier than the quartz veinlets which intersect the ankerite veins. Both the ankerite and quartz have been fractured and veinlets of later carbonate deposited in them.

Since the whole surface of the area has been deeply eroded and glaciated, there is now little evidence of secondary enrichment. The enrichment is very superficial, extending only from a few inches to a few feet in depth. The outcrops of the veins and wall rocks are usually discolored or decomposed, due to the oxidation of the iron pyrites and the ferrous carbonate in the ankerite or other iron-bearing carbonates. Cubes of iron pyrites are occasionally obtained at the surface, while copper pyrites and arsenopyrite also occur near the surface. Where the veins have been oxidized to any depth, there are generally

Quartz vein on 100-foot level, McEnaney mine. The dark spots are drill holes.

some very recent water courses in evidence. Developments so far have shown that, after this very superficial zone has been penetrated, the character of the vein material has remained the same as far as mining operations have continued.

MINING AND MILLING.

Detailed descriptions of the mining and milling operations in the Porcupine area are given in the Annual Report of the Ontario Bureau of Mines, and in Mr. A. A. Cole's Annual Report to the Temiskaming and Northern Ontario Railway Commission.

TEMAGAMI

BY

WILLET G. MILLER.

Lake Temagami, with its numerous islands and bays and its shores covered with evergreen timber, is one of the most beautiful sheets of water in North America. It is situated in the Government Forest Reserve, and since the completion of the Temiskaming and Northern Ontario Railway, the lake has become very popular with tourists and sportsmen. Fish and game are abundant in the vicinity of Temagami and the numerous adjacent lakes and streams. The locality is especially noted for moose and for bass and trout fishing.

Near Temagami station there are exposures of the Keewatin and Cobalt series. Within a half mile northward of the station an iron range of interbanded magnetite and jasper, which has a width of several hundred feet, is to be seen. Two or three miles northward there are deposits of mispickel, pyrrhotite, and copper pyrites. The last-named mineral is also found near the lake.

Good contacts of the Cobalt series with the Keewatin are exposed along the railway a short distance north of the station.

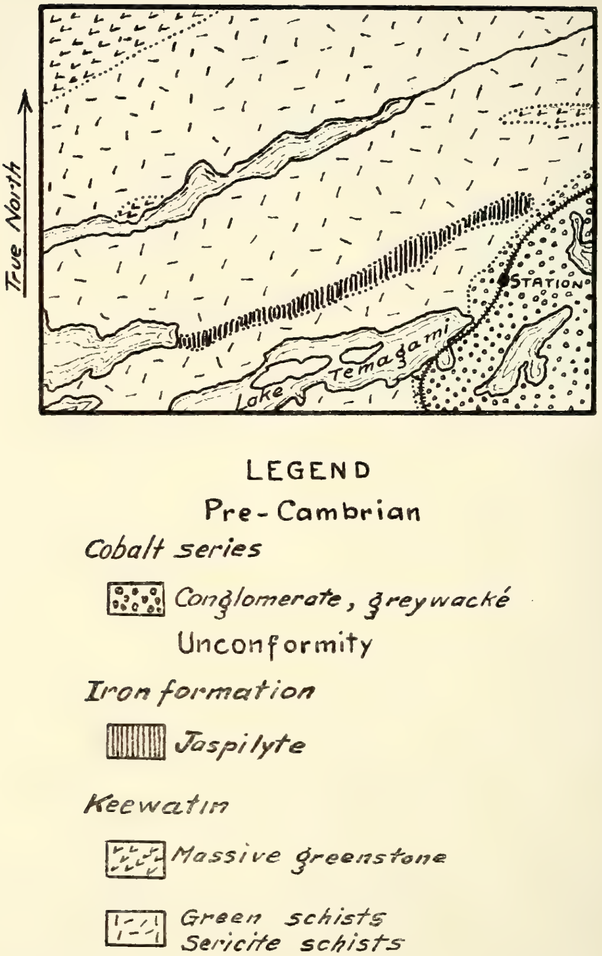
The schistose rocks of the Keewatin may be divided into the paler-colored and more acid varieties, which are deformed quartz porphyries or porphyrites, and the more deeply colored or basic schists resulting from the shearing of hornblende porphyrites, basalts and diabases. The extreme deformation of the more acid types produces sericite schists, which reveal little or no trace of their original structure.*

The iron-formation (jaspilyte) is similar to that of the well known Vermilion range of Minnesota. It is infolded with the Keewatin schists, all dipping at high angles.

The iron-formation, in places 1,000 feet in width, probably represents chemical sediments that were deposited on the surface of the Keewatin volcanic rocks. At the base of the iron-formation, there is frequently a comparatively thin layer of fine-grained greywacké.

Frequently the interbanded material of the iron-formation contains 35 to 40 per cent. of metallic iron. By magnetic concentration, judging from experiments that have been performed, a merchantable ore can be produced.

*Geol. Sur. Canada, Vol. XV., 1902-3, p. 128A et seq. Map No. 944.



Geological map of area near Temagami railway station, scale 1 mile to 1 inch.

(From map No. 944, Geological Survey of Canada.)

ANNOTATED GUIDE.

