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GEOLOGICAL SURVEY BRANCH
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SUMMARY REPORT

ON THE

SERPENTINE BELT OF SOUTHERN QUEBEC

BY

J. A. Dresser.

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SERPENTINE BELT OF SOUTHERN QUEBEC.

(J. A. Dresser.)

INTRODUCTION.

In accordance with the Director's instructions, the past field season was spent in an examination of a portion of the serpentine belt of southern Quebec, between the St. Francis and Chaudière rivers. After a preliminary examination of a part of the county of Brome, where some prospecting for asbestos was being done, and a short visit to some of the asbestos prospects of northern Vermont, I was joined, on June 10, by Mr. A. MacLean, graduate student of Toronto University. Camp was made at convenient places in the district, and work was continued until October 24.

Using the Eastern Townships map—enlarged to a scale of 1 mile to 1 inch—for a topographical basis, the geological mapping was carried on principally by chain and compass surveys. Certain cross sections requiring greater precision were measured by transit and stadia. Material has now been obtained for a preliminary map of the serpentine areas thus far examined.

I am indebted to A. MacLean, B.A.—who acted as assistant for the third year—for most efficient services; to W. J. Messenger, M.A., for valuable temporary assistance; and to the managers of the various mines of the district for many courtesies.

Dr. C. H. Richardson, of the Geological Survey of Vermont, spent several days of his field work in showing me over a section across a part of that State. An opportunity was thus afforded of following the complicated structure of this region from Ordovician to Pre-Cambrian, including the serpentine belt, under most favourable conditions. I must acknowledge with warmest thanks Dr. Richardson's valuable aid and kindly courtesy.

LOCATION AND AREA.

The area examined forms a narrow belt which extends from the St. Francis river in the county of Richmond to a point near the Chaudière river, in the county of Beauce. The northern extremity is near the town of Beauceville, on the Quebec Central railway, about 50 miles from Quebec city. Toward the south the work was carried to Corris station, on the Grand Trunk railway, 81 miles from Montreal, on the main line to Portland. The length of the area examined is about 80 miles, its greatest breadth 8 miles, and the average less than 2 miles.

PREVIOUS WORK.

The first geological examination of this area was made by Sir William Logan, whose work was supplemented by chemical and mineralogical investigations by T. Sterry Hunt, principally between the years 1847 and 1863. The general distribution of the serpentines and associated rocks was ascertained, and their economic importance pointed out.

In the Report of Progress of the Geological Survey for 1880-1-2, Dr. F. D. Adams published the results of a microscopic examination of a suite of specimens of these rocks, and showed that the serpentines are derived by alteration from peridotite, an igneous rock, and not from sediments as had been previously supposed.

Between the years of 1883 and 1886, soon after the beginning of asbestos mining in the district, a re-examination was made by Mr. R. W. Ells, who carried out an extensive revision of the areal geology of the southern part of the Province of Quebec.

In 1905, a monograph by Fritz Cirkel, M.E., was issued by the Mines Branch of the Department of the Interior, which describes the occurrence, uses, and methods of mining and concentrating asbestos. In 1908, a similar volume on the subject of chromite, also by Mr. Cirkel, was issued by the Mines Branch of the Department of Mines.

In 1907, a detailed examination of the serpentine belt was begun for the Geological Survey by the writer, and in 1909 a short paper on the mode of occurrence of asbestos was published in *Economic Geology*, and a somewhat more general one on the mineral resources of the serpentine belt, in the Journal of the Canadian Mining Institute.

OBJECT OF THE PRESENT INVESTIGATION.

The present investigation, which was begun in 1907, was designed to obtain the fullest information possible regarding the geological structure and economic resources of the serpentine belt, with especial reference to the asbestos and chromite deposits. Accordingly, the work of the first season, which was a short one, was principally spent in a study of the character and mode of occurrence of the mineral deposits themselves, and was confined to the mines and their immediate vicinity. The work was suspended during the following year, but was resumed in 1909, when a study was made of the distribution and extent of the mineral-bearing rocks and of the geological features which govern the occurrence of the mineral deposits.

The work is now so far advanced as to permit of issuing a preliminary report and map of the portion of the district which lies between the Chaudière and St. Francis rivers. Further field work is necessary to the south, through the counties of Richmond, Sherbrooke, and Brome to the International Boundary, before a final report can be prepared.

SUMMARY AND CONCLUSIONS.

Asbestos occurs in serpentine of two varieties which are thought to be of different ages. They may be conveniently called the Thetford and the Broughton types, and the rocks associated with them, the Thetford and the Broughton series, from townships in which they are well known.

Asbestos of the Thetford type occurs in veins, and is generally longer and stronger than that of Broughton. Chromite also occurs in the Thetford series. The asbestos of Broughton occurs principally as 'slip' fibre, or fibre arranged parallel to cleavage faces of the rock. It is more cheaply mined than that at Thetford, but being shorter and of less tensile strength it has a lower market value. The Broughton asbestos deposits are often associated with talc or soapstone, which is not found in any important amount at Thetford. There are no deposits of chromite in the serpentine of Broughton.

In both quantity and quality of the minerals produced, much the greater value is obtained from the serpentine of the Thetford type. It forms the greater part of the serpentine belt, and includes the mines of Thetford, Black Lake, and Danville, with much of the intervening areas. It also extends southward beyond the St. Francis river.

The Broughton serpentine contains the mines and prospects of East Broughton and the vicinity of Robertson. The property of the D'Israeli Mining Company, Limited, in Garthby, and some prospects in ranges I, II, and III of Tring, also belong to this class.

The production of asbestos has increased steadily from the beginning of mining in the district thirty years ago to the present. It now has an annual value of $2,500,000.

Chromite occurs in workable deposits in the Thetford serpentine, but not, as far as known, in that of Broughton. The value of the annual production for several years has been about $80,000.

Soapstone, or talc, is found in important quantity associated with the Broughton serpentine, but not with that of Thetford. Some shipments were made from these deposits over twenty years ago, but a stable industry has not yet resulted.

The serpentine of the Thetford class has been derived by alteration from peridotite. The origin of the Broughton serpentine has not yet been satisfactorily determined, but it has doubtless been derived from the same, or from a closely allied rock.

In both cases the original rock was a member of a series of intrusive rocks differentiated from a single magma. The series comprises peridotite, pyroxenite, gabbro, diabase, porphyrite, and hornblende granite, the latter sometimes passing into aplite. The granite has usually been injected a little later than the other members of the series, and, therefore, in many places forms dikes and sills or intrusive sheets. These probably had a favourable influence in the formation of asbestos deposits, especially in the vicinity of Thetford Mines.

The igneous complex takes the form of a batholith, or thick laccolith, in the area between Thetford and Danville, and elsewhere is in sheets or sills. The serpentine of the Thetford type occurs both in sills and batholithic masses, while the serpentine of Broughton is only in sheets or sills.

The different rock varieties are arranged in order of decreasing density: in sills, from the base upwards; in batholithic masses, from the centre outward. This order is peridotite, pyroxenite, gabbro, diabase, and porphyrite. The peridotite alters to serpentine, and the serpentine is purest and so most likely to carry asbestos, near the base of a sill, or the centre of a batholithic mass.

