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DEPARTMENT OF MINES

SIR JAMES LOUGHEED, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

Summary Report, 1920, Part D

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OTTAWA
THOMAS MULVEY
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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No. 1881

SUMMARY REPORT, 1920, PART D

THUNDER BAY DISTRICT, ONTARIO

By T. L. Tanton

A considerable amount of prospecting has been done in the area immediately surrounding Thunder bay, and a variety of minerals have been discovered, but the only discoveries that have warranted mining operations appear to have been certain small but rich deposits of silver ore, of which the one on Silver islet was the most important. When the Geological Survey commenced the preparation of an areal geological map of the Port Arthur region, in 1919, it was noted that all the known silver deposits near Thunder bay occurred in faults. There was no indication that all the faults had been systematically prospected, especially where they cross drift-covered depressions. It was recognized that there may be many factors determining the location of the silver deposits of the district, but, in the existing state of knowledge, it seemed that no better contribution could be made by the Geological Survey than to indicate on a map the localities which appear to have geological relationships approximately equivalent to those where ore has been found. The results of a preliminary examination of the area near Silver islet[1] were of sufficient interest to lead to the selection of this field for detailed examination.

Accordingly, in 1920, the writer commenced a detailed geological examination of an area, approximately 26 square miles, in that part of Sibley township which embraces Thunder cape on lake Superior. A contoured map of this area, scale 3,000 feet to the inch and contour interval 50 feet, was prepared by a party in charge of R. Bartlett of the Topographic Division. This map will be of value to prospectors and others interested in the development of the district, for there is a distinct inter-relation between the geological features and the topographic forms.

The results of the work of 1920 indicate a great number of drift-covered faults in the district. In the subsidiary faults, which are exposed on the margins of depressions, veins have been found, and in a few of these small amounts of galena, zinc blende, and other metallic minerals occur. Grab samples from ten of the veins were assayed for silver with negative results. Progress has been made in determining the relative ages of various faults and in distinguishing differences in the ages of the numerous intrusions of diabase and related rocks. Various acidic differentiates of the diabase bodies have been recognized, equivalent to those which occur in the Gowganda and Cobalt areas, but, as yet, no aplite body comparable in size to that in the Silver Islet dyke has been seen.

After having lain idle since 1884, work was resumed at Silver islet in June 1920. The mine workings were pumped out to a depth of about 100 feet and thorough sampling of the exposed deposit carried on. An examination of the dyke extension in the immediate vicinity of the islet and of the submerged vein near the east headland of Perry bay was made; a plan for winter development work was formed and operations for the year ceased on August 22.

Among the additions to scientific knowledge collected in 1920 the following are of interest. On the east side of Thunder mountain a locality was found where the Keweenawan sediments overlie the Animikie shales with perfect accordance, and the basal conglomerate of the younger series is absent. This is the only locality known to the writer where the evidence of a time break between the two series is lacking. A

[1] Bull. Can. Min. Inst., May, 1920, pp. 415-430.

fossil algal growth was found in a loose block of red-mottled, grey limestone of Keweenawan age, on the beach at Tee harbour. A modified cone-in-cone structure was found in a dark grey limestone stratum which had evidently fallen from the upper part of the Animikie cliff on the west side of the Sleeping Giant, 3¼ miles from Thunder cape; this structure is of unknown origin and has been found in similar rocks on Welcome island and at Federal mine, Paipoonge township.

NIPIGON-SCHREIBER DISTRICT, ONTARIO

By T. L. Tanton

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INTRODUCTION

The field work of the season of 1920 was a continuation of the geological mapping of a sheet extending from Port Arthur to Schreiber and from latitude 49°10′ on the north to the shore of lake Superior and adjacent islands on the south. The principal contribution to the areal geological mapping was the examination of the shore of lake Superior and the numerous islands off Nipigon bay. Traverses up to 4 miles in length were made into the areas on the mainland lying between the previously explored water routes; and a number of land traverses were run in various directions from near the headwaters of Whitesand river.

Map 964, published by the Geological Survey in 1911, scale 8 miles to the inch, shows the results of early geological investigations in this district. No important contributions have been made to geographical knowledge of the district since the publication of this map, though the charts issued by the Hydrographic Survey, Ottawa, show the shore-lines of lake Superior with more precision.

The inland parts of the area are very difficult of access since many portages are necessary on the few known canoe routes and there are no roads other than the short ones near settlements. The winter roads which were cut from Rossport and Selim to the Zenith mine are now blocked by second growth and fallen trees. The Canadian Pacific railway follows rather closely the shore-line of lake Superior and does not give easy access to any considerable area that cannot be reached by a small boat on the lake.

The largest town in the district is Schreiber, a divisional point on the Canadian Pacific railway. Nipigon, at the intersection of the Canadian Pacific and Canadian National railways, is the outfitting base for tourists and sportsmen visiting Nipigon lake and river; a rapid growth in its population is taking place on account of hydro-electric power developments on Nipigon river, the settlement of local agricultural lands, and the establishment of a pulp mill. Rossport is the headquarters of the commercial fishing enterprise of the district. Small patches of land suitable for farming occur at wide intervals along the shore of lake Superior; the largest of these occur near the settlements at Nipigon and Pays Plat.

Though the entire district was at one time forested, fires have destroyed most of the timber on the mainland which might have been available for commercial purposes. The local pulpwood industry now depends on the forests on the islands near Rossport. Except for the scarcity of jackpine, the forest is of the same general character as that which prevails over the greater part of northern Ontario, the predominant trees being black and white spruce, balsam, poplar, birch, and cedar.

Mining claims were staked in the district as early as 1846, and many additional claims were staked in succeeding years during periods of prospecting activity, resulting in the discovery of zinc, lead, copper, silver, and gold ores, and anthraxolite. The Zenith mine, worked 1898-1900, was one of the earliest producing zinc mines in Canada. It is situated about 11 miles north of Selim, a station on the Canadian Pacific railway. Other deposits of zinc blende have been found in the district, but none of these has been proved to be of commercial value. At present the chief interest in mining affairs is connected with the development of the gold deposits near Big Duck lake, north of Schreiber, the search for nickel ores in large pyrrhotite bodies near Nickel lake in the same general area, and in the redevelopment of gold prospects a short distance east of Schreiber.

D. C. Maddox, F. M. Mooney, and D. K. Mackay acted as assistants on the writer's field party.

GENERAL CHARACTER OF THE DISTRICT

Within the area several different types of topography are to be observed. On the mainland east of Gravel river the normal Precambrian peneplain occurs north of Big Duck lake; but to the south the Precambrian basement rocks are deeply dissected and the local relief in this hilly section becomes progressively greater approaching lake Superior; there reaching approximately 1,000 feet. Between Nipigon river and Gravel river erosion remnants of almost flat-lying diabase sills and Nipigon sediments form high, cliff-walled mesas of irregular shape, and in the lowlands which lie between them the rocks of the basement complex gently rise to the north with the general surface character of the normal peneplain.

The islands in this area present a variety of topographic features, but since the rocks of the crystalline basement complex are not exposed, a pronounced difference is to be noted between their surfaces and the nearby areas on the mainland. The dissected Keweenawan lava fields present the most minutely rugged surface in the district, the maximum local relief being 1,260 feet, whereas the adjacent areas of Keweenawan sediments have been more evenly eroded. Traversing both lavas and sediments, diabase dykes project as prominent ridges in many localities. In general the character of the land surface is markedly influenced by the various solid rocks of the district; the influence of the unconsolidated deposits being in evidence only in small areas near the mouths of post-glacial streams.

Nipigon river is the only large stream in the district. The boundary of the drainage basin of this great river system in its course from near the northern end of lake Helen to the height of land has an average distance of only about 25 miles from the shore of lake Superior. The comparatively small area which lies between the headwaters of the Nipigon River system and lake Superior is drained by a series of small, southward-flowing streams characterized by many falls and rapids. Many small lakes occur in the explored parts of the district. The progress of areal exploration in this hilly country is largely controlled by the discovery of lakes which may be joined by portages to form a route; and much time and labour are necessary to construct such routes, except where they follow the obvious course of the principal river systems.

GENERAL GEOLOGY

The solid rocks of the district are of Precambrian age and may be classified in two main divisions: the basement complex, and a younger division embracing the Animikie and Keweenawan. The basement complex is made up of a schist complex and batholithic granitic intrusives which hitherto have been mapped as Keewatin and Laurentian, respectively.

The rocks of the schist complex occur on the mainland in the eastern part of the district. They have been mapped over an area of about 60 square miles in the vicinity of Big Duck lake, and smaller bands occur to the south near Schreiber. These areas appear to be the western extensions of larger areas occurring in the Black River basin. No considerable area appears to be underlain by these rocks between Pays Plat basin and Nipigon river, though included fragments of schist are frequently encountered in the widespread granite gneiss. Extrusive rocks of various compositions, their pyroclastic equivalents and their schistose derivatives, are the prevailing types in the schist complex, though the diorite which occupies a large part of the schist complex area in the vicinity of Zenith mine appears to be a plutonic intrusive. As the result of observations taken on traverses across the main area of the schist complex between Whitesand river and Nickel lake, the writer tentatively concludes that the banded mica-schist series which occurs to the north is in general older than the complex of altered extrusives which occur around Big Duck lake, that the latter are in general older than the diorite stock which occurs near Zenith mine, and that all of these rocks are older than certain dykes of massive quartz-feldspar porphyry observed near Big Duck lake. A great deal of intensive study in the field would be required in order to make a satisfactory age subdivision of the schist complex, or to map separately the various rocks composing it.

The batholithic intrusives underlie the greater part of the area on the mainland and are most continuously exposed between Whitesand river and Gravel river. Many lithological types are found, such as granodiorite, syenite, hornblende and mica granite, and biotite gneiss, but it was impossible in field mapping to determine geological boundaries between any of these granitic rocks, though it is probable that all are not of the same age.

Animikie sediments occur on the shore of the mainland near Schreiber and in the vicinity of Winston, also on Powder island in Pays Plat bay, and on the small islands near Rossport. The mapping of these isolated remnants of an important series constitutes one of the most interesting scientific results of the season's work. Near Winston the base of the series is exposed; the basal conglomerate, 2 feet thick, lies on granite and 4 feet of iron formation, and 15 feet of thin-bedded, fissile, black shales are superimposed. On the shore of the bay southwest of Schreiber the basal conglomerate rests on lava of the schist-complex. On Powder island 35 feet of interbedded black shales and limy argillites are exposed. In general the series dips at a low angle toward the south.

Keweenawan rocks occur on all the islands and on all the highlands in the district west of Gravel river. The lava series which is over 1,000 feet thick on the outer islands becomes thinner toward the north and does not reach the mainland. Nipigon sediments as much as 400 feet thick are exposed around the shores of the western part of Nipigon bay. Thick diabase sills cap the great mesas on the mainland west of Gravel river, and diabase dykes are of frequent occurrence throughout the district. A great number of diabase dykes form an almost parallel series trending east and west through the islands. The lava and sedimentary series have a low regional dip toward the south. Several faults have been recognized in these formations. The conclusions arrived at in 1919 regarding the local geological history during the Keweenawan epoch, which were published in the Summary Report for that year, are in accord with the data collected in this district. The mineralization found in the Keweenawan rocks and in the dislocations which affected them is of the same character as that described in the Port Arthur-Nipigon section, but in this district no ore-bodies of silver, lead, or copper have been reported.

ECONOMIC GEOLOGY

There are no producing mines in the district and the only mine which has shipped ore, Zenith zinc mine, has lain idle since 1901. A comparatively small amount of systematic or intensive prospecting has been done, since travelling in the greater part of the district can only be accomplished with difficulty. The valuable minerals which have been observed on mining claims are gold, silver, copper, chalcopyrite, zinc blende, galena, barite, and anthraxolite.

In 1920, the development of gold prospects near Schreiber and Big Duck lake was the feature of chief interest to those concerned in mineral affairs, and a party in charge of Mr. P. E. Hopkins of the Ontario Department of Mines, made a detailed geological examination of the mineralized area. The following brief notes on local gold mineralization have been prepared from the writer's observations.

Gold

The mineralized deposits in the Big Duck Lake district are of two distinct types which are probably genetically related. Those of type one are quartz veins, locally feldspar-bearing and hence pegmatitic, carrying disseminated pyrite and small quantities of chalcopyrite and yielding upon assay low gold values. Native copper occurs near the surface in veins carrying chalcopyrite. Commonly there is a thin gossan, less than a foot deep at the surface of these deposits, but on one of the Longworth claims a highly pyritiferous vein has been weathered to a depth of 12 feet, and fine gold can be panned from the gossan. This is locally known as the Mud vein though it does not occur in a fault plane. These veins range from less than a foot to about 15 feet in width and their walls are fairly distinct, though a narrower marginal zone of country rock is frequently found impregnated with quartz and pyrite. These deposits have the appearance of fissure fillings which have a minor amount of marginal replacements of country rock associated with them. Faults are very difficult to recognize in the regionally deformed schist complex and insufficient information is at hand to permit of any generalizations regarding the cause of the vein distribution, though evidence of faulting can be seen locally in connexion with certain veins. A vein on the Estelle property has been traced for 60 chains and other veins of this type apparently show a considerable degree of continuity, though much stripping would be necessary to expose this feature. The veins trend in various directions.

The second type of gold deposit is in carbonate replacement bodies. Part of the carbonate is pale grey, fine-grained calcite; this locally carries finely disseminated galena, zinc blende, chalcopyrite, pyrite, molybdenite, and gold. Enclosed in this material, lenticular masses of rusty weathering dolomite, from 6 inches to 2 yards in maximum diameter, occur, within which there are plicated streaks rich in bright green chlorite, mica, and serpentine. Barren quartz veinlets cut the assemblage. The shape and size of the carbonate bodies are irregular and variable in different localities. Lenticular masses having approximate diameters of 10 feet and 100 feet occur; and on the McCuaig property, where ore has been found, the carbonate body has been traced for 4 chains with widths varying from 3 feet to a few inches. The known carbonate bodies occur in a zone trending north 60 degrees east from the northern part of Little Duck lake to near the northwest part of Big Duck lake. In general these bodies have their longer dimensions parallel to the foliation of the sheared rocks and occur in sheared quartz porphyry, andesite, and along the contact between these rocks.

Near the top of a hill on the Estelle claim, T.B. 1911, a mineralized quartz vein and a marginal calcite replacement body are exposed. The intimate relationship of the two typical deposits here indicates a close genetic relationship.

The origin of the gold-bearing solutions is not known. The igneous rock which appears to be most closely related to the gold deposits in time and place is the massive, pale pink, quartz porphyry. This rock is thought to be younger than the sheared, grey, quartz porphyry in which some of the replacement bodies lie.

Assays of gold to the value of over $1,000 to the ton are reported to have been obtained by Mr. W. S. Jackson from his claim, R 425, about 2 miles east of Schreiber. The mineralized veins in common with others developed farther east occur in the schist complex very close to the contact of the intrusive granitic batholith. The mineralized veins carry very little visible gold and average about one foot in width; they are well defined and occur as a nearly parallel series with certain additional cross veins. The extent of the high-grade ore in the deposits has not yet been determined.

Copper

No copper deposits of economic value are known in the district though copper minerals occur in deposits of at least three types: (1) chalcopyrite disseminated through quartz veins cutting the schist complex, the best known examples being on claims T.B. 2091 and T.B. 1911 and eastern extensions, in the Big Duck Lake district; (2) native copper in amygdules and veinlets in the Keweenawan lavas on the outer islands; and (3) chalcopyrite associated with lead and zinc minerals in quartz calcite veins cementing fissures and fault planes which formed in Keweenawan or post-Keweenawan time.

Veins Carrying Copper, Lead, Zinc, and Silver Minerals

A great series of such veins is now known to occur in a zone bordering the shore of lake Superior as far west as Pigeon river. In the opinion of the writer systematic prospecting should be carried on in the exposed veins of this type and an effort should be made, where feasible, to expose veins in fault zones of late Keweenawan age. In the writer's summary report of 1919 special mention was made of veins of this type and it was pointed out that new discoveries of silver ores may possibly be found analogous to those at Silver islet and along the north shore of Thunder bay. The mineral assemblage in veins of this type is remarkably similar over a large area, though the proportions of the constituents vary considerably even within short distances; the principal minerals are: galena, zinc blende, chalcopyrite, pyrite, and occasionally silver and argentite, together with quartz, amethyst, calcite, fluorite, and barite.

A number of mining claims have been staked with the apparent purpose of taking up for development veins of this type, but no work was in progress at the time of the writer's visit and no deposits of commercial value were seen. It is reported that a small amount of native silver was found near the surface in a vein on claim R 570, 1½ miles north of Pays Plat village; the occurrence of silver has been reported from two other localities to residents of the district, but from the available data on the location of these deposits the reports could not be verified. A trace of silver was found in the analysis of a sample from a narrow galena-bearing vein on lot 9, con. IV, Nipigon tp. Samples from several of the veins elsewhere in the district show no silver content upon assay. The greater part of the silver found in neighbouring areas has occured as recognizable silver ore; not carried by the galena or other minerals in the veins.

The recently staked claims to the north of Ozone siding embrace a granite area in which a number of small veins occur trending approximately east and west. The veins are of the normal late Keweenawan type. Zinc blende is locally abundant in parts of the veins, but no ore deposit of economic importance has been encountered, as yet.

Anthraxolite

A small amount of anthraxolite occurs along with quartz and other minerals as cement filling rock fissures in the basement complex near Animikie rocks. This material was found on the Canadian Pacific railway one mile west of Rossport at the outlet of a small lake half a mile northwest of Rossport and on the shore of lake Superior south of railway Mileage 5.4 west of Schreiber. The mineral contains a high percentage of carbon and resembles anthracite; it is regarded as an altered liquid bitumen. The anthraxolite in the above-mentioned localities was probably derived from bituminous shales in the overlying Animikie sediments.

Investigation of Reported Deposit of Kaolin

Wyatt Malcolm of the Geological Survey examined the Nipigon sediments on Cooke point, lake Nipigon, which had been staked for kaolin. He found no material of prospective commercial value as a source of kaolin. The stratified rocks at this locality are pale grey with red and green streaks and are composed of partly kaolinized feldspar, altered amphibole, and calcium-magnesium carbonates.

GENEVA MAP-AREA, SUDBURY DISTRICT, ONTARIO

By T. T. Quirke

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Illustration

INTRODUCTION

The greater part of the field season of 1920 was spent by the writer in geological exploration of the townships of Hess and Moncrieff, for the purpose of determining the geologic succession and identity of the supposed Huronian sediments, which can be seen in places along the railway between Mile 2 and Mile 7 west of Cartier. Reconnaissance trips were made near the end of the season from Benny on the Canadian Pacific railway to Lower Onaping lake whereby the work was carried to the border of the Onaping map-area, and one trip was made southward from Cartier to Levack, in order to connect the work of the Geneva area with the geology of Sudbury nickel basin. During most of the season the writer had the assistance of W. F. James.

GEOLOGY

The rocks of Geneva area fall naturally into the following groups, listing the oldest first: (1) Keewatin, mainly stratified pyroclastics; (2) batholithic intrusions of granite; (3) Huronian, including both the Bruce and Cobalt series; (4) Keweenawan diabase and olivine diabase; (5) batholithic intrusives, chiefly porphyritic syenites; (6) Pleistocene deposits. The chief result of the exploration was the discovery of another area, and one readily accessible, in which a young acid intrusive is seen invading the Huronian rocks. Another result of importance was the recognition of three different conglomerates any one of which without careful work might be mistaken for the Cobalt conglomerate. The exploration was valuable also because of the discovery of an almost complete Bruce series many miles north and east of its previous locus of identification on the north shore of lake Huron. Incidentally, many interesting variations in both the Bruce and Cobalt series were made known.

The geologic succession is expressed in the following table.

Table of Formations

Pleistocene deposits		
Unconformity		
Keweenawan	Younger batholithic intrusions (syenite) Basic intrusions (diabase and norite)	
Intrusive contact		
Cobalt series		
Lorrain quartzite		1700+ ft.
Gowganda formation		1200 ft.
Unconformity		
Bruce series		
Serpent formation		700 ft.
Espanola formation		120 ft.
Mississagi formation		470 ft.
Unconformity		
Granite intrusions (alaskite)		
Keewatin volcanic rocks and schists.		

STRUCTURE

The Huronian rocks of Geneva area lie in one of a series of nearly parallel synclines which run generally northeast and southwest across the main line of the Canadian Pacific railway between Windy lake and Lower Onaping lake. Near Geneva lake, however, there is a syncline folded more deeply into the underlying rocks than its neighbours and, therefore, preserving a considerable thickness, roughly 4,200 feet, of Huronian sediments.

This syncline has been sliced by two great faults in a north-northeast, south-southwest direction and is offset laterally, in the case of the eastern fault, about ½ mile, and in the case of the western fault, about 2 miles. The vertical throw is unknown, but apparently not very great. The syncline is cut off at the southwestern end by one or more faults of a similar general trend. Further faulting has occurred along planes generally parallel to the axis of the syncline, so that, notably near the centre of Hess township, repetitions of formations and interrupted successions have resulted.

The geologic structure is rendered all the more confusing by the intrusion not only of the ubiquitous diabase, but of the younger acid intrusive, which seems generally to have followed the zones of major faulting, notably in the case of the great transverse faults which have sliced the main structure into three members. The two gaps resulting are more or less plugged with intrusions of the younger acid porphyry.

Otherwise the structure is apparently simple; the area south and east of the great syncline is granitic, the area north and west is mainly of stratified pyroclastics dipping generally nearly vertical and northwestward.

PHYSIOGRAPHY

Nearly all hills are ridges parallel to the strike of the sediments or pyroclastics; otherwise the hills have the irregular shape characteristic of eroded, massive igneous intrusions. The height of the hills is generally proportional to the resistance of the constituent rocks, valleys commonly following the outcrops of Espanola formation (largely limestone) and the lines of weakness along contact zones and fault planes. In general the massive Gowganda conglomerates form ridges, the greywacke bands form valleys, and the Serpent formation underlies lowlands. Here and there rather notable hills of diabase rise above the general level, and large, rounded hills form the surface of the pre-Huronian granite. In the area of Keewatin stratified pyroclastics ridge follows ridge, in successive hogbacks, parallel to the strike of the rocks. The outstanding features of the area are the great hills of Lorrain quartzite, which rise high above the surrounding country, stretching northeast and southwest like a long, twice broken wall, bounded north and south by precipitous sides unscalable in many places. The gaps through this wall of resistant rock follow fault planes and igneous intrusions, and evidently are the result of differential stream erosion. These quartzite hills, structurally the remnant of a great syncline, indicate a former stage of erosion so advanced that the drainage had become adjusted to the structure, a stage in the erosion cycle not less advanced than late maturity. The adjustment of this ancient drainage system to the structural conditions and to the distribution of the rocks of varying resistance has nearly all been destroyed by the accident of glaciation, which has partly filled the valleys, diverted the streams, and generally thrown back the drainage system to a present condition of extreme youth.

PRE-HURONIAN ROCKS

The oldest rocks in Geneva are are stratified pyroclastics composed mainly of fine tuff-like schists and volcanic breccias. There are also some schists of indefinite origin, which are either highly metamorphosed felsites or badly sheared quartzitic greywackes. In addition to these rocks of uncertain origin are certain interbedded

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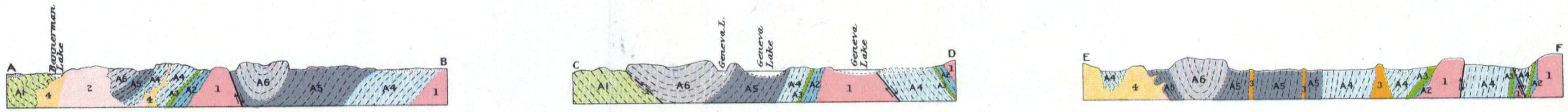


Section along line A B
Vertical scale exaggerated

Section along line C D
Vertical scale exaggerated

Section along line E F
Vertical scale exaggerated

LEGEND

KEWEENAWAN(?)

- 4 — *Syenite-porphyry intrusives*
- 3 — *Basic intrusives*

HURONIAN

COBALT SERIES

- A6 — Lorrain quartzite
- A5 — Gowganda formation

BRUCE SERIES

- A4 — Serpent formation
- A3 — Espanola formation
- A2 — Mississagi formation

PRE-HURONIAN

BATHOLITHIC INTRUSIVES

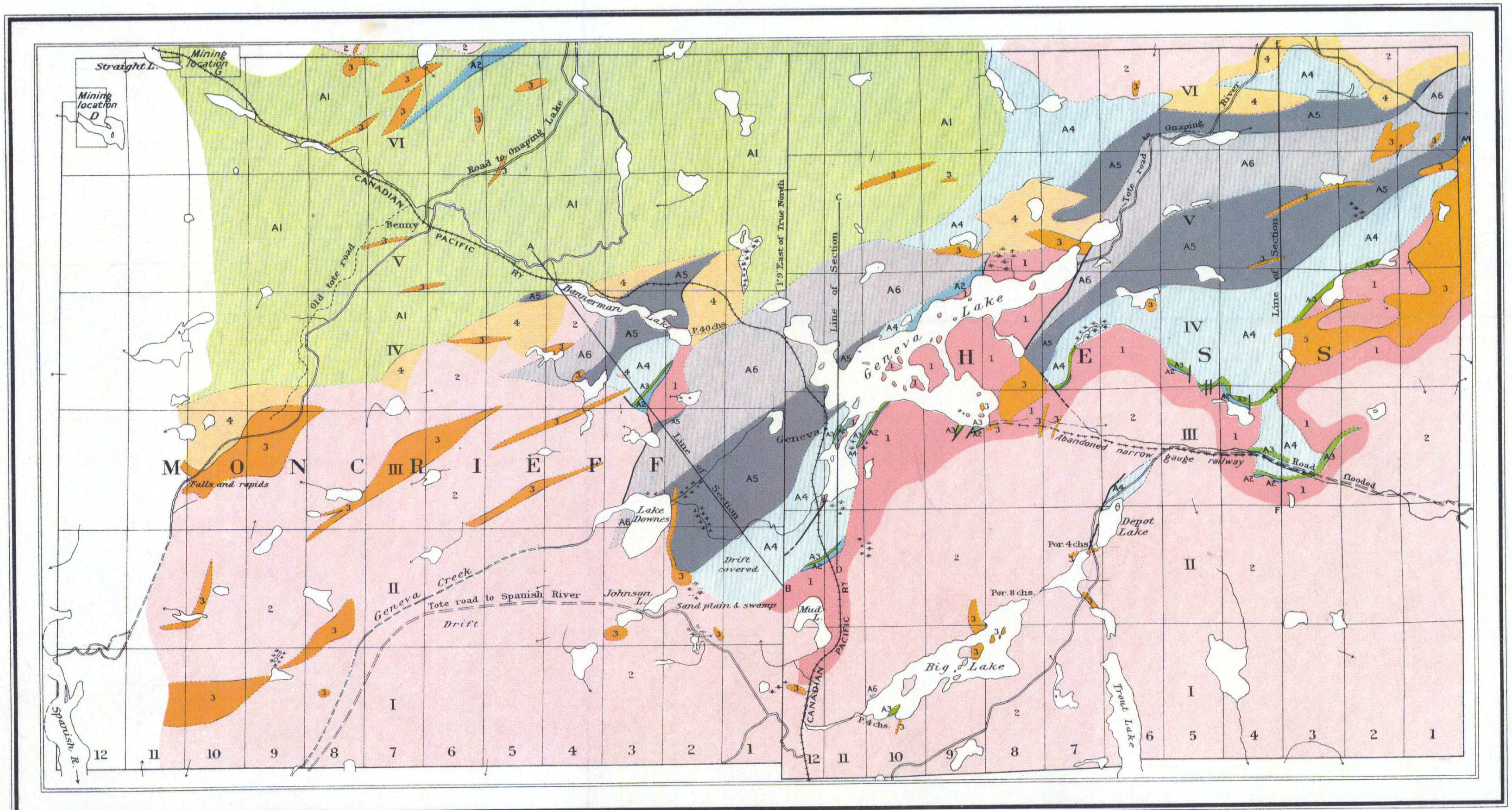
- 2 — *Undifferentiated mixture of Pre-Huronian granite and gneiss and Keweenawan syenite-porphyry*
- 1 — *Granite and gneiss*

KEEWATIN

- A1 — *Volcanic and contemporaneous sedimentary rocks*

Symbols

- Geological boundary (defined)
- Geological boundary (assumed)
- Fault



Publication Nº 1865

C. O. Senécal, *Geographer and Chief Draughtsman.*
A. McGregor, *Draughtsman.*

MONCRIEFF AND HESS TOWNSHIPS, SUDBURY DISTRICT, ONTARIO.

Scale of Miles

To accompany Report by T. T. Quirke, in Summary Report, Part D., 1920.

Geology by T. T. Quirke, 1920.

Moncrieff and Hess Townships.
Sudbury district.

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bands of water-laid, fine-grained greywackes, probably derived in large measure from volcanic tuff. It is reported that bands of iron formation have been discovered in the district, but none was seen by the writer. These schists are classed with Keewatin rocks: they were folded and intruded, previous to the deposition of the Huronian formation, by granite which is the so-called older intrusive of the area, consisting nearly everywhere of alaskite, changed in places into a gneiss but in many places apparently of massive texture. However, under the microscope a distinctly cataclastic texture is seen. In distribution the Keewatin rocks outcrop in a band about 3 miles wide north of Bannerman lake, bounded on the north side and on the south by intrusions of the older granite. Almost one-half of the area, roughly that part lying south of the middle line of Moncrieff and Hess townships, is underlain by granite.

HURONIAN FORMATIONS

The Huronian formations are divided into two series, the upper being known as the Cobalt series, and the lower, the Bruce series.[1] In Geneva area the Bruce series is represented by the Mississagi, Espanola, and Serpent formations. No equivalent has been found in this area of the Bruce conglomerate, and the formations differ in many respects from their equivalents found along the north shore of lake Huron.

The Cobalt series is represented by the Gowganda formation and the uneroded remnant of the Lorrain quartzite.

Bruce Series

Mississagi Formation. The Mississagi formation in most places on the north shore of lake Huron is characterized by a rather thin, exceedingly arenaceous, basal conglomerate which grades in certain places into a simple arkose, and throughout the major part of the formation the arkosic characteristic is predominant. In small fragmentary outcrops this formation has been identified in the Geneva district. It is found in Hess township in many places, on the south side of the limestone, lying unconformably upon granite. It is excellently exposed along the railway tracks at a little more than 2½ miles from Cartier. So far as the writer has been able to find, the conglomerate in Hess township is never as wide as 500 feet. Nearly everywhere it appears to be a thin remnant between a limestone formation and the pre-Huronian granite, and in some such places it is lacking altogether. In Moncrieff township, however, almost on the concession line 1½ miles west of Mile 4, on the Canadian Pacific railway there is a distinct basal conglomerate overlain by 350 feet of fine-grained, white-weathering quartzite underlying a gradational phase of greywacke, giving place to limestone. Thus it is clear that the whole formation consists of a basal conglomerate followed by a quartzite. In one place the basal conglomerate is 170 feet thick, followed by 300 feet of quartzite. This conglomerate is dark in colour, massive in structure, heterogeneous in composition, and lies unconformably upon the older granite, having conformable relations with the quartzite above, and the quartzite in turn grades through a greywacke band into limestone, with no apparent stratigraphic break.

North of Benny station, near the tote road to Lower Onaping lake, various outcrops of conglomerate, tentatively correlated with the Mississagi quartzite basal conglomerate, appear to be stratigraphically above the Keewatin stratified volcanic rocks, but as there are no other sedimentary rocks exposed it is not possible to determine other geological relations. The conglomerate is very dark coloured, and is, apparently, derived from the basic pyroclastic rocks upon which it lies. Numerous faults, however, have completely isolated many of the outcrops from their stratigraphic sequence, and make the relations of the scattered conglomerates difficult to determine.

The lower surface of the Mississagi formation is very irregular. In fact, in one place the surface was apparently one of subaerial weathering. The basal conglo-

[1] Collins, W. H., Geol. Surv., Can., Mus. Bull. No. 8, pp. 19-21.

merate is nearly everywhere entirely unsorted, although it is overlain by a well-bedded arkosic quartzite. In some places the old pre-Huronian surface weathered in such a way that the granite broke out along joint planes. About a mile south of the northeast end of Geneva lake the contact between the Mississagi quartzite and the pre-Huronian granite exposes the old granite blocks moved very slightly from the joint faces from which they fell, and also shows in the granite a continuation of that pre-Huronian joint system. It is concluded that this basal conglomerate is a continental deposit which was covered by water-laid arkosic sandstone and that these conditions of clastic deposition gave place to precipitation of limestone, presumably of bio-chemical origin.

