UNIVERSITY OF TORONTO STUDIES

GEOLOGICAL SERIES.

No. 2. THE MICHIPICOTEN IRON RANGES,

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THE MICHIPICOTEN IRON RANGES

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THE MICHIPICOTEN IRON RANGES

The development of the Helen mine at Michipicoten, now the largest producer of iron ore in Canada, and the work of prospecting the region, which has gone on so actively for the last two or three years, have called attention to the iron ranges of Ontario, and have suggested the desirability of a more detailed geological survey of the district than has hitherto been attempted in the iron mining districts of the province. For the sake of economy of labour, the work has been divided between the geological staff of the Bureau of Mines of Ontario and Professor Willmott, with his assistants, representing the Messrs. Clergue, the proprietors of the mine; the latter have taken up more especially the mine and its relationships. The topographical groundwork for the accompanying maps has been obtained from various sources, the most important being the surveys carried out by the Lake Superior Power Co., under the direction of the Messrs. Clergue, to fix the boundaries of mining claims and townships, and to locate the railway from Michipicoten harbour to the Helen mine, a distance of nearly twelve miles, and also the branch line from Talbot lake to the Josephine mine. The immediate vicinity of the mines has been mapped in detail by the engineers of the company.

Where the lines mentioned were insufficient the gaps have been filled in by prismatic compass and micrometer surveys or by paced compass surveys through the woods, a dial compass being used to check the results of the magnetic compass where the proximity of the iron range made this desirable. It may be noted, however, that very little correction of the compass was needed, even when working along the iron range itself, no doubt because most of the iron ore occurs, not in the form of magnetite, but as siderite, limonite or hematite.

As the Laurentian rocks were considered to be barren of economic minerals, the field work was confined to the Huronian, or carried into the Laurentian only far enough to examine the contact of the two groups of rocks. Outcrops of rock are frequent in the region, which is hilly or even mountainous in parts, though the forest hides the rock in some places with undergrowth and a carpet of moss, and wide deposits of sand do so even more completely in the low ground.

On account of the work being carried on jointly, no sharp division of the responsibility between the authors can be made, though the special account of the mines and the final compilation of the maps are the work of Professor Willmott. The authors are under great obligations to the Messrs. Clergue for their kindness in placing the results of surveys, mining operations, etc., at their service.

TOPOGRAPHY

The region studied is about twenty-five miles long from southwest to northeast and seven miles broad, and runs from the mouth of Doré river to a few miles beyond Park lake on the northeast. Just to the southwest is Michipicoten river near its entry into the bay of the same name on the northeast side of Lake Superior, and access is easy by steamer from the Sault Ste. Marie.

The topography is of the rugged character usual on the north shore of Lake Superior, and Hematite mountain, the highest point, rises 1,100 feet above the lake within a distance of seven miles. In general the hills form steep ridges with a direction of about 70° east of north corresponding to the strike of the schists, and travelling is difficult across the line of strike. On the other hand, there are broad sand plains rising, as one goes inland, to the height of 450 feet in terraces formed by Lake Warren and higher stages of the post-glacial lakes. As usual in archæan districts in Canada, there are numerous lakes, varying in size from mere ponds enclosed in muskeg to Lake Wawa, five miles in length, and at all levels up to 800 feet above Lake Superior. Two important rivers, the Doré and the Magpie, a tributary of the Michipicoten, cross the region, but do little to open it up, since they have a descent of about 300 feet in the last two or three miles of their course, and form a succession of rapids and waterfalls.

From the summit of Hematite mountain, which is situated about in the middle of the region and rises 200 feet above any of its neighbours, there is presented more than the usual variety of surface, including long ridges of Huronian schist, rounded hills of eruptives, which sometimes rise like islands out of lacustrine plains, stretches of the hummocky surface so common in glaciated archæan districts, lake basins, rock-rimmed or bordered with muskeg, rivers with lake-like stretches of dead water, tumultuous rapids over morainic boulders and falls over rocky descents, and finally the splendid promontories of the shore of Lake Superior and the expanse of water beyond, broken only by the dim form of Michipicoten island to the southwest. The contour lines on the map indicate roughly the relief of the land, but in so ruggedly hilly a region the working out of details would be very laborious, and has therefore not been attempted. The railway, in its line of twelve miles from the harbour to the Helen mine, climbs 650 feet, making use as far as possible of old lake terraces, but requiring also many rock cuttings, which afford valuable sections for the geologist.

The intimate dependence of the topography on the geological history of the country is well brought out in the Michipicoten region, where the folding of the schists has determined the direction and steepness of the main ranges of hills; while bosses and irregular masses of eruptives give rise to less uniform hills or groups of hills associated with the ridges or standing isolated. The basis of the topography is to be found in the pre-Cambrian arrangement and the varying power of resistance to weathering and erosion shown by the different rocks; so that the prominent features may be of very ancient date, even palæozoic. While the hills belong to antiquity, the valleys show the impress of the very latest event in the history of the region, the Ice age with the great lakes that accompanied its close. To the deposit of moraines and boulder clay blocking the valleys are due most of the dozens of lakes and ponds scattered over the country; though a few, like Wawa lake, the largest of them, seem to have been dammed by bars thrown across bays during post-glacial times. Two small lakes near the Helen mine are rock basins dissolved out of the less resisting parts of the iron range, and are certainly pre-glacial in origin. The only level parts of the district are the sand plains of post-glacial great lakes, which cover many square miles. The watercourses are broadly determined by the ancient topography, but their details have been fixed by the glacial and old lake deposits, through which, in many places, they are now cutting their channels.

CLASSIFICATION OF THE ROCKS

The terms Huronian and Laurentian have already been used in previous pages, but it is necessary to define the sense in which they are employed and also to subdivide the Huronian into convenient groups for mapping and description. When Sir William Logan described the Laurentian, it was supposed that the schistose structure of gneisses indicated stratification and that the greater part of the Laurentian was sedimentary. Starting from this assumption the conclusion was naturally reached that the Laurentian gneiss, which underlies all other rocks in Canada and perhaps in the world, was the oldest known rock; and that the overlying Huronian came next in age. It has, however, been shown by Lawson and other geologists that the Laurentian proper, excluding the Grenville and Hastings series, is eruptive and has penetrated the overlying Huronian, and hence is later in age. This was proved first for the Keewatin or Lower Huronian, and afterwards for the Upper Huronian as well, at least in certain cases.*

The original Huronian as mapped by Logan and Murray is subdivided into numerous groups, but no attempt has been made to extend these subdivisions over other areas, and in general the Huronian in other parts of Canada has been mapped as a unit except in the west, where Lawson and his successors have separated two or more lithological divisions. It has, however, been recognized of late that a very marked break separates an Upper Huronian from a Lower Huronian, the most distinctive features in the division being the banded siliceous iron range

**The Michipicoten Huronian Area* (Amer. Geol., Vol. xxviii, No. 1, pp. 14-19).

rocks near the summit of the Lower Huronian, and a thick basal conglomerate containing iron range pebbles in the Upper Huronian. These two easily determined rocks have been found in every large Huronian area in Ontario over an extent of 800 miles, so that the subdivision is evidently far reaching; but singularly enough the Lower Huronian is very little developed in the original region, though well shown in other districts defined as Huronian by Logan. It is possible that on this account it might be better to call the Lower Huronian Keewatin, using Lawson's term for the western rocks, which are largely lower than the conglomerate, but the fact that the mapping done in Canada up to the present includes both divisions under the name Huronian induces us to retain that name, with the subdivision into upper and lower. The terminology used by Professor Van Hise in his latest work on the American iron ranges would naturally be adopted if he had not ignored the work of Logan and later Canadian geologists and given the name Upper Huronian to the Animikie,* which is almost certainly much later in age than the original Huronian.

For the subdivisions of the Upper and Lower Huronian we suggest the following names derived from localities where the different lithological types occur:

Archæan	Laurentian	Gneisses and Granites
	Upper Huronian	Basic Eruptives Acid Eruptives Doré Conglomerate
	Lower Huronian	Eleanor Slates Helen Iron Formation Wawa Tuffs Gros Cap Greenstones

In the classification as given here, it will be noticed that the Laurentian is put as the latest of the archæan formations, since the gneisses and granites are really eruptives which solidified after the Huronian was solid rock. The Gros Cap greenstones are greatly weathered dark green basic eruptives, sometimes with an ellipsoidal structure and sometimes distinctly

*_Iron Ore Deposits of the Lake Superior Region_ (U. S. Geol. Surv.,1901, p. 317). See reply to this in _Journ. of Geol._, Vol. x, No. 1, pp. 67-76.

schistose. The Wawa tuffs are usually greenish, yellowish or pale brownish schists, containing much silica and sericite, as well as carbonates, and at times so little schistose as to be properly called quartz-porphyry or felsite. The Helen iron formation consists principally of cherty or white granular silica banded with iron ore, and of siderite. The Eleanor slates are gray fissile fine-grained rocks with a cleavage crossing a banding due to sedimentation. They form only thin bands, and it is uncertain whether they should be placed above the Helen iron formation, or beneath it. The Doré conglomerate is the most important series of rocks in the Upper Huronian. It is usually schistose and the pebbles are often greatly rolled out, when the rock resembles closely an ordinary Huronian schist. The eruptives, apart from those shading into the Gros Cap or Wawa schistose rocks, are classed with the Upper Huronian, though they penetrate both Upper and Lower Huronian and in reality may be later than Upper Huronian. Since there is no means of determining their exact age it is convenient to take them up in the way suggested.

The subdivisions given above are indicated by different colours with an additional colour for undivided Huronian, used in parts of the map where it was found impracticable to separate them. No distinct colour is used for acid eruptives, the Laurentian including both granites and gneisses. On a map of this scale, acid and basic dikes could hardly be indicated, and in any case few of the scores of dikes observed have been traced out.

THE LOWER HURONIAN

From the classification given above, it will be seen that the Lower Huronian of Michipicoten includes a considerable range of rocks, the Gros Cap greenstones, the Wawa tuffs, the Helen iron formation and the Eleanor slates. These will now be taken up in detail, beginning with the lowest.

The Gros Cap greenstones. The oldest rock in the Lake Superior region according to Professor Van Hise is the Ely greenstone, which corresponds to the Gros Cap greenstone in position and character, consisting largely of an ellipsoidally parted basic igneous rock. This structure is best seen on weathered surfaces, where the rounded blocks stand out distinctly, each enclosed by a fine-grained harder rind, the space between them occupied by a small amount of a more easily weathered cementing material. On a fresh surface this structure is hard to make out, blocks and matrix seeming to have the same composition. The rock is believed to be a lava, which has partly cooled on the surface while the lower portion was still somewhat fluid and in motion, thus breaking up the cooler layer into blocks; these were then rolled along and given ellipsoidal forms. Good exposures are seen just west of Michipicoten harbour and on the trail to the old fishing station at Gros Cap. Many parts of the greenstones show no ellipsoidal structure, and are apparently greatly weathered diabases, while other parts are distinctly schistose, probably tuffs of the volcanoes which poured out the lavas; but the three varieties run into one another and cannot be separated in mapping.

The Gros Cap greenstones, the lowest rocks in the region except the Laurentian, which is eruptive through them, might naturally be looked on as oldest. But there is evidence that a part of them at least is younger than the Helen iron formation, since bands of the latter rock are sometimes imbedded in them as if carried off eruptively. Examples of this may be seen along the south shore of Gros Cap and on the shore just east of the harbour. What portion of the greenstones is older and what younger than the iron range is hard to determine, and no attempt has been made to separate them.