A result of this arrangement of the igneous rocks is, that, when the structure is known, the location of the purest serpentine may be determined. Most of the sheets dip towards the southeast, and in such areas the best prospecting ground is along the northwest side of the igneous belt. Where the sills dip to the northwest, the best prospecting ground is near the southeast border.

In the batholithic bodies serpentine is exposed only by erosion of the original rock masses. This has been most effective on the northeast side of the hills, that being the side against which the ice has moved in the glacial period.

Besides the purity of the original peridotite, which is necessary that pure serpentine may form, the degree of alteration of peridotite to serpentine is an important factor in the formation of asbestos. The degree of alteration is indicated by the relative hardness of the rock. If the original rock were a pure peridotite—that is, composed essentially of olivine—the more completely it is altered to serpentine the softer the resulting rock and the better the prospect for asbestos. But, if the original rock contained a considerable amount of pyroxene which has been altered to soapstone, the resulting rock may be softer than the purest serpentine, but will be unlikely to contain asbestos. Therefore, soft rock is a good indication of asbestos, if there is no soapstone present.

The presence of granite, also, seems to have a bearing upon the occurrence of asbestos veins. The granite rock has generally been injected later than the other rocks; it fills fissures formed in the solid peridotite and forms dikes and sills. Either the fissuring or the action of the granite in filling the fissures has probably aided in forming asbestos.

Since the parent rock of the serpentine was a deep-seated one, and since the alteration to serpentine may occur at great depths, there appears to be no reason why the asbestos deposits also may not continue to as great depths—probably to the limits of profitable mining.

The chromite occurs in segregated masses, that are thought to be primary, in the outer part of the peridotite or serpentine portions of the batholithic masses, near the pyroxenite zone.

Chalcopyrite and pyrite occur in bodies of possible importance, in the diabase of Garthby and other places in the district. They are thought to be primary segregations.

Antimony occurs in South Ham, as a contact deposit in schists, adjacent to serpentine and diabase. The deposit contains native antimony, kermesite, valentinite, and a little stibnite.

Platinum is known to occur in the drift, and this has come from the direction of the chromite deposits, which are the probable source of the metal.

GENERAL CHARACTER OF THE DISTRICT.

Physical Features.

The portion of the Province of Quebec which lies south of the St. Lawrence river consists of two distinct parts, the St. Lawrence plain, and the Appalachian highlands. The St. Lawrence plain, so-called, is really a broad, flat valley, which, since it has an average gradient of scarcely 10 feet in a mile, appears to be a level plain. It extends southeast of the St. Lawrence river for a distance of 50 miles near the International Boundary line, but grows narrower farther down the river, and terminates where the Notre Dame highlands reach the river about 100 miles below Quebec city. The St. Lawrence plain is part of the greater lowland which extends from the lower part of the St. Lawrence river to Georgian bay.

The highlands which form the rest of the Province south of the St. Lawrence are known as the Shickshock mountains, in the Gaspé peninsula; while in the southern part of the Province, or Eastern townships, they are sometimes called the Notre Dame hills. They are a northward extension of the Green and White mountains of New England, and form the most westerly member of the Appalachian mountain system in Canada.

The topography of the district is in an early stage of maturity. The altitude varies from 400 feet to 2,000 feet above sea-level. The relief is characterized by numerous northeast and southwest running ridges and valleys, and a smaller number of larger, transverse valleys.

The transverse valleys are those of the Chaudière, Beçancour, Nicolet, and St. Francis rivers. These rivers all follow northwesterly courses, and empty into the St. Lawrence. It is not yet known whether they are older than the present hills and have cut through the folds as they were formed; or have been superimposed upon them by the removal of later formations, of which remnants are found in the district.

The tributary streams often run in structural valleys, and are probably younger than the main rivers. They generally have narrow valleys with steep sides, and frequently enter the main rivers by distinct falls.

These furnish the principal water-power of the district, and have given rise to such manufacturing centres as the city of Sherbrooke, at the junction of the Magog with the St. Francis; or Windsor Mills, at the entrance of the Wattopekah to the same river.

While the country as a whole is fairly well cleared of timber, many parts of the more rugged surface of the serpentine belt are still densely wooded. In the valley through which the Quebec Central railway runs there is generally a heavy drift covering, which, with the thick second growth that covers the surface for several miles between Coleraine and Thetford Mines, makes detailed work in some places difficult. On the high land and hill tops forest fires have recently exposed much of the surface to view.

Transportation and Communication.

The parts of the district in which the principal mining is done have good railway facilities. The asbestos mines of Thetford, Black Lake, and East Broughton are in no case more than a mile from the Quebec Central railway, and little farther from ship-

ping stations. Most of these mines have sidings, or short spurs connecting the mills with the railway. At Danville, the Asbestos and Asbestic Mining Company, Limited, has built a branch line, about 3 miles in length, connecting the mine with the Grand Trunk railway.

The areas remote from the railways are all accessible by public highways of the ordinary character. The chromite mines are less favourably situated in this respect, but none are more than 7 miles from a railway.

GENERAL GEOLOGY.

The region of southeastern Quebec is underlain by strata of Palæozoic age, resting upon the Pre-Cambrian complex, which emerges from beneath the later rocks a short distance north of the St. Lawrence. The Palæozoic strata form an ascending series toward the south, except where folding and subsequent erosion have disturbed the order of exposure. Every formation from Cambrian to Devonian is represented.

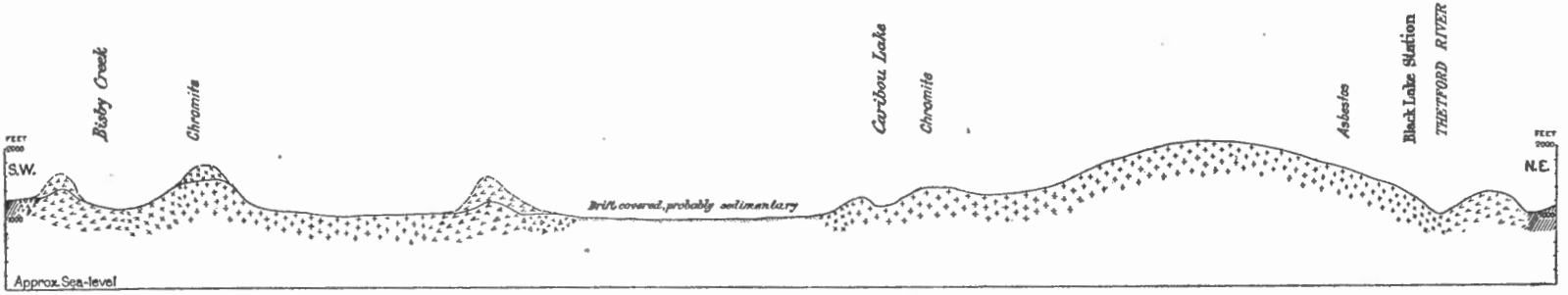
The structure, however, is far from uniform. In the northwestern part of the St. Lawrence plain, the strata are conformable from Potsdam to Hudson River. They are little disturbed in position, and dip toward the southeast at a low angle, usually 5° or 6°. This regularity ends abruptly at the line of the St. Lawrence and Champlain fault, a great dislocation which extends from the foot of Lake Champlain northeasterly to Quebec city and thence to the Gulf of St. Lawrence, running in or near the present channel of the river. On the southeast side of this fault the strata are highly folded, and have otherwise suffered greatly from regional metamorphism. The conditions of deposition were also different. The marine fossil fauna indicate cold, perhaps sub-arctic, conditions, and an unconformity is found at or near the base of the Ordovician, which is not found on the west side of the fault.