Espanola Formation. Outcropping throughout the area in elongated strips here and there may be found a silicified limestone which is correlated with the Espanola limestone. In certain places it is as much as 120 feet thick, in many places less, and in some places has an outcrop wider than 120 feet, due to crumpling and folding. Nearly everywhere one side of the formation either abuts directly against massive granite or adjoins remnants of the Mississagi formation. It is overlain conformably by a curious mixture or alternation of conglomerate, greywacke, and quartzite.

In most parts of the country between Sudbury and Sault Ste. Marie there are two limestones, named by Collins[1], Bruce limestone and Espanola limestone. These are really highly calcareous phases of the Espanola formation, a calcareous, indurated silt. The Espanola limestone occurs at the top of the Espanola formation; the Bruce limestone lies at its base and directly upon the Bruce conglomerate. In no place in the Geneva area were two limestones discovered, although in some places parallel bands of limestone can be recognized. Naturally, the question is, should this limestone be called Espanola or Bruce? Apparently there is no Bruce conglomerate in the Geneva area; certainly, where the relations are clear, the limestone lies upon the Mississagi formation. The Bruce conglomerate being absent, it is possible that the Bruce limestone also is wanting. The relations of the limestone at Geneva with the overlying greywacke and quartzite also correspond to the relations of the Espanola limestone with the overlying Serpent greywacke and quartzite. Pebbly dykes were found cutting parts of the Espanola group and the Serpent quartzite in the other places[2], but they were not known elsewhere to cut the Bruce limestone. Similar dykes were found cutting the limestone on the northeast shore of Mud lake and on the southeast shore of Geneva lake. On the other hand the Espanola limestone as encountered on the north shore of lake Huron is much more variable than the Bruce limestone, varying in thickness from 0 to 75 feet, so its absence at Geneva would not be surprising.

The limestone formation at Geneva may perhaps best be regarded as equivalent, not to the Bruce limestone nor to the Espanola limestone of the north shore of lake Huron, but to Bruce limestone, Espanola calcareous silt, and Espanola limestone combined, just as the Kona dolomite of Marquette district, Michigan, may be regarded as the equivalent of all three.

The original character of the Espanola formation is unknown. Although called a limestone it really contains a very small proportion of carbonate. It is highly silicified, the silica being distinguishable under the microscope as very small grains of quartz. The writer has never seen any structures within the limestone which look like algal growths, nor any other suggestion of organic origin. However, it is probable that at the time of formation bacteria at least were in existence, and that the Espanola formation originated through some bio-chemical agencies.

Serpent Formation. In most places where the relations are clear, the Espanola formation is overlain by a greywacke formation grading into a peculiar, characteristic, easily distinguished rock known as the Serpent quartzite. In the Geneva area there is a formation which is not merely quartzitic but markedly conglomeratic. However,

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1 Collins, W. H., Geol. Surv., Can., Mus. Bull. No. 8, 1914, p. 19.

2 Collins, W. H., Geol. Surf., Can., Mus. Bull. No. 22, p. 5, and Quirke, T. T., Geol. Surv., Can., Mem. 102, p. 39.

this is not a bouldery coarse conglomerate, being lenticular; not persistent either laterally or stratigraphically; giving way both to quartzite and to greywacke bands; generally siliceous and gritty; and composed of characteristically well-worn pebbles. The writer believes this formation to represent both the greywacke (silty) and quartzite phases of Serpent formation, and ordinarily an attempt would be made to subdivide the formation at Geneva into parts that could be correlated with the greywacke phase and the quartzite member of the Serpent formation. But that cannot be done. There are parts near the bottom of the formation at Geneva which look exactly like typical Serpent quartzite; there are parts well up in the formation lying above both quartzite and conglomerate, which could not be distinguished from typical Espanola greywacke in the Espanola area. These are followed again by conglomerate and by quartzite which seems to be precisely like typical Serpent quartzite. The conglomeratic phase of this formation is so unlike any of the Serpent quartzite that the writer has seen elsewhere, except for a 6-inch band in the Espanola area, that he hesitates to give it the same name. However, it has the stratigraphic position of the Serpent formation, being conformable upon limestone and unconformable beneath the Gowganda formation. It bears all the peculiarities of the Serpent formation, especially the sandy and pebbly dykes, striking and characteristic lining[1]' greywacke members, and conglomerate streaks. But it has the unusual quality of great development of the conglomerate phase, far in excess of its development elsewhere so far as it has been recognized. A good idea of the character of the Serpent formation at Geneva may be gathered from sections, compiled in different parts of the area. In one place the formation includes much laminated greywacke, in another place the formation is almost solely of coarse, elastic materials, especially conglomerate. The formation is between 600 and 700 feet thick.

The following detailed sections (pages 13-16) show the great variation of this formation, stratigraphically and laterally, and should be studied to distinguish between the Serpent and Gowganda formations, for their characteristics must be recognized before attempting stratigraphic geology in this region. On page 13 various types of the Serpent formation are distinguished by the letters A to J: these variations, characteristic of the Serpent formation in the eastern part of Hess township, are not so well represented at Geneva station farther west, and are almost entirely displaced by different phases in Moncrieff township still farther west. The basal part of the Serpent formation is a rubbly conglomerate in the west changing in texture to a fine-grained arkosic greywacke in the east. Between the coarse-textured material and the Espanola formation there is a sharply-defined erosional contact, whereas, under the finer material there is a gradation between these formations. The outstanding peculiarity of the formation, bearing upon its origin, is extreme variability as shown by change from rock composed of granite and schist pebbles to other of pure quartzite and argillite; from coarse, angular conglomerate to very fine-grained greywacke; from massive structure to finely laminated bedding; from regular bedding of wide spacing (characteristic of deep water deposits) to alternating quartzite and greywacke containing rill-marks and ripple-marks, and exceedingly crossbedded lenses of sandstone and grit (characteristic of shallow water and of deposits exposed occasionally to the air). Some of the sandy beds and lenses are so exceedingly crossbedded that a reasonable interpretation is that they were deposited by the action of the wind. Much of the material of this formation was not transported far nor weathered greatly previous to its deposition, and the whole formation is taken to represent a time of great variations in the extent and depth of the basin of deposition. Conditions on the land which would give rise to such a formation must have been extreme, resulting in rapid mechanical disintegration with a minimum of chemical decomposition.

Cobalt Series

Gowganda Formation. Lying upon the Serpent formation with relations which are inconspicuously unconformable, is the equivalent of the Gowganda formation,

[1] Quirke, T. T., loc. cit., p. 40.

known also, locally, as the Cobalt conglomerate. This is a bouldery, partly stratified and partly massive formation, consisting for the most part of bands of impure quartzite, separated from one another by streaks of pebbly conglomerate and bands of greywacke, containing, however, two thick, massive bands of boulders which can be distinguished from the other conglomerates of the area and which constitute its distinguishing features. The boulders are imperfectly rounded and bevelled as though by glacial action. The bands of greywacke contain numerous pebbles and boulders, scattered irregularly through the rock, in a manner similar to those in the Dwyka, so-called "boulder mudstone". The formation is about 1,200 feet thick and passes, after a long gradation of several hundred feet, into the overlying Lorrain quartzite without apparent stratigraphic break. The essential characteristics of the Gowganda formation at Geneva area are similar to those elsewhere. The detailed sections, pages 13-16, show that the formation is made up of a massive bouldery conglomerate containing a slate-like greywacke matrix; thinly laminated argillites; well-bedded, slate-like rocks carrying scattered pebbles and boulders; sub-angular and bevelled boulders, similar in shape to those found in glacial conglomerates. In the Geneva area no striated boulders have been found but they may be there. These peculiar and highly characteristic phases of the Gowganda formation are mixed in with greywackes, arkoses, quartzites, and conglomerates of inconspicuous and ordinary characteristics, so that, without detailed study, the significant peculiarities of the formation are likely to be overlooked. The common type of the Gowganda formation is so similar to the common type of the Serpent formation, that a stratigraphic quantity of each formation must be examined before the outcrop can be identified. For this reason detailed sections of both the Serpent and Gowganda formations are here included. The distinguishing characteristics of the two formations may be contrasted as follows: the Serpent in certain places is cut by sandy dykes; the Gowganda is not. The Serpent is characterized by a quartzite containing fine parallel linings, due to the alternated deposition of quartz sand and feldspar sand and greywacke[1]; the Gowganda lacks this type of quartzite. The matrix of the Serpent conglomerates is uniformly arkosic; the matrix of the Gowganda conglomerates is characteristically, but not uniformly, slate-like. The grit-sized particles of the Serpent quartzite are pieces of disintegrated rock; many particles of the same size in the Gowganda formation are discrete particles of granite. The Serpent contains angular and sub-angular, but not bevelled, boulders, whereas the Gowganda includes all three types. The Serpent contains some thick layers of well laminated slate, but the Gowganda contains well-bedded slate layers carrying irregularly spaced pebbles and boulders. The Serpent quartzite is characterized by ripple-marks in certain layers; lacking ripple-marks, the Gowganda formation contains layers which appear to have been contemporaneously disturbed as though by ice-shove. These distinctions are in harmony with the supposition that the Gowganda formation, at least in part, has a glacial origin, in which it differs from the Serpent formation.

Lorrain Quartzite. The Lorrain quartzite, of all the formations in the Geneva area, is the most easily recognized by any one familiar with Huronian rocks. It is a most striking, uniform, pale green rock, carrying, especially near the upper part, characteristic streaks of white quartz and pink jasper pebbles. These pebbles, rarely more than one inch in diameter, and commonly less than half an inch, constitute an essential and persistent characteristic of the formation, having been recognized all the way from near Sault Ste. Marie to Onaping area and La Cloche mountains.

Erosion in the Geneva area has removed the upper part of the Lorrain, leaving a maximum thickness of about 1,700 feet. The quartzite outcrops in high hills stretching from the northeast corner of the area nearly to the middle of Moncrieff township. The outcrops form three masses in synclinal folds, each having nearly the same strike, offset from one another by great faults along which have followed intrusions

[1] Quirke, T. T., Geol. Surv., Can., Mem. 102, p. 40.

of porphyritic syenite. These high ridges of gleaming white Lorrain quartzite are a repetition, on a smaller scale, of the beautiful La Cloche mountains.

Detailed Section of Serpent Formation One-half Mile Southeast of the Northeast Arm of Geneva Lake, from the Base Upward

Espanola Limestone:

6 to 9 feet unexposed
22 feet well-bedded, laminated, siliceous, dark grey arkose which weathers with pale lines or striped surfaces (type A)
10 feet of massive greywacke
20 feet laminated, rather vaguely bedded, partly quartzitic greywacke
5 feet notably banded rock consisting of half-inch layers of pale coloured arkose and fine-grained, green greywacke (type B)
15 feet massive greywacke (type C)
5 feet alternately banded arkose and greywacke of half-inch bands like type B
10 feet less banded, massive, fine-grained arkose and greywacke like type C
6 feet well laminated greywacke like type A
6 feet banded greywacke like type B
35 feet of banded greywacke and arkose, consisting of a foot of massive greywacke interbedded with 6 inches of banded greywacke like type B; this is repeated until near the top the massive greywacke becomes coarser and quartzitic (type D)
10 feet crossbedded, coarse, arkosic grit consisting of grains ⅜ of an inch in diameter (type E)
19 feet like type D, only more quartzitic and arkosic
22 feet laminated, fine-grained greywacke, not striped surface like type A, but massive-looking, becoming coarse and gritty near the top
26 feet type D
4 feet massive, siliceous greywacke (type G)
1 foot greywacke streaks
8 feet massive greywacke, very siliceous (type G)
10 feet well-lined, rather arkosic typical Serpent quartzite (type H)
6 inches of greywacke streaks
10 feet coarse grit in a massive arkose with some lenses of greywacke and crossbedding: near the top becomes very crossbedded like type E
15 feet unexposed
34 feet well-lined Serpent quartzite, type H with every 2 or 3 feet a well-marked bedding plane
5 feet gritty arkose with crossbedding
10 feet Serpent quartzite (type H)
9 feet massive, siliceous, arkosic greywacke (type I)
5 feet crossbedded grit (type E)
10 feet massive siliceous arkose (type I)
5 feet siliceous, interbedded (type D)
6 feet lined quartzite (type H)
3 feet crossbedded grit
8 feet lined quartzite (type H)
6 feet crossbedded grit (type E)
1 foot banded greywacke (type B)
10 feet of exceedingly crossbedded arkose
12 feet unexposed
44 feet interbedded siliceous greywacke and slate-like argillites
30 feet arkosic quartzite, bedded by numerous greywacke partings every 3 inches to 20 inches apart
15 feet massive greywacke separated into banks by streaks of greywacke
1 foot gritty, crossbedded arkose
32 feet well-lined quartzite becoming distinctly arkosic and gritty near the top
4 feet massive arkose
9 feet very crossbedded arkose, so coarse in texture as to be a grit, or nearly all grains of feldspar
17 feet massive arkose with lenses of crossbedded material 2 feet in thickness
57 feet well-lined arkose separated with bands every 12 or 13 inches by a thin sheet of greywacke; in places it has a dense, porcelain-like appearance, containing fine colour bands due to alternation of quartz and feldspar, typical Serpent quartzite.
6 inches streaked greywacke
2½ feet crossbedded arkose with streaks of greywacke and grit
13 feet unexposed
3 feet coarse arkose
6 inches very fine-grained greywacke
14 feet coarse, crossbedded arkose with some streaks of clear quartzite like type H
16 feet unexposed
5 feet coarse arkose

Detailed Section of Gowganda Formation, Immediately Overlying the Foregoing Section of the Serpent Formation

16 feet bouldery conglomerate with a very siliceous pebbly matrix containing boulders as large as 20 inches in diameter and lenses of siliceous greywacke becoming especially siliceous in the upper part
6 inches streak of grit
8 feet arkose
18 feet unexposed
5 feet arkose
8 feet conglomerate with 12-inch boulders having pebbly conglomerate above and below
20 feet unexposed
3 feet arkose
55 feet unexposed
10 feet quartzitic greywacke with scattered pebbles
9 feet well-lined quartzite
42 feet massive slaty groundmass carrying many small rock chips and scattered pebbles
28 feet unexposed
3 feet quartzite
47 feet slaty greywacke carrying scattered pebbles, becoming siliceous towards the top
21 feet unexposed
5 feet slaty greywacke with scattered pebbles
3 feet lens of quartzite
22 feet greywacke which weathers in a characteristic and peculiar manner with a chipped-out surface looking something like the breeze-rippled surface of water; this greywacke carries pebbles scattered throughout
100 feet unexposed
55 feet of massive green greywacke which weathers with the chipped-out wavy surface described above. This grows more siliceous and less green in colour towards the top
165 feet unexposed
20 feet of very finely laminated greywacke with wave-like surface.
15 feet quartzite with 6-inch bands of greywacke and thin streaks every 3 inches to 2 inches apart
6 feet banded, quartzitic greywacke
10 feet bands of quartzite 3 to 6 inches thick separated by streaks of greywacke
6 feet quartzite
4 feet pebbly and rubbly conglomerate.
14 feet arkosic quartzite becoming finer towards the top
24 feet unexposed
4 feet of arkose
115 feet unexposed
30 feet dense, massive, sugary quartzite with occasional streaks of greywacke showing the bedding
60 feet unexposed
10 feet massive quartzite
110 feet unexposed
24 feet dark green greywacke with siliceous lining
45 feet unexposed
Lorrain quartzite

Detailed Section of Parts of the Serpent and Gowganda Formations on a Line Passing Through Geneva Station, from the Base Upward

200 feet grey, well-lined, clearly bedded, arkosic quartzite like the typical Serpent quartzite along the north shore of lake Huron
15 feet well-stratified pebbly conglomerate
55 feet massive quartzite
7 feet rubbly, gritty, pebbly conglomerate
2 feet crossbedded grit
3 feet finely banded greywacke
2 feet crossbedded grit
18 feet coarse pebbly grit
2 feet thickly-set large pebbles
8 feet pebbly grit
1 foot well-bedded greywacke
13 feet well-bedded grit
6 inches streak of cobbles 3 inches in diameter
10 feet pebbly grit
15 feet of grit carrying lenses of pebbles and cobbles
15 feet of bedded, coarse grit
12 feet well-bedded quartzitic greywacke
4 feet interbedded greywacke and crossbedded grit
18 feet pebbly grit interbedded with streaks of greywacke
11 feet banded greywacke
2 feet of grit
1 foot of greywacke

10 feet of massive quartzitic greywacke
14 feet of quartzitic grit
1 foot of greywacke
5 feet of grit
9 inches of greywacke
6 feet of coarse grit
6 inches greywacke carrying ripple-marks
6 or 7 feet of coarse, unstratified grit and fine conglomerate
2 feet of quartzitic greywacke
21 feet of well-bedded and crossbedded streaks of quartzite and greywacke
19 feet of well-bedded quartzitic greywacke
1 foot of quartzite
31 feet of coarse, arkosic quartzite
1 foot greywacke streaks
8 feet arkose
2 feet greywacke
7 feet grit
1 foot coarse, pebbly arkose
14 feet grit
3 feet pebbles
38 feet arkosic grit
10 feet of quartzite
30 feet arkosic quartzite
Unconformity

Gowganda Formation:

4 feet of bouldery conglomerate, rounded and angular masses up to 14 inches in diameter
8 feet massive pebbly grit
10 feet coarse boulders crowded together, as large as 26 inches in diameter, including many subangular pieces. In order of abundance the boulders are composed of granite, felsite, greenstones, quartz, and chert
9 inches bedded grit
8 feet 6 inch cobbles scattered in grit
10 feet pebbles and cobbles
2 feet quartzite
30 feet conglomerate carrying crowded pebbles and occasional large boulders (12 inches in diameter) with layers of grit
5 feet quartzite
1 foot pebbly conglomerate
20 feet massive arkose
50 feet dense, massive quartzite grading into
30 feet dense porcelain-like quartzite
20 feet well-lined quartzite
38 feet grit
15 feet bouldery conglomerate crowded with boulders and pebbles
60 feet pebbly conglomerate becoming coarser at the top
28 feet arkose
32 feet crowded boulders and pebbles
50 feet unexposed
10 feet bouldery conglomerate
10 feet pebbles
4 feet quartzite
23 feet quartzitic greywacke containing scattered pebbles and cobbles
78 feet unexposed
9 feet massive arkose
18 feet unexposed
4 feet quartzitic arkose
183 feet quartzite
3 feet gritty quartzite with scattered pebbles
100 feet quartzite
40 feet dense, impure quartzite carrying a few scattered pebbles
100 feet massive, dark coloured greywacke with pebbly conglomerate and layers of quartzite scattered throughout
10 feet dark almost black greywacke carrying contorted layers of sandy material which look like contemporaneously disturbed deposits
40 feet almost massive greywacke
6 feet greywacke with scattered granite pebbles among ripple-marked greywacke and in gritty greywacke layers
90 feet poorly bedded, dark coloured greywacke
2 feet ripple-marks and rill-marks
52 feet of poorly-bedded, dark greywacke
15 feet dark coloured greywacke, very well-bedded, with sandy streaks and ripple-marks
100 feet very dark poorly-bedded greywacke
12 feet interbedded dark quartzite and greywacke
75 feet unexposed
20 feet dark quartzitic greywacke which grades into whitish green quartzite with lenses of white pebbles up to 3 inches in diameter, typical Lorrain quartzite.

Detailed Section of Serpent and Gawganda Formations in Moncrieff Township Within a Mile South of the East End of Bannerman Lake, Starting from the Base Upward

60 feet Espanola limestone
15 feet well-bedded transition of greywacke and limestone
10 feet interbedding of limestone, greywacke, and quartzite, chiefly limestone
10 feet of quartzitic greywacke poorly bedded
Unconformity

Serpent Formation:

141 feet of rubbly conglomerate with an arkosic and not greywacke matrix including irregular pieces as well as pebbles up to 8 inches in length, carrying also occasional streaks of coarse arkose. Nearly all the inclusions are granite, but some consist of schist. Many pieces are not rounded, being actually block shaped
8 feet pebbles and cobbles set as closely together as they can be
12 feet conglomerate containing larger boulders up to 18 inches in diameter
200 feet more of heavy bouldery and arkosic material
200 feet chiefly unexposed, but where exposed is pebbly, arkosic conglomerate
60 feet unexposed
150 feet well-lined quartzite, grey in colour but marked with typical lining
80 feet clean quartzite
60 feet quartzitic greywacke
5 feet banded greywacke
20 feet banded greywacke and quartzite
190 feet finely laminated greywacke, slaty in character, like typical Espanola greywacke of the Espanola area. Cut in one place by a sandy dyke 10 feet wide
The greywacke is capped by a series of arkosic quartzite and ripple-marked greywacke bands
20 feet massive greywacke
Unconformity

Gowganda Formation:

65 feet dark green, slaty conglomerate in massive bands between streaks of quartzitic greywacke; at the base there are large boulders 1½ feet in diameter scattered sparsely, most of the inclusions being pebbles and cobbles less than 3 inches in diameter. The pebbles are scattered throughout a greywacke matrix, irregularly spaced, and round in shape.
220 feet dark green conglomerate, carrying scattered pebbles and boulders; 150 feet up the boulders are thickly set and large boulders are numerous. Thereafter the groundmass is gritty and pebbly, but for the most part is of very fine-grained, clay-like material. Nearly all the boulders are of granite.
40 feet gradation through quartzitic greywacke free of pebbles, cobbles, and boulders into Lorrain quartzite.

Keweenawan Rocks

There are numerous dykes and sill remnants of diabase, similar to the diabase found throughout northwestern Ontario, which is generally accepted as Keweenawan in age. In undetermined relations to these basic intrusions (of Keweenawan age) there are granitic intrusions apparently to be correlated in age with the intrusions at Killarney and Cutler[1], known to be younger than the basic rocks. These acid intrusions were observed cutting the Bruce and Cobalt series in both Hess and Moncrieff townships. The relations are very clearly exposed along the tote road about a mile northeast from lake Geneva, where recent fires have exposed the rocks. On the accompanying map (No. 1865) this young intrusion, supposedly of Keweenawan age, has not always been separated from the old Laurentian granite, for the two rocks are very similar in appearance, and the distinction could not be made until most of the area had been mapped. However, enough distinction has been made on the map clearly to indicate that certain parts are underlain by the younger intrusive; and other parts have been mapped as areas of the older acid intrusive. The unmistakable intrusive relations are as follows: a very coarse-grained syenite porphyry in apophyses cuts across an interbedded conglomerate and greywacke series. The apophyses are both parallel to the bedding of the sediments and cut it transversely. The sediments show the effect of contact metamorphism in the following ways: in some places the quartzitic layers of the greywacke have been converted into gneiss; slaty layers have been changed into mica schists; the boulders of conglomerate have

[1] Collins, W. H., Geol. Surv., Can., Mus. Bull. 22.

been elongated until the girth is only 10 per cent of the length. Places were found in which a streaked gneiss intruded by syenite dykes was broken at right angles to the surface, so that the cross-section of the long gneissic streaks was oval, and the shape of the inclusions was pencil-shaped and not tabular, which, taken into consideration with the less severely metamorphosed conglomerates farther from the contact zone, showed that what appears to be a basal complex is really a Huronian conglomerate affected by contact metamorphism. In such places the conglomerate and greywacke cannot be traced directly into slightly metamorphosed Huronian formations, but underlie with synclinal structure a great hill of Lorrain quartzite, on the other side of which, completing the syncline, Cobalt conglomerate is identified. However, in the southeast corner of lot 3, con. IV, Moncrieff tp., a syenite porphyry dyke intrudes the Serpent formation which immediately underlies the Cobalt conglomerate. The writer feels that there can be no question as to either the identity of the conglomerate or the intrusive character of the contact.

Pleistocene

The general geology of the Pleistocene of Sudbury district is in striking contrast with the glaciated areas to the south. In Geneva area no boulder clay was seen, and the drift is composed of boulders, gravel, and sands. In many places great masses of granite have been moved only a short distance from their native spot. Perched boulders, regardless of topographic relations, are common, even on the summits of high hills or in the middle of swamps. However, the greater part of the Pleistocene consists of sand-plains and sandy drift covering lowlands and gentle slopes. In certain places sandy deposits contain kettle-holes. In other places deposits have an irregular and abrupt ending without relation to running water, a clear indication that they owe their origin neither to post-glacial water sorting nor to glacial out-wash deposition, but that they represent the glacial drift contained in the ice-sheets at that particular place. Apparently some of these flat areas are plains of glacial deposition. The constitution of these deposits indicates that near their source the ice-sheets contained chiefly sandy drift, but in their advance accumulated a higher proportion of clay. Geneva area, therefore, is an example of a glaciated area of crystalline rocks near the gathering ground of the continental ice-sheets.

General Geological Relationships

The Geneva area lies about midway between the northern edge of the nickel basin of Sudbury and the southern border of Onaping map-area and is almost due north of the western edge of the Sudbury norite. The rocks of this region have been mapped by A. P. Coleman[1], who seems to have relied largely upon the map of R. Bell[2]. In neither of these preceding maps was any distinction made between the bedded volcanic rocks and the sedimentary formations, nor between the acid intrusions of different ages. The rocks of the Geneva area serve to link the north shore surveys with the survey of the Onaping sheet[3].

In going north from Geneva to Lower Onaping lake and over to the southern borders of the Onaping map-area another syncline containing Huronian rocks was found to lie across part of Lower Onaping lake. This syncline is bounded on the south, east, and part of the northern sides by faults and on part of the northern side by acid intrusions. The western end of the syncline was not mapped. The Huronian rocks in this area are so different from rocks in the Geneva area that definite correlation was not successful, but the following observations were made: on the northern shore of Lower Onaping lake is a high mass of Lorrain quartzite, to the south side of which is a clastic formation not identified. No limestone formation was seen, the

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[1] Coleman, A. P., 14th Ann. Rept., Ont. Bureau of Mines, 1905, pt. 3.
[2] Geol. Surv., Can., Sheet No. 130, Sudbury Sheet, 1891.
[3] Geol. Surv., Can., Map 179A, 1917, W. H. Collins and assistants.

pre-Lorrain formations consisting of an alternation of greywacke, quartzite, and pebbly conglomerate are exposed for several miles along the shores. A characteristic of the clastic materials is the bright pink colour due to the abundance of pink feldspar grains or pink granite pebbles. The Gowganda formation might, naturally, be looked for underlying the Lorrain quartzite here as elsewhere. However, there are certain typical rocks—such as slate conglomerate—characteristic of the Gowganda which do not seem to be represented on Lower Onaping lake; nor does the formation contain many lenses of boulders. There is no phase consisting of well-bedded greywacke containing scattered pebbles and boulders as there is in the Gowganda formation. The writer, therefore, believes that the Gowganda formation is wanting at Lower Onaping lake, where greywacke lies many hundreds of feet beneath the Lorrain quartzite, and where large bands of arkosic quartzite are interbedded with pebbly conglomerate and thick beds of well laminated greywacke. This group of greywacke, arkosic quartzite, and conglomerate is thought to be part of the Serpent formation, but further exploration may modify this view.

Relation of the Geneva Area to the Sudbury Nickel Basin. The Canadian Pacific railway, running south of Geneva area and north of the Sudbury nickel basin, affords a convenient means of examining the country rock. There are apparently no recognizable sediments nor any recurrence of the younger acid intrusions, but remnants of gneisses in apparent synclines seem to represent highly metamorphosed sediments intruded by granite. If the granite is—as it appears to be—the older acid intrusive, the banded gneiss is of pre-Huronian age. The intrusive rock shows the effect of assimilation, being in places quartzitic, for instance near Mileage 106½, which is well within an area of intruded gneiss. Again the acid rock becomes pale coloured, syenitic, almost pure feldspar at Mileage 104½, also within an area of gneiss. At Mileage 103·9 a half mile of olivine diabase is succeeded by the Sudbury norite. A granite agglomerate which occurs in many places between Cartier and Windy Lake stations, and which may be mistaken for a conglomerate, is due, probably, to the intrusion of diabase along a fault zone of crush breccia through the granite.

PALÆOZOIC STRATIGRAPHY OF PAGWACHUAN, LOWER KENOGAMI, AND LOWER ALBANY RIVERS

By M. Y. Williams

CONTENTS

Illustration

INTRODUCTION

From July 25 until September 16, the writer was engaged in an examination of the stratigraphy along the water route used by fur traders and prospectors, between Pagwa on the National railway and Fort Albany on James bay. This is the only uninterrupted water route from rail to tidewater on the great inland sea, and is used during the high water in the spring to transport supplies by means of 15-ton scows down to the various trading posts of the Revillon Freres fur trading company. Lately the Hudson Bay ports on the Albany River system have also been supplied, in part, by this means. Revillon Freres have two large power boats on the river to assist in handling their fleet of scows, which are built at Pagwa from British Columbia lumber, and broken up for building purposes down river. Two fleets are usually taken down stream, the power boats wintering either near the head of the Albany estuary or at English River post. During the summer of 1920 men were employed by Revillon Freres to blast boulders out of the Pagwachuan and Kenogami rivers. As a result, there is no obstruction during high water for shallow draft boats, between Pagwa and Fort Albany. The route is practicable for canoes throughout the open season, although the Pagwachuan (meaning shallow) has long stretches of bars and flat limestone which make transportation of loaded canoes very laborious during low water. There are only two rapids of consequence on the route, both being on the lower Albany, one about 5 miles below Upper Fishing creek, and the other known as the Upper Bill fall in the estuary on the north side of Big island near its head. The former rapid is easily run but Upper Big fall is dangerous at all heights of water unless properly understood. Numerous riffles occur on various stretches of the river, but these are easily run by experienced canoemen.

The party consisted of a student assistant, a guide, and the writer. The assistant and guide travelled in an 18-foot canoe equipped with an Evinrude engine, and the writer travelled in a 16-foot canoe, which was towed by the larger boat when the water was suitable. Two months' supplies of provisions and fuel were carried at the start, but the water in the Pagwachuan was so shallow that serious damage was done the canoes by hauling them with their heavy loads over bars and flat-lying limestone. As a result of the condition of the canoes and the very low water, the work planned for the side streams was given up, excepting that the Albany branch was explored for 25 miles above the Forks.

Supplies were cached at intervals from English River post (Mammawemattawa) down, the small canoe and all surplus supplies being left on the north bank of the river opposite the foot of Fishing Creek island.

Rock outcrops were located as closely as possible in relation to points identified along the river; fossils were collected and the attitude of the strata noted wherever there were appreciable departures in dip from the horizontal.

W. J. Embury was an efficient assistant and canoeman, and Victor K. Stevens also assisted in geological work when required as well as acting as an efficient guide and cook.

GENERAL CHARACTER OF DISTRICT

The route followed leads across a plain of remarkable regularity, the slope of whose surface to the north averages less than 2 feet per mile. The river has cut down through the surficial deposits to an average depth of about 40 feet, although the incised trench is considerably deeper at some localities, for example at Pagwa, which is in the region of greater diversity of surface, characteristic of areas underlain by Precambrian rocks, and again on the Albany above the Forks, where the glacial till, and outwash materials are thicker than the average for such deposits elsewhere. In general there is a river terrace from 10 to 30 feet above low-water level, this grading steeply upward to the main level of the plain. The river terrace is commonly covered with stands of white spruce, white birch, white or balsam poplar, or with a mixture of these with some scattered cedar, tamarack, ash, and jackpine. The general surface of the country is muskeg covered with sphagnum moss, laurel, and labrador tea, and sparsely studded with stunted black spruce. Isolated stands of ash and elm occur at the junction of Kebinakagami and Kenogami rivers and below the mouth of Little Current river, as already described by Wilson[1].

Rock outcrops, whether of Precambrian granite or Palæozoic limestone, rise in general but little above mean water level, and in many cases are exposed only at low

[1] Wilson, W. J., "Report on a portion of Algoma and Thunder Bay districts," 1909, p. 33.

water. It is noteworthy, however, that the rocks rising highest in the banks of the rivers, are the soft, red and green shales. These beds are exposed in the banks of the Kenogami to an elevation of 30 feet and along the Albany above the Forks to 70 feet.

