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DEPARTMENT OF MINES

HON. MARTIN BURRELL, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY

WILLIAM MCINNES, DIRECTING GEOLOGIST.

Summary Report, 1918, Part E

CONTENTS

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SUMMARY REPORT, 1918, PART E.

THE CANADIAN NATIONAL RAILWAYS BETWEEN LONGUELAC AND OBA, NORTHERN ONTARIO.

By T. L. Tanton.

CONTENTS.

GENERAL STATEMENT.

In 1916, the Geological Survey undertook an investigation of that part of northern Ontario which is traversed by the Canadian National railways (formerly the main line of the Canadian Northern railway) between Gogama and Nipigon stations. The railway had been only recently completed, and there was need for information relating to the natural resources of the area which had thus become accessible. The field season of 1918 was devoted to the section between Longuelac and Oba, the part which remained to be examined after the field seasons of 1916 and 1917. This section is approximately 125 miles long and 35 miles wide.

A considerable part of the work consisted in making micrometer surveys of canoe routes which are not shown on existing maps. The rock outcrops along all canoe routes accessible from the railway were examined and also those along the railway line, and land traverses were made in several localities for the purpose of determining the distribution of certain rock formations.

L. G. Thompson, A. G. Smart, and J. F. Shupe performed their duties as assistants in a very satisfactory manner.

GENERAL GEOLOGY.

Pre-Cambrian rocks underlie the entire district. Previous reports[1] which mention limestone and pale green dolomite overlying gneiss on the southeast shore of Pine lake, refer to calcite veins, which are probably genetically related to the diabase intrusives in this vicinity and not to Palæozoic sediments as might be inferred. The rock formations in the Longuelac-Oba section are of the same character as those farther west except that Keweenawan sediments are absent. They may be classed under four headings: (1) schist complex; (2) Windegokan series; (3) granitic batholithic intrusives; and (4) diabase dykes.

Schist Complex.

Mineralization appears to be confined to areas of the schist complex, though the minerals themselves have in many cases been introduced by intrusive rocks of later age.

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[1] Rept. Ont. Bureau of Mines, 1908, p. 127.
Rept. survey and exploration of northern Ontario, 1908, p. 149.

The largest belt of schist complex crosses Long lake between 6 and 15 miles south of its north end and continues eastward across the entire area, crossing Kabinakagami river 10 miles north of the railway, where it is 6 miles wide. Several narrower belts were observed in the great granite areas to the north and south of the main belt; the more important of these being seen on Pine lake and Kabinakagami lake and river. Recognition of the main belt is of some importance; since future detailed study of it may furnish a basis for correlating the schist complex in the Timiskaming and Nipigon districts. Between Long lake and Hollow Rock lake its central part is occupied by volcanic members, stratified tuffs, and banded iron formations. The marginal parts and the major part of the same belt farther east are composed of banded mica schists and fine-grained gneisses, which in many localities are garnetiferous.

Complex stock-works of granite and pegmatite cut the mica schists in a broad zone adjacent to the major granite masses, and large inclusions of mica schists are frequently found far within the great granite areas. Consequently, no sharp line can be mapped between these two formations.

Pleistocene.

The glacial drift mantles the solid rocks, but varies greatly in thickness and character from place to place. Stratified clay deposits occur around the northern end of Long lake and in the valley of Kenogami river between Long lake and Pine lake; also in the river valleys in the vicinity of Shekak station and Oba village. These deposits, together with the stratified, limy silt on the shores of Nagagamisis lake, constitute the best lands for agricultural purposes, observed in the district. A small deposit of marl which occurs on the railway line 2 miles and 15 chains east of Osawin station is of interest on account of the scarcity of that material throughout this region.

Gravel, sand, and silt deposits of fluvioglacial origin form the greater part of the drift, as exposed along the railway line. Till is frequently seen in the section near the crossings of the height of land.

MINERAL OCCURRENCES.

Graphite.

Fine scales of graphite are disseminated through the mica schist and fine-grained biotite gneiss which are exposed in the rock-cuts along the railway at mileages 70·6, 70·5, 56·6, 49·5, and 49·4, west of Hornepayne. These rocks are cut by numerous dykes of pegmatite and veins of quartz, some of which carry pyrite and pyrrhotite in small amounts, and it is in the rusty-weathering zones bordering the quartz veins that the greatest concentration of graphite occurs. The richest material observed, the rusty zone at mileage 70·6, was found upon analyses to contain 4·70 per cent graphite. The largest of the known occurrences is in the rock-cut at 56·6 miles; a grab sample of the rock, which appeared to be quite uniform for 20 feet at least, contained 3·32 per cent graphite. The rock which contains the graphite is quite similar in appearance to the rest of the biotite schists with which it is associated, and there are no bands of crystalline limestone in this district.

Iron.

Banded iron-formation is exposed on both shores of Long lake. The greatest amount is to be seen on the east shore about 5 miles south of the Hudson Bay post; there, two bands, 40 and 60 feet wide respectively, occur 500 feet apart. The iron-formation is like that on Little Long lake or the band which lies to the south of Standing

Stone lake in the Poplar Lodge district; layers of finely granular magnetite, up to ¼-inch in thickness, alternate with thin layers of black or grey, siliceous, slaty material. The beds strike north 60 degrees east and dip nearly vertically. The associated rocks are altered andesite and fine-grained chloritic schists.

Banded iron-formation outcrops on Mud lake and also on the east shore of Hollow Rock lake 55 chains north of its outlet. At the last-mentioned locality, which is the most easterly point to which the iron-formation has been traced in this district, four beds of magnetite are exposed in a width of 2 feet; each carries small scattered crystals of pyrite and hornblende. The largest is 4 inches in width. The associated rock is fine-grained, siliceous, hornblende schist. The iron-formation strikes north 68 degrees east and dips 80 degrees south.

No concentration of iron ore of commercial importance has been observed in this district.

Molybdenite.

Molybdenite deposits occur on the Chabish mining claim on the west shore of Burrows lake; on the Hayne claim at Longuelac station; and on the Seagers claim near the east bank of Oba river, 2 miles south of Langdon, on the Algoma Central railway. The Chabish claim was not examined by the writer, but samples from this claim are of friable biotite gneiss carrying small disseminated scales of molybdenite, which would make up 3 per cent of the rock. A considerable amount of this ore is said to be exposed; if this is the case, the Chabish claim is the most promising prospect in the district.

Small occurrences of molybdenite were discovered by the party in rock-cuts on the Canadian National railways, 48 miles plus 50 chains, and 14 miles plus 72 chains, respectively, west of Hornepayne. In both localities small scales of molybdenite occur in pegmatite dykes which cut banded biotite schist and gneiss.

Chalcopyrite.

Chalcopyrite in very small quantities is associated with pyrite in quartz veins which appear to be related to the pegmatitic intrusions in the schist complex. Occurrences of this nature were observed at a number of localities in different parts of the district. The largest observed is on the Hayne claim at Longuelac.

Chalcopyrite occurs on Pine lake. It makes up one-half of a seam 1 foot wide and 50 feet long in a 12-foot vein or replacement band of pyrite and pyrrhotite on the shore about one mile southeast from the inlet. Smaller amounts of chalcopyrite were seen in the 9-foot and 27-foot bands of iron sulphide which have been exposed by stripping a short distance to the south. The strike of the sulphide bands is north 60 degrees west and the dip 65 degrees towards the north. This conforms very closely to the structure of the banded gneiss which forms the country rock. A dyke of diabase one chain wide and trending north 8 degrees east, was observed 125 feet east of the sulphide bands on the lake shore, and there is reason to believe that the sulphide deposit is genetically related to this intrusive. The sulphides bear a close resemblance to the nickel ore at Sudbury, but assays for nickel and gold gave negative results. This deposit was examined by E. V. Neelands in 1900 and he states that "several samples gave on assay a trace of gold and nickel."[1]

A sample of the stratified clay from the east shore of Long lake near the mouth of Making Ground river was submitted to J. Keele, of the Mines Branch, for examination. He reports that this material is suitable for the manufacture of building brick and field drain tile. It is not refractory and could not be used in the manufacture of vitrified wares.

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[1] Report survey and exploration of northern Ontario, 1900, p. 149.

THE ORE DEPOSITS OF GOUDREAU AND MAGPIE-HAWK AREAS, IN MICHIPICOTEN DISTRICT, ONTARIO.

By W. H. Collins.

CONTENTS.

Illustrations.

INTRODUCTION.

Large deposits of pyrite have been known in Michipicoten district, Ontario, for about twenty years; but because of their distance from a market and the low price of pyrite ores very little work was done on them. The war eliminated one of these handicaps. In three years it caused the Canadian and United States production of pyrite to increase 32 per cent, thereby just offsetting the foreign supply, which was practically cut off. Sulphuric acid makers in the United States suddenly became dependent upon American raw materials and pyrite soared in price from an average of $3.81 per ton in 1914 to $5.37 per ton in 1917.[1]

The entire effect of the change on the pyrite industry in Michipicoten district is not yet fully apparent. United States consumers who are now looking there for supplies of pyrite may yet forsake this Canadian field unless they become established in it before the market is again normal and pyrite from Spain is once more available. In the meantime, however, there is exceptional activity in pyrite mining, development of new deposits, and prospecting. Interest in the areas dealt with here is centred mainly upon the pyrite deposits, but iron ore deposits have also been known for many years, and in 1918 gold was discovered.

The Geological Survey entered this field in 1918 with the intention of aiding prospecting and development operations. During that summer two areas, each of about 25 square miles, were examined and mapped on a scale of 2 inches to the mile. One area contains the important pyrite deposits near Goudreau, the other the less known and as yet non-productive deposits between Magpie and Hawk junctions on the Algoma Central railway.

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[1] Domestic production in United States.

The two areas so dealt with do not include all the important pyrite deposits in the district; nor are the opinions advanced here more than tentative, preliminary ones. Further work must be done before the subject can be treated as completely as it deserves. The field work already done, however, was conducted under most favourable conditions. The writer had associated with him Mr. Ellis Thomson of the Department of Mineralogy, Toronto university, whose assiduity and experience in Pre-Cambrian geology proved of very great value. Work was facilitated in many ways by officials of the operating mining companies and the Algoma Central railway, and by prospectors and residents. Particular thanks are due the officials of the Algoma Steel Corporation, the Nichols Chemical Company, and the Rand Consolidated Mining Company for the generous manner in which their exploration records were placed at our disposal. For information relating to the Josephine mine the writer is indebted to Judge John McKay, of Port Arthur, Ontario, and to L. L. Bolton, of the Department of Mines, Ottawa. Very useful information was also derived from the reports upon earlier work in this field, listed below.

Bell, J. M., "Iron ranges of Michipicoten West," Ann. Rept., Ont. Bureau of Mines, vol. 14, pt. I, 1905, pp. 278-355.

Coleman, A. P., "Iron ranges of eastern Michipicoten," Ann. Rept., Ont. Bureau of Mines, vol. 15, pt. I, 1906, pp. 173-206.

Parsons, A. L., "The productive area of the Michipicoten iron ranges," Ann. Rept., Ont. Bureau of Mines, vol. 24, pt. I, pp. 185-215.

GENERAL CHARACTER OF THE DISTRICT.

Either of the two areas mapped in 1918 is easily reached via the Algoma Central railway, from Sault Ste. Marie, or Michipicoten Harbour on lake Superior, or from the junctions of the Algoma Central with the Canadian Pacific, and the two transcontinental routes of the Canadian national railways. Hawk Junction, in Magpie-Hawk area, is 165 miles by rail from Sault Ste. Marie, and Goudreau station is 178 miles. Points within Goudreau area are made still more accessible by a spur line 3 miles long from Goudreau station to the Nichols Chemical Company's properties, and Magpie-Hawk area is traversed by the Michipicoten branch of the Algoma Central railway. There are no good wagon roads, however; points away from the railway have to be reached on foot or by canoe. Excellent accommodation for visitors is afforded in Goudreau area by the Rand and Nichols Chemical Companies, but the conveniences in Magpie-Hawk area are not so good.

This part of Michipicoten district is somewhat hillier than most parts of northern Ontario. It lies between 1,000 and 1,450 feet above the sea. The highest hills are about 350 feet. Except for occasional sand-plains, of no agricultural value, the country is rocky, so that there are no roads and no settlements other than those connected with the mines and the railway. Much of the dense, spindly forest has been burnt off near the railway. Lakes are extraordinarily numerous, but the streams that drain them are all small. Magpie river is the nearest stream that can supply any considerable water-power.

Goudreau area was burnt over, apparently, fifteen or twenty years ago, and is now partly bare, partly covered with small second-growth, and in places still covered with old forest. Some good pine timber occurs near Pine lake, and in other parts there is enough spruce and birch for local fuel and constructional requirements. The forest fires have compensated for the loss of timber, however, by burning away the moss and forest mould, thereby greatly facilitating prospecting work in an area which would otherwise be very difficult to examine. Even so, the rocks are extensively concealed by rolling sand-plains, especially from Goudreau lake eastward. The sand and fine gravels forming these plains are deep enough to soften appreciably the relief of the old rocky floor and to hinder seriously or prevent prospecting for mineral deposits.

Magpie-Hawk area is distinctly rougher, rockier country than Goudreau area; yet, because of the covering of trees, moss, and vegetable mould, it offers quite as much difficulty to the prospector and the geologist. It contains only two small sand-plains to obscure the solid-rock geology, but on the other hand, it has not been visited recently by any extensive forest fires. It is forested almost exclusively with spruce and birch suitable for pulpwood and fuel.

GENERAL GEOLOGY.

OUTLINE.

The rocks underlying the part of Michipicoten district which includes Goudreau and Magpie-Hawk areas are separable into four groups quite unlike in appearance, origin, and age, and quite easily distinguished from one another. These groups are well known to geologists and prospectors as: the Keewatin, Laurentian, Keweenawan, or late Pre-Cambrian, and the Pleistocene, or Glacial.

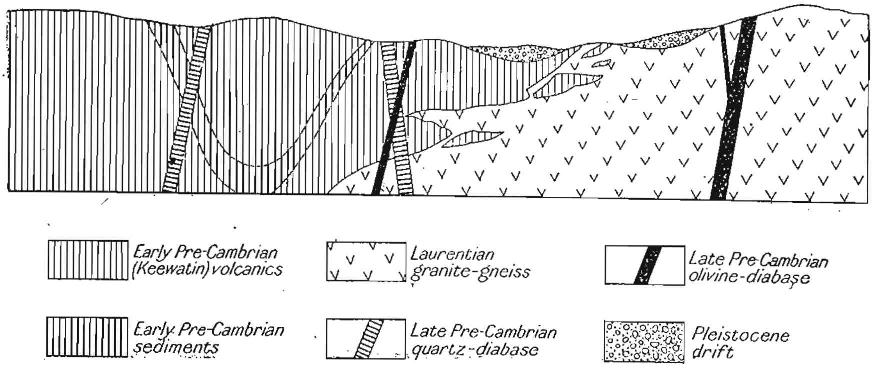

Figure 1. Diagram representing the main structural relationships of the rocks in Michipicoten district.

The Keewatin group consists of a great variety of volcanic rocks, along with which are a few, thin, stratified deposits—either conglomerate and slate or banded iron formation. Since their deposition all these rocks have been greatly folded and faulted, and more or less changed to schists. The Laurentian division consists of granite gneiss, coarse-grained, light-coloured rocks representing great bodies of once molten material which intruded the Keewatin from beneath. Near Keewatin contacts the granite-gneiss has admixed with it varying quantities of Keewatin material that was engulfed and partly digested by the invading molten matter. The late Pre-Cambrian or Keweenawan division is much younger than either the Keewatin or the Laurentian. It consists, in this part of Michipicoten district, altogether or nearly altogether of diabase dykes, which cut through both Keewatin and Laurentian. There are two distinct sets of these dykes; an older set of quartz-diabase and a younger, more numerous set of olivine diabase. Intrusion of the older dykes accompanied profound faulting in the older rocks, but no displacement is perceptible along the younger ones. The fourth, or Pleistocene group includes the sand, gravel, and other loose deposits which constitute the drift sheet of the district. These materials are vastly younger than any of the solid rocks upon which they lie.

The structural relationships to one another of the four groups of rocks are expressed fairly well by the accompanying diagram (Figure 1), representing a vertical cross-section of part of Michipicoten district.

KEEWATIN.

As a rule geologists do not try to resolve this folded, faulted, and schistified complex of volcanics into its component formations. The task is either too difficult or has no economic justification. In the present instance, however, it appeared desirable to know whether the iron-formation, which contains the pyrite and iron ores, occurs at any definite stratigraphic horizon in the Keewatin. Moreover, the iron-formation itself and certain sedimentary formations seemed to afford serviceable reference planes for distinguishing volcanic formations older than these from younger ones. A tentative effort was, therefore, made to recognize some of the members of the Keewatin group, arrange them in order of age, and even to represent them thus on the maps.