Over considerable areas east of the fault, the folded rocks have been planed down by erosion, so that they now underlie the eastern part of the St. Lawrence plain without expressing their structure in the topography. The sediments of the region consist of shales, limestones, and sandstones, with schists, slate, and quartzites on the east side of the great fault.

The highlands, or Notre Dame hills, consist of three anticlinal ridges running in a northeasterly direction, with two broad, intervening basins, which each have a width of about 25 miles. The ridges are usually distinguished as the Sutton, Sherbrooke or Stoke, and Lake Megantic anticlines. The last forms a part of the boundary line between the Province of Quebec and the State of New Hampshire. The first mentioned is the most westerly of the Appalachian folds in this region, while the second forms the Capelton hills and Stoke mountain, in the vicinity of the city of Sherbrooke, and the hills of Weedon farther to the north.

The ridges contain a considerable development of ancient volcanic rocks, porphyry, and greenstones. These are overlain by sediments, some of which are probably of Pre-Cambrian age.

On the southeast side of the Sutton ridge and closely following its course is the series of basic intrusive rocks which form the serpentine belt. Entering the Province at the Vermont boundary line, they continue northeasterly, with little interruption, to the vicinity of the Chaudière river. They are part of a series of similar rocks which appear at frequent intervals in the eastern part of North America, from Georgia to Newfoundland. In Quebec, they consist of peridotite and serpentine, pyroxenite, gabbro, diabase, porphyrite, hornblende-granite, and aplite, and are regarded as differentiates from a single magma. They form hills 1,500 feet in elevation, covering 10 to 20 square miles in some parts, and in others appear as only narrow bands a few hundred feet wide. In width they rarely exceed 5 miles, and are usually less than 1 mile. In structure they are considered to form batholiths or thick laccoliths, and intrusive sheets or sills.



DIAGRAMMATIC SECTION ALONG POWER LINE OF ST. FRANCIS HYDRAULIC CO, BETWEEN THETFORD RIVER AND BISBY CREEK

Horizontal scale: 1 mile to 1 inch
Vertical scale: 2640 feet to 1 inch

In the area to be described the rocks of the serpentine belt cut no rocks later than Sillery (upper Cambrian), though they probably alter some Ordovician strata. To the south of this district, however, in the county of Brome, they cut Ordovician, and alter strata of Devonian age. It is not yet proven, however, that the rocks of the series were all intruded at or nearly at the same time. The rocks of the district thus far examined appear to be of at least two different ages, and other periods of intrusion may yet be found. Hence the age of the series as a whole can only be determined approximately.

TABLE OF FORMATIONS.

SEDIMENTARY.

1. Quaternary..	Sands and gravels. Stratified clay. Boulder clay.
2. Ordovician—Farnham?..	Black slates. Conglomerate.
3. Cambrian—Sillery..	Red and green slates and sandstones.
L'Islet..	Quartzose, grey schists, and quartzite.

IGNEOUS.

(Intrusive, and of different ages.)

Post-Sillery; in part, at least, later than lower Devonian—Thetford Series..	Peridotite, altering to serpentine. Pyroxenite, gabbro, diabase, porphyrite, Granite and aplite.
Post-L'Islet—Broughton Series..	Serpentine. Soapstone. Greenstone schists.

Sedimentary.

QUATERNARY.

The covering of drift throughout much of the district is heavy. Sands, gravels, and stratified clays are found in all the depressions, and obscure the geological structure, especially in the valley through which the Quebec Central railway runs from D'Israeli to Thetford Mines. In the valleys of the principal streams well marked terraces have often been developed. An especially good example may be seen on the northeast side of the valley in which the road runs from Broughton station to Harvey hill.

No marine fossils have been found in these deposits. In composition they represent complementary parts of the underlying boulder clay, from which they have been principally derived.

The ice movement which has had the most marked effect on the surface of the country has come from the north-northeast, the general course being S 20° W. Another set of glacial striæ running northwest indicates a weaker glacial movement. The former of these ice movements has eroded the northeast side of the principal hills so far as to have an important effect on the exposure of the serpentine.

ORDOVICIAN.

A series of sediments which are near, but not in contact with, the intrusive rocks in this district, consists of graphitic, argillaceous, and sometimes calcareous slates. They are in many places soft and very fissile, and everywhere steel grey or black in colour.

They occupy a large part of the basin between the Sutton ridge and the next to the east, and so appear on the southeast side of the serpentine belt throughout the district, usually at a distance of less than a mile. They occupy the troughs of many of the minor synclines in the underlying sediments, and in such cases generally contain pebbles of earlier sediments. Such outliers approach nearer to the intrusives and may be cut by them, but no such contact has been found. The series is the lowest member of the Ordovician here found, and is tentatively referred to the Farnham series of the lower Trenton formation.

CAMBRIAN.

The rocks which in most places border the serpentine belt are believed to be of Cambrian age. They occupy an area 5 to 10 miles wide, in which is included the outliers and erosive remnants of Ordovician mentioned above. The principal rocks of the series are red, green, and grey slates and schists, sandstone, and quartzite.

Sillery.—The red and green slate and the sandstone are a southerly extension of the Sillery formation of the vicinity of Quebec city and the lower St. Lawrence plain. This formation is regarded by Dr. Ells as belonging to the upper part of the Cambrian system.

L'Islet.—The grey schists and quartzites are lower members of the series. No fossils have been found in them, and no basal conglomerate, or other mark of unconformity, to indicate that the base of the group has been reached. While the rocks are principally sedimentary, some of the grey schists and slates may prove to be altered volcanics.

This formation has been previously called the L'Islet, from its large and well-defined development in L'Islet county beyond the northern boundary of the present district, where it is distinguished by its geographic position and stratigraphic relations, as well as by the lithologic characters of the rocks comprised in it.

STRUCTURAL RELATIONS OF THE SEDIMENTARY ROCKS.

The boundaries between the Ordovician and the Cambrian are usually definitely marked by the conglomerate at the base of the former. This consists of pebbles of the underlying Cambrian sandstone in a matrix of the overlying Ordovician schist. It, therefore, marks an unconformity, indicating a time break between the two formations, and shows this part of the Ordovician to be the base of that system.

The lower limit of the Cambrian is not so well defined. No basal conglomerate, or other certain mark of an unconformity, has been found in this district, and it is a matter of some doubt whether the earlier intrusives of Broughton lie wholly in the Cambrian, or partly in still older rocks.

The strata here described are on the southeast side of the Sutton anticline, one of the major axes of the Notre Dame hills. Consequently the strata have a general dip toward the southeast, with minor folds giving dips in the opposite direction.