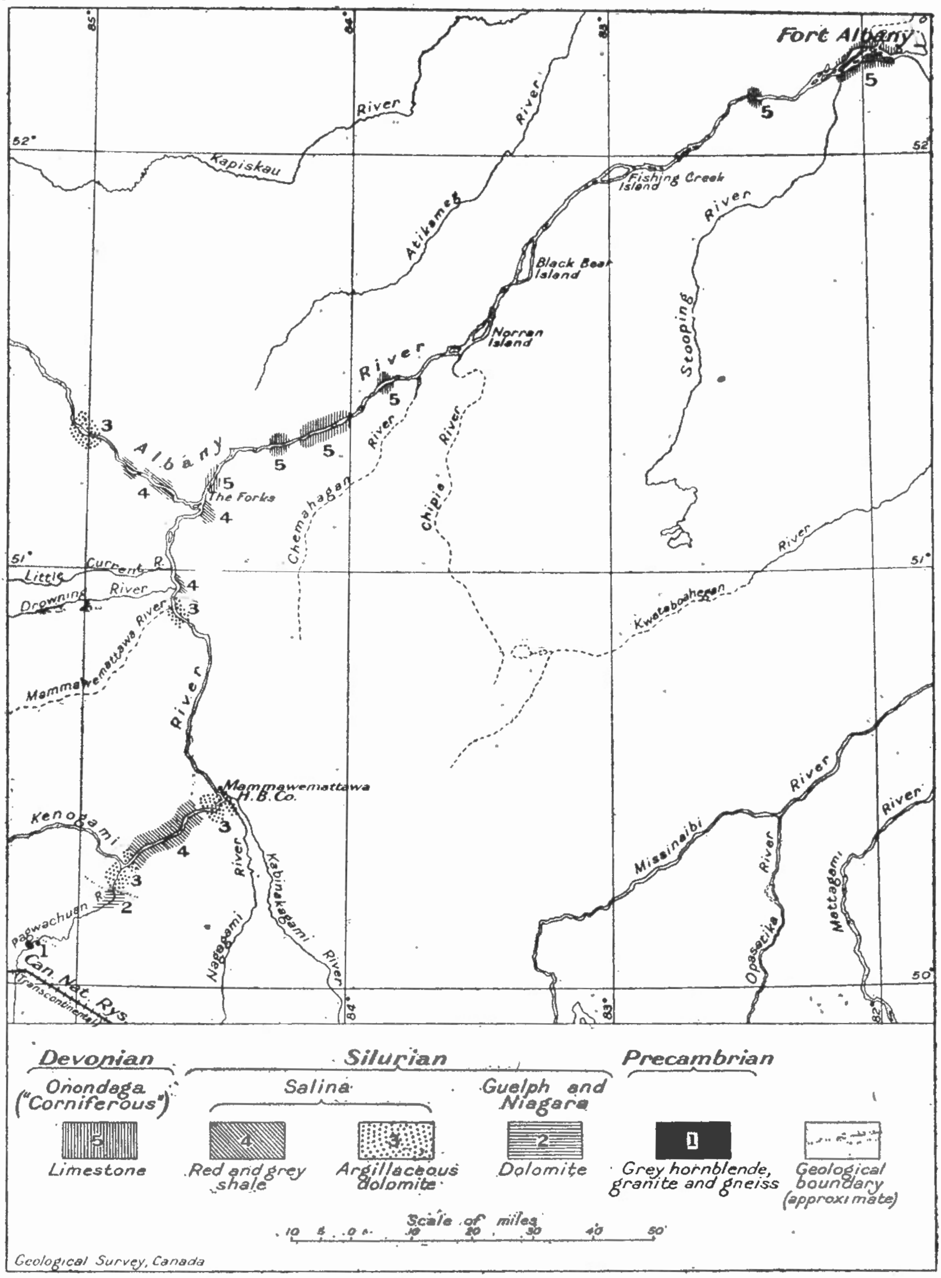

Figure 1. Diagram showing the Palæozoic and Precambrian geology along the lower Pagwachuan, Kenogami, and Albany rivers, Ontario.

The Palæozoic rocks dip in general downstream at slightly higher degree than the fall of the river, and thus in travelling down to the bay the section is crossed in ascending order.

GEOLOGICAL SUMMARY

Table of Formations

Quaternary		Recent soils. Marine silts, up to 380 feet above sea-level at Mammawemattawa. Boulder clay, and fluvioglacial sands and gravels. Slits and lignites, probably interglacial. Covered interval, probably boulder clay.
Devonian		Onondaga buff and grey limestone.
Silurian	Salina	Red shales and sandstones. Green shales and dolomites.
	Guelph Niagara	Grey and buff dolomite.
		Covered interval.
Precambrian		Grey hornblende granite and gneiss.

The geological formations of the region may be divided into three main divisions: the basal Precambrian crystalline rocks; the Palæozoic limestones and shales; and the unconsolidated glacial and post-glacial boulder clay, sands, gravel, peat beds, and soil.

The Precambrian rocks outcrop at two places down the Pagwachuan within 2 miles of the railway, in the form of glaciated knobs of grey granite gneiss.

The Palæozoic formations may first be divided into rocks of Silurian and Devonian age, the Silurian being represented by the outcrops along Pagwachuan and Kenogami rivers, and along the Albany above the Forks. Below the Forks all outcrops are of Devonian age.

Glacial clays and outwash sands and gravels occur throughout the region south of James bay; the lignite beds occur at the Forks, and about 20 miles above the Forks on Albany river; and the marine silts occur a short distance from Mammawemattawa and northward to the bay.

DETAILED GEOLOGY

Silurian Formations

The oldest sedimentary rocks seen on the trip are exposed in the bed of the Pagwachuan about 8 miles below the lowest Precambrian outcrop. The rock is flat-lying, cream-coloured limestone. A fragment lying on the outcrop is composed of comminuted shell fragments, including brachiopods and bryozoa. Rhynchonellid forms occur but all are too fragmentary for identification. A fragment, which probably came from this horizon, contained *Orthis flabellites*.

Flat-lying limestone occupies almost the whole bed of the Pagwachuan from a point about 1½ miles above the mouth of a large stream from the south (which enters the river about 7½ miles in a straight line from its mouth) to a sharp bend about one-half mile below the small rapid. This rock contains much chert, and from slabs lying on the outcrop the following fossils were collected:

Enterolasma caliculum (*Hall*)*?*
Palæocyclus praeacutus Edwards and Haime?
Chonetes edmundsi Williams.
Camarotoechia? sp. nov.; and a species of ostracod.

Limestone from the bed of the Pagwachuan about 1½ miles above the rapid contains the following species of fossils:

Favosites favosus (Goldfuss);
Halysites catenularia (Linnaeus);
Leptaena rhomboidalis (Wilckens);
Orthis flabellites Foerste;
Dalmanella elegantula (Dalman);
Camarotoechia? n. sp.; and a species of ostracod.

The faunas, as listed above, indicate Niagara age, and suggest that the limestone be correlated approximately with the Lockport formation of New York state and southwestern Ontario.

Near the lower extension of the rock outcrop as described, and just above the small island in the river, the limestone contains a small variety of *Pycnostylus guelphensis* Whiteaves. This species is characteristic of the lower horizons of the Guelph formation in southwestern Ontario, but it also occurs sparingly in the coral reefs at the top of the Lockport formation. It suggests late Niagara or early Guelph age.

Salina

Fine-grained, pea-green dolomite is generally exposed in the bed of the Pagwachuan for about 3 miles above its mouth. The dolomite is closely laminated and contains thin, tabular crystals of calcite. The general attitude is nearly flat or gently dipping downstream. Local dips occur up to 3 or 4 degrees, but the direction of these is commonly reversed within a few yards. Much of the rock is closely jointed. At one point the main vertical jointing strikes north and south and is spaced about 18 inches apart, but the main joints are divided in two or more parallel fractures about 2 inches apart. Secondary jointing runs east and west. Similar pea-green dolomite occurs on Albany river at the rapids opposite the mouth of Upper Sturgeon river. Here the lower beds are thick, the upper beds being thinner and grading upward into calcareous shales. The dolomites are laminated and unfossiliferous, but contain remains of "salt hoppers" or pseudomorphs after salt cubes. The dolomite exposed is about 20 feet thick.

On both Pagwachuan and Albany rivers the dolomite grades upward into pea-green shale with interbeds of dolomite. Salt hoppers occur in these beds as exposed a short distance below the mouth of the Pagwachuan. The green shale is probably about 50 feet thick.

Above the green shale, are red, nodular shales, with calcareous interbeds. These red shales are exposed in a 30 to 40-foot section for about 10 miles along the Kenogami midway between the mouth of Pagwachuan river and English River post, and also about 2 miles above the mouth of Nagagami river. Small exposures of these shales occur on Kenogami river opposite the mouth of Drowning river, and also at the Forks. On Albany river, red shales are exposed almost continuously for from 5 to 17 miles above the Forks, and rise in banks 65 feet or more in height. The total thickness of red shales is probably about 100 feet. About 5 feet of green dolomitic shale occurs approximately 40 feet above the base of the red shales, at their upper exposures on Kenogami river. This probably is a part of a series of green shales and yellow limestones occurring in the east bank of the river at the Forks, where the section is in ascending order—firm red shale 5 feet; green and yellowish shale about 10 feet; yellow oolitic dolomite 4 feet; firm yellow dolomite 5 feet; red shale 3 to 4 feet exposed. The oolitic dolomite is full of spherules of calcite about one-tenth inch in diameter, which dissolve on weathering, the dolomite in consequence becoming perforated with more or less spherical openings[1].

Exposures of yellow limestone, probably belonging near the horizon of the oolites, occur in the river bed at the mouth of the Nagagami, at a bend in the Kenogami about 2 miles above the mouth of the Nagagami, and in the west bank of the Kenogami just above the mouth of Little Current river. At these localities, numerous lamellibranchs, and some corals and brachiopods occur in the limestone. These are generally poorly preserved, but include *Favosites hisingeri,* Milne-Edwards and Haime, undetermined brachiopods, and *Cypricardinia* sp. nov.

The red shales are the highest Silurian strata seen.

[1] Bell, R., Geol. Surv., Can.

Devonian Formations

Buff, unfossiliferous limestone occurs in a small bay on the east shore of Albany river opposite Oldman island, and again on a point about one mile below this island on the west bank of the river. In general characters this limestone is very similar to the basal beds of the Onondaga limestone overlying the gypsum deposits of Moose river. On evidence of its occurrence and characters, it may be considered the oldest Devonian limestone of Albany river, or of early Onondaga age. Down river other outcrops of Devonian limestone occur at intervals to a point within sight of Fort Albany. In general these may be considered as representing successively higher beds, and they will be described in order of occurrence.

Limestone fragments litter the shore for one-half mile along the north side of the river below Snake island, and rock is in place near the lower extent of the debris. The following fossils were collected from the upstream portion of the base rock: *Chonetes hemisphericus* Hall; *Centronella glansfagea* Hall?; *Dielasma calvini* (Hall and Whitfield); and *Spirifer arenosus* (Conrad). Fossils collected one-quarter mile farther down river, partly from rock in place and partly from debris, are as follows: *Orthothetes chemungensis* (Conrad)?; *Chonetes hemisphericus* Hall; *Orthis? eryna* Hall; *Atrypa reticularis* (Linnaeus); *Spirifer arenosus* (Conrad); *S. andaculus* (Conrad); and *Nucleospira concinna* Hall.

About 5 miles below Snake island, on the north side of the river, about 4 feet of thin-bedded dolomite is exposed dipping toward the river at about 4½ degrees. *Spirifer andaculus* (Conrad) is the commonest fossil, and *Stropheodonta patersoni* Hall? was found in a loose slab. Chert occurs in these beds.

Similar beds occur on the south side of the river about 8 miles below Snake island. The limestone contains some chert and striking with the river dips 3 or 4 degrees to the north. The following species of fossils were collected: *Zaphrentis ampla* Hall; *Favosites hemispherica* Yandell and Shumard?; *Stropheodonta hemispherica* Hall; *S. perplana* (Conrad); *S. perplana nervosa* Hall; *S. demissa* (Conrad); *Amphigenia elongata* Vanuxem; *Dielasma calvini* Hall and Whitfield; *Atrypa reticularis* (Linnaeus); *Spirifer duodenaria* (Hall); *S. macrus* Hall; *Reticularia fimbriata* (Conrad); *Conocardium cuneus* (Conrad); *Dalmanites anchiops* (Green); and *Proetus macrocephalus* Hall?

A 12-foot section of limestone, with a chert bed 10 feet up occurs on the south side of Albany river, just above the mouth of Tchakaskapug river. The dip is low but appears to be toward the river. The chert bed is highly fossiliferous and contains *Atrypa reticularis* (Linnaeus); *Pterinea chemungenis* (Conrad); and *Lyriopecten priamus* Hall?

Flat-lying limestone occurs below water in the river bed about 25 miles above Fort Albany, and also along shore and in the water from the upper end of Big island to the island southwest of Fort Albany. At Upper Big fall the following fossils were observed: *Atrypa reticularis* (Linnaeus); *Leptaena rhomboidalis* (Wilckens); *Conocardium cuneus* (Conrad); and large Pterinea-like forms. On the island east of Big island the following were observed: *Atrypa reticularis* (Linnaeus); *Leptaena rhomboidalis* Wilckens; casts of large lamellibranchs suggesting *Plethomytilus ponderosus* Hall; also cup corals and poorly preserved casts of gastropods.

A review of the fossil lists given above shows a predominating number of species characteristic of the Onondaga limestone of New York; so many of the species are also found in the Upper Helderberg and Oriskany formations that an early Onondaga age is suggested. Other diagnostic species, however, such as *Stropheodonta perplana nervosa; Orthothetes chemungensis; Dielasma calvini;* and *Spirifer andaculus* suggest Hamilton, Marcellus, or Portage-Chemung affinities. Such species as those last cited are in the minority, and probably developed earlier in this region than in New York state.

Quaternary Deposits

The Glacial, inter-Glacial, and post-Glacial deposits may be best illustrated by giving the following sections: A short distance below Pagwa, on the Pagwachuan, the boulder clay section is about 24 feet thick and is capped by fine, sandy silt, the sand hills rising to a considerable elevation. Along the Kenogami about 35 feet of glacial clay overlies the red Salina shale beds, with 2 or 3 feet of fine sand and clay forming the soil at the top. The section at English River post is as follows, from low water up: sandy till containing boulders up to 1 foot in diameter, 24 feet; dark grey plastic clay containing numerous specimens of *Saxicava rugosa* Linnaeus[1], 8 feet; crossbedded sand containing *S. rugosa,* 3 feet; argillaceous sand and gravel, 3 feet; sandy loam, 3 feet.

The section of unconsolidated strata at the Forks of the Albany is as follows, from the underlying red shale (top 25 feet above low water) up: grey silt with boulders mostly covered, 20 feet; yellow water-laid sand, containing fragments of limestone and Precambrian rocks, 12 feet; brown carbonaceous silt, 6 inches to 1½ feet; reddish silt containing *Mya truncata* Linnaeus, *Cardium ciliatum* Fabricus, *Saxicava rugosa* Linnaeus, *Macoma calcarea* Gmelin, *Buccinum tenue* Gray, 7 feet.

A section seen on the south side of Albany river, 21 or 22 miles above the Forks is as follows: brown, shaly clay from water up, 6 feet; 2-inch bed of compact lignite composed mostly of moss, 1½ feet of blue clay; 2-inch bed of lignite containing compressed roots, about 2 inches in greatest diameter and 15 inches long; a few feet of blue clay overlain by boulder clay.

Similar clay occurs in a 90-foot section on the north bank of the Albany a short distance below the lignite exposure. The bedding is clearly defined. Above this clay is 50 feet of boulder clay.

Samples of the clay 2 and 5 feet below the lignite beds and from the section across the river were submitted to J. Keele, Department of Mines, who reports that they represent silts which "appear to be derived from glacial drift by the washing of boulder clay and deposition as sediments in still water. These silts appear to have been leached, because they burn to a red colour, which indicates that their lime content is low.

"Owing to their leached condition, and to the fact that they underlie a lignite or peat bed, I would be inclined to class these sediments as interglacial."

It is possible that glacial till may occur at the base of the silts, but it was not visible. Should the lignite beds be the equivalent of the carbonaceous silt about 60 feet up in the section at the Forks, boulder clay clearly underlies them. R. Bell has reported lignite from the section at the Forks, and the writer found pieces of weathered lignite on the shore, but did not find it in place.

A section on the north side of Albany river, just east of Comb island, is as follows: glacial till extending 35 feet above water; bedded silt 3 feet, with *Mya truncata* Linnaeus and *Saxicava rugosa* Linnaeus in the lower layers.

A water-lain silt occurs in the north bank of the river across from Chipie island, about 10 feet above low water level. This contains: *Mya truncata* Linnaeus, *Cardium ciliatum* Fabricus, *Saxicava rugosa* Linnaeus, and *Macoma calcarea* Gmelin.

White boulder clay forms the conspicuous landmark known as Wilson's Bank, on the north shore of the river just above Upper Fishing creek. This bank is probably 60 feet high. A few feet of silt occurs at the top.

ECONOMIC POSSIBILITIES

Coursing Stone

Rough coursing stone is available in the banks of the rivers where solid rock outcrops occur. As quarries are opened, it is probable that stone suitable for dressing could also be obtained.

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[1] All Pleistocene fossils identified by E. J. Whittaker.

Brick

Common red brick of good quality may be made from the clays associated with lignite deposits, 20 miles above the Forks on Albany river. Mr. Keele reports: " The Albany River clays would make very good common red brick, but would not be suitable for the manufacture of higher grades of ware, as they are easily fusible." When it is remembered that one 90-foot section of this clay is exposed, it is clear there is plenty of raw material for bricks in this section of the north country.

Boulder clays could doubtless also be used locally for making brick, but they are in general too variable in character and contain too many boulders and stones.

Petroleum

In reporting upon the oil possibilities of virgin territory such as the James Bay basin, three main points must be considered. These are, indications of oil such as seepages or springs; the presence of sedimentary formations similar in character and age to those which bear oil elsewhere and the presence of impervious cover and rock structure favourable for oil accumulation.

In the region traversed, no oil seepages have been reported. However, as the outcrops are mostly in the river beds at or below water level, the seepages may easily have been overlooked or they may be obscured by gravel and sand. Of the formations observed, the lower Salina and upper Niagara or Guelph, and the Onondaga limestone contain oil elsewhere. The Onondaga limestone is, however, unpromising on the Albany, since it is everywhere exposed and eroded, the shale which elsewhere retains accumulations of oil in rock of this age having been long since removed. The Trenton limestone—oil-bearing in Ohio and elsewhere—underlies the younger rocks to the northwest, but its presence in the Albany region, though probable, is not certain.

Thus the dolomites of Guelph and Salina age are the most likely containers of petroleum pools. A sufficient cover is probably present to retain oil from the upper outcrops of red Salina shale on Kenogami, Albany, and the tributary rivers down to the bay, but conditions would appear more favourable both for cover and thickness of formations from the Forks down. It is probable also that the Trenton limestone underlies this region.

The general structure observed is too flat to favour the accumulations of large oil fields. There are, however, indications of fairly marked structure along Albany river, between Snake and Hat islands, where a syncline, with sides dipping at from 3 to 4 degrees, is followed by the river. Accompanying anticlines may be looked for to the north and south. Outcrops are so scattered that it is not possible to draw definite conclusions as to structures, but where the shale beds are well exposed, little indication of other than slight undulations is present.

Prospecting. Drilling machinery and supplies may be taken down river from the Canadian National railway at the crossing of the Pagwachuan near Pagwa station, by means of scows, provided that advantage be taken of high water in the spring. Should locations be made below the Forks, the scows could be used during the summer, except in very low water, for transporting the outfit to successively lower points as wells were completed. Arrangements could probably be made with Revillon Freres for bringing out machinery and other equipment the following spring, provided work were abandoned.

The first wells should be drilled to the Precambrian crystalline rocks, and samples of cuttings should be kept every 5 feet, and sent to the Geological Survey for examination. It is not probable that the total thickness of the sedimentary formations is more than 600 or 700 feet.

OIL POSSIBILITIES OF MANITOULIN ISLAND

By M. Y. Williams

CONTENTS

Illustrations

INTRODUCTION

From June 5 until July 19, 1920, the writer was engaged in studying the geological structure of the eastern half of Manitoulin island, and in collecting other information bearing upon the possibilities of oil production.

W. J. Embury and P. S. Warren were capable assistants, taking charge of levelling work, and assisting with geological traverses.

Field operations consisted of locating points at the base of the Manitoulin dolomite (the one definite horizon available over wide areas); obtaining the elevations of these points, and the tops of test wells (where logs were available) by means of lines of levels; and taking dips and strikes where practicable.

Among those to whom the writer is indebted for assistance and information, the following deserve special mention: Messrs. Malone and Smith of the Kyto Oil Company of Dayton, Ohio, H. C. Gordon of Parkersburg, W. Va., R. McMullen and J. Young of Manitowaning.

An oil spring was early discovered on Smith bay near the Indian village of Wekwemikong by the Jesuit missionaries, the pioneer among them being Father Poncet who spent the winter of 1648-49 on some part of the island.

In the early sixties, following the oil development at Titusville, Pa., and in southwestern Ontario, a Montreal company drilled five wells on Manitoulin island, the location being near the Smith Bay oil spring as indicated by tradition and field evidence.

This enterprise was abandoned on account of trouble between the drillers and the Indians.

"In 1905 the Northern Oil and Gas Company drilled several holes about 2 miles southeast of Wekwemikong"[1] and about 500 barrels of petroleum were produced. About the same time the Benedum-Trees Oil Company of Pittsburgh, Pa., were drilling in the vicinity of Manitowaning, several wells west of the town starting with considerable flows of oil. Drilling was also carried on near Gore Bay, and one unfinished well was drilled at Providence bay. The hard times of 1907 caused a cessation of drilling and no new development was undertaken until 1912 when Senator Pascal Poirier leased property south of Pike lake (about 3 miles southwest of Sheguiandah) and started to drill. Conditions arising from the Great War resulted in the closing down of these operations. The anxiety regarding oil supply at the close of the war once more focussed attention on Manitoulin island where several thousands of acres of oil leases were taken up in 1919 and 1920. The Kyto Oil Company re-leased the Poirier and adjacent properties and drilled three wells during the summer of 1920, and H. C. Gordon drilled two wells within the west margin of the property tested

[1] Malcolm, W., Geol. Surv., Can., Mem. 81, p. 85.

previously by Benedum-Trees. Results of the drilling during 1920 verified the previous reports from the same areas, viz., that oil occurred but not in commercial quantities. Valuable data were, however, obtained from the well records.

DESCRIPTION OF OIL PROSPECTS

The oil spring which attracted the Jesuits' attention is located on the south side of Smith bay about 4 miles from Wekwemikong. It is at the level of the water of the bay and is only about 10 feet from the shore, the waves washing into it in rough weather. A thick scum of oil covers the surface of the spring, which shows no visible flow.

Of the five wells drilled by the Montreal company in the early sixties[1], two were located near the oil spring mentioned, the caved-in pits being still visible. According to Hunt, the greatest depth reached was 524 feet, the log being as follows:

	Depth.
Soil, 32 feet	32 feet
Black shale, 100 feet	132 "
Limestone, 340 feet	472 "
Red sandstone, 52 feet	524 "

Saline water was struck at 192, and oil at 193, 248, and 270 feet, about 120 barrels of "excellent petroleum" being produced before the supply failed. A few barrels were obtained from another well, and two wells were not complete when the report was made.

Of the 1905 operations, the only evidence seen by the writer is an abandoned well located about 1¼ miles south of Wekwemikong. The ground around the well is saturated with oil for a radius of several yards, this evidence corroborating the statement of one of the Indians that the oil gushed for some time—or, until the well was shot. This was probably the well that produced most of the 500 barrels of oil mentioned by Malcolm.

A number of abandoned wells mark the area tested by Benedum-Trees and others in the vicinity of Manitowaning.

About 1½ miles west of Manitowaning, five old wells are located on lot 45 and one on lot 46, con. II, Assiginack tp. Of these three have oil in the casings at the present time and one was dipped for local use, by means of a tripod and sand pump until some time after 1912 when the tripod was blown down. Gas is bubbling up in three of these wells. Other wells noted are located as follows: one near the middle of the east side of lot 51, con. I, Assiginack; one in the northeast corner of the same lot; one near the middle of the east line of lot 20, con. I, Sheguiandah; and one 1¼ miles south of Manitowaning at the top of the hill above the bay. A well flowed gas for some years on the Tucker farm, lot 35, con. II, Assiginack, and a show of oil is reported from a well on lot 30, con. II, of the same township. There were other wells of which no record is available drilled in this vicinity.

The following logs were furnished by the Benedum-Trees Oil Company.

Well on James A. Watson farm, lot 46, con. I, Assiginack tp.

	Top	Bottom
Richmond limestone	6	130
Lorrain and Utica shale	130	305
Trenton limestone	455	566
Oil	464	474

On Lehman farm, lot 45, con. I, Assiginack tp. Drilled in 1907.

	Top	Bottom
Richmond limestone	14	130
Lorrain shale	130	410
Utica shale	410	430
Trenton limestone	430	..
Oil and gas	442	477

Note: This well is said to have produced 45 barrels of oil in 15 minutes.

[1] Hunt, T. S., Geol. Surv., Can., 1863-66, pp. 252-253.

Several wells were drilled during this period in the vicinity of Gore Bay, and several produced some oil. A well located near the wharf (now covered by a stable) at Providence bay is said by the driller, H. F. Slater of Toronto, to have struck the Trenton at about 960 feet, and to have penetrated about 100 feet when the tools were lost. This is the only record of a well drilled on the south side of the island.

The operations started by Senator Poirier about 1912 were principally centred about lots 3 and 4, cons. VIII and IX, Bidwell tp. At least twenty wells were drilled at this locality, of which eleven are said to have produced oil, and three to have had traces of oil. The drilling contractor stated that some of these wells produced as much as 27 barrels a day for a short time. Four are reported as "dry". Following is analysis of a sample of oil from Renny Byers' farm, lot 3, con. IX, Bidwell tp., Green bay, Manitoulin island.

Specific gravity at 15·5°C.—0·864

Distillation—continuous method.

First drop	100°C.
Up to 150°C.	10%
150°—200°C.	7%
200°—250°C.	8%
250°—300°C.	11%
300°—350°C.	18%
Residue (by difference)	46%

Calorific value:

Calories per gram, gross	10600
B.T.U. per lb. gross	19080

Sulphur:

0·2%

Poirier also drilled a well on the south end of lot 34, con. I, Howland tp., and another on the north end of lot 24, con. XI, Bidwell tp. Both of these wells are reported by local observers to have stopped in the Utica shale. A well which flows salt water is located near the road on lot 25, con. XI, Bidwell tp., but the data regarding the well or the source of the water are not at hand.

During 1920, three wells were drilled on the old Poirier leases, No. 1 being dry, No. 2 producing some oil with a small amount of salty, sulphur water, and No. 3 not being reported on. The top of the Trenton in No. 2 is 9 feet higher than in No. 1. The log of No. 1 as determined by the writer from samples is as follows:

Well drilled by Kyto Oil Company, near southeast corner of lot 4, con. IX, Bidwell tp.

	Feet	Depth Feet
Surface clay	5	5
Buff limestone	11	16
Grey shale	356	372
Black Utica shale	28	400
Light coloured, hard, semi-crystalline limestone	9	409
Show of oil at		418

Of the two wells drilled by H. C. Gordon, west of Manitowaning, No. 1 is situated about 70 yards from the east line and 90 yards from the north line of lot 50, con. II, Assiginack tp. The top of the well is about 10 feet below the base of the Manitoulin dolomite, of the Cataract formation, as exposed a few rods away, and the log, taken by the writer, from the samples, is as follows:

	Feet	Depth Feet
Richmond and Lorrain formations—		
Surface	5	5
Hard, dark grey limestone and shale	360	365
Grey shale	20	385
Utica—		
Brown shale	65	450
Black shale	15	465
Trenton—		
Grey semi-crystalline limestone	15	480
Calcareous shale	5	485
Grey semi-crystalline limestone	65	550

This well was dry except for a small show of gas.

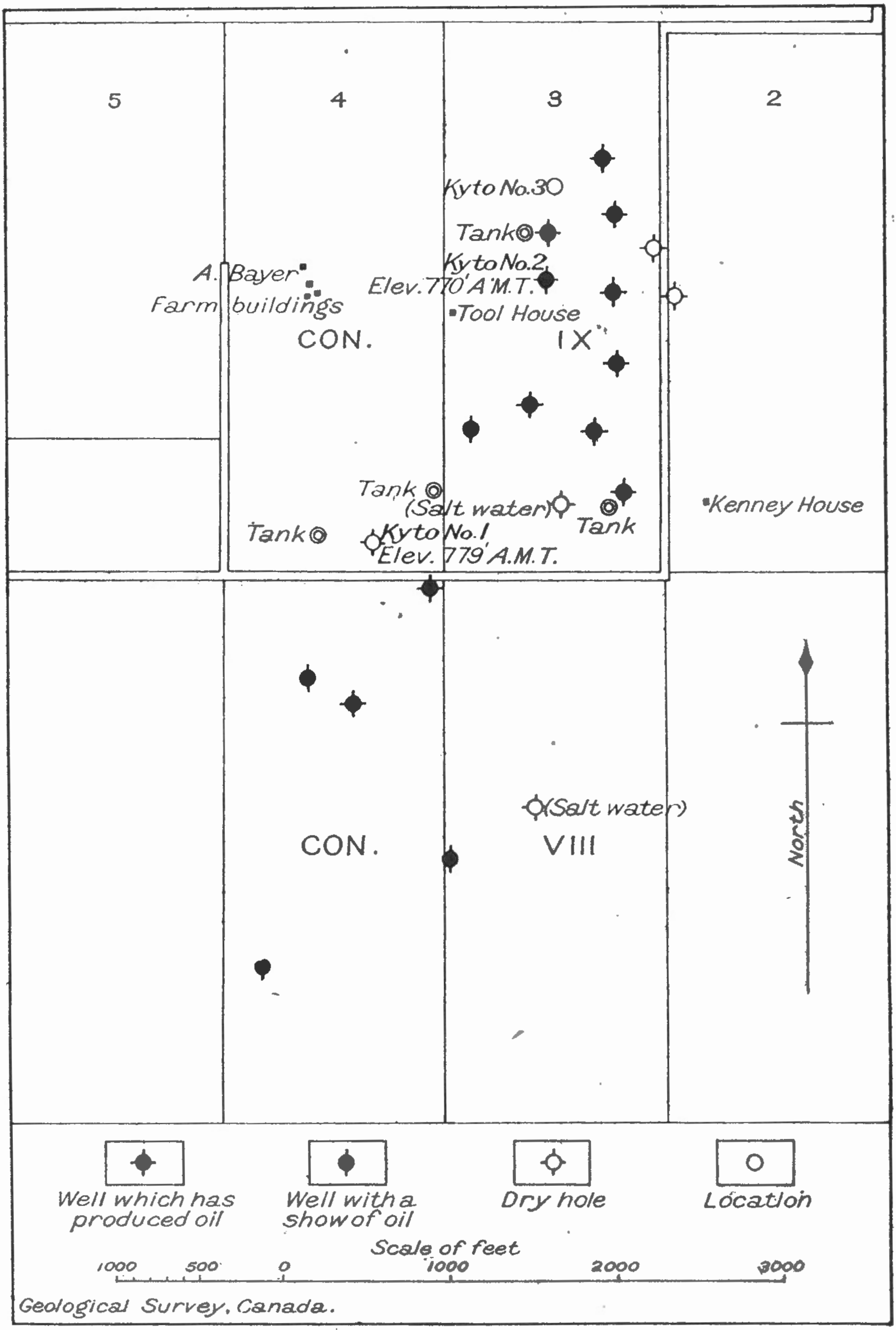

Figure 2. Diagram showing area prospected for oil in Bidwell township, Manitoulin island, Ontario, by Senator Poirier, 1912-1914, and by the Kyto Oil Company of Dayton, Ohio, 1920.

No. 2 well is located on lot 45, con. II, Assiginack tp., a short distance north of the main road and about 130 yards from the west side of the lot. The Trenton is reported to have been struck at about 445 feet from the surface. At about 17 feet in the Trenton limestone, considerable gas and a little oil were obtained. After shooting with dynamite, there was little change, but considerable salt water was reported. Following is an analysis of oil from: A—lot 44, con. II, Assiginack tp.; B—M. W. Brett's farm, lot 6, north side of Hall street, Gore Bay.

	A	B
Specific gravity—		
At 15.5°C.	0.877	0.881
Distillation—continuous—		
First drop	220°C.	180°C.
Up to 250°C.	10%	9%
250°—300°	20%	19%
300°—350°	18%	18%
Residue (by difference)	52%	54%

Note. The yield obtained between 300°C. and 350°C. is uncertain owing to the tube of the condenser being clogged with the wax formed. This holds for both samples.

	A	B
Calorific value—		
Calories per gram. gross	10790	10800
B. T. U. per pound gross	19430	19440
Sulphur	0.2%	0.2%

GEOLOGICAL STRUCTURE AND OIL OCCURRENCES

As seen on Figure 3, the best oil wells are located well within the syncline, the conditions being similar to those prevailing in the Trenton oil fields of Dover township, Kent county, Ont. Some water occurs in the wells of Manitoulin island but it is not a normal flow such as is found in the shallow fields of southwestern Ontario. It has not been definitely established, either, that the water and oil occur in the same beds, although that is probably the case.

