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DEPARTMENT OF MINES

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GEOLOGICAL SURVEY

R. W. BROCK, Director.

GUIDE BOOK No. 2

# EXCURSIONS in the Eastern Townships of Quebec and the Eastern Part of Ontario

OTTAWA
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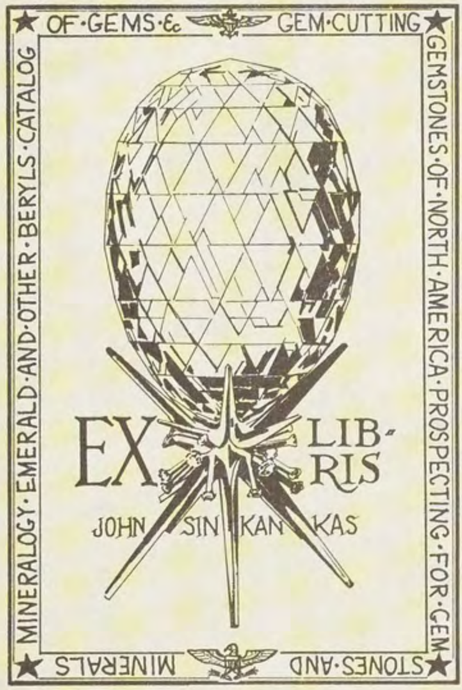
1913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GUIDE BOOK No. 2

# EXCURSIONS

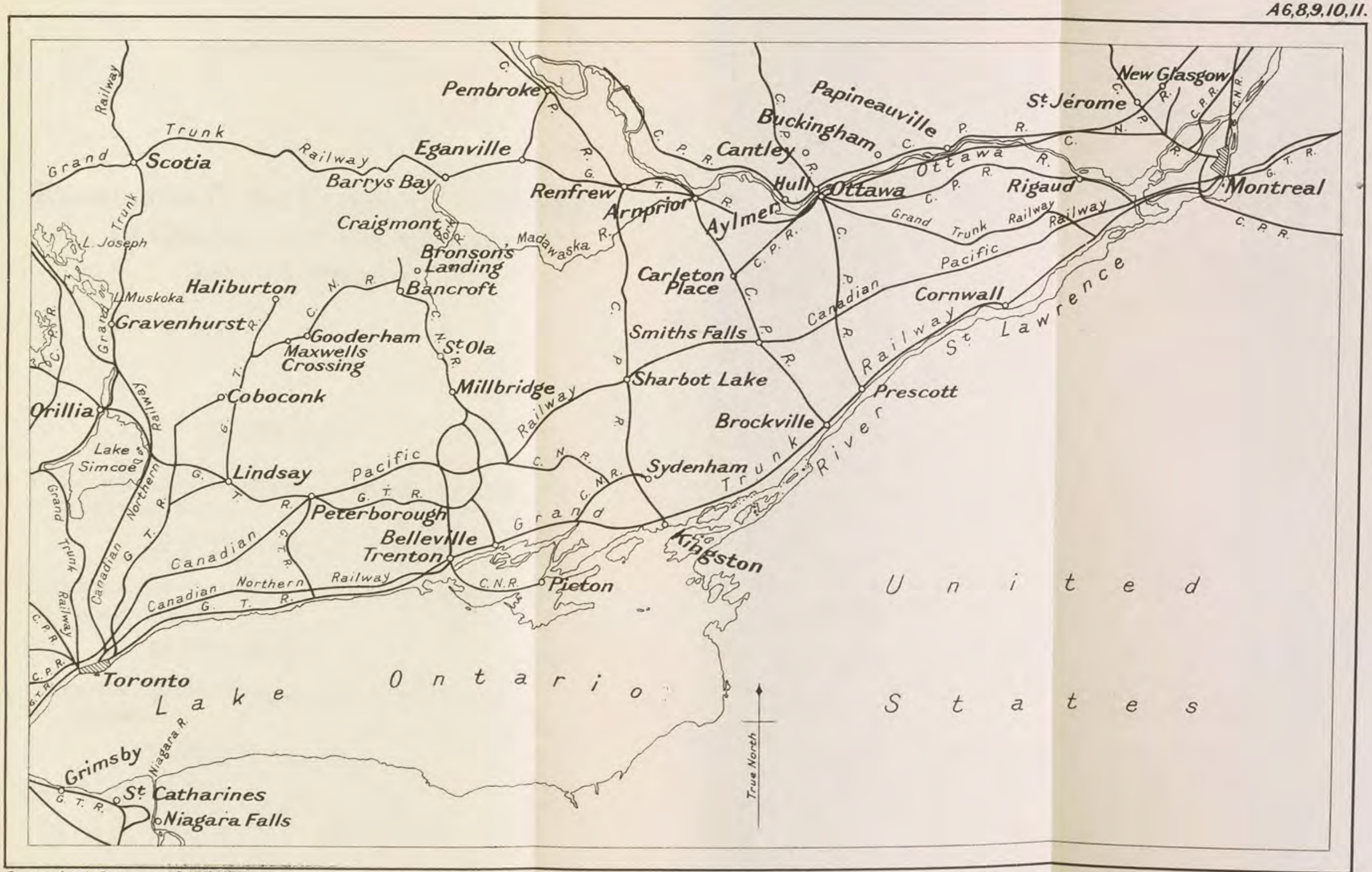
IN

# The Eastern Townships of Quebec and the Eastern Part of Ontario.

(EXCURSIONS A2, A5 AND A9.)

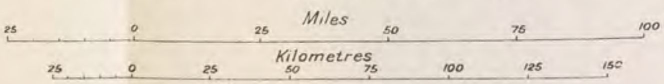
*ISSUED BY THE GEOLOGICAL SURVEY*

OTTAWA
Government Printing Bureau
1913




Geological Survey, Canada.

Route map between **Montreal**, **Ottawa**, **Kingston**, and **Toronto**.



GUIDE BOOK No. 2

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# Excursions in the Eastern Townships of Quebec and the Eastern part of Ontario

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35064—1½

Corundum crystal, (Natural size.)
Craigmont, Ont.

## EXCURSION A 2.

# THE HALIBURTON-BANCROFT AREA OF CENTRAL ONTARIO.

BY

Frank D. Adams
AND
Alfred E. Barlow.

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## INTRODUCTION.

This excursion has been arranged to enable members of the Twelfth International Geological Congress to see a typical Pre-Cambrian area in Eastern Canada.

Like other parts of the Canadian Shield, this area is strikingly different in physiographic character from the great Paleozoic plain which lies to the south and west. It is a rough and rugged country, supporting a more or less scattered farming population, but still largely forest-clad, especially in its northern portion. The Pre-Cambrian in this portion of Central Ontario probably presents a greater variety of rock types than has yet been described from any similar area of ancient cyrstalline rocks in North America. It shows in a striking manner the progressive metamorphism of the Grenville-Hastings series resulting from Laurentian batholithic intrusions. These limestones, together with their associated paragneisses and amphibolites—the Grenville-Hastings series—are regarded as the greatest accumulation of Pre-Cambrian sediments in North America.

This area also contains a very extensive and remarkable development of nepheline rocks, among which are many rare and some unique types. These present, in places, the phenomenon of the crystallization of a magma supersaturated with alumina, the excess of which has separated out in the form of corundum, forming deposits of this mineral of economic value, which have been extensively worked. These nepheline rocks occur almost without exception along the border of the granitic batholiths when the latter come against the limestone series.

## HISTORY OF GEOLOGICAL EXPLORATION IN THE LAURENTIAN OF EASTERN CANADA.

When Mr. W. E., afterwards (1856) Sir William, Logan, of the Geological Survey of Canada, made an examination in 1844 of the region bordering the Ottawa river, he found great areas underlain by very ancient foliated crystalline rocks. These seemed to him, on further study, capable of subdivision into two conformable series, which he subsequently (1853) called the "Laurentian series." This designation was proposed by the fact that these rocks constitute the bulk of the "Laurentide Mountains," a name suggested by F. X. Garneau, the historian of Quebec, for that great stretch of rocky country which forms the highlands to the north of the River and Gulf of St. Lawrence. This sharply defined series of elevations is not strictly a mountain range, but merely the steep margin of the great rocky plateau of the Canadian Shield.

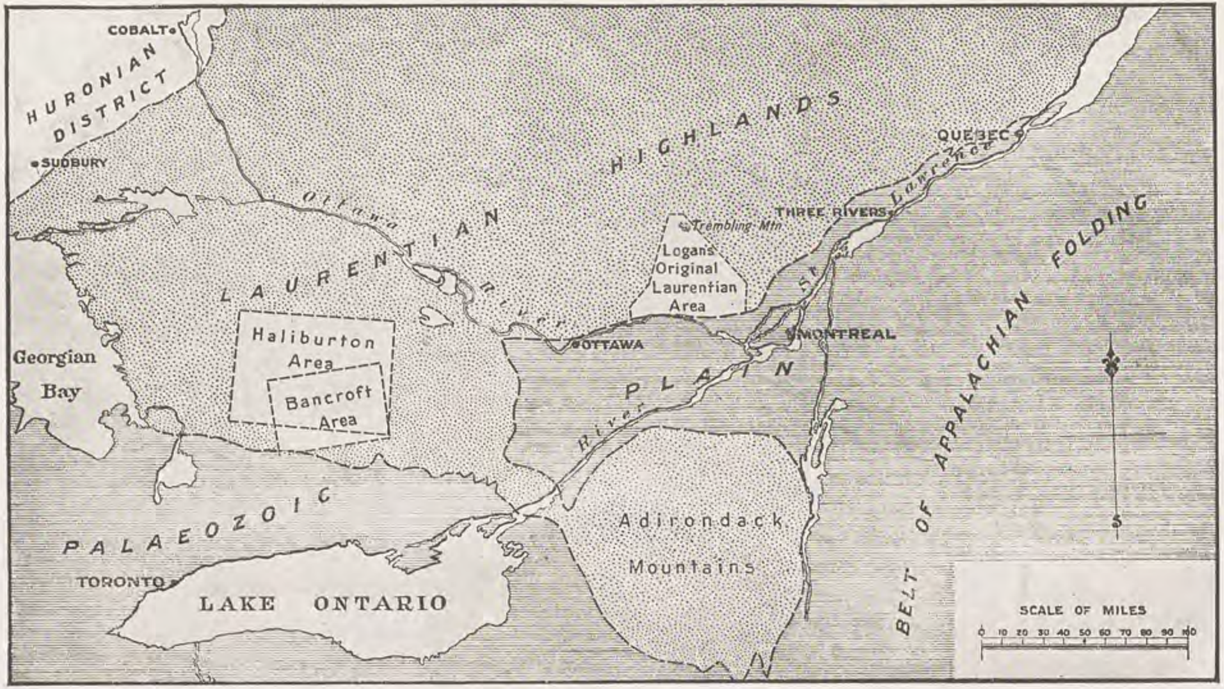
Logan's lower or older group consisted exclusively of "syenitic gneiss showing no end to the diversity of arrangement in which the minerals and the colours will be observed, but there is a never-failing constancy in respect to their parallelism. But this, though never absent, is sometimes obscure." These rocks were supposed by Logan to form a low anticlinal arch in the region extending from Mattawa river to the vicinity of Montreal river on Lake Temiskaming. The upper group is stated to crop out in the district south of Mattawa and Ottawa rivers and to be characterized "by the presence of important bands of limestone which have undergone extensive crystallization as a result of extreme metamorphism," while the different gneissic rocks which separate the various bands of limestone "differ in no way either in constituent quality or diversity of arrangement from the gneiss lower down."

Subsequently this lower gneiss was called the "Ottawa Series" while the upper group, differentiated in the first place solely on account of the presence of the limestones, was included under the name Middle Laurentian or "Grenville Series." He afterwards found in Eastern Ontario a series of rocks which he considered in all probability to represent the Grenville series in a less altered state and to this he gave the name of the "Hastings Series." The foliation of the gneisses was regarded by him as the survival of an almost obliterated bedding. The name Upper Laurentian was given to a terrane formed chiefly of anorthosites which were afterwards shown to be of irruptive origin, and with which were classified by mistake certain gneiss and limestone bands identical in character with those included as the Grenville series, to which they clearly belong. For many years very little light was thrown upon the relations of the Grenville series and the Ottawa series or "Fundamental Gneiss" as it was frequently called. The relationship of the Grenville and Hastings series also remained a matter of uncertainty.

In 1885 Dr. Andrew C. Lawson showed the presence in the region north-west of Lake Superior of great bodies of foliated granitic rocks forming the base of the geological column and the equivalent of the "Fundamental Gneiss" of Logan. This gneiss, as Lawson conclusively demonstrated, is intruded through the oldest sedimentary rocks (Keewatin group) of that region in the form of great batholiths. This work marked an epoch in the interpretation of Pre-Cambrian geology not only in Canada but in all North America.

Then followed, in 1893, Adams' demonstration that Logan's "Upper Laurentian" did not exist as an independent geological series, the anorthosites, which were considered as constituting its main features, being in reality great intrusive masses. In a subsequent (1895) paper he showed that two distinct classes of rocks could be distinguished in the remaining portion of the Laurentian, the first being beyond all doubt igneous rocks and the second consisting of highly altered rocks of aqueous origin.

From the results of these investigations, it became evident that if a satisfactory knowledge of the origin, character, structure and relations of the Laurentian




Sketch-map, showing the position of the Haliburton and Bancroft areas in relation to the Laurentian Highlands, etc.

succession in Eastern Canada was to be obtained, it would be necessary to select some large area of these rocks and map it in much greater detail than had hitherto been attempted, the examinations in the field being supplemented by thorough petrographical study of the various rock types represented in the area. The area selected for such detailed study was that designated as Sheet No. 118 (Haliburton sheet) of the Ontario series of geological maps which are being issued by the Geological Survey of Canada. As will be seen by the accompanying sketch map, this district lies close to the margin of the great Northern Protaxis, north of Lake Ontario and to the east of Georgian bay.

Dr. Frank D. Adams, with whom Dr. Alfred E. Barlow was subsequently associated, undertook for the Geological Survey a detailed geological study of this region, concerning the geological structure of which nothing was known at that time but which, from its position, promised to yield valuable results if carefully studied. During the progress of this work it became evident, if the substantial results expected were to be realized, that the work should be extended to cover the district lying to the south-east of the Haliburton sheet. This was accordingly done and two maps were prepared; one, the Haliburton sheet, on a scale of four miles to an inch (2·53 km. per cm.), and the other, embracing the south-eastern portion of the Haliburton sheet and the district lying to the south-east, on a scale of two miles to an inch, (1·27 km. per cm.), which was designated as the Bancroft sheet. The Haliburton map-sheet embraces an area of 3,456 square miles (8,600 sq. km.); the Bancroft map-sheet 1,955 square miles (4,900 sq. km.); and the two map-sheets together cover 4,200 square miles (10,500 sq. km.) The field and accompanying laboratory work occupied a period of about eight years, the results being embodied in Memoir No. 6 issued by the Geological Survey of Canada in 1910. [**1.**].

## PHYSICAL FEATURES OF THE AREA.

The general character of the surface of the area is uniform throughout its entire extent. The country is a great uneven plain which may be called a peneplain,

Laurentian peneplain, looking east from Fort Stewart, township of Carlow.

although this term implies that it has had its origin in long continued processes of sub-aerial denudation. In how far these processes have contributed to the formation of the plain or have been assisted by marine erosion are questions which remain unanswered.

The depressions in the surface of the country give it a decidedly hilly or rolling appearance, but its character as a great peneplain is at once recognized when the landscape is viewed from any of the higher points in the area, when the sky-line will be seen to be flat and even around the whole horizon, its uniformity being rarely interrupted by low monadnocks. It is impossible on this excursion for the party to visit any of the highest points in the area, but the even character of the skyline to the north and east will be seen from a point on lot 29, con. IV in the township of Glamorgan. But, while the plain appears very even, viewed from any one point of outlook, it is not quite horizontal. From the south-western part of the area, where this plain emerges from underneath the Palaeozoic cover, it gradually rises toward the north and attains a maximum elevation of 1,500 feet (457 m.) above sea level near the northern limit of the Haliburton sheet, the gradient in this interval being from 6½ to 8 feet per mile (1·24 to 1·52 m. per km.). The depressions in the surface of the plain are shallow. It is very unusual indeed, in any part of the area, to find hills whose summits (representing the surface of the plain) rise as much as 200 feet (61 m.) above the river or lake at their base.

One of the most characteristic landscape features of this region, as of most other parts of the great Northern Protaxis in Canada, is the immense number of lakes, great and small, which are scattered over its surface. Some 525 lakes occur in the area of 4,200 square miles (10,500 sq. km.) embraced by the Haliburton and Bancroft map-sheets, that is to say, there is on an average one lake to every eight square miles of surface. These lakes range in size from comparatively large ones, like Hollow lake, which has an area of 22 square miles (55 sq. km.), to small ponds which cover only a fraction of a square mile. They discharge in a multitude of streams which, with the lakes, form a wonderful series of waterways by means of which, it is possible to traverse the area by canoe in almost any direction, without making portages of any great length.

These lakes either occupy true rock basins or depressions in the mantle of drift or they have banks formed in part by rock and in part by drift, occupying in some instances portions of a larger rock basin which has been partitioned off by masses of drift.

Over the greater part of the area the drift is comparatively thin, so that, while it forms the soil of the country, the underlylng rock in the form of smooth *roches moutonnées* protrudes through it at frequent intervals. On the higher levels the drift is unstratified and filled with boulders. Stratified sands and gravels, however, are found around the lakes and in the river valleys.

A glance at the Haliburton sheet will show the remarkable influence which the strike of rock underlying the area has had upon the distribution and position of the lakes and upon the courses of the streams. In the southern portion of the area these follow very closely the course of the bands of Grenville limestone, while in the granitic region of the north they form a delicately etched pattern on the surface of the great plain of granitic gneiss, occupying shallow depressions whose course is determined chiefly by the strike of the country rock; and even when the lake runs across the strike, the long arms and bays in its deeply indented shore line will be found to follow the directions of the foliation.

## GEOLOGY OF THE AREA.

The Haliburton and Bancroft map area is a very typical Archean or Pre-Cambrian area, near the southern margin of the Canadian Shield or great Northern Protaxis which stretches with almost unbroken continuity to the borders of the Arctic ocean. Ordovician strata, which survive as evidence of the transgression of the Palaeozoic sea from the south occur as isolated outliers of various sizes and shapes. They form conspicuous steep-faced hills of horizontally stratified rocks in the townships of Lake, Methuen, Burleigh and Harvey, in the south-west angle of the Bancroft sheet. To the south of Stony lake, the northern portions of Dummer and Smith townships are forms by the main body of the Ordovician which forms the great plain stretching southward to Lake Ontario and beyond.

The line of contact between the highly inclined crystalline rocks of the Pre-Cambrian and the horizontal limestones and sandstones of the Palaeozoic is marked by a very distinct and abrupt change in the character of the country. The Pre-Cambrian region is decidedly rocky and uneven and is thus in large part unsuited for purposes of agriculture. It is pre-eminently a grazing country with great streches of uncleared forest land still remaining. In marked contrast the country underlaid by Ordovician strata is prevailingly flat and fertile, well cleared, and occupied by a large farming population.

As shown by the accompanying geological maps, the Laurentian country is underlain by a diversified series of altered sedimentary rocks among which limestones predominate, resting upon and invaded by enormous bodies of gneissic granite.

The sedimentary series is largely developed to the south-east where it is comparatively free from igneous intrusions. Towards the north-west, however, the granite, in ever-increasing amount, arches up the sedimentary series and wells up through it, in places disintegrating it into a breccia composed of shreds and patches of the invaded rock scattered through the invading granite, until eventually connected areas of the sedimentary series disappear entirely and over hundreds of square miles the granite and granite-gneiss alone are seen, holding, however, in almost every exposure, inclusions which represent the last scattered remnants of the invaded rocks. The type of structure presented by the invading granite is that of a batholith. The term batholith is used in the sense in which it was employed by Lawson in his classic work on the Lake of the Woods and Rainy Lake districts, to designate great lenticular or rounded bosses of granite or granite-gneiss which are found arching up the overlying strata through which they penetrate, disintegrating the latter, and displaying at the same time a more or less distinct foliation, which is seen to conform in general to the strike of the invaded rocks when these latter have not been removed by denudation.

## I.—The Invading Batholiths.

The batholiths of the area are well shown on the Bancroft sheet, and have a general trend in a direction about N. 30° E., which is also the direction in which the area is folded. They occur isolated or in linear series so arranged that a very small amount of additional erosion, by removing the intervening cover, would evidently convert the series into a single, long, narrow batholith.

Within the batholiths themselves the strike of the foliation follows sweeping curves, which are usually closed and centred about a certain spot in the area where the foliation becomes so nearly horizontal that its direction and even its existence, where the surface is level, becomes difficult to recognize. From these central areas of flat-lying gneiss, the dip of the gneiss (where it can be determined) is usually found to be outward in all directions. The batholiths are, therefore, undoubtedly formed by an uprising of the granite magma from below, and these foci indicate the axis of the greatest upward movement. These centres are not all areas of more rapid uplift. On the contrary, the gneissic foliation in some cases dips inward in all directions towards the centre, thus marking them as places where the uprise of the magma was impeded, that is to say, places where the overlying strata have sagged down into the granite magma.

If this district presents the basement of a former mountain-range, now planed down, the direction of this mountain range was about N. 30° E., or, in a general way, parallel to the course of the valley of the St. Lawrence.

The movements in the granite to which reference has been made did not take place solely while the rock was in the form of an uncrystallized or glassy magma. They continued as the rock cooled and while it was filled with abundant products of crystallization, the movement being brought to a close only by the complete solidification of the rock. Evidence of protoclastic structure can therefore be seen throughout all the areas coloured as granite or granite-gneiss on the map, except in the case of a few small bodies of granite apparently of more recent age. This protoclastic structure is marked by the presence of more or less lenticular, broken fragments of large individuals of the feldspar, in a fluidally-arranged mosaic of smaller allotriomorphic feldspar grains with quartz strings and a few biotite flakes. This fluidal arrangement, which constitutes the foliation of these rocks, is seen in every stage of development, there being an imperceptible gradation from the perfectly massive forms occasionally seen, through the more or less gneissic varieties, to thinly foliated gneisses. It is impossible to separate the several varieties. They constitute progressive developments of one and the same structure, and are different phases of one and the same rock mass.

The granite-gneiss is undoubtedly of igneous origin, is very uniform in its mineralogical composition, and differs distinctly from the sedimentary gneisses (paragneisses) of the area. It is medium to rather fine in grain, and composed almost entirely of quartz and feldspar, the latter preponderating. Biotite is present in very subordinate amount. The rock in the southern batholiths occasionally contains a little hornblende. While the feldspar is always reddish in colour, a large proportion of it is really an acid oligoclase. The rock would ordinarily be classed as an albite-granite or granite-gneiss, and, although the soda feldspar preponderates, should be so classed, since it resembles a granite in every respect.

Two analyses of typical specimens of this granite are tabulated below:—

| — | I. Per cent. | II. Per cent. |
|---|---|---|
| $SiO_2$ | 73·33 | 76·99 |
| $TiO_2$ | 0·17 | .......... |
| $Al_2O_3$ | 13·55 | 12·45 |
| $Fe_2O_3$ | 0·58 | 1·03 |
| Feo | 1·53 | 0·49 |
| MnO | 0·04 | tr. |
| CaO | 1·66 | 0·98 |
| MgO | 0·45 | 0·21 |
| $K_2O$ | 3·12 | 4·29 |
| $Na_2O$ | 5·01 | 3·46 |
| $CO_2$ | .... | None. |
| $H_2O$ | 0·45 | 0·26 |
| Totals | 99·89 | 100·16 |

I. Gneiss, Township of Methuen, Lot 17, Range V. (M. F. Connor, analyst.)

II. Gneiss, Township of Livingstone, Lot 10, Range V. (N. Norton-Evans, analyst.)

No. I consists of microcline and plagioclase, with small amounts of quartz and of an untwinned feldspar, as well as very subordinate amount of biotite and hornblende. It is impossible in the case of this analysis to calculate the exact proportions of the iron-magnesia constituents which are present, on account of the fact that the exact composition of these minerals is not known. The 'norm,' however, is given below. By this is meant the calculation of the analysis into the form of certain standard minerals, showing the mineralogical composition of a rock into which such a magma might crystallize under slightly different conditions [**3**, p. 47]. The norm represents in this case very nearly the true percentage of the various minerals present, although diopside and hypersthene are calculated as present, which are represented by other combinations in the actual rock. It is as follows:—

| | |
|---|---|
| Orthoclase | 18·35 |
| Albite | 42·44 |
| Anorthite | 5·28 |
| Quartz | 27·72 |
| Diopside | 2·57 |
| Hypersthene | 1·92 |
| Magnetite | 0·93 |
| Ilmenite | 0·30 |
| Total | 99·51 |

In this rock the albite and anorthite shown in the analysis are combined in an acid plagioclase which exceeds in amount the potash-feldspar, a fact which is also shown by separations with Thoulet's solution. The rock takes its place in the quantitative classification as a lassenose.

No. II is seen under the microscope to be composed essentially of feldspar and quartz, with a small amount of biotite. Untwinned feldspars, apparently orthoclase and microcline, are present in large amount, and the proportion of feldspar grains showing the ordinary albite-twinning is small. A little iron ore and a very few minute individuals of apatite and zircon complete the list of constituents present. A separation of the constituents of the rock by means of Thoulet's solution showed that the amount of oligoclase present was considerably greater than that of orthoclase and microcline taken together, a conclusion confirmed by the analysis. This, when calculated out, shows the rock to have the following percentage composition (mode):—

| | |
|---|---|
| Orthoclase | 25·58 |
| Albite | 29·34 |
| Anorthite | 5·00 |
| Quartz | 37·68 |
| Biotite | 0·90 |
| Magnetite | 1·39 |
| Water | 0·26 |
| Total | 100·15 |

It will thus be seen that the amount of anorthite present is sufficient, when united with the albite, to give 34·34 per cent of an acid oligoclase having the formula $Ab_6$ An, thus bearing out results obtained by the Thoulet separation. This combination as compared with the orthoclase, is present in about the proportion of 3 to 2. This rock, in the quantitative classification, is a tehamose.

Dark inclusions are present throughout the granite-gneiss almost everywhere in the area. These are often very abundant, and consist of amphibolite or closely allied rocks. In some places, on account of their abundance and angular character, the granite presents the appearance of a breccia. These fragments, while usually more or less angular, have sometimes been softened and drawn out in the direction of the movement of the gneiss so as to impart to the rock a streaked or banded appearance. In other places, the inclusions have been so completely permeated by the granite-magma that they are utterly disintegrated. Every stage of passage from the sharply angular inclusions to the final products of disintegration can be traced in many places, although in most cases the inclusions are well marked and sharply defined against the enclosing gneiss. At many points throughout the red granite-gneiss of the batholiths, moreover, streaks of grey gneiss are found. It is estimated that, taking the granite-gneiss of the whole area examined, the amphibolite inclusions represent about 10 per cent of its volume and this grey gneiss another 10 per cent.

The origin of these amphibolite inclusions and of the masses of grey gneiss is not only a question of much interest, but one of considerable importance to the true understanding of the geological processes which have been at work in this region. As is well known, similar inclusions of dark basic rocks of the nature of amphibolite are found in very many occurrences of granite, especially those of Pre-Cambrian age, in various parts of the world, and they have been the subject of much investigation and widespread discussion. By many geologists they have been considered to be basic differentiation products from the acid magma, while others have looked upon them as fragments of foreign rocks caught up by the granite.* In the region at present under discussion there are three ways in which it would be possible to consider them as having had originated:—

(1) As the basic differentiation products (Ausscheidungen) from the granite magma.
(2) As portions of the rock forming the walls or roof of the batholith, which had fallen into the granite magma and had partaken of its subsequent movements.
(3) As fragments of intrusive masses, dykes, stocks, etc.

A careful study of all parts of the area has failed to furnish any evidence that the first is the true explanation anywhere. There is positive proof that the second is the correct and only explanation of the inclusions in several parts of the area, and it is an explanation not opposed to the facts in any part of the area. The inclusions in some places, more especially in the great northern granite-gneiss areas, may have originated in part as set forth in the third explanation. The form of the inclusions sometimes suggests this; but the movements in the granite have been so great, and the inclusions have been so torn to pieces, that it has been impossible to decide whether any of them have been derived from the source indicated under this head.

*C. H. Smith, Jr., 'Report on the Crystalline Rocks of St. Lawrence County, N.Y. State Mus. 49th Ann. Rep. 1895, vol. ii (1898), p. 490. The black inclusions in the granite-gneisses of the Adirondacks are considered to be broken masses of an older rock caught up by the granite-gneiss when the latter was still in a molten condition. B. Frosterus, 'Bergbyggnaden i Sydostra Finland', Bull. Comm. Geol. Finl. vol. ii, No. 13 (1902), p. 157, considers that the amphibolites, which are characteristic associates of the granite-gneiss of Southern Finland, are probably for the most part altered dyke-rocks. Some of them still show a gabbro-like structure, which, if the granite be supposed to represent the original subcrust in a softened or remelted condition, cut through this crust, and were connected with basic effusives at the surface: these masses, having been torn to pieces by the subsequent movements of the softened granite, now appearing as scattered fragments.

