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PRELIMINARY REPORT ON THETFORD-MINES - BLACK LAKE AREA, FRONTENAC, MEGANTIC AND WOLFE COUNTIES

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MINERAL DEPOSITS BRANCH

PRELIMINARY REPORT

ON

THETFORD MINES - BLACK LAKE AREA

FRONTENAC, MEGANTIC AND WOLFE COUNTIES

BY

P. H. RIORDON



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by

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INTRODUCTION

During the 1950, 1951 and 1952 field seasons the writer mapped the geology of a zone extending from Nicolet lake northeast through Thetford Mines and 8 miles beyond. The area includes all the known asbestos deposits and major intrusive bodies in the district. It extends from latitude 45° 50' to latitude 46°10' and from longitude 71°10' to longitude 71°35', and includes the whole of Coleraine township together with parts of Adstock, Garthby, Ham-North, Ham-South, Ireland, Leeds, Price, Stratford, Thetford and Wolfestown townships. The north boundary of the area is 44 miles south of Quebec city. The Quebec Central Railway and the Quebec-Sherbrooke highway traverse the area from north to south.

The geology of the district has been described by many investigators. The bibliography compiled by Cooke (1,p. 3) lists the most important contributions.

Areal mapping was done on a scale of 1 inch equals 1,000 feet. Pace and compass traverses were run at intervals of 1,000 feet. The open pits at Thetford Mines were mapped by plane table on a scale of 1 inch equals 50 feet, and all other operating pits, on a scale of 1 inch equals 100 feet. The map which accompanies this report (Map No. 1030) is on a scale of 1 inch equals $\frac{1}{2}$ mile.

TOPOGRAPHY

The maximum relief in the area is represented by Adstock mountain and Trout lake, which have a difference in elevation of approximately 1,700 feet. There are three prominent northeasterly-trending ranges in the area.

The most northerly range in the area forms a part of the Sutton range, which is the main feature of the Notre Dame mountains and can be traced southwest to the Green mountains of Vermont and northeast to the Shickshock mountains of the Gaspé peninsula. This range reaches a height of 2,100 feet at a point 3 miles west of St. Antoine de Pontbriand. Its continuity is interrupted by the valley of the Bécancour river in which Trout lake, at an elevation of 640 feet, occupies the lowest part of the map-area.

(1) References are at the end of the report, p.23

The central range of hills extends from Caribou mountain southwest to Sunday lake and northeast to the vicinity of Sacré Coeur de Marie. Caribou mountain, the highest point in this range, has an elevation of 1,800 feet. Two gaps in the range are occupied respectively by Black lake, at an elevation of 751 feet, and Pine river, at about the same elevation.

The most southerly of the three ranges extends, with some breaks, from Adstock mountain in the northeast to Louise mountain in the southwest, terminating at Ham mountain, which lies outside the map-area 3 miles southwest of Nicolet lake. The ends of this broken chain of hills are thus marked by two prominent peaks, which reach elevations of 2,300 feet. The gaps in this range are occupied by the Coldstream river, Little St. Francis lake and Disraeli bay.

There are a few isolated hills between the central and the southerly ranges.

GENERAL GEOLOGY

The rocks of the Thetford Mines-Black Lake area are classified as shown in the table of formations on page 3 . In this classification it has been found necessary to make a number of changes in the correlation of the rocks as previously mapped.

The oldest rocks, which belong to the Caldwell group, underlie more than half of the area. The lower series of the Caldwell group is made up mainly of schist, with occasional thin beds of quartzite. The upper series includes quartzite, slate and basic volcanic rocks.

Lying unconformably on the Caldwell group are the rocks of the Coleraine group, which are mainly andesite and trachyte, with associated tuff, agglomerate and breccia.

The Coleraine rocks are overlain by the conglomerate, slate, quartzite and arkose of the Beauceville group.

Folding of the Beauceville sediments was followed by the intrusion, during late Ordovician time, of dunite, peridotite, pyroxenite, gabbro, syenite and granite and the formation of amphibolite and some serpentine. After a further period of faulting, some of the rocks were metamorphosed to serpentine and steatite.

During Pleistocene time glacial deposits of boulder clay, and stream and lake deposits of sand, gravel and clay were formed.