The attempt met with only a small degree of success. It was soon found in Goudreau area, explored first, that most of the iron-formation rests upon light coloured porphyries which, being volcanic flows, are, therefore, older. Also, that the flows above the iron-formation are largely, if not altogether, dark-coloured greenstones. On this basis the Keewatin in Goudreau area was separated into three parts: an older group of light-coloured acid volcanics, an intermediate one of iron-formation, and a younger one of dark-coloured, basic volcanics. Later on, however, it developed that this classification is only approximate; that there are a few acid volcanics apparently younger than the iron-formation and quite a few basic volcanics older than it. Nevertheless, the subdivision was successfully used in searching for and locating belts of iron-formation not theretofore known, so it has some practical value.

An attempt to make a like threefold subdivision in Magpie-Hawk area failed. It is quite remarkable how many of the volcanics found in Goudreau area are also present in this area; but the distinction between acid and basic volcanics is not so pronounced. There are many of intermediate character, which could not be placed unhesitatingly in one division or the other, even on a lithological basis. It was also discovered, in the case of the Bartlett range, that the iron-formation does not lie between acid and basic flows but apparently within one acid tufaceous formation.

Description of Formations.

Though the results of the above tentative stratigraphic study are not complete, they have, nevertheless, enough importance for those interested in the pyrite and gold deposits, to be stated briefly. The acid volcanics will be described first, the basic next, and the iron-formation last.

Ottrelite Porphyry. This rock was found only in Goudreau area. It forms a prominent range of hills south of the Nichols Chemical Company's railway, from the Algoma Central eastward to Teare lake, and occurs in smaller amounts still farther east. It forms the foot-wall of the iron-formation, and for that reason its recognition is important to those engaged in diamond-drill exploration for pyrite.

In most places this is a massive, fine to moderately coarse-grained rock, looking more like an intrusive than a lava flow; but at some points on Goudreau lake there is an agglomerate phase. It is a pale grey rock sprinkled rather plentifully with rectangular crystals of a black mineral, which was taken in the field to be hornblende, but on microscopic examination proved to be ottrelite. These rectangular black crystals distinguish it from all the other porphyries seen in the district.

As the presence of ottrelite in a tolerably fresh volcanic is unusual a few particulars regarding the rock may be of interest to petrologists. It has a pronounced porphyritic texture. Phenocrysts of ottrelite, quartz, and feldspar oriented in all directions are distributed through a much finer groundmass of quartz and feldspar, partly altered to sericite. No second generation of ottrelite was observed in the ground mass. Ottrelite crystals constitute from 5 to 15 per cent of the rock. Quartz and feldspar phenocrysts are much less abundant, or lacking. In fact, there are all gradations from a quartz-porphyry carrying a little ottrelite to an ottrelite-syenite-porphyry. The ottrelite is pale bluish-green in transmitted light. Sections normal to the c axis are irregular; those parallel thereto are rectangular, the basal plane being represented by a straight edge, whereas the prismatic edges are frayed. The largest of the rectangular sections are 2 by 1 millimetres, with the long side parellel to the basal plane. They are polysynthetically twinned, with extinction angles up to 20 degrees. The pleochroism is: a = green, b = bluish green, c = pale yellowish green. Other optical properties are normal.

The ottrelite would appear to be a primary constituent, since the porphyry carrying it is not as a rule much altered, deformed, or otherwise metamorphosed. Nevertheless, in most of the sections examined the crystals of this mineral are full of inclusions of the groundmass of the rock, giving them the characteristic worm-eaten appearance of secondary phenocrysts; and in cases where the groundmass has been schistified the inclusions are oriented in lines continuous with the planes of schistosity in the groundmass, although the ottrelite crystals are oriented with no regard for the schistosity.

Feldspar Porphyry. This rock occurs chiefly from Teare lake eastward to Pine lake in Goudreau area. Like the ottrelite porphyry it forms the foot-wall of the iron-formation. The gold-bearing quartz veins in Goudreau area also appear to be confined within it, so that its identification is a matter of some economic importance. It is a dull, pale grey rock blurred in texture and without visible dark constituents, that, once seen, is not hard to distinguish from the other acid volcanics of the district. It has much the same mineral composition as the Laurentian granite gneiss, being composed of lime-soda and potash feldspars, quartz, and a little black mica, but is so much finer-grained that it is unlikely to be mistaken for granite gneiss.

Quartz Porphyry. A fine-grained, nearly white porphyry containing small glassy crystals of quartz occurs between mile-posts 175 and 176 on the Algoma Central railway. This porphyry is probably different from either of the preceding varieties, but its age relationships could not be ascertained.

Sideritic Flows and Tuffs and Associated Sediments. The formations grouped under this heading were found in close company and seem to be of about the same age. They form a considerable belt contiguous with and stratigraphically partly above, partly below, the principal iron range in Magpie-Hawk area. This belt crosses the Algoma Central railway east of Goetz lake. Small bodies of the volcanic members were also seen near Morrison lake in Goudreau area.

The tuff ranges from a medium-grained, quite massive variety whose clastic texture is not noticeable in the field, to a finer-grained, distinctly stratified one. It can always be distinguished, however, by the small rusty crystals of siderite, which speckle a pale-brown background. It is evidently the tufaceous equivalent of an acid lava, for it is made up of angular pieces of quartz, feldspars, and fine groundmass with little or no interstitial material. Crystals and aggregates of secondary siderite are scattered through the other constituents. The flow phase is probably represented by a light bluish-grey lava on Baldry lake.

Paralleling the tuff, and not far away from it is a narrow belt of sediments which extends from Mildred lake to an undetermined distance beyond Parks lake. This belt, however, is not continuous, nor are the sediments alike at all points along it. One section in the railway cut at the southwest end of Parks lake is about 15 feet thick. It consists of conglomeratic greywacke and slate in alternating bands ½ inch to 2 inches thick. South of it lies the iron-formation, and a short distance to the north the sideritic tuff. All of these formations stand nearly on edge. The greywacke is composed of the same fragmental materials as the tuff, together with some opaque dusty matter. It also carries an occasional subangular pebble, one-eighth to three-quarters of an inch across, of light-coloured, igneous rock. The alternating slaty layers are much finer-grained and have a pronounced secondary cleavage. The slate in one part of the section merges into a rusty-weathering phase in which secondary crystals of siderite have replaced up to one-third of the other constituents.

Between Baldry and Mildred lakes there is a much wider belt of sediments, which has been prospected rather carefully, apparently in the belief that it was an iron range. A section exposed in a trench in mining claim S.S.M. 1699 shows an apparent thickness of 75 feet of pebble-conglomerate. The conglomerate consists of well worn, subangular pebbles of white quartz (banded iron-formation) bonded together by an equal quantity of impure sandy matter. Most of the pebbles are less than an inch across, but there are occasional ones up to 3 inches. The sandy cement consists of angular particles of quartz and felspar. Another section in S.S.M. 1700 shows 26 feet of conglomerate followed on the north by 21 feet of fissile green slate, the sediments being terminated on either side by volcanic rocks. At this place the conglomerate pebbles are all composed of fine-grained, grey and green, volcanic materials and the cement is a schist similar to the adjoining slate. The slate is finely laminated and resembles the slate exposed at Parks lake.

Mica Diorite or Monzonite. This rock exhibits, perhaps better than any other Keewatin formation, the common tendency to be replaced by carbonates. It is much coarser-grained than the other Keewatin rocks and is probably intrusive rather than extrusive. A large body occurs on the west side of Baldry lake. Dyke-like masses were also seen on mining claim J.L. 28, Goudreau area, and in the feldspar-porphyry north of Webb lake. It is probably younger than the iron-formation. It seems to have been composed originally of feldspars and biotite, but now the biotite is changed to chlorite and both biotite and feldspars are partly replaced by large crystals and aggregates of carbonate. In most of the thin sections examined carbonate forms 20 to 30 per cent of the whole. It is either siderite or a mixture of iron and other carbonates, for it weathers to a rusty colour, staining the whole rock a distinctive yellowish-brown.

There is an enormous quantity of this secondary rusty-weathering carbonate in the Keewatin of the district. Of 32 thin sections of acid, intermediate, and basic igneous Keewatin rocks examined, scarcely any contain less than 2 or 3 per cent of carbonate, whereas the majority carry from 5 to 40 per cent and some as high as 60 per cent. Basic and intermediate rocks are as a rule more replaced than acid rocks, but 60 per cent of carbonate was found in one of trachytic composition. There even came under observation a number of rocks, composed of siderite and 10 per cent or less of quartz, chlorite, or other silicates, which, judging from their field relationships, had once been ordinary igneous rocks. The siderite body on the railway at Leg lake (Magpie-Hawk area) is a case in point. One can scarcely leave these facts out of consideration when inquiring into the origin of the iron-formations of the region.

Ellipsoidal Greenstone. Of all the basic rocks in the two areas mapped this is by far the most extensive and interesting. It underlies all the northern and western part of Goudreau area, and forms in most places the hanging-wall of the iron-formation. An ellipsoidal greenstone of lighter colour but very similar composition surrounds Loonskin lake in the Magpie-Hawk area and also occurs extensively between Goetz lake and Magpie Junction. The total volume of ellipsoidal lava appears to be many times greater than that of any other Keewatin formation in the district.

It is a dark green rock of basaltic composition, though now so decomposed that the name greenstone fits it better. Parts of the flow are coarse-grained and massive enough to resemble an intrusive formation, as for example, near Goudreau station. More commonly, however, it has a more or less well-developed pillow, or ellipsoidal structure. Very fine examples of this structure were seen on the dumbbell-shaped pond south of Jackson lake and near mile-post 181 on the Algoma Central railway. Belts of stratiform, highly fissile green schist which were taken to be tufaceous and ashy products of the same eruption are also associated with the massive and ellipsoidal phases. The flow portions are little or not at all schistified, probably because they were stronger and more competent than the fragmental materials.

There is some ground for believing that extrusion of this greenstone was attended by very considerable exhalations of carbonate-bearing solutions. At most places the angular spaces among the pillows are either empty or filled with a soft, green mixture of chlorite, epidote, and other secondary silicates; but near mile-post 181 on the railway they are filled with calcite, the colour and granular texture of which recalls the crystalline limestone member of the Goudreau iron-formation. From an inspection of the face of ellipsoidal greenstone in the railway cut, calcite would appear to make up between 1 and 2 per cent of the rock mass.

Latitic Greenstone. In mining claim J.L.1, Goudreau area, again on the Algoma Central railway near Loonskin lake, and in other places the ellipsoidal greenstone is accompanied by another greenstone of quite similar appearance. This latter rock is distinguished, however, by small particles of milky-blue quartz, and on microscopic study proves to be much more acid than might be expected from its field appearance. It is about equivalent in composition to quartz-diorite.

Iron-formation. This name is applied to a stratified association of banded silica, iron oxides, pyrite, and siderite or limestone, linear belts of which occur in Goudreau and Magpie-Hawk areas. As the pyrite ore deposits of both areas are part of this formation, the description of it and discussion of its origin are relegated to the section of the report that deals with economic geology.

LAURENTIAN.

Great areas of granite gneiss intrusive in the Keewatin occur in Michipicoten district, but these do not figure largely in the areas under consideration. The eastern part of Magpie-Hawk area is underlain by granite gneiss. There is none in the Goudreau area, though a large mass lies only a mile or so northward.

The granite gneiss in Magpie-Hawk area is not known to contain any ore deposits and does not present any geological feature of special interest, except possibly at its contact with the Keewatin. This contact is not quite ordinary. At most Keewatin-Laurentian contacts a broad contact-zone of coarsely crystalline amphibolite and other metamorphic products has been developed by the invading granite magma. The granite, both in the main batholithic mass and in apophyses that have penetrated the Keewatin, is usually a coarsely crystalline product of slow cooling. In Magpie-Hawk area, the contact-zone is not as wide as usual. The main intrusive mass of granite gneiss is of ordinary coarseness, but the smaller masses advanced into the Keewatin range in texture all the way from granite to a dense porphyry difficult to distinguish from acid volcanics that properly belong to the Keewatin. Fine-grained apophyses of this sort were found as far within the Keewatin as Loonskin lake. These chilled advance bodies and the narrowness of the contact aureole indicate, presumably, that the heating effects of the Laurentian along this contact were considerably weaker than usual.

LATE PRE-CAMBRIAN.

The Keewatin and Laurentian formations are intersected by two sets of dykes, both of late Pre-Cambrian age. The older set consists of quartz diabase, the younger, more numerous set, of olivine diabase. It is rather important to distinguish between them, for many of the quartz diabase dykes coincide with faults that have displaced the older formations, including the iron-formation, whereas the olivine diabase dykes are not accompanied by appreciable displacements.

The quartz diabase is a dark green, fairly coarse-grained rock not in all cases easily distinguished from the coarser and more massive among the Keewatin greenstones. Its recognition is aided, however, by the fact that it becomes distinctly finer-grained towards the dyke edges, which are in knife-sharp contact with the older formations. As a rule, too, the quartz diabase is more massive than the Keewatin rocks; it shows little or no schistosity. It is quite similar to the Keweenawan diabases of the Lake Superior region, of Cobalt district, and other parts of northern Ontario, consisting, like them, of about equal quantities of augite and plagioclase with a small percentage of black iron ore and a few areas of quartz and feldspar micrographic intergrowth in the interstices between the plagioclase and augite crystals. The augite is usually changed to secondary hornblende.

The olivine diabase, although of the same dark green colour as the quartz-diabase, is free even from traces of schistosity, and so fresh that the slender crystals of feldspar are still quite glassy. There are also present in all but very narrow dykes occasional rectangular, white crystals of feldspar from one-quarter inch to over an inch in diameter, which aid greatly in distinguishing the olivine diabase from the older variety. These large crystals are not found in narrow dykes, nor in the chilled edges of wide dykes. They are, therefore, believed to have developed after the molten magma had filled the dykes. As a rule they weather faster than the groundmass, forming shallow rectangular pits. Under the microscope the rock proves to be a fresh diabasic aggregate of plagioclase, augite, olivine, and black iron ore, indistinguishable from the olivine-diabase found in Sudbury, Cobalt, and other northern Ontario districts.

There are certainly many more of these late Pre-Cambrian dykes than the accompanying figures indicate, for they were noted only incidentally to the field examination of the older formations. Olivine diabase dykes are about three times as numerous as those of quartz diabase. Most of the former are extraordinarily straight and show practically no signs of having been bent or faulted. That there has been some disturbance since their intrusion, however, is proved by the dyke which parallels the railway just northwest of Loonskin lake. This dyke is quite sinuous and is shattered into blocks from a few feet down to an inch or so in diameter. Nearly all the quartz diabase dykes, on the contrary, have been considerably deformed, and are crooked and slightly schistified. Judging by the manner in which the iron-formation adjacent to them is displaced, more than half of them must also coincide with important faults.

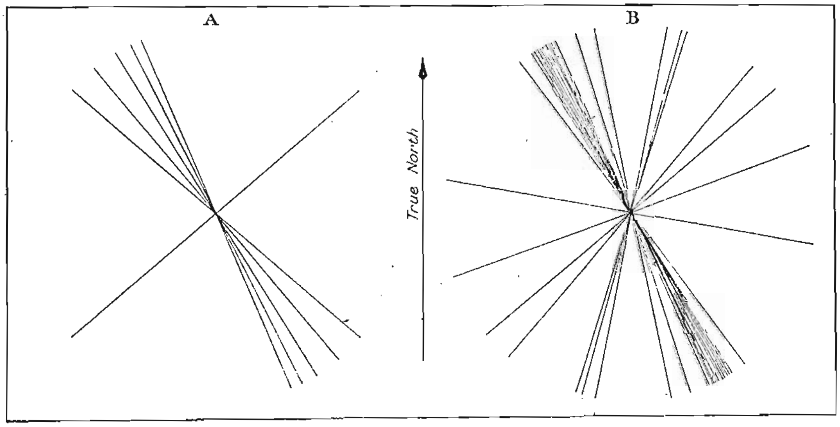

Figure 2. Plan showing the courses of the late Pre-Cambrian dykes in Goudreau and Magpie-Hawk areas, plotted through a common centre. A = quartz diabase dykes; B = olivine diabase dykes.

Most of the dykes strike in about the same direction, and in this respect quartz-bearing and olivine-bearing groups behave alike. An endeavour has been made in Figure 2 to express this graphically by plotting through a common centre the courses of the dykes in both map-areas. The diagram shows that a majority of both kinds strike about north 30 degrees west; also that the olivine-diabase dykes conform somewhat more closely to this direction than the older dykes.

Beyond the fact that the quartz diabase dykes are more deformed than the olivine diabase dykes and more weathered, no evidence was found within the district to prove that they are the older. That conclusion comes from the extraordinary similarity of the two diabases to the quartz-bearing and olivine-bearing diabases which occur from lake Superior to Quebec, where the quartz diabase is generally regarded as Keweenawan, and the olivine diabase dykes are known to intersect and to be much younger than the quartz diabase.