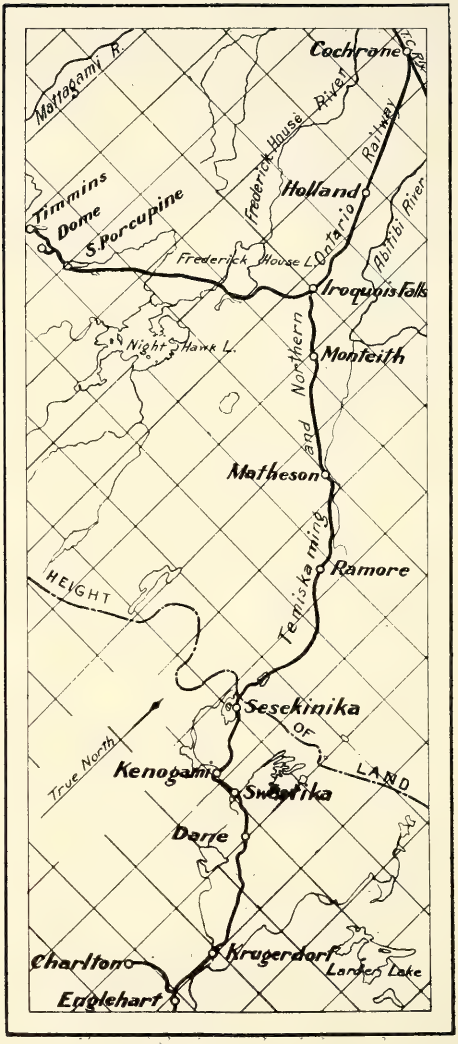
HAILEYBURY TO SWASTIKA, IROQUOIS FALLS JUNCTION AND PORCUPINE.

Miles and Kilometres.

107.44 m. 173 km. Altitude 766 ft. (233 m.). The town of Haileybury has a splendid location on the easterly slope of a clay ridge, over-looking Lake Temiskaming, an expansion of the Ottawa river which here forms the boundary between the Provinces of Ontario and Quebec. From the railway station to the lake there is a descent of 175 ft. (53.2 m.). The clay, which is finely stratified, is utilized in the manufacture of red brick at Haileybury and New Liskeard.

One-half mile west of the station is an exposure of Silurian limestone (Niagara) which is prolific in fossils. This limestone has been burned for lime, and is also used for road material and building stone. It lies nearly horizontally, and is the youngest compact rock in the area.

112.64 m. 181.2 km. Altitude 642 ft. (195.6 m.). Leaving Haileybury there is a descent to New Liskeard, which is situated in a valley on Wabi bay. Between the towns are several cuttings on the railway which show the beautifully banded character of the clay. Good exposures of the Temiskaming series are to be seen along the lake shore. Niagara limestone can also be observed in the ridge directly west of the New Liskeard station. New Liskeard lies almost on the southerly boundary of a farming country, which stretches 35 miles along the railway to Krugerdorf station. This area is entirely drift-covered, while the Pleistocene deposits consist of stratified clay, sand and gravel, considered to have been laid down in lake Ojibway, the last of the glacial lakes. Here and there recent water courses have cut deep valleys in the Pleistocene deposits, but generally the country has a rather flat or rolling appearance. The high ridge



Route map between Englehart and Cochrane

Miles

10 0 10 20 30

Kilometres

10 0 10 20 30 40 50

which may be seen to the east of New Liskeard, known as Wabi point, is composed of Niagara limestone. Seven miles northeast of New Liskeard station is the Casey Cobalt silver mine, which is one of the few properties, outside of the main Cobalt silver area, which has shipped high-grade silver ore.

128.59 m. 206.7 km. Altitude 816 ft. (248.6 m.). At Earlton a branch line extends from the main line to the Elk Lake silver area.

138.48 m. 232.7 km. Englehart, altitude 677 ft. (206.2 m.). From this point a short line extends westward to the Charlton farming area A part of this line from mileage one to two and three-quarters has been constructed along the north side of a high, rocky ridge. In the rock cuttings are exposed massive and schistose Keewatin rocks, some of which are greatly altered, showing torsion cracks, filled with calcite and quartz. numerous faults and crushed areas. The Keewatin is intruded in places by diabase dikes. Where schistose, the rocks strike N. 80° E. and dip N. 60°.

146 m. 234.8 km. Altitude 770 ft. (234.6 m.). The first outcropping of rock on the main line occurs at the crossing of the Blanche river, just south of Krugerdorf station. Here the track is 110 feet (33.4 m.) above the rapids which are formed by a barrier of massive, flesh-colored granite.

North of this point rock exposures become more numerous, showing here and there through the stratified clay. These consist of coarse, reddish granite as far as mileage 153. Just south of this mile the acid rock is gneissoid, showing pink and grey bands striking N. 72° W. Glacial striæ are well preserved on the granite showing a direction of S. 10° E. This granite has been used in the construction of the station at Matheson.

North of mileage 153 a Keewatin area is entered. The rocks are largely greenstones, some of which are basalt, showing occasionally ellipsoidal or pillow structure. At the south end of the first rock cutting north of mileage 153 there is Keewatin iron formation carrying considerable iron pyrites; at one point there is a rusty band eight feet wide carrying streaks of massive iron pyrites. The basic rocks are cut by narrow, reddish, feldspathic dikes which contain much mica. Just south of mileage 154, one of these dikes, two feet in width, shows in a rock cutting on the southwest side of the track. Fifteen chains north of this mileage, a dark mica lamprophyre cuts the greenstone.

Marked ellipsoidal structure is seen at mileage 156 on the northeast side of the track.

159.74 m. 256.7 km. Altitude 1,035 ft. (315.4 m.). At Dane a 17-mile (27.3 km.) wagon road leads to the Larder Lake gold area, where the gold occurs in rusty-weathering carbonate and porphyry rocks which are cut by veinlets of quartz.