## II. Rocks of Sedimentary Origin.

(a) *Limestones.*

The limestones in this Laurentian area are very thick, and underlie a large part of it. In their more altered form they closely resemble those described by Logan in the areas examined by him; but to the south-east of the Bancroft sheet, where the invading granite is less abundant and the alteration of the invaded strata is correspondingly less pronounced, the limestones appear in less altered forms, and eventually pass into fine-grained, greyish-blue varieties in which the bedding is perfectly preserved and concerning whose truly sedimentary character there can be absolutely no doubt. It is impossible to represent on the map the gradual transition of the comparatively unaltered blue limestones into the coarsely crystalline white marble. This, however, takes place by the development in the former of little strings or irregular patches of coarsely crystalline white calcite, usually following the bedding-planes. These become larger and more numerous on going north in the area towards the granite intrusions, until eventually the whole is transformed into a great development of white marble. Here and and there through the marble, where the bodies of the rock are very thick, small remnants of the original blue limestone can occasionally be found, as is indicated on the map in the township of Monmouth.

Enormous bodies of nearly pure limestone occur in many parts of the area; but elsewhere this limestone is impure, owing to the presence of grains of various silicates distributed through it, or to the presence of little bands of silicates representing impurities in the original limestones, which, under the influence of metamorphism, develop into gneisses and amphibolites of various kinds. Where these little gneiss bands or amphibolite bands become increasingly abundant, the limestone passes over into paragneiss or into some one of the varieties of amphibolite.

(b) *Quartzites.*

Quartzite is not common in this area, the most extensive development being that which occurs as a band crossing the township of Monmouth. It is found interstratified with crystalline limestones and rusty-weathering gneisses of sedimentary origin.

Interbanded crystalline limestone and granular amphibolite. Wellington road, lot 6, Con. III. Chandos township.

Interbanded crystalline limestone and granular amphibolite, Wellington road, lot 6, Con. III. Chandos township.

There is every reason to believe that these quartzites represent, in most cases at least, altered sandy sediments.

(c) *Gneises of Sedimentary Origin* (*Paragneisses*).

These rocks differ distinctly in appearance from the foliated granite- gneisses already described as constituting the batholithic intrusions. They are fine in grain, and show no protoclastic or cataclastic structure, the original material having been completely recrystallized. They have, therefore, an allotriomorphic structure with a tendency for certain of the constituent minerals to be elongated in the direction of the original bedding. While quartz, feldspar and biotite are among the constituents present, the mica is usually more abundant than in the granite-gneisses. In addition to these, garnet, sillimanite, graphite and pyrite are very frequently present, the oxidation of the last mineral giving rise to a prevailingly rusty colour on the weathered surface. These gneisses occur in well-defined beds, and are usually found intimately associated with the limestones. They resemble in many respects the hornstones which are found in granite contact-zones, but are rather more coarsely crystalline than is usual in this class of rocks.

## III.—Amphibolites.

Intimately associated with these sedimentary gneisses and the limestones on the one hand, and with the gabbros and diorites on the other, is another class of rocks which is grouped under the name of amphibolite. While many varieties of these rocks occur in the area, differing considerably one from the other in appearance, they have in common a dark colour and a basic composition. Quartz, one of the commonest constituents in the gneisses, is absent or is present only in very small amount; while hornblende and feldspar, the latter chiefly plagioclase, are the main constituents of the rock. Pyroxene and biotite often replace the hornblende in part.

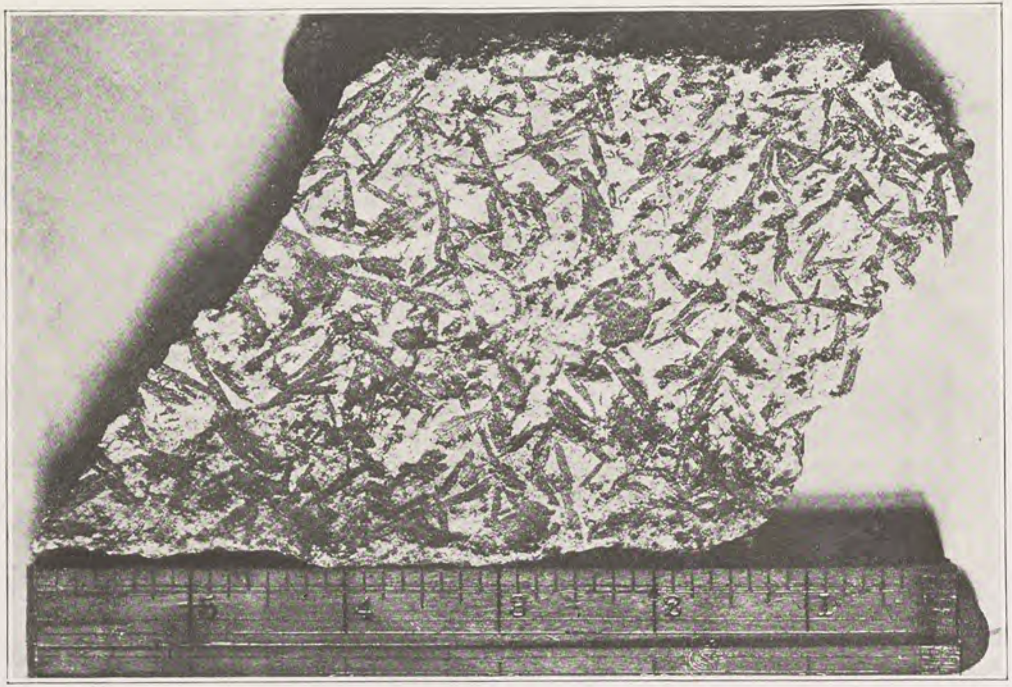
These rocks underlie large areas, as represented on the Bancroft sheet. They also occur as interbedded layers so intimately associated with certain developments of the limestones that these limestone-amphibolite occurrences have been mapped separately. In places the sedimentary gneisses also fade away into occurrences of amphibolite when traced along the strike. Masses of amphibolite also abound as inclusions throughout the granite of the batholiths.

These amphibolites are not peculiar to this area, but occur abundantly everywhere in the Laurentian. They have always proved to be one of the chief difficulties in the way of a correct understanding of the geology of this system, seeing that it has been impossible to do more than indulge in conjectures concerning their origin. The same difficulty has been encountered in the case of these and allied rocks occurring elsewhere, as, for instance, the trap-granulites of the Saxon Granulitgebirge or the amphibolites of the crystalline complex of certain portions of the Alps, the origin of which remained in doubt, while that of the rocks wherewith they were associated had been definitely determined.

Two of the more common varieties of these amphibolites are represented by special designations on the map. One of these, which has been termed "feather-amphibolite," always occurs in thin bands interstratified with limestone, and derives its name from the curious feather-like development displayed by large skeleton crystals of hornblende or pyroxene which appear on the plane of stratification of the rock, to which they give a striking appearance when it is split along this direction. The other variety of amphibolite, which also frequently occurs as heavy bands in the limestones, is of a finely granular character without very distinct foliation. On weathered surfaces it presents a uniformly, minutely speckled appearance, owing to the intimate admixture of the minute grains of hornblende and feldspar. On this account, during the prosecution of the field-work, this variety was designated as 'the pepper-and-salt amphibolite', and in the legend of the Bancroft sheet it is designated as granular amphibolite.

Still other varieties differ from this granular amphibolite, in being somewhat coarser in grain or less regular in composition.

As the result of a very careful examination, it has been possible to prove conclusively that in this area the amphibolites have originated in three entirely different ways, the resulting rocks, a'though of such diverse origin, often being identical in appearance and composition. This



Weathered surface of feather amphibolite, township of Wollaston.

remarkable convergence of type, whereby rocks of widely different origin come to assume identity of character, explains the difficulty which has been experienced up to the present time in arriving at a satisfactory conclusion concerning their genetic relations.

(a) Some of these amphibolites result from the metamorphism and recrystallization of sediments. To this class belong the feather-amphibolites above described, which usually occur in thin bands alternating with crystalline limestone, and are evidently of like origin. They represent siliceous or dolomitic laminae in the calcareous deposit. In many cases the bands of crystalline limestone become thinner and less abundant, and the composite rock passes gradually over into a body of pure feather-amphibolite. Whether the granular amphibolite, which is also found alternating with bands of limestone very frequently and over wide areas, is in some cases of similar origin, it has not been possible up to the present time to decide.

(b) Certain granular amphibolites represent altered igneous intrusions, for they are found in the form of dykes cutting across the stratified white crystalline limestone on the shores of Jack's lake in the township of Methuen. The limestones here dip at a low angle to the south, and are excellently exposed in low cliffs about the lake. The typical granular amphibolite can be seen rising above the surface of the water in the form of vertical dykes one to two feet (·3 to ·6 m.) wide which cut directly across the stratification of the limestone. These can frequently be seen to have been diverted along certain bedding-planes and torn apart by movements in these planes, the limestone-strata having experienced somewhat extensive movements along their bedding-planes during their upheaval. The dykes, after following the bedding-planes for a certain distance, once more cut vertically across them and so reach the surface. Such dykes when seen on limited exposures of the bedded surface of the limestone, especially in contorted districts, would usually present the appearance of interstratified masses of amphibolite.

This amphibolite has the regular allotriomorphic structure of a completely recrystallized rock, and differs from any of the normal igneous rocks. Under the microscope it is identical with an amphibolite described by Dr. Teall, which was developed by the alteration of a diabase dyke where crossed by a line of shearing. In the case of these Canadian dykes, however, the amphilbolite is not confined to that portion which has been clearly subjected to movement, but forms the whole mass of the dyke.

(c) Amphibolites which are identical in physical character and in composition with those described under (b) are also produced by the metamorphic action exerted by the granite-batholiths on the limestones through which they cut. This is a remarkable fact, and one which at first sight seems scarcely credible. It is, however, a change which has undoubtedly taken place on a large scale.

In addition to the amphibolites which have originated in the three ways above mentioned, it is highly probable, judging from their character and mode of occurrence, that the amphibolite bands associated with the large gabbro and diorite masses—as, for instance, that running in a north-easterly and south-westerly direction through the township of Wollaston, and that extending from the south-eastern portion of the township of Cardiff, into Anstruther—represent highly altered basic volcanic ashes and lava-flows, connected with vents represented by the gabbro-stocks. The latter of these amphibolite bands presents a great variation from place to place in the character of the constituent rock. While in some places it is well banded, elsewhere it is streaked or presents an appearance strongly resembling flow-structure, with lighter coloured lath-like forms highly suggestive of feldspar phenocrysts thickly scattered through it. Yet elsewhere the appearance suggests an original amygdaloidal structure. The rock, however, is so completely recrystallized, that a microscopic examination does not yield any conclusive evidence concerning its original character.

## IV. Gabbros and Diorites.

These rocks differ from the amphibolites in that they are massive and usually coarse grained. They also differ in their mode of occurrence as great basic intrusions. While some of these intrusions are pretty uniform in character, others display a very marked differentiation and present many petrographical varieties within a single intruded mass.

Many of them, in addition to pyroxene, a basic plagioclase and iron ore, hold a large amount of hornblende

In certain places, especially about the border of the Glamorgan batholith, where the line of contact is especially well exposed for study, a gradual passage of the limestone into amphibolite can actually be observed, the former rock having gradually developed in it feldspars, hornblende and pyroxene in progressively greater amount, until it eventually becomes an amphibolite. A detailed description of this form of alteration, with a chemical and mineralogical

Limestone passing into pyroxene gneiss and amphibolite cut by granite. Southern border of Glamorgan batholith, Maxwell's Crossing.

study of the transitional rocks, will be found in the report on the geology of the Haliburton and Bancroft areas to which reference has already been made. (See also pp. 63-73 of this Guide Book.)

Evidences of alteration of the third class are less frequent and less striking. Nevertheless, in certain cases it appears to be practically certain that there has been a distinct solution of the invaded rocks by the granite. This, however, probably took place on a comparatively small scale.

An occurrence of this kind is found on the southern extension of Kasshabog lake, in the township of Methuen. Here the banded amphibolite is invaded by the granite-gneiss, which has broken it into fragments and partly dissolved some of them, giving rise to a greyish, streaky-looking mass of irregular composition, much lighter in colour than the amphibolite and darker than the granite, being grey instead of reddish.

Other examples of the same phenomenon, but on a larger scale, may be seen at many places about the margin of the Anstruther batholith. At the northern end of this occurrence, where the granite-gneiss of the batholith runs up into the township of Monmouth, it is bounded on the north by an extension of what is known as the Catchecoma gneiss. This is a basic rock which resembles in appearance a light-coloured amphibolite. To the north of the Catchecoma gneiss is a dark amphibolite, and then a band of limestone. The granite-gneiss, elsewhere red, becomes grey in colour and poor in quartz as the northern boundary is approached, and passes into the Catchecoma gneiss, which is at first seen to hold a few tear-shaped inclusions of the amphibolite; these become increasingly numerous as the contact is approached where the amphibolite is reached, through which there run streaks of the invading rock. Evidently the amphibolite has been partly dissolved by the granite magma, and here the Catchecoma gneiss consists apparently of the granite magma rendered basic by the solution of amphibolite.

## VII.—Distribution and Thickness of the Grenville Series.

In an area where the geological structure is so complicated, and where the strata must have been invaded by such immense bodies of igneous material, it is difficult to determine the true succession and thickness of the sedimentary series. The area is traversed by the Hastings road, which for a distance of 25·3 miles (40·7 km.) passes continuously across the limestones and amphibolites of the Grenville series, and throughout this whole distance crosses these rocks nearly at right angles to their strike.

Furthermore, throughout nearly the whole distance these strata dip in a southerly direction at high angles.

It must be noted, also, that along the whole length of this section a continuous alternation of beds of varying character is presented, and therefore it is not a foliation, but a true bedding that is observed. It is, furthermore, to be noted that, although this series may have been repeated by isoclinal folding, there is no stratigraphical evidence that such is the case, and this folding has nowhere brought up the basement upon which the series was deposited—a fact which indicates again that the series, even if so folded, is extremely thick.

It may be safely stated that the Grenville series presents by far the thickest development of Pre-Cambrian limestone in North America, and that it presents at the same time one of the thickest series of Pre-Cambrian sediments on that continent.

Not only has the Grenville series a great thickness, but it has a great superficial extent. It is exposed more or less continuously over an area of 83,000 square miles (208,000 sq. km.) in Eastern Canada and the State of New York. In areal extent, therefore, it can be compared in North America only with certain of the greatest developments of the Palæozoic limestones, as, for instance, the Knox dolomites of the southern Appalachians. In all probability, its original areal distribution was considerably greater than above stated, although this cannot be definitely determined on account of the great erosion to which the Laurentian protaxis has been subjected.

It may here be mentioned that the 'Hastings series,' a designation given by Logan to certain rocks of the Madoc district, has proved, as Logan conjectured might be the case, to have no independent existence, but to be merely the less metamorphosed portion of the Grenville series seen in the southern part of the Bancroft area. It is, however, practically certain that in this Madoc district the comparatively unaltered rocks, which were designated by Logan as the Hastings series, really consist of two unconformable series; and it is possible also that in the Grenville series, as shown upon the Bancroft sheet, there may be two formations separated by an unconformity, as suggested by the occurrence of certain conglomerates. If, however, there are proved to be two formations within this area, these are identical in petrographical character, and are so intimately infolded and so highly metamorphosed that their respective distribution in the Bancroft area cannot now be determined.

## VIII.—Relation of the Grenville Series to other Pre-Cambrian Series.

In the southern portion of the Laurentian highlands to the west of the area occupied by the Grenville series, that is, north of Lake Huron and in the district about Lake Superior, Rainy lake and Lake of the Woods, other Pre-Cambrian series, differing essentially in petrographical character from the Grenville series, are found. These are, enumerated in ascending order, the Keewatin, Huronian, and Keweenawan series. Up to the present time the Grenville series has nowhere been found in contact with these; but it is hoped that the relation of these eastern and western Pre-Cambrian developments may eventually be determined, in order that a correlation may be made between them. Until this has been done, however, their relations must remain a matter of mere conjecture. The two successions, then, are as follows:—

| Western District. | | | Eastern District. | |
|---|---|---|---|---|
| Upper Cambrian—Potsdam sandstone | | | Upper Cambrian—Potsdam sandstone. | |
| | | *–Unconformity–* | | *–Unconformity–* |
| Pre-Cambrian | Keweenawan. | | Pre-Cambrian | Grenville series. *Intrusive contact.* |
| | *–Unconformity–* | | | |
| | Huronian | Upper (Animikie).<br>*–Unconformity*<br>Middle.<br>*–Unconformity*<br>Lower. | | |
| | *–Unconformity–*<br>Keewatin.<br>*Intrusive contact.* | | | |
| Laurentian. | | | Laurentian. | |

It will be noticed that here the term Laurentian is used in a somewhat different sense from that in which it was employed by Logan. In Logan's original classification of the Laurentian this term—apart from the Upper Laurentian, which was proved to be composed essentially of anorthosite intrusions—included two series differing in character, namely, the Lower Orthoclase ( Fundamental') gneiss and the Grenville series. Now that investigations have shown that these two series differ in origin (one being essentially a great development of very ancient sediments, and the other consisting of great bodies of igneous rock underlying and intruded through them), it becomes necessary to separate these two developments in drawing up a scheme of classification. As the lower gneisses, forming what has been termed the 'Fundamental gneiss,' have an enormously greater areal development than the overlying sedimentary series, constituting as they do a very large part of the whole Northern Protaxis, and forming the basis upon which the Grenville series rests, it has been proposed that the term Laurentian be restricted to this great development of igneous gneisses [**5**, p. 89 and **6**, p. 191.

The Grenville series is thus separated from the Laurentian system, and the name is employed to designate the sedimentary series which overlies the lower gneisses and granites. The name Laurentian will, in addition to its geological use, continue to have a geographical or physiographical significance, as, for instance, in the term Laurentian Protaxis, which latter forms so striking a feature of the continent of North America, and is underlain chiefly by the gneisses of the Laurentian system.

In its petrographical character and in the display of the products of metamorphism which it presents, this great area on the southern border of the Canadian protaxis resembles in many respects certain classic localities of the 'Grundgebirge' on the continent of Europe [**10**], but in none of them, with the possible exception of the Scandinavian peninsula, can the successive stages of metamorphism be so clearly traced, or its final products be studied in such enormous development. The area is very instructive, as presenting a section of the *appareils granitiques*, the 'roots of the mountains,' laid bare for study by the processes of denundation.

The Laurentian protaxis from early times has been relatively an area of progressive uplift; while that of the great plains to the south has been an area of progressive sinking, since upon it has been deposited in successive stages a series of great systems of sedimentary rocks.

Here along the border of these two great geological units, the deep erosion reveals, it would seem, the mechanism of elevation, the granite magma rising from the depths and in all probability passing out from beneath the subsiding area to the south, lifting the old Laurentian highlands as the liquid in the Bramah press lifts the ram when the piston sinks.

## IX.—Summary.

(1) The Laurentian system of Sir William Logan in Eastern Canada consists of a very ancient series of sedimentary strata—largely limestones—invaded by enormous volumes of granite in the form of batholiths, representing what Logan termed the Fundamental gneiss.

(2) This sedimentary series is one of the most important developments of Pre-Cambrian rocks in North America, and presents the greatest body of Pre-Cambrian limestones on that continent.

(3) This great Pre-Cambrian limestone series is best designated as the Grenville series.

(4) The invading batholiths of granite are of enormous extent. They possess a more or less distinct gneissic structure, due to the movement of the magma, which developed a fluidal and, in the later stages of intrusion, a protoclastic structure in the rock.

(5) The granite-gneiss of the batholiths not only arched up the invaded strata into a series of domes, but 'stoped' out portions of the sides and lower surface of the arches, the fragments torn off from the walls and roof by the invading granite being found scattered throughout the mass of the invading rock. This 'stoping' [**4**, p. 269], however, probably developed only a small part of the space which the granite now occupies.

This structure is thus identical with that found by Dr. Lawson in the Keewatin area of the Lake of the Woods district, west of Lake Superior, and by Adams in the district north of the

Island of Montreal. It is a structure which probably persists throughout the whole northern protaxis of the continent [**2**].

(6) The invading granite not only exerted a mechanical action upon the invaded strata, but also by its action upon these latter gave rise to a variety of metamorphic products, among which one of the most important is amphibolite produced by its action upon the limestone.

(7) The nepheline syenite is a peripheral phase of the granite intrusions, and is developed chiefly along the contact of the granite with the limestone. The nepheline syenite magma frequently contained a large excess of alumina which, upon the cooling of the rock, separated out as corundum, giving rise to corundum syenites, which are extensively worked for this mineral.

(8) The invading batholiths and allied intrusions of granite appear to occupy the greater part of the great northern protaxis of Canada, which has an area of approximately 2,000,000 square miles (5,000,000 sq. km.) It has therefore been considered advisable to restrict the name Laurentian to this great development of the Fundamental gneiss, which, although intrusive into the Grenville series, nevertheless underlies and supports it.

(9) The relation of the Grenville series, forming the base of the geological column in Eastern Canada, to the Huronian and Keewatin series, which are the oldest stratified rocks in the western part of the protaxis, has yet to be determined, the two not having so far been found in contact; nowhere, moreover, either east or west, has the original basement upon which the first sediments were laid down been discovered. These are everywhere torn to pieces by the granite intrusions of the Laurentian.

# ITINERARY OF THE EXCURSION.

ANNOTATED GUIDE.—(Montreal to Ormsby Junction.)

Miles and Kilometres.

0.m. 0.km. **Montreal** (Bonaventure station, Grand Trunk railway), with a population of 592,000, is the largest city and the commercial metropolis of Canada. It is situated on the south side of an island of the same name at the confluence of the Ottawa and St. Lawrence rivers. It is at the head of ocean navigation and at the commencement of lake and river navigation. The city has been built about the base of Mount Royal, an intrusive mass of Devonian or post-Devonian age, composed principally of essexite and nepheline syenite, which rises to a height of 763 feet (232·56 m.) above the sea or 742 feet (226·16 m.) above the standard low water of the river. On its sides may be seen terraces and beaches, the records of post-glacial subsidence, the highest shore line having an altitude of 568 feet (173·1 m.) above the sea. St. Catherine and Sherbrooke streets respectively follow two of the most important terraces. The city is underlain by rocks of the Trenton group, which furnish the grey limestone so much in use locally for building purposes. Utica shale outcrops at Verdun and Point St. Charles and underlies the harbour and the south end of St. Helen's island. Masses of limestone included in the igneous breccia of St. Helen's island are of Lower Helderberg (Upper Silurian) and Oriskany (Lower Devonian) ages. These occurrences are of interest as evidences of the extension of the Upper Silurian and Lower Devonian seas as far inland as Montreal. The Trenton is usually credited with a thickness of 600 feet (183 m.) and the Utica 300 feet (92 m.) in the region surrounding Montreal.

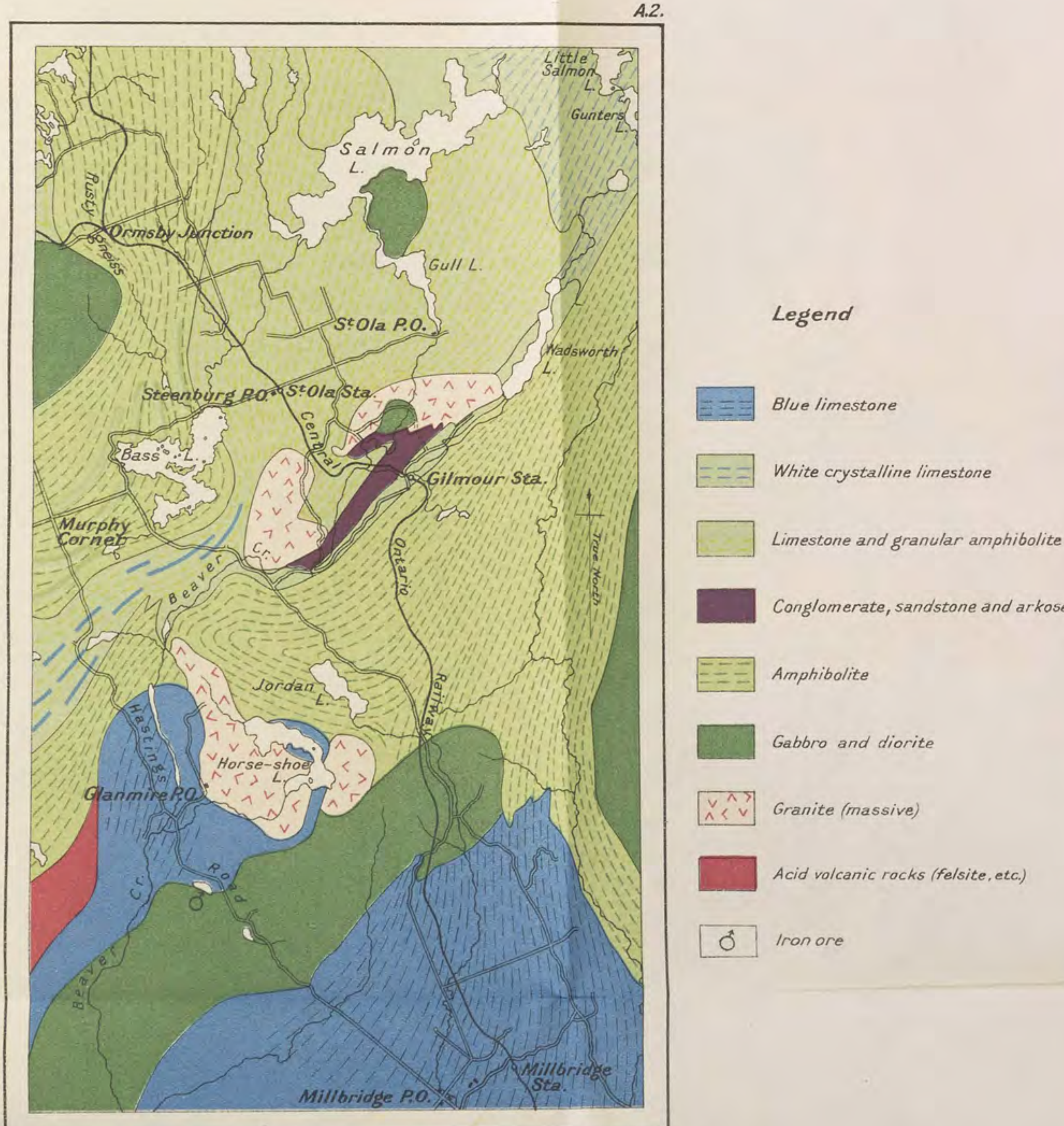
Leaving Montreal the railway runs to the southwest following a natural depression, which extends nearly to the shores of Lake St. Louis, an expansion of the St. Lawrence river. Between Lachine and Ste. Anne de Bellevue, the railway passes through a beautiful and highly cultivated stretch of country, sloping gently to Lake St. Louis. The great expanse of comparatively low flat land which borders the St. Lawrence river from Montreal to Trenton is underlain by the almost horizontal strata of Upper Cambrian (Potsdam formation) and Ordovician ages (Chazy, Calciferous, Black River and Trenton formations) with the exception of the region between Brockville and Kingston where this succession is interrupted by granitoid gneisses and quartzites of Archean or Pre-Cambrian age. Throughout the greater part of this area, the underlying rock formations are concealed by a heavy mantle of marine sands and clays of Champlain age. This great drift-covered Palaeozoic plain with its eminently flat surface presents a strong contrast to the uneven topography of the Archean rocky plateau. The average elevation of this plain in the vicinity of Montreal is about 100 feet (30·5 m.), gradually rising westward until in the vicinity of Central Ontario Junction, it is almost 600 (183· m.) feet above the sea.

232·85m. **Trenton.**—(Grand Trunk Railway station).
375·0 km. Alt. 280 ft. (85·3 m.) At Trenton the train is switched from the Grand Trunk railway to the Central Ontario railway, now being operated by the Canadian Northern railway.

**Trenton.**—(Central Ontario Railway station) Alt. 258 ft. (78·6 m.).

257·86 m. **Canadian Pacific Railway Junction.**—
415·0 km. Alt. 598 ft. (182·3 m.) From the junction with the Canadian Pacific railway, known also as Central Ontario Junction, the railway runs north. The main mass of Archean or Pre-Cambrian rock is not reached until Bannockburn station is approached. The transgression of the Palaeozoic sea along this portion of the great protaxis began early in Ordovician time. This marine invasion was inaugurated by the shallow water conditions resulting in the deposition of

A.2.