The quartz diabase dyke exposed in the railway cut northwest of Loonskin lake appears to be intersected by another rock different from either of the above types. This body of rock is not fully enough exposed to show that it is undoubtedly a dyke intrusive in the quartz diabase rather than an inclusion of older material, but the first conception seems the more likely one. It is a dark, medium-grained rock characterized by an abundance of black mica and lustrous cleavage faces of a mineral resembling bronzite. The original mineral constituents are too badly decayed to be fully determined, or to admit of naming the rock with certainty. It is either a minette or picrite, or closely allied to these types. The microscope shows it to consist of biotite, another dark mineral, probably either a magnesian pyroxene or olivine, now completely changed to serpentine, a few areas of decomposed feldspar, and a rather large amount of black iron ore changing to leucoxene.

This rock was seen only at one place, but it is perhaps identical with a basic micaceous dyke rock found cutting the ore-body at Magpie mine and known there as "mica-dyke". According to the evidence given above it is probably younger than the late Pre-Cambrian quartz diabase dykes; but its relationship to the olivine diabase dykes was not observed.

STRUCTURAL FEATURES OF THE PRE-CAMBRIAN FORMATIONS.

The sediments and iron-formation afford the only ready means of ascertaining how much the Keewatin complex has been folded and faulted. They dip at angles ranging from as low as 20 degrees in Goudreau area to over 90 degrees in Magpie-Hawk area, and strike about 60 degrees east of north; that is to say, sediments and volcanics alike have been closely folded along an axis pointing 60 degrees east of north. According to current geological theory, this folding is referable to the period of intense crustal disturbance which preceded or coincided with the Laurentian intrusion of granite-gneiss.

Intrusion of the late Pre-Cambrian quartz diabase was intimately connected with another, milder crustal disturbance, which resulted in faults of considerable magnitude. Faulting and intrusion of the diabase appear to have been closely related, for many of the diabase dykes were injected along the fault planes. For example, the main iron range in Magpie-Hawk area is displaced 3,000 feet horizontally along the broad dyke which crosses the middle of the area. In Goudreau area the iron-formation is displaced an undetermined distance southward along a dyke at the west end of the Morrison No. 2 property, by another dyke which crosses mining locations J. L. 9 and 10, and by still another in J. L. 20 and 21. In the first two cases the formations east of the dykes have been displaced northward, in the other two, southward.

PLEISTOCENE.

A large part of the district, including nearly all the high ground, is bare rock. Anything worthy of being called a drift sheet is limited to occasional sand-plains a square mile or so in extent, that lie well down among the hills. Goudreau area is exceptional, almost half of it being heavily drift-covered. Magpie-Hawk area, on the other hand, contains only two sand-plains, each between 1 and 2 square miles in area.

The Goudreau deposits are somewhat diversified. In the neighbourhood of Pine lake there is an extensive, pitted plain, that looks like a glacial outwash deposit. It consists of clean, medium to quite fine sand, varied by an occasional low ridge of more gravelly composition. No fresh-cut banks could be found, to ascertain if the sand is stratified. The surface, however, is pitted with numerous, kettle-like depressions, some of which are dry, whereas others contain the various small ponds that lie near Pine lake. This plain is said to extend for some miles eastward. At about Spring and Dobbs lakes, in the opposite direction, it merges into coarse gravels and bouldery materials, which appear to be morainic. These are well exposed along the Nichols Chemical Company's railway spur, and in the open-pit on mining claims J. L. 9 and 15. A great many of the boulders are of pyrite, banded silica, and other Keewatin formations that occur in the immediate vicinity. The boulders are embedded in fine gravel or loamy sand.

Horizontally stratified sand and gravel replace the morainic deposits in the valley of McVeigh creek which the Algoma Central railway follows. Good sections from 8 to 20 feet thick are exposed along the railway. These show well-stratified, fairly clean sand, overlain by 10 feet or more of coarse gravel, composed principally of fairly well worn, subangular or round pebbles and boulders ranging from 6 inches in diameter downwards. The surface is distinctly level and stands 1,225 feet above the sea. The sand and gravel were evidently laid down in water, but they are not accompanied by the stratified clay or silt that are so characteristic of glacial lake deposits.

The sand-plains in Magpie-Hawk area were not observed carefully. They are quite level, and consist of fairly clean, horizontally stratified sand like that found in the pitted plain near Pine lake. The plain at Hawk Junction lies 1,050 feet above sea-level, and that at Magpie Junction a few feet higher. A mixture of sand and boulders occurs at higher elevations.

There are in Goudreau area certain secondary pyrite deposits which shall be referred to here, though their fuller description is reserved for the section dealing with the ore deposits. They consist of loose pyrite sand, granular white silica, and iron oxide (limonite), which have been derived from the Keewatin iron-formation by the solvent action of surface waters and have been reprecipitated locally along the plane of contact between the solid rocks and the overlying sand and gravel, completely replacing the latter. Their precipitation has been closely governed by the underground water-level, for the pyrite sand lies just beneath water-level, and the friable white silica and iron oxide just above it. One of these deposits was observable during the 1918 field season in the Rand Consolidated Company's open-pit in mining location A.C. 50. Since the pyrite and silica replace Pleistocene sand they must have formed quite recently. In fact, they are no doubt still being deposited from the sulphate-charged waters that drain off the iron range.

ECONOMIC GEOLOGY.

PYRITE AND IRON ORES.

Pyrite, siderite, and hematite are constituent parts of the Keewatin iron-formation in Michipicoten district. In the two small areas under consideration here, pyrite is of chief interest at the present time, though important bodies both of siderite and hematite are also known.

Most of the pyrite deposits belong to the iron-formation and for that reason may be called range deposits. There are a few smaller bodies of high-grade pyrite, like the Holdsworth, lying just north of mining claim S.S.M. 1054 in Magpie-Hawk area, which occur among the Keewatin volcanics unaccompanied by banded silica or siderite. These are thought to be either fissure-fillings or replacement deposits, which derived their pyrite from the iron ranges by solution, transportation, and redeposition. There are still other small bodies in the Pleistocene drift where the drift has been replaced by pyrite sand and granular silica, deposited from the mineralized waters that drain off the iron ranges. This type is exemplified in the Rand open-pit at Goudreau. There are, thus, three distinct types of pyrite deposits to be considered.

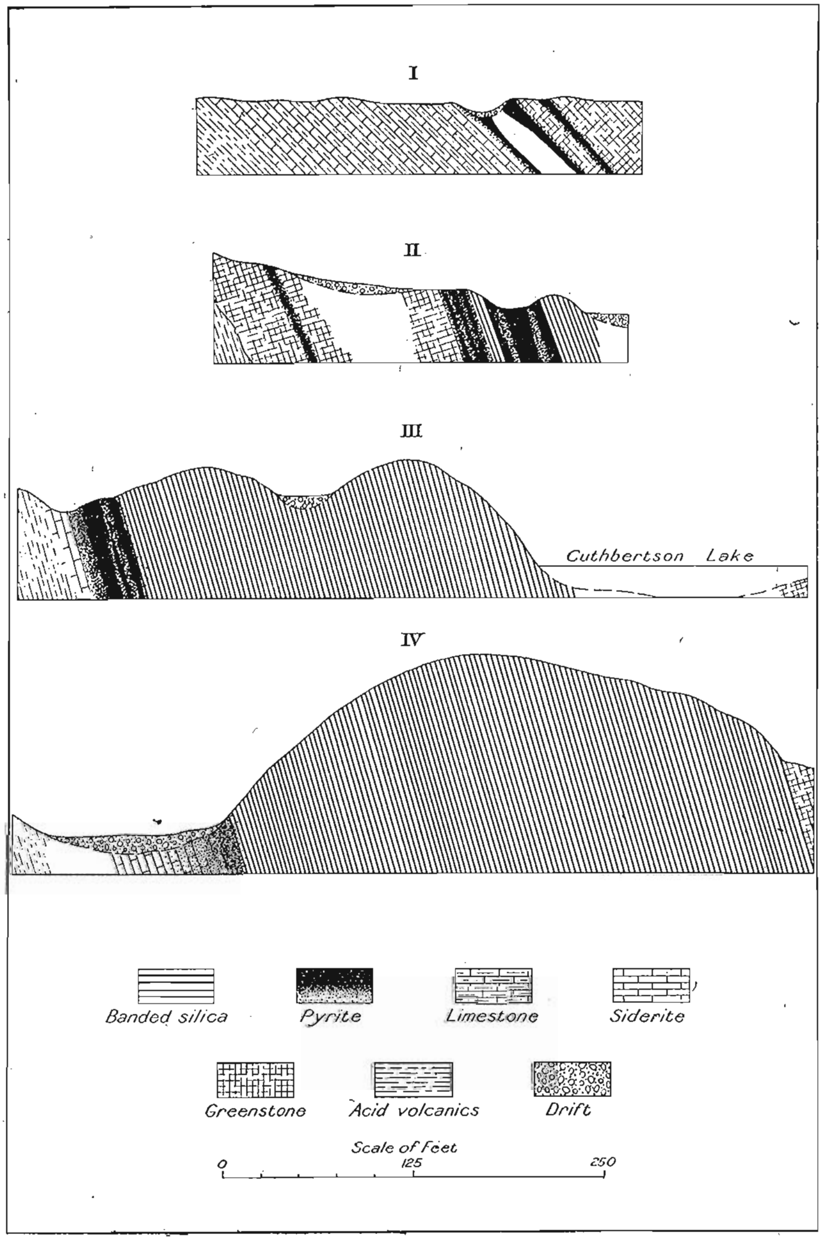

Figure 3. Cross-sections of iron formations showing the stratigraphic arrangement of banded silica, pyrite, and siderite, or sideritic limestone, and the topographic expression of each. I. Near middle of mining location J. L. 10, Goudreau area. II. Along east boundary of mining location A. C. 39, Goudreau area. III. Near east end of Cuthbertson lake, Magpie-Hawk area. IV. Near middle of the Bartlett group, Magpie-Hawk area.

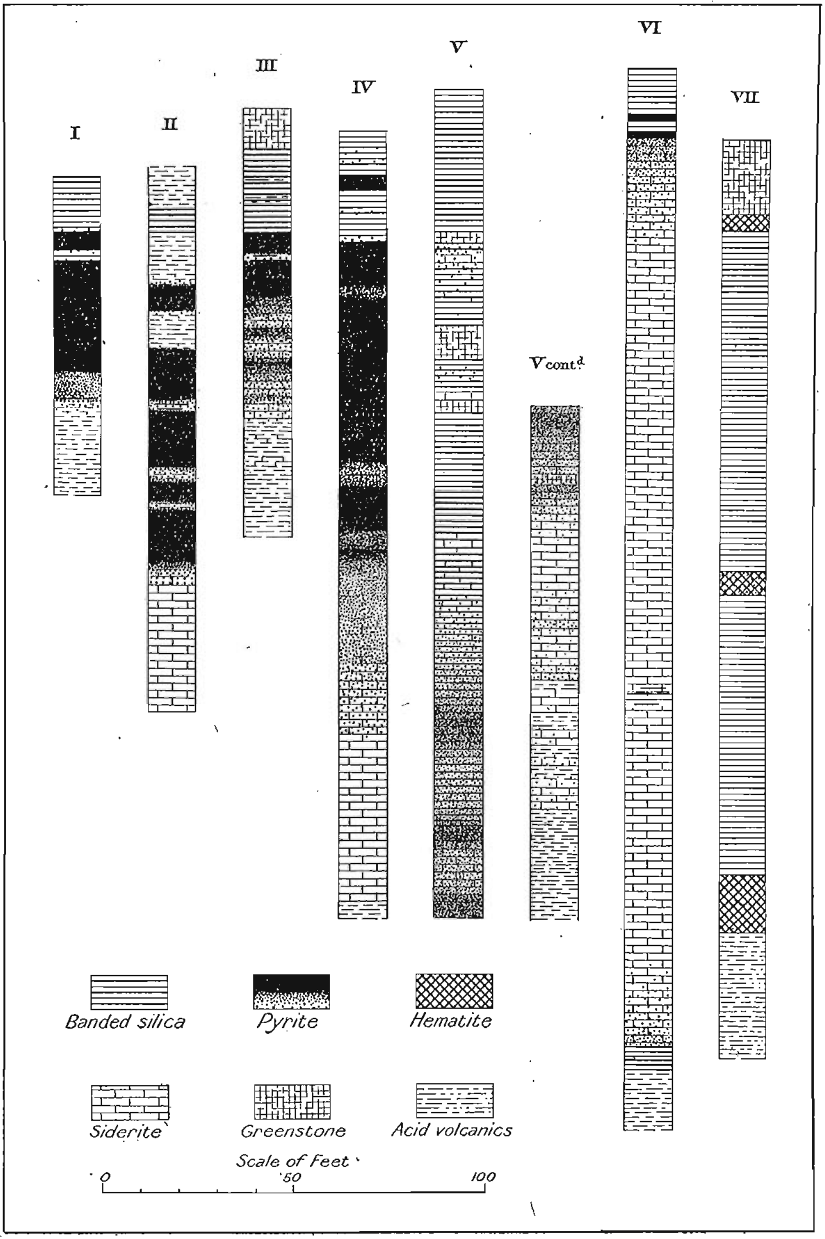

Figure 4. Diamond-drill sections of iron formations showing in more detail than Figure 3 the stratigraphic arrangement of banded silica, pyrite, and siderite, or sideritic limestone. The drill-logs have been corrected so as to show true thicknesses in each case. I. Hole No. 15, C deposit, Nichols Chemical Company's property, Goudreau area. II. Hole No. 8, Morrison No. 2 property, Goudreau area. III. Hole No. 16, Morrison No. 3 property. IV. Hole No. 8, Morrison No. 1 property. V. Hole No. 1, Bartlett property, Magpie-Hawk area between 950 feet and 30 feet. VI. Hole No. 111, Helen mine. VII. Hole No. 17, Josephine mine, Magpie-Hawk area between 450 feet and 850 feet.

Range Deposits.

General Description of the Iron-formation. Iron-formation is composed essentially of banded silica, pyrite, and siderite or sideritic limestone arranged in stratiform fashion. The banded silica in particular is so perfectly stratified that the whole iron-formation must be assumed to have been deposited horizontally in the first place, and over considerable areas. But, in common with the other Keewatin formations, it has since been closely folded and now outcrops in discontinuous and rather complex linear belts, or ranges. These ranges have been repeatedly broken and offset by faults, most of which coincide with quartz diabase dykes. To complicate relationships still more, the iron-formation is not confined to a single horizon in the Keewatin; west of mile-post 176 on the railway, for example, there are two ranges, one about 1,000 feet stratigraphically above the other.

An effort has been made in Figures 3 and 4 to indicate the general stratigraphic character of the iron-formation by placing side by side cross sections of different parts of the ranges in both areas, those in Figure 3 representing surface exposures, whereas those in Figure 4 are from diamond-drill borings. The sections were selected so as to be as representative as possible of the principal ranges examined. They do not, however, illustrate such extreme types as the body of siderite at Leg lake, Magpie-Hawk area, or the Dreany range, near mile 182 on the railway, which consists solely of banded silica.

The iron ranges vary in thickness from about 2 feet to 500 feet, and in apparent length from a few yards to more than 7 miles. They are associated exclusively with volcanic formations. No clastic sediments occur near them, with the exception of the conglomerate and sideritic greywacke on Parks lake, and these appear to be only a volcanic tuff modified by water action. As a rule the underlying volcanics are acid, and more or less tufaceous. The overlying volcanics are prevailingly greenstones, especially in Goudreau area, where they are also ellipsoidal; but the range east of Parks lake lies in part between acid flows and tuffs. There is nothing then in the environment of the iron-formation that suggests it to be sedimentary.

The iron-formation itself is made up of banded silica, pyrite, and siderite or sideritic limestone. Exceptionally, as in the neighbourhood of Parks lake, layers of hematite are also present. With the silica, pyrite, and siderite there may or may not be intercalated, at any horizon and in varying thicknesses, bands of volcanic schist. The proportions in which each of these constituents occurs vary greatly. The lenticular bodies at Leg lake and at the pond just north of mining claim S.S.M. 1054 consist solely of siderite. Parts of the Goudreau range, as in mining claim J.L. 10 and north of J.L. 9 and 15, consist of sideritic limestone and pyrite. Other parts of the Goudreau range comprise a varying, but on the whole not large proportion of banded silica in addition to pyrite and limestone. The Bartlett range, east of Parks lake, is formed mainly of banded silica and a relatively small amount of pyrite and siderite. The " C " deposit in mining claim J. L. 15 at Goudreau contains banded silica, pyrite, and only traces of siderite. Most of the small lenses near Spring lake are composed entirely of banded silica. In other words, there are all phases between a pyritic siliceous siderite at one extreme and a banded silica formation at the other.