At mileage 160½, reddish syenite occurs on the south side of the track. The high range of hills observed to the south are reddish hornblende syenite which intrudes the Keewatin greenstone.

Just east of mileage 162 there is a rock cutting through banded iron formation. The rock is very rusty, and melanterite has been formed from the disseminated iron pyrites. Keewatin greenstone is observed continuously in the cuttings as far as Amikougami creek, east of Swastika. The Lucky Cross mine is to the south of the track, just east of the Amikougami creek, while about half a mile to the southwest is the Swastika mine. Between the last mentioned creek and the Blanche river is a ridge of grey feldspar-porphyry. Along this porphyry ridge a number of mining claims have been staked out, and the chief gold veins occur where the greenstone has been intruded by this rock.

164.7 m. 265. km. Altitude 1,007 ft. (306.9 m.). The town of Swastika is underlain by conglomerate which contains numerous pebbles of porphyry and jasper, while the high ridge southwest of the town is also conglomerate. Numerous narrow dikes of red feldspar-porphyry intrude the conglomerate for two miles beyond Swastika.

Conglomerate and greywacké are shown in the cuttings as far west as Kenogami station.

168.16 m. 270.4 km. Altitude 1,013 ft. (308.8 m.). In the cutting south of Kenogami station, the conglomerate and greywacké have a vertical dip. This conglomerate has been provisionally classed as "Temiskaming." The glacial striæ seen on the polished surfaces near Kenogami strike S. 55° E.

Another Keewatin greenstone area extends north of Kenogami to mileage 178½. At the fourth crossing of the Blanche river there is basalt which is intruded by a dike of porphyritic diabase.

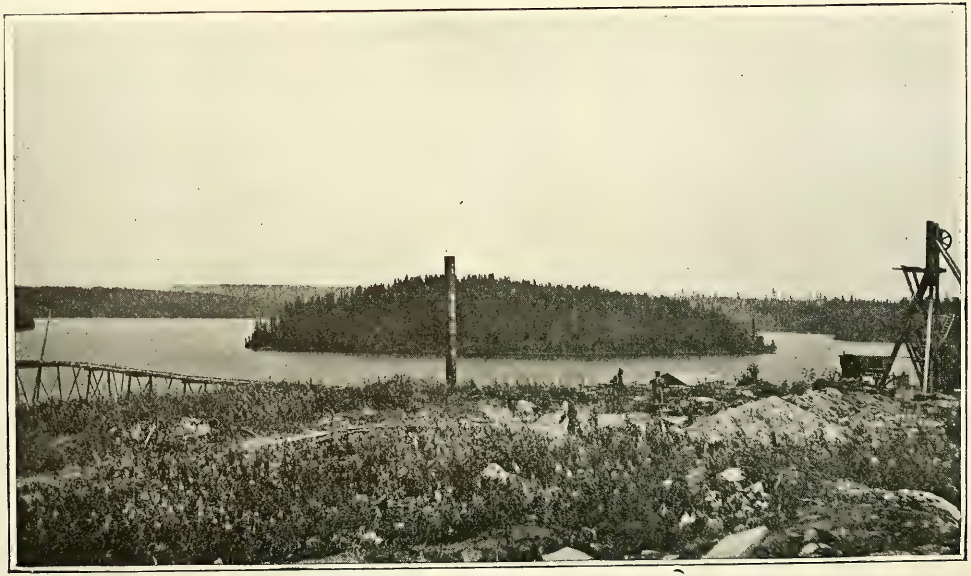
At mileage 169 is a basalt which has been crushed to a friction breccia.

On approaching Sesekinika lake there are several dikes of fresh quartz-diabase. At mileage 172 one of these has a width of 60 feet.

175.56 m. 282.4 km. Altitude 1,022 ft. (311.4 m.). Sesekinika lake contains numerous islands on which Keewatin rocks occur. On account of its picturesqueness this lake has been reserved as a summer resort.

HEIGHT OF LAND.

The divide between the St. Lawrence and Hudson Bay waters is crossed at mileage 177½. At mileage 178½ the Keewatin greenstone is intruded by dikes of hornblende syenite. Numerous large boulders of conglomerate of the Cobalt series are scattered along the right of



Otto lake from Swastika mine.

way south of mileage 179. This conglomerate occurs in place at mileage 179, where the strata of the Cobalt series are almost horizontal, showing a succession in ascending order of slate, quartzite and conglomerate.

Twenty-five chains north of mileage 180 the Cobalt series is exposed, showing in ascending order: slate conglomerate, two feet (0.6 m.) of grey and red slate, 10 feet (3 m.) of coarse boulder conglomerate. Just beyond, opposite the north end of Twin lake, is a bluff of conglomerate and slate, on the west side of the track, which is 140 feet (42.6 m.) high. A splendid view of the pre-Cambrian peneplain can be obtained from this bluff. North of Twin lake Keewatin greenstones again occur, but rock exposures become infrequent.

Ellipsoidal basalt occurs north of mileage 188, and one-half mile southwest of mileage 190 there is a ridge of Keewatin basalt 300 feet (91.4 m.) in elevation.

205.27 m.
330.2 km. Altitude 873 ft. (266 m.). (Matheson, the centre of a farming area, is on the Black river, a branch of the Abitibi river. McDougal's chute is formed by a barrier of later diabase which intrudes basic, schistose Keewatin. The greenstone is also cut by a dike of grey porphyry.)

Eleven miles east of Matheson is the Munro township gold area. Here narrow auriferous quartz veins occur in the Temiskaming greywacké and slate.