Table of Formations

Cenozoic	Pleistocene	Glacial, stream and lake deposits		Boulder clay, sand, gravel, clay
Palaeozoic	Late Ordovician	Metamorphism		Serpentine, steatite
		Faulting		
		Intrusions, accompanied by the formation of amphibolite and some serpentine		Granite, syenite Dunite, peridotite, pyroxenite, gabbro
		Folding		
	Middle Ordovician	Beauceville group		Conglomerate, slate, quartzite, arkose
		Unconformity (?)		
	Ordovician (or Cambrian)	Coleraine group		Andesite, trachyte, breccia, tuff, agglomerate
		Folding and faulting		
Precambrian (or Cambrian)		Caldwell group	Upper series	Quartzite, metabasalt, tuff, slate
			Lower series	Undifferentiated schist (quartz-sericite, sericite, graphite, quartz-biotite-chlorite, quartz-sericite-biotite, albite-sericite-chlorite, albite-epidote-chlorite, chlorite, rare quartzite)

Caldwell Group

Schist

The schists of the Caldwell group occupy the northwest part of the map-area. They appear to grade into the quartzite and slate members which lie to the southeast. Lenses of schist are found within the areas occupied by the quartzite, and the presence of a schistose facies, along the margins of the amphibolite in the southeast part of the area, suggests the close association of the schists and the other members of the Caldwell group. Similarly, some quartzite is found within the schist area. The contact between the schist and quartzite is commonly ill-defined, and apparently does not conform to any particular stratigraphic horizon. This relationship is readily seen near Pine river in range I, Ireland township, where the schist appears to interfinger with the quartzite, although there is no indication of any complex series of folds, in this locality, that might permit the two rock types to be distinguished as two different formations.

The quartzite found within the schist area is normally a fairly pure variety, but displays a noticeably schistose structure, in contrast to the more massive members found to the southeast. One of the commonest varieties of schist is a quartz-sericite type, which is no doubt the metamorphosed equivalent of the arkosic members commonly found in the quartzite area proper. The altered equivalent of a greywacke occurs as a quartz-sericite-chlorite schist. Sericite schist is probably the most abundant variety and is considered to be derived from the more slaty members of the Caldwell group. Graphitic schist occurs in broad and narrow bands interlayered with the quartz-sericite and sericite schists. Its origin is puzzling, as none of the Caldwell slates appear to be carbonaceous. A distinctive green variety of quartz-epidote schist, carrying numerous octahedra of magnetite up to 2 millimeters in size, occurs to the south and southeast of Trout lake, and may possibly be a derivative of an iron-rich greywacke. Bands of chlorite schist, up to 100 feet wide, are found scattered through the schist area; they are presumably derived from basic lava flows.

Quartz veins, commonly parallel to the planes of foliation, are widespread throughout the schist area. In places the presence and abundance of the veinlets make it difficult to distinguish between the sericite schist and the quartz-sericite schist.

The best exposures of schist in the area are in the beds of McLean and Ragged brooks, to the north and east of Trout lake. The close relations between bedding and schistosity may be observed in the sharp contacts, which are exposed in many places.

Quartzite

The upper Caldwell quartzites are generally arkosic. The size of the grains varies from very fine to 2 or 3 millimetres. Thin layers of arenaceous slate are found throughout the quartzite beds. The quartzites appear to grade upward into grey slates which lack the arenaceous character of the interbedded slate and are generally quite fissile. Foliation is common in the quartzite, and is accompanied by numerous quartz stringers. Veins of barren white quartz are encountered in various localities, but are more numerous in the quartzite in the northwest part of the area.

Quartzite, and minor amounts of interbedded arenaceous slate, occupy a belt, up to 2 miles wide, which extends from the northeast to the southwest corner of the map-area. The contact with the schist to the northwest is gradational. Another area of quartzite is exposed in Bécancour hills, 2 miles southeast of Thetford Mines. In the northeast part of range III, Garthby township, the Carineault hills rise abruptly in the centre of another large area of quartzite. The quartzite northwest of Black lake might more properly be termed a sandstone, for it presents a rough sandy surface. Similar rocks were seen at a few other localities, along the southeast margin of this belt. The cement of all these rocks, however, is dominantly quartz.

Basalt

The Caldwell lavas are predominantly basaltic, with a little associated andesite. They occupy a belt extending from Sacré Coeur de Marie, in the northeast part of the area, to the north end of Black lake. These lavas are commonly pillowed, and, although the pillows are distorted, the rock is generally massive and resistant to erosion. Its presence is marked by a series of prominent ridges and hills. In the vicinity of Thetford Mines this belt of lava is interrupted by a lobe of the main peridotite mass.