Wherever all three constituents are present, they tend to be arranged with banded silica at the top, succeeded downward by pyrite, and the pyrite by siderite or sideritic limestone. This sequence obtains in its simplest form at the Nichols Chemical Company's pit in J. L. 15. As a rule, it is more complex, owing to repetitions of the banded silica and pyrite members, to the presence of bands of volcanic schist, and at the bottom of the formation to a feeble development of banded silica and pyrite in reversed order (section VI, Figure 4). But, when any range is considered as a whole in cross-section (Figure 3) the general sequence, banded silica—pyrite (or hematite)—siderite, is obvious and without exception, whether all three or only two members are present. The structure, however, is not a simple superposition of bed upon bed. Diamond-drill cores from different holes in the same part of a range usually show the individual bands of schist, pyrite, etc., at different depths and even in different order. They cannot be connected so as to represent a succession of continuous layers. It seems fair to conclude, rather, that the successive materials passed through are discontinuous, lenticular bodies more or less complexly imbricated. On this account diamond-drill holes have to be placed fairly close together before the stratigraphic structure of the iron-formation can be interpreted accurately or in detail.

Banded Silica. The banded silica of the Michipicoten ranges, like that in other parts of northern Ontario, is a thinly stratified or laminated rock in which layers of nearly pure silica alternate with iron-bearing layers composed of silica mixed with some iron ore mineral. As a rule the siliceous layers are grey or white, and the iron-bearing layers black or brilliant red, producing a conspicuous banded appearance; but all that was seen in Goudreau and Magpie-Hawk areas is a distinctively pale variety ranging from snow-white to a faintly banded type composed of white and either grey or light red bands. It is also more granular than the banded silica of other parts of Ontario, though in this respect the Michipicoten type varies rather widely, even in a single cross-section of a range; for example, the upper bed represented in section II, Figure 3, is a loosely granular, snow-white variety so friable that it can be reduced to sand by rubbing two pieces together, whereas the next one, 30 feet lower, is hard and glassy.

The white layers consist almost entirely of interlocking quartz grains about as large as fine sand grains. A few shreds of colourless secondary mica may also be present. Where grey or reddish layers alternate with the white layers they are narrower than the white ones and are composed of the same granular quartz mixed with some iron ore mineral—magnetite, pyrite, siderite, or hematite. The iron-bearing constituents are usually less than half as abundant as quartz. If siderite is present the layers are apt to be reddish, owing to partial alteration of the siderite to iron oxide. Siderite occurs in irregular grains, magnetite and pyrite mostly in well-formed crystals. The boundaries between siliceous and iron-bearing layers are gradational, though sharply so.

Deposits of banded silica lie characteristically between Keewatin volcanics and pyrite or pyritic siderite (Figure 4). Their boundaries are definable within a few inches, except in uncommon instances, where the banded silica grades more easily into pyritic siderite.

Pyrite. The pyrite of the iron ranges is not so well segregated from the other iron-formation materials as the banded silica. There are all variations from an ore carrying 90 per cent of pyrite down to carbonate or schist sparingly impregnated with pyrite. In Figures 3 and 4 the portions in solid black carry 60 per cent or more of pyrite, the stippled areas from that down to 10 per cent. Range ore, in brief, is a mixture of pyrite and siderite or schist. The mixture is not uniform; vaguely defined spots and patches of siderite or schist are scattered through the sulphide, like the vestiges of country rock in a replacement ore. In some of the ore being taken from the Nichols Chemical Company's pit in mining claim J.L. 15 these vestiges are arranged so as to give a rude banded appearance. Range pyrite is characteristically granular and rather easily pulverized, the individual crystals being about as coarse as ordinary sand. The granular ore, however, is commonly traversed by veinlets of harder and much more lustrous pyrite. A point, perhaps of chief interest to drill and mine operators, brought out in Figure 4, is that the pyrite is richest just under the banded silica and tends to become leaner in depth.

—	Ia.	Ib.	IIa.	IIb.	IIIa.	IIIb.	IV.	V.	VI.	VII.
Fe.	......	57·84	......	58·02	......	57·04	......	43·49	41·40	45·14
S	38·48	2·43	34·31	3·18	33·47	2·70	35·93	26·37	26·57	50·04
As	tr.	......	0·01	......	0·01	......	......	0·01	0·02	0·005
P.	......	0·014	......	0·010	0·010	0·013	......	......	......	0·003
Mn	......	1·10	......	0·64	......	1·81	......	......	......	0·21
Zn.	......	......	......	......	......	......	......	1·08	1·48	0·24
Cu.	......	......	......	......	......	......	0·12	None.	None.	None.
Ni.	......	......	......	......	......	......	0·52	......	......	......
Insoluble siliceous material	......	4·56	......	1·36	......	2·40	......	1·02	4·40	3·62
Total	......	......	......	......	......	......	......	......	......	99·258
Magnetic portion	12·15	......	9·56	......	10·52	......	......	......	......	1·36

I. Sample of range pyrite from carload of lump ore from Rand Consolidated Company's pit, mining claim A.C. 50, Goudreau; (a) as received; (b) roasted. Analysed by H. A. Leverin, Mines Branch, Ottawa.

II. Sample of range pyrite from carload of lump ore from Nichols Chemical Company's pit, mining claim J.L. 15, Goudreau; (a) as received; (b) roasted. Analysed by H. A. Leverin, Mines Branch, Ottawa.

III. Sample of range pyrite from carload of fines from Nichols Chemical Company's pit, mining claim J.L. 15, Goudreau. (a) as received; (b) roasted. Analysed by H. A. Leverin, Mines Branch, Ottawa.

IV. Average of six drill core samples of range pyrite from hole No. 3, mining claim J.L. 15, Goudreau. Analysed by Algoma Steel Corporation, Sault Ste. Marie, Ontario.

V. Average sample of range pyrite from drill core from mining claim J.L. 21, Goudreau. Analysed by H. A. Leverin, Mines Branch, Ottawa.

VI. Average sample of range pyrite from railway cut, mining claim Y 454, Magpie-Hawk area. Analysed by H. A. Leverin, Mines Branch, Ottawa.

VII. Sample of pyrite sand replacing glacial drift from Rand Consolidated Company's pit. Goudreau. Analysed by H. A. Leverin, Mines Branch, Ottawa.

Analyses I-VI on the accompanying table, although incomplete and carried out only with the object of determining the commercial qualities of the ore, indicate in some degree that, chemically and mineralogically as well as physically, there is a marked sameness about range pyrite, from whatever part of the district it may come. Around 10 per cent of each sample is magnetic, consisting presumably of pyrrhotite, or pyrrhotite and magnetite. Arsenic, manganese, and probably also zinc are regular constituents. Copper appears, from the data available, to occur only locally. Half of one per cent of nickel was found in the only sample among the six which was analysed for this metal. Gold is associated with iron-formation at the Emily mine on Dog lake[1], and is reported to have been found in assays of ore from the narrow pyritiferous lenses near Lovell lake; but it is not known whether the gold at these places belongs to the iron-formation or was introduced by some later mineralizing process. All the analyses show more iron than is necessary to satisfy the sulphur, even after allowance has been made for the pyrrhotite present. The surplus is present as iron carbonate and probably to a less extent as magnetite, as both these minerals are recognizable in microscopic preparations of the ore.

Siderite. The third and lowermost zone of the iron-formation consists of siderite or sideritic limestone (Figures 3 and 4). This carbonate zone differs in width from little or nothing up to 200 feet in different ranges, and it is a common experience in diamond-drill explorations to find wide variations in thickness within short distances in the same range. Both upper and lower limits are indefinite. The carbonate usually merges upward into pyrite by easy gradations. It gives place downward through poorly

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[1] Coleman, A. P., "Iron ranges of eastern Michipicoten," Ann. Rept. Ont. Bureau of Mines, vol. XV, pt. 1, p. 187.

defined alternations of volcanic schist and carbonate into continuous volcanic rock, the latter being in nearly all cases an acid variety and, in many cases at least, a tuff. The change into the volcanic foot-wall is usually complete in less than 10 feet. Rarely, as at the Helen mine (section VII, Figure 4), a little banded silica and pyrite intervenes between the carbonate zone and the foot-wall of the range.

In all the ranges in Magpie-Hawk area, in the range just west of mile 176 on the railway, and in several parts of the main Goudreau range the carbonate member is a siliceous, pyritic siderite, a close-grained, pale grey material not difficult to confuse with decomposed rhyolite or other acid lava because the admixed silica renders it considerably harder than ordinary siderite. It weathers, however, to rusty brown limonite. Microscopic preparations appear as a mosaic of carbonate (siderite) grains, through which are scattered occasional grains of quartz and occasional crystals or small aggregates of pyrite. Samples taken not far from the bottom of the iron-formation show irregular bands and scattered shreds of chlorite and of colourless secondary mica. In a sample of pyritic siderite from the bottom of the Nichols Chemical Company's pit, a few grains of ottrelite were found, a rather uncommon mineral, which, with this exception, appears to be confined to an ottrelite porphyry that forms the foot-wall of the iron-formation. Judging from the indefinite boundaries between the siderite and underlying volcanics, and the presence in it of such minerals as ottrelite and chlorite, the siderite seems, to some extent at least, to have attained its present position by replacing the volcanics. One thin section of siderite from the range west of mile-post 176 shows a porphyritic arrangement of coarsely crystalline areas of pure siderite surrounded by a finer-grained mixture of siderite and quartz, as if a porphyry had been changed to siderite and quartz without obliterating its original texture.

According to the analyses quoted here of siderite from different parts of Michipicoten region, it has certain constant and rather distinctive features. These and other analyses not available for publication show from 2 per cent upwards of silica and about half as much or less of pyrite, but the rock is composed mainly of iron carbonate, with lesser proportions of calcium, magnesium, and manganese carbonates. The manganese adds considerably to the favour with which the roasted siderite is received in the iron ore market.

—	I.	II.
SiO_2	9·20	8·31
Al_2O_3	3·04	
Fe	35·11	38·80
Mn	2·86	-
CaO	8·40	-
MgO	4·17	-
S	7·43	5·21
P	0·019	0·006
Loss on ignition	21·50	28·92

I. Sample of pyritic siderite from diamond drill hole, mining claim S.S.M. 1777, Goudreau. Analysed by the Algoma Steel Corporation, Sault Ste. Marie, Ontario.

II. Sample of pyritic siderite from diamond drill hole, Bartlett range, east of Parks lake, in Magpie-Hawk area. Analysed by the Algoma Steel Corporation, Sault Ste. Marie, Ontario.

Crystalline limestone takes the place of siderite in a large part of the Goudreau iron range—that lying between Goudreau station and Goudreau lake. This limestone resembles the calcite that fills interstices in the ellipsoidal greenstone of the district (see page 10). It is for the most part a medium to coarsely crystalline, pale grey or pale brown rock carrying a few scattered grains and bunches of pyrite. Parts of it are uniformly grey, but other parts become speckled with brown on weathered surfaces, suggesting an admixture of iron carbonate. It seems likely that the limestone actually merges into siderite since typical siderite occurs in what appear to be other parts of the same range; but the formations are too heavily drift-covered for ocular confirmation of this opinion.

Replacement Deposits in the Drift.

While stripping the cover of gravel and stratified sand off their pyrite range in mining location A.C. 50 the Rand Consolidated Company laid bare another body of pyrite which, although vastly younger than the range deposits, bears certain striking and suggestive resemblances to them. When first visited, the excavation had been pumped out and the vertical section reproduced somewhat diagrammatically in Figure 5 could be seen. The first 6 feet or so from the surface consisted of interstratified sand and gravel lying horizontally and cemented by iron oxide (limonite) to the consistency of a weak sandstone. Beneath this lay an uneven bed of snow-white, granular silica resembling lump sugar in appearance but more easily crumbled. This bed varied in thickness, not exceeding a foot and tapering out toward the west side of the pit. It was underlain by from 0 to 5 feet of loose pyrite grains comparable to ordinary sand. The pyrite sand reposed upon lean Keewatin iron-formation consisting of pyrite and siderite mingled with some country rock. The surface of contact was indefinite in places, definite in others, and at the west end of the pit was continuous with the contact between Keewatin and Pleistocene drift.

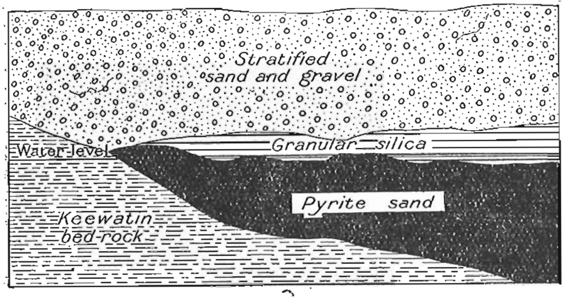

Figure 5. Diagram showing geological relationships of the body of pyrite sand in the Rand Consolidated Company's pit, Goudreau. This body, is younger than the Pleistocene drift.

At all later visits water had risen to the line between pyritic sand and granular silica. According to the manager of the property, Mr. A. W. Jackson, the water remains stationary at this level.

It is clear that the granular silica and loose pyrite had chemically replaced their own volume of sand and gravel at the bottom of the Pleistocene drift and must have been deposited there since the sand and gravel were laid down. Neither is it hard to find a source for these materials, particularly the pyrite. The water that fills the excavation, like all the surface water that drains off the neighbouring iron range, contains sulphuric acid, and no doubt also iron sulphate, since encrustations of that salt are found on the pit-walls. These waters are conducted through the drift along channels determined by the slope and inequalities of the underlying, impervious Keewatin bedrock. It remains only to interpret the reactions whereby sulphuric acid and iron sulphate are reconverted to the pyrite from which they were derived in the first place. In this connexion it is suggestive of reducing conditions that the upper limit of the pyritic sand should coincide so closely with the underground water-level, above which there is limonite instead of pyrite. Whether the reducing agent is the organic acids that probably occur in the water, or something else, or these in more complex relation with the silicates in the replaced sand and gravel, the essential reaction leading to the reproduction of pyrite is presumably of the type:

$FeSO_4 +$ reducing agent $= FeS_2 +$ oxidized reducing agent. Presumably, also, the deposits are being added to at the present time.

Siderite is not present in these modern deposits, but the silica and pyrite are strikingly like the silica and pyrite of the Keewatin iron ranges, in appearance and in their stratigraphic relationship to one another. The granular silica is not laminated and is more loosely granular than most of the banded silica of the ranges, but in both these respects it is not greatly different from the upper deposit of granular silica shown in section II, Figure 3. It may be said to form one extreme of a series of types ranging from loosely granular, poorly banded, snow-white silica to a glassy laminated variety in white and light red colours. The pyrite sand, on the contrary, differs in several notable respects from range ore (see table of analyses). Owing to the acid nature of the depositing waters it has no admixture of siderite. Indeed, the pyrite sand shows 95 per cent pyrite by chemical analysis. Manganese and zinc are reduced to insignificant percentages. Likewise, the magnetic portion, which amounts to 10 or 12 per cent in range ore, is only 1·36 in the pyrite sand.

The similarity between the recent replacement deposits and the Keewatin iron ranges is sufficiently remarkable to suggest that the banded silica and pyrite of the lattter may have been concentrated by processes of solution and redeposition analogous to those which so manifestly gave rise to the younger deposits.

Vein-like Deposits in the Keewatin. The Holdsworth pyrite deposit, just north of mining claim S.S.M. 1054, in Magpie-Hawk area, represents a type different from either of the preceding. It lies in low ground, revealing itself at the surface only by the rusty appearance of the nearby Keewatin schists. Its character and relationships have been disclosed, however, by diamond-drill borings. According to these it is a tabular, or vein-shaped body of high-grade pyrite with Keewatin schists in both sides.

The drill cores show nothing but pyrite between walls of green schists of basic to fairly acid composition. There is no banded silica or siderite and the pyrite itself looks quite different from range pyrite. It is a massive, very fine-grained, satiny ore netted by tiny gashes filled with coarser-grained and more lustrous pyrite. An occasional nest of quartz is the only visible impurity. A complete analysis of this ore is, unfortunately, not yet at hand, but such tests as have been made confirm the idea, produced by its physical appearance, that it is distinct from range ore. A test made by H. A. Leverin of the Mines Branch, shows only 3 per cent of magnetic matter, in contrast with the 10 or 12 per cent in range pyrite. Analyses of drill-core samples by the Algoma Steel Corporation also yielded from 38·97 per cent to 49·24 per cent of sulphur, which is greatly in excess of the sulphur in range ore. Chemically and mineralogically, the Holdsworth pyrite is much more like the Pleistocene pyrite sand than range pyrite.

Description of Properties.

Nichols Chemical Company. The Nichols Chemical Company, 25 Broad st., New York city, hold under lease 1,171 acres of land immediately northeast of Goudreau station on the Algoma Central railway, comprising mining claims J.L. 1-28 (Goudreau group), and A.C. 38-42 (Morrison No. 3 group), in township 27, range 26, district of Algoma. This area includes an unusually large share of iron-formation folded into a succession of synclines and anticlines. The formation is offset in at least two places by faults of large displacement which coincide with late Pre-Cambrian diabase dykes. The principal iron-formation lies between an underlying ottrelite porphyry and overlying ellipsoidal and other greenstones. In addition there are several small and unimportant bodies of iron-formation higher up within the greenstone.

A large part of the main iron-formation carries limestone instead of siderite, but it does not differ otherwise from the typical iron-formation of Michipicoten region. All the pyrite ore-bodies are of the range type. The character of the ore is shown by analyses II, III, IV, and V in the table on page 18.