The axis of the first important syncline runs across the township of Broughton on lots 21 and 22 or 23. The trough of the syncline in Broughton is occupied by Ordovician strata, while Sillery measures appear at a distance of a mile on either side. The valley in which the Quebec Central railway runs from Thetford Mines to East Broughton is on the axis of the same syncline at Thetford Mines, but some 2 miles west of it at East Broughton. In the southwestern part of the district the structure is not as well expressed in the topography, but the general relations continue the same.

Igneous.

THETFFORD SERIES.

The rocks of the Thetford series make up the greater part of the serpentine belt. In this district they extend southwesterly from Broughton mountain, in the township of Broughton, through Thetford, Coleraine, Ireland, Wolfestown, and Garthby to Big Ham mountain. After an interval of 4 miles they reappear in Little Ham mountain, and continue in a southwesterly direction to Danville, and thence to the St. Francis river. Diabase occupies the largest area of any rock of the series, peridotite and serpentine the next. Gabbro and pyroxenite also form considerable masses, while granite and aplite are of relatively small extent.

Peridotite and Serpentine.—Serpentine forms the country rock of all the mines, and, with less altered peridotite, makes up many of the larger hills in the mining district. The hills near Little Lake St. Francis, near Black Lake, in the southern part of Ireland, and between Belmina and Chrysotile, as well as smaller areas in other parts of the serpentine belt, are composed of serpentine and peridotite.

It is difficult, and often impossible, to distinguish these rocks in hand specimens. In the field, and in mining operations, they are collectively called serpentine. The peridotite is composed of olivine, a small amount of pyroxene, and a little chromite and magnetite. The serpentine is merely an altered phase of the peridotite. The mineral serpentine is derived from olivine by a process of alteration, which consists principally of the addition to it of water, and the loss of its iron content. Pyroxene may also alter to serpentine; but it changes less readily than olivine, having originally more silica in its composition; and more frequently it alters to soapstone or talc. The olivine is sometimes completely altered to serpentine, while the pyroxene remains little changed. On freshly broken faces of serpentine, the pyroxene crystals, when any are present, show as glistening grains, usually $\frac{1}{8}$ inch or less in diameter. On weathered surfaces they stand out in relief, giving a rough surface to the serpentine, like raised nail heads, or knots in a worn floor. This is well shown in the rock near the summits of the serpentine and peridotite hills, as, near the top of the hill above Black Lake village.

Pyroxenite.—When pure, pyroxenite consists of the mineral pyroxene. There is usually present, however, more or less olivine or feldspar, the former if the rock is approaching the composition of peridotite, the latter if it tends toward gabbro.

The pyroxenite near the Danville asbestos mines is singularly coarse-textured, and much of it is composed of large pyroxene crystals, some of which measure 2 inches or more upon single faces. In general, the pyroxenite is somewhat altered to soapstone.

Gabbro.—When there is feldspar as well as pyroxene present, the coarse-grained types have been classed as gabbro. It can be distinguished by its coarse texture, shown by angular grains of grey feldspar and green pyroxene. Gabbro forms a large part of the hills above Lac Coulombre, about Nicolet lake, and Little Ham mountains. It may be seen along the roadside near the southeast shore of Black lake, and in many other places near the foot of serpentine hills. The pyroxene is sometimes altered to hornblende; the rock is then more correctly called a gabbro-diorite.

Diabase.—The diabase has the same mineral composition as the gabbro, but is much finer grained, and generally has a quite different appearance. It is a fine, green rock sometimes showing small, grey grains of feldspar. In other cases no individual mineral can be distinguished by the unaided eye. The rock can often be readily recognized by nodules and stringers of yellowish-green epidote, a mineral that has been formed by the alteration of feldspar, and, in part, also of pyroxene. There is frequently a little quartz with the epidote.

Diabase may be well seen along the Quebec Central railway between Black Lake and Thetford Mines; also near the Roman Catholic church at Black Lake. It forms the hills about Clapham lake, and near the Little Nicolet lakes. It carries copper and iron pyrites, in places, as at Lac Coulombre. In places, the diabase, by becoming more acid in composition, and losing much of the pyroxene, passes into porphyrite near the outer edges of the mass.

Granite.—The granite in this area is composed of feldspar, quartz, and hornblende or mica (biotite), or both. It is light grey in colour, and occasionally shows a pinkish tint. Portions without hornblende or mica—principally dikes—are more properly classed as aplite.

The granite is in small amount in the district, but is important, as it probably indicates conditions that favoured the development of asbestos. It forms hills in the northeastern part of Coleraine, dikes in most of the mines, and, in places, isolated masses grading into the enclosing diabase or porphyrite. These isolated masses are, probably, primary segregations.

Structural Relations.

(*a*) *External.*—The rocks of the Thetford series are very obviously intrusive in their relations to the enclosing sediments. Evidences of this are: alteration of the sediments in the outer contact zone; deflexion of their dip and strike; and developments of contact breccia.

The alteration of the sediments is sometimes shown by a hardening of a band near the contact, producing a hornstone rim. The grey slates are often given a rusty, reddish colour, due apparently to the oxidation of sulphides developed near the contact; while the originally red Sillery slates are usually bleached to pale pink. Fragments in the breccia, and larger portions of sediments near the contact, show partial absorption by the igneous magma. Some of these rocks still preserve the lines of foliation of schists on weathered surfaces, but on freshly broken faces they cannot be distinguished from the enclosing, or adjacent, igneous rock.

Dikes are very rare, and altogether there is a very noticeable absence of evidence of any violent eruption. The intrusion seems to have progressed slowly, and without any marked cataclysmic action. The contact is thus of the batholithic type.

The bodies of igneous rock appear to take two principal forms. From Broughton mountain to Little Nicolet lake, where the igneous belt crosses the stratification somewhat obliquely, the intrusions occupy elliptical or rounded areas, bordered by breccia, and giving evidence of downward enlargement. With the exception of one district, and two doubtful intervals, they form a continuous mass, and so are interpreted as being a batholith, or very thick laccolith.

In other parts of the district, the boundaries of the intrusions conform more closely to the stratification, are generally brecciated on one side only, and occupy long narrow areas. In cross section they can sometimes be seen to form sills or intrusive sheets, and are consequently considered to more generally take this form.

(*b*) *Internal.*—The peridotite, pyroxenite, gabbro, and diabase, form a continuous series, passing by gradual transitions from one variety to another in the order named. In the case of larger exposures, all of these rock types can sometimes be found in a single intrusive mass. In other cases, the differentiation is sharper, and peridotite passes into diabase with only a few feet of transitional rock between. In general, peridotite, or the serpentine derived from it, and diabase, form the larger portion of a rock mass. At the outer edges, the diabase, in places, passes into hornblende porphyrite, and this occasionally into hornblende granite, or aplite.

The granite and aplite have usually, however, been intruded a little later than the more basic rocks. The edges of these acid intrusions are generally as well crystallized as the central parts, showing that they were brought in while the basic rocks were still

heated. Occasionally, too, an injection of diabase has taken place somewhat later than the intrusion of the greater part of the mass. This may be seen at Louise mountain, in Garthby, and probably near Shipton Pinnacle, but such occurrences are not common.