The oil appears to be confined to the upper 20 feet of the Trenton limestone, suggesting the Utica shale as its source. The water present may have entered the formation through the relatively nearby outcropping of the limestone beneath the water of the North channel. The salt and sulphur content might readily be obtained from substances in the limestone such as entrapped sea salt and the oxidation products of iron pyrites.

FUTURE POSSIBILITIES

Large areas of Manitoulin island have never been tested for oil, particularly in the southern half of the island. Here, the complications arising from bay and surface water are minimized, and as water does not appear to have controlled oil accumulation, the lower structural areas are probably at least as promising as the higher areas. In but few cases has drilling been continued deep into the Trenton formation, and it is possible that oil may occur at lower horizons than those tested.

As structure is one of the controlling factors in oil accumulation, and is the factor most easily determined, prospectors should make every effort to unravel it. To do this, good logs are required, and these can best be worked out from samples of cuttings which the Geological Survey is always glad to receive. The depth to the top of the Trenton limestone (which is the same as the base of the black Utica shale) is the most important measurement to take, although in drilling on the south side of the island, all the changes of formations should be carefully recorded. A maximum of structural information may be obtained by drilling wells in groups of three, each well being at one of the angles of an equilateral triangle. In the writer's judgment the distance between the wells of a group on Manitoulin island should not be more than one mile. This distance is dependent upon the size of the folds, as only confusion results from three wells drilled in a triangle covering more than one side of a fold. Having obtained the surface elevation of three wells, and the depth in them to a known horizon, the dip and strike of the formation can be easily obtained,

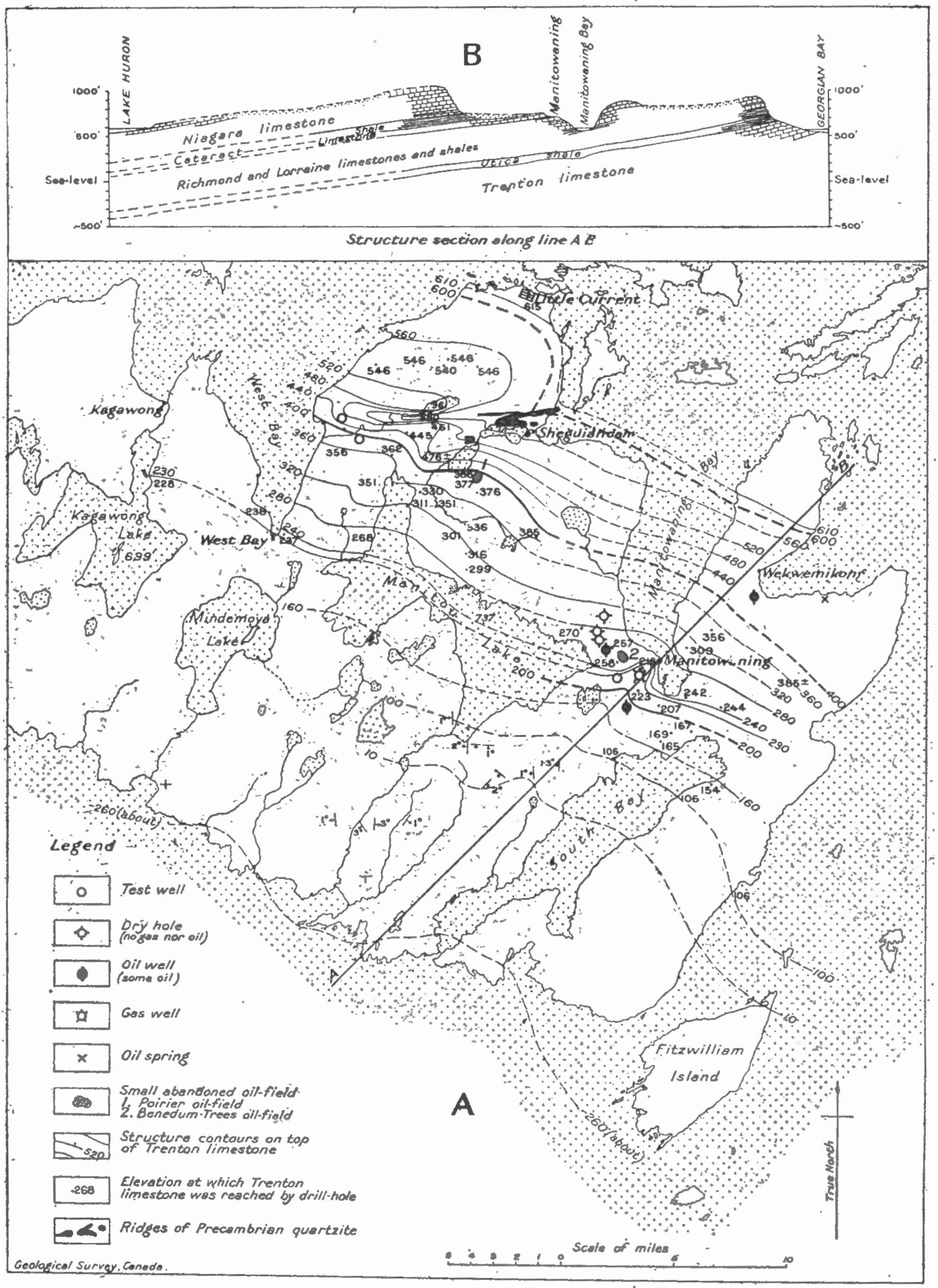

Figure 3. Diagram showing geological structure of the eastern end of Manitoulin island, Ontario.

A. Plan showing by means of sub-surface contour lines the supposed surface of Trenton limestone formation (the oil-bearing formation) as inferred from borings and other data. Elevations given for lakes, structure contours, and points at which the Trenton limestone was reached in drill-holes, referred to sea-level.

B. Vertical section of geological formation along line A-B.

provided the triangle covers but one slope or side of a fold. An extension of this method will give full structural information. Indications of gas, oil, or water should be considered in regard to the position of the well on the structure.

OIL-SHALE

Considerable areas of Utica shale have been mapped by Robt. Bell[1] as outcropping across the northern part of Howland township from Freer point south of Little Current to Sheguiandah, and across the Wekwemikong peninsula north of Wekwemikong village. The area south of Little Current has for the most part a very light covering of soil, the ditches along the road to Sheguiandah being blasted out of the shale here and there for nearly 2 miles south of Little Current.

Near Little Current the Utica is very thin, but to the south near the contact with the overlying Lorrain shale it is probably about 30 feet thick. Two samples of shale (A from Sheguiandah and B, from 2 miles south of Little Current) taken from the cuttings along the road south of Little Current are found on analysis to be as follows:

Proximate analysis—

	A	B
Moisture	0.3%	0.5%
Ash	63.2%	66.2%
Volatile matter	36.3%	33.0%
Nitrogen content	0.15%	0.20%
Calorific value, cals. per gram	960	950
B.T.U. per pound	1730	1710
Slow distillation (without steam)—		
Maximum temp.	600	580
Oil yield, gals. per ton—		
Imp.	4·8	8.1
U.S.	5·8	9.7
Gas yield, cubic foot per ton	620	850
C.V. gas B.T.U., cubic foot	620	460

Other exposures of Utica shale may be seen at Sheguiandah.

INVESTIGATION OF PEAT BOGS IN ONTARIO AND QUEBEC

By Aleph Anrep

The table on page 34 briefly summarizes the results of investigations made during the summer of 1920 of peat bogs in the provinces of Ontario and Quebec.

Edward M. Casey acted as field assistant.

The calculation of the contents of the Halton peat bog was made principally on its compact nature, but should the bog be swept by fire, it will produce less fuel and the quality will be unsuitable for manufacture on a commercial basis.

Reconnaissance investigations were made also of three small bogs located near Kossuth, about 8 miles east of Kitchener, varying from 2 to 8 feet in depth. The peat could be used locally for domestic fuel, but the bogs are too small to work commercially.

The extensive area of the southern portion of the Point Pelee peat bog is flooded, and being a government game reserve is not likely to be used for fuel; however, in the event of a pronounced scarcity of fuel, this part of the bog could be drained and worked.

The northern section of the bog, mostly dyked and drained, is used for agricultural purposes; onions are the principal crop and are becoming a large and profitable industry.

The Harrowsmith peat bog is deep and very well humified, can easily be drained, and is advantageously situated.

[1] Geol Surv., Can., Maps Nos. 605 and 570.

Several other small bogs between Harrowsmith and Wilmer are too small or too shallow to warrant exploiting. The peat is very well humified, and could be used for domestic purposes. North of Harrowsmith two small bogs, one in concession VIII, and one in concession IX, Portland township, are also too small or too shallow to justify the erection of machinery.

The Cameron bog, about 1 mile south of Verona, is between 8 and 9 miles long, and in certain places over 2 miles wide. This bog should be thoroughly investigated, for it apparently contains a very well humified fuel of a high cohesive nature, and the erection of machinery might be justified.

Certain Peat Bogs in Ontario and Quebec, Investigated in 1920

Province	Name of bog	Location: From nearest station	Location: Township	County	Area, approx.	Contents, approx.	Depth, feet	Remarks
					acres	tons		
Ontario	Beverly	$2\frac{1}{2}$ miles west of Freelton.	Beverly and Flamboro.	Wentworth	1,730	339,000	3 to 5	Well humified, principally formed of Carex plants lightly intermixed with hypnum mosses.
Ontario	Halton	Directly south of Guelph junction.	Nassagaweya	Halton	480	200,000	average 3	Heavily wooded. Very well humified and very compact, principally formed of Carex plants.
Ontario	Aberfoyle peat bog.	$\frac{1}{2}$ mile northeast of Aberfoyle.	Puslinch	Wellington	300	140,000	4 to 6	Well humified, principally formed of Carex plants lightly intermixed with hypnum mosses. Surface heavily wooded.
Ontario	Point Pelee	$6\frac{1}{2}$ miles southeast of Leamington.	Mersea	Essex	6,016	4,840,000	2 to 15	Fairly well humified, principally composed of Carex plants, the greater part of the surface of the bog is flooded.
Ontario	Harrowsmith	3 miles northwest of Harrowsmith junction.	Portland	Frontenac	378	396,000	4 to 20	Very well humified, will produce a very good peat fuel, principally formed of sphagnum mosses, slightly intermixed with Carex and Eriophorum.
Quebec	St. Luc	$1\frac{1}{2}$ miles north of Champlain station		Champlain	5,686	2,663,000	3 to 7	Well humified; principally formed of Carex plants slightly intermixed with Eriophorum.

Containing 25 per cent moisture, except in peat fit for litter, when the moisture is 20 per cent.

MESOZOIC CLAYS AND SANDS IN NORTHERN ONTARIO

By J. Keele

CONTENTS

Illustration

INTRODUCTION

During the summer of 1919 an examination was made of certain deposits of clay and sand on Mattagami river which proved to be of Lower Cretaceous age. A brief description of these deposits is given in Part G of the Summary Report 1919. Similar clays on Missinaibi river were examined by the writer in the summer of 1920.

The bottom of the Cretaceous beds has never been seen in outcrops, and borings have never penetrated the underlying rocks, but it is assumed that they rest on the upper Devonian because black and green Portage shales are found outcropping on the banks of Mattagami river in the neighbourhood of the Cretaceous beds. The view has hitherto been held that no pre-glacial rocks later than upper Devonian were ever laid down in northern Ontario, and although the existence of what now prove to be Cretaceous sediments has been known for a long time, they were erroneously classed by earlier writers as interglacial. These clays and sands are unquestionably pre-glacial and fossil plants found in them indicate that they are probably of Kootenay age, low down in the Cretaceous.

This discovery adds an entirely new chapter to the geology of Ontario, in which there took place submergence of the northern portion of the province, prolonged climatic conditions suitable for the weathering and decay of the Precambrian rocks, the erosion and sorting of the products of weathering from the Precambrian upland, and the deposition of these sediments.

CRETACEOUS DEPOSITS ON MISSINAIBI RIVER

The most extensive remnant of Cretaceous deposits known in northern Ontario occurs on the east bank of the Missanaibi, about 45 miles north of the Canadian National railway and about 4 miles above the mouth of Wabiskagami river. The Precambrian rock escarpment is about 6 miles south of these deposits.

The Cretaceous beds are exposed for half a mile along the lower part of the river bank, and in places they rise 30 feet above low-water level. The greater part of the deposit is made up of quartz sand, the particles of which are coated with white clay, but the sand is stained in places to a pink or yellow colour. The clay is of various colours, white, pink, grey, and yellow, but most of the exposed part is a mottled pink and white.

The whole deposit is overlain by the late glacial stony clay, some of which is pressed into and intermixed with the Cretaceous clay for a depth of several feet. Two small streams have cut through the overlying glacial drift and expose the lower clay. In one of the cuttings the drift rests directly on the white sand. The glacial clay has a high content of lime, some of which, redeposited in the white sands, has cemented the upper 3 or 4 feet so that they form a protective capping.

The arrangement of the Cretaceous material is irregular and although the sands are stratified in places, they generally form lens-like masses. The clay likewise occurs in lenses although such lenses may be banded in different colours. This banding does not appear to be related to bedding except that it is due to the varying quantity of iron oxide that accompanied the sediments during their deposition, and

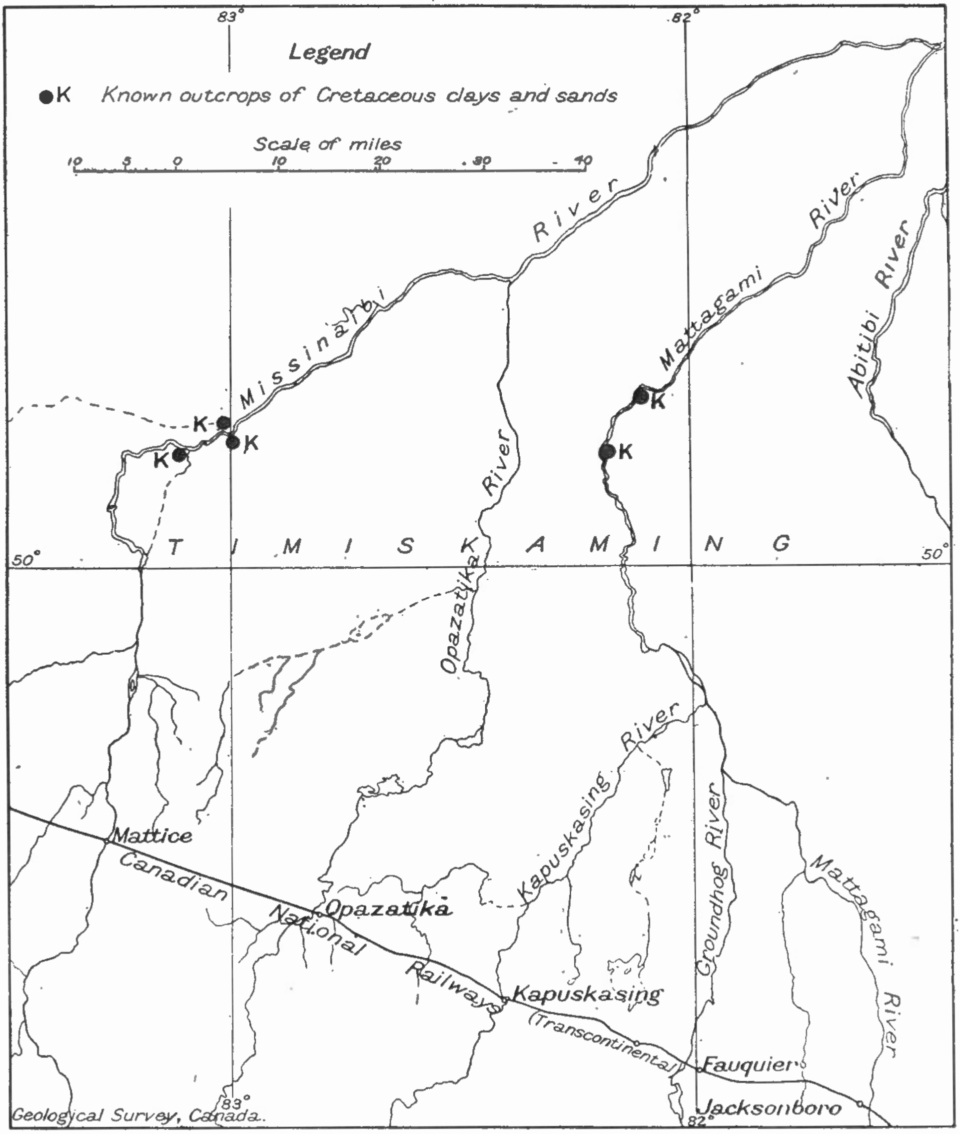

Figure 4. Diagram showing location of known outcrops of Cretaceous clays and sands, lower Missinaibi and Mattagami rivers, Ontario.

in that sense may be bedding. In the great masses of mottled clay, however, the discoloured portion and the white clay are mixed without any banding.

Similar outcrops on Wabiskagami river, about 2 miles to the west, were examined and described by J. M. Bell[1].

[1] Ont. Bureau of Mines, 1904, vol. XIII, pt. I, p. 160.

Economic Notes

Sands. The quartz sand particles are of rather coarse texture with angular outlines, and coated with white clay.

An average sample representing about 15 feet in thickness of the deposit was submitted to a washing test and found to yield 5 per cent of fine white clay. The analysis of grain size of the washed sand is as follows:

	Per cent
Retained on 10 mesh screen	8·27
" " 20 " "	19·47
" " 35 " "	38·04
" " 100 " "	32·44
" " 200 " "	1·33
Through 200	0·10

The chemical analysis of the washed sand made by A. Sadler of the Mines Branch is as follows:

	Per cent
Silica	97·72
Alumina	0·42
Iron oxide	0·32
Lime	0·28
Magnesia	0·21
Loss on ignition	0·12
	99·07

The iron content of the washed sand is rather high for the manufacture of white glass, but would be suitable for green bottle glass. The alumina content also is higher than desirable, for alumina has the effect of making the glass batch more difficult to melt. The grain size or texture of the sand is right for glass making, most of it being included between the 20 and 100 mesh screens.

The unwashed sand should be suitable for steel moulding foundry sand, for there is enough clay present to act as a binder, but not too much. The clay content is greater than 5 per cent in some parts of the sand deposit, and quite an appreciable amount of fine white clay could be obtained by washing the sand. There are also lenses of pink and yellowish sand, but the colours can be washed out and a white sand obtained.

It should be noted that there are no sands of this description either in the glacial or interglacial deposits of the region.

Properties, Composition, and Uses of the Clay

It would be difficult to mine any of the special parts of the deposit separately; the white clay, which is the most valuable part, merges into pink, yellow, or grey clay, and no great quantity of it could be extracted alone.

The mottled pink and white clay which makes up the greater part of the clay portion of the deposit was sampled for testing purposes. This clay is fairly plastic but gritty, and has good working and drying qualities. It burns to a pink coloured dense body at 1,100 degrees C. When burned to 1,300 degrees C.—the temperature at which firebrick are generally burned—the body is steel hard and of a greyish-pink colour. The total shrinkage at this temperature is 10 per cent and the absorption 13 per cent. This material does not begin to soften until subjected to a temperature of 1,670 degrees C., and would make a good commercial grade of firebrick or other refractory wares. If freed from coarse grit, it could be used for the manufacture of stoneware pottery.

The white clay is more refractory than the mottled, and when washed would probably be suitable for white floor and wall tile or for sanitary ware.

The chemical analysis of the clay is given below:

—	I	II	III	IV
Silica	58·90	55·17	53·78	53·10
Alumina	26·63	28·06	29·58	31·92
Ferric oxide	1·40	5·36	5·09	1·52
Titanic oxide	1·25	not determined	not determined	not determined
Lime	0·56	0·25	0·44	0·51
Magnesia	0·16	0·16	trace	trace
Manganese	0·01	not determined	not determined	not determined
Potash	0·31	0·26	trace	0·28
Soda	0·42	0·03	trace	0·54
Water	10·30	9·13	11·0	12·35

I. White clay, Missinaibi river. Analyst, M. F. Connor.
II. Mottled clay, Missinaibi river. Analyst, A. Sadler.
III. Mottled clay, Wabiskagami river. Ontario Bureau of Mines
IV. White clay; Mattagami river. Ontario Bureau of Mines.

The almost complete absence of lime, magnesia, and alkalis in these clays shows that they are very different materials from the glacial or interglacial clays where the sum of these impurities ranges from 15 to 30 per cent, and as they are all active fluxes, they make the glacial clays easily fusible.

No. IV is an exceptionally high-grade clay as regards refractoriness; it stands as high a temperature as English china-clay before deforming, and is the only example of a No. 1 fire-clay found in Canada.

Extent of the Crĕtaceous Deposits

Mesozoic clays, sands, and lignites of Cretaceous age were probably widespread in northern Ontario, but a long period of pre-glacial erosion and two distinct glaciations in Pleistocene times, as well as interglacial erosion, have well nigh obliterated them, and now only small remnants are found where the rivers have cut through the glacial debris deeply enough to expose them. Only five outcrops of these rocks are known on frequently travelled river routes, but there may be others on less travelled streams. The outcrops are all situated from 1 to 8 miles north of the border of the Precambrian rocks, and they probably overlie the upper Devonian.

The distance between the outcrops on Mattagami river and those on the Missinaibi is 40 miles. The most extensive deposit is that on the Missinaibi, near its tributary stream the Wabiskagami. This deposit has a visible thickness of about 30 feet between the river level and the overburden of glacial drift, but Mr. H. A. Calkins, an engineer who made several borings in the deposit, states that white clay was found 74 feet above the level of the river. The Cretaceous clay extends farther down than the lowest summer level of the river, and an unknown quantity must, therefore, be added to this thickness.

The beds on Wabiskagami river about 2 miles west of the Missinaibi outcrops were described by J. M. Bell, who states that "the deposit lies on the right or southern bank of the stream along which it was traceable for about 400 feet, rising above the summer level to a height of at least 10 feet. It is overlaid by a talus of soft boulder clay which in places entirely obscures the underlying material. The kaolinic clay is soft, plastic, and unctuous, generally almost white in colour, but sometimes stained deep hematite red or yellow by impregnation of iron oxide. Much of it is remarkably free from sand, but other parts contain lenses and small pocket-like areas composed of clear glassy quartz sand mixed with pure white kaolin."

In his report on the basin of Moose river, Toronto, 1890, Mr. E. B. Borron gives an account of borings he made on the banks of Coal brook, a small stream which enters the Missinaibi about 5½ miles below the foot of Long portage. The borings revealed a thickness of 45 feet of lignite seams and clay beds, 35 feet of which lay below water-level. All the clays are described as smooth and plastic, the colours being black, grey, white, reddish, and mottled. These clays were recognized by Mr. Borron as being quite different in colour and texture from, and a much higher grade of material than, the ordinary glacial clays of the region. This deposit was looked for by the writer in 1920, but could not be found although its position was precisely defined by a sketch map in Mr. Borron's report. An examination of the locality revealed the fact that Coal brook had undercut the portion of its bank composed of Cretaceous clay and caused the overlying glacial clay to slide into the bed of the brook and displace it, so that poplar trees nearly a foot in diameter are now growing on the former site of the outcrops.

It is difficult to estimate the dimensions of the remnants of Cretaceous clays exposed on the banks of the various rivers and streams, for only one dimension, the length of the outcrop along the stream bank, is available for measurement. The stony character of the glacial overburden renders it very difficult to bore through with the ordinary clay auger which can be carried in canoes and over portages, so that it is impossible to estimate the distance that the Cretaceous clays extend to at right angles to the outcrops on the river banks.

Wherever the Cretaceous clays were seen, the overburden of glacial drift is too heavy to remove, but there may be other occurrences where the overburden is not sc heavy.

Origin of the Sands and Clays

The Cretaceous sands and clays in northern Ontario were derived from the weathered products of the Precambrian rocks lying to the southward of the deposits.

The rocks exposed on the Missinaibi north of the railway belong principally to the Precambrian schist complex. The prevailing rock is a stratiform biotite gneiss, not necessarily the exact equivalent, but having a strong resemblance in appearance and geological relations to the Marshall Lake series. Well foliated hornblende gneisses of igneous origin are also exposed at intervals. The bedrock exposed along the canyon walls at Long portage is a binary granite and probably represents an acid differentiate on a large scale from an igneous mass. It is exposed for about a quarter of a mile along the canyon, and is flanked on the north and south by foliated hornblende gneisses. The granite is friable and appears to be softened by incipient kaolinization, and represents, probably, the lower part which lay beneath a mass of kaolinized rock, which has probably furnished the clay and quartz sand for the Cretaceous deposits farther north. On the Mattagami a wide band of highly kaolinized garnet gneiss occupies a similar position south of the Cretaceous deposits exposed on that river.[1]

There may be other bands of kaolinized rock similar to the above in this region, but kaolinized rock surfaces are easily eroded, whereas the surrounding harder rocks stand up as ridges. The universal glacial drift cover is thickest over the softer rocks, and consequently these soft rocks are seldom exposed by the stream cutting, which brings the hard rocks into view.

MADOC DISTRICT, ONTARIO

By M. E. Wilson

The geological field work of previous years in the region lying along the southern border of the Laurentian highlands of Quebec and southeastern Ontario was extended westward to the Madoc district, Ontario, in 1920. This region has long been noted not only for the variety and number of its mineral deposits but also for the presence of belts of conglomerate and other sediments belonging to what is generally known as the Hastings series, a group of rocks not known to be represented elsewhere in the

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[1] Ont. Bureau of Mines, 1920, vol. 29, pt. 2, p. 17.

Grenville-Precambrian subprovince. Although this region was examined geologically long ago in a reconnaissance way by MacFarlane[1] and Vennor[2]; and later in a local area including the villages of Madoc and Marmora by Coste[3] and more recently in a number of scattered areas by Miller and Knight[4]; nevertheless no attempt has been made, hitherto, to study the geology of this region continuously throughout an area covering several hundred square miles. For this reason and because of mining activity in the district, it was decided that the writer prepare a geological map of an area of approximately 650 square miles extending from the townships of Kaladar and Sheffield on the east to Belmont township on the west and from an east-west line through the village of Crookston (situated near the centre of Huntingdon township) on the south, to an east-west line through the village of Bannockburn (at the north end of Madoc township) on the north. In 1920 attention was directed mainly to the fluorspar deposits of the district and on that account areal mapping was carried on chiefly in those parts of the district where fluorspar deposits were known to be present.

The writer wishes to express his indebtedness to the mine owners and mine managers of the district, and especially to Mr. R. C. Bryden, manager of the Noyes mine; to Mr. Chas. Brent, manager of the Eldorado Mining and Milling Company; to Mr. George H. Gillespie of George H. Gillespie and Company; to Mr. C. M. Wallbridge; and to the late Stephen Wellington and his associate Mr. Munro.

The thanks of the Survey are also due to Mr. Donald Henderson, Mr. Chesley Pitt, Mr. Jas. O'Reilly, and other residents of the district for information given the writer regarding the various properties with which they were familiar.

Robert Ford accompanied the writer as field assistant during the season and performed the duties assigned him in a satisfactory manner.

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[1] MacFarlane, Thomas, "On the geology and economic minerals of the north riding of the county of Hastings, townships of Elzevir, Madoc, Marmora, Lake, and Tudor," Geol. Surv., Can., Rept. of Prog., 1863-66, pp, 91-113.

[2] Vennor, H. G., "On the geology and economic minerals of Hastings, Addington, and Peterborough counties, Ontario," Geol. Surv., Can., Rept. of Prog., 1866-69, pp. 143-171.

[3] Coste, E., Geol. Surv., Can., Ann., Rept., vol. I, 1885, pt. A.

[4] Miller, W. G., Knight, C. W., "The Pre-Cambrian geology of southeastern Ontario," Ann. Rept. Ont. Bureau of Mines, vol. XXII, pt. 2, 1914.

THE FLUORSPAR DEPOSITS OF MADOC DISTRICT, ONTARIO

By M. E. Wilson

CONTENTS

Illustrations

INTRODUCTION

The following description of the fluorspar deposits of Madoc district, Ontario, is based on examinations of these deposits made by the writer during the summer of 1920 while engaged in the geological investigation of the Madoc and Marmora map-areas.

That fluorspar-bearing veins were present in Madoc district was known to some of the local inhabitants more than thirty years ago, but these were not then regarded as commercially important. The first attempt to mine the mineral was made by the late Stephen Wellington who in 1905 put down a prospect pit 14 feet deep on the Bailey property. During the years following this operation a small amount of prospect work on the fluorspar deposits of the district was performed, but little interest was taken in the mineral until the year 1916 when owing to the world war the price paid for fluorspar rose to as much as $30 per ton. As a consequence of this increased demand the production of fluorspar from the Madoc district rose from no production in 1915 to 7,286 tons valued at $153,190 in 1918. Since 1918 the production has gradually declined. When the writer examined the fluorspar properties in 1920 there were six deposits on which mining operations were being performed, but the greater part of the production of the mineral was being derived from the two principal mines of the district, the Noyes and the Perry. Now, however, both of these properties are idle and active mining of fluorspar in the Madoc district has almost ceased.

PRODUCTION

The production of fluorspar from Madoc district since the year 1905 has been as follows:

Year	Tons	Value
1905	30	$ 150
1907	15	75
1910[1]	2	15
1916	1,283	10,146
1917	4,327	66,474
1918	7,286	153,190
1919	3,425	60,389
1920	3,704	67,381

[1] 1910-1920, from reports of the Ont. Bureau of Mines.

GEOGRAPHICAL POSITION AND DISTRIBUTION OF DEPOSITS

The village of Madoc, near which the deposits occur, is situated in the central part of southeastern Ontario about 25 miles north of the north shore of lake Ontario, and at the northern end of the Belleville-Madoc branch of the Grand Trunk railway. It lies 7 miles north of Ivanhoe station on the main line of the Canadian Pacific railway between Toronto and Montreal via Peterborough.

The deposits outcrop mainly in two localities: (1) the northern part of Huntingdon township; and (2) the southern part of concession I, Madoc township. Since nearly all the deposits in the first locality occur either in the vicinity of Moira lake or along the continuation of the Noyes-Perry fault which crosses Moira lake, they will be referred to collectively as the Moira Lake group. The deposits occurring in the southern part of concession I, Madoc township, on the other hand, will be designated the Lee-Miller group. The descriptions of the various properties composing these groups (pages 53-77) have been arranged in the order of their occurrence from south to north in the district and not in the order of their importance.

GEOLOGICAL RELATIONSHIPS

The geological formations with which the fluorspar deposits are associated belong to two principal groups: (1) a Precambrian basal complex; and (2) flat-lying or nearly flat-lying Palæozoic sediments belonging chiefly to the Black River formation, which rest unconformably on the irregular surface of the Precambrian.

The Precambrian basal complex consists of three subdivisions: (1) grey, banded, crystalline limestone, buff-weathering dolomite, and other sediments belonging to the Grenville or Grenville and Hastings series; (2) masses of gabbro, diorite, and related intrusives; and (3) batholithic masses of red to pink (Moira) granite or syenite intruding the rocks of subdivisions 1 and 2.

The Palæozoic sediments that overlie the Precambrian complex consist in succession from the base upward of: (1) red and grey, calcareous arkose and sandstone alternating with thin, uniform beds of red to grey lithographic limestone; and (2) massive beds of coarsely crystallized, grey limestone. The total thickness of the formation is not less than 150 feet.

The fluorspar-bearing veins of the Lee-Miller group, with the exception of the outlying Herrington deposit on lot 2, concession XII, Huntingdon township, all occur in the Palæozoic. The veins of the Moira Lake group on the other hand intersect the Palæozoic only at the southeast and northwest extremities of the zone, the most important deposits, those on the Noyes, the Perry, the Rogers, and the Kane properties being in the Precambrian.

GENERAL CHARACTER OF DEPOSITS

The fluorspar deposits of the Madoc district are all veins occupying fault fissures of post-Ordovician age. They consist chiefly of fluorspar and barite, or fluorspar, barite, and calcite intermingled or interbanded in varying proportions. The less common minerals present are celestite, quartz, pyrite, marcasite, chalcopyrite, tetrahedrite, malachite, and elaterite, but all of these with the exception of the celestite are quantitatively unimportant.