218.03 m.
350.7 km. Altitude 922 ft. (281 m.). At Monteith is an Ontario Government experimental farm.

222.03 m.
357.2 km. Altitude 897 ft. (273.3 m.). Three and one-half miles southwest of Kelso is the Alexo nickel mine, a mass of nickeliferous pyrrhotite, at the contact of rhyolite and serpentine. One theory suggests that the ore is the result of replacement in the serpentine, while another suggests a

differentiation from the basic rock. The rocks are older than those of Sudbury, being of Keewatin age.

224.87 m.
361.7 km.
Altitude 945 ft. (288 m.). The Porcupine branch of the Temiskaming and Northern Ontario railway to the Porcupine gold field leaves the main line at Iroquois Falls Junction. This line passes over a drift-covered area for most of the distance to Porcupine lake. Southwest of Iroquois there is much stratified sand and gravel, while approaching Porcupine, stratified clay is observed. Keewatin outcrops at the Porcupine river crossing, and serpentine at mileage 21.

LIST OF ILLUSTRATIONS

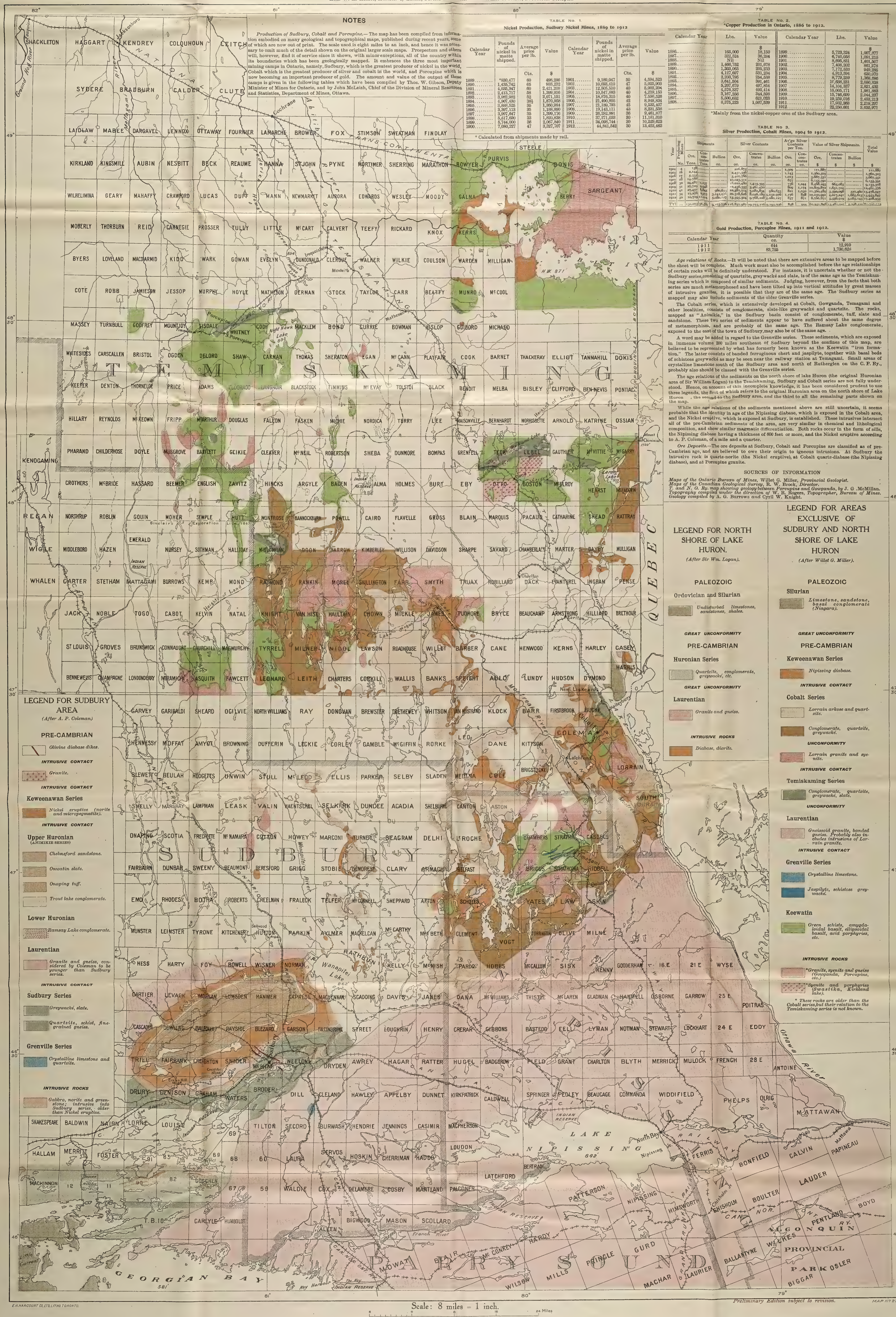
Photographs.

ONTARIO
DEPARTMENT OF LANDS FORESTS & MINES
BUREAU OF MINES

MAP
OF THE
SUDBURY—COBALT—PORCUPINE REGION
PROVINCE OF ONTARIO.

To accompany Part I, Vol. 22, Report of Bureau of Mines, 1913.