Geological Survey, Canada

Route map, **Hastings Road**

Miles 1 0 5

Kilometres 1 0 5

certain conglomerates, grits and sandstones which mark the base of the Lowville (Birdseye) and Black River formations.

Owing to inequalities of the pre-existing land surface as well as to subsequent unequal erosion, the present line of contact between the Palaeozoic and the Archean is very intricate. As a consequence large irregular-shaped masses of flat-lying Palaeozoic strata extend for many miles beyond the general direction of the line of junction, while corresponding insets of highly inclined Archean rocks break up the continuity of the main mass of the Palaeozoic rocks. This irregularity in the line of division between these two series of formations is further accentuated by the occurrence of outliers of flat-lying Palaeozoic rocks, some of which are now separaated by intervals of many miles from the main mass to the south.

263·34 m. **Marmora.**—Alt. 594 ft. (181 m.)
423·8 km.

282·92 m. **Millbridge.**—Alt. 944 ft. (287·7 m.)
455·3 km. The party will leave the railway at Millbridge, and will drive up the Hastings road to Murphy's Corners and thence to St. Ola station.

Between Millbridge station and Millbridge post office, the blue limestone of the Grenville-Hastings series is excellently exposed. It is well-bedded, heavier beds alternating with thin beds which are usually laminated. Some of these beds are more distinctly blue in colour and effervesce readily when a drop of diluted acid is placed on the surface of the rock; others are greyer in colour and give a distinct effervescence only when powdered. The lamination undoubtedly represents the original bedding of the rock, and while the rock in many places is much contorted, the limestone still retains its blue colour, showing that the alteration has not been nearly so intense as in the case of the same series further north, where metamorphism has entirely dissipated the colour of the limestones, producing at the same time a certain coarsening in grain.

A qualitative chemical examination shows that the blue beds are limestones, all more or less impure, and that the grey beds are much more impure varieties of the same rock. The proportion of magnesia present does not seem in any case sufficient to constitute a dolomite, although in the absence of a quantitative examination the actual proportion of this base present remains uncertain.

A microscopic examination of a series of thin sections of specimens of the various varieties of the rock, shows that all stages of the continuous transition from a limestone containing only a few flakes of brown mica to a micaceous paragneiss (pflastergneiss) are represented. The latter constitutes the hardest grey beds and holds scarcely any calcite, but contains, on the other hand, much biotite, in the form of individuals, which usually possess a somewhat frayed outline and lie in a fine-grained base of colourless untwinned grains, some of which are quartz, but some, and perhaps the majority, are probably orthoclase. Pyrrhotite also occcurs scattered through the rock, but no trace of any magnesia constituent, except the biotite, was found in any of the slides, nor was any mica but biotite present. In most of the sections minute rutile crystals, identical with those so commnoly found in clay slate, were found.

The occurrence evidently represents a great body of calcareous sediments, made up of an alternation of beds which vary greatly in the amount of impurity (silt or mud) which they contain, and which, under the relatively slight metamorphism which this portion of the area has undergone, has suffered a diagenetic alteration into the varieties of limestone and paragneiss above described. In the movements to which the strata have been subjected, the purer limestone beds, curiously enough, are seen to have been less resistant than the more impure gneissic beds, for they can be seen on the weathered surface to have been torn apart, while the gneissic beds flow in between the separated fragments. A considerable amount of local solution and redeposition has also taken place, as shown by the presence of a coarse-grained development of the gneissic bands along certain irregular lines often running transverse to the bedding.

This area of blue limestone, with its pure and impure bands, under a more intense metamorphism, such as that to which the more northerly portion of the district has been subjected, would develop into a series of coarsely crystalline white limestones, with interstratified bands of the rusty biotite-bearing gneisses, which are so extensively exposed elsewhere in the district, and which are so commonly found in all developments of the Grenville series in Canada. Such an occurrence as this, therefore, represents the Grenville series, in a less altered form.

284·29 m. **Millbridge Corners** is between lots 20 and
457·5 km. 21, Hastings road. Before the building of the railway this road was one of the main highways of communication, but is now little used, except for local purposes. It crosses the strike of the rocks nearly at right angles, however, and thus affords a good cross section.

At the "Corners" the bluish limestone is much contorted and nearly vertical in attitude. Very narrow, lenticular bands of white calcite are being developed as a result of recrystallization.

285·54 m. From lot 25 to lot 33 the road passes through
459·5 km. a swampy tract with exposures of similar limestones at intervals. The beds, which are nearly vertical, dip sometimes to the south, but usually in a northerly direction. In places veins of quartz together with some dolomite, intersect the limestone. On lot 32 the limestone is lighter in colour, owing to more advanced metamorphism. Between lots 33 and 36 the limestones are inclined at a very high angle to the south.

This limestone succession is interrupted on lot 40 by an intrusion of diorite. The limestone

at the contact is altered into a fine-grained aggregate of very pale green pyroxene and plagioclase, but a large included block of the limestone-paragneiss series, intensely metamorphosed, has been caught up by the igneous mass. The narrow defile occupied by the road near the summit of the hill has for a long time been
287·79 m. known as the "Hole in the Wall."
463·2 km. This diorite (about lot 48) is composed essentially of hornblende and plagioclase with a little accessory iron ore and an occasional grain of pyrite. The hornblende is pale green in colour and somewhat fibrous in character, its appearance suggesting its derivation from pyroxene, although no trace of pyroxene now remains. The plagioclase has undergone considerable saussuritization, the resulting products being mainly zoisite and epidote. It is probably the rock referred to by Vennor in his report on the geology of the district as "blotched diorite."

The diorite from lot 49 is rather finer in grain and more basic, the hornblende in well defined individuals being much more abundant than the plagioclase. Thin sections show the rock to be made up essentially of hornblende and plagioclase. It is much more altered than the "Hole in the Wall" diorite and some of the hornblende is undoubtedly secondary.

290·79 m. This diorite on lots 56 and 57 to the west of
468 k.m. the road and close to the township boundary differentiates into a large body of titaniferous magnetite opened up and worked at the Orton mine. This mine is the property of the Tivani Electric Steel Co. of Belleville, Ont. Two analyses show the ore to have the following composition:

| | | |
|---|---|---|
| Iron | 51·45 | 60·84 |
| Sulphur | trace | ........ |
| Titanium | 7·50 | 7·50 |
| Nickel | 0·112 | ........ |
| Vanadium | trace | 0·11 |

This ore has been used very successfully for the manufacture of tool steel in the electric furnace by the Evans-Stansfield process [**12**, p. 52].

290·79 m. On lot 56 the limestone series is again seen
468 km. with an almost vertical attitude although both northerly and southerly dips at high angles are seen in the exposures. At one place a small mass of gabbro, probably an apophysis of the main mass to the south, is intruded into the sedimentary rocks.

292·03 m. About lot 62 a mass of pyrrhotite about 30
470 km. feet (9·1 m.) in width is interstratified with blue limestome and lighter coloured dolomite, the whole series dipping to the south at a high angle.

294·47 m. From lot 80 to lot 86 a fine-grained and
473·9 km. evenly foliated amphibolite occurs. From this point to Murphy's Corners the limestones and amphibolites are interstratified with one another, dipping to the south at a high angle. Owing to progressive metamorphism and consequent recrystallization, the limestone has lost much of its bluish-grey colour and some bands are quite white.

The fine-grained amphibolites and gneisses which are interstratified with limestones represent either intercalations of muddy sediments analogous to those forming the paragneisses in the vicinity of Millbridge, or have originated from the complete alteration of volcanic ashes which fell into the sea during the deposition of the limestones. Their chemical composition affords very little distinctive information as to their genesis, but their association with intrusions of gabbro, possibly truncated volcanic centres, suggests a volcanic origin.

298·22 m. **Murphy's Corners.**
479·9 km. From Murphy's Corner's the road follows the town line between Limerick and Tudor until it reaches Bass lake. Thence it passes to the west and north of this lake and joins the railway at St. Ola station (Steenburg P.O.) In this interval limestones, amphibolites and rusty-weathering paragneisses interstratified with one another are exposed. The limestone is apparently relatively unimportant, but this

is probably due to the fact that this rock, being softer and more readily eroded than the amphibolite, usually occupies depressions and is thus very frequently largely drift covered.

303·52 m. **St. Ola Station.**—Alt. 1068 ft. (325·5 m.)
488·4 km. At St. Ola the party will again take the train and proceed to Ormsby Junction.

307·32 m. **Ormsby Junction.**—Alt. 1,160 ft. (353·6 m.)
494·6 km.

## Geology in the Vicinity of Ormsby Junction.

At this place there are large exposures of the typical "rusty gneiss" (paragneiss) which is so commonly associated with the crystalline limestones of the Grenville series. In the vicinity of mile post 97 to the west of the station, there are several rock-cuts blasted out to secure the required grade for the railway. This band of gneiss is approximately a mile wide. The gneiss is light grey to very dark grey on a fresh fracture, but weathers with an intensely rusty surface. A typical specimen of the rock, taken from a cutting on the railway track half a mile west of Ormsby Junction, when examined under the microssope, was found to be very fine and uniform in grain and to possess a distinct foliation. It shows a colourless allotriomorphic base, consisting chiefly of quartz and feldspar, through which are distributed a great number of little flakes of biotite, separate from one another, but all with a marked parallel alignment. The biotite is strongly pleochroic in deep brown and pale yellow colours. The feldspar, which is clear and colourless, shows no twinning. Some of the quartz grains are nearly round and have an appearance strongly suggestive of sand grains. In addition to these minerals there is present as an accessory constituent a small amount of garnet, in individuals having a well-marked polygonal outline, showing that the mineral has a good crystalline form. It is quite isotropic in character. There are also a few little rounded grains of zircon or sphene, as well as a small amount of hydrated oxide of iron, occurring as minute grains, whose form suggests their derivation either from a rhombic pyroxene such as occasionally occurs in rocks of this class, or possibly from pyrite. No pyrite, however, occurs in the sections, neither are there any carbonates present.

Other specimens from a cutting on the railway one hundred yards west of Ormsby Junction are similiar in character to the rock just described. Microsocopic examination, however, shows that while less biotite is present, the rock contains a large amount of a yellow sulphide of iron, apparently pyrrhotite. Quartz and orthoclase are the most abundant constituents in this rock, which also contains a few grains of muscovite and zircon, the former mineral occurring in occasional large individual skeleton crystals. The grains of the yellow sulphide have an irregular outline, or are present in the form of little strings running parallel to the foliation of the rock. When examined by reflected light, nearly every grain of this sulphide is seen to have intimately associated with it a black mineral with a metallic lustre, which is evidently magnetite. This latter mineral usually forms a border around the yellow sulphide, wholly or partially enclosing it. These metallic minerals occur not only in larger grains, but also as a fine dust scattered throughout the rock.

At one place by the side of the road bed a band of this gneiss has been opened up by a small pit, being mistaken for an iron ore. This variety of the rock is black in colour on a fresh fracture, and when examined under the microscope is seen to be composed chiefly of quartz, hornblende and magnetite. The hornblende is arranged in rudely parallel lines, giving the rock a distinct foliation. It is deep green in colour, and distinctly pleochroic in greenish and yellow tints. The magnetite has a black metallic lustre, and frequently possesses a good crystalline form. An immense number of very minute garnet crystals occur through the rock, resembling those in the rusty gneiss above described, but very much more abundant. Although so small, they are rather uniformly distributed, occurring not only in the hornblende and quartz, but also in the magnetite. They are isotropic and possess a good crystalline form.

This band of gneiss suggests in its appearance in the field certain belts of the magnetite-grünerite schist in the iron ranges on the south side of Lake Superior. The microscopic examination of the rocks, however, shows them to be quite different from the schist in question, biotite being the only iron-magnesia constituent present, except in the case of the narrow band above referred to as having been mistaken for an iron ore, which contains hornblende. Carbonates are also absent, except in traces, and the iron is thus present almost exclusively in the form of a disseminated sulphide, the rocks belonging to the ordinary rusty weathering paragneisses so extensively distributed throughout the sedimentary portion of the area.

ANNOTATED GUIDE—continued.

308·8 m. 497 km. **Brinklow.**

315·5 m. 507·7 km. **Turriff.** Alt.: 1,098 ft. (334·6m.)

319·76 m. 514·6 km. **L'Amable** Alt.: 1,073 ft. (327 m.).

The railway here runs through an old "brûle," with heavy rock cuttings in white crystalline limestone. The valleys between the rocky ridges are occupied by extensive deposits of sand and gravel. In the vicinity of L'Amable station "feather" amphibolite (see page 24) is seen interstratified with thinly-bedded crystalline limestones.

323·09 m. 518·9 km. **Bronson.** Alt. 1,077 ft. (328·2 m.). The first rock cut to the east of this station is in a typical crystalline limestone of the Grenville series. It is distinctly bedded and remarkably free from impurities. Some of the beds still retain some of their originally bluish-grey colour. The action of the weather is very characteristically shown in this exposure. Autoclastic action is illustrated in the dislocation of certain dykes of pegmatite intrusive with the limestone, the limestone very evidently being much more plastic than the pegmatitic material.

A short distance west of Bronson station the railway siding employed by the Ontario Marble Quarries, Limited, is reached. These quarries, which are situated on lots 29 and 30, con. X of the township of Dungannon, and lots 41 and 42 of the Hastings road, Township of Faraday, yield a great variety of ornamental marbles, including breccias of veined, streaked and clouded types of singular beauty. These are produced by differential movements accompanied by more or less intense metamorphism induced in beds of limestone and dolomite of varying degrees of purity. Among the more important varieties may be mentioned the following:

(1) "*Bancroft Cipollino*," so called from its resemblance to the Italian Cipollino, is a green and white variety.

(2) "*Laurentian Vein*," This consists of broken and faulted bands of magnesian limestone, drab and cream in colour, cemented together by a relatively small amount of dark matrix, which consists of magnesian limestone with much biotite and a smaller amount of a nearly colourless hornblende. This variety passes into a breccia with a dark base and fragments of lighter colour.

(3) "*Laurentian Blue*." A fine-grained bluish grey marble in which the original bluish colouring matter has not yet been entirely destroyed by metamorphism.

(4) "*Rose Fantasia*." A marble irregularly banded or streaked, presenting a great variety of colours, often of great brilliancy. The colours represented are white, pale pink, bright red, and cream colour.

(5) "*Bancroft Green*." This is a fine-grained light green rock composed chiefly of a very pale green hornblende with some calcite. The variety called "serpentine" is almost identical in character, the hornblende, however, being more fibrous (actinolite), while in addition pale brown biotite is present.

A white granular marble (dolomite) also occurs near the railway station at Bronson.

The company has installed a complete plant for quarrying and sawing these marbles.

Three small fine-grained black dykes of malchite cut the marble in one part of the quarry. These are composed essentially of a dark green hornblende and plagioclase. These minerals are allotriomorphic in form, although the plagioclase has a tendency to assume a lath-like development. The rock also contains a considerable amount of scapolite as an accessory constituent. A small quantity of a black iron ore in rude, more or less rod-like forms, and a few grains of pyrite are also present. The rock is very fresh.

After having inspected these quarries the party will return to the train and continue the journey to Bancroft.

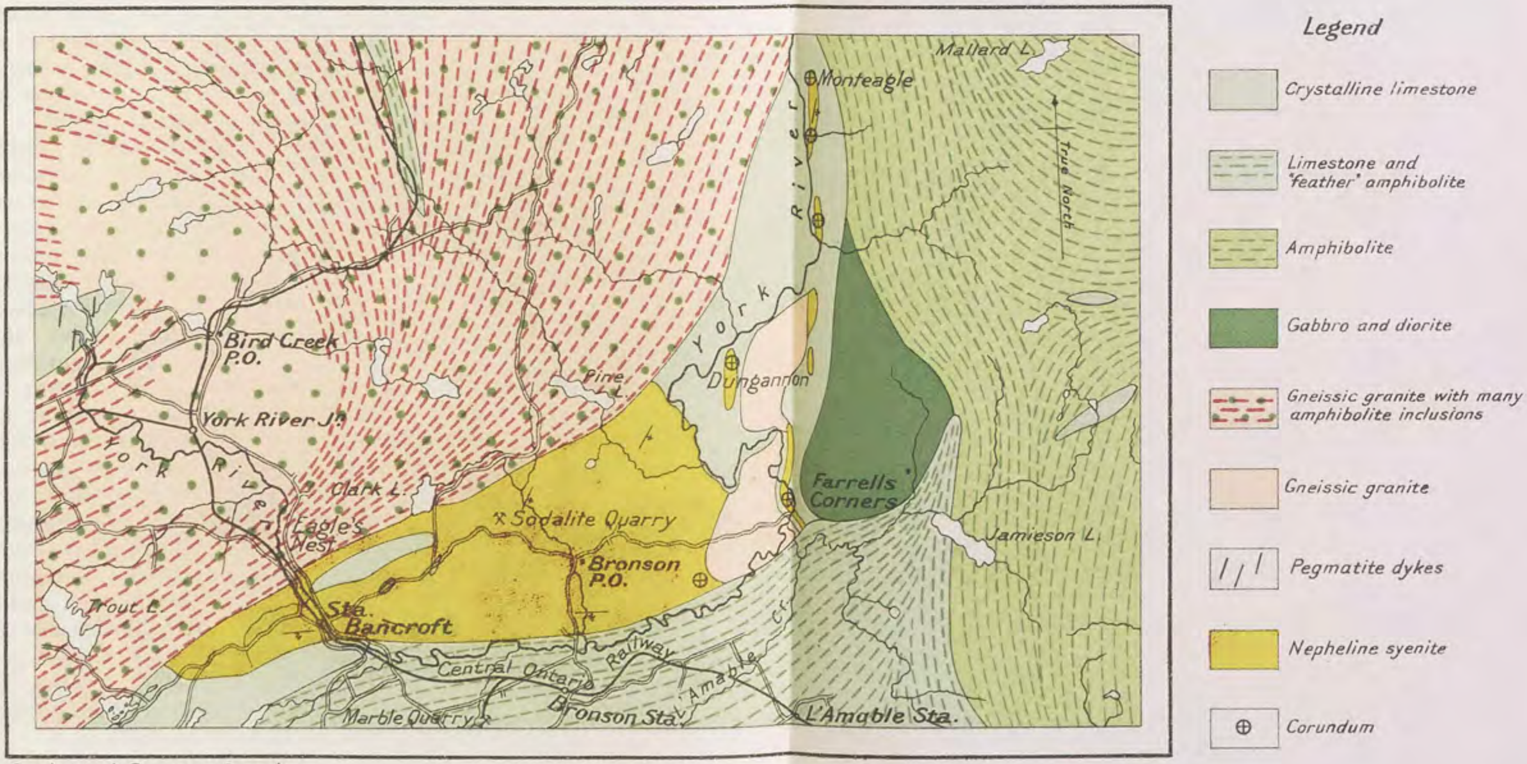
## Geology in the Vicinity of Bancroft.

The Grenville series, which with its associated intrusive masses of diorite and gabbro is traversed by the Hastings road in a direction almost at right angles to the strike of these rocks, furnishes abundant evidence of progressive metamorphism. At Bancroft, however, the continuity of this important series of very ancient crystalline sedimentaries is interrupted by the intrusion of the great northern granite batholith, flanked to the south by a wide border of nepheline and other alkaline syenites. Small and isolated inclusions of the Grenville series occur scattered through the batholith to the north, linearly arranged when they occur in the direction of the movement of its flow, as shown by their relation to the direction of its foliation. These are clearly fragments of the limestone cover of the batholith which have been folded, or have fallen down, into the magma of the invading batholith.

The nepheline syenite shows a distinct banding and foliation, conforming in strike to the foliation of the gneissic-granite, as well as to the bedding of the limestone series.

At Bancroft this nephleine syenite is nearly a mile (1·6 km.) in width measured across the strike of the foliation, the dip being to the south. East of the village it increases 1 .pidly in volume, attaining its maximum development in the vicinity of Bronson post office, where extended and often almost continuous outcrops may be found for over two and a half miles (4 km.) in a north and south direction. In this, which may be termed the Bancroft district, the nepheline and associated alkaline syenites cover an area of about 15 square miles (37 sq. km.).

A2.




Geological Survey, Canada.

**Bancroft and Vicinity**

Miles 1 0 5

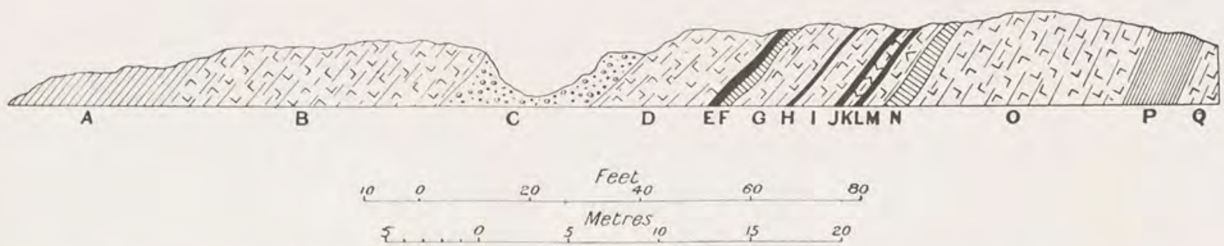
Kilometres 1 0 5

These syenites show a marked variation in the relative proportion of the principal mineral constituents. Indeed extreme and rapid variation in composition is one of the most noteworthy features of their development, so that it is possible to obtain from the same exposure, and even from contiguous bands, different and quite distinct types of rock.

Some varieties are abnormally rich in nepheline, while others contain a much smaller proportion of this mineral, passing by insensible gradation into alkaline-syenites, composed almost wholly of feldspar. Certain types are relatively rich in ferromagnesian constituents, which may be either mica or hornblende, while other phases of these rocks contain very little, if any, of these coloured minerals. Some exposures are characterized by the interesting alkali-hornblende to which the name hastingsite has been given, while in some localities garnet is present in considerable amount. The actual relation of these syenitic occurrences to the granite batholith is not observable along this line of section, since the actual contact between the two cannot here be seen, but examination elsewhere throughout the region has led to the conclusion that the nepheline and associated alkaline syenites represent a peripheral differentiation phase of the invading soda-rich granite along its contact with the limestone. The actual relations of the nepheline syenite to the Grenville series, on the other hand, is well illustrated in the railway cutting in the village of Bancroft, which exposes the line of contact. The character of this junction is shown in the accompanying section through this rock cut at Bancroft.

The nepheline syenite, which is clearly the invading rock, seems to permeate the limestone, the latter being in process of replacement by the syenitic magma. The masses of limestone caught up in the syenite become gradually disintegrated in the magma until they survive merely as separated, irregularly rounded grains of calcite often enclosed in the individuals of perfectly fresh nepheline, hornblende or other minerals of the nepheline syenite or lying between these with the form of the latter impressed upon them. The derivation of these isolated grains of calcite from the neighboring limestone is quite evident even under the microscope for they sometimes show the deformation and strain shadows observable in the invaded limestone, while the minerals of the nepheline syenite in

Section in cutting on Central Ontario railway at Bancroft, showing contact of limestone and nepheline syenite.




A. White crystalline limestone with rusty weathering gneiss.
B. Foliated syenite with segregations of black mica.
C. Sand and gravel (Drift covered).
D. Well foliated nepheline syenite; contains a little calcite.
E. Coarsely crystalline limestone with black mica.
F. Nepheline syenite with much calcite and black mica.
G. Well foliated nepheline syenite with black mica and a little calcite.
H. Coarsely crystalline limestone with black mica.
I. Well banded nepheline syenite, some bands nearly pure nepheline and feldspar. Contains a little calcite.
J. Calcite and black mica.
K. Nepheline syenite with a little calcite.
L. Very impure limestone with black mica.
M. Dark nepheline syenite, well foliated, some calcit cut by dyke of syenite.
N. Very coarse grained nepheline syenite pegmatite, containing sodalite, black mica, apatite, calcite.
O. Nepheline syenite, basic, contains much calcite chiefly as thin beds.
P. Rusty gneiss.
Q. Nepheline syenite with dark "schlieren". Contains much calcite.

which they are imbedded are absolutely free from all signs of pressure.

The banding and foliation of the nepheline syenite gradually passes over into the bedding and foliation of the limestones. Abundant development of black mica in the limestone at the immediate contact with the nepheline syenite is seen here as in many other places in the district where the contact of these two rocks can be examined. Thin beds of limestone and associated paragneisses and amphibolites included in the syenite are sometimes so filled with the minerals characteristic of the syenite that it is almost impossible in the field to determine whether they belong to the limestone series or to the invading magma. North from Bancroft on the Hastings road, exposures of nepheline syenite with some included bands of limestone are seen on the east side of the road.

One mile from the village the gneissic granite of the great northern batholith is reached, forming a great cliff known as the "Eagle's Nest". The granite-gneiss here is reddish and possesses a distinct foliation, striking almost at right angles to the road and dipping south, thus disappearing beneath the nepheline syenite border complex, which in its turn is overlaid by limestone. This gneissic granite is of medium grain with occasional coarsely crystalline segregations. Under the microscope it is seen to be composed of orthoclase, microcline, albite and quartz. Only a very small quantity of biotite is present. A ferriferous variety of sphene, magnetite and occasional small crystals of ziron complete the list of constituents. The rock shows marked evidence of pressure. This is especially seen in the quartz, which always displays strain shadows and is frequently granulated along certain lines.

It is a typical representative of the granite gneiss of the northern batholith of this area ("Fundamental Gneiss") except that here it is practically free from the dark amphibolite inclusions which are such a characteristic feature of the gneiss in almost every other part of the region.

About three miles (4·8 km.) north-east of Bancroft, the nepheline syenite is in certain places very rich in sodalite, this mineral being especially abundant in very coarse-grained pegmatite segregations which usually occur interbanded with the normal type of nepheline syenite. The colour of the sodalite varies from a very dark cobalt blue to a much paler tint, but fades somewhat on exposure to the weather. The mineral is susceptible of a high polish and is eminently suitable for interior decorative work. The prsence of irregular veins of bright red natrolite (spreustein) with clear colourless orthoclase serves to increase its ornamental value. The occurrence of sodalite found on lot 25, con. XIV of the Township of Dungannon, has been quarried in an opening 250 feet (76·2 m.) long and from 40 to 50 feet (12 to 15 m.) in width. A shipment of 130 tons of sodalite was made from this quarry (Princess Quarries) in 1906, some of the blocks secured weighing several tons. These were sawed into suitable slabs and used for the most part in the decoration of the residence of Sir Ernest Cassell in Park Lane, Hyde Park, London.

ANNOTATED GUIDE.—Continued.

Miles and Kilometres.

318·77 m. 513 km. **Bancroft.**—Alt. 1073 ft. (327 m.)—The excursion follows the Central Ontario railway over a comparatively level sand and gravel flat, showing very plainly the devastations of an old forest fire, and then passes on to the line of the Irondale, Bancroft & Ottawa railway, also operated by the Canadian Northern railway, to York River Junction.

321·57 m. 518·5 km. **York River Junction.** Alt., 1,108 ft.(337·7 m.). Beyond this station the same level land continues, but rounded hills, often with precipitous slopes, composed of the granite gneiss of the Laurentian batholith, are seen at no great distance from the railway. A stretch of "drowned land," caused by the damming of York river, is then passed. The railway then crosses a portion of the granite batholith and reaches a comparatively narrow selvage of the limestone series in the vicinity of Baptiste lake, which is again flanked to the north by more granite belonging to the same intrusion.

327·57 m. 528·1 km. **Baptiste Lake.** Alt., 1,215 ft. (370·3 m.)—For about one and a half miles (2·4 km.) west of this station, the railway follows very closely the line of junction between the Grenville series and the granite batholith to the south. The various cuttings show very typical sections of the crystalline limestones and interstratified, rusty-weathering paragneisses. The beds are twisted and contorted often into most fantastic shapes, at the same time being intruded by granitic apophyses, evidently emanating from the batholith, which occurs in close proximity. The limestone is usually very impure, owing mainly to the development in it of various silicates. In many places typical autoclastic structure has been developed by the dislocation of the more brittle gneissic bands, the separated fragments having been carried away from one another in the flowing limestone, which accommodated itself much more readily to the processes of stretching and compression. The series becomes more "granitized" on going toward the west, and, as a consequence, the limestone is in part replaced by a characteristic pale greenish pyroxene-gneiss. There are also coarsely crystalline pegmatite veins composed of red or pink feldspar, black mica and calcite.

333·27 m. **Highland Grove** (formerly Deer Lake sta-
536·3 km. tion). Alt., 1,233 ft. (375·8 m.). .