The most characteristic features exhibited by these veins are the presence of two ore-zones separated by a zone of fractured or brecciated wall-rock and of lenticular masses of ore usually situated where two such parallel ore zones unite. Where two ore zones are present, one is generally wide and the other relatively narrow. The width of the zone of fractured country rock intervening between the ore zones ranges from a few inches to 10 feet or more in proportion to the average width of the main vein. The lenses of ore that occur on the veins range from a few feet to 200 feet in length and from 2 feet to 17 feet in maximum width. The longer direction of the principal lenses that have so far been opened up on the Noyes-Perry vein all appear to extend diagonally down the vein towards the southeast. The structural explanation of this feature was not determined by the writer.

The material composing the fluorspar deposits occurs chiefly in two ways: (1) as alternating bands; or (2) as an irregular network forming the partitions between caverns. In vein material of the first variety cavities are relatively uncommon, whereas in vein material of the second class cavities form a large part of the total volume. On this account the two varieties of the ore may be appropriately designated for the purpose of description the "banded" and "cavernous" types respectively.

CHEMICAL COMPOSITION OF ORE

It has been previously noted that the material composing the fluorspar-bearing veins consists chiefly of varying proportions of fluorspar, barite, and calcite. Furthermore, the relative abundance of these minerals varies so greatly, even in adjacent parts of the same vein, that the grade of fluorspar produced from different properties or from the same property at different times varies considerably. The analyses contained in the following table indicate approximately, however, the grade of some of the material produced from the Noyes mine, the most important property, from the standpoint of production at least, so far developed in the district.

Analysis	I	II	III	IV	V	VI	VII
CaF_2 (Fluorspar)	80·68	84·35	74·05	80·24	73·52	81·81	76·61
$BaSO_4$ (Barite)	5·10	5·34	9·34	7·54	11·88	5·30	8·13
$CaCO_3$ (Calcite)	10·04	6·75	10·76	7·16	10·31	7·85	9·11
R_2O_3 (Alumina, ferric oxide, etc.)	2·00	2·10	3·00	1·20	1·20	1·88	3·07
SiO_2 (Silica)	2·33	1·37	3·60	3·07	2·40	2·97	2·74
Total	100·15	99·91	100·75	99·21	99·31	99·91	99·66

Nos. I to VI, typical shipments; Nos. VII, average of 16 shipments.
Analysis by Algoma Steel Corporation.

MINERALOGY

The minerals comprising the fluorspar veins, named in the order of their abundance, are: fluorspar, barite, calcite, celestite, quartz, marcasite, pyrite, chalcopyrite, tetrahedrite, malachite, and elaterite. The character and mode of occurrence of each of these are briefly described in the following paragraphs.

Fluorspar (CaF_2, Calcium 51·1 Per Cent, Fluorine 49·9 Per Cent)

This mineral occurs in the veins partly in the massive form and partly as crystals encrusting the walls of cavities.

The most common crystal forms of the fluorspar are the cube modified by the octahedron, but in some deposits the relative prominence of the two forms is reversed and the octahedron is modified by the cube. With the exception of the large, clear crystals that occur embedded in celestite in the Kane vein, the cubical crystals of the mineral generally have surfaces pitted with angular depressions owing to the presence within the larger crystal of numerous small cubes or cubes modified by the octahedron, intergrown in nearly parallel positions. In addition to the common forms the cube, a (100) and the octahedron, O (111) assumed by the mineral, the following have been observed by Dr. T. L. Walker on crystals from the Kane property; rhombic dodecahedron, d (110), tetrahexahedron, f (310), trisoctahedron, p (441), and icositetrahedron, B (322).[1]

The refractive index of the fluorspar according to a determination by C. W. Greenland is 1·4340[2].

[1] Fluorite from Madoc, Ontario; Am. Min., vol. IV, 1919, p. 95.
[2] Am. Min., vol. V, 1920, p. 211.

The colour is most commonly white, grey, or green, but honey-yellow, blue, purple, rose, and red varieties are also common. Some of the large, brilliant, clear crystals embedded in celestite in the Kane vein and the transparent, pale green crystals obtained from the deposit on the Perry property are exceptionally beautiful.

Barite ($BaSO_4$, Barium Oxide 65·7 Per Cent, Sulphur Trioxide, 34·3 Per Cent)

Barite, the mineral next in abundance to fluorspar, occurs chiefly in the massive form or in crystals, but columnar, nodular, fibrous, and ochreous varieties are also represented. The crystals are commonly tabular in form and range in size from plates an inch or more in diameter to minute tabulæ. Most of them project edgewise from a solid mass of barite which may have the form of a dome, a column, or a flat sheet. Where the mass is dome-shaped, the tabulæ are distributed either concentrically around the dome or parallel one another across the dome; where the barite is columnar the tabulæ are distributed radially around the column with their longer axis roughly parallel to the axis of the column[1], where they are developed on the surface of parallel sheets, the tabulæ generally occur in groups of one to six crystals distributed heterogeneously. The faces observed on the barite crystals included the forms, a (100), c (001), m (110), c (011), and a series of macrodomes. The nodular type of barite occurs in several of the fluorspar deposits of the district and was especially common in the Noyes vein. It consists of nodular or concretionary-like masses of resinous material in which a concentric structure can usually be observed. A specimen of this nodular barite was submitted to R. A. A. Johnston of the Mineralogical Division of the Geological Survey, who found that it contained a considerable proportion of bituminous material. The fibrous and ochreous varieties of barite are evidently uncommon forms, for they were observed in only one locality, the fibrous in an ore mass lying adjacent to the east vein on the Miller property and the ochreous in the dump adjacent to the Bailey shaft. The colour of the barite is most commonly white, but red to yellow phases were observed in the vein on the Noyes property. The crystallized barite composing the deposit on the Bailey property ranges in colour from cream-white and snow-white to pale blue. A specimen of this barite analysed by Dr. T. L. Walker was found to have the following composition:

BaO	43·78
SiO_2	13.95
CaO	0·98
MgO	1·01
Al_2O_3	1·92
Fe_2O_3	0·48
SO_3	36·94
H_2O	0·26
	99·32

Calcite ($CaCO_3$, Lime 56·0 Per Cent, Carbon Dioxide 44·0 Per Cent)

The calcite is generally white or grey in colour and occurs both in the massive form and in large, semi-translucent crystals up to 6 inches in diameter. In some of the veins that intersect the Palæozoic, nodular masses of calcite covered by a multitude of small projecting hexagonal pyramids were present.

Celestite ($SrSO_4$, Strontia 56·4 Per Cent, Sulphur Trioxide 43·6 Per Cent)

The celestite occurs partly as radial, fibrous aggregates up to several feet in diameter and partly as pale blue, transparent crystals projecting from the walls of cavities. The grey, fibrous variety of celestite has been found chiefly in the vein on the Kane property, where it contains numerous included crystals of brilliant transparent fluorspar suitable for optical purposes. The pale blue crystals of transparent celestite were observed by the writer on the 250-foot level in the Noyes property. They are

[1] Walker, T. L., Am. Min., vol. IV, 1919, p. 79.

from ½ inch to 1 inch in diameter and like the barite are tabular in habit. The forms observed on the crystals were:

c(001), d(102), O(011), and m(110).

Quartz (SiO_2, Silica)

Quartz was observed in only three of the fluorspar deposits, in all of which it occurred as a zone adhering to the wall of the vein and was encrusted on its outer surface with small projecting crystals having the form of the hexagonal prism terminated by the hexagonal pyramid.

Pyrite (FeS_2, Iron 46·6 Per Cent, Sulphur 53·4 Per Cent)

The sulphide of iron, pyrite, is not an abundant mineral in the fluorspar deposits but occurs here and there in most of the veins either in small aggregates enclosed in the fluorspar or as a thin encrustation on the fluorspar crystals. Examples of the latter mode of occurrence were especially abundant in the vein on the Noyes property. Well-formed crystals of the mineral are uncommon.

Marcasite (Composition the same as that of Pyrite)

Marcasite occurs in the fluorspar deposits as small flattened and striated five-sided crystals. It is not common in most of the veins and its presence is, therefore, merely of mineralogical interest.

Chalcopyrite ($CuFeS_2$, Copper 34·5 Per Cent, Iron 30·5 Per Cent, Sulphur 35 Per Cent)

Copper pyrites or chalcopyrite was noted to be present in a few of the veins, generally as a small aggregate enclosed in fluorspar. The largest mass of the mineral seen in the whole district occurred in association with barite in a small vein exposed in a prospect pit situated near the northeast corner of the east half of lot 2, concession I, Madoc township.

Tetrahedrite ($Cu_8Sb_2S_7$, Copper 52·1 Per Cent, Antimony 24·8 Per Cent, Sulphur 23·1 Per Cent)

Tetrahedrite or grey copper ore has been found in only one of the fluorspar deposits, that on the Bailey property. It occurs in small masses up to 3 inches or more in diameter enclosed in pale green fluorspar.[1]

Chalcocite (Cu_2S, Copper 79·8 Per Cent, Sulphur 20·2 Per Cent)

Chalcocite was not seen by the writer in any of the fluorspar deposits, but has been found on the dump on the Bailey property by Mr. A. L. Parson.[2]

Malachite ($CuCO_3\ Cu(OH)_2$, Cupric Oxide 71·9 Per Cent, Carbon Dioxide 19·9 Per Cent, Water 8·2 Per Cent)

Malachite was observed in only one locality, the northeast corner of lot 2, concession I, Madoc township, where it occurs as a bright green encrustation on chalcopyrite.

Elaterite (Carbon 86 Per Cent, Hydrogen 14 Per Cent)

Elaterite or elastic bitumen was found by Mr. Bryden, in 1918, in small quantities in the underground workings on the Noyes property.[3] It is a dark brown, soft material and occupies caverns in the interior portions of the vein.

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1 Johnston, R. A. A., Geol. Surv., Can., Sum. Rept., 1909, p. 252.
2 Personal communication.
3 Knight, C. W., Ann. Rept. Ont. Bureau of Mines, vol. XXVIII, pt. 1, 1919, pp. 90-93.

STRUCTURAL FEATURES

Faulting

That the fissures occupied by the fluorspar-bearing veins are related to faulting is indicated (1) by the abundance of fractured and brecciated wall-rock associated with the fissures, (2) by the slickensided and striated character of the wall-rock on either side of the vein, and (3) by the displacement of contacts observed in underground workings. The first and second of these features can be observed almost anywhere in the workings along the veins, but the third feature was seen only in the underground workings on the Noyes and Perry properties.

The displacement that has occurred along the Noyes-Perry vein is shown at the extreme southeast end of the underground workings on the Noyes property by the manner in which the contact between the Precambrian granite and the overlying Palæozoic limestone has been dislocated (Figure 8). Here the contact was encountered on the southwest side of the vein at a point approximately 40 feet lower than on the northeast side indicating apparently that the southwest side had been downthrown 40 feet with respect to the northeast side. The striæ on the walls of the vein, however, are not vertical but nearly horizontal and indicate, therefore, that the faulting in reality was in a horizontal direction and consisted either of a movement of the rock on the southwest side of the vein towards the northwest or of the rock on the northeast side towards the southeast. Since neither the slope of the Palæozoic-Precambrian contact at the point of dislocation nor the direction of movement along the fault plane is definitely known, the exact amount of displacement resulting from the fault movement cannot be determined, but it probably was not less than 100 feet and may have been considerably greater than this amount.

The evidence of displacement on the Perry property is the dislocation of the contact of the grey banded Precambrian limestone and an intruded mass of granite. The contact of this granite mass, which outcrops south of the vein and forms the wall-rock in the workings adjacent to No. 3 shaft (Figure 10) should under normal conditions cross the vein in a north-south direction so that in drifting along the vein to the southeast the limestone would be met first on the northwest side of the vein. In reality, however, the relationships were reversed at the end of the drift driven to the southeast from No. 3 shaft at the 140-foot level, for the wall-rock on the southwest was limestone, and on the northeast granite. Furthermore, since the striæ on the walls of the vein in this locality also are approximately horizontal it is evident that at this point, as on the Noyes property, either the rock on the southwest side of the vein has moved towards the northwest or that on the northeast side of vein has moved towards the southeast. When the writer last visited the Perry property in September, 1920, the limestone-granite contact was situated about 20 feet from the end of the drift on the southwest wall of vein, but had not yet been intersected on the northeast wall so that the amount of displacement along the vein was not determined, but it was at least greater than 20 feet.

Regional Structural Relationships of Veins

The fluorspar veins almost without exception trend in a northwesterly direction. The veins belonging to the Moira Lake group likewise are distributed in a northwesterly trending zone; the veins belonging to the Lee-Miller group, on the other hand, although individually trending in a northwesterly direction, lie in a zone trending only 15 degrees west of north (Figure 5).

The most striking structural feature exhibited by the fluorspar veins is the presence of horizontal or nearly horizontal striæ on the wall-rock of the veins belonging to the Moira Lake group. The well-developed character of these striæ, their presence on the wall-rock of every vein belonging to the group, and the absence of striæ in any other direction seem to indicate that all the displacement along these fissures was in a horizontal direction.

Owing to the secondary alteration along the outcrops of the veins of the Lee-Miller group and the shallow depth to which most of these veins have been followed, striæ were not seen on the wall-rock of many of these deposits, but wherever they were observed they had a vertical or nearly vertical attitude.

The phenomena described in the preceding paragraphs indicate that the fissures in which the fluorspar veins occur are very closely related in origin to the other fissures of the group to which they belong, but that the two groups in which the fissures occur are not only geographically separate from one another but have been formed by different movements of the earth's crust.

SECONDARY ALTERATION

The secondary alteration that has occurred along the outcrops of the fluorspar veins has been relatively small. It consists chiefly in the leaching away of the calcite in the vein material with the resultant breaking down of the ore into small fragments constituting what is known to the miners of the district as "gravel spar". In some properties this type of material has been found to extend to a depth of 40 feet.

It is confined almost entirely to the veins that intersect the Palæozoic and especially to those of the Lee-Miller group. It may be noted in this connexion that the pits and shafts on the veins in which the disintegrated fluorspar occurs, become dry in late summer. It is probable, therefore, that the depth to which the "gravel spar" descends is controlled by the depth of the groundwater level during the summer season.

In the Bailey property, a cavern containing stalagmites and stalactites of barite and fluorspar was met in a drift driven from the bottom of a shaft 35 feet in depth. Since this cavern also becomes dry in the late summer these forms are possibly not original but have been formed by the solution and redeposition of the vein material secondarily.

With the exception of a small amount of malachite formed on the surface of chalcopyrite in a vein situated at the northeast corner of lot 2, concession I, Madoc township, no minerals formed by secondary alteration were seen in any of the deposits and any change of this character that has occurred has been unimportant.

AGE

The age of the fluorspar-bearing veins cannot be definitely fixed within wide limits. It is known, of course, since they intersect Ordovician strata, that they have been formed since the Ordovician. It is probable also that the fault fissures occupied by the veins were formed either during the period of igneous activity that occurred during the late Devonian in eastern Canada, or at the time of the Appalachian revolution that took place at the close of the Palæozoic era. The time at which the fluorspar was deposited, however, whether immediately after the fissuring occurred, or more recently, cannot be determined without a knowledge of the way in which the deposits were formed.

ORIGIN

General Statement

Fluorspar occurs in so many different geological relationships as to indicate that it can be formed under all or nearly all physical conditions and that it, therefore, belongs to the class of minerals known as "persistent".[1] It is a common constituent of igneous rocks,[2] it has been observed in a number of pegmatite dykes belonging to the basal Precambrian complex of the Laurentian highlands of Ontario and Quebec[3], is

[1] Lindgren, W., "The relation of ore deposition to physical conditions," Econ. Geol., vol. II, 1907, pp. 105-107.

[2] Clarke, F. W., "Data of geochemistry," U.S.G.S. Bull. No. 695, p. 331.

[3] Barlow, A. E., Geol. Surv., Can., Ann. Rept., vol. X, 1897, p. 159.

DeSchmid, H. S., "Mica, its occurrence, exploitation, and use," Mines Branch, Dept. of Mines, Can., pp. 197 and 199.

abundant in the molybdenite-bearing segregations that occur in quartz syenite in the Quyon district, Quebec, and is a common accessory mineral in the mica-apatite and molybdenite-bearing pyroxenites of contact metamorphic origin that occur throughout the Grenville-Precambrian subprovince of southeastern Ontario and the adjacent parts of Quebec. It is also found in veins deposited in the deep vein zone and near the surface[1] and has been noted to be present in numerous localities in sedimentary rocks.[2]

The most important deposits of fluorspar from a commerical standpoint, however, are the veins that occur in Palæozoic sedimentary rocks in Durham and Derbyshire in England[3] and in southern Illinois and western Kentucky, in the United States; and it is to this class of deposit that the veins of the Madoc district belong.

Summary Statement of Theories

The theories that have been suggested to explain the origin of the fluorspar deposits of the Madoc type, although somewhat varied in detail all fall into four main classes according to the source from which the material composing the deposits or the solutions depositing the material is assumed to have been derived. These briefly stated are as follows:

(1) That the vein material has been concentrated from the adjacent sedimentary rocks and redeposited in fissures through the agency of the ordinary ground water circulation.

(2) That the vein material has been derived from the adjacent sedimentary rocks through the solvent action of ascending heated waters.

(3) That the lime contained in the fluorspar has been derived from the limestone wall-rock but that the fluorine and other elements composing the vein material have been brought up in solution from a magmatic source.

(4) That both the vein material and the solutions from which the vein material has been deposited are of magmatic origin.

The first of these theories is that proposed by Whitney to account for the origin of the lead and zinc deposits of Wisconsin[4] and subsequently applied to the fluorspar-bearing veins of southern Illinois and western Kentucky by Norwood,[5] Shaler[6] and Emmons.[7]

The second was suggested by W. S. Tangier Smith in his report on the lead, zinc, and fluorspar deposits of western Kentucky[8]. In this publication the presence of mica peridotite dykes which have the same general trend as one of the systems of fissures and which have probably been introduced at the time of the general faulting of the region, is cited as evidence that the waters by which the fluorspar was concentrated were probably ascending and hot.

The theory that the fluorspar has been formed by the interaction of fluorine compounds contained in ascending magmatic waters with the limestone composing the wall-rock of the veins has been advanced by Fohs in a number of publications on the fluorspar deposits of Kentucky.[9] Fohs suggests, following Bain, that the fluorine

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[1] Emmons, W. H., "A genetic classification of minerals," Econ. Geol., vol. III, 1908, pp. 611-627, and "Principles of economic geology," 1918.

[2] Andree, K., Eeber einige Vorkommen von Fluszpat in Sedimenten, Tsch. Min. und Pet. Mitt. Bd. XXVIII, 1909, S. 535-556.

[3] Carruthers, R. G., Pocock, R. W., and Wray, D. A., with contributions by H. Dewey and C. E. N. Bromehead, "Special report on the mineral resources of Great Britain." Memoirs of the Geological Survey, vol. IV, Fluorspar, 1917.

Egglestone, William Morley, "The occurrence and commercial uses of fluorspar," Trans. Inst. Min. Eng., vol. XXXV, 1907-08, pp. 236-268.

[4] Whitney, J. D., Geol. Surv., Wis., vol. I, 1862, pp. 388-406.

[5] Norwood, C. J., "Report of a reconnaissance in the lead region of Livingstone, Crittenden and Caldwell counties," Geol. Surv., Kentucky, pt. 7, vol. I, 2nd ser., 1876, pp. 461-64.

[6] Shaler, N. S., "On the origin of the galena deposits of the Upper Cambrian rocks of Kentucky," Geol. Surv. Kentucky, pt. 8, vol. II, 2nd ser., 1877, pp. 277-330.

[7] Emmons, S. F., Trans. Am. Inst., Min. Eng., vol. XXI, 1892-93, pp. 51-53.

[8] Ulrich, E. O., and Smith, W. S. Tangier, Prof., Paper, U.S.G.S., No. 36, 1905, pp. 150-54.

[9] Fohs, F. Julius, "Fluorspar deposits of Kentucky," Geol. Surv., Kentucky, 1907, pp. 61-63, Econ. Geol., vol. V, 1910, pp. 377-386.

was probably brought up in the form of fluosilicates of zinc, lead, copper, iron, barium, and calcium.

According to the fourth theory the deposits are of magmatic origin and hence have been developed in a similar manner to that generally assumed to be the mode of origin of most other mineral deposits found in intimate association with igneous rocks. That the fluorspar veins of Kentucky might have originated in this manner was suggested as an alternative possibility by Tangier Smith; it was believed to be the most probable mode of origin for the fluorspar deposits of southern Illinois, by Bain,[1] and has been adopted by Wedd and Drabble[2] as on the whole most in accord with geological conditions in the case of the fluorspar deposits of Derbyshire.

Madoc District

Since some of the largest deposits of fluorspar in the Madoc district occur where the veins intersect batholithic masses of impermeable Precambrian granite or syenite, it is scarcely possible that the material composing the veins could have been concentrated from the adjacent wall-rock by ascending heated water or that the fluorspar could have been formed by the interaction of the lime in the wall-rock with fluorine in ascending magmatic waters. There are, therefore, only two theories that need be considered in endeavouring to ascertain the probable mode of origin of the Madoc fluorspar deposits, namely: that they have developed superficially by concentration from the Palæozoic limestone through the agency of the groundwater circulation or that they have been brought up from a deep-seated magmatic source by ascending heated waters.

Deposits of Superficial Origin. Field evidence that might be cited in support of the theory that the Madoc fluorspar deposits are superficial in origin, is as follows:

Throughout the region lying along the southern border of the Laurentian highlands of southeastern Ontario and the adjacent parts of Quebec, there are numerous veins consisting of varying proportions of galena, calcite, barite, sphalerite, and fluorspar that occur either in the basal Palæozoic formations that lie along the Precambrian border, or in the Precambrian in close proximity to the Palæozoic.[3] The occurrence of these deposits in these relationships and their apparent absence in the Precambrian remote from the Palæozoic border, and in the upper Palæozoic formations even where these have been abundantly fractured and faulted supports the assumption that the material composing the deposits has been derived from the Palæozoic sediments and has been deposited in fractures or other openings at their base through the agency of meteoric waters.[4]

The presence of numerous underground channels and caves in the Palæozoic limestone of the Madoc district, and the chasm-like openings that occur along the numerous joint planes intersecting the limestone indicate that much of this rock has been dissolved away by the groundwater circulation and hence may have been the source from which the minerals composing the fluorspar-bearing veins have been concentrated. Furthermore, the enormous quantities of water pumped from the mines and the effect of this pumping on the neighbouring wells proves that the

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[1] Bain, J. Foster, "Fluorspar deposits of southern Illinois," Bull. U.S.G.S., No. 255, 1905, pp. 66-67.

[2] Wedd, C. B., and Drabble, G. Cooper, "The fluorspar deposits of Derbyshire," Trans. Inst. of Min. Eng., 1907-8, pp. 521-525.

[3] Logan, W. E., Geology of Canada, 1863, pp. 516, 687-89.
Baker, M. B., "The geology of Kingston and vicinity," Ann. Rept. Ont. Bureau of Mines, vol. XXV, pt. 3, pp. 31-34.
Uglow, W. L., "Lead and zinc deposits in Ontario and eastern Canada," Ann. Rept. Ont. Bureau of Mines, vol. XXV, pt. 2.

[4] See Vennor, H. G., Geol. Surv., Can., Rept. of Prog., 1874-75, p. 163.

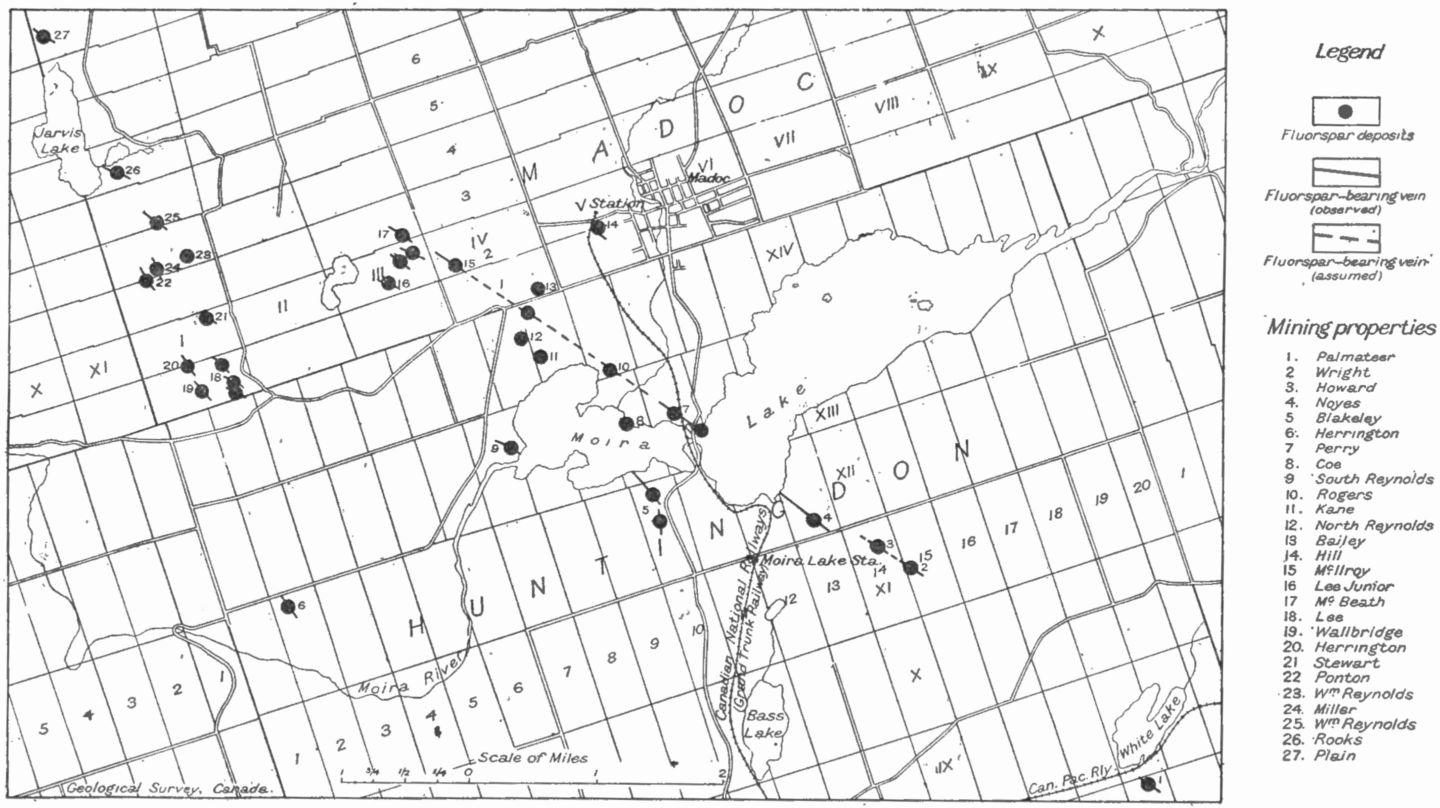

Figure 5. Diagram showing location of fluorspar deposits in the vicinity of Madoc, Hastings co., Ont.

fissures in which the fluorspar deposits occur form important channels for the ground-water of the district.

The occurrence of stalagmites and stalactites composed of barite or of barite the fluorspar in a cave on the Bailey property indicates that at this point at least barite and fluorspar were probably deposited by meteoric water.

Igneous rocks of post-Ordovician age with which the deposits might be genetically connected are entirely absent in the district and are not known to occur within 200 miles of the region.

The banded (crustified) and cavernous character of the vein material and the small amount of metallic minerals which it contains suggest that the deposits have been deposited by meteoric rather than by magmatic waters.

The galena-calcite-barite-fluorite veins that occur in the Palæozoic border zone of southeastern Ontario and Quebec are remarkably similar in their character and relationships to the galena-sphalerite deposits occurring in the Mississippi valley of the United States that are generally regarded as of meteoric origin. The Madoc deposits are similar in their character, structural and age relationships to the other veins occurring in southeastern Ontario, in which galena predominates, and are almost certainly of similar origin.

The presence of a nodular bituminous variety of barite and the mineral elaterite, in the fluorspar veins, can best be explained by the assumption that this material has been derived from the Palæozoic limestone, for these sediments are known to contain aggregates of oil.[1]

Deposits of Deep-seated Origin

Among the data that might be cited in support of the theory that the deposits are of magmatic origin are the following:

The principal deposits of the mineral occur on fault fissures showing that the deposition of the vein material was preceded by crustal disturbances which might be related to magmatic movements at depth. Moreover, one of the faults at least is continuous for many miles and no doubt descends to a considerable depth. This would, therefore, afford a channel along which magmatic solutions might ascend.[2]

Although fluorspar is present in geodal cavities in the Palæozoic formations of later age at Niagara and elsewhere in southwestern Ontario, so far as known to the writer, the mineral occurs only in fissures in the Palæozoic of southeastern Ontario, and it is scarcely conceivable that such large quantities of fluorspar could be concentrated from the Palæozoic formations (Black River and Trenton) of this district, without some evidence of its presence in these rocks being found.

The fluorspar-barite-calcite galena veins that occur along the Precambrian border in southeastern Ontario, and the adjacent parts of Quebec are exceedingly variable in composition even in the same district. Thus the vein on the property of the Kingdon Mining, Smelting, and Manufacturing Company at Galetta, Ontario, consists almost entirely of galena and calcite, whereas the vein occurring in a fault fissure at Quyon, Quebec, just 6 miles away, consists entirely of barite and fluorspar. Since the composition of the successive beds composing the various Palæozoic formations is approximately uniform, there is no apparent reason why the mineral composition of the vein material should be so different in the same district if the veins have been derived from Palæozoic sediments. On the other hand, this variability is not uncommon in mineral veins that are believed to be derived from a common magmatic source.

Discussion. It is obvious that in the summary of evidence presented in the preceding pages no data have been cited from which any one of the theories proposed

[1] Several gallons of oil are said to have been encountered in places in the limestone quarries at Crookston situated 6 miles south of Madoc.

[2] Pirsson, L. V., "Economic Geology," vol. X, 1915, pp. 180-186.

to explain the mode of origin of the fluorspar deposits of the Madoc district, or other deposits of the Madoc type, can be established. The principal objection to the meteoric origin is the inadequacy of the groundwater circulation to perform the concentration involved. It has long been known that fluorine is a constituent of sea water, that it has been noted to be present in both surface and underground waters, and that it is a constituent of calcareous corals and shells.[1] It has also been shown by Tangier Smith from analyses made by Steiger that the unaltered Palæozoic limestone of Kentucky contains small quantities (0·04 - 0·10 per cent) of fluorine. It is possible, therefore, that the Palæozoic limestone of the Madoc district, especially since it contains an abundance of fossils, likewise contains a small proportion of fluorine. The objection to the concentration of the fluorspar by meteoric waters has not been based so much, therefore, on the inadequacy of the supply of fluorine in the Palæozoic sediments, as on the assumption that the concentration of the fluorine made it necessary that the fluorine be leached out of the Palæozoic in some way while the limestone in which the fluorine was present remained behind, an obviously impossible hypothesis. It has been previously pointed out, however, that the presence of chasm-like openings along the outcrops of the numerous joints that intersect the Palæozoic limestone indicate that enormous quantities of limestone have been dissolved away by meteoric waters in the Madoc district. Furthermore, since the fissures in which the fluorspar occurs were probably formed in late Palæozoic time, and since southeastern Ontario has been a land area continuously or almost continuously since the Palæozoic, huge thicknesses of limestone must have been carried away in solution from this region during the long interval that has elapsed since the fissures in which the fluorspar occurs were developed. Thus, if the Palæozoic limestone of the Madoc district contains the same proportion of fluorine as that present in the limestone of Kentucky (0·04 to 0·10 per cent) the fluorine that would go into solution due to the dissolving away of a mass of limestone 1 foot thick, over an area 100 feet square, would be sufficient to form at least one ton of fluorspar and the fluorine that would go into solution as a result of the dissolving away of a similar thickness of limestone over an area of one square mile would be sufficient to form at least 5,000 tons of fluorspar. As regards the fluorspar deposits of the Madoc district it is evident, therefore, that the groundwater circulation would be quite capable of effecting the concentration of the fluorspar from the Palæozoic limestone provided fluorine is present in the limestone in the same proportions as that found to be present in the limestone of Kentucky.

The principal objection to the theory that the Madoc fluorspar veins are of magmatic origin is the absence of contemporaneous igneous intrusion. It has been pointed out by Pirsson, in this connexion, however, that "magma in the pseudo-rigid, but potentially liquid form conceived by Iddings must everywhere underlie the outer rock zone," and any movement in the lithosphere such as the faulting that occurred in the Madoc district might be attended by the liberation of volatile constituents, and that in places no further action than this might happen. He suggests[2] further that in a large measure the peculiarities in the composition of many mineral springs and waters in otherwise apparently non-volcanic regions may be ascribed to activity of this type.