Diamond-drill explorations have been made at various times since 1903, in locations J.L. 3 and 4, 9 and 15, 16 and 21, 18, 26, and 28, and in A.C. 38, 39, and 40. Much surface trenching has been done in the same places. Old exploration shafts were also seen near the southwest corner of J.L. 4 and J.L. 21.

During 1918 mining or preparations for mining were under way at three places. Ore was being taken at the rate of 150,000 tons for the season from an open-pit in J.L. 15, formerly known as the C deposit. The iron-formation there dips southwest at 18 to 40 degrees, admitting of this method of mining. A heavy overburden of gravel and boulders is removed with a steam shovel, the ore broken down by blasting, loaded on dump cars with a steam shovel, and hauled by locomotive about 1,500 feet to the mill for crushing and sorting. At the mill, which has a capacity considerably greater than the 1918 output, blocks of ore from the pit, up to 2 feet in diameter, are fed into a gyratory crusher. Rock is removed by hand from the crushed product as it is conveyed on belts to the screens for separation into lump ore and fines. Lump ore consists of pieces from ½ to 3 inches in diameter and fines anything smaller. The ore is fed from bins directly into railway cars and hauled 2 miles over a standard-gauge spur to Goudreau station on the Algoma Central. From there, it is hauled 40 miles to Michipicoten harbour and loaded on boats for shipment to lake Erie ports. A large boarding-house and smaller dwellings provided excellent accommodation for the 300 men employed in 1918. The mill is operated with electric power generated from steam on the spot.

About 250,000 tons have already been taken from the C deposit. A large amount probably remains between the present pit and the diabase dyke to the west, beyond which the ore-body is faulted out of reach. The iron-formation dips, however, at such an angle in the direction of the dyke that quarrying will likely have to be replaced by underground mining before long. There are several streaks of pyrite in the green schist west of the dyke, but these appear to be secondary impregnations along shear zones and not true extensions of the iron-formation. A large area of pyrite which outcrops a few hundred feet south of the pit seems to be distinct from the deposit now operated, and somewhat higher up in the Keewatin. This body has not yet been touched.

During 1918 a narrow-gauge extension of the railway was run from the mill to the Bear claim (J. L. 28) and the drift cover stripped off a large outcrop of pyrite preparatory to mining. No ore had been raised, however, as late as August. From surface indications the Bear ore-body promises to be much less regular in form than the C deposit, and to pitch much more steeply. Underground mining methods may have to be employed.

The pyrite range in the Morrison No. 3 group of claims was diamond-drilled during the summer of 1918, disclosing a workable belt of ore. Since then a shaft 300 feet deep has been sunk, at an angle of about 45 degrees.

Preparations were also being made for opening up the A deposit in J.L. 16 and 21. A ditch has been dug in order to drain into Spring lake the shallow ponds and swamp which cover the ore-body. The iron-formation dips about 45 degrees to the north so that only a small part of the ore-body can be recovered by open-pit methods. It is also offset southward on the east side of the diabase dyke which crosses J.L. 21.

The iron-formation appears to attain its greatest exposed width in J.L. 4, 5, 6, 7, and 8. Rock outcrops are not numerous enough there for its continuity to be placed beyond doubt, but the dips are shallow enough—15 to 45 degrees—to suggest that the iron-formation lies in a number of shallow folds. This structure would lend itself readily to cheap, open-pit, mining operations, and very fair pyrite has already been found there by diamond-drilling, test-pitting, and in the old shaft at the southwest corner of J.L. 4. Further development has been discouraged, however, by the nature of the surface. Part of it is swampy, the remainder a succession of hills of bouldery drift

Rand Consolidated Company. This company has leased mining locations A.C. 44, 45, 46, and 50, at Goudreau, and a group of ten unsurveyed claims west of milepost 176 on the railway. The two groups are known respectively as the Morrison No. 4 and Morrison No. 2 properties.

The iron-formation on the Morrison No. 4 group is a continuation of the Nichols Chemical Company's main range. It passes immediately south of the railway spur, under which it dips at about 60 degrees. In spite of the high dip it is being successfully operated as an open-cut. The ore is blasted and handled in the same general manner as at the Nichol Chemical Company's C pit. As the workings are only 500 feet away from Goudreau siding the company was able to ship a considerable quantity of ore in 1918, although operations had begun only during that year. In addition to the range pyrite, a considerable body of high-grade pyrite sand was found in stripping off the overburden of sand and gravel (see foregoing analyses).

The Morrison No. 2 property comprises two parallel iron ranges, the northern range of which is about 1,000 feet higher up in the Keewatin succession than the southern. Both ranges are situated on a high ridge and dip 60 to 75 degrees towards the north. They disappear eastward under the stratified sand and gravel that fill the valley of McVeigh creek. It is possible that they have been displaced 6,000 feet southward by a fault in the creek valley and were originally continuous with the Goudreau range, for no extension of them could be found directly across the valley. Towards the west the northern range becomes drift-concealed, but the southern range terminates abruptly against a large diabase dyke. There is reason to believe that the dyke coincides with another fault and that the iron range and other Keewatin formations west of it were faulted southward. Careful exploration in that direction should lead to the discovery of the offset part of the range.

The southern range appears to be the better one, both from surface indications and from the results of diamond-drill exploration. Eighteen holes were bored in 1915, sixteen of which were located in the southern range at intervals of from 200 to 400 feet apart for a total distance along the range of 3,800 feet. These holes reached vertical depths of from 65 to 235 feet. All that were directed in such a manner as to intersect the iron-formation showed a pyrite deposit ranging in thickness between 12 and 50 feet, at depths of from 60 to 200 feet. Correlating the drill sections with surface outcrops it appears that the pyrite forms a tabular ore-body extending along the range and dipping steeply between 75 degrees north and a like amount southward.

If this ore-body is assumed to be continuous between the drill holes it should contain 1,250,000 probable tons of ore, in the depth penetrated by the drill. The drill-core analyses, in the possession of the Nichols Chemical Company, are not available; but it is evident from the appearance of the cores that a considerable share of the pyrite ore contains only between 25 and 35 per cent of sulphur. With the information at hand even an approximate estimate cannot be made of the amount of ore carrying over 35 per cent sulphur.

Teare Claims. This property comprises two unsurveyed claims, S.S.M. 94 and 102, contiguous with the north boundaries of J.L. 9 and 15. It contains an extension of the Nichols Chemical Company's A deposit. The iron range consists, like the A deposit, of pyrite and sideritic limestone, which dip north about 45 degrees between a hanging-wall of greenstone and a foot-wall of ottrelite porphyry. It is 2,300 feet long and is cut off at the west by the same fault and diabase dyke which lie west of the C deposit. Cross trenches expose pyrite to a maximum width of 60 feet.

Morrison No. 1. The Morrison No. 1 group consists of twelve surveyed claims (S.S.M. 1708-1711, 1769-1772, and 1775-1778 containing 437·7 acres) situated just north of Goudreau lake in township 27, range 27. It is owned by the Algoma Steel Corporation, Sault Ste. Marie. The iron-formation on these claims lies in a close double fold that pitches northeastward under ellipsoidal greenstone. The foot-wall consists mainly of feldspar porphyry. Most of the range is narrow and consists largely of banded silica, but a large body of pyrite occurs at the nose of the pitching syncline on S.S.M. 1709-1710, and 1777. The exposed part of this nose was diamond-drilled in 1914, and found to contain a large tonnage of pyrite ore carrying from 38 to 42 per cent sulphur.

Wilcox. This property lies one-third of a mile north of the east end of Pine lake, in township 26, range 27. Iron-formation is bent sharply back upon itself like a hook, and apparently representing a close anticline pitching westward, is exposed for 700 feet. It disappears under a heavy cover of sand toward the east, but was located in that direction for 1,200 feet more by dip-needle measurements. The outcropping portion has been trenched so as to expose a thick gossan of limonite and pyrite mixed with limonite for a width of 20 to 30 feet.

McCarthy-Webb. There is reason to believe that a narrow iron range, 4,000 feet long, which does not reach the surface, underlies the deeply drift covered part of the area just south of Webb lake. Its presence is inferred principally from dip-needle measurements made across the contact between porphyry and ellipsoidal greenstone. More substantial evidence was found only at one point on the small stream which enters the south side of Webb lake. At that place there are stagnant pools of water tasting of iron salts and depositing limonite on the bottom. The length of this presumptive range has not been determined as the dip-needle readings were carried only as far east as a little pond lying about 160 feet south of the south shore of Webb lake.

Other Deposits in Goudreau Area. Narrow bodies of pyrite and pyritic schist occur: (1) along the Pick road northeast of Lovell lake; (2) on Goudreau lake near the south boundary of township 27, range 27; and (3) on Goudreau lake opposite the outlet of Teare lake. The first of these is apparently part of an iron range and deserves further surface exploration, especially towards the west. The others are impregnations of pyrite in green schists. A considerable amount of surface stripping was done on the first two in 1918.

Holdsworth. Two surveyed claims (S.S.M. 1054 and 1055) and seven unsurveyed ones near mile-post 25 on the Michipicoten branch of the Algoma Central railway are held by John Holdsworth of Hawk Junction. These claims contain the vein-like, high-grade pyrite deposit described on page 21. An option to purchase has been given to the Algoma Steel Corporation and during the past summer the corporation had two diamond drills at work exploring the ore-body.

There is very little sign of the ore-body at the surface. It outcrops in low, and for the most part, swampy ground. There must have been some natural outcrops in the first place, but all the writer saw were in recently-made trenches. These had exposed a rusty belt of schist about 30 feet wide. In places the belt is capped under the drift by a foot or less of a dull-black, slag-like or powdery material, known as "black sand," which is probably a ferrous oxide resulting from the oxidation of pyrite. No pyrite whatever could be seen.

At the time of writing, however, sixteen holes have been drilled so as to crosscut this belt at intervals of 50 to 200 feet at depths ranging from 150 to 525 feet. They have revealed a deposit of pyrite which appears to be in the form of two thin lenses in alignment with each other and dipping 68 degrees north. The two lenses are about 200 feet apart. The western lens has been located horizontally for 500 feet and to an extreme depth of 490 feet, at which point it attains its maximum determined thickness of 38 feet. The eastern lens has a determined horizontal extent of at least 450 feet and a maximum determined depth of 525 feet, at which it likewise attains a maximum thickness of 28 feet. Although both lenses taper out they apparently average 24 and 25 feet in thickness, respectively, so that a large tonnage of ore is already assured. The ore-bodies have sharply defined boundaries, drill-cores showing a change from wall rock to high-grade pyrite in a distance of a couple of inches.

According to assay returns kindly supplied by the Algoma Steel Corporation, the pyrite in these lenses averages 45 to 46 per cent sulphur and is free of arsenic. The ore-body lies within 3,000 feet of the railway and only 24½ miles by rail from Michipicoten harbour.

Before this deposit was found, a mass of very similar pyrite 10 or 12 feet wide had been uncovered on the shore of the small lake in S.S.M. 1054. Not enough of this mass is exposed at the present time for its relationship to be ascertained and as far as could be learned, it never has been thoroughly explored. Nevertheless, an opinion has arisen locally that the pyrite is only a great erratic block carried there, probably by glacial agencies, from some deposit lying to the north. The adjacent country in that direction has been carefully prospected, on the strength of this opinion, leading to the discovery of the deposit now being drilled and also the Bartlett range, a little farther north. The former of these might have furnished blocks of pyrite like that on the lake shore; but, in the writer's opinion it is not an erratic, but may be in place and part of a vein-like deposit of the same nature as the ore-body which is being drilled.

Bartlett. Practically all the iron-formation in Magpie-Hawk area belongs to one range that extends from the granite contact northwest of Hawk Junction to the south end of Mildred lake. This range is broken into three sections by two faults, one of which coincides with a diabase dyke running from Goetz lake southeastward, and the other with the line of ponds between Baldry and Loonskin lakes. It is distinguished from any of the Goudreau ranges by a preponderance of banded silica over pyrite and siderite. The banded silica member is about 300 feet thick and rises in a conspicuous ridge from end to end of the range.

Almost the whole range is owned or held by private interests. The easternmost section from the granite to location Y 453 was explored and located for the Algoma Steel Corporation by James Bartlett and W. M. Goodwin. It is known as the Bartlett range. The section between the Bartlett property and Goetz lake may be designated as the Josephine property. This and the remainder of the range is held by Alois Goetz, of Sault St. Marie, Michigan, and associates.

The Bartlett range dips steeply toward the north or is overturned enough in places to dip just as steeply southward. It is fringed on the south side by a relatively thin zone of pyrite and siderite exposed only in the trenches dug in examining the range. Three diamond drill holes were bored during 1912 on the fourth claim from the east end of the property. They show a thickness of about 50 feet of good siderite and a considerable quantity of mixed pyrite and siderite. The latter is not high enough in sulphur to be mined as pyrite.

Josephine. The iron range adjacent to Parks lake (mining claims Y 451-2-3) is known as the Josephine property. This part of the range was staked at about the same time in 1899 by rival representatives of E. V. Clergue and Alois Goetz, following which the ownership remained in dispute until 1906 when a settlement was arbitrated by the Minister of Lands, Forests, and Mines, of Ontario.

"Ruling on mining claims Nos. 738 to 747, inclusive (late) Michipicoten Mining Division.

"The above mining claims, otherwise known as the Josephine Iron mine, have for a long time been in controversy between Alois Goetz *et al.* and the A.C. and H.B. Railway Company, the former claiming them by virtue of original discovery and the latter under the land grant made by the Legislative Assembly of Ontario.

"Having gone thoroughly into the case . . . . I am bound in equity to recognize Goetz's claim, but, in view of the large amount of work done and money expended on the lands by the company I think they should have the opportunity of acquiring the same at a reasonable figure.

"I, therefore, rule that, on the company paying to Goetz the sum of $50,000 the ten claims in question . . . . be allowed to the company. In default of the company paying over, or securing, to Goetz the said sum of money within thirty days from this date, Goetz to have the liberty of choosing five of the claims, the remaining five to be given to the company.

"August 24, 1906. "F. COCHRANE, *Minister.*"

Following this decision Goetz selected claims Nos. 738, 739, 744, 745, and 746, and in October, 1906, had them surveyed as Y 455, 454, 451, 452, and 453, respectively.

Early in the period of dispute H. A. Wiley, of Port Arthur, secured an option upon the Josephine property from Goetz and had three diamond-drill holes bored. Between 1900 and 1906, the Clergue interests had twenty-one holes sunk, which revealed very considerable bodies of hematite under the banded silica formation. Between December, 1901, and 1903, they also sank two shafts, one about 150 feet deep on the south side of the lake opposite the middle of Schist island, and one at the east end of the lake; but owing to the uncertainty of their title to the property and other handicaps, these operations were discontinued before any ore had been raised. During 1913 and 1914 five more diamond-drill holes were bored by the Algoma Steel Corporation, which had secured a lease and option of purchase from Goetz. At the present time the shafts are dismantled and full of water and steel has been removed from the railway spur that was built from Josephine Junction.

There is very little evidence of an iron ore deposit at the surface of the Josephine claims. The iron range is well enough exposed in Y 453 and 452, but it consists there mainly of banded silica, with only a little pyritic siderite along the south side. Under Parks lake, where the ore-body occurs, the range is concealed, except for the island of banded silica in the middle of the lake. Erratic blocks of hematite are said to have been scattered along the shore at one time, but the writer saw none of these. The diamond-drill work done between 1900 and 1914, however, showed that the iron-formation under the lake consists of banded silica underlain by hematite or hematite mixed with pyrite. The usual siderite member of the iron-formation and most of the pyrite appear to have been converted into iron oxide.

Plans and descriptions of most of the drill holes have been furnished by Judge John McKay of Port Arthur. The holes range in depth from 41 to 1,696 feet, but as most of them are inclined from 35 to 80 degrees, they penetrate the iron-formation at vertical depths ranging between 40 and 1,550 feet. A majority do so between 200 and 900 feet. According to these explorations the iron-formation—banded silica, hematite, and intercalated schist—is from 75 to over 350 feet thick. Near the surface it dips northwestward, the angle being 60 to 80 degrees at the foot of the lake and 80 to 85 degrees at the other end. Hole 51, which crosses the iron-formation at about 1,500 feet below the surface, indicates, however, that the formation becomes slightly overturned in depth and dips about 80 degrees south. The iron-formation under Parks lake is to be conceived, therefore, as a slightly concave slab-shaped body 75 to 350 feet thick, and 1,500 feet or more wide, lying on edge from one end of the lake to the other. It consists of a sheet of banded silica 50-350 feet thick, against the south side of which lies a less continuous sheet of hematite and hematite interstratified with banded silica and schist ranging from 0 to 125 feet in thickness.