The basalt appears to lie conformably above the quartzite. A short distance northeast of the present area Cooke (2, p. 5) reports basalt interbedded with quartzite. The lenticular body of serpentine west of Caribou mountain appears to be associated with a narrow band of volcanic rock interbedded with the quartzite. Although it is generally schistose, flow textures are apparent on one of the two small exposures of the volcanic rocks. The rock is considered to have been probably andesitic in composition. Bands of chlorite schist, up to 100 feet in width, occur within the main area of schist, and are presumed to be derived from basic flows.

Slate

The slate which occurs interbedded with the quartzite is commonly grey and arenaceous. Toward the top of the quartzite series, where the slate is in greater abundance, some blocks of quartzite are found intermingled with the slate measures. However, immediately beneath the lavas there is an appreciable thickness of pure slate. In these upper measures the slate is highly fissile and includes red and green as well as the grey variety. The red slate is ordinarily at or near the top, and may be a variety of tuff.

The extensive areas of Caldwell slate north of Lac du Huit are largely grey slate accompanied by some small lenses of pure, fine grained quartzite, some red slate and lesser amounts of cherty material and tuff. The slate has been severely contorted and presents a twisted, knotty appearance.

Coleraine Group

The name, as originally used, included all of the volcanic rocks in the map-area (3). In the more restricted sense, now used, tha basalts of the north half of the area, and those volcanic rocks interbedded with the Caldwell rocks or associated with the amphibolite, are included with the Caldwell and therefore excluded from the Coleraine group. This group consists of breccia and a series of volcanic rocks which are chiefly acid and tuffaceous. These rocks occur in the southeast half of the map-area, occupying most of the northeasterly-trending trough between the two large intrusive masses, and a narrow northeasterly-trending belt which extends from the west side of Coulombe lake to Adstock mountain.

Breccia

This rock is largely confined to small exposures, which are, in almost all cases, closely associated with acid flows and tuffs. The only exception noted is in the Morin Hill area, where no other layered rocks are in evidence. The breccia is made up of angular fragments of foliated, quartz-veined quartzite up to 6 feet, but generally less than 1 foot, in size. The edges of the fragments are only slightly rounded. The breccia in the Morin Hill locality consists almost entirely of quartzite, with some schist and slate. Certain parts of the other exposures contain this variety of fragments only, but in most of them there is a scattering of other rock types including gabbro, acid and basic lava, and some granite. Any one of these types, except granite, may predominate locally within or along the margin of the breccia.

The relation between the breccia and overlying volcanic rocks is well displayed in an outcrop three-quarters of a mile south of Little St. Francis lake. This breccia consists largely of fragments of quartzite up to 2 feet in size. Locally, however, an abundance of trachyte fragments gives the rock the appearance of an agglomerate. Crossing the outcrop from north to south, the breccia is seen to grade into slaty material over a distance of 6 feet. The slaty material forms a fairly sharp contact with more coarse breccia to the south. A few feet farther south, the nearly vertical contact of the breccia with a trachyte flow is clearly exposed. At one point fragments of quartzite, up to 4 inches in size, were found scattered through the lava at a distance of 5 feet from the contact. About 15 feet of lava is succeeded on the south by grey fissile tuff. This occurrence of breccia indicates that the quartzite breccia is probably of explosive volcanic origin. Fron the nature of the fragments of schist and quartzite it seems evident that they were derived from the Caldwell rocks, and that a long interval of time was required to permit the formation of these metasediments prior to the volcanic activity, which probably gave rise to their brecciation, and caused this fragmental material to be buried beneath the lava and tuff. It is for these reasons that the breccias, the acid volcanic rocks associated with them, and the more basic lavas that appear to underlie conformably the acid lavas and tuffs, have been excluded from the Caldwell group.

Relationships somewhat similar to those described above were observed by Cooke (1, p. 31) along the north side of Drouin ridge, 1 mile southwest of Coleraine. The breccia which outcrops to the west of East lake appears to consist entirely of quartzite fragments. Contacts with the surrounding tuffs are not exposed. The breccia in the village of Coleraine consists of a heterogeneous mixture of fragments of quartzite, gabbro and lava. It lies adjacent to outcrops consisting essentially of brecciated tuff. In all probability folding and faulting, around what appears to be the crest of a fold, have been responsible

for the brecciation of the tuff. The great variety of rock types intermingled with the quartzite fragments suggests a sedimentary or explosive origin for this assemblage.