It has also been suggested by Uglow in discussing the origin of the fluorite contained in the lead and zinc deposits of southeastern Ontario that calcite-galena-barite veins occur in eastern Quebec where the Ordovician is cut by intrusives chronologically related to the Taconic revolution, and that it is possible that the presence of fluorine in the vein minerals has a genetic relation to the igneous activity of post-Ordovician age, which produced important results in the province of Quebec, but which as far as known did not affect Ontario.

[1] Clarke, F. W., Data of geochemistry, U.S.G.S. Bull. 695, p. 118, 1920.
Birschof, Gustav., Lehrbuch der Geologie, vol. II, pp. 78, 86-102, 1864.
Andree, K., Ueber einige Vorkommen von Fluszpat in Sedimenten. Tsch. Min. Pet. Mitt. vol. XXVIII, 1909, pp. 536-556.

[2] Economic geology, vol. X, 1915, p. 184.

Conclusion. The mode of origin of the fluorspar-bearing veins of Madoc district is obviously of considerable economic importance, because if the deposits are of meteoric origin it is probable that they will disappear at depth, whereas if they have been derived from a magmatic source they will probably continue to great depth or even become more extensive on their downward continuation. In view, however, of the conflicting character of the evidence bearing on these different theories and of the fact that the most important evidence related to the problem, namely the fluorine content of the Palæozoic limestone of the district, is unknown, the writer believes that a definite conclusion regarding the genesis of the fluorspar deposits of Madoc district is unwarranted at this stage of the investigation.

DESCRIPTION OF PROPERTIES

Moira Lake Group

Palmateer

The fluorspar deposits situated farthest to the south in the district are those outcropping at the north end of lot 18, concession VIII, Huntingdon township, the property of Mr. George Palmateer (1 in Figure 5). In this locality the Palæozoic limestone, which underlies nearly the whole of the southern part of Madoc district, is cut by several small fluorspar-bearing veins the principal data regarding which are included in the following table.[1]

No. of pit or trench	Width of vein	Trend of vein	Excavation
1	2 parallel veins 15 feet apart. North vein 1 foot wide. South vein ½ inch wide	North 60 degrees west (magnetic)	Trench 16 ft long
2	6 inches to 2 feet	North 40 degrees west (magnetic)	Pit 35 feet long, 4 feet wide, and 3 feet deep
3	6 inches wide	North 25 degrees west (magnetic)	Pit 15 feet long, 10 feet wide, and 5 feet deep
4	6 inches wide	North 35 degrees west (magnetic)	Pit 3 feet long, 8 feet wide, and 5 feet deep
5	2 parallel veins 9 feet apart; north vein 1 to 2 inches wide, south vein 6 inches wide	North 70 degrees west (magnetic)	Pit 10 feet long, 10 feet wide, and 8 feet deep

The material composing these veins consists mainly of fluorspar, barite, and calcite. The fluorspar is chiefly a colourless, massive, white or green variety, but on the ore pile near the No. 2 pit some crystallized red-looking fluorspar was observed which consists of colourless fluorspar in which red particles (probably hematite) were distributed in zones parallel to the crystal faces.

Although these veins are relatively small their presence on this property is important because they all trend in a northwesterly direction and lie directly on the continuation of the Noyes-Perry vein, thus indicating that the Moira Lake fracture system continues as far south at least as this locality (Figure 5).

Wright

Wellington and Munro of Madoc have excavated a series of ten prospect pits in the gravel which overlies the Palæozoic bedrock on this property, to discover the continuation of the vein exposed on the Howard property which adjoins this lot on the west. In one of these pits situated near the middle of the series—an excavation about 50 feet long, from 20 to 55 feet wide, and 10 feet deep—a vein of fluorspar was discovered. When the writer examined the pit the walls had caved in and the only evidence of the presence of fluorspar that could be observed was the fragments of vein material that had been piled nearby.

[1]Pits and trenches numbered in the order of their occurrence from east to west.

Howard

Several carloads of fluorspar have been shipped from a deposit situated near the north end of lot 14, concession XI, Huntingdon township (3, Figure 5). The discovery of fluorspar in this locality was made by Stephen Wellington who, with Mr. Munro, worked the deposit during January and February 1918, and then sold the property along with the Noyes mine, which adjoins the Howard on the northwest, to Canadian Industrial Minerals, Limited. The operations commenced by Wellington and Munro were not continued by the new owners, however, and the property lay idle until August, 1920, when Wellington and Munro obtained an option on the lot from Canadian Industrial Minerals, Limited, and resumed operations.

A number of scattered prospect pits have been excavated on this property, but the only openings in which a vein has been found are two northwesterly-trending pits situated about 300 feet east of the Howard farmhouse. The northern of these pits is about 70 feet long, 10 to 15 feet wide, and 2 to 15 feet deep. The other pit which is situated about 50 feet to the south is about 60 feet long, 10 to 20 feet wide, and 10 feet deep. A shaft now filled with water but said to be 25 feet deep has been sunk from the bottom of the north pit close to its southeast end. In September, 1920, a new shaft was being sunk from the bottom of the south pit near its northwest end, and at that time was 25 feet deep. The walls of the pits consist of grey, flat-bedded Palæozoic limestone overlain by gravel and boulder clay. The latter material has slumped down from the pit faces covering the bottoms of the pits so that the vein was not seen by the writer except in the southeast face of the north pit and in the faces of the new shaft. At the first of these points the vein was 2 feet wide, but was said to be 5 feet wide in the old shaft only a few feet away. In a new shaft it was from 5 to 7 feet wide but included a considerable proportion of limestone fragments in places. The vein material is mainly white to grey, massive fluorspar, but includes some barite and calcite.

A diamond-drill hole was put down on this property at an angle of 61 degrees towards the northeast from a point about 60 feet to the south of the old shaft, the record of which follows:

Depth of diamond-drill hole	Equivalent vertical depth	Material cut by drill
Feet	Feet	
0·0 to 84·5	0·0 to 73·9	Palæozoic limestone
84·5 to 85·0	73·9 to 74·3	Fluorspar
85·0 to 146·0	74·3 to 127·7	Palæozoic limestone
146·0 to 150·0	127·7 to 131·2	Red granite
150·0 to 171·0	131·2 to 149·5	Palæozoic limestone

The mass of red granite penetrated at a vertical depth of 131·2 feet was presumably a boulder and indicates that the drilling was discontinued close to the Precambrian-Palæozoic contact. The Palæozoic in this locality is, therefore, about 150 feet thick. The vein of fluorspar was cut in the drill hole about 10 feet to the southwest of the outcrop of the vein at the surface and has, therefore, an average dip of 80 degrees.

Noyes

Location and History. The Noyes mine, the property of Canadian Industrial Minerals, Limited, is situated on the top of the high area of granite that outcrops to the south of the eastern and lower part of Moira lake. It lies about one-half mile east of Moira Lake station on the Madoc branch of the Grand Trunk railway, where a siding has been constructed by the company.

The discovery of fluorspar on this property was made by Donald Henderson of Madoc in 1916. In that year Henderson, in company with Chesley Pitt, purchased an option on the mining rights of 20 acres in the southeast corner of lot 13, concession XII, Huntingdon township, and after sinking prospect pits along the outcrop of the

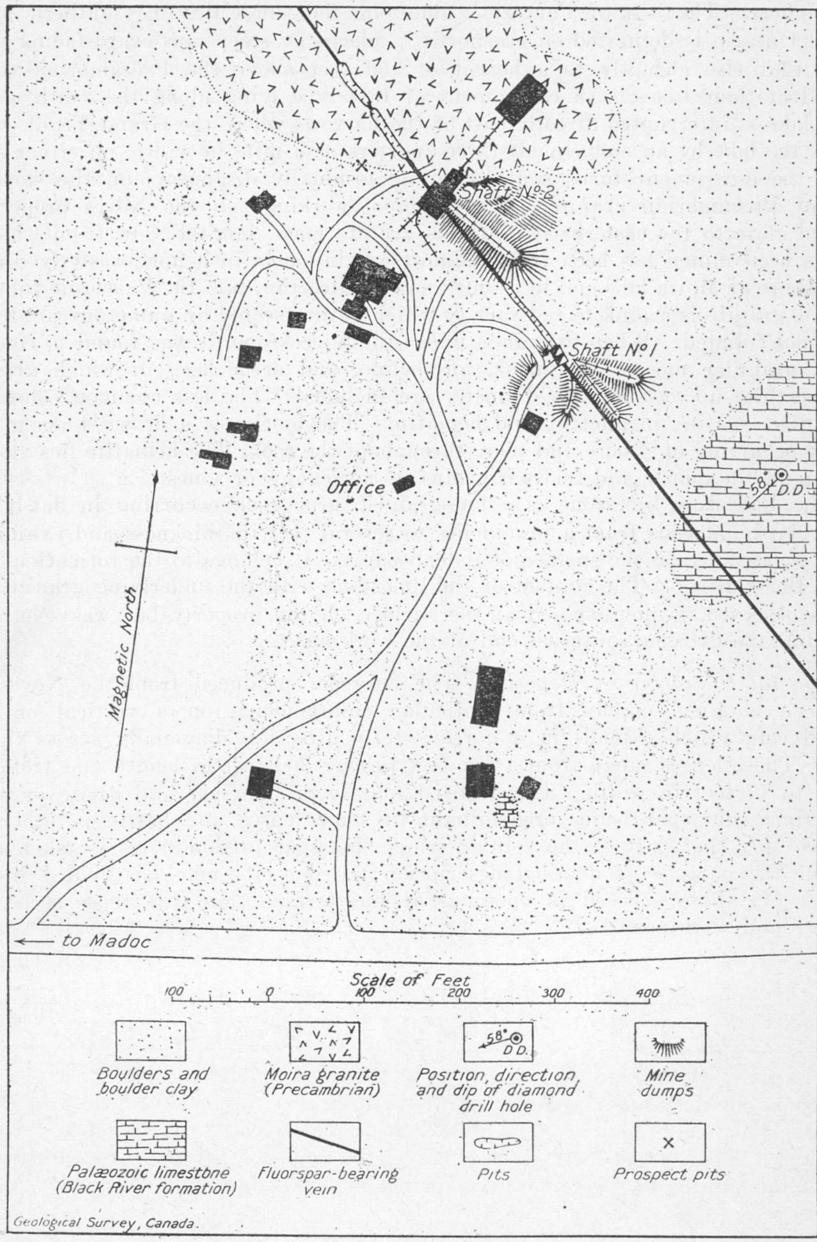

Figure 6. Fluorspar-bearing vein, lot 13, con. XII, Huntingdon tp., Hastings co., Ont.

vein they sold their option in the early part of 1917 to Wellington and Munro who had previously acquired an option on the remainder of the property. Wellington and Munro then commenced mining operations and continued to work the property until

March, 1918, when they sold their options on lot 13 with the mining rights to some adjacent lots, to Canadian Industrial Minerals, Limited. This company continued mining operations until the autumn of 1920 when the mine was closed down. Over 15,000 tons of fluorspar was produced from the mine during the period of its operation.

Geology. The belt of Palæozoic limestone that underlies the southern part of central Ontario is delimited on the north in places by steep northward-facing escarpments that rise abruptly to a height of 150 feet above the Precambrian complex exposed at their bases. An escarpment of this type lying along the south shore of Moira lake is interrupted directly east of the narrows where the Grand Trunk railway crosses the lake by an embayment three-quarters of a mile in width, on either side of which the escarpment turns southward and gradually disappears on the slope of a knob of Precambrian granite. The principal workings on the Noyes property are situated close to the eastern edge of this granite mass, but the vein from which the ore has been mined has been traced almost continuously in a northwesterly direction to the shore of Moira lake and in a southeasterly direction into the Palæozoic limestone.

The granite is a pink to red variety which is intersected by numerous joint planes but is not foliated. When examined under the microscope, it was found to consist of a fine, granular mosaic of quartz, microcline, and orthoclase, in which grains of microperthite up to 3 mm. in diameter are included. The less common constituents are biotite, apatite, magnetite, and hematite. The biotite is a brown to pale yellow variety occurring only here and there throughout the rock. The hematite lies along the contacts of the quartz and feldspar grains in aggregates or zones.

The Palæozoic limestone is a fine-grained, grey rock occurring in flat-lying or nearly flat-lying beds from a few inches to several feet in thickness and exhibiting a rubbly appearance on the surface of its exposures. It belongs to the formation known as the Black River. The contact of the limestone with the underlying granite so far as was observed, is not exposed at the surface on the property but was seen underground at the extreme southeast end of the workings.

General Character of Deposits. The fluorspar produced from the Noyes mine has been obtained chiefly from lenticular enlargements on a vertical or nearly vertical vein which extends in a northwesterly direction diagonally across the property. These lenses range from a few feet to over 200 feet in length and from a few inches to 17 feet in width. They consist mainly of fluorspar and barite in varying proportions, fluorspar being predominant in some lenses and barite in others. In practice only that part of the vein in which fluorspar predominates is taken as ore.

For the purpose of detailed description the deposits may be divided into two groups: (1) those exposed in openings at the surface; and (2) those seen in the underground workings.

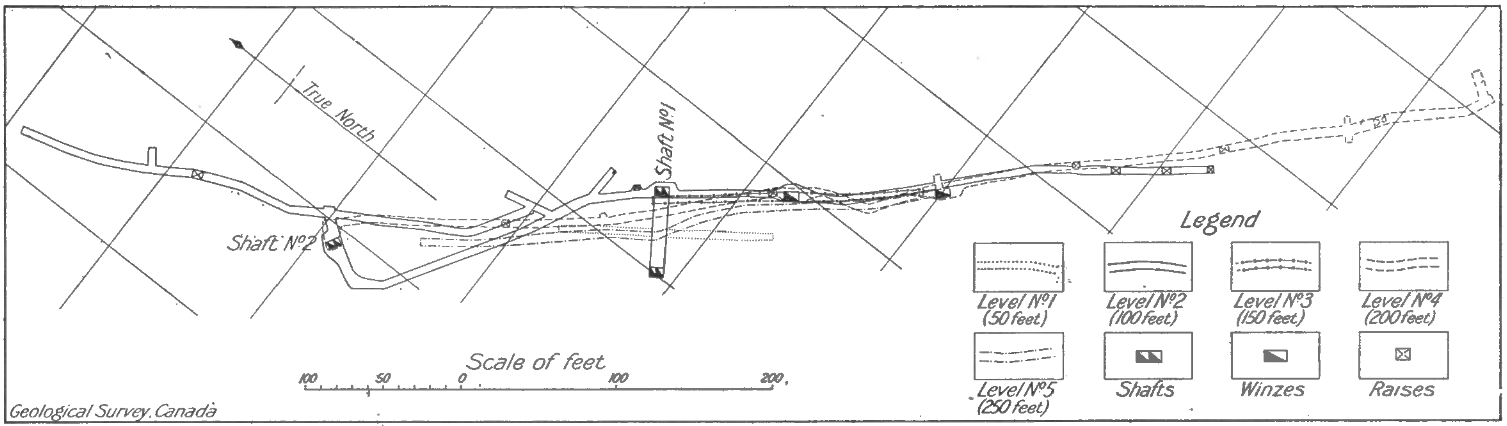

Figure 7. Plan of underground workings, Noyes mine, lot 13, con. XII, Huntingdon tp., Hastings co., Ont.

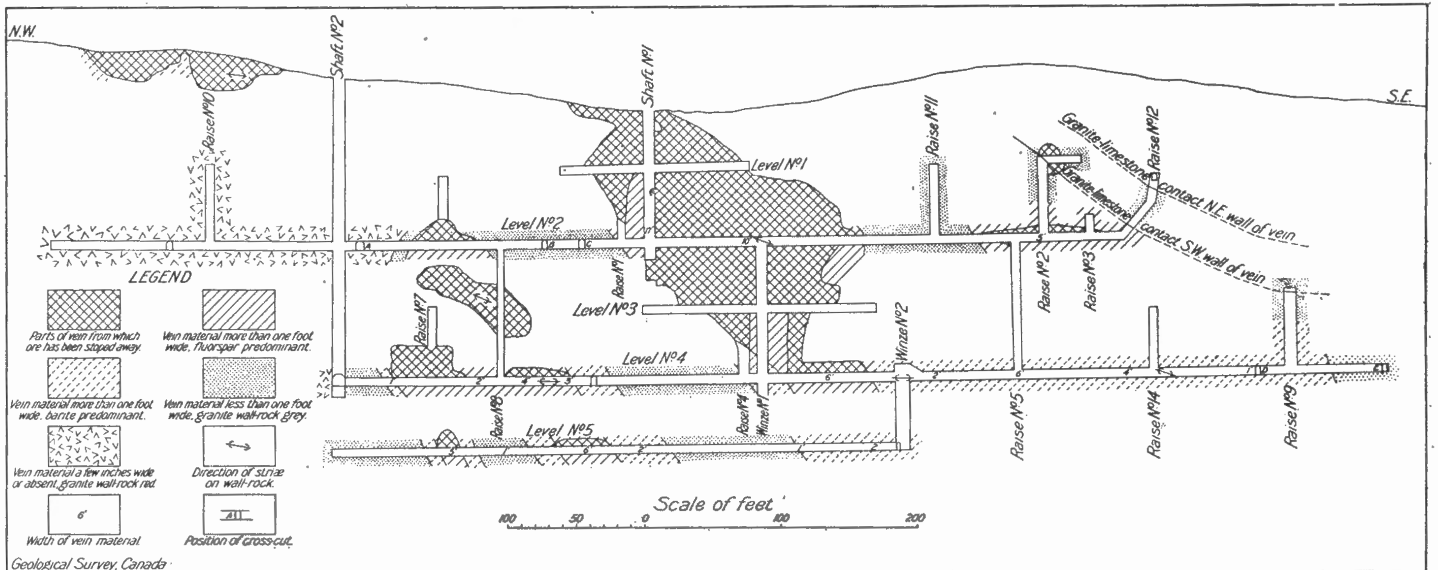

Figure 8. Longitudinal section through underground workings, Noyes mine, lot 13, con. XII, Huntingdon tp., Hastings co., Ont.

Deposits in Surface Openings. The openings along the outcrop of the vein to the southeast of the No. 2 shaft (Figures 7 and 8) are now either covered by waste dumps or filled with débris, so that the vein cannot be seen at the surface in this part of the property. Northwest of the No. 2 shaft a number of lenses are exposed in pits and trenches that have been excavated along the outcrop of the vein, but on the whole, the deposits so far discovered in this locality are small and relatively unimportant. The principal data regarding these occurrences are included in the following table:

Distance northwest of No. 2 shaft	Vein	Excavation
0 feet to 35 feet	Not exposed	
35 feet to 185 feet	Vein material 1 to 4½ feet wide	No. 1 open-cut 2 to 8 feet wide, 5 to 25 feet deep
185 feet to 465 feet	Granite fractured, but little or no vein material present	
465 feet to 520 feet	Vein 6 inches to 2 feet wide	No. 2 open-cut, 2 to 5 feet wide, to 20 feet deep
520 feet to 625 feet	Not exposed	
625 feet to 675 feet	Vein 1 inch to 2 feet wide	Trench 3 to 5 feet deep
675 feet to 775 feet	Not exposed	
775 feet to 1,000 feet	Vein 3 to 10 inches wide	A series of 8 prospect pits in drift
1,000 feet to 1,750 feet	Not exposed	
1,750 feet to 1,815 feet	Vein 3 inches to 8 inches wide	Three prospect pits in drift
1,815 feet to 2,050 feet, Moira lake	Not exposed	

At the time the writer examined the openings in the northwest part of the Noyes property, the bottoms of the pits were hidden by débris so that the vein could be seen only at the ends of the openings, or in the case of No. 1 open-cut, in the faces of the mass that remains in the centre of the cut (Figure 8). In open-cut No. 1, the vein material occurs chiefly in two parallel banded zones separated partly by horses of broken granite, and partly by vein material of the cavernous type. The banded vein material consists of bands of pink to white barite from ½ to 4 inches wide, alternating with bands of honey-yellow fluorspar from ½ to ⅛ inch wide. The cavernous type of vein material has the same composition as the banded type except that it contains a small proportion of calcite. The zones of banded ore range from 6 inches to 1½ feet, and the cavernous masses up to 2½ feet in width. The total maximum width of vein material observed was 4½ feet. Some barite was shipped from this pit in 1918 by Wellington and Munro.

In open-cut No. 2, also, there are two parallel zones of banded vein material, but wherever these are exposed they are separated by unbroken red granite. The zones range from 6 inches to 1 foot in width and have a total maximum width of 2 feet. In places the vein material occurs in peculiar dome-like forms within which the barite and fluorspar bands exhibit a concentric structure. The maximum diameter of the domes was 3 inches.

Deposits in Underground Workings. The principal data regarding these deposits are indicated in Figures 7 and 8. In Figure 8 the extent and grade of the vein material encountered on the various levels are shown in the following ways.

Parts of vein from which fluorspar has been stoped away. In this subdivision are included the parts of the vein in which the vein material was sufficiently extensive and high enough in grade to be mined. Three separate lenses or groups of lenses belonging to this class were present, (*a*) a large lens lying mainly to the southeast of shaft No. 1 from which about 10,000 tons of fluorspar was obtained:

(*b*) a group of five small lenses situated on the 100, 200, and 250-foot levels to the southeast of shaft No. 2; (*c*) a small lens situated at the southeast end of the 100-foot level.

Vein material more than 1 foot wide, fluorspar predominant. In this class are included all those parts of the vein in which a width of at least 1 foot of vein material of marketable grade is present, but which, either because it is too much intermingled with wall-rock, or too limited in extent was not mined. It may be observed that these parts of the vein all lie adjacent to the openings from which the vein material has been stoped away.

Vein material over 1 foot wide, barite predominant. This subdivision includes the parts of the vein in which the vein material is over 1 foot in width but contains too great a proportion of barite to be mined for fluorspar. Vein material of this type is found chiefly in the lower workings and most extensively at the southeast end of the 200-foot level.

Vein material less than 1 foot wide, granite wall-rock grey. In this subdivision are indicated the parts of the vein where the width of vein material is less than 1 foot, but where the circulation of the depositing solutions has been sufficient to alter the colour of the granite wall-rock from red to grey.

Vein material a few inches wide or absent, granite wall-rock red. In this subdivision are shown the parts of the vein where the vein material is only a few inches wide or is absent, and where there has not been sufficient circulation of the solutions depositing the vein material to change the colour of the granite wall-rock. They occur mainly in the vicinity of shaft No. 2 and along workings to the northwest of shaft No. 2.

Diamond Drilling. Two diamond-drill holes were put down on the Noyes property by Canadian Industrial Minerals, Limited, the principal data regarding which are included in the following table:

No.	Position of drill hole	Direction of dip	Angle of dip	Depth in Palæozoic feet	Equivalent vertical depth in Palæozoic feet	Depth in granite	Total depth
1	250 feet east of shaft No. 1, and 105 feet northeast of vein (Figure 8)	SW.	58	49	43	117¼	166¼
2	632 feet north of southeast corner and 57 feet west of east boundary of property	SW.	55	134	110	9	145

Hole No. 1 was drilled for the purpose of cutting the Noyes vein at depth, but was discontinued approximately 30 feet above the necessary depth. Drill hole No. 2 was put down to intersect the continuation of the Howard vein on the Noyes property but was probably placed too far north for this purpose (Figure 5).

Blakeley

The Blakeley property is situated west of the Madoc-Belleville road (Figure 5), where it ascends the Palæozoic escarpment that adjoins the south shore of Moira lake. The discovery of the fluorspar on this lot was made by James O'Reilly in 1916, but most of the development work was performed by the late Stephen Wellington and his associates. Several carloads of fluorspar were shipped from pit No. 1 and shaft No. 1 by Wellington during the summer of 1920.

Character of Deposits. There are at least three fluorspar deposits present in this lot which for the purpose of description may be referred to as the north vein, the south vein, and vein in pit No. 1.

North Vein. The north vein as shown in Figure 9 trends approximately north 40 degrees west (magnetic) and has been traced at intervals for over 500 feet. The principal data regarding the character of the vein as exposed in the various openings that have been excavated along the vein are included in the following table:

Excavation (Figure 9)	Character of vein	Width of vein material	Dimensions of excavation
Pit No. 2	Well-defined, mainly honey-yellow fluorspar	1 to 2½ feet	15 feet by 15 feet 12 to 15 feet deep
Shaft No. 1	A well-defined vein along east wall, remainder of wall-rock traversed by numerous veinlets	1 to 3 feet	10 feet long, 8 feet wide, 25 feet deep
Pit No. 3	Two veins separated by horse 2 feet wide on northwest face, vein material adhering to southwest wall.	2 feet	60 feet long, 10 feet wide, 10 feet deep.
Adit No. 1	Lenticular enlargement on vein, 30 feet long	6 inches to 2 feet	30 feet long
Adit No. 2	Vein crossing end of adit	6 inches	60 feet long
Trenches along outcrop of vein northwest of adit No. 1.	Not exposed	1 foot or less	1 to 3 feet deep

South Vein. The south vein on the Blakeley property (Figure 9) trends north 4 degrees west (magnetic). It can be observed in pit No. 4, in shaft No. 2, and in a trench situated about 80 feet north of pit No. 4. Pit No. 3 is an excavation 40 feet long, 10 feet wide, and 6 feet deep, from the bottom of which, at a point about 10 feet from its south end, shaft No. 2 has been sunk to a depth of 25 feet. The vein material exposed in these openings consists mainly of alternating bands or zones of white barite and colourless to honey-yellow fluorspar. The proportion of barite and fluorspar varies greatly from point to point, but on the whole the barite predominates. The width of vein material exposed in shaft No. 2 ranges from 2 to 6 feet. The vein material observed in the trench that has been excavated along the outcrop of the vein farther to the north ranges from 6 inches to 1 foot in width and is similar in character to that seen in pit No. 4.

Vein in Pit No. 1. Pit No. 1 is an excavation 50 feet long, 6 feet wide, and 30 feet deep that was opened up by Stephen Wellington during the summer of 1920. The vein material exposed in the pit consists mainly of fluorspar and occurs in two zones separated by a much fractured mass of the limestone wall-rock. The total width of the vein material ranges from 1 to 3 feet. Since this vein trends north 35 degrees west (magnetic) and is situated 30 feet to the southwest of the continuation of the north vein (Figure 9), it might be assumed that it is a separate parallel vein

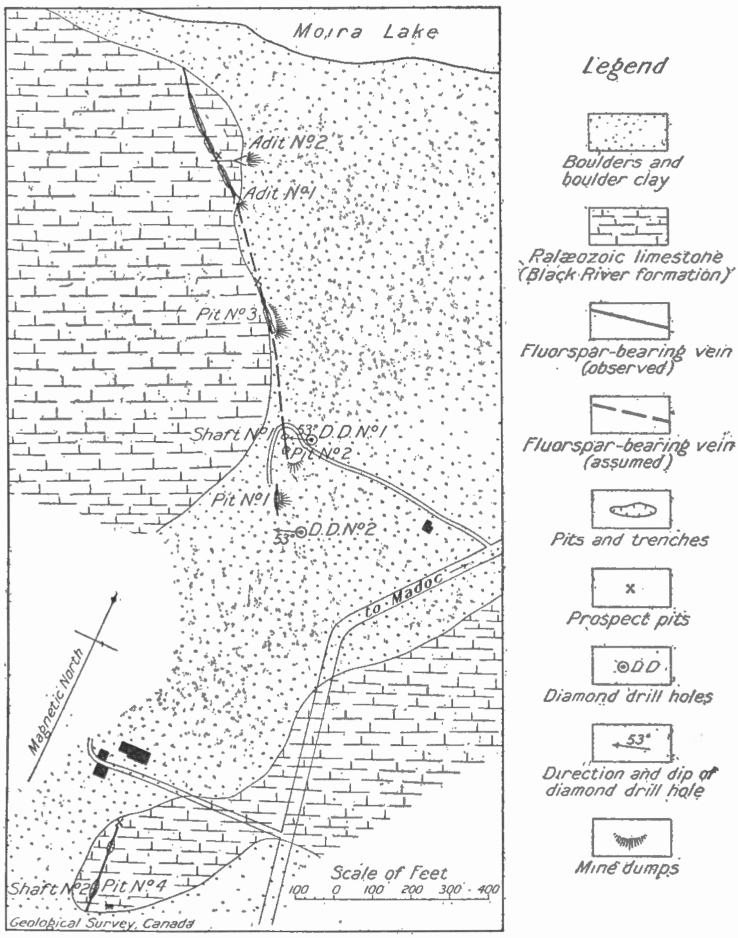

Figure 9. Fluorspar-bearing veins, lot 10, con. XII, Huntingdon tp., Hastings co., Ont.

having no connexion with the north vein, but the results from diamond-drill hole No. 1 have shown that the north vein dips to the southwest, so that at depth it lies almost directly on the continuation of the vein in pit No. 1. It is possible, therefore, that this vein is a branch from the north vein. The walls of the pit are polished and striated, indicating that the fracture in which the vein occurs is also the locus of a fault. Since the striæ trend almost horizontally the direction of movement along the fault was presumably nearly horizontal.

Diamond Drilling. Two diamond-drill holes were put down on the Blakeley property in 1918 by Canadian Industrial Minerals, Limited. The positions, and the directions and angles of dip of these are shown in Figure 9. The depths were 172 and 235 feet respectively. In hole No. 2 no fluorspar was found, but in hole No. 1, 7 feet of vein material was cut at a depth of 142 feet. From these data it can be calculated that the vein was crossed by the diamond drill at a vertical depth of 114 feet and at a point situated about 25 feet to the southwest of shaft No. 1.

Perry

The Perry mine is situated about 2 miles south of the village of Madoc and close to the north shore of the narrows that divides Moira lake into upper and lower divisions. The principal workings on the property lie only a few hundred feet to the west of the Belleville-Madoc branch of the Grand Trunk railway with which the mine is connected by a siding.

History. The outcrop of the vein on the Perry property is said to have been laid bare at the time the Belleville-Madoc branch of the Grand Trunk railway was being built, but no attention was paid to the discovery until the year 1912, when Messrs. Cross and Wellington purchased an option to prospect the property. Actual mining operations were first undertaken in the autumn of 1915 and except for an interval of about 11 months between December 1, 1917, and November 1, 1918, were carried on continuously from that time to the autumn of 1920.

Geology. The rocks occurring adjacent to the Perry mine, so far as observed, are all of Precambrian age and fall into two principal groups: (1) a number of sedimentary types belonging to the Grenville series; and (2) masses of quartz syenite and granite similar in character to the Moira granite that outcrops in extensive areas south and east of Moira lake.

The rocks of the first class are chiefly rusty-weathering, cream-coloured dolomite and finely banded, light and dark grey, impure limestone. The rusty-weathering dolomite outcrops adjacent to No. 2 shaft and in the area adjoining the north shore of Moira lake to the southwest of the No. 2 shaft. The finely laminated grey limestone is exposed near No. 1 shaft and in the northeastern part of the property. About 200 feet to the north of the No. 3 shaft a small outcrop of a dark brown, dense rock occurs which when examined under the microscope was found to consist of dark brown mica, sericite, and fine, granular quartz and feldspar. Since this rock occurs in an outcrop only 20 feet in diameter and is not in contact with any of the other rocks exposed in the area, it is not possible to determine definitely its age relationships or origin. It resembles a banded argillite or tuff seen elsewhere in the region, however, and is probably either a metamorphosed argillaceous sediment or pyroclastic rock contemporaneous in age with the Grenville limestone and dolomite.

The quartz syenite and granite exposed near the Perry mine occur in scattered, irregular masses, the largest of which forms the ridge that lies directly south of No. 1 and No. 3 shafts. Since this ridge, except where it adjoins No. 1 shaft, is surrounded by swamp or glacial drift, the extent of the granite-quartz syenite mass is not known, but at its west end it evidently extends for some distance to the north beneath the drift cover, for it forms the wall-rock in No. 3 shaft and in the adjacent underground workings. At these points, just as in the case of the Noyes mine, the colour of the granite changes from its normal red or pink to pale grey in the vicinity of the vein. A thin section of a specimen of this grey phase of the rock taken from the dump adjoining shaft No. 3, when examined under the microscope, was found to consist of fine, granular orthoclase partly altered to sericite, plagioclase, quartz, muscovite, and scattered grains of pyrite, tourmaline, and calcite.

Character of the Deposit. The fluorspar found on the Perry property occurs in a northwesterly-trending vein that outcrops in two rock-areas that protrude through the swamp adjoining the north shore of Moira lake. Since this vein trends in the same direction as, and lies directly on the continuation of, the vein on the Noyes property to the south of Moira lake, it is evident that the veins on the two properties belong to the same fracture system and are probably parts of the same vein. One of the two rock areas in which the vein is exposed adjoins the north shore of Moira lake, whereas the other area is situated across the swamp about 700 feet to the northwest.