The Wawa tuffs. Above the greenstones are acid schists generally having the composition of quartz-porphyry or felsite, and in some cases still containing crystals of quartz or feldspar as evidence of their origin. In most cases, however, they are apparently tuffs or ash rocks, perhaps deposited in water, as they show more or less stratification. A few are brecciated, perhaps crush breccias or formed of larger volcanic fragments than the ash. A curious variety looking like conglomerate, found on the west corner of Wawa lake, is really of concretionary character, but seems to blend into the ordinary quartz-porphyry schist.

The evidence for original stratification is not commonly well marked, and the usually distinct schistose structure obscures it; but occasionally a banding across the direction of schistosity can be distinguished, probably indicating bedding. While the tuffs were being deposited or since their formation important chemical changes took place, so that they are now greatly silicified, and even changed into a rock like chalcedony with a small amount of sericite. In other cases siderite, ankerite, dolomite or calcite have been deposited along with cryptocrystalline silica, suggesting a change to the overlying iron range rocks. Associated with the greenish or yellowish acid schists are numerous bands of softer, darker gray or green schist with much less silica but with a considerable amount of carbonates and dark silicates, such as chlorite, biotite, or less often hornblende, evidently representing basic tuffs or possibly sheared dikes of greenstone. One coarse-grained dioritic-looking schist consisting of chlorite and siderite is probably a chemical sediment, since no eruptive would contain so much iron. Small amounts of dolomite or of a carbonate containing calcium, magnesium and iron with little or no admixture of silicates occur in the western part of the region, for instance along the railway, northeast of Goetz lake and also as a band along the north side of the Brooks lake iron range. The schists rich in carbonates belonging to the Wawa tuffs contain also, as a rule, more or less silica of a finely granular kind, and are looked on as sediments of a chemical nature.

The Eleanor slates. In addition to the schists just described, thin bands of distinctly sedimentary slates occur near Eleanor lake and elsewhere in the northeastern part of the district. They are buff to dark gray or black rocks with slaty cleavage sometimes cutting the banding due to sedimentation at an angle of 25°. Some varieties are carbonaceous, and at a point east of Wawa lake such a slate was taken up as a coal mine. Whether the black graphitic slate often connected with the iron ranges belongs to the Eleanor slates is not certain, nor has it been positively determined whether the slates are older or younger than the neighbouring iron-bearing rocks. The longest stretch of these slates observed is traceable at intervals for a mile along the north shore of Parks lake; and considerable bands of it occur under the Doré conglomerate on the Grassett road north of Lake Eleanor.

The Helen iron formation will not be described in detail at this point, since the account of the geology of the Helen mine, to come later, will cover the ground sufficiently.

STRATIGRAPHY OF THE LOWER HURONIAN

The lowest of the Lower Huronian rocks, the Gros Cap greenstones, are commonly so massive in character that a strike or dip can hardly be determined, though there are considerable bands of green schist among them which have the usual strike and dip of the schists of the region, either because of their original bedding as ash rocks or since they have undergone the same stresses and have thus developed a similar schistosity. As the greenstones often underlie the Wawa tuffs and appear on each side of them, we may suppose that they have the same synclinal structure, though later eruptive masses of diabase interfere with the regularity of the arrangement and make attempts to estimate the thickness of the formation very uncertain. Since much of the rock was formed as lava flows the thickness would naturally be variable.

The most extensive area of the Gros Cap greenstones stretches eastward from Gros Cap to the mouth of the Magpie river, and then north from the Michipicoten river to the eastward bend of the Magpie. Other large areas lie northeast of Lake Eleanor, including most of the shore of Loonskin lake and a band along the Josephine branch railway from mile 13½ to mile 17. Numerous smaller areas will be found indicated on the map, and there are bands of greenstone and greenschist in the Wawa tuffs that have the same characteristics, but are on too small a scale to be conveniently indicated by the colouring.

The Wawa tuffs have an average strike of 70° east of north, though with considerable local variations, and a dip of 50° to 90° toward the south. Near the Helen mine and south of Lake Eleanor they are found arranged as a syncline enclosing the

Helen iron formation in a trough having a pitch toward the east. As the dips are alike on each side of the synclinal axis the fold is evidently a closed one. Since it was formed the archæan surface has been eroded down until at various points the iron range has been completely removed, leaving the lower schists across the whole width of the syncline. The greatest measured thickness of the schistose tuffs is to the south of Sayers lake, where they reach the southern shore of Lake Wawa, at a distance of about two miles and a quarter; with a dip of 70° this would give a thickness of more than 11,000 feet. Included in this, however, are some diabase masses which should be deducted to give the correct thickness. As many parts of these schists are known to be sheared eruptive masses their thickness may be quite variable, and estimates of their original volume would be of little value.

The Wawa tuffs are the most extensively developed of the the Huronian formations of the region, for though toward the southwest they form only narrow bands on each side of the Doré conglomerate, in the central and northeastern portions they are widely spread and enclose almost all of the iron range bands, with which they are generally connected by siliceous and sideritic varieties. The boundary toward the Laurentian is very irregular, as might be expected, since the latter rocks have erupted through the Huronian and encroached on them unequally. At the Laurentian contact the Wawa tuffs have been somewhat influenced by the eruptives and are coarser in grain and more gneissoid in appearance than elsewhere. As they have essentially the same composition as the Laurentian gneiss the actual boundary is not always easy to determine. The boundary as indicated on the map must therefore be looked on as only approximate.

The iron range rocks which come at or near the summit of the Lower Huronian are the most interesting of all; but the relationships of the most important of them will be described later in connection with the account of the Helen iron mine, and only the less important parts will be taken up here. While the Helen iron formation is most fully developed near the mine itself, rocks of the formation are found at many other points, which will be referred to briefly. Beginning at the southwest there are several bands of siliceous iron range rock on Gross Cap peninsula, the largest at the Gros Cap mine on the south shore, where mining operations were carried on for a time years ago.* The materials here are chert and granular silica interbedded with thin sheets of hematite, but with little solid ore. Two or three similar bands with the same strike of about northwest and southeast and a dip of 50° to the southwest occur near by in the greenstone; and ore is found also on the main shore north of the portage across the narrow neck of the peninsula, a very pyritous band associated with a little quartz-porphyry schist, running nearly east and west with a dip to the south. The bands on the peninsula appear to have been swept off eruptively in the greenstone, but the one on the mainland is probably still in place, since it runs parallel to the schistose structure of the Doré conglomerate a short distance to the north. It is of special interest as the nearest source of the pebbles of iron range rock so widely found in the conglomerate.

Two or three small patches of banded silica are found in the greenstone east of Michipicoten harbour, apparently carried off eruptively; but beyond this no outcrops have been found for eight miles to the northeast, where the Helen iron range begins. As this will be described later, it need only be mentioned that it runs for a mile and a quarter a little north of east, when there is another interruption of a mile and a half, followed by the Lake Eleanor iron range.

The iron range south of Lake Eleanor, which commences west of the Grassett road as a narrow band in hills of quartz-porphyry schist, is broken by a fault along the valley followed by the road, two small patches just to the east representing remnants left by the dragging at the fault plane. The main part of the range south of Lake Eleanor attracted attention years ago with its rusty cliffs just to the east of the old portage road, and was taken up as a mining location, though no work was ever done upon it. Beginning with a north and south strike at the west end this part of the range quickly bends in a direction 70°

* Geol. Surv. Can., *Report*, 1863-69, p. 131; also Ont. Bur. Mines, *Report*, 1899, pp. 145 and 254.

east of north along the south shore of a small lake, then turns northeast for a short distance and ends against a mass of greenstone.

A section across this part of the range going south from Lake Eleanor shows fine-grained greenstone, partly ellipsoidal in structure ; the narrow basin of a little lake ; a sharply rising ridge of the iron range, consisting of 250 feet of grained silica followed by twenty-five feet of somewhat schistose siderite, partly interbedded with quartz-porphyry schist, which extends about 1,000 feet to the south, where it is cut off by diabase.

At the west end of this part of the range the relationships of the different formations are well shown in the cliff. Grained silica forms the upper part of the cliff with siderite beneath, passing down into a thin sheet of quartz-porphyry schist, while the base of the cliff is of greenstone. It is evident that the structure is synclinal, the iron range being enclosed in a fold of the lower part of the Huronian; and the trough thus formed has a pitch to the east as in the more important Helen iron range.

Iron-bearing rocks are next found about two miles to the northwest, beginning just east of a long unnamed lake and running 60° east of north past the north side of Brooks lake almost to Bauldry lake, a distance of about two miles. Here again a fault of great magnitude has been suggested, the fault plane running northwest and southeast, and appearances favour this view, though it cannot be said to be proved. The rocks of the Brooks lake range are the usual banded granular silica and a more or less schistose siderite, rising as a sharp ridge 100 or 200 feet above the surrounding country. Some narrow lakes lie along the north side, as at the Eleanor range, and a band of impure dolomite along that side, being more easily attacked than the silica, may have been hollowed into these basins. The banded silica is often brecciated or greatly crumpled and folded, but in general has the strike of the ridge as a whole, with a steep, often vertical dip. The rocks here also probably have a synclinal form, the Wawa tuffs enclosing the iron range, but this has not been worked out so certainly as elsewhere.

The next range begins as a small strip to the southwest of Bauldry lake and extends eastwards to Parks lake where diamond drilling has been done at the Josephine mine. A few small outcrops farther east and north are not of practical importance and have not been studied in detail.

Though the bands of iron range rock are so narrow, seldom having a width of more than 1000 feet, and often sinking to less than 100 feet, they are the most distinctive formation of the Lower Huronian, since they generally form sharp ridges and consist of very easily recognized rocks. The ridges have a surprising uniformity of strike, from 60° to 80° east of north, the usual strike of the schistose rocks of the region; but the different ranges have been separated, partly by faulting, partly by eruptive masses, and partly by the iron rocks in the centre of the syncline having been completely cut through by erosion. Immediately under the rocks of the iron range there is at many points a thin sheet of black graphitic slate, but in other places the sideritic variety of iron range rock passes by easy gradations into the schists below.

The source of the immense quantities of silica and iron contained in the Helen iron formation is obscure. We must remember that hundreds or even thousands of feet of these rocks have been destroyed, forming the pebbles so common in the Doré conglomerate, or worked up into still finer forms now lost to sight, and that the underlying Wawa tuffs are greatly charged with silica and siderite, especially near the iron range. It is often suggested that the iron range represents chemical sediments, and this is perhaps the most probable view; but it leaves untouched the question of the source of the silica and iron. Whether basic volcanic rocks and ash, like the Gros Cap greenstones, could under certain conditions provide these solutions seems doubtful, unless the waters acting upon them were hot and under pressure, conditions which can hardly be imagined on so large a scale and in an open sea.

THE UPPER HURONIAN

The Doré conglomerates form almost the only undoubted Upper Huronian rocks of the Michipicoten region, and so will be described somewhat fully. Sir William Logan gives a detailed section of part of them at the mouth of Doré river, evidently looking on them as a typical example of the Huronian,* but he was able to examine only 1,700 feet of them lying on or near the shore of Lake Superior. Of the formation to the north (inland) he says, "Towards the lower part it assumes more the character of the gneiss which usually succeeds it, and becomes interstratified with reddish feldspathic layers."