In the area northeast of Brousseau hill, the breccia is also somewhat heterogeneous and appears to be overlain by tightly folded, thin-bedded tuff. The most northerly group of outcrops in the Morin Hill area consists of fragments of quartzite up to 6 feet across. The group of outcrops to the south is made up of much finer material with only a few coarse fragments. There is some possibility that this occurrence is a crush breccia.

Volcanic Rocks

These rocks are predominantly grey, red and green tuff and agglomerate, with lesser amounts of rhyolite and trachyte. Andesite, and possibly some basalt, form discontinuous bands which appear to underlie the more acid lava and tuff. The more basic members of these lavas are in part pillowed, and locally coarse tuff is found interbedded with them. There is an evident increase upward of tuff, into an assemblage of agglomerate and thin-bedded tuff, accompanied by some trachyte and a few flows of rhyolite.

These volcanic rocks are best exposed in a belt along the Bisby river, from Disraeli bay northwest to Peach lake. Other exposures are found on Oak Hill and around the margins of the slate which occupies the middle of the trough west of Coleraine. Only a few scattered outcrops mark the extension of these rocks northeast of Coleraine.

MacKay has noted the presence of acid lavas and tuffs at the base of the Beauceville group in the vicinity of rivière des Plantes, about half way between St. Joseph de Beauce and Beauceville (4, p. 25); between these volcanic rocks and the Beauceville slate there is a conglomerate (4, p. 26). In the Beauceville group as described by Cooke (1, pp. 33 to 35) there are no volcanics, but a succession consisting of (a) basal conglomerate, (b) slate and (c) slate quartzite and conglomerate. From MacKay's description of his Beauceville conglomerate and Cooke's description of the basal conglomerate of his Beauceville series, it may be concluded that these two members are equivalent. In the Thetford Mines - Black Lake area, as in the Beauceville area, the conglomerate is underlain by volcanics, both acid and basic. The absence of the basic lavas beneath the acid volcanic rocks in Beauce county can be explained by considering these acid rocks to be in faulted contact with the adjacent Caldwell rocks lying to their north.

Beauceville Group

The Beauceville group consists almost entirely of slate, with a slaty basal conglomerate, and interbedded greywacke and conglomerate. These rocks occupy the southeast part of the map-area, and the troughs to the east and west of Coleraine. The slate measures found in these troughs are correlated with the rocks of the Beauceville area, to the southeast, on the basis of their position relative to the Coleraine volcanic rocks, which they overlie, and their evident similarity in composition. They consist for the most part of highly fissile black pyritiferous slates. Slaty conglomerate, typical of the basal Beauceville member, is found at a number of localities, notably adjacent to the tongue of volcanic rocks which extends northward 1 mile east of Belmina ridge.

Thin beds of greywacke are interbedded with the slates throughout the area, but are found in greater numbers along the low ridge southeast of the St. Francis river. A sandy conglomerate, measuring 100 feet in thickness, occurs interbedded and interfingered with, the slate immediately northeast of Disraeli bay. Subangular pebbles of shale, and possibly tuff, up to 1 inch in size, are scattered through a fine grained ground mass of what appears to be similar material. A highly carbonated, massive conglomerate, with a thickness of about 1,000 feet, occurs 2 miles south of the outlet of St. Francis lake. It appears to consist almost entirely of subangular pebbles of slate up to one-quarter of an inch in size.

The basal conglomerate of the Beauceville group contains what have been described as pebbles of Caldwell slate. It is probably true too that many of the pebbles are composed of tuff and weathered lava derived from the Coleraine rocks. An erosional unconformity between the Beauceville and Coleraine groups is therefore indicated. Further, the manner in which the Coleraine volcanics terminate abruptly against the Beauceville slate in a number of localities, particularly to the west of the village of Coleraine, suggests an angular unconformity. The age of the Beauceville rocks has been established as Middle Ordovician (5), and it is therefore assumed that the Coleraine group is either Lower Ordovician or Cambrian in age

Intrusive Rocks

The intrusive rocks in the area can be divided into two distinct assemblages, one extending from Thetford Mines southwest to Nicolet lake and the other from Lac à la Truite to Disraeli bay.

The northwesterly assemblage is made up, for the most part, of olivine-rich peridotite with some dunite and minor amounts of pyroxenite. Of a similar character are the Pennington sill, which extends from Thetford Mines to the northeast corner of the map-area, and the numerous isolated intrusive masses which are confined mainly to the northwest half of the area.