The principal data regarding the superficial workings on the property are included in the following table.

Excavation (Figure 10)	Character of vein	Width of vein material	Dimensions of excavation
Southeast area			
Pit adjoining shaft No. 2 on southeast.	Honey-yellow to pale green fluorspar....	5 feet..............	25 feet long, 6 feet wide, and 7 feet deep
Shaft No. 2..........	Vein not seen (shaft filled with water)...	Said to be 5 feet wide to bottom of shaft	35 feet deep
Pit 60 feet northwest of shaft No. 2	Vein not seen (pit filled with water and debris)	....	20 feet long, 4 feet wide, and 6 feet deep
Northwest area			
Pit between shaft No. 1 and railway	Vein well defined......................	1 foot to 18 inches ..	25 feet long, 1 to 4 feet wide, 10 to 12 feet deep
Shaft No. 1..........	Not observed.........................	Not observed.......	75 feet deep
Pit adjoining shaft No. 1 on the west	Two veins 6 inches to 2½ feet wide enclosing a mass of broken limestone........	1 to 3 feet..........	30 feet long, 10 feet wide, 20 to 40 feet deep

With the exception of a small stope said to be 20 feet long to the southeast of shaft No. 1, all the underground mining on the Perry property has been carried on from No. 3 shaft. This shaft, which is 140 feet deep, has been sunk close to the west end of a lenticular mass of granite 50 feet long and 10 feet wide that lies between northeast and southwest branches of the vein. Between the surface and the 90-foot level, to the southeast of the shaft the northeast branch of the vein is only a few inches wide, whereas the south branch widens at a depth of 50 feet to a lens having a maximum width of 4 feet; to the northwest of the shaft both branches of the vein unite forming a single lens 100 feet long and 6 feet wide. Between the 90-foot and the 140-foot levels, to the southeast of the shaft the southwest branch is only a few inches wide, whereas the north branch widens into a lens 80 feet long and 5 feet wide at its maximum point; to the northwest the lens terminates at about 50 feet from the shaft. In reality, therefore, most of the fluorspar found in the vicinity of No. 3 shaft occurs in a lens having a horizontal length of 100 to 130 feet and extending diagonally down the vein to the southeast at an angle of about 65 degrees. From this lens a branch lens extends southeast for about 50 feet at the 50-foot level. Since the main lens has a width of 5 feet at the 140-foot level and no vein material has been removed below that depth the total length of this lens is not known, but its length from its northwest termination down to the 140-foot level is 150 feet. The height of the lens measured parallel to the shaft is about 200 feet, but measured at right angles to its longer direction only 100 feet. Its maximum width is 6 feet. All the ore present in this lens has been removed down to the 140-foot level. During the latter part of the summer of 1920 a drift was driven along the continuation of the vein for 75 feet from the southeast end of the 140-foot level, that is, to a point 160 feet from shaft No. 3 and hence almost directly beneath shaft No. 1. In this distance the vein had an average width of 2 feet.

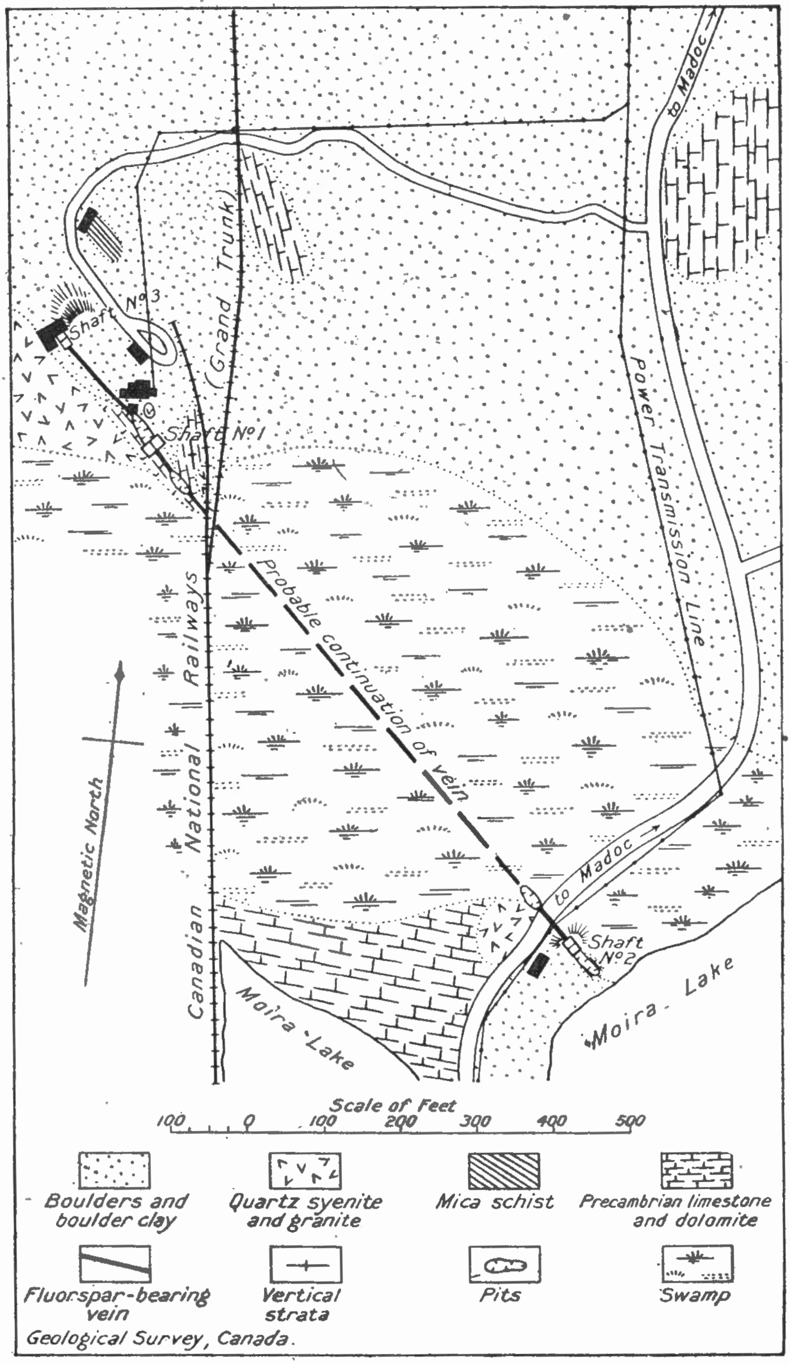

Figure 10. Fluorspar-bearing vein, lot 11, con. XIII, Huntingdon tp., Hastings co., Ont

The vein material on the Perry property is mainly the banded type and consists chiefly of fluorspar, barite, and calcite. The fluorspar greatly predominates, however, and practically all the vein material is sufficiently high grade to be mined. The fluorspar is a honey-yellow, colourless to pale green variety and for the most part occurs in well developed crystals. The less common constituents are fibrous celestite and pyrite.

Coe

Two parallel northwesterly-trending veins are exposed in some shallow pits that have been excavated close to the north shore of Moira lake on lot 10, concession XIII, Huntingdon township, the property of Mrs. Arthur Coe of Madoc. The principal data regarding these deposits are included in the following table.

Vein	Character of vein	Width of vein material	Dimension of excavation	Trend of vein	Country rock
East vein...	Fluorspar and barite, fluorspar predominant	6 to 18 inches...	90 feet long, 3 to 5 feet wide, 1 to 18 feet deep	North 40 degrees west (magnetic)	Buff-coloured dolomite Precambrian
West vein...	Fluorspar, calcite, and barite, calcite abundant	4 to 18 inches...	40 feet long, 3 feet wide, 5 feet deep	North 40 degrees west (magnetic)	Buff-coloured dolomite Precambrian

South Reynolds

A fluorspar-bearing vein trending north 45 degrees west (magnetic) occurs on the South Reynolds property, lot 7, concession XIII, Huntingdon township, directly north of the outlet of Moira river into Moira lake. The vein can be seen at present along the bottom and faces of an open-cut, 200 feet long, 2 to 6 feet wide, and 20 feet deep, that has been excavated at right angles to the slope of the ledge of Palæozoic limestone that parallels the west shore of Moira lake in this locality. Throughout a considerable part of the length of the open-cut the deposit consists of two parallel veins ranging from a few inches to 18 inches in width and separated by lenses of limestone up to a foot or more in width. In places along the northeast face of the pit subsidiary veins branch from the main vein, and fade out towards the north, a feature that was also observed along the north side of the Noyes-Perry vein on the Noyes property. The material composing the vein on the South Reynolds property, as in the case of most other deposits, consists chiefly of fluorspar with barite and calcite as less abundant constituents. The walls of the open-cut are slickensided and striated in places and as in the case of the other deposits of the Moira Lake group, the striæ are almost horizontal. Two carloads of fluorspar were shipped from this property in 1917.[1]

Rogers

The occurrence of a northwesterly-trending fluorspar-bearing vein at the south end of lot 10, concession XIV, Huntingdon township, is of considerable interest because the vein at this point lies directly on the continuation of the Noyes-Perry vein and hence affords evidence of the continuity of the Noyes-Perry vein from the Perry mine on the east across the Roger's property to the Kane mine on the west (Figure 5). The discovery of the vein at this point was made by Donald Henderson and Chesley Pitt of Madoc about the year 1909, but actual mining was first undertaken by Messrs. Gillespie, Cross, and Wellington, in 1910. In the following year Gillespie, Cross, and Wellington sold the property to Mr. L. L. Battle from whom it was afterwards purchased by the present owner, Mr. C. M. Bowman. Mining operations have been attempted on the Rogers property at frequent intervals during the

[1] Ann. Rept., Ont. Bureau of Mines, vol. XXVII, 1918, p. 138.

twelve years that have elapsed since the vein was discovered, but the greater part of the work on the deposit was performed during 1910, 1911, and 1914.

The principal excavation on the property, an open-cut about 100 feet long and from 5 to 10 feet wide, was partly filled with water at the time the writer examined the property in the summer of 1920, so that neither the depth of the pit nor the character or extent of the vein present in the bottom of the pit could be determined. The form of the opening indicated, however, that the vein material originally present occurred as a lens about 80 feet long and 8 feet wide at its middle. The only vein material seen on the property was a mass that stood above the surface of the water at the northwest end of the pit. This had a width of about 5 feet, and consisted mainly of green to honey-yellow fluorspar. The striæ on the walls of the pit are almost horizontal. At a point about 40 feet northwest of the pit a vertical shaft said to be 65 feet deep has been sunk, from the bottom of which a cross-cut has been driven to intersect the vein. It was reported to the writer, however, that no fluorspar was mined by way of this cross-cut. The country rock exposed near the vein and the rock composing the dump from the shaft are mainly the buff-coloured Precambrian dolomite that outcrops extensively elsewhere in the vicinity of the north shore of Moira lake.

Kane

The fluorspar deposits occurring on the Kane property, lot 9, concession XIV, Huntingdon township, are especially interesting because the principal vein contains a considerable proportion of brilliant transparent crystals of fluorspar up to 4 or 5 inches in diameter.[1] The discovery of the main vein on the property was made by Mr. Kane, owner of the lot, in the latter part of the summer of 1917, when deepening the outlet of a spring. In the autumn of 1917 Mr. Rinaldo McConnell purchased a lease of the lot from Kane, and the following spring after sinking a pit 10 feet deep on the vein, sold his lease to a company known as Canadian Fluorite, Limited, that had been organized in Toronto for the purpose of purchasing and developing the property. The new company continued operations until April, 1919, when the mine was closed down, and all equipment with the exception of the shaft house and ore shed was removed.

Two occurrences of fluorspar are known to be present in the territory included in the Kane property: (1) the main vein which is situated near the north end of the lot, and lies directly on the continuation of the Noyes-Perry-Rogers vein (Figure 5); and (2) a group of veinlets exposed in a small prospect pit situated near the southwest corner of the lot.

Main Vein. Since the main vein on the Kane property is not exposed at the surface and all the mining operations performed on the vein were carried on underground from a single vertical shaft, which is now inaccessible, the following description of the deposit is based for the most part on an examination of the material exposed on the dumps adjoining the shaft. The rock fragments observed on the dumps indicate that the wall-rock of the vein consists partly of dark grey banded, impure Grenville limestone, and partly of a dark, fine-grained, metamorphosed, igneous intrusive, and is, therefore, of Precambrian age. The limestone in places contains dark phenocryst-like inclusions which on microscopic examination were found to be crystals of microcline. The bands in the limestone range from $\frac{1}{32}$ inch to 1 inch in width. The igneous rock when examined under the microscope was found to consist almost entirely of blue green to pale yellow amphibole and plagioclase having the optical properties of andesine, and has, therefore, the mineralogical composition of a diorite. The vein material is said to have a width of 8 to 9 feet in the shaft and as in the case of the other deposits in the district consists chiefly of fluorspar, barite, and calcite, but unlike any other known deposit, contains on the

[1] Walker, T. L., "Fluorspar from Madoc, Ontario," Am. Min., vol. IV, 1919, pp. 95-96.

whole more calcite than fluorspar or barite. The fluorspar is either white, pale green, honey-yellow, or rose-red in colour, and is commonly transparent. The brilliant crystals of transparent fluorspar suitable for optical purposes occur as inclusions in a grey, fibrous celestite which is evidently present in the vein in masses of considerable size, since the broken fragments of the mineral in the dumps were a foot or more in diameter. The barite occurs partly in separate tabular crystals and partly in dome-like aggregates of concentrically arranged tabulæ. These domes generally range from ½-inch to 1 inch in diameter. The underground workings on the main vein consist of a vertical shaft said to be 65 feet deep and drifts along the vein at a depth of 50 feet for 100 feet to the southeast, and for 160 feet towards the northwest. At a point on the 50-foot level, 150 feet northwest of the shaft, a winze was started, and had been sunk to a depth of 16 feet on March 15, 1919.[1] No stoping was done on the vein but several carloads of fluorspar obtained in the course of development work were shipped from the property in 1918.

Southwest Vein. Near the southwest corner of the Kane lot, there is a shallow prospect pit about 12 feet long and from 2 to 6 feet wide and 3 feet deep in which three fluorspar-bearing veinlets 6 inches in width are exposed. Two of the veinlets lie along the north wall of the pit and strike north 80 degrees west (magnetic) parallel to the structural trend of the Precambrian limestone wall-rock. The third veinlet which is possibly a branch from the other two veinlets outcrops about 3 feet farther to the south and trends in a northeast-southwest direction. The material composing the veinlets consists mainly of zones of minute crystals of quartz overlain by pale green crystals of fluorspar ranging from $\frac{1}{16}$ inch to over 1 inch in diameter. The common crystal forms assumed by the fluorspar in this locality, as elsewhere in the district, are the cube and the octahedron, but in this occurrence the octahedron is the dominant form.

North Reynolds

Near the southeast corner of the north half of lot 8, concession XIV, Huntingdon township, and hence almost directly south of the shaft house on the adjacent lot to the east (Kane property) an area of impure, grey, banded Precambrian limestone is exposed, in which two small deposits of fluorspar have been found. The larger of the two deposits is exposed in an east-west trending pit 12 feet long, 2 to 6 feet wide, and 2 to 12 feet deep, and is a mass of the cavernous type about 10 feet long and ranging in width from 6 inches at its extremities to 5 feet at its middle. The solid parts of the mass consist of white, massive fluorspar and calcite in which fragments of the grey limestone wall-rock are enclosed. The crystallized parts of the mass occur as a lining on the walls of the cavities and consist of honey-yellow crystals of fluorspar on which tabular crystals of barite projecting edgewise from the cavity-wall are present in places. The crystals of fluorspar have the form of the cube modified by the octahedron, and have a maximum diameter of about three-quarters of an inch.

The smaller of the two deposits is exposed in the bottom of a shallow trench situated about 75 feet to the northeast of the larger mass. It consists of a vein or mass of material similar to that in the larger deposit, has a width of 1 to 2 feet, and an exposed length of 3 feet. At the time the writer visited the property a few tons of fluorspar had been piled on a platform near the main pit.

Bailey

The discovery of fluorspar on the Bailey property is said to have been made about thirty-five years ago by Nicholas Fleming, owner of the lot, while excavating the cellar for a house, but no attention was paid to the discovery at that time, and it was not until 1905, when Stephen Wellington purchased an option on the property, that mining operations were undertaken. In that year Wellington sunk the shaft to a depth of 14 feet, and took out a carload of fluorspar in the course of this operation, but the following year allowed the option to expire. In 1907 Wellington

[1] Ann. Rept., Ont. Bureau of Mines, vol. XXVIII, 1919, pt. I, p. 156

renewed the option from William Bailey, who meanwhile had purchased the lot from Fleming,[1] but after taking out a half carload of ore again dropped the option. During the years following the operations of Stephen Wellington, numerous options were taken on the property but actual mining was not resumed until late in 1916, when Mr. H. Hungerford took an option on behalf of the Hungerford Syndicate. This syndicate, after taking out one carload of ore during the early part of 1917, in 1918 purchased the mining rights to the lot outright. When the writer examined the property in the summer of 1920 there was a shaft on the deposit 45 feet deep from the bottom of which a drift had been driven 35 feet towards the southwest. A stope had also been excavated for about 20 feet to the northeast of the shaft.

The only outcrop of rock occurring near the Bailey mine is a mass of fine, dense, green andesite or dacite 50 feet in diameter, situated about 100 feet east of the shaft, but the presence of fragments of grey Precambrian limestone on the dump adjoining the shaft indicates that limestone occurs in the underground workings. The outcrop of andesite or dacite had been fractured and broken along its southern margin and the fractures and the interspaces between the fragments filled with quartz and barite. Fragments of the andesite or dacite were also observed in masses of breccia in the dump, but the matrix in this case included red fluorspar, calcite, and minute flakes of biotite, as well as barite and quartz.

The fluorspar-bearing ore mass occurring on the Bailey property trends approximately north 55 degrees east (magnetic) and dips steeply to the south. The foot-wall of the deposit is fairly well defined, but the hanging-wall is most irregular and poorly defined. The deposit as seen underground at present consists of a zone of banded fluorspar and barite from 6 inches to 2 feet in width, adjacent to the foot-wall, and of caverns separated by fragments of wall-rock enclosed in barite, or fluorspar and barite elsewhere. The width of the mass ranges from 3 to 8 feet, but the maximum width of vein material actually present—owing to the presence of numerous caverns—is considerably less than 8 feet. In the drift southwest of the shaft beneath the Bailey farmhouse, a large open cavern in which stalactites and stalagmites of barite and fluorspar are said to have been present was met. The fluorspar contained in the deposit is mainly a pale green, or honey-yellow variety, but a few specimens were observed on the dump which were red in colour; the principal forms of the mineral are the cube and the octahedron, but unlike the fluorspar in most other deposits, the octahedron is generally dominant. The barite contained in the ore mass occurs partly in a white, massive form, partly as a yellow powder, but chiefly in well developed, white, or pale blue tabular crystals arranged either irregularly, or in the form of domes or columns. Other minerals composing this deposit in addition to the barite and fluorspar are calcite, quartz, and tetrahedrite.

Hill

A number of pits and trenches have been excavated along the outcrops of two small veins or vein-zones of fluorspar exposed on the north slope of a ridge of Precambrian limestone situated a few hundred feet south of the Grand Trunk Railway station in Madoc village. The fluorspar occurs in the excavations on the south deposit as a zone of two or more parallel veinlets, which range from ½ inch to 2 inches in width, and lie from 1 to 2 feet apart. The trend of the veinlets is approximately north 35 degrees west (magnetic); the length of the zone exposed is about 75 feet.

The other fluorspar deposit is exposed in a series of openings lying about 75 feet to the northeast of the south group of pits and consists of one principal vein having a maximum width of 2 feet and an average width of approximately 9 inches. The outcrop of this vein exhibits a peculiar structural feature in that it consists of a number of sections from 25 to 50 feet in length having an echelon distribution, but connected obliquely at their extremities. The echelon sections of the vein all trend 75 degrees east of north (magnetic), and lie parallel to the bedding of the grey,

[1] Ann. Rept. Ont. Bureau of Mines, vol. XIV, pt. I, 1905, p. 106.

banded Grenville limestone which forms the country rock and which in this locality stands nearly vertical. The parts of the vein connecting the echelon sections obliquely trend in a southeasterly direction, however, so that the average trend of the vein as a whole is approximately east-west (magnetic). The zigzag trend of this vein evidently owes its origin to the structure of the Grenville limestone, the bedding in which afforded a plane of easy parting, making an angle of only a few degrees from that of the plane along which the fracture occupied by the vein would have developed had the structure of the country rock been uniform.

The material composing the veins consists mainly of fluorspar but includes a considerable proportion of calcite and some barite. A few small aggregates of pyrite are also present. These occur partly included in the fluorspar and partly resting on the faces of the fluorspar crystals. The fluorspar is an opaque white to honey-yellow variety, and occurs mainly in well-crystallized zones, encrusting the walls of cavities. The crystals are all similar in form, consisting of cubes modified by octahedra. The largest observed had a diameter of about 1¼ inches. When the writer examined the property several tons of fluorspar had been placed in piles adjacent to the openings along the outcrop of the veins. Most of the fluorspar crystals in these piles were covered with an encrustation of iron oxide, indicating that a certain amount of superficial oxidation had occurred in the veins.

McIllroy

The McIllroy property comprises part of the west half of lot 2, concession IV, Madoc township. Mining operations were commenced in this locality in 1916 by Mr. C. R. Ross and were continued at intervals during 1917 and the early part of 1918 by Mr. Ross as manager for a company known as Mineral Products, Limited, which, in the meantime, had been organized to take over the property. Since 1918 the mine has been idle. Several hundred tons of fluorspar are said to have been shipped from the property during the period of its operation.

The deposit from which the fluorspar produced from the McIllroy property has been obtained consists of a northwesterly-trending vein that, as is shown in Figure 5, lies directly on the continuation of the Noyes-Perry-Kane vein. The vein is exposed almost continuously in pits and trenches across the southwest corner of the lot, but throughout the greater part of this distance the vein material is only a few inches wide so that the most of the fluorspar has been obtained from a single lens approximately 70 feet in length. The fluorspar was removed from this lens partly by means of an open-cut and partly by means of a vertical shaft 60 feet deep. When the writer examined the property in July, 1920, the shaft was inaccessible, but the vein is said to have a width of 2 feet in its bottom. The principal data regarding the character of the deposit and the amount of development work performed along its outcrop are indicated in the following table.

Excavation	Character of vein	Width of vein	Dimensions of excavation
Adit No. 1	Merely a fracture, no vein material observed		40 feet long
200 to 100 feet southeast of shaft No. 1	Chiefly fluorite, some barite	2 to 6 inches	2 to 6 feet wide, 1 to 8 feet deep
100 to 80 feet southeast of shaft No. 1	All ore removed but apparently a short lens originally present	Not observed	1 to 4 feet wide, and 25 feet deep
80 to 40 feet southeast of shaft	West wall well defined, vein material fluorspar	6 inches	Trench 4 feet deep
40 feet southeast of shaft No. 1 to 20 feet northwest of shaft No. 1	Lens of fluorspar with horse of wall-rock in centre	Total width of vein material 3 feet	2 to 10 feet wide
20 to 215 feet northeast of shaft No. 1	A series of pits, west wall of vein well defined	Nowhere more than 6 inches wide	Pits 2 to 25 feet deep and 1 to 6 feet wide
Shaft No. 2	Not observed	Not observed	20 feet deep

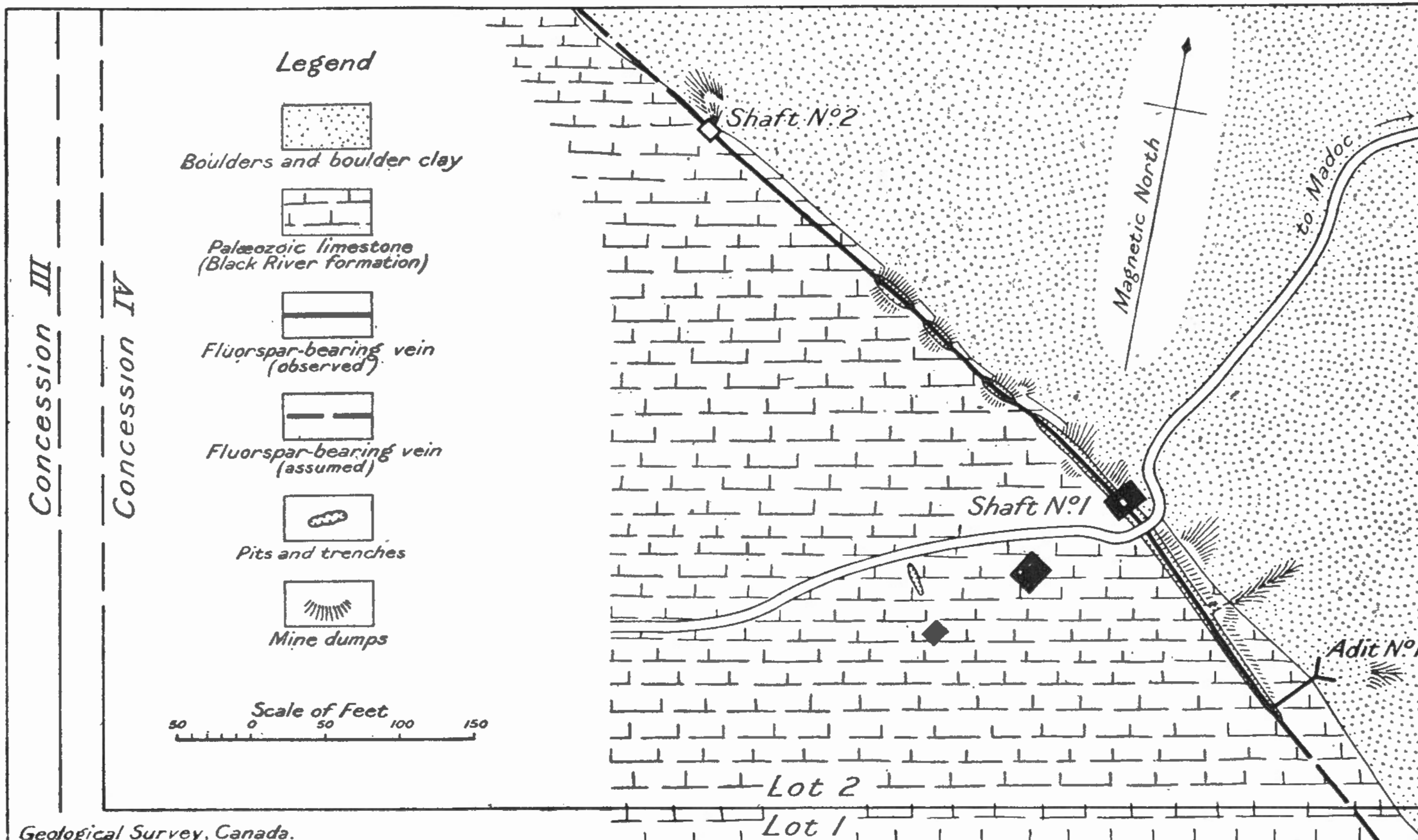

Figure 11. Fluorspar-bearing vein, lot 2, con. IV, Madoc tp., Hastings co., Ont.

Lee Junior

Three fluorspar-bearing veins from one of which three carloads of fluorspar are said to have been shipped by Mineral Products, Limited, in 1917, occur on lot 2, concession III, Madoc township, the property of Mr. George Lee, jun. The principal data regarding these deposits are included in the following table.

No. of vein[1]	Character of vein	Width of vein material	Trend of vein	Dimensions of excavation
1	Barite and fluorspar, barite predominant	6 inches	North 50 degrees west (magnetic)	3 feet long, 2 feet wide, 2 feet deep
2	Interlaminated barite and fluorite	6 to 18 inches	North 45 degrees west (magnetic)	40 feet long, 1 to 3 feet wide, 1 to 3 feet deep
3	White to pale green, massive fluorspar	Not observed, said to be 1 to 2 feet wide	North 50 degrees west (magnetic)	155 feet long, 2 to 5 feet wide, 5 to 15 feet deep

McBeath

A northwesterly trending vein of fluorspar and barite about 1 foot in width is exposed in a trench near the south boundary of the east half of lot 3, concession III, Madoc township, the property of Mr. D. McBeath. No fluorspar has been mined from this deposit, however, and it is of interest chiefly because it lies almost directly on the continuation of the McIlroy vein and is the most northern known occurrence of fluorspar belonging to the Moira Lake group.

Lee-Miller Group

Herrington (Lot 2, Concession XII, Huntingdon Township)

A narrow vein having an average trend of north 30 degrees west (magnetic) is exposed on this property. The principal feature of interest with regard to the deposit is the manner in which the vein is offset at intervals towards the left so that the various parts have an echelon distribution. This peculiar feature appears to be related in its origin to the fact that the average trend of the vein is almost but not quite at right angles to the strike of the grey banded, Precambrian limestone that forms the wall-rock of the deposit; and that this rock fractures more readily at right angles to, rather than obliquely to, its strike; consequently, parts of the vein trend at right angles to the strike of the limestone, whereas the intervening parts trend obliquely. The most important data regarding the deposit are included in the following table.

Excavations numbered from north to south	Character of vein	Width of vein	Dimensions of excavation
1	Calcite chiefly	6 to 10 inches	5 feet long, 3 feet wide, 3 feet deep
2	Calcite and fluorite, calcite predominant	1 to 18 inches	100 feet long, 2 to 4 feet wide, 1 to 10 feet deep
3	Calcite and fluorite, calcite predominant	1 to 2 feet wide	50 feet long, 3 to 6 feet wide, 2 to 10 feet deep
4	Calcite and fluorite, calcite predominant	6 inches to 2½ feet	120 feet long, 2 to 6 feet wide, 1 to 4 feet deep

Lee Senior

A number of fluorspar-bearing veins have been discovered on the east half of lot 1, concession I, Madoc township, by Mr. George Lee, sen., to whom the property

[1] Veins numbered in order of their occurrence from east to west.

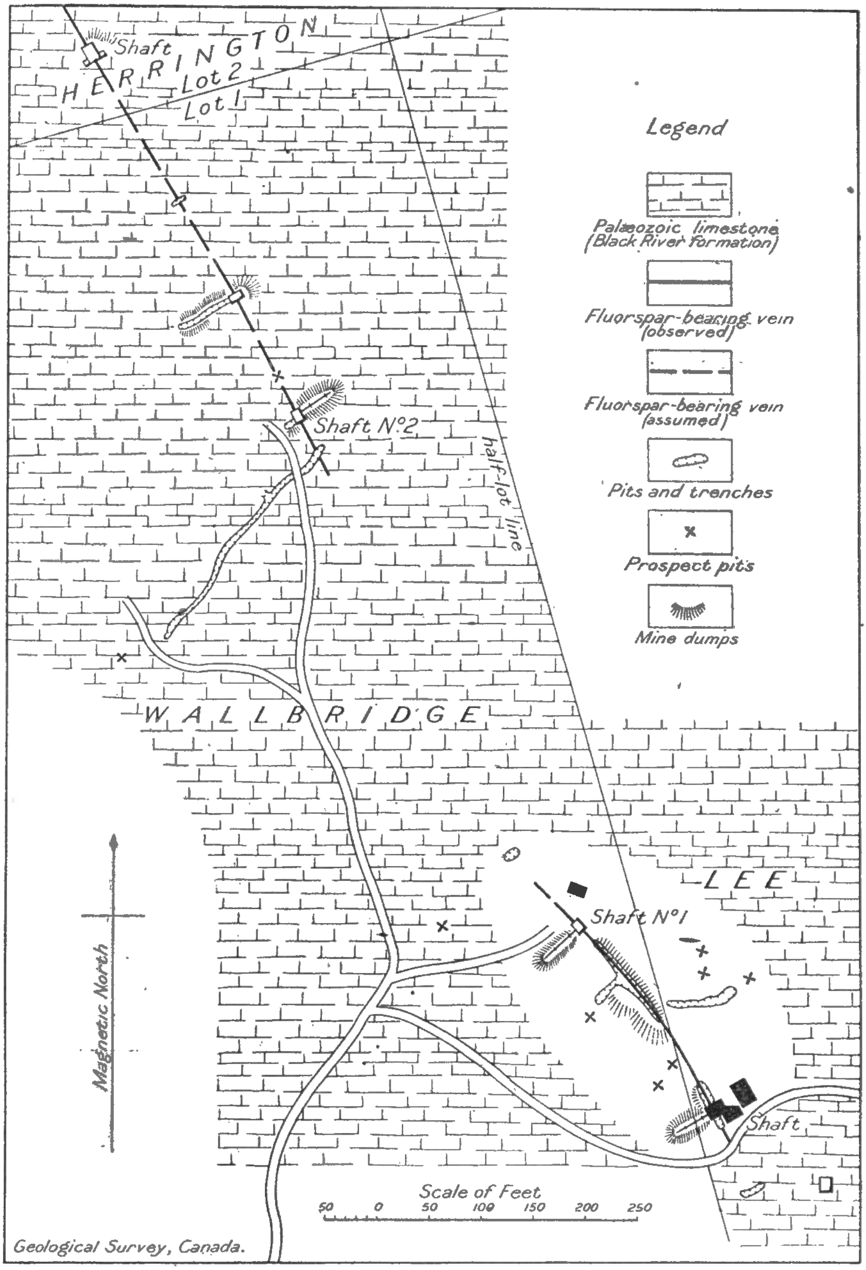

Figure 12. Fluorspar-bearing veins, lots 1 and 2, con. I, Madoc tp., Hastings co., Ont.

belongs. The most important of these occurrences is the No. 5 vein that outcrops close to the west boundary of the property and extends diagonally across the half lot line into the territory belonging to the Wallbridge estate. About 800 tons of fluorspar are said to have been mined from this deposit in 1918 by H. L. Osborne who worked the vein under lease during the greater part of that year. The deposit consisted of a lenticular mass of fragmental or "gravel" fluorspar, 90 feet in length and 8 feet wide at its middle. The fluorspar was mined from the lens chiefly by way of a vertical shaft 60 feet deep from the bottom of which drifts were driven along the vein for 30 feet towards the north and 60 feet towards the south. These workings were inaccessible when the writer examined the property in 1920, but the vein is said to have a width of 2 feet in the bottom of the shaft. The principal data regarding the various veins on the Lee Senior property are included in the following table.