337·57 m. **Mumford.** Alt., 1,259 ft. (383·7 m.)—A
543·2 km. nepheline-bearing rock, which has been exposed in the railway cutting immediately west of the saw-mill at Mumford, forms part of a narow band which here lies on the contact of an almost pure white crystalline limestone with the granite of the Cardiff batholith. The limestone underlies the wooded area to the north of the railway, while the contact of the nepheline rock with the granite to the south is concealed by drift. A large included mass of this limestone, however, occurs by the side of the railway to the west of the nepheline rock to which reference has just been made. This nepheline-bearing rock shows a rapid and marked differentiation from place to place. One variety is composed almost entirely of salic constituents (chiefly nepheline), while the dark coloured phases consist almost entirely of the ferromagnesian minerals. A

thin section of one of these darker coloured varieties shows the rock to be a hornblende ijolite composed essentially of nepheline and a deep green hornblende. Oligoclase and sphene are very subordinate accessory constituents. In addition to these constituents, a considerable amount of calcite in large allotriomorphic individuals is also present, which is identical in character and mode of occurrence with that so commonly found in the nepheline rocks of this region. This calcite is especially abundant in a large exposure of the rock 25 paces west of the siding to the saw mill already mentioned. Another variety has a pseudoporphyritic structure, due to the development of larger, somewhat irregularly shaped individuals of nepheline through a fine-grained, almost black matrix, composed of deep green pyroxene and brown garnet. A little microperthite and calcite occur as accessory constituents, the latter mineral occurring as already described.

The New York Graphite Co. are reported to be erecting a mill about a mile from Mumford to treat the graphite secured from what is said to be a large and rich deposit of this mineral occurring in association with hornblende and pyroxene gneisses. In a cutting for the railway near the west end of Cardiff lake, the limestone of the Grenville series is again exposed, holding at this place both graphite and chondrodite. Further west, near the east end of Dark lake, the rock is cut by veins composed of orthoclase, biotite, calcite, etc., which were formerly worked for mica.

342·37 m. **Wilberforce.** Alt., 1,194 ft. (363·9 m.).—
551 km. Graphite occurs in many places in the Grenville limestone which underlies this district, and a large mill for the separation of this mineral has been erected here by the Virginia Graphite Co. There is an outcrop of highly graphitic limestone adjacent to the mill. This limestone contains, in addition to the graphite, a small amount of colourless pyroxene, microcline and sphene. The graphite-bearing rock—a graphitic

and micaceous limestone—treated by the mill is, however, brought from near Maynooth.

344·57 m. 554·7 km. **Monmouth Road.** Alt., 1,181 ft. (360 m.).

347·87 m. 560 km. **Toryhill.** Alt., 1,147 ft. (349·6 m.).

## The Nepheline Syenite-Granite Intrusion in the Central Part of the Township of Monmouth.

In the vicinity of Tory-hill there is a large and very interesting occurrence of nepheline syenite, which is found as a border or marginal phase of a body of pegmatitic granite running through the centre of the Township of Monmouth in a direction about N. 30° E. for about six miles (9·6 m.). This granite mass has a maximum width of a little over one mile. The border of nepheline-syenite is from one-eighth to half-a-mile (200 to 800 m.) in width. The whole occurs as an intrusion into the white crystalline limestones of the Grenville series.

The granite is pink or red in colour and is usually of medium grain. It frequently shows the rapid variation in size of grain common in pegmatite. At the north-eastern end of the mass it is distinctly foliated. Further to the south this foliation becomes less distinct, but the rock presents a streaked appearance.

The feldspars present are albite, microperthite, orthoclase and microcline, the two first mentioned minerals predominating. The ferromagnesian constituents are present only in very small amount and consist of biotite and two varieties of hornblende.

The granite is nowhere rich in quartz, although in the north-eastern part of the mass this mineral is present in considerable amount. To the south-east this mineral decreases in amount and the rock assumes a syenitic facies.

This syenite is red in colour and is composed almost exclusively of feldspar, which is for the most part microperthite, the iron-magnesia constituents occurring in occasional dashes with rudely parallel arrangement. It differs from the granite not only in the fact that no quartz is visible in the thin sections but also in that hornblende is absent. In the quantitative classification the rock is a phlegrose.

An analysis of the rock is given on page 96.

This syenite passes imperceptibly into the nepheline syenite on either side by an increase of soda feldspar. The transition is also well seen on the southern end of lot 15 of concession VIII of the Township of Monmouth at the corners near Hotspur post office. The nepheline syenite here has a schlieren structure caused by a variation in the relative amount of constituent minerals in the different streaks. Some of these schlieren consist of red syenite, others are intermediate in composition between red syenite and the nepheline syenite. There are thus represented in these schlieren a complete transition from the red syenite to the white or grey nepheline syenite.

The nepheline syenite which forms the border of the mass has a distinctly foliated structure and is coarse in grain. It is white to dark grey in colour according to the proportion of the ferromagnesian constituents which it contains. It usually possesses a rudely banded or schlieren structure which conforms in direction to the foliation of the rock, which in its turn conforms to the outline of the intrusion, that is to say, the foliation of the nepheline syenite strikes around the mass as does also the intruded limestone.

In the nepheline syenite some of the schlieren are rich in nepheline, while in adjacent schlieren nepheline is present only in small amount. A similar variation is to be observed in the case of the dark constituents of the rock. The party will examine this occurrence along two of the roads which cross it.

Leaving Tory hill the road running in an easterly direction will first be taken and followed for one mile. Along this road the white crystalline limestones are first seen in large exposures and are succeeded on lot 21 of range XI of the Township of Monmouth by large exposures of the nepheline syenite showing the usual schlieren structure and foliation, which in most places is rich in nepheline and coarse in grain.

The party will then return to the train which will proceed as far as McCue's crossing, and leaving the train will walk south to the corners near Hotspur post office, where they will take the road running in a westerly direction to Hadley, where they will meet the train again. This represents a distance of five miles (8 km.)

The road going south from McCue's crossing first crosses drift with a few exposures of the white crystalline limestone protruding through it.

This is succeeded by the nepheline syenite, the actual contact of the rock with the limestone being obscured by drift. About the middle of the nepheline syenite belt, the road passes over an included body of limestone.

A variety of nepheline syenite rich in albite and poor in nepheline is exposed in the low cliffs on the east side of the road one mile north of Hotspur Corners on lot 16, range IX of Monmouth.

Under the microscope it is seen to possess a hypidiomorphic structure and to consist of the following minerals: Albite, microcline, microperthite, nepheline, lepidomelane, magnetite and calcite. In some few schlieren a dark green hornblende (probably hastingsite) replaces a portion of the biotite. Albite and lepidomelane are the chief constituents. The albite is well twinned and must be a variety approaching the pure soda molecule, as it has a specific gravity of 2·618 and shows a maximum extinction against the line of the twinning lamellae of 15°. In a single slide a few grains having an extinction as high as 20° were observed, showing that a plagioclase somewhat more basic than albite is also occasionally present in very small amount. The microcline presents its usual characters and is frequently intergrown with albite, forming microperthite. The nepheline is in large individuals similar in shape and dimensions to those of the albite. Smaller individuals of it are sometimes included in the albite, while in other cases it includes individuals of albite. It is very fresh and free from alteration products. The lepidomelane is the same dark brown, highly pleochroic variety of biotite which occurs in the transitional rock lying between the granite and the nepheline syenite and has the same form of short laths. A lighter coloured mica is also present in smaller amount. The calcite occurs in large single individuals, often rounded, sometimes enclosed in the feldspars, nepheline or lepidomelane, but usually lying between the other constituents. The enclosing minerals show no signs of alteration and the calcite shows no sign of secondary origin. The magnetite is in large subangular or more or less rounded grains. There seems to be no definite order of succession in the crystallization, seeing that the various minerals enclose and penetrate one another. The lepidomelane, however, has a much better form than the other constituents and would thus seem to have crystallized earlier.

An analysis of the biotite-bearing variety is given on page 96. This nepheline syenite in the quantitative classification ranks as an essexose. It contains 3·45 per cent of calcite.

The road then passes further in toward the centre of the intrusion, affording excellent exposures of the red syenite described on page 55. Near Hotspur Corners the relation of the syenite and the nepheline on the western side of the mass will be seen.

Leaving this interesting intrusive mass, the road then continues in a westerly direction over limestone penetrated in one place by a small intrusion of granite to another intrusion of nepheline syenite and allied rocks, which is of interest.

### Nepheline syenite intrusion in the western part of the Township of Monmouth.

This occurs on lots 9, 10 and 11 of ranges VII and VIII of the Township of Monmouth. It is a lenticular mass approximately one mile (1·6 km.) long and 700 yards (640 m.) across at its greatest width and is formed of a body of nepheline-bearing rock presenting an example of extreme differentiation. As usual in this district, these rocks have a marked foliation and are developed as a series of schlieren rudely parallel to one another and conforming to the strike of the enclosing limestone. Some of the schlieren are highly feldspathic varieties of nepheline syenite, but others contain little or no feldspar. Others are composed almost exclusively of nepheline, while still others consist essentially of nepheline and ferromagnesian constituents.

The following three varieties have been carefully studied:

(1) *Nepheline syenite* (*1st variety*).

This variety is coarse in grain, dark in colour and rich in hornblende. Under the microscope it is seen to consist of nepheline, albite, hornblende and calcite, with a small amount of apatite as an accessory constituent. These minerals, with the exception of the apatite, are all in large individuals, and like most of the nepheline syenites of this area, have a peculiar structure which approaches an allotriomorphic structure in character. None of the minerals have good crystalline forms, but all have a tend ency to occur with more or less rounded outlines and to come against one another in curved lines. Inclusions of one mineral in another are common, no definite order of succession can be observed in the crystallization, and the structure in some respects approaches the "mosaic" structure seen in the metamorphic rocks when a complete recrystallization has taken place.

The nepheline is considerably altered to a very fine-grained turbid aggregate resembling kaolin, but in places it is quite fresh and shows its usual optical properties. It frequently holds rounded inclusions of albite and of calcite. The albite is well twinned and possesses the usual characters. The hornblende is the most abundant constituent, and, if not hastingsite, is a variety closely resembling it. It is deep green in colour and looks black on the fractured surface of the rock. Although the rock is so basic, it contains no iron ore, which is elsewhere common as an accessory constituent in such rocks. The calcite, as usual, occurs as rounded inclusions in the albite, nepheline or hornblende, or filling spaces between the grains of these minerals. No microcline nor microperthite is present in the sections.

An analysis of the variety is given on p. 96. Under the quantitative classification it ranks as essexose. Its "mode" or mineralogical composition as calculated from the analysis is as follows:—

| | | Per Cent. |
|---|---|---|
| Orthoclase | | 2·78 |
| Albite | 22·27 | 23·94 |
| Anorthite | 1·67 | |
| Nepheline | 15·91 | 26·23 |
| Kaolin | 10·32 | |
| Hornblende | | 39·75 |
| Apatite | | ·34 |
| Calcite | | 5·50 |
| | | 98·54 |
| Water | | 1·10 |
| | | 99·64 |

(2) *Nepheline syenite (2nd variety).*

This is rich in nepheline and contains a large percentage of pyroxene. It is much lighter in colour, but otherwise bears a general resemblance to the variety just described. Under the microscope all the constituents are seen to be fresh, but they frequently show signs of having been submitted to pressure, as shown by the presence of a more or less uneven extinction. This is especially marked in the case of the calcite, and the albite can in some few instances be seen to have been not only bent but actually fractured. The nepheline also occasionally shows strain shadows. As before, no microcline nor microperthite is present in the sections and a Thoulet separation shows that the rock contains no potash feldspar. The albite has a specific gravity of very nearly 2·61.

The pyroxene is very deep green in colour and slightly pleochroic. Around the individuals of this mineral and occasionally about the calcite grains, there is sometimes a narrow border of garnet. The pyroxene is evidently very rich in iron and holds rounded inclusions of calcite and nepheline.

An analysis of the variety is given on p. 96. Under the quantitative classification it ranks as vulturose. Its "mode" or mineralogical composition as calculated from the analysis is as follows:—

| | |
|---|---|
| Albite.... | 19·39 |
| Nepheline.... | 50·57 |
| Pyroxene.... | 18·35 |
| Garnet.... | 1·45 |
| Iron ore.... | 1·86 |
| Apatite.... | ·34 |
| Calcite.... | 6·80 |
| | 98·76 |
| Water.... | ·88 |
| | 99·64 |

(3) *Monmouthite (3rd variety).*

This is the type locality for this rock which is allied to urtite, but differs from that rock in containing a relatively small amount of ferromagnesian constituents. It is a nearly pure nepheline rock. It is coarse in grain and has a rudely foliated structure. On the weathered surface there is a marked contrast between the nepheline, with its smooth grey surface from which the accessory albite present stands out in chalk-white grains, and the black hornblende.

Under the microscope the rock is seen to consist of nepheline and hornblende, with albite, cancrinite and calcite as accessory constituents, as well as sodalite, apatite, sphene, biotite, pyrite and iron ore, these latter mainly being present in extremely small amounts. The rock is very fresh. The hornblende is a variety allied to hastingsite. The calcite occurs in large individuals which are found as inclusions in the nepheline and hornblende. The individuals are often circular in outline and the enclosing mineral is fresh and sharply defined against them. In other cases the calcite grains lie between the other constituents of the rock, but in all cases have the character of inclusions. They generally show marked strain shadows, while the other constituents of the rock show little or no evidence of pressure phenomena.

An analysis of the rock is given on p. 96.

The "mode" or percentage mineralogical composition of the rock calculated from the analysis is as follows:—

| | |
|---|---|
| Albite | 1·83 |
| Nepheline | 72·20 |
| Sodalite | ·28 |
| Cancrinite | 5·14 |
| Hornblende | 15·09 |
| Hematite | ·50 |
| Calcite | 3·12 |
| Pyrite | ·14 |
| | 98·30 |
| Water | ·50 |
| Excess of Alumina | 1·20 |
| | 100·00 |

The rock when described represented a new rang and sub-rang in the quantitative classification.

Monmouthite, lot 11, Con. VIII. Monmouth township. Nepheline (grey) with subordinate albite (white) and hastingsite (black).

In addition to these relatively fine-grained varieties, there are several fine exposures of nepheline syenite pegmatites holding calcite.

ANNOTATED GUIDE—continued.

Leaving this occurrence of nepheline rocks, the party will continue westward to Hadley, visiting en route a quarry in a fine-grained microcline granite on the line between lots 7 and 8, Cons. VII and VIII of the Township of Monmouth, from which paving sets are being taken.

351·97 m. **Hadley,** Alt. 1,120 ft. (341·4 m.)—The party
566·4 km. will again entrain at this railway crossing. Following Burnt river, there are only a few exposures before reaching Gooderham.

355·57 m. **Gooderham,** Alt. 1,023 ft. (342·3 m.)—The
573·8 km. railroad first crosses the Grenville limestone with an intrusion of nepheline syenite and then runs close to the contact of the limestone series with the Glamorgan granite batholith to Maxwell's Crossing.

361·27 m. **Maxwell's Crossing.** Alt. 1,023 ft. (342·3 m)
581·4 km.—In the rock cuttings on the railway at this place, certain characteristic contact phenomena of the intrusion of the Grenville limestones by the Glamorgan granite batholith are well seen.

CONTACT PHENOMENA IN THE VICINITY OF MAXWELL'S CROSSING.

The limestones are part of the south-western extension of the great belt which underlies the north-west corner of Monmouth and the eastern part of Glamorgan townships. The granite belongs to a great batholith which extends northward and westward into Dysart and Snowdon townships. The invading granite, in the form of apophyses, wanders through the limestone series in all directions, sometimes cutting across the bedding, but very frequently in the form of narrow dykes forcing its way between the beds of the invaded limestone, changing it into amphibolite and presenting a typical instance of *lit-par-lit* injection. The granite, furthermore, not only penetrates the series, but floats off masses of the altered rock which, in the form of bands, streaks, and isolated shreds are seen thickly scattered through the granite in the vicinity of the contact, and which, while less abundant, are found throughout practically the whole extent of this batholith. The separate fragments of amphibolite, where completely surrounded by the granite, while clearly nothing more than masses of altered limestone, are rather harder and more "granitized" in appearance than the amphibolite which is still interstratified with the limestone, and the fragments sometimes have somewhat flowing outlines as if they had been subjected to a certain amount of movement when in a softened condition.

When examined in thin sections under the microscope the limestone which is in the act of passing into amphibolite is seen to do so by the development in it of certain silicates. These, when the change is complete, are so abundant that they entirely replace the calcite, while in the intervening stages some of the original calcite still remains. These silicates belong to the following species: pyroxene, hornblende, sphene, scapolite, plagioclase, microcline, orthoclase, and quartz. The relative abundance of these minerals varies in different bands and from place to place in the rock. Their characters are as follows:

The *pyroxene* is rather deep green in colour and non-pleochroic. It is one of the chief constituents, being present in large amount in the earlier stages of the change. It first appears in rounded individuals which possess neither crystallographic outlines nor any approximation to crystalline form. In those varieties rich in calcite, the sections of the pyroxene grains are frequently nearly circular.

The *hornblende*, which at first is much less abundant than the pyroxene, is also green in colour, but it is a much deeper green than the pyroxene. The grains are similar to those of the pyroxene in form, but are usually less rounded. It is intimately associated with the pyroxene, often forming adjacent grains, but there is no conclusive evidence that one mineral is derived from the other. It is strongly pleochroic.

The *sphene* is present only in very small amount in the form of small rounded grains of brown colour.

*Scapolite* is usually present in considerable amount. It polarizes in brilliant colours, is uniaxial and negative, and shows the other microscopical characters of this mineral.

The *feldspars* vary greatly in amount. In places they form a considerable part of the rock, while no scapolite is present. In other places the scapolite seems to take their place and they are reduced to the rank of accessory constituents. All three varieties of feldspar mentioned often occur in the same specimen, their relative abundance varying from slide to slide. The polysynthetically twinned plagioclase in some cases equals the potash feldspar in amount, but usually the potash feldspars seem to be rather more abundant.

*Quartz* is found only in a few of the thin sections and is then present only in very small amount.

When *calcite* survives, it can be seen that the original rock had the character of a coarsely crystalline limestone or marble. Under the action of the metamorphic processes the silicates have grown into it in the form of rounded grains which, increasing gradually in size, have finally left the calcite merely as a filling of the surviving interstitial spaces. The grains are about the same size as those of the other minerals.

An examination of thin sections of a suite of specimens of this amphibolite—some of them still containing little surviving bands of calcite and others of the harder and more altered varieties—shows that pyroxene and scapolite accompany the hornblende and feldspars in the former, while as the alteration becomes more pronounced these former minerals become less abundant and eventually disappear, giving rise to a rock composed of hornblende and feldspar, associated with which a little biotite is seen in some specimens and with certain accessory minerals common to both rocks. Although, as above mentioned, no actual passage of pyroxene into hornblende could be definitely observed, the hornblende individuals often have a minutely serrated edge where they come against the pyroxene, as if they were gradually enlarging themselves at the expense of the latter mineral and thus replacing it.

The amphibolite, representing the final product of the alteration, while possessing a more or less distinct foliation, has the "pflaster", "pavement", or mosaic structure characteristic of rocks which have resulted from recrystallization brought about by metamorphic processes. It presents no evidence of crushing or of having been caused to move since its recrystallization took place. This structure is quite distinct and different from that seen in the little injected bands of granite. In these, which are composed of quartz, microcline, orthoclase and plagioclase, the quartz occurs for the most part in thin leaves with undulatory extinction and the structure of the rock is suggestive of the "mortel" or granulated structure seen in the granite gneisses.

In this remarkable occurrence, therefore, the crystalline limestone can be seen under the influence of the granite intrusion to have changed into a typical hornblende-feld spar amphibolite, having passed through the intervening stage of a pyroxene-scapolite-hornblende-feldspar amphibolite (pyroxene-scapolite gneiss).

Three specimens of these amphibolitic rocks from Maxwell's Crossing, chosen to represent three steps in the progressive change from limestone to amphibolite, have been analysed by M. F. Connor, of the Department of Mines. The figures given are in every case the mean of two determinations which agree closely with one another. The results of these analyses are as follows:—

| | No. 1. | | No. 2. | No. 3. |
|---|---|---|---|---|
| | (a) | (b) | | |
| $SiO_2$ | 32·88 | 50·20 | 50·00 | 50·83 |
| $TiO_2$ | 0·49 | 0·75 | 0·82 | 1·10 |
| $Al_2O_3$ | 9·04 | 13·80 | 18·84 | 18·64 |
| $Fe_2O_3$ | 0·77 | 1·18 | 2·57 | 2·84 |
| FeO | 3·48 | 5·31 | 5·51 | 5·97 |
| MnO | .......... | .......... | 0·08 | 0·10 |
| CaO | 30·90 | 17·71 | 10·65 | 7·50 |
| MgO | 4·18 | 6·38 | 4·63 | 4·90 |
| $K_2O$ | 0·85 | 1·30 | 1·18 | 1·83 |
| $Na_2O$ | 1·17 | 1·79 | 4·46 | 4·22 |
| $CO_2$ | 15·20 | .......... | 0·10 | 0·11 |
| Cl | undet. | .......... | 0·10 | 0·03 |
| S | undet. | .......... | 0·03 | 0·01 |
| $H_2O$ | 1·08 | 1·66 | 1·00 | 1·40 |
| | 100·04 | 100·08 | 99·97 | 99·48 |

No. 1 represents the first stage of alteration, and was made from a specimen which shows an alteration of narrow, lighter and darker coloured bands. The specimen was broken across the strike of the rock and thus included several of each of these bands, giving in this way an approximate average of the composition of the rock as a whole. Under the microscope the lighter coloured bands are seen to consist of calcite, pyroxene and a little hornblende. In the darker bands the calcite is largely replaced by the silicates, the constituent minerals of these bands being scapolite, pyroxene, some hornblende, some calcite, and a little microcline. A very small amount of sphene is also present in the rock.

The analysis as given under No. 1 (a) represents the composition of the specimen as collected; that given under No. 1 (b) represents the composition of the rock as it appears when the calcite present (determined by calculation from the amount of $CO_2$ present and also by direct experiment) is deducted and the amount of the remaining constituents is recalculated on the basis of 100. No. 1 (b) therefore represents the percentage composition of the silicated portion of the specimen, or, to put it in another way, it represents, except in the case of the lime, the additions made to the limestone by the granite magma in this first stage of alteration. The specimen contains 34·50 per cent. of calcite, leaving 65·50 per cent. of silicates. This silicated portion of the rock, as will be seen by comparing analysis No. 1 (b) with Nos. 2 and 3, bears a general resemblance in composition to the two latter rocks, which represent the subsequent stages of alteration, the percentage of silica being practically identical in all cases.

No. 2 is the analysis of a typical specimen of the amphibolite which alternates with thin bands of the limestone at Maxwell's Crossing. It represents a second stage in the alteration, this particular specimen being practically free from calcite. Under the microscope it is seen to be composed of hornblende and pyroxene, more or less completely replacing each other in the alternate bands, together with a considerable amount of scapolite, plagioclase and untwinned feldspar. The rock also contains many minute rounded grains of sphene scattered everywhere through it, but holds no iron ore and no biotite.

No. 3 is the analysis of a harder variety, a typical amphibolite representing the last stage of the change. It occurs as an inclusion in the granite in the same series of exposures as that from which the other specimens were taken. The field relations show that it has been derived from variety No. 2 by further alteration. Although not differing much from No. 2 in chemical composition, under the microscope it is seen to differ considerably from it in structure, the individuals of the several constituents showing a less marked tendency to a rounded outline than in the case of No. 2. In mineralogical composition also it presents certain differences, the pyroxene and scapolite having disappeared and a certain amount of biotite having been developed.

A comparison of the analyses shows that the granite at first transfuses into the limestone, silica, alumina, oxides of iron and magnesia, with some alkalies and a small amount of titanic acid. As the alteration progresses, all these constituents continue to increase in amount. But in these later stages of the alteration the alumina, oxides of iron, and alkalies are added in relatively greater proportion than the other constituents, while no further addition of magnesia or lime takes place, the proportion of these constituents remaining essentially the same, the carbonic acid escaping and carrying the rest of the lime with it.

This means, speaking generally, that pyroxene and some scapolite were first developed in the limestone and that later the feldspathic constituents increased in amount, the calcite present being removed in solution.

A calculation of the analysis shows that Nos. 1 (b) and 2 have the following mineralogical composition:

| — | No. 1 (b) | No. 2. |
|---|---|---|
| Feldspathic constituents | 48·57 | 67·35 |
| Pyroxenic (iron magnesia) constituents | 46·63 | 26·28 |
| Iron ores | 3·2 | 5·27 |
| | 98·40 | 98·90 |
| Water | 1·66 | 1·00 |
| | 100·06 | 99·90 |

During the change of No. 1 into No. 2 and this into No. 3, the information afforded by the analyses bears out that obtained from the study of the thin sections, showing that there has been a very considerable rearrangement among the constituents of the rock. Thus it is seen that while the alumina and alkalies increase in No. 2 and No.3 there is not a corresponding increase in the total amount of silica; the silica required to make additional feldspathic constituents is derived from some other reactions going forward in the rock.

It seems also that after the development of a certain percentage of silicates in the limestone, as shown in No. 1, during which process carbonic acid was expelled and the lime combined with it used in the production of new minerals, no further lime was fixed. In the earlier stages the waters given off by the granite having accomplished the transference of material in the limestone, passed off with the replaced $CO_2$ in solution, leaving the lime behind. In the later stages of the alteration, however, these waters while continuing to deposit silicates in the limestone, made place for them by carrying off carbonate of lime in solution.

As will be seen, the difference in chemical composition between Specimen 2 and Specimen 3 is very small. The more highly altered rock, No. 3, is rather richer in iron, magnesia, and alkalies, while it is considerably poorer in lime and contains less chlorine. These difference are seen to represent a slight increase in the proportion of hornblende and orthoclase present and a decrease in the amount of plagioclase and scapolite in the rock.

If, for the purpose of comparing the composition of these alteration products with that of igneous rocks, the norms are calculated, these are found to be as follows. Since No. 3 is essentially the same as No. 2, the norm of the latter rock may be taken to represent both specimens and with it is given the norm of the silicated portion of No. 1 (No. 1 (b)).

| — | No. 2. | No. 1 (b) |
|---|---|---|
| Orthoclase | 7·23 | 7·74 |
| Albite | 26·20 | 15·24 |
| Anorthite | 27·94 | 25·59 |
| Nepheline | 5·56 | .......... |
| Sodalite | 0·42 | .......... |
| Diopside | 19·78 | 34·81 |
| Akermanite | .......... | 6·97 |
| Olivine | 6·30 | 4·85 |
| Calcite | 0·20 | .......... |
| Ilmenite | 1·52 | 1·40 |
| Magnetite | 3·71 | 1·80 |
| Pyrite | 0·04 | .......... |
| | 98·90 | 98·40 |
| Water | 1·00 | 1·66 |
| | 99·90 | 100·06 |

In the quantitative classification the rocks, therefore, have the following position:—

| No. 2. | | No. 1 b. | |
|---|---|---|---|
| Class II | Dosalane | Class III | Salfemane |
| Order 5 | Germanare | Order 5 | Gallare |
| Rang 3 | Andase | Rang 4 | Auvergnase |
| Subrang 4 | Andose | Subrang 4 | Auvergnose |

While, therefore, the quantitative classification is intended to apply only to igneous rocks, this final product of the metamorphism of the limestone when compared with igneous rocks readily takes its place as an andose, a group which includes many rocks which are commonly known as diorites, gabbros, basalts, diabases and essexites.

For purposes of comparison the analysis of this amphibolite (No. 2) is here repeated together with that of an amphibolite (No. 5) produced by the alteration of a basic igneous intrusion (probably a diabase originally) and with the analyses of three other typical igneous rocks which have been produced by the solidification of molten magmas.

| — | No. 4. | No. 5. | No. 6. | No. 7. | No. 8. |
|---|---|---|---|---|---|
| $SiO_2$...... | 50·00 | 48·81 | 50·86 | 50·73 | 48·85 |
| $TiO_2$...... | 0·82 | 0·74 | .......... | 1·59 | 2·47 |
| $Al_2O_3$..... | 18·84 | 16·62 | 15·72 | 19·99 | 19·38 |
| $Fe_2O_3$..... | 2·57 | 1·17 | 9·77 | 3·20 | 4·29 |
| FeO...... | 5·51 | 7·47 | 2·48 | 4·66 | 4·94 |
| MnO..... | 0·08 | 0·12 | .......... | 0·05 | 0·19 |
| CaO...... | 10·65 | 10·30 | 10·52 | 8·55 | 7·98 |
| MgO...... | 4·63 | 8·28 | 3·55 | 3·48 | 2·00 |
| $K_2O$...... | 1·18 | 0·76 | 0·90 | 1·89 | 1·91 |
| $Na_2O$..... | 4·46 | 3·31 | 3·89 | 4·03 | 5·44 |
| $CO_2$...... | 0·10 | 0·55 | .......... | .......... | .......... |
| Cl........ | 0·10 | 0·03 | .......... | .......... | not det. |
| S......... | 0·03 | 0·06 | .......... | .......... | .......... |
| $P_2O_5$...... | .......... | .......... | .......... | 0·81 | 1·23 |
| $H_2O$...... | 1·00 | 0·95 | 2·53 | 0·77 | 0·68 |
| | 99·97 | 99·17 | 100·22 | 100·13* | 99·36 |

*Including BaO 0·27.