Our sections across the conglomerate show that Logan was mistaken in his suggestion that they blend downward into the gneiss, for beyond the schists which he thought transitional there are undoubted conglomerates once more. These rocks are best studied on the small islands off the mouth of Doré river, where they have undergone less compression than elsewhere, and where the smooth, wave-beaten, glaciated surfaces show marvellous cross sections of the pebbles and boulders. A census of the pebbles one inch or more in diameter was made on one square yard of surface, and the results were 38 examples of green schist, 13 of granite, 11 of granular silica (iron range rock), 8 of spotted schist, 7 of porphyry, 3 of felsite and 1 of conglomerate or breccia; total 81. The matrix at this point consists almost entirely of smaller pebbles somewhat squeezed and flattened. The list just given includes most of the varieties of rocks occurring as pebbles, and it will be noticed that all of them except the granites are characteristic Lower Huronian rocks. No undoubted Laurentian gneisses have been found after careful search.

In most cases these conglomerates are distinctly schistose, not slaty as Logan's name suggests; and they are often so rolled out and flattened that the pebbles are changed into thin lenses. The granite boulders resist best and may be almost round, while the softer schists are pressed thin and wrapped round them. In the last extreme the pebbles show on cross sections as thin

* *Geol. Can.*, 1863, pp. 52-55.

bands of slightly varying colour, and on cleavage surfaces are invisible, so that the rock is readily taken for a chloritic or hornblendic schist. There are occasional bands sparsely strewn with pebbles or free from them, indicating the bedding, and in general the schistose cleavage is about parallel to the stratification where it can be determined, though at one point a difference of about 25° was found between the two directions.

The conglomerate is penetrated at many points by dikes, acid or basic, the earlier ones almost or quite as schistose as the enclosing rock, so that they appear now as bands of green or yellowish red schist free from pebbles. In some of the acid dikes, remnants of porphyritic crystals of quartz or feldspar occur, proving their eruptive origin; and it is these bands, no doubt, which Sir William Logan took for transition rocks toward the Laurentian. As they are probably offshoots from the adjoining eruptive masses of Laurentian gneiss, they may still be looked on as closely related to those rocks, though not in the way suggested by Logan.

Some bands of the Doré conglomerate seem to be much more easily eroded than others, giving rise to a succession of narrow ridges with steep walls, even overhanging on the north side, since the dip is toward the south. These ridges conform to the direction of the strike, which is usually about 70° east of north, while the dip is from 60° to 90°; there are, however, rapid variations in the strike near some of the eruptive bosses.

Sections were made across the Doré conglomerate in several places, with results which may be indicated. The first shows 2,500 feet of the conglomerate on islands and the shore; but north of the mouth of the river there is no certain conglomerate observed for about a mile, the rocks being the felsite schists mentioned by Logan and soft gray and green schists with some dark eruptives. They are followed, however, by about 600 feet of undoubted conglomerate before the narrow band of quartz-porphyry schist indicated on the map intervenes between the Upper Huronian and the eruptive contact of the Laurentian. A section north of Michipicoten harbour shows more than half a mile of undoubted conglomerate, then gray schist with only a few pebbles visible, a quarter of a mile of swamp with no rock exposed, a ridge of diabase, and another half-mile of conglomerate. A mile east of this there is almost unbroken conglomerate from a point somewhat south of the railway, where Gros Cap greenstone occurs, to the Laurentian, a mile and an eighth to the north; and a mile still farther east there are five-eighths of a mile of schist with distinct pebbles, broken only by some lake deposits near the middle of the section. A little east of this, near mile 3 on the railway, the strike changes to north and south, and the conglomerate is cut off by a tangle of eruptives, greenstones, felsites and porphyries, with some bands of schist in which no pebbles were observed.

To the east of this no large areas of Doré conglomerate have been found, though comparatively narrow bands occur along the line of strike of the main mass at two successive bends of Magpie river, and two other strips have been mapped, one just south of Lake Eleanor, and the other about two miles to the north on the Grassett road. The last outcrop is of a typical kind and is crowded with pebbles and boulders very little flattened and reaching a diameter of two feet. This area of conglomerate, like the one south of Lake Eleanor, is associated with certain gray schists readily crumbling into coarse brownish sand and gravel, apparently interbedded with them, so that they must be included in the Upper Huronian. The conglomerate here rests, at least in part, on Eleanor slate, and includes at its base many dark, angular slate pebbles. The two small bands of Doré conglomerate just mentioned are parallel to one another and a mile and a quarter apart, the space between being occupied by Lake Eleanor and a wide sand and gravel plain, so that there is a possibility that they are connected. Two or three small outcrops of conglomerate south and east of Wawa lake need not be mentioned in detail, though they are of interest as showing that the rock was probably once much more widespread than now. The most easterly mass of conglomerate is a mile and a half south of the high falls of the Michipicoten river; while strips and patches of the same rock are found along the shore of Lake Superior west of Doré at Dog river, Eagle river and Pucaswa river, giving a total length of 57 miles, though with several long gaps between the western outcrops.

The relationship of the main area of Doré conglomerates to the other rocks of the region is not absolutely certain. Their fairly uniform strike and dip from south to north suggest that they are, as supposed by Logan, a continuous series of strata resting on the Laurentian to the north; in which case they would have a thickness of about 7,500 feet. However it is not easy to imagine such a mass tilted bodily, and it is more natural to think of the series as forming a close fold, most probably a syncline with the two sides closely squeezed together and tilted slightly against the Laurentian mass to the north. In this case we may suppose that the strata were to some extent pulled asunder at the base of the fold, which was in tension, allowing felsites and diabases to penetrate parallel to the lines of easy parting, whether of bedding or schistosity. The syncline, with a thin sheet of Wawa tuffs and an irregular mass of Gros Cap greenstone beneath it, sagged trough-like into the plastic Laurentian, which rose on each side in a batholithic way, squeezing the Huronian rocks between, flattening the pebbles of the conglomerate, and with the aid of heat and moisture producing the recrystallization of the sediments into the present schistose form, while dikes pushed up from below into the disrupted lower part of the fold.

Assuming a single syncline, the thickness of the conglomerate is 3,700 feet without allowing for increase in thickness due to the dikes, nor for reduction in thickness due to squeezing. As the pebbles and boulders are often flattened till their thickness is only one-fifth or one-tenth of their length in cross section, there must have been a great compression as compared with the original mass of sediments. It is of course possible that the folding is more complex and that instead of a single syncline there are several close folds in succession, but this view is unsupported by field evidence.

There is one puzzling relationship between the Upper and Lower Huronian of the region. If the Upper Huronian follows the last formation of the Lower Huronian, the Helen iron rocks, in regular succession, we should expect to find somewhere a syncline in which the conglomerate occupied the middle, followed by the iron range rocks on each side, and then by Wawa tuffs and Gros Cap greenstones, with the Laurentian forming an eruptive contact with the last rock; but this has not been found. Instead, we see the Doré conglomerate occupying the centre of one syncline with Wawa tuffs, etc., on each side; and the Helen iron formation forming the core of other synclines enclosed in the Wawa tuffs; but the two never occur together. In fact the conglomerate has never been found in immediate contact with the iron range from which so many of its pebbles were obtained, though the two rocks are sometimes within a quarter of a mile of one another.

It is certain that the rocks of the iron range had undergone great destruction before the conglomerate was formed; and it may even be that the Lower Huronian had been thrown into folds before the erosion took place which furnished the pebbles of granular silica and other Lower Huronian rocks contained in the conglomerate; so that the synclines of the Upper Huronian may be of an entirely later age. However, in a region which has been so disturbed by later eruptives and probably also by extensive faulting, great regularity in the arrangement of the different formations can hardly be looked for.

While some of the eruptives so common at Michipicoten are distinctly Lower Huronian, forming part of the Gros Cap greenstone or Wawa tuffs, there are others which are evidently later in age, penetrating both Lower and Upper Huronian rocks as dikes or bosses. Of these the acid eruptives, quartz-porphyry and felsite, are probably the older rocks, being apophysae from the neighbouring Laurentian, which made their way into the schists while the Huronian was sinking as troughs between the adjoining granitic batholiths. Dikes of this kind are not found in the Animikie, which overlies both Huronian and Laurentian unconformably; so that we may consider the acid eruptives later than the Doré conglomerate but much earlier than the Animikie.

The basic dikes and bosses, chiefly diabase and diabase porphyrite, are apparently the latest rocks of the region, cutting all of the others including the Laurentian, and often crossing the strike of the schists. As they are post-Laurentian and no later rocks have been found overlying them, their age is somewhat indefinite, though their resemblance to dikes in the Animikie at other points on the north shore of Lake Superior, supposed to be connected with the Keweenawan lava flows, hints that they may be of the latter age.

The Laurentian granites and gneisses have not been studied in detail in the Michipicoten district, but their associations with both Lower and Upper Huronian prove them to be post-Huronian eruptive masses, as shown on previous pages.

HELEN IRON REGION

Beginning on the west the iron range as found at the Helen mine is in two long fingers reaching the shore of Talbot lake, but not crossing it. The southern finger, long and narrow, possibly reaches a short distance into the water of the lake, but does not appear on the opposite side. It extends easterly up the valley of a small creek until it reaches the main body of the formation near Sayers lake. Following the boundary northwards are several minor folds which are seen to rest on Wawa tuffs. Then crossing the railway track near the outlet the range extends westward to within a few feet of the shore of the lake, being bottomed by Wawa tuffs. On the north side the range seems to extend quite regularly towards the east, the formation standing almost vertically. At the outlet of Sayers lake, as shown in cuttings along the railway, the formation has been thoroughly shattered, and a beautiful breccia has resulted. A small tunnel driven at right angles to the formation at the foot of the outlet of Sayers lake disclosed cherts carrying pyrite and a small amount of carbonate. South of the railway track and west of Sayers lake Mr. Ely did considerable work in stripping the formation, but nothing was shown by his trenches except pyritic quartz rock and ferruginous cherts with a small amount of surface oxidation. On the south side of Sayers lake, a little further east, a tunnel was driven by Goetz at right angles to the formation, which disclosed considerable pyritic quartz rock, in some places becoming almost pure pyrite. Wawa tuffs striking east and west bound the formation on the south. Along the north side of Sayers lake, where the formation has been exposed by railway cuttings, the belt of cherty rock is shown to have been badly disturbed by folding and faulting, the strikes and dips changing very rapidly, but on the whole the formation is seen to run east and west. Near the inlet from Boyer lake a small amount of pyrrhotite is associated with pyrite.

At the outlet of Boyer lake the iron range contains a considerable amount of carbonates as well as banded chert carrying pyrite, and one hundred feet eastward along the railway track a lens of pure carbonate is found carrying as much as 35 per cent. of iron. This changes gradually until it becomes a quartz-porphyry schist by a progressive decrease of carbonate, but so gradual is the change that no definite line of demarcation can be drawn. Along the south shore of Boyer lake the rocks exposed are the ordinary quartz-porphyry schists, though near the stairway there is a small dike of greenstone now altered to schist four feet in width. The southern boundary of the ore body is the same quartz-porphyry schist already described. On the surface at the top of the hill near the camps it is seen to contain a small amount of carbonate, and in a drill hole to be described later, which entered this rock several hundred feet deeper, it is found to contain comparatively pure siderite.