There appear to be two sheets of ore. The better explored and apparently the larger one begins about 200 feet east of Jasper island and extends northeastward at least 1,000 feet, being crossed farthest in this direction by hole No. 18. It is intersected in this distance by thirteen holes which show iron ore at depths ranging from 200 feet to 950 feet, and in the case of hole No. 51, 1,550 feet below the surface of Parks lake. The drill holes define an oval or kite-shaped body of iron ore 1,000 feet in maximum length, 1,350 feet in maximum depth, and 5 to 125 feet thick, which, like the rest of the iron-formation, stands on edge. Of the total thickness only 5 to 50 feet is ore, the remainder being layers of banded silica or schist 5 feet and upwards in thickness, which alternate with like sheets of ore. The greatest observed band of ore in any of the holes is 45 feet thick. The upper boundaries of this oval area seem to coincide fairly closely with the actual limits of the ore sheet, for there the ore is both thin and low grade. It seems quite likely, however, that the lower limits could be extended considerably if deep holes like No. 51 were drilled on either side of it.

If all ore carrying over 30 per cent metallic iron is taken into consideration the oval sheet explored by the thirteen drill holes is estimated to contain 2,250,000 probable tons of hematite. If ore carrying less than 50 per cent iron is excluded the probable tonnage will be reduced to 1,300,000 tons. Owing probably to the manner in which the drill holes are spaced and to the varying quality of the ore the tonnage estimates of different investigators do not accord very closely. According to Goetz and McKay[1] "there is proved up 850,000 tons of ore running 59 per cent iron and in addition there is a very large tonnage of banded ore capable of being concentrated or roasted." "Reports furnished in February, 1918, by Malcolm A. McKay of Port Arthur, Ont., give estimates ranging from 1,250,000 to 2,000,000 tons of ore proved up by diamond drilling. At least 850,000 tons of this are believed to be recoverable."[2]

According to information supplied to Judge John McKay by the late A. B. Willmott, the high-grade part of the ore located by drilling up to 1906, carries 59 per cent iron and 0·04 per cent phosphorus. All the ore is said to carry a certain amount of sulphur, and in the case of the ore reached by the deep hole No. 51 a large proportion of pyrite is mixed with the hematite. The ore is said to resemble the Helen mine hematite in its physical character.

For 1,200 feet southwest of this oval ore-sheet no hematite was encountered by the drill, but just beyond that distance, holes Nos. 19 and 12 cut across a sheet of fairly high-grade hematite 20 to 40 feet thick, at depths of 700 and 500 feet respectively. Unfortunately these holes are close together and there are no others near enough to afford any idea of the size of the ore-body.

If the Josephine ore-bodies are mined it will probably be advisable to drain Parks lake. This lake is about 70 feet deep in its deepest part. There is a descent of nearly 100 feet to Goetz lake, but in order to take advantage of this fall the present rocky channel between the two lakes would have to be deepened by a rock-cut or tunnel. Moreover, the deepest part of Parks lake is 3,000 feet away from the outlet.

Goetz. The balance of the range, from where it is faulted east of Cuthbertson lake to Mildred lake, is known as the Goetz range. It consists, like the eastern half of the same range, of a great ridge of banded silica 200 to 350 feet thick, flanked on the southeast by a thin and apparently discontinuous band of siderite and pyrite. At the east end of Cuthbertson lake the railway cuts southward through banded silica followed by 35 feet of pyrite and 8 or 10 feet of siderite before entering the acid tuff that forms the foot-wall of the iron-formation. A sample taken across the whole width of pyrite exposed yielded results given in the foregoing table of analyses. Apparently this pyrite body extends 1,000 feet or so southwestward, for limonite and some pyrite can still be seen in cross trenches which were made some years ago. It is reported to change in this direction into siderite, of which there is a body 850 feet long and 90 feet in maximum width.

According to the owner, Alois Goetz, the siderite consists of:

Iron	35·00 per cent.[3]
Silica	8·00 "
Sulphur	not determined.
Phosphorus	0·012 per cent.
Lime	5·08 "
Magnesia	6·71 "
Manganese	not determined.

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[1] "Iron ore occurrences in Canada," Dept. of Mines, Can., Mines Br., vol. II, p. 80.

[2] Ibid—footnote, page 80.

[3] Lindeman and Bolton, "Iron ore occurrences in Canada," Dept. of Mines, Can., Mines Br., vol. II, p. 80.

At the south end of Baldry lake a low grade hematite lies in the same position relative to the banded silica. There is also said to be a considerable width of siderite on the south side of the range near Brooks lake, but the trenches there are now too badly caved and filled with soil for the underlying rock to be seen.

Lindeman and Bolton say of this property:

"Trenching across the range has disclosed three lenses of siderite, one 400 feet long by 30 feet wide, a second 1,800 feet long with a width varying from 30 to 100 feet, and a third 1,200 feet long with a width, in places, of 75 feet. The largest one should yield 1,000,000 tons of siderite with each 100 feet of depth."[1]

Arnott-Wilks. The belt of sediments extending from the south end of Baldry lake to the east end of Mildred lake has been staked and explored for iron ore and pyrite. Considerable surface trenching has been done and several test pits and tunnels have been started. Most of these revealed nothing except conglomerate and fissile, rusty slate. Near the southeastern corner of S.S.M. 1704, however, a tunnel driven about 20 feet southward passes through a brecciated mixture of pyrite and sideritic material into a blue-grey, highly sideritized lava.

Other Deposits in Magpie-Hawk Area. Remnants of another iron range occur at intervals all the way along the southeast side of Loonskin lake. At one time, probably, these remnants were parts of a continuous range which was reduced to its present broken state by faults and by bodies of granitic magma advancing into the Keewatin from the main Laurentian mass that lies a mile farther southeastward. Thorough exploration would probably reveal somewhat more of the vestiges than appears on the map. Those which were seen consist, alike, of banded silica and mixtures of siderite and pyrite. No good ore was seen and the geological conditions are not such as to encourage further prospecting.

A narrow range of banded silica and siderite or sideritized acid lava was found a quarter mile south of the Bartlett range and one mile east of Parks lake. Judging from the natural outcrops, this range does not hold much promise of useful ore deposits.

Patches of siliceous siderite are shown on the map at the southwest end of Leg lake and at the east end of Siderite lake, a pond near the east end of the Bartlett range. Both of these appear to be thick lenticular bodies in the Keewatin volcanic complex, unaccompanied by banded silica or pyrite concentrations. They are probably too low-grade to be mined as siderite.

Surface Characteristics of the Pyrite Deposits.

The pyrite-bearing iron ranges examined in 1918 present a number of recognitive features which may prove useful to prospectors new to Michipicoten district. In the first place range pyrite is associated in a definite manner with banded silica and siderite or limestone and its possible presence may be inferred from outcrops of these associated rocks. It weathers easily and usually occurs in low ground concealed by drift or soil. The banded silica, on the contrary, is strongly resistant to erosion and tends to form well exposed and in many cases conspicuous ridges. The banded silica member of the Bartlett range, for example, forms a commanding ridge 100-160 feet high and miles in length.

Where the iron-formation is concealed by drift, as it is in many parts of Goudreau area, it can be located closely and with considerable reliability with a dip-needle. The instrument used by the writer recorded 5 to 35 degrees more inclination over iron-formation than over the Keewatin schists. This increase occurs chiefly over the banded silica, owing, no doubt, to the magnetite mixed with the silica; but a similar, weaker effect is observable in places over the pyrite, which carries about 10 per cent of pyrrhotite and magnetite. The iron-formation south of Webb lake and part of that north of Pine lake were located with a dip-needle.

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[1] Ibid, p. 79.

Pyrite decomposes readily to limonite, and in so doing is apt to give a distinctive appearance to the ground that receives the drainage from a pyrite range. The limonite may be exposed as a conspicuous rusty gossan, as at the Bear claim. Where the ground is low, it is likely to cement the drift into a material impervious to water and to the roots of plants. In such cases the surface is muskeg-like, and covered with grass and shallow pools of water but not with large trees. Unlike muskeg, however, it is surprisingly firm and unyielding to the tread owing to the limonite-cemented soil beneath. A good example of this adjacent to a known pyrite range can be seen in locations A.C. 39 and 40, Goudreau area. An identical surface condition exists along parts of the small creek that leads from J.L. 25 to Teare lake, though no pyrite range has yet been found there.

Pyrite deposits like the Holdsworth are harder to find. They are unaccompanied by banded silica and have no influence upon the dip-needle which can be distinguished from magnetic irregularities in the Keewatin schists. Owing to the readiness with which the pyrite weathers they are also likely, as in the case of the Holdsworth, to occur in low ground. The Holdsworth deposit was located by intensive local exploration based upon the belief that the supposed erratics of pyrite on the lake shore had come from some near-by ore-body in place. If equally careful examination is made of other parts of Michipicoten district, it does not seem unreasonable to anticipate that other deposits of this type will be discovered.

GOLD.

Gold was reported from near Webb lake, Goudreau area, early in 1918. Considerable prospecting ensued during the summer of that year, trending in the direction of Missinabi station, on the Canadian Pacific railway. Fresh discoveries were reported during July and August from the east side of township 26, range 27. Only those within the Goudreau map-area, however, were visited by the writer.

The most important among these lie in the McCarthy-Webb group of claims situated just north of Webb lake. Small veins of the same appearance were seen near S.S.M. 1778 and also on the portage between Bearpaw and Pine lakes. At all three places the prospective ore-bodies are quartz veins intersecting an ash-grey feldspar porphyry, the second Keewatin formation described in this report.

McCarthy-Webb Property. Messrs. D. J. McCarthy and W. H. Webb, Sault Ste. Marie, Ontario, hold and are doing the assessment work on a group of seven claims situated around Webb lake, township 27, range 27. The gold-bearing veins lie north and northwest of the lake, in a small rocky area circumscribed by heavily drift-covered country. This area is underlain by a fairly massive feldspar porphyry, traversed in a direction of about north 60 degrees east by occasional shear zones a yard or less in width. The porphyry is intersected by two sets of veins, one parallel to the shear zones, one at right angles to them. A dyke of late Pre-Cambrian olivine diabase cuts across veins and porphyry alike.

Veins of the first set are vertical, from ½-inch to 18 inches wide, and rather crooked, as if they had been disturbed a little since they were formed. Individual veins do not appear to continue greatly in length, but veins and veinlets are commonly grouped lengthwise along shear zones. They consist of white quartz carrying some pyrite and occasional small particles of visible gold. The schistified porphyry for 2 or 3 inches on each side carries pyrite and, when crushed and panned, yields finely divided gold.

Veins of the second set cut across the others at right angles and are plainly younger than the first set. They dip vertically but, unlike the first series, are clean-walled and occur singly. They are from 6 to 24 inches wide and apparently longer than the older veins. They contain the same association of white quartz, pyrite, and some visible gold, but in addition a surprisingly large amount of tourmaline in the form of shiny black, needle-shaped crystals. The cross-veins have not as wide margins of mineralized wall rock as the older group.

Though none of the veins seen in July, 1918, is large, there is an extraordinary number of them. Over a dozen were seen, and gold was observed in almost as many places. A majority are too narrow to be mined singly and too far apart for two or more to be exploited from a single opening. One of the vein-filled shear zones, however, is 4 feet wide and reported to carry gold across that width. There is also a mineralized width of 3 or 4 feet at one place close to the trail between Webb and Lovell lakes, where a cross-vein 18 inches wide intersects one of the shear zones. Satisfactory assay samples were not obtained, but encouraging returns are said to have been obtained from cross-section samples collected by the owners.

OIL FIELDS OF SOUTHWESTERN ONTARIO.

By M. Y. Williams.

CONTENTS.

Illustrations.

INTRODUCTION AND ACKNOWLEDGMENTS.

The field work of 1918 lasted from June 4 until September 8 and from October 17 until October 27. Of this, two months were spent at Petrolia, seventeen days at Glencoe, and eight days at Delaware; Rockwood, Bothwell, the oil field in Dover township, Kent county, and other places were also visited.

The work included collecting records of wells drilled for oil and gas and obtaining the elevation of the top of located wells, by means of an engineer's level. Of the thousands of wells drilled in the older oil fields, only a few hundred records are available and these must be sought patiently from all available sources.

The writer is indebted to many oil and gas operators for information and assistance and particularly to Messrs. John Scott, W. E. Armstrong, James Salisbury, C. Jenkins, J. D. Noble, W. McIntosh, Thomas Johnson, and A. Deacon, of Petrolia; F. J. Carman, John McLeod, and James Quillinan, of Glencoe; and Leo Wilson, of Delaware.

The writer was assisted in the field by Hubert R. Sills and Henri Emond, who rendered faithful and satisfactory service.

GENERAL STATEMENT.

The oil of Lambton and Middlesex counties is found in what is popularly called the "Big lime," "Lower lime," or "Corniferous" limestone. This limestone is properly subdivided into the upper or Delaware limestone and the lower or Onondaga limestone. As will be shown, oil occurs in both divisions.

The top of the Delaware limestone was used in working out structure, as in 1917, because its depth from the surface is most generally recorded by drillers. By means of surface elevations at mouths of wells and the depths to the top of the Delaware limestone, the elevations of a large number of points on the Delaware limestone were determined and from these the structure of the formation has been worked out over large areas. This structure is expressed by sub-surface contours, each contour connecting points on the top of the Delaware limestone which have the elevation indicated by that particular line (Map 1750).

The largest oil pools of the Corniferous formation occur at the top of rock domes, only smaller, short-lived accumulations of oil being found on terraces. Because erosion has eaten stratigraphically deeper into domes than other structures the black Ohio shale has, in almost every case, been stripped from over the oil fields. Knowing this, drillers rarely continue drilling where black shale is found.

OIL FIELDS OF LAMBTON COUNTY.

Petrolia Oil Field.

This has been the largest producing field in Canada and, excepting the recent production in Mosa township, is still the largest producer. As may be seen from map 1750 it joins the Moore Township field on the west.

The formations underlying this field are in the form of a flat-topped, elliptical dome with longer axis extending northwest. The custom has been to drill the oil wells about 475 to 490 feet in depth. The following log of a well drilled on the Lawson property, in Petrolia (formerly south part of lot 14, concession XII, Enniskillen) may be considered as typical of the field.[1]

	Thickness.	Depth.
Surface..	100	100
Ipperwash limestone or "top rock"..	50	150
Petrolia shale or "upper soap"..	134	284
Widder beds or "middle lime"..	15	299
Olentangy shale or "lower soap"..	45	344
Delaware limestone or "lower" or "big lime" about.. ..	50	394
Onondaga limestone, penetrated..	82	476

Oil-bearing rock reported to be from 462 to 471 feet in depth.

On the edges of the field the formations are lower and the wells in consequence have to be drilled deeper.

Besides the porous limestone near the bottom of the wells, which supplies most of the oil, some oil is also obtained from what is known as a "mud vein." Thus on the Dennis property in Petrolia (near what was formerly the middle of lot 12, concession XII, Enniskillen) three wells forming a triangle about 150 feet to the side, pump oil from a vein at 459 to 460 feet in depth (or about 120 feet below the top of the Onondaga limestone), and the pumping of any one affects the other two. That there is a porous horizontal stratum containing free channels for the movement of liquids is thus well established. The greatest production is from the porous oil rock, generally called "oil sand." It is not sandstone, however, but porous limestone.

The wells drilled early in Petrolia were generally cased to the Widder beds or "middle lime," and the Olentangy shale, or "lower soap," was left to cave into them. This has occasioned much cleaning out of the wells and properties that are not properly cared for get into very bad condition. In many cases it has been found profitable to clean the wells out and case them to the top of the Delaware limestone. Old holes, however, soon plug themselves, thus shutting off much of the fresh water which ordinarily enters the oil stratum through abandoned wells, reduces the output, and coagulates the oil, so as to reduce its value greatly. Through the efforts of the provincial oil inspector, Mr. John Scott, of Petrolia, wells abandoned at the present time are being properly plugged to keep the field free from water troubles.

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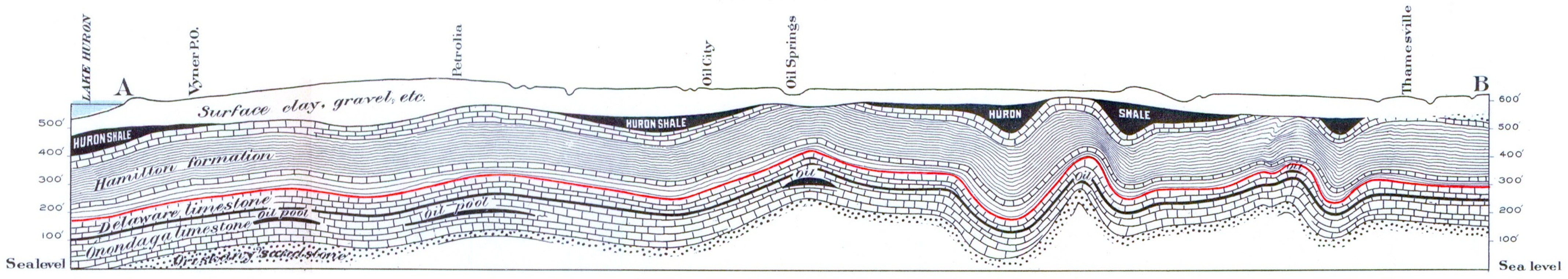
[1] This log was obtained from Dr. C. O. Fairbank.