No. 4. Amphibolite resulting from the alteration of limestone—Maxwell's Crossing, Lot 5, Range VI, Township of Glamorgan, Ontario.

No. 5. Dyke cutting limestone—Lot 27, Range VIII, Township of Methuen, Ontario.

No. 6. Gabbro, near Baptism river, Minnesota, U.S.A. (Wadsworth, Geol. Survey of Minn., 2 p. 79, 1887).

No. 7. Diorite—Big Timber creek, Crazy mountain, Montana (Wolff, Bull. U.S.G.S., 148, p. 144, 1897).

No. 8. Normal essexite—Mount Johnson, Quebec (Adams, Jour. of Geol., April-May, 1903.)

In connection with this alteration of limestone to amphibolite it is to be noted that the change is not one of solution or digestion of the limestone by the granite, for the fragments preserve their sharp and well-defined forms even when the alteration is complete.

The limestone, at a distance from the granite, is a white crystalline marble, containing scarcely any impurities and effervescing freely in fragments with cold dilute hydrochloric acid, showing that it is an essentially pure carbonate of lime.

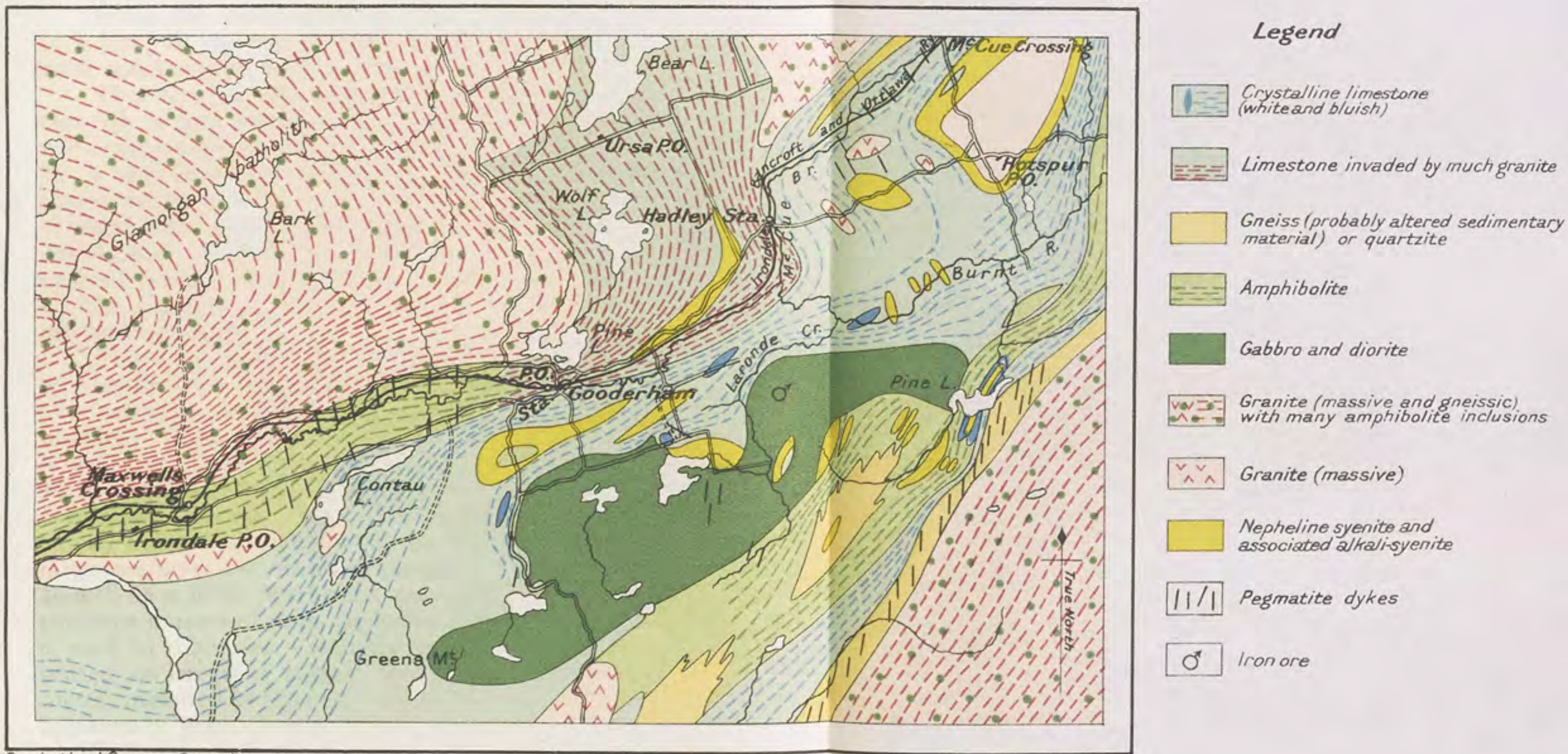
The changes are the result of the transfusion into the limestone of certain constituents which are present in the granite magma. A remarkable fact in connection with the alteration, is that the granite, which is an acid variety of the rock containing a very small amount of biotite as its only bisilicate, where the limestone was bathed by it or

Amphibolite resulting from alteration of limestone, cut by pegmatite. Eastern border of Glamorgan batholith near Bear lake.

actually immersed in it as in the case of the included fragments, has notwithstanding this fact transfused into the limestone not only silica, alumina and alkalis, as might be expected, but also large amounts of magnesia and iron. The limestone evidently fixed certain constituents of the granite magma in relatively greater abundance than others, exerting a species of selective action.

In the cutting just west of Maxwell's Crossing there is an exposure of a coarse pegmatite rather rich in ferromagnesian constituents, holding an inclusion of limestone

A2.




Geological Survey, Canada

**Gooderham and Vicinity**

Miles
1 0 5

Kilometres
1 0 5

into which the constitutens of the pegmatite have grown with well defined crystal faces.

## Geology in the Vicinity of Gooderham.

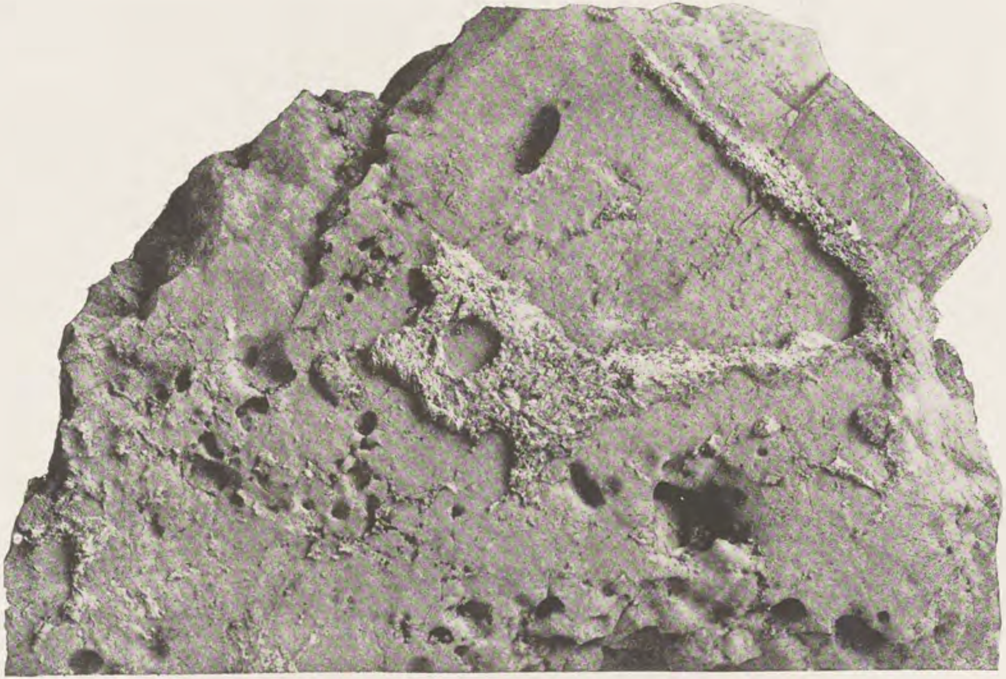
From the road crossing about one and a half miles (2·4 km.) to the east of Gooderham station, the party will walk southward for two and a half miles (4 km.)

This road in the first half mile crosses a sand plain through which Burnt river meanders. Then the party will cross lot 30 of Con. V. of the Township of Glamorgan by a trail leading southwards, passing over crystalline limestone to a large occurrence of an albite-rich variety of nepheline syenite containing a hornblende allied to hastingsite. This rock is distinctly foliated, of medium grained texture, with schlieren of coarse grained nepheline syenite pegmatite. The micaceous constituent is biotite, not lepidomelane.

This is succeeded by crystalline limestone penetrated by masses of a remarkable nepheline syenite pegmatite. One exposure on lot 30, Con. IV, has been opened up by blasting. The rock, as shown in the accompanying illustration, consists essentially of nepheline and albite, with occasional individuals or small masses of coarsely-crystalline calcite. The iron-magnesia constituents—chiefly biotite—are present in very small amount, and over large surfaces are entirely absent. A black hornblende, as well as a little pyrrhotite, may also be seen. The rock contains masses of pure nepheline which in places measure a yard in diameter. Sodalite is also occasionally represented as irregular masses sometimes two inches in diameter, included in the large masses of nepheline and having apparently been derived from them by secondary action.

The party will then go to a point by the roadside on lot 29 of Con. III, where a good view over the district to the north can be obtained, and whence, on a clear day, the character of the peneplain can be seen (see p. 11.)

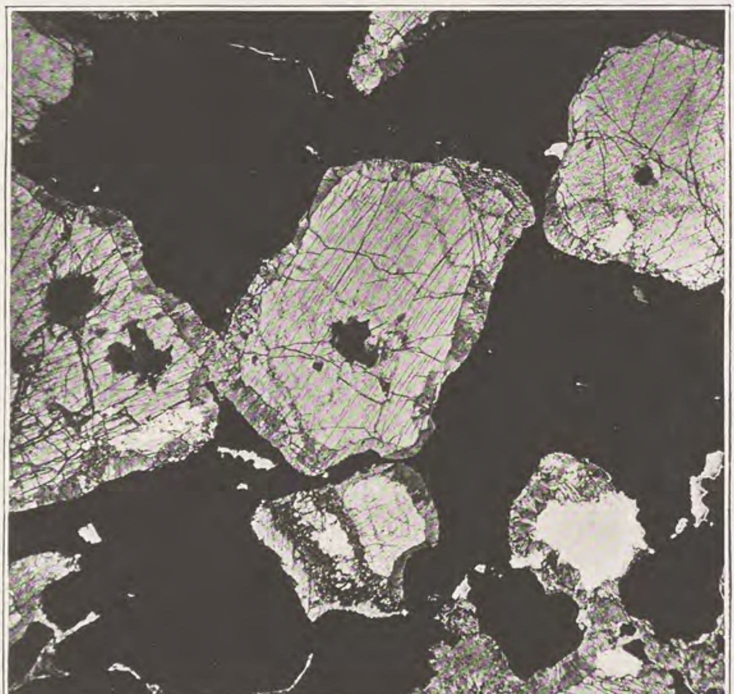
The country rock at this point shows one phase of the gabbro of a great intrusion which underlies a large area of the country to the south. This intrusion has a length of eight miles (12·9 km.) and a maximum width of two and a half miles (4. km.). The gabbro composing it shows a very marked variation in composition from place to place, ranging in character from a rock in which plagioclase pre--



Nepheline syenite pegmatite, showing characteristic weathering, from lot 30, Con. IV. Glamorgan. Nepheline with albite (standing out on weathered surface). The cavities in the surface of the nepheline are caused by the weathering out of calcite.

ponderates largely through increasingly basic varieties to a pyroxenite and an iron ore. No regular order is observable in the distribution of these varieties.

The party will not have time to visit the occurrences of iron ore in question, but some large blocks of it have been brought out to the main road and from an examination



Pusey's iron ore. Glamorgan, lot 35 of con. IV (X 19 diam.) Pyroxene individuals enclosed in iron ore. About each pyroxene there is a narrow border of hornblende.

of these its character may be seen. It is a titaniferous iron ore, containing a small percentage of vanadium, as shown by the following analysis:—

| | |
|---|---|
| $Fe_2O_3$ | 39·27 |
| FeO | 21·73 |
| MnO | ·37 |
| $Ni_8O$ | ·27 |
| CoO | ·07 |
| $Al_2O_3$ | 4·61 |
| $SiO_2$ | 10·77 |
| $P_2O_5$ | ·02 |
| S | ·11 |
| $TiO_2$ | 13·52 |
| $V_2O_5$ | ·52 |
| MgO | 2·34 |
| BaO | ·07 |
| CaO | 4·84 |
| $Na_2O$ | ·31 |
| $K_2O$ | ·24 |
| Moisture | ·44 |
| Total | 99·50 |

Under the microscope this ore is seen to consist essentially of titaniferous magnetite and pyroxene. The pyroxene individuals are enclosed in the titaniferous magnetite, but about each individual of pyroxene there is a narrow border of brown and usually highly pleochroic hornblende. The structure is well shown in the accompanying microphotograph.

The party will then visit an interesting occurrence of nepheline syenite which appears on lot 32 of Con. III, Glamorgan township. This nepheline syenite, which is exposed on the road, is very fresh and represents a variety which is very distinctly foliated and dark in colour. Nepheline and hornblende preponderate largely in the rock, the feldspar being subordinate in amount. The hornblende has the optical properties of hastingsite and the feldspar is albite. The rock also contains some grains of calcite, rounded in form and occurring as inclusions in the other constituents of the rock. They are clearly not of secondary origin but are similar in character to those found in the nepheline syenites in other parts of the area as already described (see pp. 58-62).

An anlaysis of the rock by M. F. Connor of the Department of Mines is given on page 96).

Miles and Kilometres.

**Bancroft**. From Bancroft the party will drive to Bronson's Landing on York river.
403·7 m. The region traversed is underlaid almost wholly
649·6 km. by nepheline and associated alkali syenites

Nepheline syenite from lot 32, Con. VI, Glamorgan township, showing biotite, nepheline and microcline, with two included grains of calcite.

with some included masses of crystalline limestone. The original hastingsite was found in the nepheline syenite near this road about 2 miles (3·2 km.) from Bancroft. The latter part of this journey, after leaving the main road (about 5·5 miles (8·8 km.) from Bancroft), is through the old Egan or Bronson farm, an old lumber depot and farm owned by the lumbering firms whose names it has borne. It is now known as the Lancaster farm, from the name of its present owner. A now deserted lumber road connects the farm buildings with the old camping ground on York river still known as Bronson's Landing.

410·37 m. 660·4 km. **Bronson's Landing.** At this place the party will embark in canoes for the trip down York river. York river or York branch of Madawaska river, as it is sometimes called, was formerly known as Shawashkong river. As the last mentioned name implies, it flows through extensive marshy flats, especially along its lower and upper reaches. It may here be mentioned that for the first ten or twelve miles below Bronson's Landing the stream flows through a region which still preserves the general character and aspect possessed by the primeval forest before the coming of the white men. The river was well known to the early inhabitants, and was much used by Indian hunting and war parties. Most, if not all, the pine trees have been removed by the lumberman, but the river banks are thickly wooded to the water's edge, principally by maple elm, ash, balsam and spruce. The red deer is a very frequent visitor to the river and is by no means a rare sight to those ascending or descending the river in canoes. Muskrats, rabbits, porcupines and other small wild animals may also be seen, especially in the early morning or evening. The largest of the canoes used by the party on this present trip is similar in size and material to those in use by the brigades of the Hudson's Bay and Northwest companies in the fur trade and is an exact model of the canoe used by Sir George Simpson, Governor of the Hon..Hudson's Bay Company in his memorable voyage from Hudson's bay to the Pacific ocean in 1828.

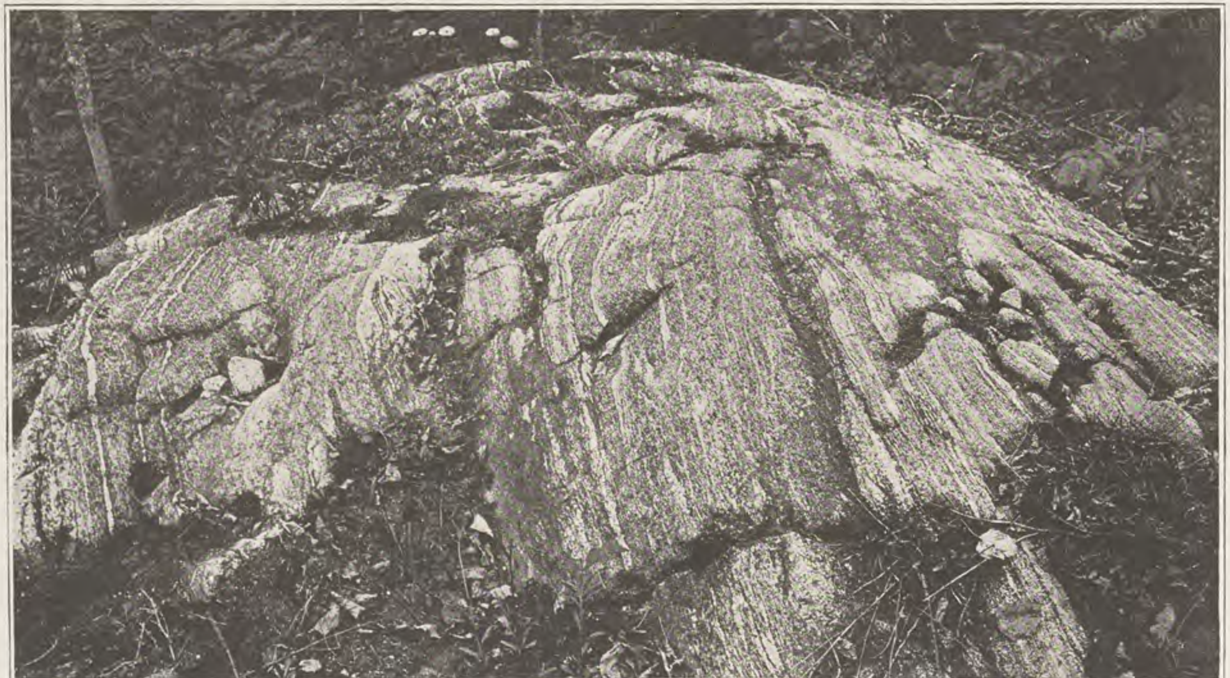
The stream, in its somewhat tortuous course, flows with a gentle current between low banks of drift and alluvium. In places the underlying crystalline limestones with associated alkaline syenites outcrop, but there are comparatively few exposures in the immediate vicinity of the river banks. For a distance of nearly 17 miles (27·3 km.) from Bronson's Landing to the head of Foster's rapids, there is uninterrupted and comparatively deep water suitable for the passage of canoes and other small craft.

### The Occurrence of Dungannonite.

In the Township of Dungannon, Cons. XIV and XV, lot 12 is the locality from which the original dungannonite, a corundum-bearing alkali syenite with accessory nepheline, was obtained.

The typical dungannonite contains nepheline only in small amount and as an accessory constituent. Associated with it in the same series of exposures, however, there are differentiation phases of the magma which are rich in nepheline, the nepheline syenite thus resulting having as its essential constituents nepheline, plagioclase and biotite. This rock in places contains dark basic patches which are rich in hornblende, as well as others of a yellowish colour which contain an abundance of scapolite. The whole series has a well-defined foliation striking N. 25° E.

The dungannonite under the microscope is seen to be made up largely of plagioclase having the composition of andesine. Next to this feldspar corundum is the most important mineral constituent. Scapolite is also present, usually in subordinate amount, the larger individuals occupying the interspaces between the feldspars. Biotite is present in small amount, while muscovite occurs both intergrown with the biotite and as mantles of variable width surrounding the corundum individuals. This muscovite is regarded as a primary constituent formed at a time immediately preceding the complete solidification of the magma. Occasional grains or imperfect crystals of magnetite, with a small amount of calcite, complete the



Nepheline syenite showing regional foliation. Near York River bridge, lot 13, Con. XII. Dungannon township.

list of minerals found in the thin sections of this rock. The corundum is often very abundant. Some of the individuals show a nearly perfect crystallographic development, but the mineral as a general rule occurs as imperfect crystals or as irregular grains. It frequently shows very distinctly the parting planes parallel to the faces of the rhombohedron and the base. The colour varies even within the same individuals; the mineral has usually a distinct and often pronounced sapphire blue colour, but the corundum is sometimes white or brown in colour. The individuals of corundum frequently have a distinct corona of muscovite surrounding them, although this is not invariably present. The corundum is by no means uniformly distributed through the rock. A large portion of the rock is completely free from this mineral, while other areas, rather ill-defined in shape, contain a very high percentage of it. In outcrops exposed to the weather the corundum becomes very conspicuous, weathering out as it does in pronounced relief from the surface of the rock. In some places characteristic barrel-shaped hexagonal crystals, several inches in length, may be seen on these weathered surfaces. In the freshly broken rock, on the other hand, the corundum is detected only with difficulty, unless it assumes the usual bluish colour which enables it to be readily distinguished from the other constituent minerals of the rock.

In the exposures these rocks are seen to be cut through in various directions by dykes of fresh red pegmatite composed chiefly of red feldspar (orthoclase), microperthite and quartz, with a little hornblende. In some places imperfect crystals of this last-named mineral can be found which measure from 4 to 6 inches (10 to 15 cm.) in diameter. These dykes are evidently differentiation forms of a red syenite, which occurs in considerable volume immediately to the south of these exposures, and which is probably a somewhat quartzose type of the normal red variety of alkali syenite.

An analysis of this rock was made by Prof. Norton-Evans, with the following results, under I.—

Dyke of nepheline syenite pegmatite, cutting nepheline syenite parallel to the foliation, lot 25, Con. XIV. Dungannon township.

| — | I. | II. | III. Molecular | Ratios. |
|---|---|---|---|---|
| $SiO_2$ | 49·56 | 58·32 | ·972 | ·972 |
| $Al_2O_3$ | 33·70 | 23·80 | ·233 | ·240 |
| $Fe_2O_3$ | ·93 | 1·09 | ·007 | |
| FeO | 1·42 | 1·67 | ·023 | |
| CaO | 5·89 | 6·67 | ·119 | |
| MgO | ·97 | 1·14 | ·029 | ·280 |
| $K_2O$ | 1·23 | 1·44 | ·015 | |
| $Na_2O$ | 4·95 | 5·83 | ·094 | |
| $CO_2$ | ·17 | | | |
| $H_2O$ | ·84 | | | |
| | 99·66 | | | |

Deducting the excess of alumina present as corundum, which was determined by trial, neglecting the loss on ignition($H_2O$) and deducting the amount of lime (CaO) necessary to form calcite with the $CO_2$ in the rock, the results given under II are obtained. This is the composition of the residual or alumina-saturated magma.

Morozewicz [**9**, p. 1 and 105] has shown by direct experiment that in super-saturated alumino-silicate magmas, whose general composition is RO, n $Al_2O_3$, $SiO_2$ (where $R = K_2$, $Na_2$ or Ca; and n = 2), the whole of the excess of alumina separates out (1) as corundum if no considerable amount of MgO or FeO is present and if **n** is less than 6; (2) as sillimanite and corundum if **n** is greater than 6; (3) when the magma is rich in magnesia, as spinel or spinel and corundum, if **n** is less than 6; (4) as cordierite or cordierite with one or more of the other minerals if **n** is greater than 6. The absence of corundum in the nepheline syenites of India is explained by Holland as due to the fact that this rock, as shown by analysis, contains too much MgO and FeO, and he refers to the abundance of iron-magnesia minerals in the nepheline syenite, and the scarcity of such minerals in the corundum syenite, as amply accounting for the abundance of free alumina in the latter and its absence in the former. A similar low content of iron and magnesia is noticeable in the Canadian corundum syenites, and, together with the high percentage of alumina in the magma, probably explains the development of corundum in them.

The ratios of the molecular values of ($CaO$, $K_2O$, $Na_2O$): $Al_2O_3$: $SiO_2$ in the rock at present under consideration are as follows:—

| | | | | |
|---|---|---|---|---|
| ·222 | : | 233 | : | 972 |
| 1 | : | 1 | : | 4·2 |

The ratio of $K_2O : Na_2O = 1:6$ and alumina to the bases is a little in excess of 1:1. As a magma for the solution of alumina and its complete separation as corundum on crystallization, it is therefore in perfect agreement with Morozewicz's law. Of the alkalies, soda largely predominates, this lending the necessary assistance in the solution of the alumina. There is an excess of ferrous iron and magnesia above what has been thought permissible (0·05 per cent) by Morozewicz's law, but these amounts have been necessary to assist in the formation of the comparatively small quantities of magnetite and biotite present in the rock. It is therefore evident that Morozewicz's law, as remarked by Holland [**7**, p. 208] does not represent the whole truth, for it might be expected, with this excess of ferrous iron and magnesia, that spinel would be formed in addition to the corundum. This mineral was, however, not seen in the thin sections, nor was it found in any of the outcrops in the vicinity where this rock specimen was collected.

The norm of the rock is as follows:—

| | |
|---|---|
| Quartz | 1·26 |
| Orthoclase | 7·23 |
| Albite | 41·92 |
| Anorthite | 29·19 |
| Corundum | 13·46 |
| Hypersthene | 4·12 |
| Magnetite | 1·39 |
| Calcite | ·37 |
| | 98·94 |
| Water | ·84 |
| | 99·78 |

In calculating this norm from the chemical analysis, there was, as shown, an excess of 1·26 per cent of silica above that required and which appears in the norm as quartz. By direct experiment it was subsequently shown that most, if not all, of this silica was derived from the agate mortar and pestle which was used in grinding the sample. There is no free silica or quartz shown in the thin sections, nor was any of this mineral found in the separation of the rock by means of the heavy solution.

The mode or actual mineralogical composition cannot be calculated with certainty on account of the presence of the two micas and the scapolite, the latter having about the same formula as the feldspar. The corundum, magnetite and calcite are normative, that is, they are present essentially in the percentages given in the norm. From an inspection of the slides the following would seem to be a very close approximation to the mineral composition of the rock:—

| | |
|---|---|
| Andesine (near $Ab_3An_2$)......... | 72·00 |
| Nepheline...................... | 3·00 |
| Scapolite...................... | 2·00 |
| Corundum (by trial)............ | 13·24 |
| Biotite........................ | 5·00 |
| Muscovite...................... | 3·00 |
| Magnetite...................... | 1·39 |
| Calcite........................ | ·37 |
| | 100·00 |

Owing to the large percentage of corundum present, the rock is a very peculiar and unusual one, and when discovered occupied a new sub-class, order, rang and sub-rang in the quantitative classification. The following names were accordingly proposed for the new rang and sub-rang, and the name dungannonite for the rock itself:—

| | |
|---|---|
| Class I...................... | Persalane. |
| Sub-class II (section I).......... | Dosalane. |
| Order 5...................... | Indare [**13**p.217] |
| Rang 3...................... | Dungannonase. |
| Sub-rang 4.................... | Dungannonose. |

An analysis of the andesine occurring in the rock was made by M. F. Connor. This is given under I. The material for the analysis was obtained by separating the feldspar with Thoulet's solution, but was somewhat impure, owing mainly to the admixture of a small amount of biotite. This accounts for the iron, potash and magnesia found in the analysis. Neglecting these the composition corresponds rather closely to that of an andesine with the formula $Ab_3An_2$, with 0·96 per cent too little of silica and 1·68 per cent too little of lime. The specific gravity for such a mixture should be 2·68, while that of the andesine separated from the rock was 2·668, this slight decrease in weight being, no doubt, due to the unusually low lime. For purposes of comparison, the theoretical composition of andesine corresponding with the generally accepted formula for this species of plagioclase with the ratio of the soda to the lime of 1 : 1 ($Ab_2An_1$). is given under II, while under III is quoted the composition of andesine, made up of a mixture of albite and anorthite in the ratio of 3 : 2.

| — | I. | II. | III. |
|---|---|---|---|
| $SiO_2$ | 57·15 | 59·84 | 58·11 |
| $Al_2O_3$ | 26·74 | 25·46 | 26·6 |
| $Fe_2O_3$ } $FeO$ } | 0·25 | | |
| $CaO$ | 6·66 | 6·97 | 8·34 |
| $MgO$ | 0·59 | ........ | ........ |
| $MnO$ | trace | ........ | ........ |
| $K_2O$ | 0·38 | ........ | ........ |
| $NaO$ | 6·83 | 7·73 | 6·93 |
| $H_2O$ | 0·90 | ........ | ........ |
| | 99·50 | 100·00 | 100·00 |
| Specific gravity | 2·668 | 2·671 | 2·680 |

An analysis of the blue corundum which occurs associated with this rock was made by Mr. M. F. Connor, with the following results:—

| | |
|---|---|
| $SiO_2$ | none. |
| $Al_2O_3$ (diff.) | 96·90 |
| $Fe_2O_3+FeO$ | 0·76 |
| $CaO$ | 0·46 |
| $MgO$ | 1·00 |
| $H_2O$ | 0·88 |

In the Township of Monteagle, Cons. I and II, lots 2, 3 and 4 are other outcrops of dungannonite very similar in composition to those already described as occurring in the township of Dungannon. The exposures are in the form of a comparatively narrow ridge or ridges, for the continuity of the ridge is broken at one point by a ravine which is traceable for a little over half a mile. The rock is very distinctly foliated and often schistose, bands of light and dark grey alternating with one another. Most of the exposed surfaces show crystals and aggregates of corundum in strong relief, this mineral having resisted weathering processes better than the other constituents of the rock. Near the southern end of the ridge a dyke a few feet wide crosses this gneissic syenite. It is composed of large individuals of nepheline and muscovite and small patches of blue sodalite.