On the eastern boundary of the Helen claim, as shown in detail on the accompanying map, succeeding the quartz-porphyry schists to the north is a band of grained silica, and following this almost to the northern boundary of the claim is a band of very pure carbonate of iron. On the northern boundary, and running almost parallel with it, are beds of ferruginous chert dipping almost vertically and extending for 450 feet to the north. This banded chert continues regularly along the north shore of Boyer lake to the part already described near the outlet of Sayers lake.

The ore body itself lies at the eastern end of Boyer lake and is surrounded on three sides by steep and high hills and on the west by the waters of Boyer lake. The accompanying plan shows the contours of these hills as determined by aneroid barometer and the contours of the ore body as actually levelled. It will be noticed that the highest point of ore is almost 100 feet above the original level of Boyer lake and that the surface of the ore body dips from this point in all directions. A small valley running east from Boyer lake on the south side of the ore body was originally filled largely with glacial materials, but in the eastern end with boulders of ore and siderite also. The ore body was for the most part covered with a very slight mantle of moss and earth, but on the east the glacial material was from 15 to 20 feet thick and in the valley just mentioned it was even deeper.

To the west of the ore body lies Boyer lake, a pond about a quarter of a mile in length and hardly as wide, rock-rimmed throughout and 133 feet deep. This lake is now being pumped out, and on some boulders exposed along the shore a film of oxide may be noticed, which must have been deposited on them there. As one of these boulders was a gneiss certainly brought there in glacial times, the thickness of the crust on it, from one-sixteenth to one-eighth of an inch, represented the deposition which has taken place in the lake since that era.

Along the shore near the ore body a yellow ochre was exposed which on analysis showed :—

Iron	49.50	per cent.
Manganese	0.36	"
Silica	6.63	"
Lime	trace	
Carbon dioxide . . .	4.13	"

Near this yellow ochre was a dark green mud which apparently will be found to cover the bottom of the lake. Analysis showed :

Silica	47.58	per cent.
Iron	11.23	"
Manganese	0.14	"
Lime	0.95	"
Carbon dioxide . . .	3.19	"

Into the ore body several drill holes were put down, and the cores of these were examined by Mr. C. H. Clarke, chemist of the Company, analysis being made of representative samples at various depths. Drill hole No. 1, near the point, was sunk vertically 188 feet, all in ore containing on the average 63.89 per cent. of iron, 0.0345 per cent. of sulphur, 0.1159 per cent. of phosphorus and 2.24 per cent. of insoluble matter. The highest assay showed 69.16 per cent. of iron, and the lowest 59.87. Drill hole No. 3, 440 feet from the point, was started at an elevation of 734 feet above Lake Superior, and was put down vertically for 72 feet, the first 18 feet being soil. Below this, ore was found running 56.73 per cent. of iron, 0.015 per cent. of sulphur and 0.017 per cent. of phosphorus, with 8.40 per cent. insoluble.

A drill hole sunk 558 feet at an angle of 45° on the south side of the claim showed chiefly siderite, though with some felsite and pyrite. The purest siderite contained 44.03 per cent. of iron, and average examples contained 29.82 to 37 per cent. of iron with about 2.5 per cent. of manganese. A shaft sunk toward the eastern boundary of the exposure of ore, starting at a level of 745 feet above Lake Superior, or 95 feet above Boyer lake, penetrated soft brown ore for the whole depth of 100 feet, and in a drift from it two bands of pyritic sand, almost pure, two feet in width, were found, and near the second one a deposit of very fine-grained almost pure white sand. A drift from about the same point running a little north of east for 200 feet exposed a large amount of soft brown hematite, crossed at 35 feet in by a band of the same sand nine feet in width. At the end of this tunnel lean ore was encountered ending in a band of chert. Other drifts and tunnels disclosed similar associations of brown ore, sand, siliceous ore and chert.

At points in the ore body the open pit workings have uncovered pockets of pyritic sand, consisting largely of tiny crystals, the largest one, 45 by 8 feet, cut off very abruptly by the ore, with no gradation between the two. Occasionally in this bed some boulders of solid ore were noticed, the largest two feet in diameter. Little stringers of pure white fine sand were occasionally seen in the pyrites, but apart from these minor occurrences the pyritic sand seemed to be a pure concentrate. It is said that on the surface this deposit first made its appearance as a chimney of sand about 30 feet in diameter, and that as followed down the siliceous sand was gradually replaced by pyritic sand until the present level was reached, and that the pyritic sand has been replaced in the bottom with solid ore just as abruptly as it changed on the sides.

Behind the ore body, as above mentioned, is a high hill rising about 1,700 feet above sea level; costeans made at several points have enabled the structure to be fairly well made out. One costean was sampled by Mr. Clarke, who made analyses of the siderite, beginning at the south and passing to the north. The siderite, which averaged 34.94 per cent. of iron and 7.70 per cent. of insoluble matter, has a total width of 136 feet.

ORIGIN OF THE HELEN ORE BODY

So far the description of the Helen mine has been confined to the facts observed, but we may now attempt to explain the manner in which the formation was probably deposited. Apparently at one time volcanoes were in active operation in this vicinity, lava flows took place, ashes fell abundantly on the neighbouring lands and in the adjoining seas. These on consolidation gave rise to the quartz-porphyry schists or Wawa tuffs as they are marked on the map. At intervals the volcanic activity would naturally become quiet, and apparently then chemical sediments were precipitated from the waters, which seem to have been heavily charged with carbonates of lime and iron and also with silica. These intervals would be of varying duration, and the rate of precipitation would also vary, and so lenses small or large of carbonates or of silica would occur in the tuffs. On the recurrence of volcanic activity the carbonates being precipitated would be scattered throughout a large volume of volcanic ash. In this way for the most part have been formed the Wawa tuffs of the region and interbedded lenses of limestone and siderite and the grained silica, small in amount but widely distributed.

Later, there was an entire cessation of the volcanic ashes, and chemical sediments were precipitated for a considerable time, in some places carbonates and in other places silica having been precipitated first. The deposition of one or the other went on until beds perhaps 500 feet in thickness were built up. Later, the Wawa tuffs and the Helen iron formation were both folded and tilted, by which the schists were formed into a trough underlying the iron formation, while that formation, lying closely on this, occupied the interior of the basin. In the sections accompanying both the general map and that of the Helen mine this folding has been expressed.

The foldings were not uniform for the whole extent of the iron range, but being greater in one part than another pitches were given to the formation at approximately right angles to the lines of the folds. At the Helen mine numerous observations along the shore of Boyer lake and the ore body seem to indicate that the Wawa tuffs pitch about thirty degrees to the east. By this change in the pitch the iron formation would become lower in some places, and after erosion had still further lowered the general level, would appear as isolated fragments rather than a continuous formation. That this is now the case can be seen by reference to the map. Similar conditions seem to have existed in the Vermilion iron range in Minnesota.

The folding and tilting of the iron range was naturally accompanied by a great fracturing of its component parts, and the breccia which often resulted is well shown on the railway track near Talbot lake. The origin of the deep ponds Boyer and Sayers lakes is doubtless connected with this brecciation, for they are rock-rimmed and extend for a depth of 130 feet, and are naturally supposed to have been brought about by solution. Brecciation of these rocks would promote the circulation of solvents, and so assist in gradually deepening them.

Several solvents may have had an influence in dissolving and removing the carbonates, but probably the most effective would be a solution of acid ferric sulphate or sulphuric acid, probably resulting from the oxidation of the iron pyrites found in considerable quantity throughout the iron formation both in the chert and the carbonate. The ore body itself is the result of the oxidation of the iron carbonates which existed in such large quantities at this point, the iron pyrites probably contributing very little to the ore body. On the surface of the hill, where oxidation of siderite has progressed inwards about half an inch, leaving that amount of brown hematite, it is found that grains of pyrites which were scattered through the siderite still remain unaltered; this goes to show that pyrites is changed comparatively slowly. Moreover, the presence of pyrites in the pit itself as described above shows that it may be deposited as concentrates and still undergo comparatively little oxidation.

Apparently the process of ore formation has proceeded as follows. A solution of the iron carbonates derived from the overlying parts of the iron formation (which we may assume to have been several hundred feet higher than at present), penetrated downwards to a point at which the ore is now found, where it came into contact with a current of water charged with oxygen. This would result in the precipitation of the iron as an oxide or as a hydroxide. The fact that the ore body seems to dip in all directions from its highest summit would suggest that at this point the precipitation must have occurred more rapidly than elsewhere, and that here the water carrying the oxygen met the iron solutions.

Apparently the upper parts of the ore body were formed much as stalagmite is deposited on the floor of caverns. This, of course, assumes that surrounding the ore at that time there were masses of the iron formation, probably in the main siderite, which formed the walls of the cavern. Such a hole as may have existed here may be observed on a much smaller scale on the south shore of Long lake near the Josephine mine. It is in this region very unusual to find caves or caverns, but at this point of the iron range a small opening about one foot in diameter comes to the surface, opening below into a cavern about twenty-five feet in depth and widening out to an unknown but probably small extent. No doubt the cavern has been produced in part by the folding and partly by solution, and it is possible that a similar but larger cavern existed where the Helen ore body is now deposited. In this cavern one can see how there might be deposited at times, through the inrush of water, large quantities of pyritic sand, the residue from the solution of the overlying siderite. As already explained, the pyrites are observed to weather much less rapidly than the carbonate, and being comparatively heavy might be swept along by some stream, but deposited where the velocity was checked. In this way one can see how at intervals in the ore body concentrates of almost pure pyritic sand could be brought about, and in these concentrates one can well understand finding some boulders of ore or partially decomposed siderite and even a little sand as already described.

The origin of the pure white sand is found in the silica distributed through the siderite, which contains from five to ten per cent. of it, even when tolerably pure. Some may have been dissolved and removed, but most of it probably remains in the ore body.

The siderite also contains commonly about two per cent. of manganese. This is not at all unusual in deposits of carbonates of iron, and is the case in other iron locations near Lake Superior. It is to be noticed that almost no manganese occurs in the ore deposit, but as is well known the carbonates of manganese behave somewhat differently from carbonates of iron in regard to solvents. It seems in this case to have been dissolved at the same time as the carbonate of iron, but not to have been precipitated at the same place, being carried further and so becoming dissipated.

After the formation of the ore body as outlined above, the mass of siderite which formed the boundary wall to the south, and also the siliceous matter overlying the ore body, which were left after the leaching of the carbonates from them, were all removed by erosion. This would leave a valley almost one hundred feet deep along the south side of the ore body between it and the green schists, which was filled at the time of the retreat of the ice with glacial débris, and also with boulders of ore and undecomposed siderite from lenses known to exist in the overhanging green schists. In the upper drifts several boulders of ore resulting from the decomposition of siderite are found, and mixed indiscriminately with these are beds of white sand. Pyritic sands also in these drifts are due to concentration.

In the section accompanying the map of the Helen mine an attempt has been made to show how the iron formation was probably folded, two troughs resulting from a double fold, the limbs of which are so closely pressed that the parts now remaining stand almost vertical. The southernmost of these troughs probably at one time extended up the steep hill near the incline hoist, and many years ago may have resembled somewhat the southern finger shown on the map as now stretching to Talbot lake. Erosion has, however, removed all the upper part, and it appears to be merely a widening of the main fold. The northern fold is represented as deeper, because it is believed to be part of the range which continues under Boyer lake to Sayers lake and Talbot lake.