The rocks of this igneous complex are generally distributed in one or other of two different modes of arrangement, according to the form of the igneous intrusion. They are arranged in order of decreasing basicity and density:—

(*a*) In sheets from the base upwards.

(*b*) In batholithic intrusions from the centre outwards. Serpentine, or diabase, may sometimes be much in excess of the other rocks, and thus give an asymmetric arrangement. But the more acid rocks, wherever present, are, as far as known, invariably nearest the tops of sheets or the margins of batholithic intrusions, and the basic rocks in correspondingly opposite positions.

In the case of sheets, the arrangement of the rocks accords with the relative densities of the principal minerals of which they are composed, and also with the order of their crystallization.

In the case of batholithic intrusions, the differentiation from basic to acid extremes, from the centre outwards, is in agreement with well known cases of magmatic segregation in intrusive rocks where differentiation has taken place prior to intrusion. The igneous complex of Magnet cove, Arkansas, is a parallel in alkaline rocks.[1]

An instance is given by Mr. Chas. Camsell (see Mr. Camsell's Summary Report in this volume) of a volcanic stock from the platinum locality in the Tulameen district of British Columbia, where a core of peridotite is bordered by a differentiated rim of pyroxenite. An adjacent intrusion of augite syenite took place a little later.

The batholithic intrusions near Thetford characteristically consist of a dome-shaped central mass of peridotite, bordered, or sometimes nearly surrounded, by an erosion valley. The outer side of the central mass is formed by a ridge of diabase, or porphyrite, which passes into breccia at its outer edge. These fractures can be seen in a section extending from the top of the hill above Black Lake station, which is part of the central dome, to the valley of the Thetford river, and thence to the diabase at the Roman Catholic church in the northern part of the village. (See diagram, page 185.)

BROUGHTON SERIES.

The Broughton series consist of serpentine, soapstone, and greenstone schists. They are the rocks containing, and adjacent to, the asbestos and talc deposits of Robertson, East Broughton, and Broughton, and of several isolated locations in the vicinity.

The rock differs from that of Thetford and Black Lake, in being much softer and more shattered. It is almost completely serpentinized, the only exception being certain hard blocks which carry no asbestos. The asbestos that is recovered here rarely occurs in veins, but generally as slip or parallel fibre, being, in fact, only the softer and partially fibrous, outer portions of the individual pieces into which the rock is shattered. A microscopic examination of these rocks is still necessary in order to determine the actual mineral composition of these hard blocks, and to find out, if possible, whether the asbestos-bearing portion was originally similar to that in the Thetford series. The presence of considerable bodies of talc, and steatite or soapstone, indicates that there was a good deal of pyroxene in the original rock. There is very little chromite in the serpentine of this class.

The altered greenstones are chloritic and epidotic schists, which probably were originally diabase, together with hornblende schists which grade into them. The latter

[1] Washington, H. S., 'Igneous Complex of Magnet Cove.' Bulletin, U.S. Geol. Surv, Vol. XI, pp. 389-416, 1900.

may be the altered, more acid parts of the primary rock, perhaps corresponding to the porphyrite of the Thetford series. The precise character of these rocks can only be determined by detailed lithological examination, which has not yet been made.

The greater alteration of these rocks indicates that they are earlier in age than the Thetford series. The rocks enclosing them are the grey schists and quartzites—in no case the red slates, of the Sillery formation. It can, therefore, only be said of their relations that, they are intrusive in, and hence later than the L'Islet formation which conformably underlies the Sillery.

ECONOMIC GEOLOGY.

The minerals of economic value that have been found in the serpentine belt are asbestos, chrome iron ore, talc, antimony, copper, and platinum. Of these, asbestos and chrome iron ore are at present being mined; the former constituting in value one-half of the total mineral production of the Province of Quebec, and producing upwards of 80 per cent of the world's supply of asbestos. Antimony and talc have been mined; there has been a small development of the copper ore; and platinum has been found in the gravels.

Asbestos.

History.—The discovery of asbestos in commercial quantities in this district dates from 1877, although it was known for many years previously as a mineral occurrence of prospective value. Mining operations began at Thetford, Black Lake, and Danville very shortly afterwards, and have continued ever since. Since the introduction of a successful method of mechanical concentration, about 1893-4, the production has increased regularly, until it now has an annual value of $2,500,000. Notwithstanding this steady and increasing production, no well-established mine has yet been worked out. Aside from the abandoned pits incidental to early prospecting, the only closed works are those of ill-judged enterprises that probably ought never to have been begun.

The production for the past four years has been as follows:—

	Tons.	Value.
1905	50,669	$1,486,359
1906	60,761	2,036,428
1907	62,130	2,484,767
1908	66,548	2,555,361

In addition to this, there has been produced 'asbestic' to the value of $17,974 during the past year.

The asbestos is of the chrysotile variety—hydrous silicate of magnesium—and has the same chemical composition as the serpentine rock which contains it, but is distinguished from it by its fibrous form.

Character of the Veins.—In the Thetford-Danville section, the asbestos occurs almost wholly in veins which are usually 2½ inches or less in width, the greater number being less than ½ inch. The fibres lie at right angles to the walls of veins, hence the length of the fibre is limited by the width of the vein; but it rarely equals it; for there is usually a parting in the vein which is marked by a film of iron ore, generally magnetite. The veins are invariably bordered by a band of pure serpentine on each side of the vein, whether the country rock be a serpentine or partially one, or even a slightly altered peridotite. These serpentine bands bordering the veins are usually as well defined as the vein itself, and in width are proportionate to it, each being nearly three times the width of the asbestos vein.

From a consideration of these facts, and of the number, size, and directions of the veins, it is believed that they were formed not by the filling of once open fissures, but by the replacement or crystallization—more or less perfect—of the pure amorphous

serpentine of the side walls. This process is thought to have begun at a fracture now indicated by the parting or film of iron ore within the vein, and to have extended into the wall rock on one or both sides to a distance proportionate to the width of the serpentine bands. They thus belong to the class of veins sometimes called oxogenous or *outward* growing, as distinguished from those that are formed by filling a fissure from the edges *inward*. Measurements of many veins have been made, which show the proportion of asbestos to the two bands of serpentine and the included asbestos to be 1:6·6, or that approximately 15 per cent of the serpentine has taken the crystalline form of asbestos.

Origin of the Fractures.—In the Thetford or later serpentine many of the larger veins can be seen to follow joint planes in the original rocks. Another class seems to have grown from fractures caused by regional folding, as is indicated by their approximate parallelism. Fractures produced in early stages of disintegration of the rock by casting off shells from the jointed blocks give a series of crescent-shaped veins, surrounding a core of peridotite. Where all of these classes of veins are found together there results a very intricate network, but by careful observation many of them can be referred to one or other of these classes.

In the supposedly older serpentine of East Broughton there are comparatively few veins. The exact mode of occurrence of the asbestos in this rock has not yet been studied in detail, but the asbestos seems to occur as 'slip' or 'parallel' fibre, which is on or in the rock, parallel to cleavage faces.