No. of vein[1]	Character of vein	Width of vein material	Trend of vein	Dimensions of excavation
1	Massive fluorspar.....	2 to 12 inches...	North 50 degrees west (magnetic)	80 feet long, 2 to 6 feet wide, 2 to 10 feet deep
2	Fluorite and barite, chiefly fluorite. Two parallel veins in places	3 to 12 inches...........	Variable, north 40 to north 65 degrees west (magnetic)	A series of pits extending 250 feet along vein, 2 to 6 feet wide, 1 to 8 feet deep
3	Massive fluorspar.....	6 inches to 2 feet........	North 35 degrees west (magnetic)	350 feet long, 6 inches to 10 feet wide, and 10 feet deep
4	Chiefly barite and calcite	4 to 12 inches...........	North 30 degrees west (magnetic)	70 feet long, 3 to 8 feet wide, 20 to 25 feet deep
5	White to honey-yellow fluorspar, barite, and calcite, chiefly gravel fluorspar	$2\frac{1}{2}$ to 8 feet..............	North 40 degrees west (magnetic)	Open pit 50 feet long and 10 feet wide, shaft said to be 60 feet deep near south end; drifts 30 feet to south and 60 feet to north at bottom of shaft

Wallbridge

There are two fluorspar-bearing veins known to be present on the Wallbridge property which for the purpose of description may be designated the north and south veins, respectively. Of these, the south vein is the continuation of the No. 5 vein on the Lee property and the north vein the continuation of the vein on the adjacent (Herrington) lot to the north. These deposits were discovered by Mr. C. M. Wallbridge during the summers of 1918 and 1919 while prospecting for the continuation of the Lee vein. Three hundred and eighty tons of fluorspar were shipped from the property in 1918.[2] The principal data regarding the deposits are included in the following table.

[1] Veins numbered in order of their occurrence from east to west.
[2] Ann. Rept., Ont. Bureau of Mines, vol. XXVII, pt. 1, 1918.

Excavation	Character of vein	Width of vein material	Trend of vein	Dimensions of excavation
South Vein:				
Trench between No. 1 shaft and half lot line	Fluorspar and barite	6 to 18 inches.......	North 40 degrees west (magnetic)	125 feet long, 2 to 6 feet wide, 4 to 10 feet deep
Prospect pit adjoining half lot line to south of main vein.	Fluorspar and barite	2 veinlets 6 inches wide		5 feet long, 4 fee wide, 3 feet deep
No. 1 shaft..........	"Gravel" fluorspar forming matrix around fragments of Palæozoic limestone	6 feet..............	North 40 degrees west (magnetic)	55 feet deep
North Vein:				
Trench 40 feet south of No. 2 shaft	2 veins: one on the continuation of the main vein and one 75 feet west of main vein	Width of main vein not determined, width of vein to west of main vein 6 inches	....	1 to 3 feet wide, 2 to 5 feet deep
No. 2 shaft..........	Fluorspar, barite, and calcite	5 to 6 feet of breccia on west, 1 to 2 feet of ore on east. Total width 7 feet	North 30 degrees west (magnetic)	25 feet deep
Opening on parallel vein 5 feet west of No. 2 shaft	Fluorspar, barite, and calcite, forming matrix of breccia in part	5 feet of breccia on west, 2 feet of cavernous ore on east. Total width 7 feet	....	12 feet deep
Pit and trench 130 feet north of shaft No. 2	Gravel, fluorspar, and breccia	4½ feet wide in pit, veinlet 4 inches wide in trench 30 feet from pit	North 30 degrees west (magnetic)	Pit, 15 feet long, 4 feet wide; 15 feet deep. Trench 55 feet long
Pit 240 feet north of shaft No. 2	Chiefly breccia.....	Veinlets 1 to 6 inches wide, breccia 5 feet wide	North 30 degrees west (magnetic)	20 feet long, 2 feet wide, 10 feet deep

Herrington (West Half Lot 2, Concession I, Madoc Township)

The fluorspar-bearing vein occurring in this locality is the northern continuation of the north vein on the Wallbridge property. The outcrop of the vein at the point where a pit has been sunk was overlain by a solid mass of limestone 5 feet thick and at least 25 feet in diameter, which appeared at the surface to be in place but which, on examination of the pit faces can be seen to be underlain by 2 to 3 feet of glacial drift, and has, therefore, been transported into its present position by glacial action. When the writer last visited the property in September, 1920, a vein of "gravel" fluorspar 6 feet wide was exposed in the bottom of the pit which at that time was 12 feet long, 8 feet wide, and 20 feet deep.

Stewart

A northwesterly trending vein of barite and fluorspar 4 inches in width is exposed in a trench and prospect pit in Palæozoic limestone near the northeast corner of lot 2, concession I, Madoc township, the mining rights to which belong to Mr. D. E. K. Stewart of Madoc. The principal point of interest with regard to this deposit is the presence of a small proportion of the minerals chalcopyrite and malachite in the vein.

Ponton

The discovery of fluorspar in this locality (Figure 13) was made by Mr. G. M. Ponton, in 1917. The deposit consists of a northwesterly trending vein from 4 inches to 2 feet in width which is exposed in the bottom of a pit 160 feet long and from 2 to 15 feet deep. Four carload lots of fluorspar are said to have been shipped from the property during the summer of 1919.

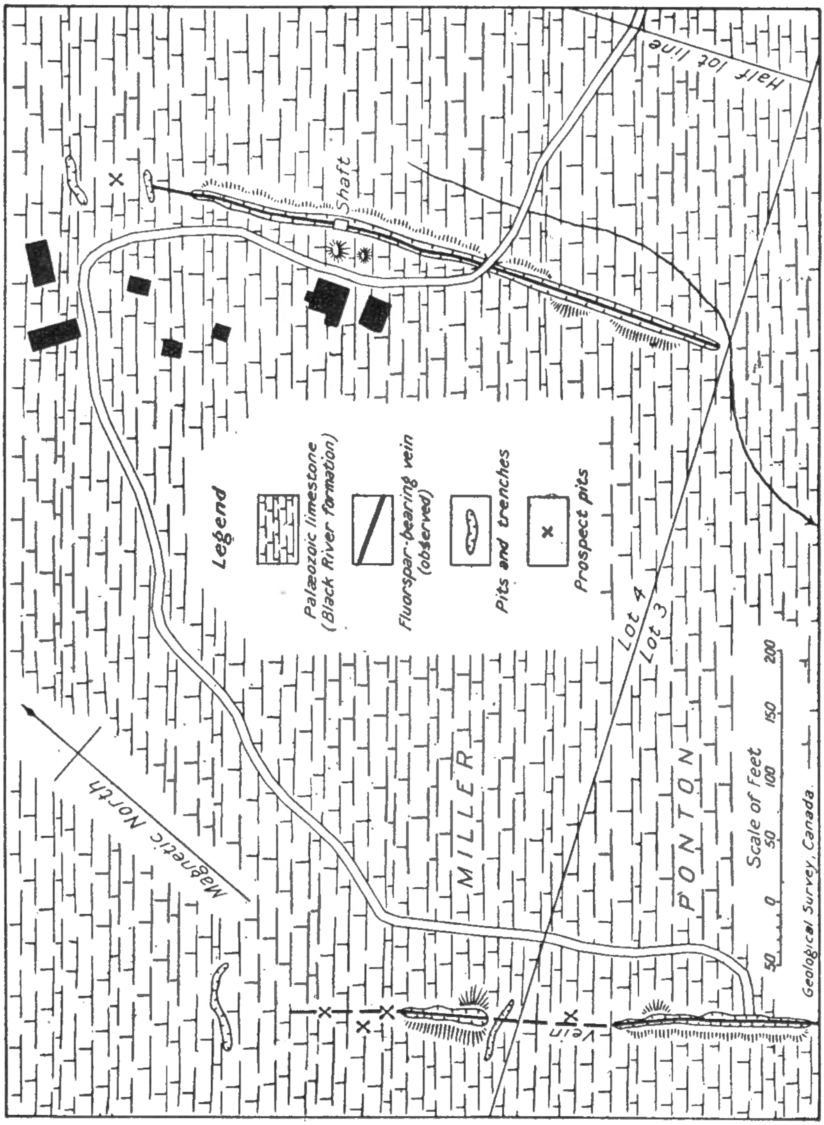

Figure 13. Fluorspar-bearing veins, lots 33 and 4, con. I, Madoc tp., Hastings co., Ont.

Miller

The veins occurring on this property were discovered by Mr. C. M. Wallbridge in the spring of 1917 and were worked by him during the summer of 1917 and the winter of 1917-1918. In the spring of 1918 Wallbridge sold the property to Mr. H. L.

Osborne who continued operations during the following summer and for a short period during the spring of 1919. Since 1919 the property has been idle.

There are two fluorspar veins on the property (Figure 13) which for the purpose of reference may be designated the east and west veins respectively. The principal data regarding these deposits is included in the following table.

Excavation	Character of vein	Width of vein material	Trend of vein	Dimensions of excavations
East Vein:				
Pit south of shaft....	Fluorspar, barite, and calcite	10 inches to 3 feet...	North 25 degrees west (magnetic)	300 feet long, 1 to 5 feet wide, 3 to 10 feet deep
Shaft...............	Fluorspar, barite, and calcite	3 feet at surface to 6 inches at bottom	....	75 feet deep
Pit north of shaft....	Fluorspar, barite, and calcite (barite fibrous in part)	18 inches to 4 feet...	....	130 feet long, 1 to 5 feet wide, 3 to 10 feet deep
West Vein:				
	Honey-yellow fluorspar	2 parallel veins 1 to 2 feet apart. Total width 3 inches to 9 inches	North 40 degrees west (magnetic)	75 feet long, 1 to 5 feet wide, 2 to 20 feet deep

William Reynolds (Lot 5, Concession I, Madoc Township)

A northwesterly trending vein consisting of grey to green fluorspar and calcite was discovered on this property by Donald Henderson and James O'Reilly during the summer of 1920. A shaft 20 feet deep and two pits situated 70 and 140 feet respectively to the northwest of the shaft have been excavated on the vein. The total width of vein material exposed in these openings ranges from 18 inches to 2 feet.

Rooks

The fluorspar-bearing vein occurring on this property was opened up by James O'Reilly during the summers of 1916 and 1917. Several carloads of ore were shipped from the property by O'Reilly as a result of these operations.

The vein outcrops close to a northward facing escarpment and like the other fluorspar-bearing veins of the Lee-Miller group trends in a northwesterly direction (north 45 degrees west magnetic). When the writer visited the property in August, 1920, the vein had been mined away to a depth of 2 to 20 feet for over 300 feet along its outcrop. The bottom of the excavation was hidden by debris, but judging from the width of the excavation from which the vein material had been removed, the vein had a width ranging from 6 inches to 2½ feet.

Plain

Near the north end of Jarvis lake on lot 9, concession I, Madoc township, some prospect pits have been sunk along the outcrop of a veinlet of fluorspar and barite that intersects the red granite exposed in this part of the Madoc district. This veinlet, so far as known, is the most northerly occurrence of fluorspar belonging to the Lee-Miller group.

Other Occurrences of Fluorspar in Madoc District

A number of other fluorspar deposits are present in the district, which either because they are relatively unimportant or because they have been discovered since the writer returned from the field, or because they do not belong to either the Moira Lake or Lee-Miller groups, have not been separately described. The deposits of this class are included in the following table.

Locality	Character and extent of deposit
Lot 14, concession XI, Huntingdon township.......	Vein said to be 5 feet wide
Lot 11, concession XIV, Huntingdon township	Masses of calcite including some fluorspar, maximum diameter 5 feet
West half lot 1, concession II, Madoc township.....	Veinlets of fluorspar and barite a few inches wide
West half lot 3, concession II, Madoc township.....	Veinlets said to be 5 inches wide
West half lot 14, concession IV, Madoc township....	Massive, granular fluorspar, dimensions of deposit unknown to the writer

BROCKVILLE-MALLORYTOWN MAP-AREA, ONTARIO

By J. F. Wright

CONTENTS

Illustration

INTRODUCTION

The writer, assisted by A. N. MacIntosh, spent the field season 1920 collecting data for the preparation of a detailed geological map of the Mallorytown area and the southern part of the Brockville area. The topographic maps of these areas prepared by the Militia Department were used as a base map. The area mapped is triangular and lies along the St. Lawrence just west of Brockville. All the Canadian islands of the Thousand Islands group between Brockville and Lansdowne Dock, approximately 23 miles, were examined. Short visits were also made to some of the important localities in the areas, to the south of the St. Lawrence, already mapped in detail.[1] At the end of the season three days were spent examining the Delta hematite deposits and a description of these deposits is given here.

GENERAL GEOLOGY

General Statement

The Frontenac axis, a low neck of Precambrian rocks, crosses the Mallorytown-Brockville area and connects the elevated Adirondack region of New York state with the great Laurentian plateau of Canada. This axis is underlain by rocks belonging

[1] Cushing, H. P., "Geology of the Thousand Islands region," New York State Mus. Bull. No. 145, 1910.
Martin, J. C., "The Precambrian rocks of the Canton quadrangle," New York State Mus. Bull. No. 185, 1916.

to the Grenville sedimentary series, which are intruded by alkali granitic and syenitic rocks referred to in this report as the Granite-syenite series. Except for a few minor intrusives, these two series represent the Precambrian rocks of the area.

Table of Formations

Quaternary	Post-Glacial	Stratified clay and sand
	Glacial *Unconformity.*	Boulder clay, gravel, and sand
Palæozoic	Beekmantown *Disconformity.*	Sandy limestone
	Potsdam	Sandstone
	Unconformity.	
Precambrian	Minor intrusives	Gabbro and diorite bosses Diabase dykes
	Granite-syenite series	Granite, granite gneiss, syenite, and syenite gneiss
	Intrusive contact.	
	Grenville series	Quartzite, biotite and garnet gneiss, and crystalline limestone

Grenville Series

Quartzite. In this area the most abundant member of the Grenville series is quartzite which outcrops as long ridges or irregularly shaped inclusions in the Granite-syenite series. The contact between igneous rock and quartzite is usually sharp, but in places the quartzite is granitized. The quartzite is a light grey, massive, fine-grained, very poorly-bedded but well-jointed rock, consisting of irregular grains of quartz with abundant alkali feldspars (microcline, orthoclase, and oligoclase albite). All sections contain tourmaline and many diopside and titanite. Some of the apatite and zircon grains are rounded and corroded but most of them show their crystal outline, and are fresh. These rocks are so thoroughly crystallized that it is difficult to decide whether the alkali feldspars are residual or have been introduced later by igneous solutions.

Biotite and Garnet Gneiss. This group includes those dark-coloured foliated gneisses that are interbanded with the quartzite and crystalline limestone or outcrop as inclusions and bands in the Granite-syenite series. They consist of quartz with abundant brown biotite, alkali feldspars, and in some sections red garnets. In many cases the field relations or the red garnets prove the sedimentary origin of these gneisses. Many of the bands and inclusions in the igneous rocks do not contain red garnets, but because of their similiar mineralogical composition and appearance to these known sedimentary gneisses are classed as Grenville sediments.

Crystalline Limestone. The limestone member of the series is not as abundant as in other areas of the Grenville subprovince. The limestone outcrops as impure, narrow bands in the quartzite and in masses on the islands in Charleston lake. The rock is a coarse white to bluish coloured variety and consists of calcium carbonate with abundant diopside, albite, flakes of graphite, and other accessory minerals.

Granite-syenite Series

Rocks belonging to the Granite-syenite series outcrop very extensively and represent different facies of a single great magma which penetrated the Grenville sediments and spread in various directions along planes of weakness. The rocks are medium to coarse grained, pink to greyish in colour, and massive or slightly foliated, but always showing cataclastic texture. In mineralogical composition they range from medium-grained, acidic microcline-granite to coarse-grained syenite such as hornblende, and containing also microperthite and oligoclase. The granitic members of the series are the most abundant; the syenitic members outcrop around the edge of the central granitic mass. In no place was one type seen to cut another, although in a number of places gradations occur between the different members of the series.

Correlation. This Granite-syenite series is equivalent to that which Cushing[1] mapped, directly south of this area on the islands and mainland of northern New York, as Laurentian, or that which Baker[2] mapped as Algoman in the Kingston area 15 miles to the west. No equivalents of Cushing's Picton granite of the New York area or of Baker's Laurentian granite of the Kingston area were found.

Minor Intrusives

A number of small, round outcrops of gabbro and diorite and the diabase dykes are placed in this group. The gabbros and diorites are massive, medium-grained, pyroxene-rich rocks which intrude the Grenville series, but their relation to the Granite-syenite series is unknown. The diabase dykes outcrop throughout the area but are more abundant southwest of Mallorytown. These dykes strike about northeast and vary from 10 to 200 feet in width, but cannot be traced continuously for any great distance. They vary but slightly in mineralogical composition and consist of labradorite and augite with ophitic texture. In a large number of the dykes both the labradorite and the augite are badly weathered. These dykes intrude both the Grenville and the Granite-syenite series.

Palæozoic Formations

The Palæozoic formations have been divided into a non-fossiliferous sandstone and limy sandstone group called the Potsdam sandstone and a fossiliferous limestone group called Beekmantown. Over the whole area mapped the Potsdam member outcrops as outliers, but the Beekmantown limestone outcrops only north, and a short distance west, of Brockville. The Potsdam varies from 5 to 150 feet in thickness and on the basis of the presence or absence of calcareous material can be divided into a number of members which may correspond to the divisions Cushing[3] made in the areas to the south where the Palæozoic formations are better developed.

Quaternary Deposits

The Quaternary or superficial deposits are largely Pleistocene in age. They include glacial deposits and deposits formed in bodies of standing water, and partly fill the depressions between the rock ridges, or form extensive flat areas such as that west of Mallorytown.

The glacial deposits consist of boulder clay and fluvioglacial drift in the form of eskers, kames, and outwash sheets. The finely laminated clay and sand were deposited in standing water closely associated with the retreating ice-front, or possibly in the Champlain marine waters. The many cuts in these clays, made during the summer by the construction of the Montreal-Windsor highway, were examined in detail, but no marine shells were found. In these clays subangular boulders were occasionally seen in place.

ECONOMIC GEOLOGY

No metalliferous deposits are being worked in the area. At various periods from 1868 to 1884 the pyrite deposit, about 2 miles northwest of Brockville, was mined, but the shafts have been filled and the dump used for road material.

Mineralization is scarce in the area and pegmatite and aplite dykes are rarely associated with the Granite-syenite series. Solutions may not have accompanied

[1] Cushing, H. P., "Geology of the Thousand Islands region," New York State Mus. Bull., No. 145, 1910, pp. 36-43.

[2] Baker, M. B., "Geology of Kingston and vicinity," Ont. Bureau of Mines, vol. XXV, pt. III, 1916, pp. 10-15.

[3] Cushing, H. P., "Geology of the vicinity of Ogdensburg," New York State Mus. Bull., No. 191, 1916, pp. 23-52.

the magma or the intrusion of the magma may have fractured the brittle quartzite, so abundant in this area, and the magmatic solutions responsible for pegmatites may have escaped along these fractures and have been destroyed by erosion during the unroofing of the igneous mass.

West of Escott the medium-grained hornblende granite can be very easily trimmed into paving blocks and has been quarried for that purpose. Potsdam sandstone and massive pink granite are being extensively quarried and crushed for road foundation. Some of the diabase dykes are very accessible for road material, but no diabase quarries have yet been opened.

Delta Hematite Deposits

Location. The village of Delta is on the Brockville-Westport branch of the Canadian National railway about 6 miles southeast of Forfar, the junction of the

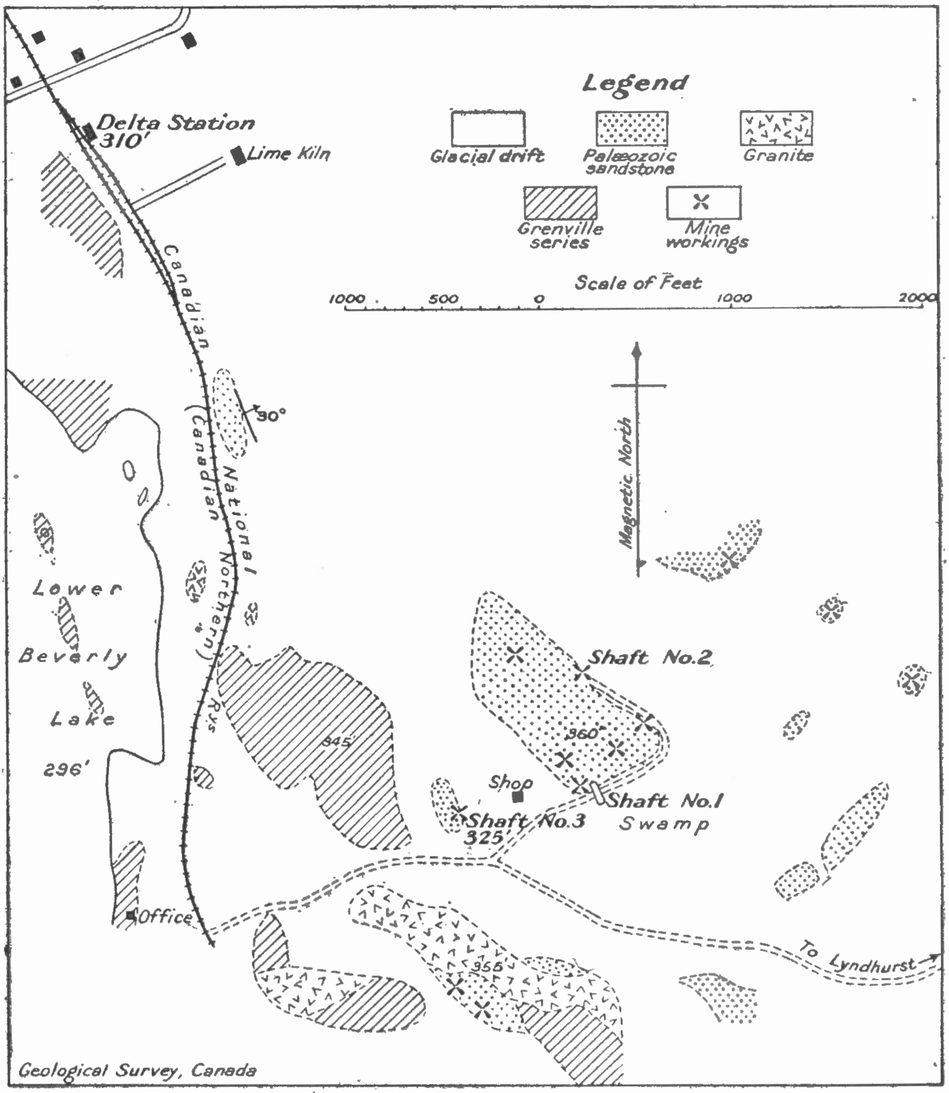

Figure 14. Diagram showing Delta hematite deposits, Leeds co., Ont.

Ottawa-Toronto Canadian National and the Brockville-Westport branch. The deposits are on lot 23, con. X, Bastard tp., Leeds co., and about one mile south of the village and a quarter of a mile east of the railway (Figure 14). The transportation facilities are excellent.

History. These deposits have been known for over 110 years. The early settlers, in 1810, operated a primitive smelter, the ore being ground out by a water-wheel. Since that date the local farmers or prospectors from time to time sunk pits, but little ore was obtained. In 1898 Ingall[1] visited these deposits and described them as similar to many other hematite deposits in this region. He reported the material, in places, to be of good quality, but, in other places, to consist of sandstone impregnated with ochreous hematitic matter.

From October 1918 Drainey Brothers of Toronto worked these deposits, except in winter, until November 1919. In August 1919 the Consolidated Iron and Steel Corporation took over the property. Three small shafts and some prospect pits were sunk, and four carloads of ore were shipped, which according to the smelter records, averaged 68 per cent iron. About one carload of ore was left on the dumps.

Geology. Precambrian. Delta is only 6 miles west of Charleston, the northwest corner of the Brockville-Mallorytown area and the geology of the two areas is very similar. The oldest rocks are the Grenville crystalline limestones, intruded by a coarse white granite. This granite consists of microcline 35 per cent, quartz 25 per cent, oligoclase 20 per cent, and orthoclase 10 per cent. The accessory minerals form about 5 per cent and consist of magnetite, titaniferous magnetite, pyrite, tourmaline, allanite (orthite), apatite, and zircon. Calcite showing rhombohedral forms or occurring as grains along fractures makes up the remaining 5 per cent[2]. The calcite probably assimilated from the crystalline limestone. Ferromagnesian minerals are entirely absent.

Early Palæozoic (Potsdam) Sandstone. The hematite deposits occur in sandstone of early Palæozoic age which outcrops as outliers and forms 50 per cent of the surface rock. This sandstone is greyish to white in colour, but some beds are slightly hematite-stained. A few angular quartzite pebbles are scattered through the sandstone and in a few places a basal conglomerate about 2 feet in thickness is exposed. The rock consists of angular to slightly rounded quartz grains averaging about 2 mm. in diameter. The grains contain abundant rutile needles and dust inclusions. The cementing material is either calcite or silica. Near the workings, however, hematite has partly or completely replaced the calcareous cement.

At the workings the sandstone lies about horizontal. Along the railway track about 1,000 feet south of Delta station a small outcrop of sandstone strikes north 5 degrees west magnetic and dips 30 degrees east. Almost vertical joints are well developed and fall into two groups, one striking north 35 degrees west and the other north 50 degrees east. Along the northwest set considerable fracturing and movement have taken place. The large outlier, around the south and east edges of which shafts No. 1 and 2 were sunk, is 50 feet thick and represents the thickest outlier near the deposits.

Description of Important Workings. Shaft No. 1 (16 feet). The sandstone is massive, thick-bedded, and well jointed. Water in the shaft prevented the ore being seen in place. According to the mine foreman the ore occurs in irregularly shaped pockets. The ore on the dump is either hard, massive hematite mixed with specular hematite, siderite, and calcite or sandstone impregnated with hematite.

Shaft No. 2 (20 feet). About 600 feet north of No. 1. A vertical joint plane forms the northeast wall and to the west of this is a fracture zone along which the sandstone is impregnated with hematite, and veins of hematite, from 1 inch to 2 inches

[1] Ingall, E. D., "Iron ore deposits along the Kingston and Pembroke railway in eastern Ontario," Geol. Surv., Can., vol. XII, 1899, p. 79 I.

[2] Determination made by planimeter method. A. Johannsen, Jour. of Geol., vol. XXVII, 1919, pp. 276-285.

wide, fill a number of the fractures. Most of the ore from this pit was sandstone saturated with hematite.

Shaft No. 3 (15 feet). Occupies a small outlier about 700 feet west of No. 1. The sandstone is jointed. The ore-body consists of two irregularly shaped veins of massive, hard hematite from 3 to 6 inches wide.

Description of Ore. The ore is either a hard, massive, red hematite variety or a sandstone impregnated with hematite. The ore-bodies take the form of small veins and replacements along jointed or fractured zones in the sandstone.

Polished sections of the massive hematite variety show needles or plates of specular hematite in a groundmass of hematite in which is included small bits of calcite, siderite, and probably magnesite.

These carbonate minerals were deposited contemporaneously with, or have been almost completely replaced by, the hematite. A few small stringers of calcite and siderite cut the ore.

The following is a copy of a partial chemical analysis of this ore:

Iron (calculated as metal)	63·95
Phosphorus	0·262
Sulphur	0·011
Silica	0·68
Alumina	0·05
Calcium oxide	3·01
Magnesium oxide	0·26
Manganese	Trace
Carbon dioxide	2·70

Thin sections and polished surfaces of the impregnated sandstone show small, round quartz grains entirely surrounded by hematite and in places the hematite penetrates the quartz grains in the form of short needles or embayments. Secondary enlargement of the quartz grains is common and the quartz added can easily be distinguished because it contains hematite. This secondary enlargement tended to make subangular grains round. Sections from the contact between impregnated sandstone and massive hematite show a very sharp line, although a few small quartz grains were noted an inch or so from the contact in the massive hematite. A section a foot from the contact of one of the veins showed a little calcite as cement along with the hematite. A section 3 feet from a vein contained very little hematite and the cement was almost all calcite. In no place was the proportion of hematite in the sandstone over 33 per cent.

Origin of Ore. The iron minerals appear to be due to solutions circulating along joint planes or fracture zones in the sandstone. The most likely source for the ore minerals is the weathering of overlying sedimentary formations containing iron, probably in the form of the carbonate. No remnants of later Palæozoic formations were found in this particular locality, but a study of nearby areas shows that the sandstone was deeply buried by later Palæozoic formations. The iron was probably carried down as ferrous carbonate and after or during precipitation was oxidized to the ferric oxide hematite. The solutions filled all the open spaces, spread into the sandstone, and replaced the calcareous cement but only slightly the quartz. Flakes of specular hematite in the ore indicate that these deposits have been subjected tc moderately intense metamorphic forces.

Extent of Deposits. Since the ore deposits are mineralized fractured zones in early Palæozoic sandstone their extent depends upon the extent of the sandstone, the continuation of the fracture zones in the sandstone, and the degree of mineralization or filling along the fracture zones. The sandstone outliers form about 50 per cent of the surface outcrops, but in no place are much over 50 feet in thickness. Most of the outcrops are jointed, but not closely jointed, as the face of the workings shows. All the other pits within a mile of the main workings show sandstone stained by hematite. No large ore-body will ever be found but it may be possible to follow these narrow veins and by removing a lot of sandstone obtain a small tonnage of hematite ore.

ASBESTOS: WEIR TOWNSHIP, BONAVENTURE COUNTY, QUEBEC

By Robert Harvie

In view of the publicity given to the efforts to interest capital in the exploitation of the asbestos occurrences of Weir township, it was considered desirable to make an examination to determine their probable commercial possibilities. The trip was made in company with Mr. John George McGinnis of Port Daniel, who has been in charge of recent prospecting operations.

The deposits are in ranges I and II, Weir township—which is only partly surveyed—occupying portions of lots 32 to 36. The principal exposures are on the southwest bank of East river about 12 miles from Port Daniel. Access is by a rough wagon road for 4 miles and the balance of the distance by a poor foot trail.

The asbestos occurs sparingly in serpentine which forms two or three narrow belts, striking approximately northeast-southwest with a nearly vertical attitude, and a maximum thickness of less than 300 feet. Outcrops are sufficiently abundant and the belt may be readily examined since the forest covering has been removed by fire.

The conclusion that this occurrence has at present absolutely no commercial possibilities was arrived at for the following reasons. Any fibre seen was very short and hence would command a very low price. The proportion of fibre is extremely small. Access at present is very poor, and to build even a wagon road, on account of the deeply entrenched V-shaped valley of East river, will be both difficult and expensive. Lacking the essential features of quality, quantity, and location, it seems impossible that this occurrence can be worked profitably in competition with established operations in the Thetford district where many properties of much greater merit are perforce lying idle as being unprofitable.

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The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts, and each designated by a letter of the alphabet. A review of the work of the Geological Survey for the year with lists of reports and maps published during the year, forms part of the Annual Report of the Department of Mines.