As will be seen from this section, the green schists form under the Helen ore body an impervious basin which is tilted about thirty degrees to the east. If this interpretation is correct, it is quite possible that the ore body may be found to extend to the east beneath the siderite outcrops which are found on the eastern part of the Helen claim. The section also shows that the southern fold has been slightly overturned and dips about seventy degrees to the south. No doubt the ore body will be found to follow this dip somewhat to the south, but it does not seem probable that it will go to any great depth in this direction. The main formation on the north is also bottomed by the impervious basin of green schists, so that in this basin also deposits of ore may occur. Indeed they may have existed where Boyer and Sayers lakes are now found, but may have been largely carried away by later erosion.

Eleanor Ranges

The four small ranges of the iron formation occurring on the trail from Wawa to Eleanor lakes are so narrow, and so little iron is seen on them, that they are probably entirely useless from an economic standpoint. The same is to be said of the similar occurrence of banded silica occurring on the

Josephine branch of the Algoma Central Railway to the north of the Helen, and the small occurrence of banded silica carrying pyrites on the trail leading to the southwest end of Loonskin lake is also useless as an iron location. The latter was originally taken up as a gold location, and an analysis of the pyritous material does show a trace of gold, but not in economic amount. Similar traces of gold are found at many points of the iron range, particularly where pyritous.

Brooks Lake

The iron formation exposed on the north of Brooks lake is about two miles in length, and in places is several hundred feet in width. It consists of ferruginous chert with lenses of siderite, and is surrounded by Wawa tuffs, which in all probability form an impervious basin at its base where ore may yet be found.

Long Lake

The details of the iron belt occurring in the vicinity of Long lake are shown on the map, the narrow end of it, extending from Long lake to Bauldry lake, being too small to be of any importance, but where the belt widens out in the central part of Long lake it is of sufficient width to have yielded on concentration an ore body, other conditions being favourable. Considerable stripping has been done in this vicinity, exposing well the surface of the iron range, which is seen to consist of ferruginous chert, pyritic grained silica and lenses of carbonate. One of the latter on the south shore near Leg lake is of considerable size and of the usual purity, carrying about thirty-five to thirty-eight per cent. of iron. On the hillside overlooking Long lake there is a small cavern in the iron range, probably due to folding, which has been mentioned earlier in this paper. Surrounding the formation here are the Gros Cap greenstones and Wawa tuffs, which either singly or together doubtless form an impervious basin at the bottom of the belt. While no ore is visible at the surface, it is quite possible that at the bottom of this belt ore deposits may have formed.

Parks Lake

The discovery of boulders of hematite on the south shore of Parks lake can only be explained by assuming that at one time there existed in the bottom of the lake a deposit of iron ore. Whether all this was removed by glacial action, or whether the deeper parts still remain, can only be proved by diamond drill work. As is already known, drill holes indicate that a considerable deposit of ore still lies at the western end of the lake. Westerly from Parks lake towards Goetz lake there is a considerable belt of the iron formation which underlies and is surrounded by Gros Cap greenstone. As the siderite is not in large amount in the formation here it would seem quite possible that at the western end test pits might reveal a body of ore. East of Parks lake the range continues for about two miles, and was carefully examined as far as Kimball lake. In this distance the formation occurs as banded grained silica with more or less pyrite and small quantities of siderite. The four small patches of iron range shown on the map to the north of Parks lake are probably represented a little too large, their exact distribution not having been worked out. They are so small that they will be useless from an economic standpoint.

Beginning on the west, the possible places where ore may exist are Gros Cap, Sayers and Boyer lakes, just east of the Helen mine, around Brooks lake, south of Long lake, just east of Goetz lake, in Parks lake, and between Parks and Kimball lakes.

PETROGRAPHY OF THE MICHIPICOTEN REGION

The Eruptives

The band of Upper and Lower Huronian running from the mouth of Doré river northeasterly to beyond the Josephine mine consists partly of ordinary sedimentary rocks, partly of ash rocks and agglomerates or pyroclastic sediments, and largely of sheared and metamorphosed eruptives passing on the one hand imperceptibly into the pyroclastics, and on the other into eruptives which show no schistose structure. These eruptives are generally included in the mapping with the schists and sediments, since well defined boundaries are very hard to draw between them, and also since they are often intimately connected in origin and character with the adjoining schists. They include both acid and basic rocks, quartz-porphyries and porphyrites, as well as greenstones, all greatly metamorphosed. Their age relationships are not very certain though it is probable that most of them belong to Huronian times, so that they have undergone all the squeezing, folding and faulting of the sedimentary rocks, and thus have been subject to great changes due to crushing and the circulation of water at considerable depths, in general below the level of plasticity.

Besides these more or less certainly contemporaneous eruptives there are numerous others undoubtedly later in age, forming dikes or bosses which penetrate the schists, in many cases across the strike, and which are seldom sheared or squeezed or greatly metamorphosed. Among them are acid rocks such as quartz-porphyrite and granite, and also basic rocks such as diabase, diabase porphyrite and picrite. At what date after the folding of the Huronian schists these later rocks were erupted is uncertain, though they are all supposed to be of comparatively ancient origin, pre-Cambrian or Cambrian. The later eruptives are often fairly fresh and furnish satisfactory materials for study, while the earlier ones are in general very unsatisfactory, the whole of the original minerals often having been replaced by secondary minerals.

The Acid Eruptives

The acid eruptives include various types of granite, quartz-porphyry, quartz-porphyrite and felsite, belonging to the group of alkali-feldspar-quartz rocks, and quartzless porphyry of the alkali-feldspar rocks without quartz. The granites proper belong mainly or altogether to the Laurentian, even the rare, isolated bosses of granite in the Huronian having generally a thoroughly Laurentian appearance, and they merge into the schistose variety of gneiss. Not much attention was paid to the Laurentian rocks and comparatively few thin sections of them have been studied, but in general they are flesh-coloured to pale gray, coarse-grained rocks, with comparatively few darker bands or areas.

A boss of bright flesh-red granite from near the northeast boundary of the main Upper Huronian conglomerate may be spoken of as a binary granite, since neither mica nor hornblende is present in appreciable amounts. It is thoroughly leucocratic, and is made up almost entirely of quartz, orthoclase with a very little microcline, and a plagioclase having the low extinction angles of oligoclase. Though the rock has undergone much crushing, as shown by the granulation of some of the quartz and the "mortar structure" around the larger feldspar masses, it is still quite fresh.

A specimen from the Laurentian boundary to the west of the rock just described is a normal granite, flesh-red, coarse-grained, and composed of quartz, orthoclase, microcline, oligoclase, muscovite and biotite.

A pale gray granite still further west, near Doré lake, has a similar composition, but with much muscovite and little or no biotite. The feldspars in this case are not so fresh as in the others and contain many small scales of muscovite. All the granites studied from the north side of the Huronian band show evidence of squeezing and crushing.

From the south side of the Huronian only one Laurentian granite section has been examined, from a grayish flesh-coloured outcrop a little south of Lake Wawa. This rock is melanocratic and very different from the northern granites, containing biotite, hornblende and magnetite in considerable quantities. The quartz is extended into the feldspars as micropegmatite or is poecilitically intergrown with them, but the feldspars are too greatly weathered for their species to be determined.

A handsome flesh-coloured granite porphyry with white dihexahedra of quartz, sometimes a third of an inch in diameter, which forms bosses near the second falls of Magpie river and east of the Mission near the south of Michipicoten river, has much the composition of the last-mentioned granite, but with a marked tendency to idiomorphy in the quartz and feldspar, the latter often having good crystalline forms with quartz or sometimes biotite filling in the spaces between. The megascopic dihexahedra of quartz prove under the microscope to have been crushed or rearranged and do not appear as single individuals. The feldspars are quite largely striated, with very small extinction angles, except one crystal which has an angle of 14 degrees from the twin plane, suggesting a variety like andesine. All the feldspars are more or less turbid and contain muscovite scales or crystals. There is no definite ground mass enclosing them as in true quartz-porphyries, so that this rock must be called granite porphyry. In reality it comes near to being panidiomorphic in the original sense of that word, since almost all of the components show more or less of their crystal form.

The quartz-porphyries vary much in appearance, some being flesh-coloured, others pale greenish or gray, and still others purplish gray ; and also in texture, some having large well formed phenocrysts of quartz and feldspar, while in others the phenocrysts are obscure and the rock resembles felsite as seen in the field. Those which are associated with the Lower Huronian schists of the Wawa formation are usually greatly weathered, so that often only the cloudy outlines of the feldspars and the clear spaces of the quartz crystals remain to show the character of the rock. Where the feldspars are less completely weathered they include both orthoclase and plagioclase, often in equal amounts or with the plagioclase exceeding the orthoclase in amount; the rock should then properly be called quartz-porphyrite. The two varieties are, however, so closely alike in other respects and so intimately connected in field relations as to make it difficult to draw a sharp line between them. Thin sections of the darker porphyries contain hornblende or biotite, the latter in porphyritic crystals in one case, and pyrite is a frequent accessory mineral. The ground mass is generally microgranitic rather than felsitic, but is always in definite contrast with the phenocrysts, which are many times larger than the quartz and feldspar of the ground.

Some of the specimens display no traces of shearing, but most have suffered in this way and show stages approaching the sericitic and other schists with which they are associated ; and sometimes rhombs or irregular areas of a carbonate, dolomite or siderite appear in them, suggesting changes connected with the formation of the iron range rocks. There are a few examples in which the phenocrysts of quartz with inclusions of what was once glass, and the more or less weathered feldspars, are found beside vague concretionary forms, apparently the beginning of structures found more complete in the conglomerate-like rock near Lake Wawa.

The felsites are generally flesh-coloured or pale greenish, and are very much weathered and often penetrated by narrow seams of quartz, showing that faulting and other effects of the Huronian re-adjustments of the region have left their mark upon them. Under the microscope they are very unsatisfactory, and beyond stating that they have the same character as the ground mass of the porphyries there is little to be said regarding them.

The quartzless porphyries stand farther from the quartz-porphyries than the felsites do, not only in their characters, but also in their field relations, since they have not been found associated with the Lower Huronian schists, but only with the schist conglomerate of the Upper Huronian and the greenstone at Michipicoten harbour. They are found as well-defined dikes at the points mentioned, and are evidently later in age than any of the Huronian rocks. The examples from the conglomerate between Doré river and Gros Cap are medium-grained rocks of a grayish flesh-colour, sometimes merging at the edge of the dike into a very fine-grained or compact felsitic phase. The phenocrysts, which are not large nor distinct, are chiefly plagioclase, often with very complex twining, but a few orthoclase crystals occur also. The ground mass is reddish and felsitic rather than microgranitic, and contains a second generation of tiny porphyritic crystals, mainly of plagioclase. There is some undoubted quartz in the ground mass.

The other dikes, near the shore southeast of the large mass of greenstone on Michipicoten harbour, are more evidently porphyritic, being crowded with feldspar phenocrysts up to a quarter of an inch in diameter. The rock as a whole might at first be taken for a syenite until it is noticed that the feldspars have crystal forms. The colour on fresh surfaces is speckled gray. Under the microscope the phenocrysts are found to be predominantly plagioclase with low extinction angles, not far from oligoclase, but some of the crystals show no striations. The ground mass is distinctly granitic with comparatively large grains of quartz, feldspar and biotite. About one half of the rock consists of badly weathered phenocrysts of plagioclase, but with no suggestion of shearing or of strain in their sections. It is doubtful if this rock should be called a quartzless porphyry, since quartz forms an important part of it, though only seen with the microscope. The name feldspar-porphyry or porphyrite might be more appropriate, thus suggesting the most striking feature, the phenocrysts.