Hon. W. H. Hearst, *Minister of Lands, Forests and Mines.* Willet G. Miller, *Provincial Geologist.*



NOTES

Production of Sudbury, Cobalt and Porcupine.—The map has been compiled from information embodied on many geological and topographical maps, published during recent years, some of which are now out of print. The scale used is eight miles to an inch, and hence it was necessary to omit much of the detail shown on the original larger scale maps. Prospectors and others will, however, find it of service since it shows, with minor exceptions, all of the country within its boundaries which has been geologically mapped. It embraces the three most important mining camps in Ontario, namely, Sudbury, which is the greatest producer of nickel in the world, Cobalt which is the greatest producer of silver and cobalt in the world, and Porcupine which is now becoming an important producer of gold. The amount and value of the output of these camps is given in the following tables which have been compiled by Thos. W. Gibson, Deputy Minister of Mines for Ontario, and by John McLeish, Chief of the Division of Mineral Resources and Statistics, Department of Mines, Ottawa.

TABLE No. 1.
Nickel Production, Sudbury Nickel Mines, 1889 to 1912

Calendar Year	Pounds of nickel in matte shipped.	Average price per lb.	Value	Calendar Year	Pounds of nickel in matte shipped.	Average price per lb.	Value
		Cts.	$			Cts.	$
1889	*830,477	60	498,286	1901	9,189,047	50	4,594,523
1890	1,435,742	65	933,232	1902	10,693,410	47	5,025,903
1891	4,035,347	60	2,421,208	1903	12,505,510	40	5,002,204
1892	2,413,717	58	1,399,956	1904	10,547,883	40	4,219,153
1893	3,982,982	52	2,071,151	1905	18,876,315	40	7.550,526
1894	4,907,430	38½	1,870,958	1906	21,490,955	42	8,948,834
1895	3,888,525	35	1,360,984	1907	21,189,793	45	9,535,407
1896	3,397,113	35	1,188,990	1908	19,143,111	43	8,231,538
1897	3,997,647	35	1,399,176	1909	26,282,991	36	9,461,877
1898	5,517,690	33	1,820,838	1910	37,271,033	30	11,181,310
1899	5,744,000	36	2,067,840	1911	34,098,744	30	10,229,623
1900	7,080,227	47	3,327,707	1912	44,841,542	30	13,452,463

* Calculated from shipments made by rail.

TABLE No. 2.
***Copper Production in Ontario, 1886 to 1912.**

Calendar Year	Lbs.	Value	Calendar Year	Lbs.	Value
		$			$
1886	165,000	18,150	1899	5,723,324	1,007,877
1887	322,524	36,284	1900	6,740,058	1,091,215
1888	Nil	Nil	1901	8,695,831	1,401,507
1889	1,466,752	201,678	1902	7,408,202	861,278
1890	1,303,065	205,233	1903	7,172,533	949,285
1891	4,127,697	531,234	1904	4,913,594	630,070
1892	2,203,795	254,538	1905	8,779,259	1,368,686
1893	3,641,504	391,461	1906	10,638,231	2,050,838
1894	5,207,679	497,854	1907	14,104,337	2,821,432
1895	4,576,337	492,414	1908	15,005,171	1,981,883
1896	3,167,256	344,598	1909	15,746,699	2,044,237
1897	5,500,652	621,023	1910	19,259,016	2,453,213
1898	8,375,223	1,007,539	1911	17,932,263	2,219,297
			1912	22,250.601	3,635,971

*Mainly from the nickel-copper ores of the Sudbury area.

TABLE No 3.
Silver Production, Cobalt Mines, 1904 to 1912.

Year	Producing Mines	Shipments: Ore,	Shipments: Concentrates	Shipments: Bullion	Silver Contents: Ore,	Silver Contents: Concentrates	Silver Contents: Bullion	Av'ge Silver Contents per Ton: Ore.	Av'ge Silver Contents per Ton: Concentrates	Value of Silver Shipments: Ore,	Value of Silver Shipments: Concentrates	Value of Silver Shipments: Bullion	Total Value
	No.	Tons.	Tons.	oz.	oz.	oz.	oz.	oz.	oz.	$	$	$	$
1904	4	158	....	....	206,875	....	....	1,309	....	111,887	....	....	111,887
1905	16	2,144	....	....	2,451,356	....	....	1,143	....	1,360,503	....	....	1,360,503
1906	17	5,335	....	....	5,401,766	....	....	1,013	....	3,667,551	....	....	3,667,551
1907	28	14,788	....	....	10,023,311	....	....	677	....	6,155,391	....	....	6,155,391
1908	30	24,487	1,137	....	18,022,480	1,415,395	....	736	1,244	8,468,293	665,085	....	9,133,378
1909	31	27,729	2,948	....	22,436,355	3,461,470	....	809	1,174	10,809,872	1,651,704	....	12,461,576
1910	41	27,437	6,845	980,6[illegible]	23,581,7[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1911	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1912	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T'tl		130,075	31,5[illegible]	9,193,736	116,837,987	29,775,116	9,193,736	858	944	60,951,848	15,481,047	5,298,220	81,731,115

TABLE No. 4.
Gold Production, Porcupine Mines, 1911 and 1912.

Calendar Year	Quantity oz.	Value $
1911	644	12,910
1912	83,735	1,730,628

Age relations of Rocks.—It will be noted that there are extensive areas to be mapped before the sheet will be complete. Much work must also be accomplished before the age relationships of certain rocks will be definitely understood. For instance, it is uncertain whether or not the Sudbury series, consisting of quartzite, greywacké and slate, is of the same age as the Temiskaming series which is composed of similar sediments. Judging, however, from the facts that both series are much metamorphosed and have been tilted up into vertical attitudes by great masses of intrusive granites, it is possible that they are of the same age. The Sudbury series as mapped may also include sediments of the older Grenville series.