ANNOTATED GUIDE—Continued.

Miles and kilometers.

422·77 m. 680·4 km. **Norway Bay**—Alt. 948 ft. (289 m.)—is a small bay-like expansion on the west side of the river.

424·52 m. 683·2 km. **Papineau creek**—Alt. 947 ft. (288·7m.)—enters the river from the north-west.

426·77 m. 686·7 km. **Foster's rapids,**—Alt. 946 ft. (288·4 m.)—have a fall of about six feet (1·82 m.), where a portage of nearly a quarter of a mile on the north side of the river, is often necessary, especially during low water, To the north of the clearing on this portage very basic nepheline rocks occur, while boulders of nepheline syenite occur in the clearing. Between Foster's rapids and Conroy's rapids, the stream is in places shallow and rapid owing to an accumulation of boulders.

429·02 m. 690·4 km. **Conroy's rapids,**—Alt. 936 ft. (285·3 m.) with a fall of three feet (·91m.) are in front of the old farm known as Campbell's farm. A short distance below these rapids the river widens and flows through a great swamp often known as "Campbell's marsh."

From the foot of Conroy's rapids,—Alt. 933 ft.; (284·4 m.)—the party to Combermere where the night will be spent, passing through Campbell'smarsh, an expansion of York river which has been flooded by a dam at Palmer's rapids on Madawaska river (of which York river is a branch). The hills on either side are of the prevailing granite gneiss with inclusions of amphibolite and occasional areas of the Grenville series. In the vicinity of Craigmont a wide band of nepheline and alkali syenites crosses the river.

435·52 m. 700·9 km. **Combermere** or "The Bridge" (Alt. 931 ft. 283·8 m.) as it is sometimes called was an important and busy village in former years when lumbering operations were being actively prosecuted in this district. The party will spend the night here and in the morning will return on the steamer to Francois point.

442·62 m. 712·3 km. **François point**—Alt. 931 ft.; (283·8 m.), is the landing place for Craigmont. From here the party will walk or drive to Craigmont.

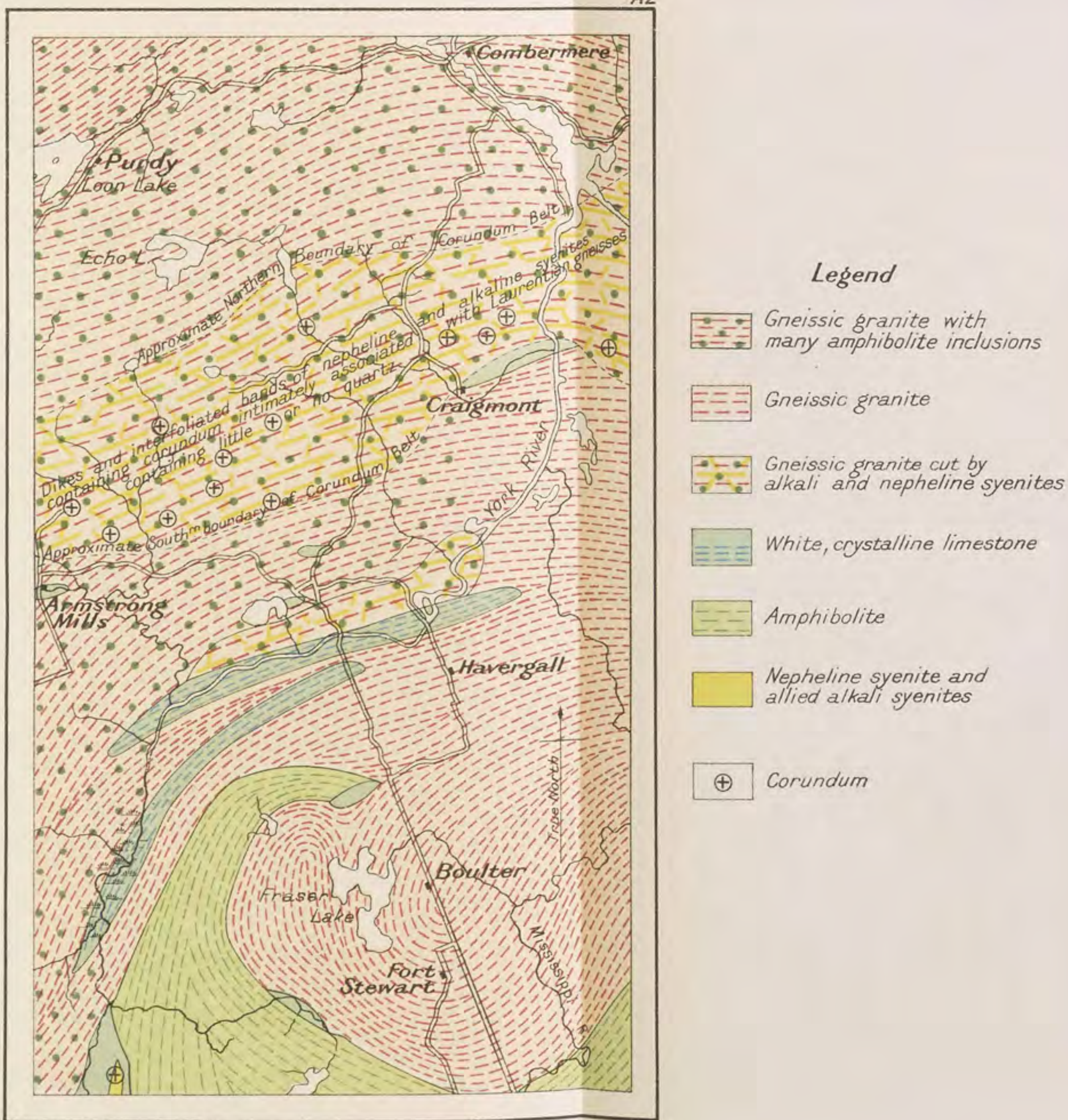
444·87 m. 715·9 km. **Craigmont,**—Alt. 1426 ft. (434·6 m.).

GEOLOGY OF THE VICINITY OF CRAIGMONT.

Craigmont (formerly Robillard mountain) is a well marked topographical feature rising abruptly from Campbell's marsh and extending as far west as the post road between Combermere and Fort Stewart. It covers most of the first four lots in Cons. XVIII and XIX, Raglan township, the line between these two concessions running along the southern slope of the mountain. According to the mean of several observations with two aneroid barometers, it is 595 feet (181·35 m.) above the marsh or 1426 feet (434·6 m.) above mean sea level.

The northern portion of the "mountain" is composed of the reddish granite-gneiss of the Laurentian batholith so prevalent throughout the region. This gneiss is well banded as well as very distinctly foliated and contains the usual amphibolite inclusions, for the most part elongated in the direction of the strike. This granite gneiss is intruded by many dykes and masses of granite pegmatite, often with a very marked "augen", probably a protoclastic structure, induced in the rock mass during the

A2




Geological Survey, Canada.

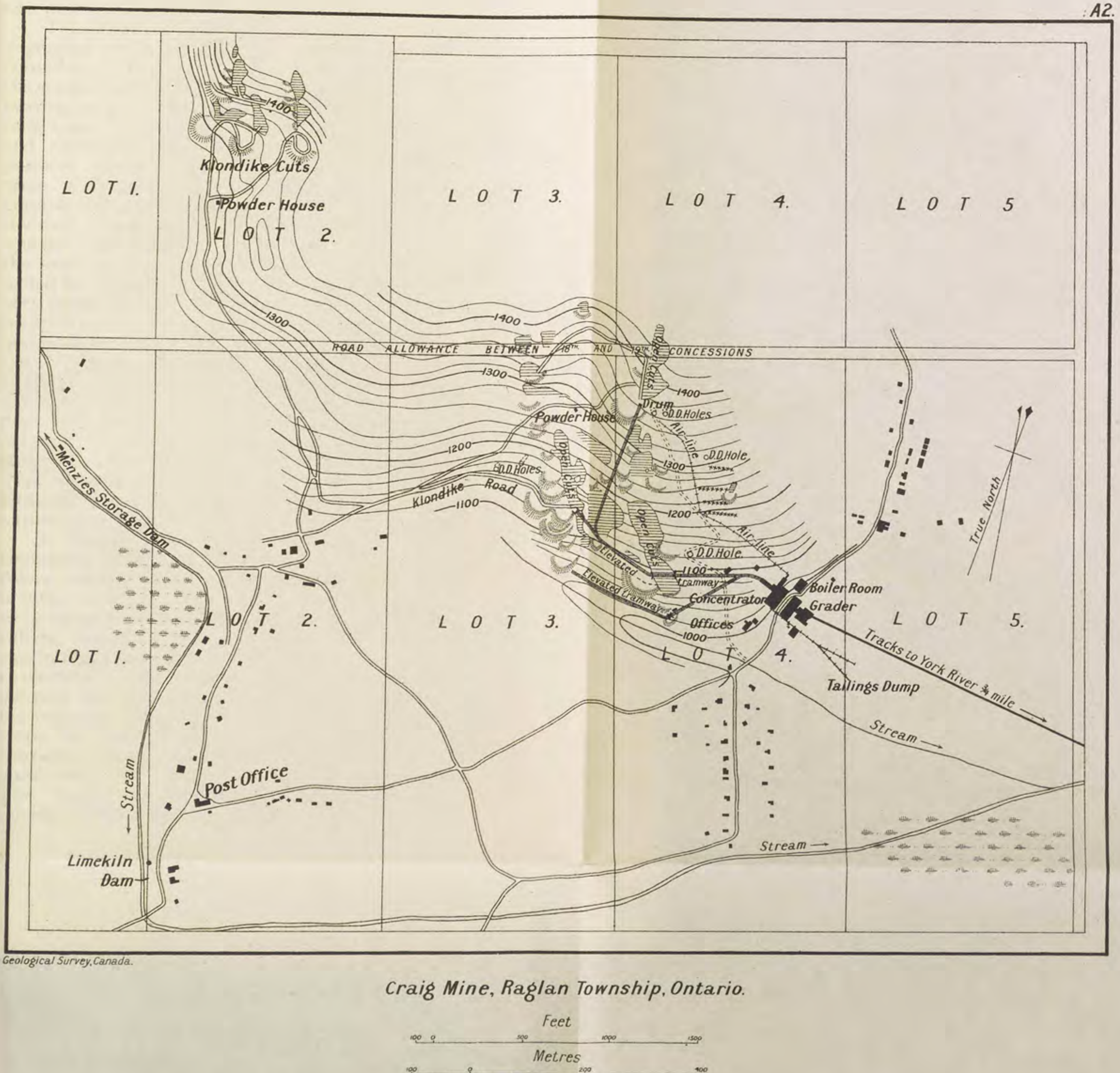
**Craigmont Corundum Belt**

Miles

1 0 2 4 6

Kilometres

1 0 3 6 9




Geological Survey, Canada.

*Craig Mine, Raglan Township, Ontario.*

later stages of its consolidation. The granite gneiss contains quartz while the granite pegmatite is often quite rich in this mineral.

The gneissic granite series to the north of the hill, by a gradual decrease in quartz, seems to merge into the corundum-bearing series which overlies it and which form the summit and southern slope of the hill. The corundum-bearing series is a complex of diverse though closely related rock types, differentiation products of one highly alkaline and aluminous magma and representing one phase of plutonic activity. These different rock types usually occur in irregularly sinuous, rather ill-defined bands, the gradual transition from one type to another being a distinctive characteristic of this occurrence. They are usually foliated, the strike being N. 75° E. with a dip to the south at an angle of 10°-12°. These rocks are intersected by dykes and masses of syenite pegmatite, which are very frequently parallel to the foliation, merging into the normal or finer grained types. Superimposed upon this corundiferous series and represented by small and infrequent outcrops protruding through the sand plain to the south of the hill are the crystalline limestones of the Grenville series. As elsewhere through the region, the nepheline bearing rocks are intermediate in position between the crystalline limestones and the granite-gneiss batholith. The following types have been selected as the more important representatives of this igneous complex, although it must be understood that no sharp line exists in nature between these several varieties.

1. *Craigmontite.*—This is a very nepheline-rich syenite containing corundum. The rock is prevailingly pinkish in colour, owing to incipient alteration of the nepheline, and is rather coarse in grain. Under the microscope it is seen to be composed of nepheline, oligoclase, muscovite, biotite, calcite, magnetite and corundum. The corundum (as also in raglanite) occurs in well defined crystals, often with characteristic, barrel-shaped outline and so disposed in the rock that their longer axes are often at right angles to the foliation. Smaller individuals viewed with the microscope are often irregular shaped, owing to magmatic corrosion, usually surrounded by a corona or mantle of muscovite. An analysis of the rock is given on p. 96. The "mode," or actual mineralogical composition, as calculated from this analysis, is as follows:—

| | |
|---|---|
| Nepheline | 63·18 |
| Oligoclase | 29·66 |
| Muscovite | 4·39 |
| Calcite | 1·42 |
| Corundum | ·50 |
| Biotite | ·50 |
| Magnetite | ·10 |

2. *Congressite.* —This rock represents the product of differentiation in which nepheline is most abundant. It is allied to monmouthite and urtite but is richer in alkalies belonging to the 9th. order of the persalanes in the quantitative classification. The rock appears as great exposures in that part of the Craigmont hill known as Congress Bluff. It is rather coarse in grain and usually possesses a more or less well marked foliation, as in the case of the other members of the series. It is pale pink in colour owing to the large amount of nepheline which it contains this mineral having a pink colour and a distinct oily lustre. In places, however, the rock displays little white bends or streaks of albite. Sodalite when present occurs enclosed in the nepheline in the form of small grains which are bright blue in colour, while the other constituents occur as little flakes or grains, distributed through the rock serving to mark the foliation. The mica in some cases displays a tendency to segregate into little bunches.

An analysis of the rock is given on page 96.

The following is the "mode" or actual mineralogical composition of the rock as calculated from the analysis:—

| | |
|---|---|
| Nepheline | 72·48 |
| Orthoclase | 4·14 |
| Albite | 3·67 |
| Sodalite | 2·22 |
| Muscovite | 6·55 |
| Biotite | 3·36 |
| Apatite | ·34 |
| Magnetite | 3·71 |
| Ilmenite | ·46 |
| Pyrite | ·36 |
| Calcite | 1·80 |
| Water | ·71 |
| | 99·80 |

No orthoclase could be found in either Craigmontite or Raglanite when separations were made by Thoulet solution. No separation has as yet been made of the constituents of Congressite to confirm the presence of the small percentage of orthoclase indicated by analysis.

A portion of the CaO and $CO_2$ calculated as calcite is present as cancrinite which is occasionally seen in thin sections in small amount. In calculating the "mode" the nepheline is assumed to have the same chemical composition as it possesses it in the Bancroft district, viz., to contain rather more than 5 per cent of $K_2O$.

3. *Raglanite* is a white or grey corundiferous nepheline syenite poor in nepheline. The specimen analyzed was chosen as representative of the more highly feldspathic variety of the nepheline syenite of Craigmont. Since that time quarrying operations have exposed still more highly feldspathic phases, which may be referred to as plumasite, a name originally proposed by Dr. Andrew C. Lawson (Bull. Dept. Geol. of California, Vol. III, No. 8, pp. 219-229). An analysis of raglanite is given on p. 95. The rock is composed of about 69 per cent of oligoclase, 12 per cent of nepheline and 4·45 per cent of corundum, with subordinate amounts of muscovite, biotite, magnetite, calcite and apatite.

4. *Plumasite* is an alkali-syenite made up almost exclusively of white oligoclase with a relatively subordinate amount of corundum. Muscovite, biotite and scapolite are sometimes present as accessory constituents. Plumasite is closely allied to dungannonite.*

5. *Umptekite* is the red or pink alkali-syenite and differs from plumasite chiefly by reason of the fact that a considerable quantity of potash feldspar is present. Usually it is distinctly foliated, the structure being marked by minute scales of biotite. An analysis of the rock is given on p. 96. Umptekite is, perhaps, the most abundant representative of this alkali series at Craigmont. Its approximate mineralogical composition is of orthoclase and microcline (30 per cent), albite (55 per cent), magnetite with a little biotite and corundum. Some specimens contain small amounts of hornblende or pyroxene as accessory constituents replacing the biotite.

6. *Anorthosite* has only recently been recognized in some of the newer workings at Craigmont. It is a coarsely granular rock of greyish or greenish-grey colour. It is composed, essentially, and sometimes almost wholly, of a plagioclase feldspar, having a composition intermediate be-

*It is to be noted that the feldspar in Lawson's plumasite is highly altered, containing 1.7 per cent of water. It has the specific gravity and extinction angles of oligoclase but the composition of andesine.

tween oligoclase and andesine. Most of the exposures however, contain a variable quantity of deep pink garnet, magnetite and corundum. Under the microscope the thin sections show the presence of subordinate amounts of muscovite, biotite, scapolite and a deep green spinel.

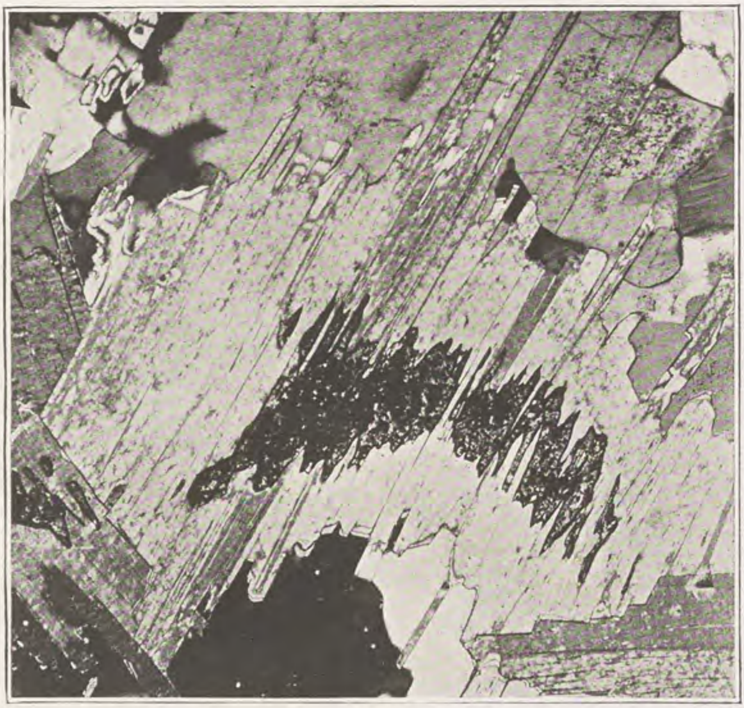
7. *Scapolite rock.*—Some of the quarries show the presence of a pale greenish granular rock made up almost exclusively of scapolite. This mineral has a specific gravity of 2·67, showing that it is of intermediate composition in the scapolite series. Associated with this scapolite are small bands of magnetite.

8. *Amphibolite* occurs intimately associated with the other members of the corundiferous series chiefly as dark greenish bands, analogous to similar inclusions in the granite gneiss batholiths. Some bands are highly micaceous, while others are composed almost altogether of hornblende. In some cases they are apparently highly deformed and altered basic dykes.

9. *Corundum syenite pegmatite* is the rock which contains the largest and most abundant crystals and masses of corundum at Craigmont and thus is the richest 'ore''which has been quarried or mined. This rock occurs in the form of dykes, which sometimes attain a width of eighteen feet. Sometimes these dykes cut across the banding or foliation of the series, but usually run parallel with these structures. There is often a distinct and perfect gradation between this coarse-grained phase and the normal type of syenite (No. 4), which also contains corundum, although in less abundance and in smaller individuals. The rock is made up almost entirely of a deep, flesh-red to very pale salmon pink feldspar, which in thin section under the microscope is seen to be an irregular intergrowth of orthoclase and albite, the latter, as indicated by the analysis, being the more abundant. Associated with this microperthite as accessory constituents, locally and usually in small amount, are biotite, muscovite, scapolite, calcite, magnetite, hematite (micaceous iron ore), molybdenite, pyrite, pyrrhotite, chalcopyrite, chrysoberyl, spinel and quartz. Although quartz and corundum are commonly supposed to be mutually exclusive, specimens have been found containing these two minerals in small amount.

This syenite pegmatite is representative of the final stages in the crystallization of this highly aluminous magma.

Mr. M. F. Connor has made an analysis of this corundum-syenite-pegmatite from Craigmont, Ont., the results adjusted to a basis of 100 being given under I. For purposes of comparison the analysis of the corundum-syenite-pegmatite, and of the corundum-syenite from



Corundum enclosed in muscovite "red syenite". Just west of Blue Mountain, Methuen, Ont. X 56 diam. Bet. crossed nicols.

Nikolskaja Ssopka in the Urals, Russia, are included under II and III. (Tschermak's Min. und Pet. Mittheil,. XVIII, 1898, p. 219). Under I (a) is given the analysis of I, omitting the corundum and adjusting it to a basis of 100. Under II (a) and III (a) are similarly included analyses of II and III, in which the corundum is neglected and the remaining constituents recalculated to a basis of 100. Under IV is an analysis of the separated microperthite from the corundum-syenite-pegmatite of Craigmont, Ont. Under V is an analysis of a similar feldspar of the corundum-syenite-pegmatite from Sivamalai, India, [**7**, p. 202].

| — | I | II | III | Ia. | IIa. | IIIa. | IV | V |
|---|---|---|---|---|---|---|---|---|
| Corundum | 34·62 | 35·40 | 18·55 | ...... | ...... | ...... | ...... | ...... |
| $SiO_2$....... | 40·53 | 40·06 | 52·34 | 62·30 | 62·71 | 64·65 | 63·43 | 63·26 |
| $Al_2O_3$...... | 13·62 | 13·65 | 16·05 | 20·93 | 21·37 | 19·83 | 20·78 | 21·87 |
| $Fe_2O_3$...... | 0·19 | 0·35 | 0·45 | 0·29 | 0·55 | 0·56 | 0·29 | 0·22 |
| FeO....... | 0·04 | ...... | ...... | 0·06 | ...... | ...... | ...... | ...... |
| CaO....... | 0·67 | 0·30 | 0·20 | 1·02 | 0·47 | 0·25 | 1·00 | 0·21 |
| MgO....... | ...... | 0·15 | 0·16 | .... | 0·23 | 0·19 | 0·07 | ...... |
| $K_2O$....... | 5·92 | 5·20 | 6·58 | 9·10 | 8·14 | 8·14 | 8·00 | 3·09 |
| $Na_2O$...... | 3·40 | 3·71 | 4·77 | 5·23 | 5·81 | 5·89 | 5·20 | 10·25 |
| $H_2O$....... | 1·01 | 0·46 | 0·40 | 1·07 | 0·72 | 0·49 | 1·00 | 0·78 |
| | 100·00 | 99·28 | 99·50 | 100·00 | 100·00 | 100·00 | 99·79 | 99·68 |

The frequent occurrence of corundum in the nepheline syenites of Ontario gives these rocks a unique petrographical position, for although similar rocks occur as differentiation products of the corundum syenites of India or Russia, no corundum has yet been found in these countries in varieties which actually contain nepheline.

There is no doubt whatsoever that the corundum in these rocks is a true pyrogenetic mineral being clearly a primary constituent which separated out of the highly aluminous silicate magma as one of the first products of its crystallization.

The amount of corundum present in certain varieties of these syenites is sometimes very large, thus the ordinary red syenite-pegmatite of Craigmont was found to contain 34·14 per cent of corundum; while dungannonite from the Township of Dungannon contains 13·46 per cent of this mineral. As a result of the crushing and concentration conducted on a large scale for a period of two years at the Craigmont mill, it was found that 10·6 per cent of corundum was separated from the rock treated, while a small portion of the mineral still remained in the tailings.

Miles and Kilometers.

**Combermere.** Returning to Combermere the journey will be continued by steamer up Madawaska river, across Kamaniskeg lake and up Barry's bay (an arm of Kamaniskeg lake) to the wharf at the north end. The exposures on either side of the lake are principally of Laurentian granite gneiss, with the usual amphibolite inclusions. In a few places there are small isolated patches of the Grenville series.

461·37 m. 742·5 km. **Barry's Bay**. Alt. 988 ft. (301·1 m.)—is a station on the Parry Sound branch of the Grand Trunk railway. From this place the railway runs through a heavily drifted country. Any exposures seen are of the prevailing granite gneiss with amphibolite inclusions.

476·3 m. 766·5 km. **Killaloe**. Alt. 601 ft. (183 m.)—Outliers of flat-lying Palaeozoic rocks are first met with to the west of Killaloe, and from this point eastward the character of the country rapidly changes, the rugged Laurentian region being succeeded by the comparatively flat or slightly rolling district underlaid by rocks of Palaeozoic age.

**Golden Lake:**—**Douglas.** From the vicinity of Golden Lake to Douglas the railway follows the valley of Bonnechère river, underlain by flat-lying Ordovician strata. Near Glasgow and Arnprior, as well as between Carp and South March, are extended outliers of Pre-Cambrian limestones and gneisses.

570·50 m. 918·1 km. **Ottawa.** Alt. 212 ft. (64·6 m.).

662·25 m. 1065·8 km. **Vaudreuil.** Alt. 85 ft. (25·9 m.).

686·70 m. 1115·1 km. **Montreal.** Alt. 47 ft. (14·3 m.).

## TABLE OF ANALYSES OF NEPHELINE AND ALKALI SYENITES FROM CENTRAL ONTARIO.

| | Syenite, (Phlegrose). Monmouth, Con. VIII, Lot 15. | Nepheline syenite. (Essexose) Mon-mouth, Con. IX, Lot 16. | Nepheline syenite. Essexose) Mon-mouth, Con. VIII, Lot 11. | Nepheline syenite. (Vulturose) Mon-mouth, Con. VIII, Lot 11. | Monmouthite. Mon-mouthose) Mon-mouth, Con. VIII, Lot 10. | Alkali syenite. (Mi-askose) Methuen. Con. X, Lot 13-14. | Alkali syenite, (Kal-lerudose) Methuen, Con. X, Lot 13-14. | Craigmontite with Corundum (Craig-montose) Raglan, Craigmont. | Raglanite, with Cor-undum. (Raglan-ose). Raglan, Craigmont. | Dungannonite with Corundum (Dungan-nonose) Dungannon, Con. XV, Lot 12. | Alkali syenite with Corundum. (Ump-tekose) Raglan, Craigmont. | Syenite pegmatite with Corundum. Raglan, Craigmont. | Congressite. Craigmont. | Nepheline syenite, (Lujavrose). Glam-organ, Con. III, Lot 32. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 64·15 | 51·58 | 43·67 | 42·72 | 39·74 | 59·68 | 65·89 | 48·38 | 55·45 | 49·56 | 56·05 | 40·53 | 41·58 | 44·00 |
| $TiO_2$ | ... | ·35 | ·78 | ·38 | ·13 | none | none | Trace | ·30 | ... | ·47 | ... | ·22 | ·75 |
| $Al_2O_3$ | 19·04 | 19·40 | 20·91 | 25·08 | 30·59 | 23·48 | 19·73 | 30·54 | 21·65* | 33·70 | 17·02 | 13.62 (°°) | 30·36 | 23·31 |
| $Fe_2O_3$ | 1·02 | 4·26 | 3·54 | 2·00 | ·44 | ·59 | 2·03 | ·40 | ·81 | ·93 | 9·10 | ·19 | 2·46 | 2·37 |
| FeO | ·93 | 5·25 | 8·01 | 4·36 | 2·19 | ·37 | T ·75 | ·06 | ·49 | 1·42 | 4·20 | ·04 | 1·64 | 7·43 |
| MnO | ·16 | ·20 | ·05 | ·16 | ·03 | none | race | Trace° | ·01 | ... | ·08 | ... | ·03 | ·22 |
| CaO | 1·37 | 3·64 | 7·37 | 6·92 | 5·75 | ·26 | ·46 | 1·87 | 3·65 | 5·89 | ·72 | ·67 | ·88 | 4·86 |
| MgO | ·37 | ·49 | 1·46 | ·97 | ·60 | ·21 | ·27 | ·19 | ·13 | ·97 | ·12 | ... | ·37 | ·25 |
| $K_2O$ | 7·10 | 4·23 | 2·25 | 2·69 | 3·88 | 4·68 | 3·95 | 3·70 | 1·62 | 1·23 | 5·12 | 5·92 | 5·15 | 3·09 |
| $Na_2O$ | 5·37 | 7·49 | 6·73 | 11·02 | 13·25 | 9·52 | 6·59 | 13·94 | 9·31 | 4·95 | 6·10 | 3·40 | 14·30 | 10·65 |
| $P_2O_5$ | ·10 | ·15 | ·11 | ·19 | (A) | none | none | Trace | ·01 | ... | ·04 | ... | ·07 | ·33 |
| $CO_2$ | ·70 | 1·53 | 2·37 | 2·99 | 2·17 | ·04 | ·44 | ·62 | ·88 | ·17 | ... | 1·01 | ·80 | ·98 |
| $H_2O$ | ·27 | 1·02 | 2·52 | ·88 | 1·00 | ·66 | ·34 | ·50 | 1·64 | ·84 | ·36 | ... | 1·01 | 1·45 |
| | 100·38 | 99·59 | 99·77 | 100·36 | 99·86 (x) | 99·49 | 100·45 | 100·20 (x) | 100·40 (x) | 99·66 (x) | 99·38 | 100·00 | 99·55† (x) | 100·06 ‡ |

(A) $SO_3$ trace, Cl ·02, S.07. (x) New type. (°) Cu trace. *There must be added 4·45 per cent of corundum which was determined separately. (°°)There must be added 34·62 per cent of corundum which was determined separately. †With ·02 per cent of BaO, a trace of $S_2O$, ·30 of Cl, and ·36 of $FeS_2$. ‡With trace of BaO, ·01 of $SO_2$, ·08 of Cl, and ·28 of $FeS_2$.