Basic Eruptives

Basic eruptives in the form of greenstones cover large areas in the Michipicoten region, especially south of the Upper Huronian conglomerate on Gros Cap and the shore between Michipicoten harbour and the river. There are also large outcrops of the rock on the shores of Wawa lake. They are usually dark green and fine-grained, and often have the ellipsoidal structure supposed to indicate lava flows, the latter variety being well displayed just west of the docks near Michipicoten harbour. Unfortunately these older greenstones, so far as examined, have almost completely lost their original minerals, so that it is not easy to decide their exact character, though they are assumed to have been diabases. Owing to the fact that they are so greatly weathered little microscopic work has been done upon them. The name greenstone as used in this paper is limited to these greatly weathered basic eruptives, those whose original composition is still distinct being taken up under separate names, diabase, etc.

The greenstone south of the railway near Michipicoten harbour shows under the microscope mainly chlorite and epidote in forms vaguely suggesting plagioclase strips. A few clear grains of quartz are the only minerals which remain unchanged, so that the rock seems to have been quartz-diabase.

Another area, between Gros Cap and Doré river, has some portions of coarser grain, which show under the microscope a somewhat different composition, of pale green hornblende in fairly well defined prisms, chlorite and lathshaped sanssuritic areas evidently once plagioclase. The hornblende is probably secondary after augite and often contains portions of chlorite in the central parts of the crystal. Quartz occurs in small amounts, partly interstitial and partly as micropegmatite. There appears to be little or no magnetite in any of the slides examined, and this fact, with the presence of small quantities of quartz, suggests that the original rocks belonged to the less basic varieties of diabase.

A coarse-textured rock from a boss rising near the railway through a sand plain east of the main conglomerate mass shows a small amount of quartz in still more marked pegmatitic intergrowth, but the change of the other minerals has gone farther, so that only chlorite and a carbonate, probably dolomite, can be distinguished. Another coarse-grained one from north of the main conglomerate area is a weathered andesine gabbro, with augite changed to hornblende.

In marked contrast with the greenstones we find various dikes and bosses of diabase of later age still fairly fresh. They are dark gray or greenish gray and usually fine-grained, but often highly porphyritic, with plate-like plagioclases an inch long and more than half as wide, but only a tenth of an inch thick. They consist of plagioclase laths with grayish augite wedged between and considerable amounts of magnetite, often rod-like in form, the whole having a marked ophitic structure. The one of coarsest texture containing the large phenocrysts has plagioclase with an extinction angle from the twin plane of 12 to 23 degrees, so that the species seems to be andesine or labradorite. The absence of quartz and the presence of large quantities of magnetite show that these later diabases and diabase porphyrites are distinctly more basic than the older greenstones.

A still more basic series of rocks is exposed as wide dikes or bosses on islands in Lake Eleanor and Goetz lake, as well as on the shore of the latter lake. These rocks are green black on fresh surfaces, but weather brownish or gray green, and are marked by a very rough surface where weathered. They are quite coarse-grained and show wide shining surfaces of biotite when broken.

The freshest sections, which come from islands in Goetz lake, consist essentially of olivine and augite with a few large individuals of biotite and a little white turbid material between the other minerals, perhaps originally plagioclase. The olivine is idiomorphic and the augite largely so, and the brown biotite is more or less filled, poecilitically, with olivine crystals. The olivine has a narrow rim of bright green serpentine, and a good deal of serpentine and magnetite along fractures in the interior. In a section from Lake Eleanor the whole of the olivine has been changed to serpentine, in which are imbedded crystals or grains of augite and a little biotite. The composition of this rock corresponds to that of a picrite, though the Germans would probably call it palæopicrite.

A somewhat related rock is found at the second falls of Magpie river, not far from a boss of porphyritic granite which has been described on a former page. The rock is apparently a dike, brownish black with many small scales of biotite on fresh surfaces, and consists of biotite, olivine, augite, magnetite and calcite. The brown biotite is not poecilitic, and forms more or less complete crystals between the larger crystals of olivine, the latter often weathered to serpentine. The augite, which is not in very large amounts, forms rather long prisms, with a tendency to radiate; and the magnetite is in large square cross sections. The calcite or dolomite filling the interstices is no doubt a decomposition product, perhaps representing small quantities of a calciplete plagioclase. This very basic rock may perhaps be called a biotite picrite, though it has relationships to the minettes also.

Acid Huronian Schists (Wawa Tuffs)

The schistose rocks of the Huronian may be divided into acid varieties corresponding to the quartz-porphyries, and basic schists having a composition like the greenstones and other basic massive rocks. They belong mainly to the Lower Huronian, though very similar schistose rocks result from the shearing of the Upper Huronian conglomerate. Among the more acid rocks, those resulting from the shearing and modification of the quartz-porphyries or porphyrites are most widely spread, and will be referred to first. In colour they are pale greenish or bluish or yellowish gray. All gradations occur from varieties having slightly crushed phenocrysts of quartz and feldspar to felsite or sericite schists, in which the squeezing has gone so far as to destroy or re-arrange all the original minerals. In the less modified schists, quartz, orthoclase, plagioclase and sericite may be recognized; but by progressive steps the granular minerals disappear and a micrographic or felsitic mass of quartz, feldspar and sericite results, with the development of a marked schistose structure. Often freshly deposited very finely granular quartz and sericite make the bulk of the more schistose varieties; and near the iron range, rhombs of siderite or ankerite appear also, showing that there has been infiltration of silica and iron compounds, resulting finally at the edge of the iron range in sideritic sericite schists or a schistose variety of siderite.

Along with the changes mentioned some other minerals show themselves occasionally, such as tourmaline, which occurs as numerous tiny prisms in quartz-porphyry schist south of the Helen mine; or rutile, as in a sericite schist from the railway cutting just west of Sayers lake. In the latter case the rutile is chiefly in thick bundles of very tiny needles, though some crystals show arrowhead or knee-shaped twins.

The most peculiar variety of the siliceous sericite schists is of a concretionary habit, best shown at the western corner of Lake Wawa, where cliffs of the rock were taken at first for conglomerates. The concretions are from the size of a pea to pebble-like oval masses more than an inch in length. They show best on weathered surfaces, and then are often hollow in the middle with a rusty inner surface.

Thin sections show rounded masses of chalcedony without radial arrangement, but often containing some siderite in the middle, and sometimes enclosing a fragment of feldspar, especially plagioclase, as if this had served as a nucleus; though the crystal is generally excentrically placed. The silica is not always chalcedonic, but may become coarser in texture until a mosaic of quartz grains results. The matrix is of greenish sericite reticulating about the concretions and forming only a small proportion of the whole. The concretionary schist occurs at several other points nearer the iron range than at Wawa lake, though only in small amounts, and has probably resulted from the circulation of solutions of silica and iron during the time when the iron range rocks assumed their present form. The beginning of the process has been described in connection with the quartz porphyries. These concretions are probably not original structures formed during the consolidation of the porphyry, but were produced much later, after the shattering and shearing which caused the schistose arrangement of the minerals.

Near the margin of the Laurentian the quartz-porphyry schists sometimes become more gneissoid, so that one may be in doubt as to the exact boundary between the two formations; and at other points also, perhaps because of contact metamorphism near eruptive masses, quite gneissoid examples may be found. A fine-grained gray gneiss from a point north of a small swampy lake southwest of Bauldry lake consists of quartz, a little orthoclase, much plagioclase and a large amount of sillimanite in fibrous bundles. A little biotite is more conspicuous on cleavage surfaces than in thin sections. It is probable that this rock is a metamorphosed sediment rather than a form of the quartz-porphyry schist, the large amount of sillimanite indicating a greater percentage of alumina as compared with alkalies than would be found in a quartz-porphyry.

A more schistose sillimanite gneiss associated with the conglomerate north of Doré river, which has much the same composition with the addition of slender tourmaline prisms, is certainly of later age than the quartz-porphyry schists, and may represent a muddy layer of sediment interstratified with the conglomerate.

Basic Schistose Rocks (Gros Cap Greenstones in part)

There are transitions between the acid and basic schists in which sericite is largely replaced by chlorite, and the quartz grains or chalcedonic aggregates diminish in amount, while carbonates become more frequent; but these are not extensively developed and will not be further described. The green schists are partly associated with the massive greenstones and partly interbedded with the lighter coloured acid schists. They are usually very fine-grained and distinctly schistose, and have a monotonous uniformity of dull green. Under the microscope chlorite is universally found with a finely granular colourless material between, in some cases partly silica but more commonly plagioclase or its decomposition products. Epidote is always present, and well-formed rhombs of a carbonate which weathers brown, ankerite or siderite, are usually to be seen; while magnetite and rutile are not infrequent. By an increase in the amount of the carbonate we have chlorite-ankerite or chlorite-dolomite schists, which weather brown but do not form crusts of limonite; and chlorite-siderite schists, which are often changed for an inch from the surface into impure brown iron ore. Several coarse-grained examples of the last rock are found south of the Helen mine. They can hardly result from the direct rearrangement of any ordinary greenstone or volcanic ash, and are perhaps to be connected in origin with the rocks of the iron range, as sediments of a chemical nature. They form transitions between the siderite of the iron range and the ordinary chlorite schists, just as certain sericite schists rich in siderite connect the acid series of schists with the iron-bearing rocks.

There are cases where the chlorite-dolomite schists include also large amounts of biotite, forming a transition to biotite-dolomite schist, which occurs south-west of Bauldry lake as a coarse-grained rock with a brown pitted surface, having the appearance of a gray gneiss when fresh.

Here may be mentioned also the very cleavable green schist occurring north of the main Upper Huronian conglomerate area in the Laurentian granite, apparently a long narrow strip of the Huronian floated off in the eruption of the granite. From its lustrous green cleavage surfaces one would naturally call the rock a mica schist or mica-chlorite schist, but the microscope shows essentially biotite and actinolite. This illustrates the same relationships as were noted by Dr. Lawson in the Keewatin region of Rainy lake, where green chlorite schists at a distance from the Laurentian contact become harder hornblende or hornblende-mica schists in immediate contact with the gneiss, in both cases evidence of the eruptive nature of Laurentian gneiss.

Upper Huronian Green Schists

The green schists thus far spoken of belong probably to the Lower Huronian, most of them being associated with the quartz porphyry schists and greenstones. There are, however, numerous green schists interbedded with the Upper Huronian schist conglomerate, some of them no doubt parts of the conglomerate originally free from large pebbles, others perhaps parts which have been so far squeezed that the soft greenstone pebbles have been rolled out flat and incorporated with the matrix as a uniform schist. Some of them may represent basic dikes turned into schist and so far rearranged as to destroy all traces of their original constituents. In many cases these schists are closely like those which have been described from the Lower Huronian, and need not be taken up in detail.

In general the chlorite schists contain some finely granular silica and dolomite; often also more or less biotite. Tourmaline needles were found in one. Others of the green schists have been more strongly acted on and are now hornblende schist, examples of the kind having been obtained from the tote road between Michipicoten harbour and Doré lake, and also at the second falls of the Doré river. They are hard dark-green fine-grained rocks consisting chiefly of hornblende prisms having strong pleochroism, (blue-green, green and yellowish brown) with a little quartz and plagioclase in the interstices.

Eleanor Slates

The chlorite schists as well as the felsite schists pass by way of certain lustrous cleavable phyllites into slaty rocks which are widely enough spread to demand mention. They are greenish gray or "slate" gray in colour, compact splintery or easily cleavable rocks, sometimes showing bands of varying colour, probably representing layers of sedimentation, across which the cleavage runs obliquely.