The Cobalt series, which is extensively developed at Cobalt, Gowganda, Temagami and other localities, consists of conglomerate, slate-like greywacké and quartzite. The rocks, mapped as "Animikie," in the Sudbury basin consist of conglomerate, tuff, slate and sandstone. These two series of sediments appear to have suffered about the same degree of metamorphism, and are probably of the same age. The Ramsay Lake conglomerate, exposed to the east of the town of Sudbury, may also be of the same age.

A word may be added in regard to the Grenville series. These sediments, which are exposed in immense volume 200 miles southeast of Sudbury beyond the confines of this map, are believed to be represented by what has formerly been known as the Keewatin "iron formation." The latter consists of banded ferruginous chert and jaspilyte, together with basal beds of schistose greywacké, as in the Cobalt area. Small areas of crystalline limestone south of the Sudbury area and north of Rutherglen on the C. P. Ry., probably also should be classed with the Grenville series.

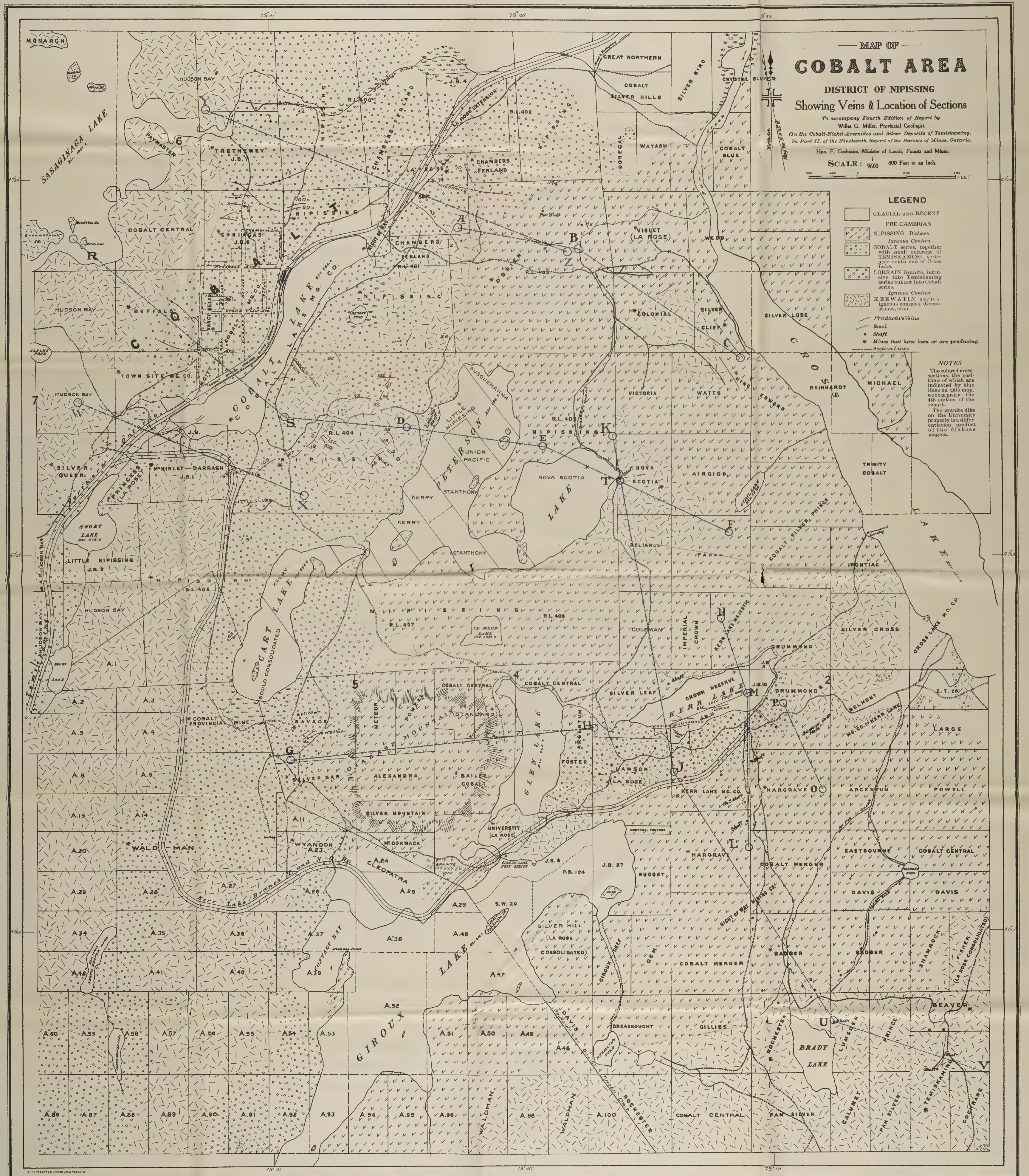
The age relations of the sediments on the north shore of lake Huron (the original Huronian area of Sir William Logan) to the Temiskaming, Sudbury and Cobalt series are not fully understood. Hence, on account of this incomplete knowledge, it has been considered prudent to use three legends, the first of which refers to the original Huronian area on the north shore of Lake Huron, the second to the Sudbury area, and the third to all the remaining parts shown on the map.

While the age relations of the sediments mentioned above are still uncertain, it seems probable that the identity in age of the Nipissing diabase, which is exposed in the Cobalt area, and the Nickel eruptive, which is exposed at Sudbury, is established. These intrusives intersect all of the pre-Cambrian sediments of the area, are very similar in chemical and lithological composition, and show similar magmatic differentiation. Both rocks occur in the form of sills, the Nipissing diabase having a thickness of 600 feet or more, and the Nickel eruptive according to A. P. Coleman, of a mile and a quarter.