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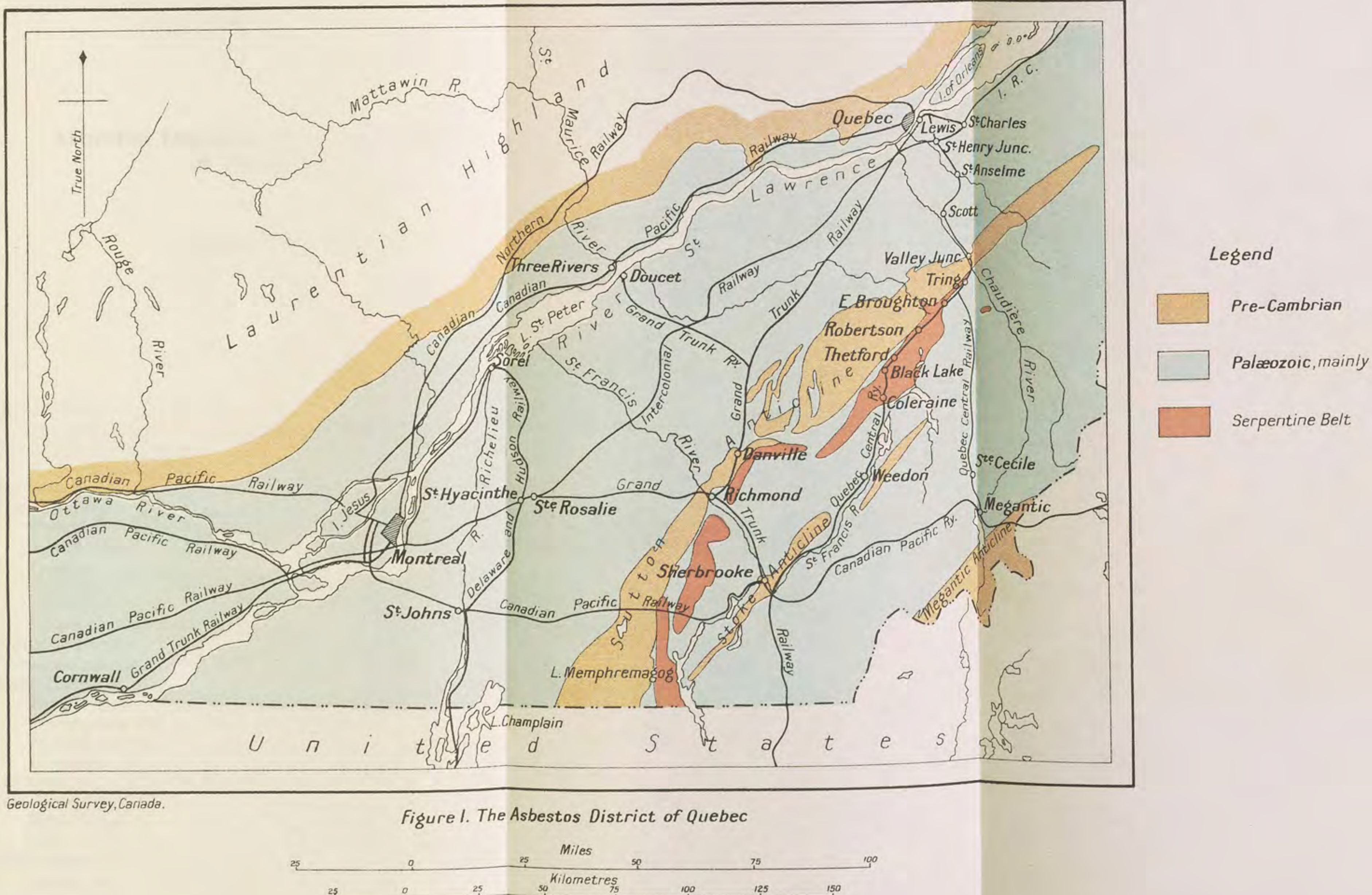



Geological Survey, Canada.

*Figure I. The Asbestos District of Quebec*

# EXCURSION A 5.

## Asbestos Deposits of the Province of Quebec.

BY

ROBERT HARVIE.

CONTENTS.

# INTRODUCTION.

The purpose of this excursion will be to examine the character and mode of occurrence of the asbestos and chromite deposits of Quebec, and to observe the methods of mining. At Thetford and Black Lake the asbestos occurs in an igneous intrusion of stock-like proportions, while at East Broughton it occurs in a sheet or sill. The most typical deposits of chromite will be examined at Black Lake.

The district yields over three quarters of the world's supply of asbestos, with an annual value, at present, of about $3,000,000.

The first geological work in the asbestos district was carried on under Sir William Logan prior to the discovery of the more important bodies of asbestos bearing rocks. Sir William drew attention to the economic possibilities of these rocks, and gives a large amount of general information about them in his "Geology of Canada, 1863."

Subsequent reports of the Geological Survey of Canada added to this information, the next important advance being the reports by R. W. Ells in 1886 and 1888, which give the results of more detailed mapping after the development of active mining. In 1903 a Bulletin on Asbestos was published.

A monograph by Fritz Cirkel was issued by the Mines Branch in 1905, which describes the occurrence, uses, and methods of mining and concentrating asbestos. Chromite was also treated in a similar manner in a further report by Cirkel in 1909. Both these volumes deal more especially with the mining side of the subject, the geology receiving relatively much less attention.

In 1907 a detailed examination of the serpentine belt in which the asbestos and chromite deposits occur was begun for the Geological Survey by J. A. Dresser. His reports of progress, appearing in the Annual Summary Reports of the Geological Survey for 1907, 1909 and 1910, give the fullest accounts of the geology of these deposits yet published. The general description of the asbestos producing area which follows is taken nearly verbatim from Dresser's Summary Report for 1909.

# GENERAL DESCRIPTION OF THE ASBESTOS PRODUCING REGION.

**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 its average gradient is scarcely 10 feet (3 m.) in a mile (1·6 km.) appears to be a level plain. Near the International Boundary line it extends southeast of the St. Lawrence river for a distance of 50 miles (80 km.), but grows narrower farther down the river, and terminates where the Notre Dame highlands reach the river about 100 miles (160 km.) 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 in the Gaspé peninsula as the Shickshock mountains; 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 region is in an early stage of maturity. The altitude varies from 400 feet (122·m). to 2,000 feet (609 m.) above sea-level. The relief is characterized by numerous northeast and southwest ridges and valleys, and a smaller number of larger, transverse valleys.

The transverse valleys are those of the Chaudiere, Bécancour, Nicolet, and St. Francis rivers. These rivers all follow northwesterly courses, and are tributary to the St. Lawrence. It is not yet known whether they are older than the present hills and have cut through them as they were elevated or have been superimposed upon them by the removal of later formations, remnants of which 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-powers 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; and Windsor Mills, at the entrance of the Wattopekah to the same river.

**General Geology.**—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 southeast, except where folding and subsequent erosion have disturbed the sequence. Every geological formation from Cambrian to Devonian is represented.

The structure 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 low angles, usually 5 to 6 degrees. This regularity ends abruptly at the St. Lawrence and Champlain fault, a great dislocation which extends from the foot of Lake Champlain northeasterly to Quebec city, and runs thence to the Gulf of St. Lawrence along 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 on this side were also different. The marine fossil fauna indicate cold, perhaps subarctic, 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, slates and quartzites on the east side of the great fault.

The Highlands, or Notre Dame hills, consist of three parallel, anticlinal ridges running in a northeasterly direction, with two broad, intervening basins, each of which has a width of about 25 miles (40 km.). 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, 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.

Closely bordering the southeast side of the Sutton ridge, is a series of basic intrusive rocks. These rocks constitute the serpentine belt, and contain the deposits of asbestos and chrome iron ore. They extend from the Vermont boundary line, with little interruption, northeasterly to the vicinity of Chaudiere river. Representatives of this series of rocks 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, all of which are regarded as differentiates from a single magma. They form hills 1,500 feet (457 m.) in elevation, which in some parts cover 10 to 20 square miles in area. Other exposures are only a few hundred feet in width. The maximum width of any of these areas rarely exceeds 5 miles (8 km.) and is usually less than 1 mile (1·6 km.). In structure they are considered to form batholiths, or laccoliths, and intrusive sheets or sills.

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 shown.

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

## TABLE OF FORMATIONS.

| | |
|---|---|
| 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. |
| 4. Pre-Cambrian ? | Porphyries and greenstones. |
| Intrusives—Post-Sillery; in part, at least, later than Ordovician—Thetford series | Peridotite, altering to serpentine, pyroxenite, gabbro, diabase, porphyrite, granite and aplite. |
| Post-L'Islet—Broughton series | Serpentine, soapstone, greenstone schists. |

## THETFORD 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 townships to Big Ham mountain. After an interval of 4 miles (6·4 km.) they reappear in Little Ham mountain, and continue in a southwesterly direction to Danville, and thence to the St. Francis river. Diabase covers 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.

**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 on single faces. In general, the pyroxenite is somewhat altered to soapstone.

**Gabbro.**—Granitoid rock types in which feldspar is present as well as pyroxene are classed as gabbro. The distinguishing feature of this rock is its coarse texture as exhibited in angular grains of grey feldspar and green pyroxene. It forms a large part of the hills above Lac Coulombre and Nicolet lake, and of 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 grained, 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; 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, by becoming more acid in composition and losing much of its pyroxene, the diabase passes into porphyrite near the outer edges of the mass.

**Granite.**—The granite, though limited in extent, is important, as it probably indicates conditions that favoured the development of asbestos. It forms hills in the north-eastern part of Coleraine, dykes 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.**—The rocks of the Thetford series are obviously intrusive in their relations to the enclosing sediments. Evidences of this are: alteration of the sediments in the outer contact zone; deflection of their dip and strike; and development of contact breccias.

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.

Dykes 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 order.

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.

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:—

(1) In sheets, from the base upwards.

(2) 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 near the tops of sheets or the margins of batholithic intrusions, and the basic rocks in correspondingly opposite directions.

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 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 again passes into breccia at its outer edge.

It may be mentioned that an identical relation of rock types has also been found in association with the platinum bearing peridotites of the Ural mountains.

## 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 greater alteration of these rocks indicates that they are possibly earlier in age than the Thetford series, although this difference may also be due to a greater degree of metamorphism. The sediments 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 alone is at present being mined, the production of which represents one-half of the total mineral production of the Province of Quebec, and is upwards of 80 per cent of the world's output of asbestos. Chromite has at times been produced in considerable quantity, but the industry has never passed the prospecting stage and at present operations have ceased altogether. Antimony and talc have been mined; there has been a small development of the copper ore; and platinum has been found in the gravels.

The discovery of asbestos as a mineral of commercial importance was made in this district in 1877, although it was known for many years previously as a mineral of prospective value. Mining operations began at Thetford, Black Lake, and very shortly afterwards at Danville, 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 about $3,000,000. 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 ten years has been as follows:—

| Year. | Tons. | Value. |
|---|---|---|
| 1902 | 30,634 | $1,161,970 |
| 1903 | 29,261 | 916,970 |
| 1904 | 35,479 | 1,186,795 |
| 1905 | 48,960 | 1,476,450 |
| 1906 | 62,375 | 2,143,653 |
| 1907 | 61,985 | 2,455,919 |
| 1908 | 65,156 | 2,551,596 |
| 1909 | 63,349 | 2,284,587 |
| 1910 | 100,430 | 3,403,358 |
| 1911 | 100,893 | 2,922,062 |

Various attempts to mine chrome iron ore in Quebec were made between 1860 and 1890, but it was not until 1894 that any considerable production was made. Between 1894 and 1908 over 40,000 tons of chromite were mined, which had a value at the railway of about $600,000. Since 1908 the industry has declined, till at present none of the deposits are being worked. The development of new ore bodies has not kept pace with the exhaustion of those being worked.

The following production during the last four yeras of active work was as follows:—

| Year. | Tons. | Value. |
|---|---|---|
| 1905............ | 8,528 | $104,585 |
| 1906............ | 8,750 | 92,100 |
| 1907............ | 7,196 | 72,901 |
| 1908............ | 7,225 | 82,008 |

## BLACK LAKE.

At Black Lake the chief points of interest are: the rock types of the peridotite series; occurrence and relation of asbestos veins; mining and milling of the asbestos-bearing rock; occurrence, mining and milling of chromite ore.

### Rock Types of the Peridotite Series.

Of the rock types of the peridotite series, diabase, porphyrite, peridotite, serpentine and granite are present at Black Lake.

The diabase and porphyrite occur as marginal phases of the peridotite stock at the contact with the sediment, in a few localities the contact being marked by a breccia in which fragments of the sediments are cemented by a paste of the diabase. In general both these rocks have been so much altered that it is only by careful microscopic work that they can be distinguished. Both are now commonly represented by a fine grained chloritic or epidotic rock. In some places typical pillow structure may be observed; at others, the rock has the appearance of a tuff or breccia.

It is difficult, and often impossible to distinguish peridotite and serpentine 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 hydration accompanied by loss of the 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, in which case 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 above Black Lake village.

The granite in this area is composed of feldspar, quartz and hornblende or biotite, or both. It is light grey in color, and occasionally shows a pinkish tint. Types without hornblende or mica,—principally dykes, are also present, but are more properly classed as aplite. The granite is considered to be the end product of the process of differentiation and nearly contemporaneous with the peridotite. The peridotite retained at least sufficient heat at the time of the intrusion of the granite dykes to enable them to cool without a fine grained border.

## Occurrence and Relations of Asbestos Veins.

The asbestos is of the chrysotile variety—hydrous silicate of magnesium—and has the same chemical composition as the serpentine which contains it, but is distiguished from it by a fibrous form. The asbestos occurs almost wholly in veins which are usually 2½ inches or less in width, the greater number being less that ½ inch. The fibres lie usually at right angles to the walls of the 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 either side of the vein, whether the country rock is wholly or partially serpentinized, 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.

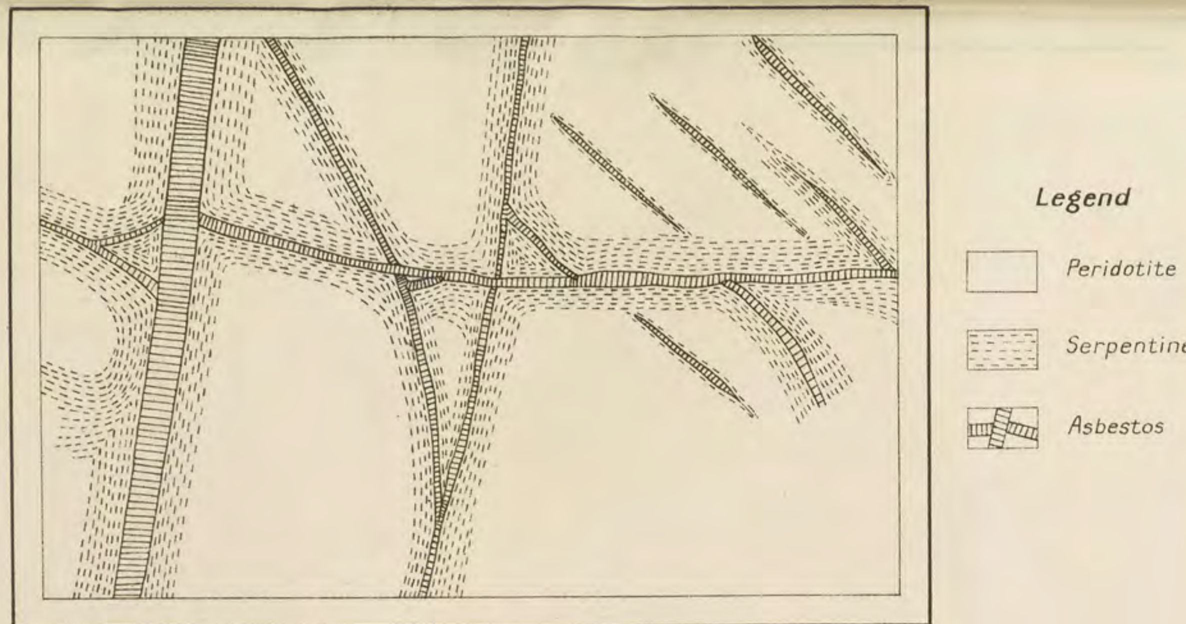
From a consideration of these facts, and of the number, size, and directions of the veins, it is believed that they were formed, not by the filling of once open fissures, but by the replacement or crystallization—more or less perfect —of the pure amorphous serpentine of the side walls. This process is 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 exogenous or outward growing, as

Photomicrograph of an asbestos vein, showing the irregular nature of the magnetite parting, and the contact of the vein with the serpentine wall-rock. X 14; crossed nicols.

distinguished from those that are formed by filling a fissure from the walls inward. Measurements of many veins show that the proportion of asbestos to the two bands of serpentine is 1 to 6·6, or that approximately 15 per cent of the serpentine has taken the crystalline form of asbestos.

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,

A5.

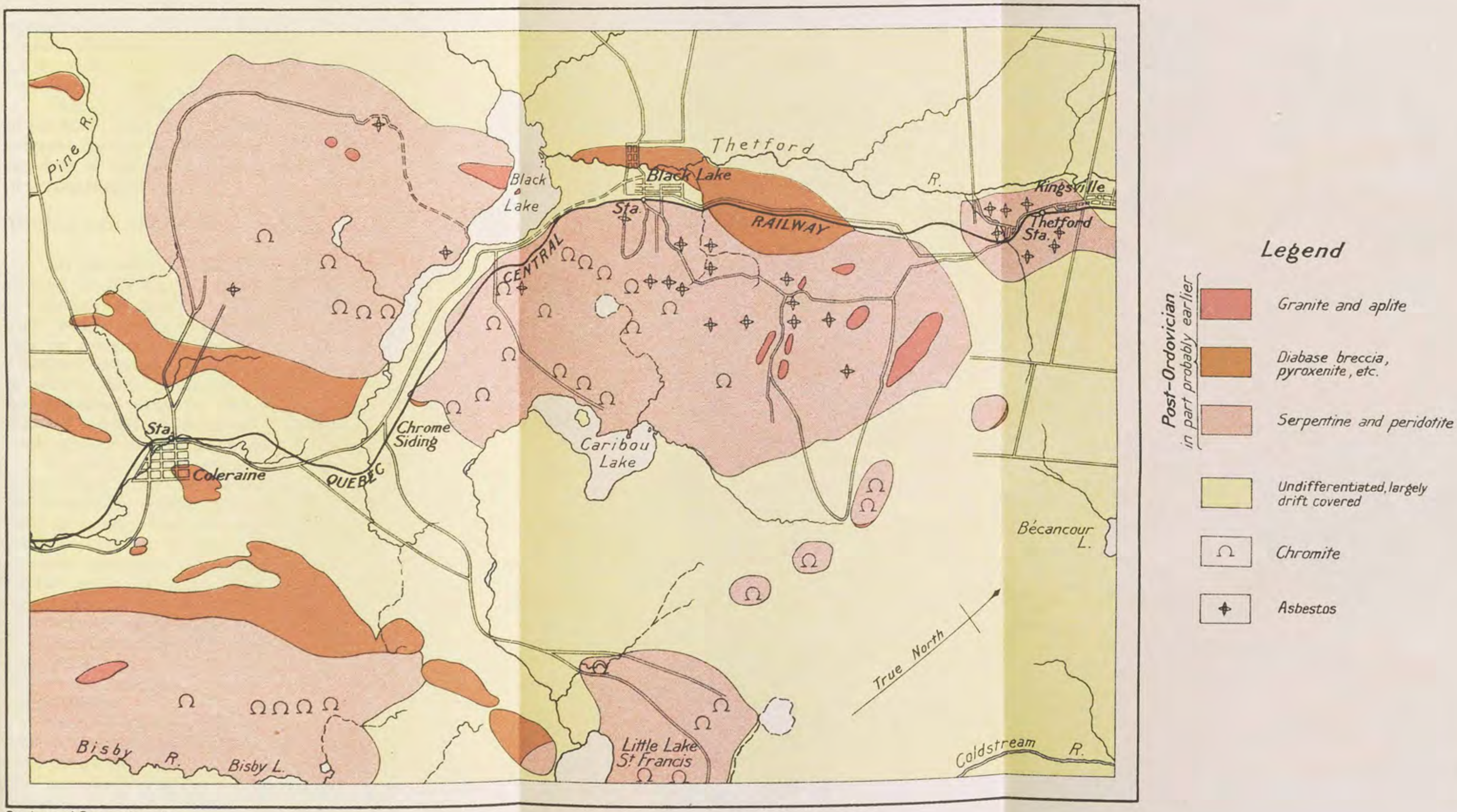



Geological Survey, Canada.

**Figure 2**, *Asbestos and serpentine in peridotite, wall of pit near Standard Mine.*

Feet
0 1 2
Metres
0 ½

A5




Geological Survey, Canada.

*Route map between* ***Thetford*** *and* ***Coleraine***

Miles
1 0 1 2

Kilometres
1 0 1 2 3

surrounding a core of peridotite. Where all of these classes of veins are found together, a very intricate network results, but by careful observation many of them can be referred to one or other of these clasess.

The determination of other causes of the shattering of the rock, such as hydration, rapid cooling, and, possibly, original gneissic structure near the edge of an intrusion, requires a full investigation covering the entire process of serpentinization.

## Mining and Milling of the Asbestos-Bearing Rock.

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 (2·4 to 4·5 m.) 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. Several of the pits have reached a depth of about 200 ft. (61 m.), with two or three times greater horizontal extension.

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. 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, drawn usually by small locamotive 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 to 60 per cent of all the rock handled, goes to the ore bins, or directly to the mill for mechanical concentration.

Except for minor differences in handling, the principles used in the treatment of the asbestos-bearing rock are the same at all the mills. The dried rock is crushed by stages. The crushing is effected by means of gyratory or jaw crushers, or both, followed by rolls, and then cyclones or jumbos, the particular style of machine employed being largely a matter of the personal taste of the manager. Between each stage of crushing, the material is passed over screens, close above which are the inlets of suction fans by which any fibre is removed. The undersize passes on to the next screens while the oversize is ground further. Partial grading of the asbestos is effected by this removal of the fibre at the various stages in the crushing process, and this grading may be further improved by screening. Magnets are usually employed over the shaking screens to eliminate particles of iron ore.

The milled fibre is separated into three or more grades, and the crude asbestos usually into two.

## Chromite.

The most important chromite deposits are reached from Black Lake village, but as they all present similar characteristics, the Montreal pit is described as a typical example.

**Mode of Occurrence.**—The Montreal pit is in a serpentinized peridotite near a contact with diabase,—the latter rock occurring in the opposite slope of the little valley. The ore body consists chiefly of a series of lens-shaped bodies of massive chromite. Associated with this is a large quantity of ore consisting of disseminated grains of chromite in the serpentine country rock, sufficiently rich to concentrate.

The whole deposit has been faulted and squeezed to such a degree as to produce an infinite number of slickensided surfaces. For this reason the ore is deceiving, as it tends to break along the film of serpentine in these slickensides so that what may appear to be merely a block of serpentine is in reality massive ore. Cutting the serpentine are several kaolinized granitic dykes, numerous blocks from which are to be found on the dump and some of which contain an unusual pink vesuvianite.

**Mining and Milling.**—The ore was mined by means of open cuts, and by a drift from the bottom of the main or lower pit. At least 2,200 tons of crude and 500 tons of concentrated ore have been shipped from these workings.

In the method of concentration used, the ore, after preliminary breaking in a jaw crusher, was fed to three batteries of five stamps each. The pulp from each battery passed over a Wilfly table, which gave three products, concentrates, middlings, and tails. The middlings from all three tables were treated on a fourth table which produced concentrates and tails. The concentrates after draining were ready for shipment.

The ore was graded, and sold according as the content of chromic oxide was greater or less than 50 per cent. The highest percentage reached was very rarely above 55, and with some ores difficulty was experienced in obtaining even 50 per cent. This last trouble was evidently due to the

Photomicrograph of chromite ore showing intergrowth of two varieties,—black, opague iron and chromium-rich variety, showing black; and brown, translucent, magnesian variety, showing mottled. The white streaks are glare from films of inclosed serpentine. X 55.

chromite having an undue amount of $Cr_2O_3$ replaced by $Al_2O_3$, so much so that the per centage of $Cr_2O_3$ remained low even with a very complete removal of the gangue.

Thin sections of some of the ore show it to be composed of an opaque black variety, high in $Cr_2O_3$, and a reddish, translucent variety containing less $Cr_2O_3$.

## THETFORD.

The visit to Thetford affords further opportunities for the study of the occurrence, mining, and milling of asbestos —subjects which have already been discussed for the occurrence at Black Lake.

## EAST BROUGHTON.

The interest at East Broughton centres in the rock types, and, the occurrence of asbestos in sills.

### Rock Types.

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 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, probably originally diabase, together with hornblende schists which grade into them. The latter 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 appearance of the rock is at first disappointing as there are no signs of the cross fibre veins which are so much in evidence at Thetford. However, on crushing the rock to a fine powder a considerable amount of short fibre is found. The asbestos produced at East Broughton is all of short fibre and of low grade, no crude whatever being obtained. The fibre appears to lie chiefly along the slipping planes, which are the result of the shattering of the rock into innumerable small pieces by some such cause as swelling during serpentinization, general regional metamorphism, or folding. The rock is much more completely altered than that of the Thetford deposits and now consists almost entirely of serpentine with a certain amount of talc—the latter indicating the impure nature of the original peridotite.

## Sills.

In striking contrast to the deposits at Thetford and Black Lake, which are in the margin of a stock several miles across, the asbestos deposits at East Broughton occur in sill-like bodies. Two pits have been opened to the full width of a sill about 100 feet (30 m.) thick of which both the foot and hanging walls are exposed. Other smaller parallel sills also occur close at hand. The main sill extends nearly continuously for 6 miles (9·6 km.), five pits having been opened up in this distance. It is also probable that the pits of the Berlin, B. & A., and the Robertson Asbestos Co., 8 miles (12·8 km.) farther on, are in the same sill, so that the sill has a probable length of about 14 miles (22·5 km.).

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EXCURSION A 9.

# Mineral Deposits near Kingston, Ontario.

BY

M. B. Baker.

CONTENTS.

## GENERAL DESCRIPTION OF THE REGION.

The district about Kingston occupies a unique position mineralogically in that it affords a great variety and abundance of well developed minerals, many of which are present in such amounts as to be of economic value. A partial list of these follows:—

| | |
|---|---|
| Actinolite, | Graphite, |
| Amphibole, | Hematite, |
| Anhydrite, | Ilmenite, |
| Anorthite, | Labradorite, |
| Anthraxolite, | Milky quartz, |
| Apatite, | Molybdenite, |
| Arsenopyrite, | Muscovite, |
| Barite, | Nepheline, |
| Beryl, | Plagioclase, |
| Biotite, | Pyrite, |
| Bog iron, | Pyroxene, |
| Bytownite, | Pyrrhotite, |
| Calcite, | Rutile, |
| Celestite, | Scapolite, |
| Chalcopyrite, | Sphene, |
| Corundum, | Talc, |
| Dolomite, | Uralite |
| Fluorite, | Wilsonite, |
| Galena, | Zinc-blende, |
| Garnet, | Zircon, |
| Gold, | |

More than half of these minerals have been mined in this area so that they are not mere accessories requiring microscopic detection.