Most of the slates mentioned here do not contain carbon in sufficient amount to have their colour lightened when heated in the blowpipe flame, thus differing from slates to be mentioned later in connection with the iron range rocks. They consist of very minute scales of chlorite or sericite with equally minute clear granules, probably of quartz, particles of a carbonate (not siderite) rutile as stout prisms or arrowhead twins, and slender pale prisms of lower refractive index having parallel extinction, probably sillimanite. The darker gray varieties, as along Grassett road south of Eleanor lake, contain dirty-looking particles of unknown nature arranged more or less in bands with the minerals mentioned above. Though little direct evidence is available to prove the origin of the slates, they are supposed to have been fine clayey sediments not directly of volcanic origin.

In connection with them may be mentioned the graywacké or arkose found on the portage between Bauldry and Goetz lakes, which is clearly a mechanical sediment though of a coarser kind. It is a dark gray rock with specks of quartz visible on its surface when broken. Under the microscope the quartz is found to be in angular fragments with turbid completely weathered bits of feldspar and also some brownish films between. It evidently represents a graywacké or arkose of the type so common in the Upper Huronian rocks north of Lake Huron, and should probably be classed as of that age, though the nearest rocks adjoining have the character of the Lower Huronian schists.

Rocks of the Helen Iron Formation

Though there are transitions between the Lower Huronian schists and schistose varieties of the siderites belonging to the iron range, in general the latter is a very distinct group of rocks, having peculiarities easily recognized in the field, and of considerable interest when studied with the microscope. Four species of rock may be distinguished in the iron range of Michipicoten, banded granular silica with more or less iron ore, black slate, siderite with varying amounts of silica, and gruenerite schist. All are found well developed at the Helen mine, and all but the gruenerite schist have been found in the Lake Eleanor iron range also, while granular silica and siderite occur in large quantities in every important part of the range, though small outcrops sometimes show the silica alone.

The name granular silica or grained silica has been chosen as most descriptive for the siliceous rock of the Michipicoten range, though varieties occur which are not granular to the naked eye. Jaspery varieties have not been found on this range though they occur only a few miles to the north, and are common in most other iron ranges in Canada and in the United States. The name jaspilyte used by the American geologists seems inappropriate therefore.

At first the grained silica was looked on as a fine-grained sandstone, since many examples are soft and pulverulent, but a microscopic examination proved that the grains are not at all waterworn. The rock is usually finely banded, white and light or dark gray, but is occasionally brown or purplish, the colour in every case being due to the presence of iron oxides. Much of the banded rock has been crushed and now forms a breccia, often with fine-grained silica as a matrix, but sometimes with a cement of siderite. In evenly banded, unbrecciated parts there are often lenses one or two inches long of white or paler gray silica running parallel to the general stratification.

Thin sections show that the white, sugary specimens of granular silica consist of quartz only, polyhedral grains closely fitting together, but not apparently cemented, since the jarring of the grinding of the section has often slightly parted them so that a film of air separates the adjoining faces. The quartz shows few inclusions and no cavities, but coloured specimens have films of yellow limonite between the grains or small masses of limonite in streaks; while gray specimens contain innumerable small black specks, probably of magnetite, though the rock is not strongly attracted by the magnet. The black particles are in general too fine to separate from the silica. None of the sections have cryptocrystalline silica, but always distinctly granular material, the grains generally of fairly uniform size in any given band of rock, though sometimes coarser grains form a row across a section, probably filling fissures in a vein-like way.

Some of the brownish examples contain many rhombs of siderite, indicating a transition towards the other usual iron range rock in the region. The size of the grains in the sections examined runs from half a millimetre in coarse-textured examples at Gros Cap down to 18 thousandths of a millimetre in a somewhat cherty specimen from Sayers lake; but a very similar granular silica from the Grace gold mine south of Wawa lake is larger in grain than the coarsest found in the iron range proper, having diameters up to 1¼ millimetres.

The origin of these curious rocks is somewhat puzzling, since their granular structure is not due to the crushing of previously existing quartz. There is no hint of water-worn grains enlarged by deposition of silica on their surfaces until they met, as in quartzites of the Upper Huronian near Lake Huron; and one must suppose that crystallization has taken place from centres about equally distant from one another. How were the partially formed grains or crystals supported? In a thick jelly of amorphous silica which became crystallized about these centres until it was entirely used up? As amorphous silica is lighter than the crystalline form one would expect the incipient grains or crystals to sink to the bottom.

Apparently the process in these relatively coarse-textured varieties of silica is not different in kind from that which produced the more fine-grained forms, jasper and chert, seen in neighbouring iron ranges. It may be mentioned here, however, that none of the thin sections prepared from jaspers or cherts of the Lower Huronian in other parts of Ontario show radiating or concretionary or typically cryptocrystalline characters. They are at most microcrystalline, while sections of Animikie chert and jasper from the Port Arthur region on the other hand have these characters well defined.

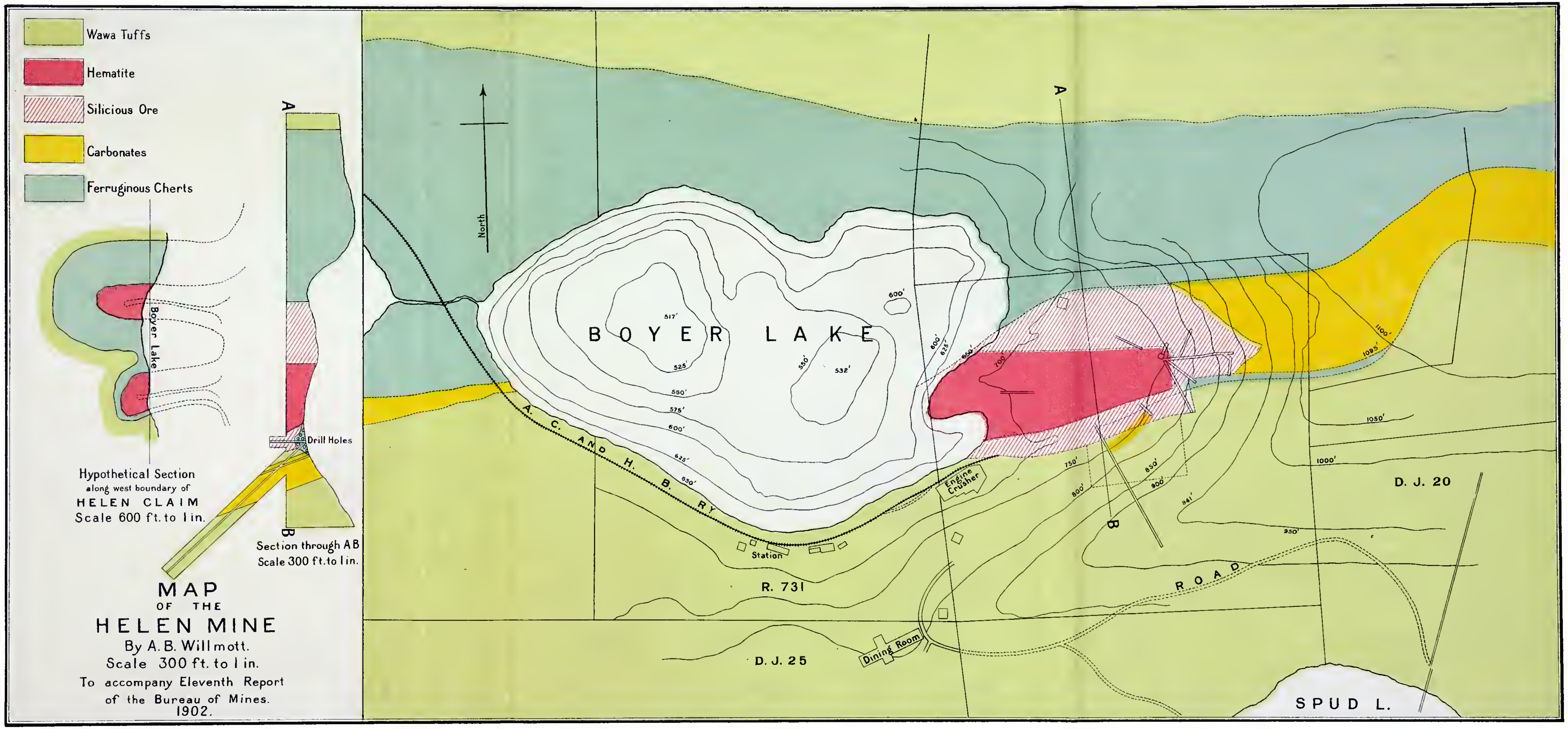
The black, graphite slate, forming a thin sheet just under the iron range proper west of the Helen mine and at other points in the region, seems closely related to the granular silica, being composed of the same material with a large admixture of carbon which smears the fingers. The grains of silica are, however, much more variable in size than in the rock described above. As the carbon is opaque, thin sections are unsatisfactory. The slate generally contains rounded masses of crystals of pyrite, which weather out, leaving curious cavities, looking like bubble holes, lined with a thin white layer of quartz, more coarsely crystalline than usual in the rest of the slate. The carbon of the slate suggests organic material and the presence of life in the sea at the time the iron-bearing material was deposited, but perhaps too much stress should not be laid on this point, since hardly any other evidence of living beings exists in the Lower Huronian. Possibly some of the dolomitic rocks found not far away may have an origin from shells, but the fact that they merge into chlorite-dolomite schists which are probably of eruptive origin seems to oppose this.

The siderite which rises in many cases to the summit of the iron range ridges beside the banded silica is usually weathered for half an inch into impure limonite, but beneath this crust is still wonderfully fresh for a rock of the character. It is bluish or pale violet in colour when fresh, some shade of brown when weathered, and has a very massive appearance in many places, though as it approaches the schists it may take on a schistose structure. Almost everywhere crystals of pyrite occur in the siderite, sometimes in large quantities.