Canada
Department of Mines
HON. MARTIN BURRELL, MINISTER; R.G. M^C^CONNELL, DEPUTY MINISTER.

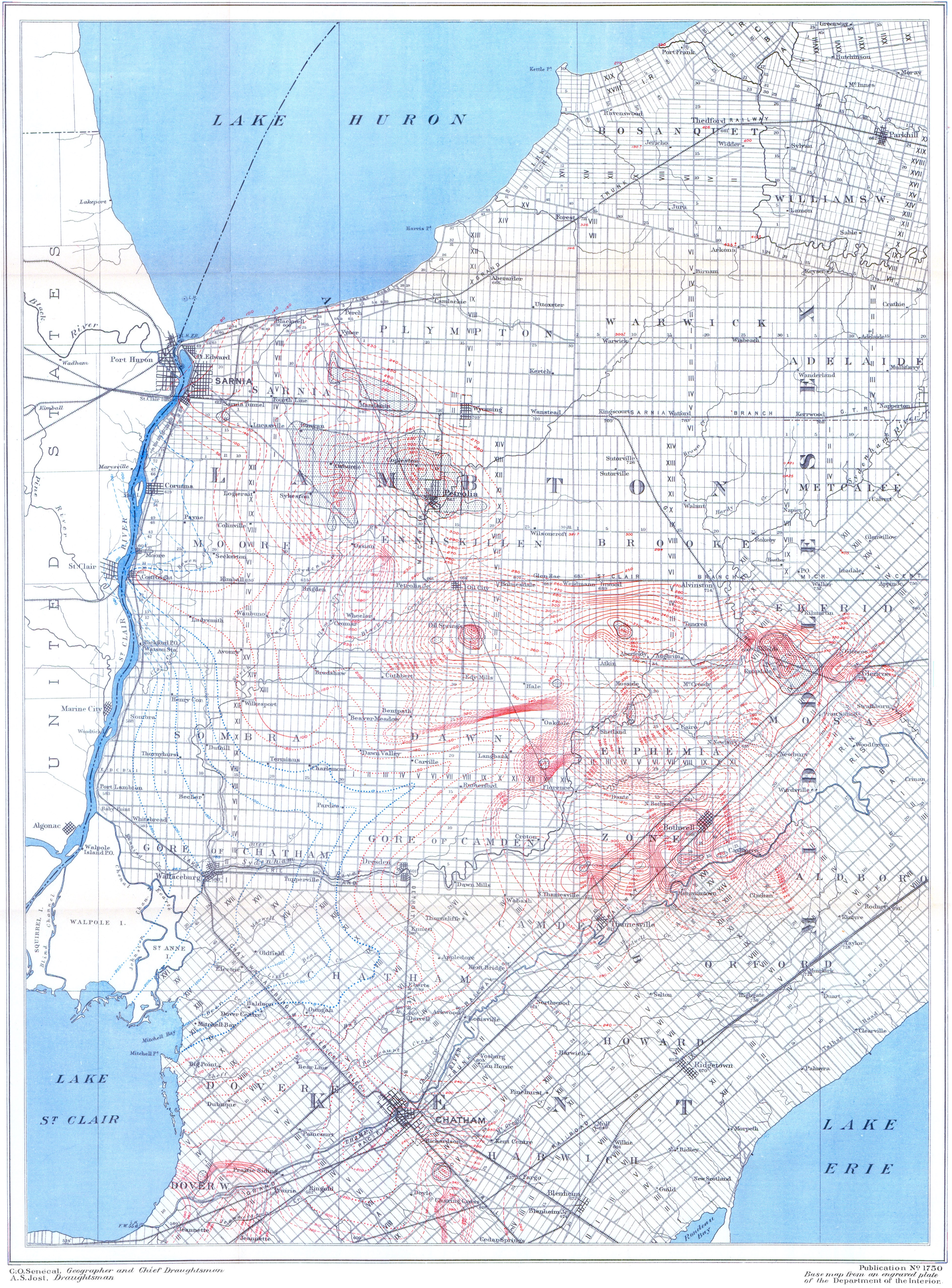
GEOLOGICAL SURVEY
WILLIAM M^C^INNES, DIRECTING GEOLOGIST

Issued 1919



Cross-section on line A B

OUTLINE MAP



C.O. Senécal, *Geographer and Chief Draughtsman*
A.S. Jost, *Draughtsman*

Publication Nº 1750
Base map from an engraved plate of the Department of the Interior.

LEGEND

▦ Limestone

■ Shale
("soap" of drillers)

░ Sandstone

Oil field

Structure contours on top of Delaware (Corniferous) limestone
showing elevations above sea level
Interval 10 feet

Structure contours on top of Delaware (Corniferous) limestone
showing elevations below sea level
Interval 10 feet

Broken contours: approximate
Dotted contours: Inferred

THE GEOLOGICAL STRUCTURE OF THE OIL REGIONS OF LAMBTON COUNTY AND ADJACENT PORTIONS OF MIDDLESEX AND KENT COUNTIES, ONTARIO.

Scale of Miles
5 4 3 2 1 0 5 10

To accompany Part E Summary Report by M. Y. Williams, 1918.

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One-half or more of the old wells are now plugged on the best managed properties, and by careful attention to the remaining wells, the production of oil is kept at or near its recent level. It seems well established that the field was originally much over drilled.

The former practice of drilling through the Onondaga limestone into a porous, salt-water-bearing sandstone (probably the Sylvania, but perhaps representing the Oriskany in its upper part) has cost the Petrolia operators considerable money in handling this additional amount of fluid, and has probably lessened the amount of recoverable oil. The theory has been that a plentiful supply of salt water prevented the wells from coating with paraffin and in general increased the flow of oil. There seems little doubt that paraffin is prevented from collecting by keeping the surface of the oil sand bathed with fluid. Many oil men, however, have operated their wells successfully without other water than that which naturally comes with the oil. The proper practice appears to be to set the oil pump just above the top of the oil stratum and leave the surface bathed in its own fluid. If the stroke of the pump is properly regulated there is little danger of trouble with paraffin.

The custom is common of using gas pumps to lessen the pressure and thus increase the flow of oil. Where the pumping has been done by gas engines, the gas from the gas pumps has been largely utilized. At present the tendency is to replace the gas engines by "hydro" power, as the three-phase motors run at a uniform speed and cause much less wear and breakage on the "jerker line" systems. The gas produced is wasted, but the hydro power required is remarkably small. On the Englehart property two 25-horsepower motors, running on a little less than half load, are pumping about 200 wells by means of many miles of jerker rods. The balanced, jerker-rod system, which was invented at Petrolia and Oil Springs, is thus shown to be very efficient.

The productivity of the Petrolia field will probably be extended many years by the methods already explained, that is, by plugging unprofitable wells and giving careful attention to the wells that are being pumped. The method adopted elsewhere, of applying pressure to the field by means of compressed air or gas and pumping from central areas, has not yet been tried at Petrolia. Such a method would involve unified ownership of large tracts of oil property or else close co-operation between companies.

Moore Oil Field.

The Moore Township oil field is a western extension of the Petrolia dome, the oil occurring on terraces and small domes. The general elevation of the oil formation is about 80 feet lower than in the main Petrolia field; but this difference of elevation is partly offset by the oil occurring, as is usual in such cases, higher up in the formation. Thus, the top of the oil stratum at Petrolia is about 118 feet below the top of the Delaware limestone and the top of the oil stratum in the Moore field is only from 57 to 83 feet below it. The top of the oil is thus from 20 to 45 feet below the oil in the main Petrolia field. Although the Moore field has pumped considerable oil and several properties are still pumping, the oil-bearing stratum is not thick, and there is much less accumulated oil than in the Petrolia field.

The following log, furnished by J. D. Noble, is typical of the best of the Moore oil field.

Location. Well near middle of north half of lot 3, con. XI, Moore tp.

	Thickness.	Depth.
Surface clay, etc.	164	164
Gravel	7	171
Ipperwash limestone or "top rock"	52	223
Petrolia shale or "top soap"	120	343
Widder beds or "middle lime"	15	358
Olentangy shale or "lower soap"	40	398
Delaware and Onondaga limestone, or "lower lime" to bottom of well	104	502

Some gas at 415 feet.
Oil at 430 to 463 feet.

Only a small part of the Moore field is now being pumped. Mr. J. D. Noble sold out his large holdings in this field in 1918 and except for some of the best wells, which are being operated by the farmers who own the land, the field is for the most part being stripped of everything of value, the wells being plugged and abandoned.

With careful management there seems no reason why production should not be maintained for some time to come from the wells now operating.

Plympton-Sarnia Oil Field.

The oil field in Plympton and Sarnia townships is little more than one mile distant from the northwest extension of the Petrolia field. The rock structure is a low anticline with axis extending about northwest by west. The elevation of the oil formation is about the same as in the Moore field.

The following is a typical log, taken from the files of the Water and Borings Division of the Geological Survey.

Location. North one-half of lot 4, con. VI, Sarnia tp.

	Thickness	Depth.
Surface	106	106
Ipperwash limestone or "top rock"	47	153
Petrolia shale or "upper soap"	123	276
Widder beds or "middle lime"	10	286
Olentangy shale or "lower soap"	52	338
Delaware and Onondaga limestone to bottom of well	132	470
Some oil at 440 feet.		

This oil field has, from its first development, produced a considerable quantity of gas which, except for the small amount used in gas engines for pumping oil, or for fuel at farm houses, has been burnt as flares in the vicinity of farm buildings. This very considerable waste of gas has been defended by the argument that oil could not be pumped from the wells unless the gas pressure was lowered, and that the presence of gas made the oil red and of comparatively small value. In recent years the oil production has fallen off until it is now very small, but the waste of gas has continued. During the summer of 1918, however, the provincial gas inspector, Mr. John Scott, of Petrolia, has ordered the gas in that part of the field not producing oil to be shut in, and he has urged the oil operators to conserve the gas as much as possible.

The Plympton-Sarnia field has fallen into poor condition, and operations are now principally carried on by farmers during slack times. In the opinion of local oil men, a considerable production could still be obtained from this field with careful, efficient management.

Sarnia Oil Field.

A very small oil field, on the Indian Reserve, about one mile south of Sarnia Tunnel station, is still equipped and may be capable of producing a few barrels of oil per month from five or six wells. When visited in August, 1918, it was shut down.

The oil has accumulated in what appears to be a small fold extending westwards from the Moore field. The formation is very low for oil production, and the field is one of those smaller areas of oil-producing rock which form outliers to the larger fields. Following is a typical log.

Location. On the MacGregor farm, lot 16, con. III, Sarnia tp., about one mile south of Sarnia Tunnel station.

	Thickness.	Depth.
Surface	120	120
Huron black shale	30	150
Ipperwash limestone or "top rock"	20	170
Petrolia shale or "upper soap"	260	430
Widder beds or "middle lime" Olentangy shale or "lower soap"	45	475
Delaware and Onondaga limestone penetrated to	55	530
Gas and oil at 480 feet.		
Oil at 518 feet.		

Oil Springs Oil Field.

This field may be considered the pioneer Canadian oil field, and is remarkable not only for its large initial production, but for the importance of its present production, considering its age and small area.

The rock structure is a typical, excentric dome, with the apex close to the northeast margin. The oil production is fairly even over the dome except on the northwest side, which appears to be barren of oil at elevations that are productive elsewhere.

Oil Springs has produced oil from three different horizons, which, however, probably are all supplied from the deepest source. Surface oil or "gum beds" in low swampy areas early attracted attention. This was doubtless inspissated oil which had the same origin as that of the springs carrying oil, along Black creek. To-day a fine, lubricating oil is obtained from wells that penetrate unconsolidated gravels just above the solid formations.

The oil from the gushing wells of the early days came from a "mud vein" or "crevice" about 7 to 11 feet from the top of the Delaware limestone. The main production of the present day is from porous limestone 100 to 120 feet below the top of the Delaware.

The following log, furnished by John Sutherland, of Oil Springs, exemplifies conditions in the centre of the field.

Location. On property belonging to Dr. C. O. Fairbank, lot 18, concession II, Enniskillen township.

	Thickness.	Depth.
Surface	76	76
Petrolia shale or "upper soap"	113	189
Widder beds or "middle lime"	17	206
Olentangy shale or "lower soap"	25	231
Delaware and Onondaga limestone penetrated to	163	394

Oil crevice at 240 feet.
Oil rock between 331 and 351 feet.

Production of Lubricating Oil. Oil production from gravel resting on the Petrolia shale is a unique feature of the Oil Springs field. The oil obtained is also unique, being a natural lubricating oil of fine quality. The production, however, is small, and is used almost entirely for the needs of the local community.

Oil Production from the "Mud Vein or Crevice." As already stated, the wonderful gushing wells, which attracted so much attention in 1862, tapped a porous stratum from 7 to 12 feet below the top of the Delaware limestone. The drill is said to drop about 4 inches in most wells when this stratum is reached, but in other wells nearby no "crevice" is found. It seems clearly established that the "crevice" consists of a very porous bed of limestone, in which are numerous interlacing channels.

The early operators in the Petrolia field were generally Americans, most of whom left the country during the excitement of the Fenian raid. During their absence, the "Scotch casing" (composed of very thin iron), which shut the freshwater from the unconsolidated surface materials out of the wells, rusted through, the crevice was flooded, and the oil was pressed back down the sides of the dome and doubtless dissipated to some extent. On the return of settled times, some of the old operators came back, but for years they could not pump the water down so that oil could be obtained. After a time, partly because the old wells had become plugged with the shale which had fallen into them, thus shutting off further supplies of fresh water, and partly through co-operation on the part of all operators, the water was reduced and oil appeared again in paying quantities. Finally the crevice at the top of the dome was emptied of both oil and water, and rival companies followed the oil down the dip of the formation by drilling wells about 25 feet apart, and pumping as hard as possible while the supply of oil lasted. The thickness of the oil floating upon the water was such that if wells were drilled down the dip much more than 25 feet apart, they penetrated the water below the oil and pumping merely shortened the time allowed the competitor for obtaining oil from his wells. The oil was followed down the dip until both oil and water were exhausted and the vein became known as an "air vein." In 1918, wells were drilled on the western side of the field to test the "crevice" there, but no oil was found.

Production from the Deep-lying Porous Limestone, or "Oil Sand." The production from the deeper oil rock is still important and the conditions affecting it are very similar to those of the Petrolia field. Fortunately for Oil Springs, the operators have in general been careful to keep the field in good condition and its life has consequently been greatly lengthened.

Gas Wells in the Guelph Formation. Five wells, located near the apex of the Oil Springs dome, are producing gas from the Guelph formation. Two of these had initial flows of 20,000,000 cubic feet of gas a day, but this decreased rapidly. No. 2 well, drilled by the Oil Springs Gas Company, struck gas from 1,840 to 1,960 feet from the surface, or 15 to 135 feet below the top of the Guelph formation.

A new well was started this summer by the Oil Springs Gas Company, but owing to drilling difficulties it was not completed.

Small Oil Field in Dawn Township.

A small oil field, situated at the west end of lot 19, con. XIII, Dawn tp., has produced considerable oil, but is now closed down. The structure appears to be a small dome, with a deep depression on the southeast.

The following typical log of the field was furnished by Dr. C. O. Fairbank, of Petrolia.

	Thickness. Feet.	Depth. Feet.
Surface	22	22
Ipperwash limestone or "top rock"	6	28
Petrolia shale or "upper soap" including beds of limestone	172	200
Widder beds or "middle lime"	15	215
Olentangy shale or "lower soap"	21	236
Delaware and Onondaga penetrated	113	349
Oil rock between 318 and 325 feet.		

A very insignificant accumulation of oil was discovered at the northeast corner of lot 30, con. XIII, Dawn tp. The structure here is moderately high, but as the dome rises only slightly above a terrace extending from the Oil Springs dome, the drainage area is very small. This field appears to be of no economic importance.

The top of the Delaware limestone here is about 308 feet below the surface.

Small Oil Field in Brooke Township.

A small oil field on lots 6, 7 and 8, con. II, Brooke tp., was producing oil from two or three wells in 1918, and it seems probable that other wells may still be brought in. The dome appears to be of considerable size, but its maximum elevation is low and only the extreme top contains oil.

The following log is of one of the best wells in this field:

Location. NW. ¼ lot 8, con. II, Brooke tp.

	Thickness. Feet.	Depth. Feet.
Surface	55	55
Ohio shale	4	59
Ipperwash limestone or "top rock"	5	64
Petrolia shale or "upper soap"	184	248
Widder beds or "middle lime"	18	266
Olentangy shale or "lower soap"	22	288
Delaware and Onondaga penetrated to	60	348
Oil at 66 feet and at bottom of well.		

Small Field West of Oil Springs.

A small producing oil field is situated on the north end of lot 13, con. I, Enniskillen tp., and about one mile west of the Oil Springs pool.

The structure appears to be a small nose or terrace on the western dip of the Oil Springs dome. The production is probably from a crevice near the top of the Delaware formation, which is from 300 to 308 feet below the surface.