Other causes of the shattering of the rock, such as hydration, rapid cooling, and, possibly, original gneissic structure near the edges of an intrusion, require a full investigation covering the entire process of serpentinization.

Mining.—All the mines are worked by open-cut methods. The ground at the bottom of the pit is usually cut into a series of benches, generally about 8 to 15 feet high, which afford a number of faces from which the rock can be quarried at the same time. At the Bell mine, Thetford, extensive underground work has been carried on in winter with apparent success? Generally, the mines are operated only by day. At the King mine, Thetford, work is carried on in the pit at night by the aid of search lights. At the Danville mine, some underground work was carried on by night during the last summer. Several of the pits have reached a depth of about 200 feet, with two or three times greater horizontal extension.

Handling and Dressing.—In some of the mines the asbestos-bearing portion is separated from the barren rock in the pit, and in part the crude from the mill stuff, and each is loaded into separate boxes and hoisted to the surface. A certain amount of hand cobbing is also done in some pits. In most, however, all hand separation is done at the surface. There, the separate products are emptied into tramcars, which are usually drawn by small locomotive engines; the dead rock is then taken to the waste dump, and the rock which will afford crude asbestos, to the cobbing sheds, where it is separated by hand work and put in bags. The remainder, usually 35 per cent to 60 per cent of all the rock handled, goes to the ore bins, or, in some cases, directly to the mill for mechanical concentration.

This concentration is an ingenious process, which has been developed by some of the pioneer mine managers of the district. The essential features are successive crushings and screenings of the rock, and the removal of the asbestos thus liberated by means of suction fans. The crushing is effected by jaw and rotary crushers of the standard type, and a finer crushing is frequently effected by means of rolls. After the first crushing much or all of the material is dried in rotary driers, with direct heat.

A final pulverizing of the rock is accomplished by a specially designed machine known as the cyclone. This consists of two 'beaters,' or heavy screw propeller-like fans of chilled iron, set end to end, which revolve at a speed of 2,000 revolutions per

minute, or more, in opposite directions in a closed chamber. The small rock fragments are thus driven together with such force as to reduce them to powder, and the smallest particles of asbestos are released and collected as before.

The fibre drawn off at the various stages of the milling process is collected in settling chambers, and conveyed to a rotary classifier, by which the product is separated into various grades according to the length of the fibre.

Suction fans for the removal of dust from the cyclone, the classifier, and sometimes from the mill are important accessories to the equipment. Magnets are usually employed over the shaking screens to eliminate particles of iron ore.

The various mills differ from one another in details, some of which are regarded as more or less secret features, but the general practice is essentially uniform. The milled fibre is classified into three or more grades, and the crude asbestos usually in two. The question of adopting a standard classification is being discussed.

Prices.—The following production by classes, as compiled by Mr. J. McLeish, Chief of the Division of Mineral Resources and Statistics, of the Mines Branch, Department of Mines,[1] shows the proportions of different grades, classified according to value:—

——	Short tons.	Value.	Range of price per ton.	Average price per ton.
		$	$ cts. $ cts.	$ cts.
Crude No. 1	857½	257,752	267 00 to 350 00	300 59
" No. 2	2,488	411,480	75 00 to 225 00	165 38
Mill Stock No. 1	5,282½	425,448	60 00 to 100 00	80 54
" No. 2	45,545½	1,345,750	20 00 to 50 00	29 33
" No. 3	12,374½	114,931	5 00 to 13 00	9 29
Total Asbestos	66,548	2,555,361	5 00 to 350 00	38 40
Total Asbestic	24,225	17,974	35 to 1 16	74
Grand Total	90,773	2,573,335		

Uses.—A small proportion of the asbestos produced, all of the highest grades, is used in making asbestos cloth and various fire-proof textiles; while much the greater part is used for covering, and insulation purposes. Boards, shingles, and roofing felts for fire-proof construction, materials for electric insulation, and protection from acids, boiler and pipe coverings are among the products in common use.

The manufacture of asbestos goods has hitherto been carried on practically only in Europe and the United States. During the past year, however, a plant for the manufacture of asbestos shingles, mill-boards, and covering material has been established at Lachine, Quebec, by The Asbestos Manufacturing Company, a Company allied to the long-established manufacturing firm of Keasbey and Mattison, of South Ambler, Pennsylvania.

Mines.—A list of the mines, with more or less detailed description of their equipment and capacity, as well as their financial organization, has been published in the Report of the Mining and Metallurgical Industries of Canada, issued by the Mines Branch of the Department of Mines, in December, 1908, and hence need not be repeated here. The following are the mines that have produced asbestos during the

[1] 'The production of Asbestos in Canada,' 1907-8, by John McLeish. Mines Branch Publication No. 44.

past year, and all in operation at the close of the summer. They are named in order of location, and the names of the owners and of the shipping stations are also given:—

King: Owners, The Amalgamated Asbestos Corporation, Thetford Mines, Quebec Central railway.

Bell: Owners, Keasbey & Mattison, Thetford Mines, Quebec Central railway.

Johnson: Owners, The Johnson Asbestos Company, Thetford Mines, Quebec Central railway.

Beaver: Owners, The Amalgamated Asbestos Corporation, Thetford Mines, Quebec Central railway.

Union: Owners, The Black Lake Consolidated Mining Company, Black Lake, Quebec Central railway—re-opened late in the season.

Johnson: Owners, The Johnson Asbestos Company, Black Lake, Quebec Central railway.

British American: Owners, The Amalgamated Asbestos Corporation, Black Lake, Quebec Central railway.

Danville: Owners, Danville Asbestos and Asbestic Company, Danville, Grand Trunk railway.

Standard: Owners, Amalgamated Asbestos Corporation, Black Lake, Quebec Central railway.

Dominion: Owners, Amalgamated Asbestos Corporation, Black Lake, Quebec Central railway.

Robertson: Owners, Robertson Asbestos Mining Company, Thetford Mines, Grand Trunk railway.

Broughton: Owners, Broughton Asbestos Fibre Company, East Broughton, Quebec Central railway.

Eastern Townships: Owners, Eastern Townships Asbestos Company, East Broughton, Quebec Central railway.

Quebec: Owners, Ling Asbestos Company, East Broughton, Quebec Central railway.

Frontenac: Owners, Frontenac Asbestos Mining Company, East Broughton, Quebec Central railway—equipped late in the season.

Properties under Development.—The Thetford Asbestos Company, about to be reorganized as the Jacobs Asbestos Company, has done some development on lot 28, range VI, of Thetford, with promising results. The construction of a mill has been begun, and the property is likely soon to be an important producer.

On the property of the Imperial Asbestos Company, a short distance south of Black Lake station, some development has been done by the Black Lake Consolidated Company, and it is announced that a mill is to be built. On the Southwark property, lots 27 and 28, range B, of Coleraine, the same Company made some very successful developments, and propose operating the property in conjunction with the Union mine, which it adjoins. A new mill is to be built to serve both properties.

The adjacent property of Dr. James Reed, in range A, Coleraine, which has had considerable development, and is partially equipped with a mining plant, has remained unused for some time.