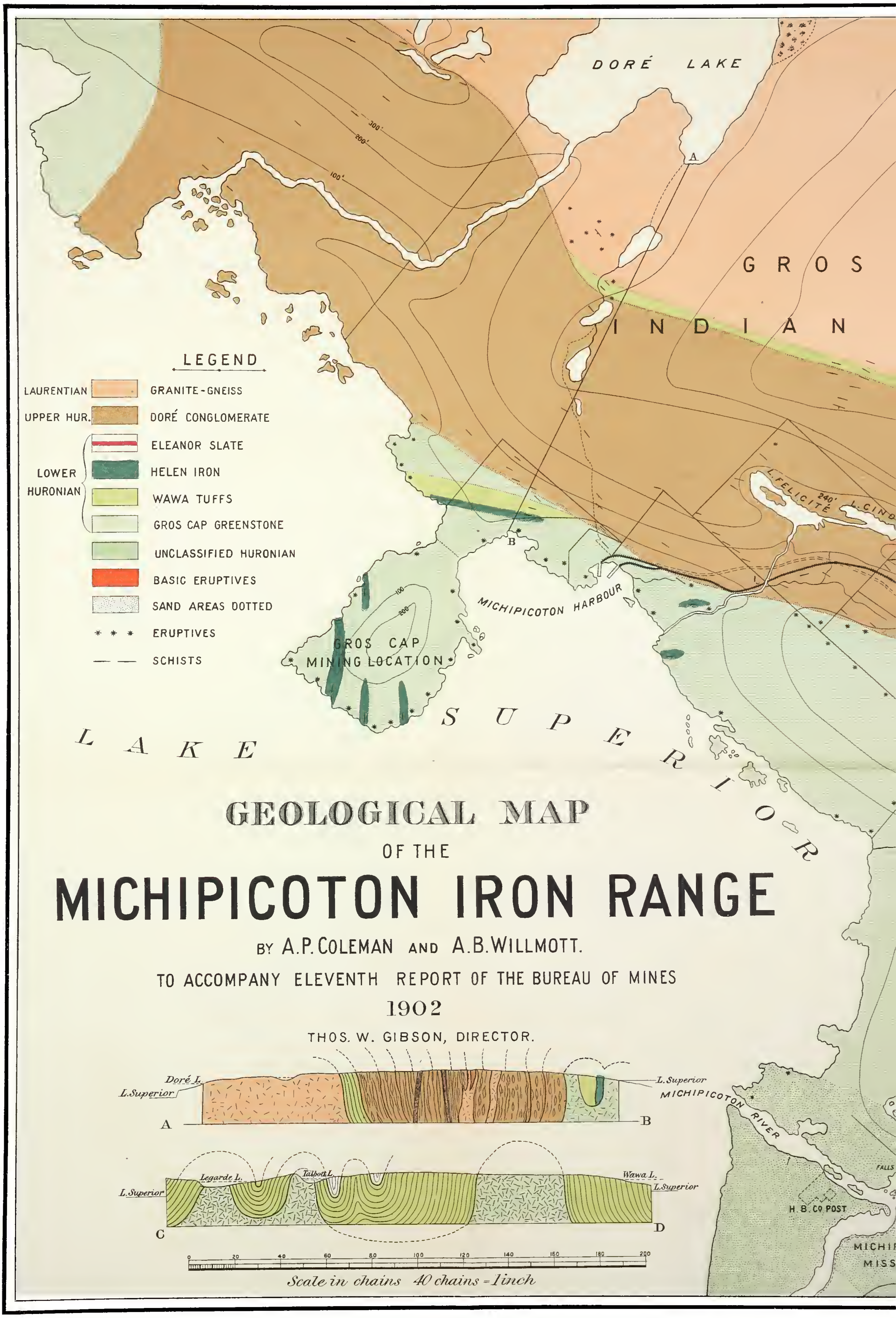
Thin sections show mainly siderite, which does not differ greatly from dolomite in appearance, though its frequent weathering into limonite distinguishes it from other carbonates. Finally granular silica is almost always present, and often small amounts of dirty bluish green hornblende of a peculiar sort, probably gruenerite, though some common green hornblende occurs also. There are very siliceous siderites linking this rock to the granular silica.

Where the gruenerite is present in large quantities the rock becomes gruenerite schist, which is pale to dark bluish or greenish gray, and weathers to brown. Examples of the rock occur just west of Sayers lake near the black slate, apparently underlying the other iron range rocks ; but it has seldom been found elsewhere in the region, and is present only in small amounts here.

Sections show hornblende, magnetite, silica and often siderite. The hornblende is almost always in rather stout prisms with jagged ends, having a turbid central core and transparent bands on the edges, with faint blue green and yellowish dichroism. Between crossed nicols it is seen that these prisms are often twinned, with longitudinal strips extinguishing in opposite directions, generally with small angles. It is possible that the centre of the prism differs in composition from the more transparent edges ; and an opaque margin often found on each side may represent the deposit of still another layer of material. No analyses have been made, but the relationships and general character of the hornblende suggest that it is gruenerite, the iron hornblende, or some nearly related species.



MAP
OF THE
HELEN MINE
By A. B. Willmott.
Scale 300 ft. to 1 in.
To accompany Eleventh Report
of the Bureau of Mines.
1902.


DORÉ LAKE
GROS
INDIAN
LEGEND
LAURENTIAN
GRANITE-GNEISS
UPPER HUR.
DORÉ CONGLOMERATE
ELEANOR SLATE
LOWER HURONIAN
HELEN IRON
WAWA TUFFS
GROS CAP GREENSTONE
UNCLASSIFIED HURONIAN
BASIC ERUPTIVES
SAND AREAS DOTTED
ERUPTIVES
SCHISTS
L. FELICITÉ
MICHIPICOTON HARBOUR
GROS CAP MINING LOCATION
LAKE SUPERIOR
GEOLOGICAL MAP
OF THE
MICHIPICOTON IRON RANGE
BY A.P. COLEMAN AND A.B. WILLMOTT.
TO ACCOMPANY ELEVENTH REPORT OF THE BUREAU OF MINES
1902
THOS. W. GIBSON, DIRECTOR.
Doré L.
L. Superior
A
B
MICHIPICOTON RIVER
Legarde L.
Talbot L.
Wawa L.
C
D
H. B. Co POST
Scale in chains 40 chains = 1 inch

ROS CAP
AN RESERVE
L. FELICITE
L. CINDERS
240'
600
500
400
300
200
100
ALGOMA CENTRAL AND HUDSON BAY RAILWAY
(MICHIPICOTON BRANCH)
TREMBLY
D.J. 19
D.J. 18
MAGPIE RIVER
WAWA STATION
D.J. 45
724
D.J. 36
723
D.J. 37
722
D.J. 44
D.J. 33
721
D.J. 34
720
D.J. 40
719
D.J. 41
700
D.J. 42
657
WHARF
WAWA CITY
W.F.I
W.R. 59
GOVERNMENT ROAD
D.J. 46
BY 9
D.J. 47
BY 10
FALLS 44'
FALLS 45'
FALLS 28'
400'
TOTE ROAD
CREEK
WAWA
H.B. Co POST
MICHIPICOTON MISSION
LAKE 93
189
Y.201
92
526

BLACK TROUT L.
526'
MAGPIE
RIVER
MAGPIE
ELEANOR CREEK
SOULIER LAKE
OTTER L.
LEGARDE LAKE
510'
MINK LAKE
TALBOTT LAKE
498
MORAN LAKE
SAYERS LAKE
BOYER LAKE
HELEN MINE
WALBANK LAKE
GULL LAKE
WAWA STATION
WHARF
WAWA CITY
WAWA LAKE
336'
Y.114
Y.115
Y.116
Y.117
Y.103
Y.104
Y.105
Y.106
Y.107
Y.111
Y.110
W.F.1
W.R. 59
W.R.60 S.E.PT.
D.J.45 724
D.J.36 723
D.J.44
D.J.33 721
D.J.34 720
D.J.40 719
D.J.41 700
D.J.42 657
Y.201
189
92
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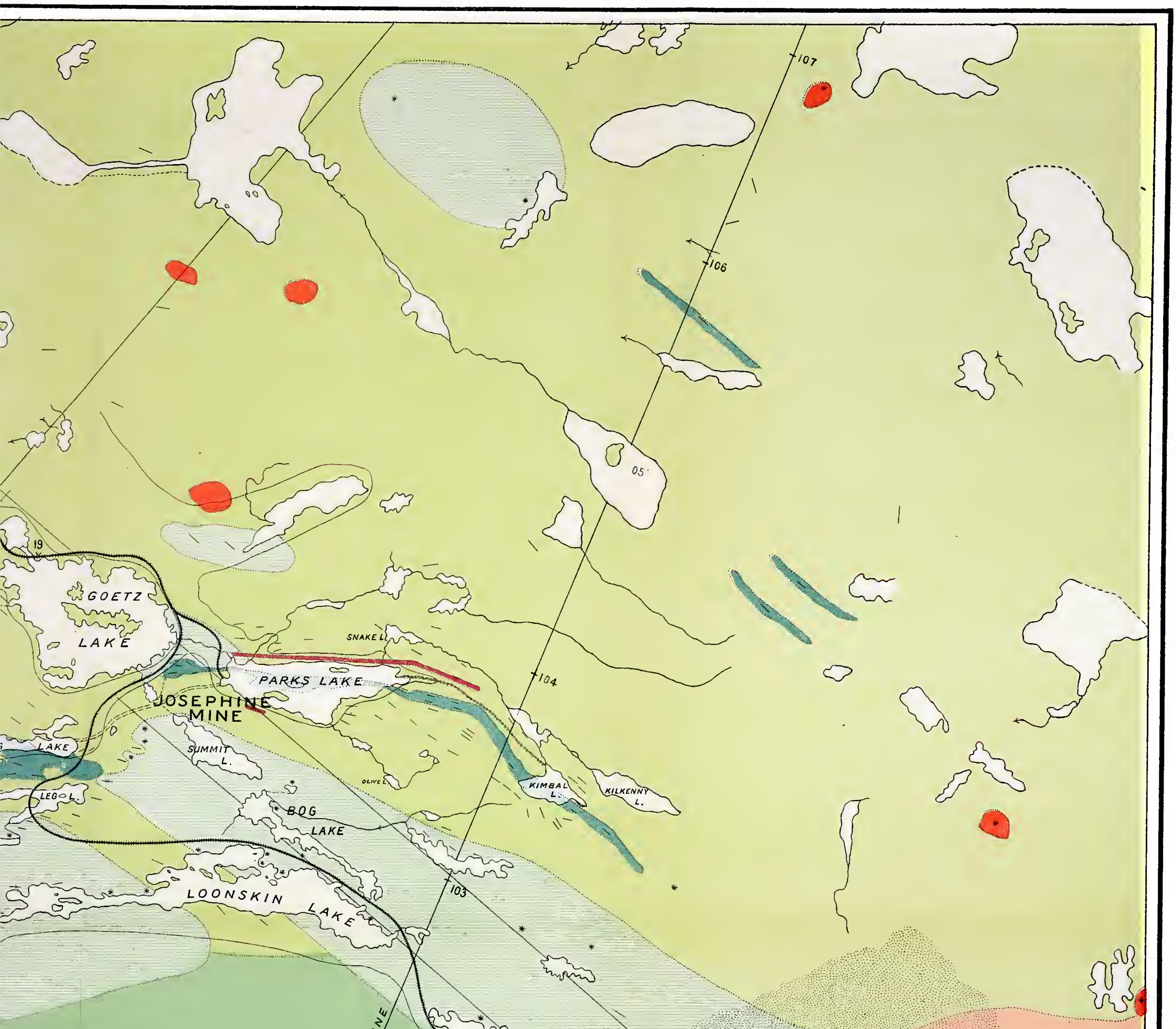
D
600'
700'
800'
900'
1000'
500'
400'

R I V E R
FALL 60'
STEEP HILL PORTAGE
JOSEPHINE CREEK
500'
600'
700'
800'
A.C. & H.B. RY. MICHIPICOTON BRANCH
ELEANOR CREEK
14
15
16
17
18
19
GOET
LAKE
BAULDRY LAKE
LONG LAKE
LEGO L.
BROOKS LAKE
GULL LAKE
FRANCIS LAKE
LOONSKIN LAKE
ELEANOR LAKE
530'
12
13
11
10
9
6
5
PORTAGE
TOTE ROAD
Moraine
HAWK


GOETZ LAKE
PARKS LAKE
JOSEPHINE MINE
SNAKE L.
SUMMIT L.
LAKE
LEG L.
BOG LAKE
LOONSKIN LAKE
KIMBAL L.
KILKENNY L.
OLIVE L.
HERRICK'S LINE
HAWK L.
McVEIGH CREEK
A.C.&H.B. RY.
107
106
105
104
103
102
101
100
19

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