Ore Deposits.—The ore deposits at Sudbury, Cobalt and Porcupine are classified as of pre-Cambrian age, and are believed to owe their origin to igneous intrusions. At Sudbury the intrusive rock is quartz-norite (the Nickel eruptive), at Cobalt quartz-diabase (the Nipissing diabase), and at Porcupine granite.

SOURCES OF INFORMATION

Maps of the Ontario Bureau of Mines, Willet G. Miller, *Provincial Geologist.*
Maps of the Canadian Geological Survey, R. W. Brock, *Director.*
T. and N. O. Ry. map showing geology between Porcupine and Gowganda, by J. G. McMillan.
Topography compiled under the direction of W. R. Rogers, *Topographer, Bureau of Mines.*
Geology compiled by A. G. Burrows *and* Cyril W. Knight.



MAP OF
COBALT AREA
DISTRICT OF NIPISSING
Showing Veins & Location of Sections
To accompany Fourth Edition of Report by
Willet G. Miller, Provincial Geologist,
On the Cobalt-Nickel-Arsenides and Silver Deposits of Temiskaming,
In Part II. of the Nineteenth Report of the Bureau of Mines, Ontario.
Hon. F. Cochrane, Minister of Lands, Forests and Mines.
SCALE: 1/9600 800 Feet to an Inch.
800 400 0 800 1600 FEET
North Ast.
Mag. Var. N. 9°45' W.
LEGEND
GLACIAL AND RECENT
PRE-CAMBRIAN
NIPISSING Diabase
Igneous Contact.
COBALT series, together with small outcrops of TEMISKAMING series near south end of Cross Lake.
LORRAIN Granite, intrusive into Temiskaming series but not into Cobalt series.
Igneous Contact
KEEWATIN series, igneous complex (Greenstones, etc.)
Productive Veins
Road
Shaft
Mines that have been or are producing.
Section Lines
NOTES
The colored cross-sections, the positions of which are indicated by blue lines on this map, accompany the 4th edition of the report.
The granite dike on the University property is a differentiation product of the diabase magma.
79°41'
79°40'
79°39'
MONARCH
SASAGINAGA LAKE
HUDSON BAY
PAYMASTER
TRETHEWEY
CONIAGAS
COBALT CENTRAL
BUFFALO
TOWN SITE MG. CO.
NIPISSING
CHAMBERS FERLAND
LA ROSE EXTENSION
GREAT NORTHERN
COBALT SILVER HILLS
SILVER BIRD
CRYSTAL SILVER
WATASH
DONEGAL
COBALT BLUE
VIOLET (LA ROSE)
WEBB
COLONIAL
SILVER CLIFF
SILVER LODE
CROSS LAKE
REINHARDT
MICHAEL
KING EDWARD
VICTORIA
WATTS
COBALT LAKE
SUSQUEHANNA
LITTLE NIPISSING
PETERSON
UNION PACIFIC
NOVA SCOTIA
NOVA SCOTIA LAKE
AIRGIOD
TRINITY COBALT
SILVER QUEEN
PRINCESS (LA ROSE)
McKINLEY—DARRAGH
LITTLE SILVER
SHORT LAKE
KERRY
STANTHONY
RELIANCE
COBALT-SILVER PRINCE
PONTIAC
LITTLE NIPISSING
KERR LAKE
GOULD CONSOLIDATED
LE NEUF LAKE
COLEMAN
IMPERIAL CROWN
KERR LAKE MAJESTIC
SILVER CROSS
CROSS LAKE MG. CO.
DRUMMOND
COBALT CENTRAL
SILVER LEAF
CROWN RESERVE
E.T. CO.
BELMONT
LARGE
COBALT PROVINCIAL MINE
SAVAGE
METEOR
TEMISKAMING
GLEN LAKE
ARGENTUM
FOSTER
LAWSON (LA ROSE)
KERR LAKE MG. CO.
HARGRAVE
POWELL
SILVER BAR
ALEXANDRA
BAILEY COBALT
SILVER MOUNTAIN
UNIVERSITY (LA ROSE)
McCORMACK
WYANDOH
WALD-MAN
CLEOPATRA
J.B. 27
NUGGET
COBALT MERGER
EASTBOURNE
COBALT CENTRAL
DAVIS
SILVER HILL (LA ROSE CONSOLIDATED)
GIROUX LAKE
BADGER
SHAMROCK
FISHER (LA ROSE CONSOLIDATED)
BEAVER
DREADNOUGHT
GILLIES
ROCHESTER
BRADY LAKE
LUMSDEN
PRINCE
WALDMAN
PAN SILVER
CALUMET
COCHRANE
COBALT CENTRAL