The Shetland or Smiths Falls Oil Field.

A field of some importance occupies parts of lots 26, 27, and 28, con. IV, Euphemia tp. This field has produced a considerable amount of oil and is still pumping.

A unique feature of the field is that the anticline upon which the oil is located is clearly visible at the ford in Sydenham river at the north end of the field where the Ipperwash limestone is exposed. This fold pitches to the north and the production of oil is almost entirely confined to the area south of the river.

No descriptive logs of this field are available, but it is stated that the production is from an oil stratum about 100 feet below the top of the Delaware limestone.

MOSA OIL FIELD, MIDDLESEX COUNTY.

The oil pool whose centre lies about 4 miles northwest of Glencoe, Middlesex county, has produced more oil during 1918 than any other field in Canada, and its phenomenal development during the past two years has attracted much attention.

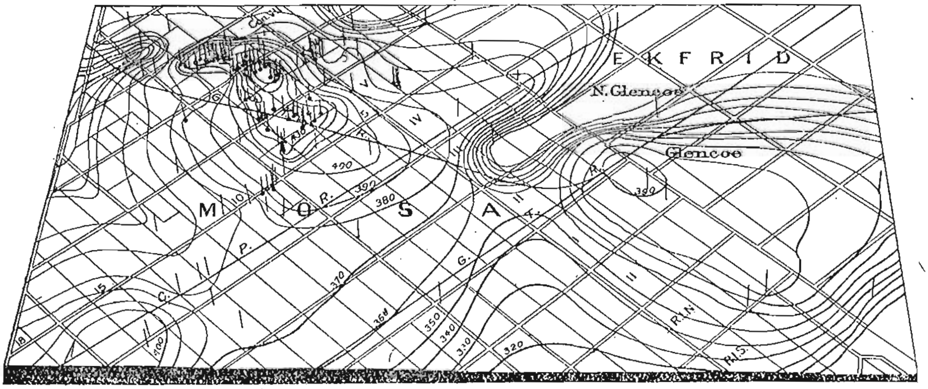

Figure 6. Photograph of model of Mosa oil field, representing the top of the Delaware (Corniferous) limestone. The edges of the cardboards used in making the model may be considered as lines of equal elevation or contour lines. The wells are marked by pins and the beads represent the oil wells producing in October, 1918.

With the willing co-operation and assistance of all concerned, and especially by means of the maps, information, and work already done by Messrs. F. J. Carman and John McLeod of the Ontario Oil Company, the writer was enabled to complete the survey of the field and to make a structural contour map of the formations. It is expected that a large scale map of the field will appear later, but for the present the reader is referred to Map 1750, accompanying this report, and to the structure model of the field (Figure 6).

It will be seen that the main oil production is entirely from the crest of the dome and that very few wells produce from terraces or structures of lower elevation.

The porous oil stratum from which steady production is obtained in the older fields, appears to be absent in the Mosa field. The production is mainly from the Delaware formation and, according to the operators, is from crevices or shatter zones in the limestone. Such a reservoir releases its oil quickly and as a rule is soon exhausted.

The following log furnished by F. J. Carman is typical of the centre of the Mosa field.

Location. 600 feet east of west line and 40 feet south of road fence, on lot 6, con. VI, Mosa tp., Middlesex co. Surface elevation 706 feet A.M.T.

		Thickness.	Depth.
Surface		77	77
Petrolia shale	Soap	58	135
	Limestone	6	141
	Soap with streaks	73	214
Widder beds or middle limestone		19	233
Olentangy shale	"Lower soap"	20	253
	Streaks of limestone	4	257
	Streaks of soap	2	259
Delaware and Onondaga limestone penetrated to		55	314

Oil at 264 feet.

Oil in this field generally occurs in the upper 20 feet of the Delaware limestone, but it also occurs in a few wells in the "middle lime" or Widder beds.

In a deep well on lot 6, con. VI, Mosa tp., the following conditions were found. The Delaware limestone and Onondaga limestones are 97 feet thick and are underlain by white sandstone, consisting of fine, rounded quartz grains. The sandstone is almost pure for 10 feet in depth and overlies 21 feet of grey limestone containing considerable sand. The sandstone generally carries black water containing much hydrogen sulphide and probably a small amount of salt. The dolomite below the sandstone does not carry oil.

The general practice in the Mosa field has been to drill only about 50 feet into the "lower lime", or just to the bottom of the Delaware limestone, as it is delimited. By this practice no water troubles have been met. Some companies, however, operating around the edges of the dome, have persisted in drilling into the sandstone mentioned above. Although this sandstone appears close-grained in many places and so does not always give immediate trouble with water, it has generally been found that water sooner or later became troublesome. The writer knows of wells whose production was entirely lost because they were flooded with water from this sandstone. From all evidence available, there appears to be no chance of increasing oil production by penetrating this sandstone, and the chances of trouble are great.[1]

A statement of the production for the Mosa field as compared with that of the other fields of the province will be found on page 41.

Oil and Gas Prospecting at Delaware.

Considerable prospecting for oil and gas has been done in the vicinity of the village of Delaware under the direction of Mr. Leo. A. Wilson. From information furnished by him, the accompanying structural diagram (Figure 7) of the Delaware limestone has been made.

The following log of a deep well drilled by Mr. Wilson is given as described by him.

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[1] Since this report was written, the Ontario Oil Company has drilled several small producing wells into the top of the sandstone. These are located near the centre of the dome.

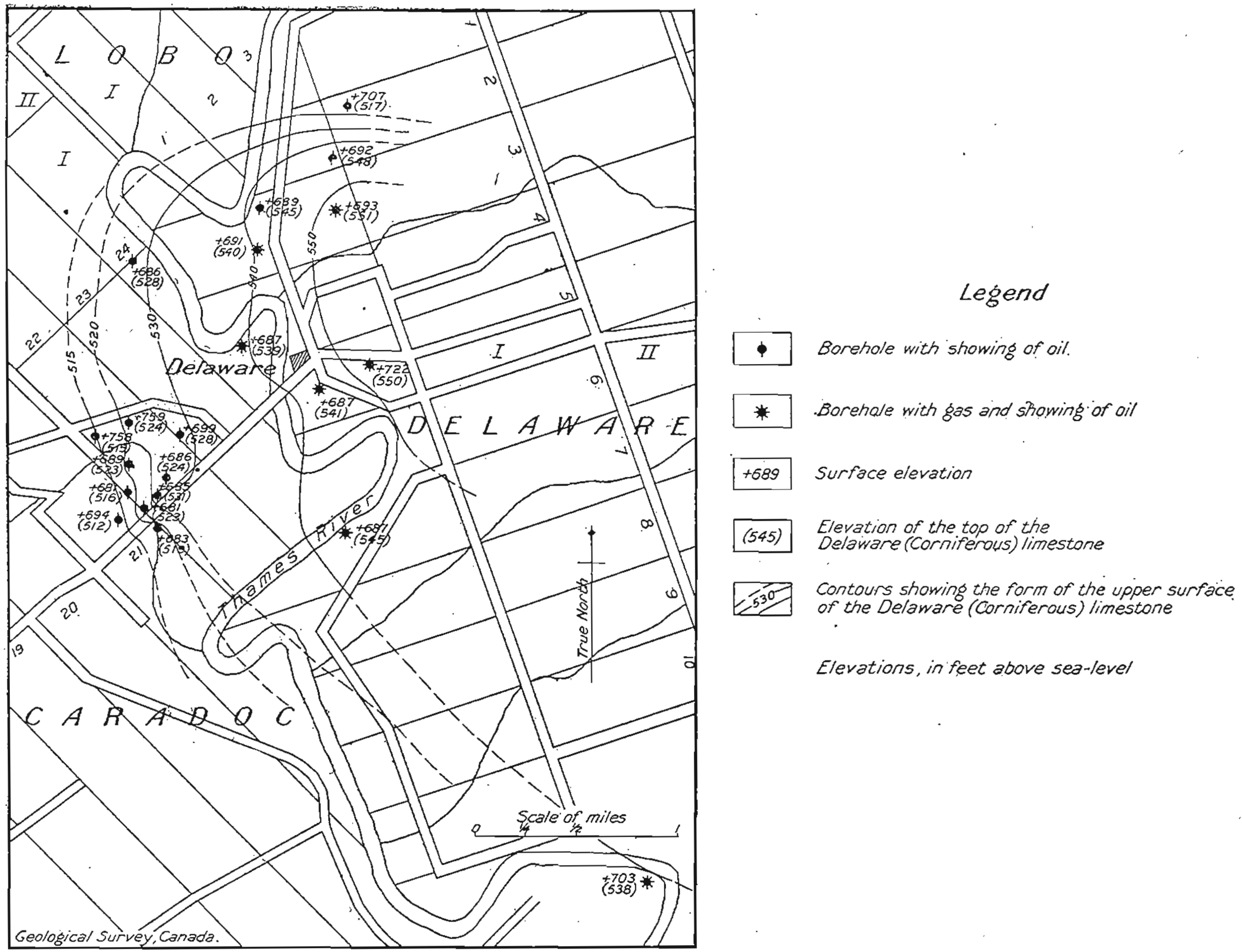

Figure 7. Oil and gas prospect at Delaware, Middlesex county.

Log of the Lowthian Well.

Surface elevation 698·6.
Location: South half lot 23, con. I north Longwood rd., Caradoc tp., Middlesex Co.

Surface (drift)	0	to	145
Hamilton shale	145	"	171
Grey limestone (Delaware and lower formations)	171	"	500
Gypsum	500	"	525
Dark grey limestone	525	"	636
Grey shale	636	"	680
Light brown limestone	680	"	790
Blue lime	790	"	825
Streaks of soft grey shale	825	"	1,130
Gypsum and lime	1,130	"	1,200
Grey lime	1,200	"	1,225
Grey shale	1,225	"	1,480
Light brown lime	1,480	"	1,535
Dark shale	1,535	"	1,550
Dark brown lime	1,550	"	1,555
Dark shale	1,555	"	1,560
Red shale	1,560	"	1,635
Streaks of white, blue, and grey shale.			
Grey lime	1,635	"	1,645
Slate and shale	1,645	"	1,655
Red shale	1,655	"	2,025
Streaks of grey shale and lime	2,025	"	2,105
Black shale	2,105	"	2,115
Light blue shale	2,115	"	2,350
Dark blue shale	2,350	"	2,510
Black shale	2,510	"	2,625
Trenton	2,625		....

NOTES.—Fresh water in gravel at	80 feet.
Hamilton shales, very oily flow of gas at	153 "
Show of oil at	170 "
" " " "	190 "
Small flow of sulphur water at	220 "
Show of oil at	636 "
" " " "	700 "
Heavy flow of fresh water at	720 "
Gas at	750 "
" "	1,130 "
Gas, heavy flow that blew out at	2,460 "
Last 10 feet of Utica shale very oily.	
Show of oil at	2,626 "

As may be seen from this well log and the accompanying diagram (Figure 7), indications of gas and oil have been found in nearly all wells. Different geological horizons have good showings, and the gas production in some wells is reported to have been considerable. At the time of investigation several wells were either full of water or else flowing mineral water, and others were plugged off, so that no actual estimate of production could be made.

It is clear that the structure here is either a terrace or a dome; but which it is cannot be determined definitely until the area just to the east is tested and surveyed. A dome is suggested, however, by the fact that the lower part of the structure, as tested, carries oil and the higher part gas. If there were a still higher structure to the east, it is probable that the gas would have migrated into it.

It is clear that the possible production of the Delaware field has been prevented by the flooding of the wells with water. Until all the wells are carefully plugged to shut off all the water-bearing strata, and the water is exhausted from the oil and gas horizons, the production of the field cannot be tested.

OIL PRODUCTION FROM THE TRENTON FORMATION IN DOVER WEST TOWNSHIP, KENT COUNTY, ONTARIO.

The discovery of oil in the Trenton formation on lot 3, con. III, Dover West tp., Kent co., Ontario, was described in the Geological Survey Summary Report for 1917.[1] Besides the original oil well, and the one mentioned in the footnote (near the west

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[1] Geol. Surv., Can., Sum. Rept., 1917, pt. E, p. 25.

line of lot 2, con. III, Dover West), both of which are still producing, another producing well is reported to have been drilled. This is situated about 650 feet northwest of the discovery well and a similar distance from the other producing well. In the second producing well the Trenton is about 20 feet lower than in No. 1 well, and the main gas and oil horizon is 92 feet lower in the Trenton formation in the second producer than in No. 1 well. In No. 1 well, gas, however, was struck at various points from 82 to 282 feet in the Trenton and in the second producing well from 25 feet to 374 feet in the Trenton. In the second producing well the main oil and gas appear to be floating on salt water, as considerable salt water is produced with the oil.

SUITABLE LOCATIONS FOR PROSPECTING IN THE DELAWARE AND ONONDAGA (CORNIFEROUS) LIMESTONE.

The accompanying map, No. 1750, is intended to show what is known or may legitimately be inferred of the structure of the Delaware and Onondaga limestone (the Corniferous or Big lime of popular usage) in Lambton and a portion of adjoining counties. The probability of finding other pools may be inferred from the structural conditions existing at the developed oil pools.

A few suggestions may be offered: from the drilling already done, we know enough about western Lambton county and northwestern Kent county to state that nearly the whole area is unpromising for further prospecting. A few localities may, however, be underlain by structure favourable for small oil pools. Among such localities in Kent county are: the area about Dawn mills; the area between Vosburg and Arkwood stations; an area north of Paincourt; and the area about Croton. No definite boundaries can be drawn for these areas, and the chances of obtaining oil from them are not great. A more favourable locality is that between Jeannette station on the Canadian Pacific railway and the Thames river directly to the north. A deep well near the river on lot 1, con. III, Tilbury East tp., drilled in 1917 by the Union Natural Gas Company, struck considerable oil in the Onondaga (Corniferous) limestone. The structure here is also favourable.

In Lambton county, Brooke, Warwick, and Bosanquet townships have not been sufficiently explored, and the elevations of the top of the Delaware (Corniferous) as given will prove suggestive to prospectors. In Plympton township there also appear to be large areas unexplored; this is especially true of that part northeast of Kertch and Camlachie.

An encouraging area lies between the northwestern extension of the Mosa pool and the small Brooke pool on concession II, Brooke township, between lots 16 and the Mosa line.

The area in the vicinity of the Mosa pool has been very thoroughly drilled, and there appears to be little additional territory in this township that is worth prospecting. The possible existence of a small pool northeast of Newbury is being tested at the present time.

CHANCES OF OBTAINING OIL AND GAS IN DEEPER FORMATIONS.

The deeper oil and gas-bearing formations, viz., the Guelph and Trenton, are so imperfectly known that it is difficult to give any useful hints to prospectors.

The fine gas wells of Oil Springs, and the smaller wells of Dawn and Euphemia townships prove that the Guelph is gas-bearing at some localities.

During the summer of 1918, the Oil Springs Oil and Gas Company started a new well for gas on lot 19, con. II, Enniskillen tp. Owing to drilling troubles this well has not been completed. The Castle Oil and Gas Company has undertaken to explore the area south of the Shetland oil field, where one well is now producing sufficient gas from the Guelph formation for the village of Shetland and the nearby farming community. Some gas has been obtained in a well recently completed. The Ontario Oil Company under the management of Mr. F. J. Carman sank a deep well in the centre of the Mosa oil pool, but no gas was found.

Although in general the structure in the Guelph may be expected to be parallel to that in the higher formations, it is clearly demonstrated that where much salt is present in the Salina the structure above and below it may not correspond. It follows that the structure of the Guelph and Trenton must be studied, as exploration advances, independently of shallow structural conditions.

OIL PRODUCTION.

The following statement of oil production is furnished by J. C. Waddell, Supervisor of Crude Petroleum Bounties, of the Department of Trade and Commerce:

"In the year 1917 the total production for Ontario was 203,000 barrels.

In the year 1918 the total production was 288,760 barrels, or an increase for the past year of 85,000 barrels.

The Tilbury district, including the Dover field, has shown up well, having an increased production of 15,000 barrels, and the bringing in of the new oil field at Glencoe in Mosa township has made up the large increase for 1918.

The Mosa oil field produced in 1917 about 21,000 barrels.

The Mosa oil field produced in 1918 about 109,000 barrels, which is a high record for a new field in Canada. Below is the crude oil production by districts:

Statement of Oil Production, Year 1918.

District of	Gallons.	Barrels.
Petrolia and Enniskillen	2,291,356	65,467,11/35
Oil Springs	1,563,487	44,671,02/35
Moore township	222,834	6,366,24/35
Sarnia township	120,322	3,437,27/35
Plympton township	14,409	411,24/35
Bothwell	1,019,060	29,116,00/35
Tilbury (including Dover township)	882,971	25,227,26/35
Dutton	65,635	1,875,10/35
Onondaga	41,513	1,186,03/35
Belle River	15,645	447,00/35
Mosa township	3,814,591	108,988,11/35
Thamesville	54,972	1,565,17/35
Total	10,106,615	288,760,15/35

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