The King property, lot 26, range III, of Ireland, and the Belmina, lots 23, 24 and 25, range II, of Wolfestown, are also partially developed properties which have not been recently worked. Both seem to give promise of favourable development.

The D'Israeli Asbestos Company has built a mill on lot 16, range III, of Garthby, and upwards of 4 miles of track to connect it with the Quebec Central railway, and is now preparing to develop the property.

At lot 24, range IV, of Wolfestown, an extensive mining and concentrating plant was installed a few years ago by the Asbestos Mining and Manufacturing Company, of Providence, Rhode Island. But the development of the property proving unsuccessful, the plant has been partially dismantled after lying idle for two years, and the property has lately changed hands.

At the Boston Asbestos Company's property, East Broughton, a mill has been built, and some development work done on a property adjoining that for which the mill was built. The mill and mine were not in operation at the time of our visit.

In lot 9, range V, of Thetford, the Beaudoin and Audet Company has done some development, as has also the Berlin Asbestos Company on lot 2 of the same range.

In lot 14, range VII, of Broughton, the old Fraser mine, once celebrated for the remarkable quality of the asbestos produced from a single vein, remains unworked. There seems likely to be a workable quantity of lower grade fibre in this property.

In all the mines of East Broughton the principal work has been done near the hanging-wall or top of the serpentine sheet, and the opinion prevails that the lower portion, that is the northwest side of the serpentine, is unproductive. The rocks of this locality have not yet been examined microscopically and chemically, hence, comparison is difficult. But in the rocks of the Danville sheet the best serpentine is at the north side, or near the foot-wall.

It would, therefore, seem advisable to test the serpentine at East Broughton near the northern edge, where asbestos, if it occurs at all, is more likely to be in well-defined veins and of greater tensile strength.

Prospects.—Asbestos has been found in various places in the district, by prospecting at different times, where little or no work has been done. In the East Broughton district, lot 13, in ranges III and IV, serpentine-bearing asbestos is shown by pits or natural exposures for a distance of several hundred feet in each range. The access to the railway is somewhat less easy, but the quality of the rock seems to compare favourably with that of the working mines at East Broughton.

Southwest of the mines of East Broughton, serpentine is found on lot 13, in ranges VIII and IX, of Broughton. In range IX it passes into lot 12, about 600 feet from the north end of the lot, and next appears near the northeast end of lot 11, in range X. From this point the serpentine appears at frequent intervals in two sheets running in a northwesterly direction to lot 2, in range XI. This change of direction in the outcrops of serpentine is caused by an arching of the strata across the strike, which gives the rocks a low northeasterly pitch, instead of a southeasterly dip. Consequently some parts of these serpentine sheets have a nearly horizontal roof of slate, and will be unavailable, since both the serpentine and the slate are too much fractured to admit of underground work, even if the prospects otherwise warranted it.

On the southwest side of this arch the serpentine is again found on lot 12, range XI, of Broughton; and in lots 1, 3, 10, 11, and 13, in range V of Thetford. Lots 2 and 9 in this range contain the properties of the Berlin Asbestos Company, and the Beaudoin and Audet Company, respectively, already mentioned; while the Robertson mine is situated on lots 16 and 17, in range XIII. The occurrence of serpentine on lot 13, range V—the property of Dr. James Reed—has led to some development work which seems to indicate that the rock is fairly productive in asbestos of the East Broughton or older type.

In lot 24, of ranges I, II, and III, of Tring, a small amount of serpentine is exposed, which contains a little asbestos. A very small amount of work was done here twenty years ago. The Tring branch of the Quebec Central railway cuts the serpentine near the line between ranges II and III.

Near Thetford Mines, prospecting was pushed on the Clarke property, lot 24, range A, Coleraine, and some work was also done on lot 27, range VI, of Thetford, by Jos. Demers and others.

The property in block B, Coleraine, formerly owned by the Coleraine Mining Company, but now belonging to the Black Lake Consolidated Company, is not being worked. A little prospecting was done near Coleraine during the past summer on lots 35 and 40, range II, of Garthby, and on lot 2, range VI, of Coleraine. No very definite results had been reached at the time of our visit.

South of the road from Coleraine to Wolfestown, several properties along the Belmina hill, chiefly in lots 23, 25, and 26, of ranges III and IV, show a little asbestos, but they have, generally, been little prospected. In lot 13, range VI, of North Ham, there is a small knoll of serpentine, on the south side of which there is a perpendicular face about 25 feet high. On part of this cliff face, about 15 x 20 feet, several veins of asbestos from 1 to 2 inches in width, and of excellent quality, are exposed. A small cutting on the top of the cliff did not show the veins to extend beyond a foot from the face of the cliff, while four small pits on other parts of the knoll did not disclose any veins of asbestos. The serpentine, which is several miles from any other known exposure, has a maximum breadth of 350 feet, and can be traced upwards of 1,000 feet on this property, and is recently reported to have been found to extend to lot 11 in range V. In view of the excellent quality of the small amount of asbestos exposed, it is to be hoped that the property will be thoroughly tested.

In range XI, of Tingwick, lots 20-25, there is a considerable area of serpentine, which has not been well prospected owing to the thickly wooded character of the area. Near the boundary of lots 21 and 22, the property known as the Ladysmith mine has had some development and equipment, including an extemporized mill. Work was closed at the time of our visit in July. There are other prospects between this property and the shore of Nicolet lake; but practically no work has been done upon them.

On lot 10, range III, of Shipton, adjoining the mine of the Danville Asbestos and Asbestic Company, the presence of asbestos-bearing serpentine beneath several feet of soil has been proven by a shaft. The question of economically utilizing the property at present has been further complicated, if not rendered impossible, by the sale of a portion of it in small building lots to several different owners.

A band of serpentine extends from the Shipton Pinnacle to the St. Francis river, a distance of 8½ miles. It occupies a part, or all, of lot 10, range VII, and lots 8 and 9, in range VIII, of Shipton; and in Cleveland, lots 8 and 9 in range IX, 7, 8, and 9 in range X, 7 and 8 in ranges XI, XII, and XIII, 6 and 7 in range XIV, and 6 in range XV. The northwestern edge of this band is a soft, but generally massive serpentine, and asbestos up to 1 inch in length has been found in several places. This is the largest unprospected or little prospected area in the district. It is not to be confused with a series of isolated outcrops of serpentine which are found nearly a mile to the northwest of the main band, running through lots 9, 10, and 11 in Cleveland, and 12 in Shipton. These are usually composed of a harder and less promising variety of serpentine; but on lot 12, range V, of Shipton, where it is associated with granite, one of these outcrops of serpentine contains a limited amount of asbestos.

Chromite.

Chromite, or chrome iron ore, is an oxide of chromium and iron. It is useful not as an ore of iron but for its content of chromium.

Various attempts to mine this ore in Quebec were made between 1860 and 1890, but it was not until 1894 that any considerable production was made. Since that date over 400,000 tons of chromite have been mined, which had a value at the railway of about $600,000. The production for the last four years has been as follows:—

	Tons.	Value.
1905	8,528	$104,565
1906	8,750	92,100
1907	7,196	72,901
1908	7,225	82,008

Mode of Occurrence.—The ore is in irregular masses, sometimes having the shape of flattened lenses. The largest single body of ore known in the district is 80 feet long x 5 feet to 50 feet wide, and has been proven for a depth of 300 feet or more.