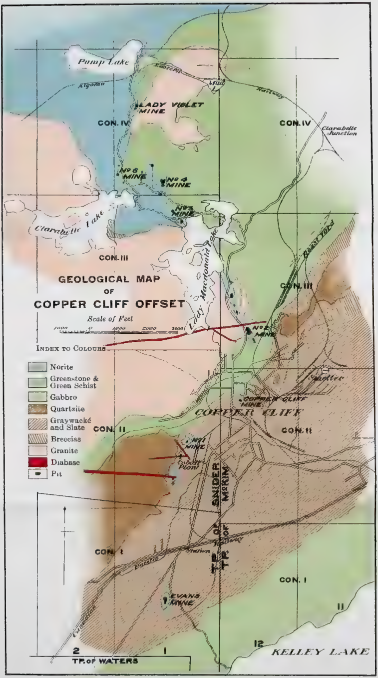
CANADA

DEPARTMENT OF MINES

MINES BRANCH

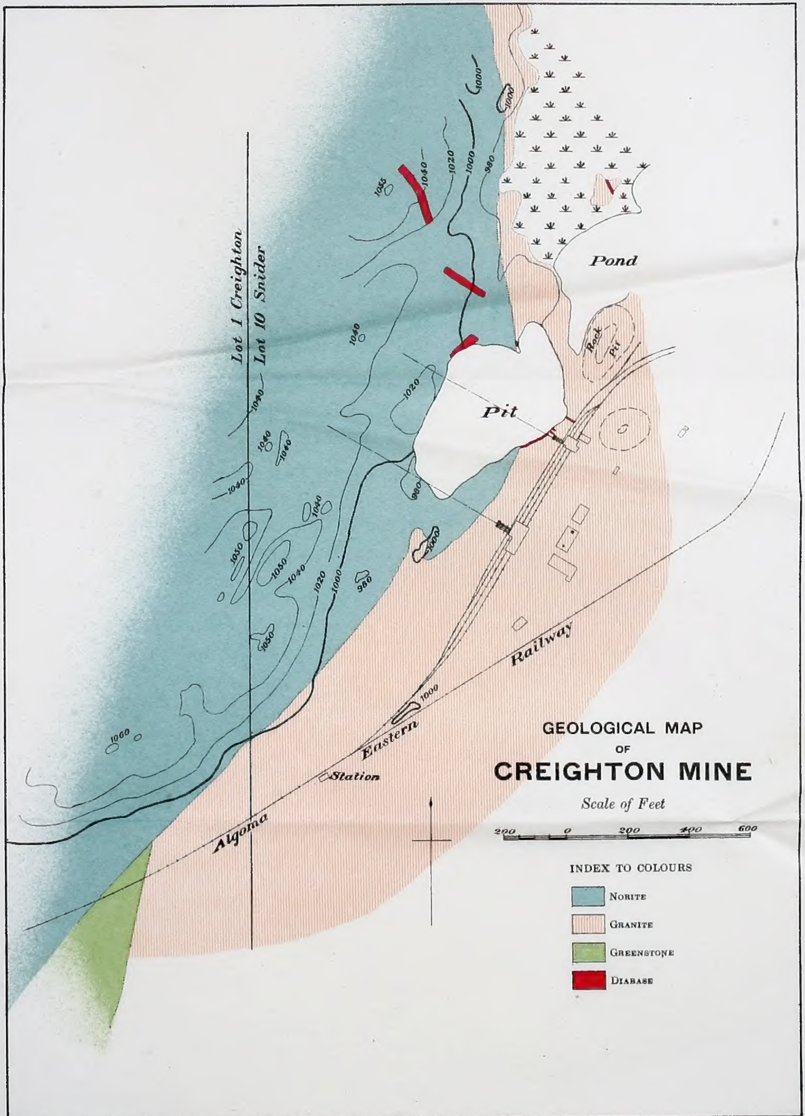
HON. ROBERT ROGERS, MINISTER; A. P. LOW, LL.D., DEPUTY MINISTER; EUGENE HAANEL, PH.D., DIRECTOR.

1912



NO. 176

CANADA
DEPARTMENT OF MINES
MINES BRANCH
HON. ROBERT ROGERS, MINISTER; A. P. LOW, LL.D., DEPUTY MINISTER;
EUGENE HAANEL, PH.D., DIRECTOR.
1912



NO. 174

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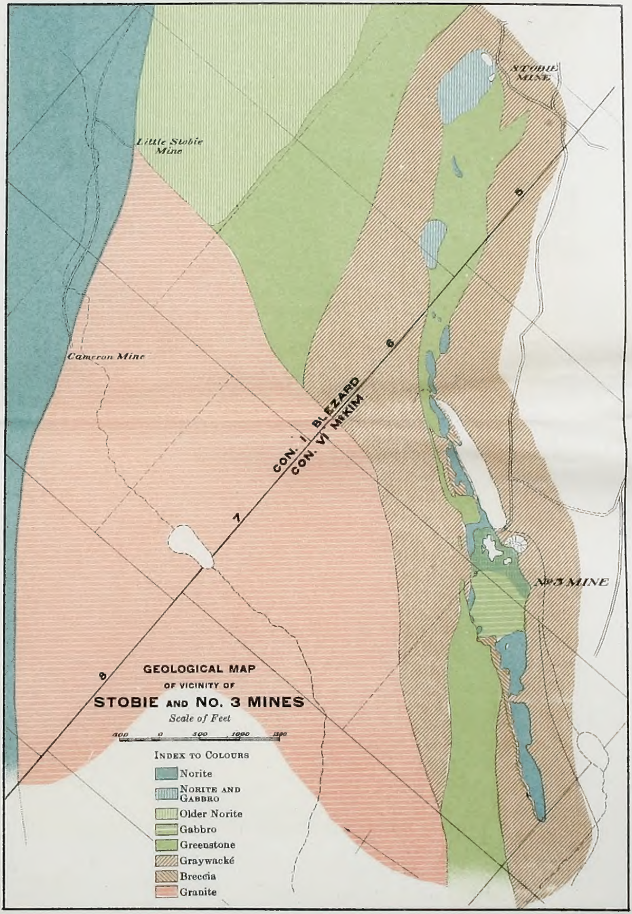

NO. 178