This area is particularly interesting, also, in showing the contact of the Paleozoic sediments with the Pre-Cambrian floor. The former lie unconformably upon the latter, and at several places the actual contact is excellently shown. Here the ancient Pre-Cambrian water-worn boulders are cemented into a basal conglomerate of the lower Paleozoic sediments; such exposures give an excellent demonstration of the character of Pre-Cambrian topography, and show clearly that the great "Laurentian Peneplain" was developed in Pre-Cambrian times,—an eloquent evidence of the enormous time which elapsed between the close of the Pre-Cambrian and the opening of the Paleozoic era.

The Pre-Cambrian portion of this district presents an undulating but not greatly elevated topography. The average elevation is about 500 feet (152m) above sea-level. There are so few exceptions to this, that the whole country presents an almost level sky-line, with few if any projections rising notably above the rest. The area is dotted with lakes, occupying from one-third to one-half of the whole area; only a few of these have been mapped, but the result is striking in bringing out their north-easterly elongation. This is governed by the strike of the gneisses of which the area is largely composed, and not by glaciation as might be suggested. This north-east and south-west system of drainage is characteristic of the whole "Laurentian Peneplain," as a glance at the map of Eastern Canada will show.

The Pre-Cambrian area under consideration on this excursion consists of the typical Laurentian, together with the Grenville phase of the Keewatin. The recent work of Adams [**1**], Barlow [**2**], Miller and Knight [**3**] would indicate that the Grenville is made up largely of highly metamorphosed sediments, and this probably accounts for the great variety of well-individualized minerals developed throughout this area. The whole Pre-Cambrian complex is so intensely metamorphosed and infolded, that with the exception of the crystalline limestones, it is not easy to distinguish the Grenville from the Laurentian metamorphic rocks.

The whole district consists essentially of gneisses. In some localities their foliated character is so faint that they might be called granites. These gneisses differ very markedly among themselves in the proportion of their constituents. The typical rock consists of quartz, orthoclase, and biotite, but in many places hornblende takes the place of the biotite; or the quartz becomes so abundant that the rock might be mistaken for a quartzite; or the feldspar so predominates, that the rock passes into a syenite gneiss. Seldom over any great area do the rocks maintain the same composition, and the minerals enter into their composition in every conceivable proportion.

It is probably safe to conclude that the distinctly lightly coloured, grayish to reddish psamitic gneisses, rich in hornblende, belong to the Laurentian, as in the case of the Lewisian gneisses of the North-west Highlands of Scotland. On the other hand the lustrous pelitic gneisses rich in mica, or other hydro-micaceous minerals probably belong to the Grenville group as in the case of the Highland schists of Scotland, or the Telemark formation of Norway. In many gneisses there is a distinct ribbon-like, or banded character, in which parallel bands of different composition, often quite thick, extend for long distances along the strike. The writer would suggest that this is due to an original difference in the material caused by the sorting action of water or other agency.

Both of these gneisses are cut in numerous places by granite dykes, many of which are pegmatitic. It is from these great pegmatitic dykes that the potash feldspars are mined in large quantities for use as glazes for earthenware. These dykes occur in great numbers, and two of the productive ones are included in the excursion programme. There is little doubt that most of the interesting minerals, so well developed in this area, are due in large measure to the metamorphism produced by these intrusives, or to solutions and gasses which accompanied them.

These occurences have been excellently exposed by the glaciation of Pleistocene times. This was sufficient to remove all the weathered material from both hill and hollow, so that the old contour of the Pre-Cambrian is preserved, while its surface is made quite fresh again for detailed study. There has not been sufficient time since glaciation for any appreciable weathering, so that all the occurrences are now seen at their best. The effects of the glaciation are in themselves interesting. The famous Glacial Gardens of Lucerne, Switzerland, scarcely surpass the examples of glaciation to be seen immediately about Kingston.

The Paleozoic portion of the area is an irregular fringe along the south-west flank of the Pre-Cambrian. The number of outliers of sediment scattered over the Pre-Cambrian suggests that they at one time completely covered it in this portion of the Dominion, but have been removed by denudation. These lie almost horizontally, dipping only 6 to 9 degrees to the south-west. They are for the most part, clean limestones running as high as 96 per cent calcium carbonate. They are shaly in a few places, but, as a rule, very compact, affording an excellent building stone. A reddish sandstone is found as the lowest member of the series, and is tentatively correlated with the Potsdam (Upper Cambrian), the evidence being purely stratigraphic, for no fossils are found in this formation. These sandstones are rather noted, however, for the purely concretionery forms they contain. To the south-west of the sandstone and at a higher horizon, are the Lowville limestones (Lower Ordovician).

As a surface covering for the whole district is the usual glacial drift of Pleistocene times. This drift is quite unsorted in most places over this area, but in a few localities has been water-sorted into great beds of clay, sand, gravel or boulders. The clays are used for the manufacture of common brick and tile; the sand and gravel for building purposes, road-metal or railway ballast; and the boulders in some cases for building rubble masonry. Most of the drift is unsorted however, so that splendid sections of glacial drift, with its variety of boulders, and its erratics can be obtained.

## LEAD, PHOSPHATE AND MICA DEPOSITS.

### INTRODUCTION.

This excursion has been planned to visit a few of the economic deposits found in the Pre-Cambrian rocks of this district. Some of these, for example the mica deposits, are amongst the largest producers in the world, and are therefore interesting. Others, like the phosphate mines, were formerly large producers, but are no longer worked. Their association is so much like that of the phosphate deposits of Norway, as described by Broegger and Reusch, that they should prove interesting. The lead property is not a big producer, but the occurrence is interesting in that it illustrates a point in ore deposition, for where the wall rocks are gneiss the ore is galena with no zinc blende, but where they are crystalline limestone both galena and zinc blende occur. This excursion will also afford an excellent opportunity for studying the general character and topography of a typically Pre-Cambrian area.

## ANNOTATED GUIDE.

Miles and Kilometres.

0 m. 0 km. **Kingston.**

Going in a northerly direction from Kingston for the first thirteen miles, the road runs over the flat-lying Ordovician sediments, whose general characters have already been described.

13 m. 20·8 km. **Loughboro Lake.**

18 m. 22·8 km. **Perth Road.**

At Loughboro Lake it passes on to the Pre-Cambrian area, and continues for 5 miles to Perth Road, where a fissure vein of white calcite carrying galena and zinc blende is being mined. This deposit was located in the early seventies, and was worked in a desultory fashion until 1875. It was then leased to an English company, which from a shaft 250 feet (76·1 m.) deep mined about 2,000 tons of ore averaging 12 per cent lead, and 5 ounces of silver to the ton of galena.

Following the strike of the vein northwestward it passes into a swamp, but emerges again after half a mile, at which point it contains both zinc and lead. Moreover the wall rocks have changed from gneiss on the south side of the swamp, to crystalline limestone on the north side, the contact lying somewhere in the swampy ground.

In 1880 a lead smelter was built in Kingston to treat these ores, but after two years of operation the property and smelter were abandoned and remained so until two years ago, when the present company took them up. This company has rebuilt the smelter and is treating domestic ores, lead refuse, as well as the concentrates from their own mines at Perth Road. They have traced the vein farther northwestward and are developing the property more thoroughly than was ever done before.

Miles and Kilometres.

Five miles (8 km.) in a southwesterly direction, is the abandoned

23 m. 36·8 km. **Foxton Mine.** Foxton phosphate mine. This was opened in 1878 by James Foxton, and from it calicum phosph ate was mined for the manufacture of fertilizers. This mineral is found in segregations within pyroxenite intrusions which cut the Grenville gneisses and crystalline limestones. The mineral varies in colour from sea-green, through reddish, pink, greyish, to brown, and is usually in large crystalline masses, but occasionally in finer granular masses or "sugar-phosphates". The pyroxenite intrusives cut the Grenville gneisses and crystalline limestones, and are therefore clearly of later age. The pyroxenite itself is cut by dykes of more acidic character ranging from diabase to pegmatite. The close association of many of the largest deposits of apatite with these later dykes would suggest that the development of the phosphate in the pyroxenite was partly due to these later intrusions. The phosphate does not occur as true veins or fissure fillings, but rather as segregations or pockets in the basic pyroxenite intrusives. Where these latter conform to the gneissoid structure of the country rocks, a banded appearance, suggestive of vein structure, would naturally be produced. This occurrence is extremely like that of the phosphate deposits of Norway, which are described by Broegger and Reusch as occurring in basic gabbro.

After a careful study of all the phosphate deposits in Canada, Mr. E. D. Ingall says "The phosphate bodies are distributed through these belts in the most irregular manner. In a few instances they show a general extension of the phosphate in a plane, which gives them the appearance of having followed a vein, but there are no walls, nor sharp planes of division which persist for any distance between the phosphate and the enclosing rock. Most of the excavations made show the bodies of mineral to be of extremely irregular shape, merging into the enclosing rock, and holding varying proportions of inter-mixed rock. At places very large bodies of almost pure phosphate have been encountered, yielding many thousands of tons."

The phosphate of this district is usually closely associated with mica and pink calcite, and in the early days of the mining industry, the mica was removed and went to the dump as a waste product—many hundreds of tons in this way being lost to commerce. In actual mining it was frequently found that the phosphate was of little economic value when it occurred with calcite and mica, for the amount was insufficient to repay the actual cost of its separation by itself. The great economic deposits of the mineral were those in which the apatite was found in large pockets without much mica being present. It would therefore appear that certain deposits within the pyroxenite are composed essentially of apatite, mica, and pyroxene; while others are essentially calcite, mica, and pyroxene. Naturally there will be deposits of intermediate character where calcite, apatite, mica, and pyroxene will be intimately associated. It is also clear that many of the phosphate mines later became mica mines, especially as the phosphate industry in Canada was soon displaced by that of the Southern States.

The phosphate in this district carried 80 per cent or more of calcium phosphate. This was shipped to the town of Smith's Falls, on the Rideau Canal, and was there manufactured into fertilizers. The mineral was ground by buhr-stones to 100 mesh, then conveyed to a vat with sulphuric acid, where it was agitated for twenty-four hours. Hydrofluoric acid was liberated, and allowed to pass off into the air, while in the vat a precipitate of calcium sulphate was formed, and calcium acid phosphate went into solution thus:—

Miles and Kilomteres.

$Ca_3(PO_4)_2 + 2H_2SO_4 = 2CaSO_4 + CaH_4(PO_4)_2$.

After drying, the whole mass was disintegrated and mixed with proportions of hydrochloric acid, ammonium sulphate, potassium and sodium nitrates, and sold in various grades of fertilizer from $32 to $44 per ton.

Many accessory minerals are to be found about the old dumps of this property, including phlogopite, scapolite, wilsonite, pyroxene, pyrite, zircon, calcite, hornblende, and many others.

28 m.
44·8 km.

**Lacey Mica Mine.**

A mica deposit of the type mentioned in discussing the phosphates, lies in a southerly direction from the Foxton mine. Segregations in such cases as the Foxton mine often contain calcite, mica, and pyroxene, and form splendid sources of mica. The best deposit of this kind yet discovered, and one of the biggest individual mica mines in the world, is the Lacey mine, which is now the property of the General Electric Company of Schenectady, New York. This mine was first opened as a phosphate mine when the market was active for that substance in 1879. It was never profitable as a phosphate mine, however, and was converted into a mica mine and worked spasmodically from 1880 to 1901 by local individuals, or small companies. It was then taken over and operated by the present company, who obtain a product from it surpassing in quality and quantity anything that had been anticipated. The property has been opened to a depth of 185 feet (33·4 m.), and pockets have been found 25 feet (7·6 m.) in width, which were almost a solid mass of mica crystals. These were of enormous sizes; the largest one is said to have been over 9 feet (2·7 m.) in diameter.

The mica of this mine is exceptionally well suited to electrical purposes. Being light

Miles and Kilometres.

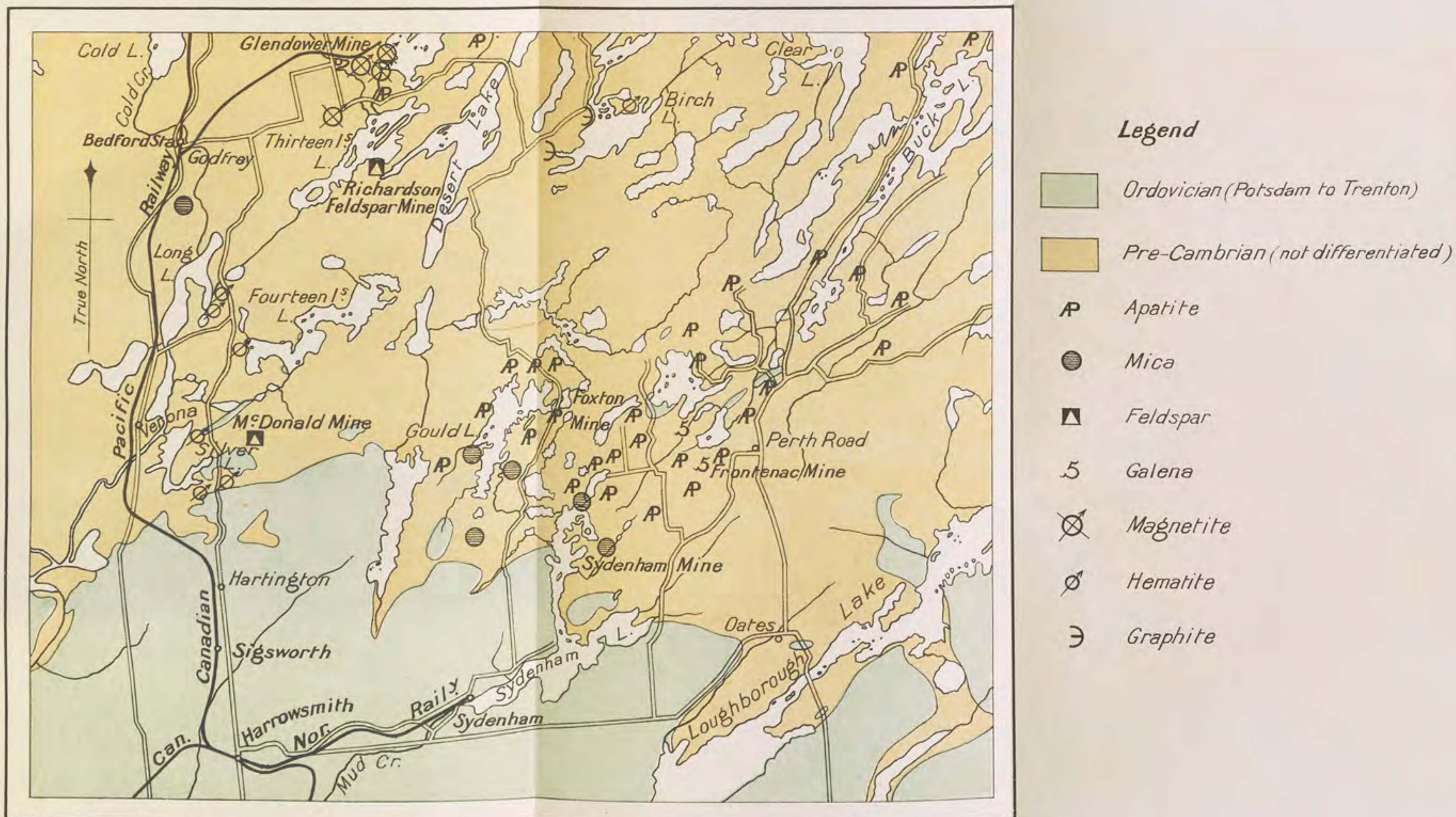
amber in colour, it is transparent, so that defects, flaws, or inclusions can be easily seen. It is quite pliable and can be bent into various shapes without cracking. Its chief use is in insulating the parts of electrical machines, and, being incombustible and resistant to decomposition, it is unimpaired by time. Lacking sufficient quantity of large-sized mica to satisfy the demand, the users have now succeeded in building up plates of required sizes from small pieces cemented together with shellac. The resulting product, called "micanite," has practically all the qualities of the larger pieces of clear mica. The mica used for this purpose is not poor scrap mica, but simply the smaller sizes of the high-grade mica. The still smaller, waste sizes are padded to make boiler covering, or finely ground to a mica flour, which may be used for tempering steel, or as an absorbent for nitro-glycerine in the manufacture of an explosive called "mica powder," or as a lubricant for wooden bearings, or, mixed with oil, for metal bearings.

39 m.
62·4 km.

**Counter's Corners.**

Returning 11 miles (17·6 km.) towards Kingston, a visit is made to a barite vein, which cuts the flat-lying Ordovician limestone. At Counter's Corners this vein is from one (3 m.) to four feet (1·2 m.) wide. It dips vertically, and strikes northwest, and can be picked up at intervals as far as Varty lake, a distance of 14 miles (22·4 km.). The limestone is dense and hard, with shaly partings, and its contact with the barite is very sharply defined, so that there is no transition from the one into the other. Moreover, along the contact is a coating of anthraxolite, and some fluorite, indicating that the vein had not filled from the surrounding country rocks, but owes its origin to a deep-seated source. Approximately 100 tons have been mined

A 9.




Geological Survey, Canada.

Route map between **Sydenham** and **Glendower**

Miles

1 0 2 4 6

Kilometres

1 0 2 4 6 8 10

Mil
Kilo

39 m.
62·4 k

from the east end of this vein, ground in a local flour mill, and shipped for paint manufacture.

Barite vein in Ordovician limestone.

# FELDSPAR, CORUNDUM AND SCAPOLITIZATION.

## INTRODUCTION.

The object of this excursion is to examine certain large pegmatite dykes, from some of which quartz and feldspar are mined in commercial quantities, a good indication of the size and perfection of their crystallization. A rather unusual occurrence of corundum will be seen in anorthosite, and examples of scapolitization will also be seen. In a series of augite gabbros, the feldspars have changed to scapolite, while the pyroxene has changed to uralite, producing an interesting rock, good samples of which may be procured. Associated with this rock is a body of titaniferous magnetite, which was formerly mined. The route of this excursion lies entirely in Pre-Cambrian country.

## ANNOTATED GUIDE.

Miles and Kilometres.

0 m.
0 km. **Kingston.**

25 m.
40 km. **Verona.**

Travelling from Kingston over the Kingston and Pembroke railway to the village of Verona, carriages will take the party to the Richardson feldspar mines on Thirteen Island lake. Half a mile (·8 km.) from the town is an exposure of Grenville dolomite containing graphite, chondrodite, and phlogopite mica in small crystals. One and a half miles (2·4 km.) farther on is a large pegmatite dyke, in which feldspar and quartz are so largely developed that they have been mined separately and shipped for industrial purposes.

33 m.
52·8 km. **Richardson Feldspar Mine.**

Six miles (9.6 km.) farther on lies the Richardson Feldspar mine, the largest mine of its kind on the continent. This deposit is an enormous pegmatite dyke, from which the potash feldspar and the quartz are mined separately. In the process of treatment the feldspar is fused, and forms a glaze for such clay products as earthenware dishes, electrical insulators, reflectors, porcelain tubs, bath-room fixtures, and household untensils. The quartz is used in electrical furnaces at Niagara Falls for fluxes, ferrosilicon manufacture, artificial abrasives, carbide, and other manufactures. This mine has turned out as much as 30,000 tons of feldspar in one year. The

Miles and Kilometres.

excavation is now 500 feet (152·3 m.) long, 200 feet (60·9 m.) wide and 130 feet (39·6 m.) deep, all of which work has been done in the last 8 years.

Crossing Thirteen Island lake, and Thirty Island lake, and about half a mile west of the latter lake are the old pits of the Glendower Iron mine. The mine is situated at, or close to the contact of Grenville gneisses with crystalline limestone. The property was worked from about 1873 to 1890, but has since been idle, apparently on account of the increase in sulphur in the ore beyond a depth of 150 feet (45·7 m.), where iron pyrites became so abundant as to render the ore unfit for use.

35 m. 56 km. **Glendower Iron Mine.**

The occurrence of interest at this point is the so called "plagioclase scapolite diorite" of Adams and Lawson, [**5**]. In the excursion to the lead, phosphate and mica deposits, it was noted that a series of pyroxenites, which cut up through the Grenville gneisses and crystalline limestones, were constantly associated with the apatite deposits. In places these intrusives appear to have been more acidic in character, becoming augite diortites which contained originally augite, hornblende, plagioclase, and some quartz. The hornblende so predominates that when foliated, they have been called amphibolites. In places they present a mottled appearance, closely resembling the "geflecter gabbro" associated with the apatite occurrence in Norway. This mottled appearance is due to concentrations of black, coarsely crystallized hornblende in a lighter colored ground mass, made up of scattered hornblende crystals in a greenish waxy looking mineral of feldspathic appearance. This lighter portion is more easily weathered than the hornblende spots and is often somewhat sunken below the general surface.

Miles and Kilometres.

An examination under the microscope shows that this greenish feldspathic mineral is scapolite secondary after plagioclase. In some places the polysynthetic twinning of the plagioclase can still be seen in the scapolite. Most of the amphibole is a rich green original hornblende, but some of it is secondary uralite after augite. This secondary hornblende is darker in color, and is more or less fibrous or shreadlike, and is intergrown with pyroxene, which often remains as "rests" with a collar or uralite surrounding. Accessory minerals in the scapolitized rock are epidote, enstatite, rutile, and pyrrhotite.

For these reasons, this rock has been termed a plagioclase scapolite diorite, and where it has been rendered more or less foliated or schistose, it is called a "plagioclase scapolite amphibolite." The scapolitized gabbro is much freer from oxide of iron than is the ordinary augite diorite or gabbro, and Dr. W. G. Miller suggests [**6**] that in the process of alteration of the gabbro, the iron oxides were leached out, and deposited from solution in the neighboring limestone, thus giving rise to the iron ore bodies.

37 m. 59·2 km. 47 m. 75·2 km.

**Godfrey Parham.**

From this point a return is made over the branch railway line to Godfrey, and thence northward over the main line to Parkham. In this vicinity the railroad passes through some cuts in the same scapolitized gabbro. One of these ridges followed northwestward leads to Eagle lake, where another abandoned phosphate mine, the Boyd Smith, is seen.

**Boyd Smith Phosphate Mine.**

This property was second only to the Foxton mine, as a producer of phosphate, when that industry was at its height. At that time considerable titaniferous magnetite was found, and some of it was formerly mined.

The magnetite carries traces of cobalt and nickel.

Scattered about this locality are many boulders of anorthosite which carry corundum. These rocks are found "in situ" a short distance north and north-east [**7**, p. 227]. Of these boulders Dr. Miller says "They are rather dark colored on the weathered surface, but have a characteristic bluish or purplish color, which can be made out even at some distance from them, and this serves to distinguish them from the boulders of trap and other dark colored rocks, which are associated with them. The majority of the crystals of corundum have a diameter of about half an inch (1·27 cm.) and show a striking uniformity in size. The color is light grey to almost white, and they average about 5 per cent of the rock. Owing to their greater hardness and durability, they stand out well above the surface of the rock which holds them."

Under the microscope the anorthosite is seen to consist of the basic plagioclase, bytownite, with common green hornblende. Scattered through the bytownite are innumerable crystallites, which are possibly corundum although nothing was determined to confirm this suspicion."

## PALEOZOIC–PRE–CAMBRIAN UNCONFORMITY.

### INTRODUCTION.

Splendid opportunities for seeing the relationship of the Paleozoic sedimentary rock to the old Pre-Cambrian floor are to be had in the city of Kingston. On this excursion several points will be visited where the Paleozoic can be seen lying unconformably upon the Pre-Cambrian. In the lower basal beds, boulders of the Pre-Cambrian are cemented by a limestone mud, which gradually passes upward into clean limestone beds away from the actual contact. At one exposure of the Potsdam

(Upper Cambrian) sandstone, a group of unique concretions is to be seen. These stand in tree-like forms, in vertical position, and cross the bedding of the sandstone. One of these cylinders is fully 15 feet (4·5 m.) in diameter. These sandstones show some interesting bleaching effects, where the red iron oxides, on being leached out of the sandstone, produce white bleached spots or streaks.

## ANNOTATED GUIDE.

Miles and Kilometres.

0 m. 0 km. **Kingston.** Leaving Kingston by automobile, the road leads in a north-easterly direction along the west side of Rideau canal. The country is flat in character, as the rocks are bedded limestones of Ordovician age. After $4\frac{1}{2}$ miles (7·2 km.) of such country, the road descends a steep hill which forms a cliff-like margin to the old channel of Rideau river, which was incised along the contact of the Ordovician with the Pre-Cambrian floor. A half mile (·8 km.) farther on is Kingston Mills.

5 m. 8 km. **Kingston Mills.** Here the limestone is seen in the railway cutting to lie unconformably on the Pre-Cambrian. A basal conglomerate composed of large water-worn boulders of granite and gneiss cemented in a limestone mud is seen. The limestone is filled with fragments of the quartz of the old floor, this being the one imperishable mineral it contains. Within 3 feet (·9 m.) of the actual contact, the limestone becomes much cleaner, and is filled with fragments of Orthoceras and Endoceras well preserved.

The granite in the railway cutting shows perfectly fresh exposures, and some of the finest possible examples of jointing in three directions are to be seen. At the east end of the rock cut are the Kingston Mills locks on the Rideau canal, where boats are lowered

Contact of Ordovician limestone and Pre-Cambrian gneiss, Dead Man's bay Kingston.

Miles and Kilometres.

52 feet (15·6 m.) to the level of Lake Ontario. A deep gorge is cut here in the Pre-Cambrian gneisses making one of the most beautiful spots on the inland water-ways of Canada.

9 m.
14·4 km.

Resuming the journey in a north-easterly direction on the east side of the canal, for a distance of 4 miles, (6·4 km.) **Blake's Quarry.** Blake's quarry is reached. This quarry is in Potsdam (Upper Cambrian) sandstone, and is noted for the peculiar concretions it contains. There are innumerable spherical to elliptical sandstone concretions, but the most peculiar ones are long cylindrical forms which are popularly called "Fossil tree-trunks". These stand in vertical position, and the writer would suggest that they represent structural forms laid in eddies, contemporaneously with the surrounding sands. That this sandstone was laid down in moving water is indicated by the abundance of "cross-bedding" shown here. The red Potsdam sandstone yields an excellent building stone in most parts of the quarry.

17 m.
27·2 km.

**Barriefield.**—At Barriefield may be seen a "qua-qua-versal", where Pre-Cambrian gneiss forms the core with Ordovician limestones dipping away from it in all directions. A short distance farther south an intrusive granite dyke of Laurentian age is exposed. This dyke has cut through the gneisses, and along its contact a number of pneumatolitic minerals have developed, for example, fluorite, tourmaline, pyrite, as well as hornblende and chlorite. The dyke itself shows well-developed joint planes, along which these minerals have collected. Excellent glacial gouges and troughs have been preserved here, as well as glacial striation. Southward from this point on the shore of the St. Lawrence river, a classic example of basal conglomerate is exposed, where the limestones are filled with boulders of the underlying Pre-Cambrian.

Tree-like concretions in sandstone near Kingston Mills.

Miles and Kilometres.

Here the limestone is so thin that the exact character of the old Pre-Cambrian floor, before the Ordovician sediments were laid on it, can be determined with certainty. This is one of the most instructive occurrences geologically to be seen anywhere.

18 m. 28·8 km. **Kingston.** Returning from this exposure towards Kingston some interesting weathered surfaces of limestone may be seen. This weathering has all taken place since the Pleistocene glaciation, and being so new, gives an excellent example of the progress of attack on a limestone surface.

## HISTORICAL NOTE.

A few items of history, for which this particular ground is noted, might prove of interest. Fort Henry, which crowns the hill had its origin in the war of 1812. At that time these heights, and all the district eastward along the St. Lawrence river were covered with dense forest. To prevent surprise by landing parties, this forest was cut down, and a strong earthwork erected on the point. Within this, heavy guns were so mounted that they commanded the approach to the harbour, as well as to the mouth of the small bay immediately west of the present Fort; for on this ground were the ship-yards, which mark the site of the first naval yards established in this country, over a century ago. While the war was going on, this fortification, and the batteries situated on Point Frederick commanding the ship-yards, saved the town from molestations by the American fleet, whose head-quarters were less than 50 miles (80·4 km.) away. The present Fort, and the Martello towers, with their pivot guns, were built between 1840 and 1846.

The long wooden bridge, which now connects Barriefield with Kingston, has been in use for over 80 years. At the east end is the entrance to the Royal Military College, which occupies the site of the old naval yards. At the west end was the old trading post, the first one built in Canada west of Montreal. The present military barracks occupies the site of this old post. A short distance southward the City Hall is passed. This hall was built

60 years ago, as the House of Parliament of the then Province of Canada.

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# ILLUSTRATIONS.

## Photographs.