Chromite in disseminated grains is found throughout practically all of the serpentine and peridotite; but in quantities large enough to form ore bodies it has been found principally in the peridotite near its outer edge, that is, close to the pyroxenite margin. The Dominion pit of the Black Lake Consolidated Company is at the southeast edge of the serpentine, and some 200 feet from diabase. The intervening ground is drift-covered, as is commonly the case in that portion of the batholithic masses. The American mine is on the northwest edge of the same mass. The Caribou pit, and the Black Lake pit No. 1, are near the southwest edge of the peridotite, where the latter carries considerable pyroxene. The Canadian Chrome Company's mine is on the southeast side of the same mass as the Caribou and Black Lake. The Breeches Lake or Leonard property, in Garthby, is on the south side of a serpentine hill with the acid rocks running around the foot, while the St. Onge, Adam, and Brosseau properties are similarly situated with regard to the serpentine hill northeast of D'Israeli.

The masses of ore are separated from one another by bands of rock of varying thickness, which makes regular production difficult. The ore occurs in a zone, that can probably be defined by a study of its place in the rock series; but this involves more detailed examination and mapping than has yet been found practicable.

Mining.—Mining is carried on in open-cuts, except at the Black Lake pit No. 1, where a shaft has been sunk. As the ore bodies are often small and discontinuous, the least expensive methods of working have usually been adopted. Power drills and derrick hoists are the principal equipment used. The diamond drill has been used successfully for prospecting.

Concentration.—The ore is bought and sold on a basis of 50 per cent chromic oxide. If higher than this, a premium is paid, if lower the ore is penalized. Consequently ore carrying approximately 40 per cent is shipped as crude; all from that quality to about 10 per cent is concentrated to 50 per cent or a little higher. The highest percentages reached in either crude or concentrated ore is rarely above 55 per cent, $Cr_2 O_3$.

The method of concentration that has been followed recently consists, successively, of crushing, stamping, and concentrating by means of Wilfley tables. The middlings from the first Wilfley's are usually treated on a second table, and a product rarely exceeding 51 per cent or 52 per cent is obtained. No data is at present at hand as to the percentage of recovery. There is, however, an apparent loss in 'float,' or very finely crushed ore, which is carried from the tables with the lighter rock particles.

Uses.—A limited quantity of these ores was used for a time by the Electric Reduction Company of Buckingham, Quebec, in the manufacture of ferro-chrome. Except for this, and occasional small shipments to Europe, the Canadian production is shipped to the United States. It is there used in the manufacture of bichromates for use in dying textiles, tanning leather, for pigments used in printing and painting, and in making chrome steel, and the lower grades for lining furnaces.

Antimony.

The only occurrence of this mineral that is yet known in the district is in range I of South Ham, lot 28 of the old, or 56 of the later numbering, on the property of Dr. James Reed, of Reedsdale, Province of Quebec.

The ores are native antimony, with less amounts of stibnite, kermesite, and valentinite. The deposit is said to have been found in 1863, and to have been soon after developed and equipped with a mining and concentrating plant. After a time the works closed, and the property passed into the hands of the present owner.

The development, as far as could be made out in the present state of disrepair, consisted of four shafts. An adit, which could not be entered at the time of our visit, starts at a lower level some 300 feet from the main shaft, and is said to reach it at a depth of 100 feet. Considerable drifting is reported to have been done along the length of the ore body.

Character of deposit.—This is a contact deposit, in which the ores occur in schists along their contact with an intrusion of diabase and serpentine. The schists strike N 50° E magnetic, and have a vertical dip. A serpentine ridge runs east and west. The serpentine just north of the main shaft is exposed for about 150 feet in length, east and west, and has a breadth of 75 feet. It is bordered by diabase on the west and northwest sides, but on the southwest comes directly in contact with the slates of which it contains fragments. The principal workings are at the south contact of the serpentine with the schists, with one small shaft on the northwest side of a similar hill, about 1,000 feet east of the mouth of the adit. As these two intrusions of serpentine are doubtless connected at no great distance beneath the slates, it is not improbable that antimony may be found in the intervening distance. On the other hand, this structure lessens the probability of the deposit continuing to a great depth.

No distinct veins of any considerable width could be found in the present state of the workings, but the principal amount of ore seems to be in flakes, along the cleavage planes of the schists. The proportion of ore becomes greater as the contact is approached.

Two specimens of antimony ore from this property which have been assayed for gold by Mr. H. A. Leverin, of the Mines Branch, yield only a trace.

Talc.

Steatite or soapstone—as well as the purer forms of talc—occurs in numerous places in the townships of East Broughton, Broughton, and Ireland. It generally bears the same relation to the older serpentine that pyroxenite has to peridotite. It is an altered form of pyroxenite, and in some places shows distinct pseudomorphs of steatite after pyroxene.

Soapstone has been quarried to a small extent at the old Fraser mine, East Broughton, lot 14, range VII, and on lot 5, range V, of Thetford. A considerable quantity is easily available on lot 2, range XI, of Broughton, and Ham, lots 42, 43, and 50, range I.

A better quality of talc is found on the farm of W. I. Porter, lot 2, Craigs Road range of Ireland, where it probably occurs in workable quantity.

Platinum.

A small amount of platinum was reported to have been found in the gravels near the Chaudière river, in the county of Beauce, by T. Sterry Hunt, in 1852. The natural habitat of platinum is in chrome-bearing peridotites. These gravels are 30 miles southeast of the serpentine belt, and it is altogether probable that they have been in part derived from it. A nugget of platinum has also been found at Plattsburg, N.Y., some 50 miles south of the serpentine belt in Brome. In the Tulameen district of British Columbia, Mr. Camsell finds the platinum to occur with the chromite. Two specimens of chromite from Black lake, which have been assayed by Mr. H. A. Leverin, Mines Branch, Department of Mines, have yielded no platinum.

Copper.

Chalcopyrite is found in small quantities, apparently as primary segregations, near the outer edges of the diabase in many places in this district. Most of them, however, are mere mineral occurrences, and not of commercial importance.

On lot 22, range I, of Garthby, is the property known as the Coulombre mine, on which a shaft was sunk over forty years ago. The ore is a compact pyrite carrying a small copper content. It is extremely free from silica, and should be useful in conjunction with some of the siliceous copper ores of the Capelton district.

While there is little facility for finding the limits of the ore body, the extent over which isolated exposures are found indicates the possibility of an important ore body: perhaps like one of those found under similar conditions to the southwest of this district, at the Huntingdon and Lake Memphremagog mines.

Smaller amounts of a better grade copper ore occur near the north shore of Clapham lake, on lot 15, range VIII, of Thetford. This is also in diabase near the contact with slate.

In lots 8 and 9, range I, of Wotton, diabase carries a little disseminated pyrite over an area of some 20 acres. It is possible that by stripping the soil from the rocks the ore might be found to be concentrated in places, into workable deposits.