The southeasterly assemblage is made up of dunite, pyroxenite and gabbro with minor amounts of peridotite. In general, these rocks are much coarser grained than those of the northwesterly assemblage.

Dunite

The dunite shown on the map is an olivine rock, virtually free of pyroxene, containing disseminated, and in some places massive, chromite. A major part of the dunite has been completely converted to serpentine, without destroying the original rock texture. The rock weathers to an ochre red when only partly altered, and to a cream or creamy brown if completely serpentinized. The less altered variety retains some of the characteristic olive green colour on the freshly fractured surface, which is normally sugary in texture. Freshly broken, serpentinized dunite is normally dense, dark olive brown, and commonly displays a somewhat conchoidal fracture.

Irregular shaped bodies of dunitic rock are scattered through the olivine-rich peridotite mass. Some of these bodies have a distinct lenticular form, but nowhere within the peridotite area were the contacts found to have intrusive relationships. One of the bodies of dunite is exposed on Quarry hill, where the presence of an adjacent pyroxenite body suggests a local, complete segregation of olivine and pyroxene. The island of peridotite at the top of Provençal hill appears to overlie the dunite, which outcrops all along the south-east side of the hill. It appears that the peridotite was isolated from the main mass to the north by erosion and exposure of the underlying dunite. Detailed mapping in this locality revealed a very irregular, sharply gradational contact between the two rock types.

The dunite found in association with the pyroxenite bears somewhat similar relation to this rock as it does to the peridotite, with the exception that the contacts between the two are much more complex. This relationship suggests that movement in the magma during the process of segregation, and co-existence of pyroxenite and dunite in a semi-liquid state, permitted a complicated intermingling of the pyroxenite and dunite. Wherever the dunite contact is approached, the outcrops display flow structures involving a twisted and contorted mixture of dunite and pyroxenite. Pyroxene crystals are broken and severely distorted, and there is every indication that this deformation occurred during the consolidation stage. Although the dunite-peridotite contacts are extremely irregular, they are at least sharp and traceable, whereas it is seldom possible to place the dunite-pyroxenite contact along any particular line, due to the intermingling of the two rocks.

Peridotite

The peridotite that makes up much of the intrusive mass extending from Thetford Mines to Nicolet lake contains about 15 per cent pyroxene in the form of enstatite, along with some accessory, disseminated chromite. The presence of pyroxene crystals gives the weathered rock an uneven surface, and on the freshly broken surface the pale green colour of the pyroxene, in contrast to the darker olivine, serves to distinguish this rock from the dunite. Even in the completely serpentinized variety, the presence of pyroxene is revealed by the uneven fracture and by either the cleavage faces of the bastite, or its darker colour, which gives the rock a spotted appearance. The pyroxene crystals are seldom more than 4 millimeters in size. Locally, minor segregations occur, which give the rock a content of up to 30 per cent pyroxene.

A type of banding, or layering, is seen at various places within the peridotite mass, and is most evident on Belmina ridge. These layers, which seldom exceed 2 inches in thickness, are generally straight or gently curved,

and contain greater concentrations of pyroxene than adjacent layers. The layering is present across widths ranging up to 50 feet, and can be traced for several hundred feet along the strike before it fades into structureless rock. Dips are normally steep to vertical, and strikes are predominantly north. Apart from these local variations, and the small occurrences of dunite already mentioned, the peridotite mass, as a whole, is remarkably homogeneous.

Pyroxenite

The pyroxenite is generally coarse grained and contains crystals of enstatite and diallage which reach sizes exceeding 2 centimeters. The bodies of pyroxenite include a good deal of intermingled dunite, and a fair proportion of pyroxene-rich peridotite.

Two generations of pyroxenite were identified. The first generally carries some olivine and weathers to a rusty red, whereas the later variety contains no olivine and weathers grey. No chilling of the second against the first is apparent, and there can be little doubt that the grey-weathering variety marks the final stage of the ultrabasic intrusion. The lack of intrusive dikes of pyroxenite anywhere well within the larger dunite bodies indicates that dikes of pyroxenite, which are found cutting the peridotite, as well as the pyroxenite, are merely a pegmatitic facies of these rocks.

Layering, similar to that found in the peridotite, is even more prominent in the pyroxenite, due to more complete segregation of olivine and pyroxene. Individual layers are normally thicker, with widths up to 1 foot. The attitude of the layering is generally steep; however, in the centre of the Red hills, sharp changes in the strike are accompanied by flatter dips, which suggest the presence of a pseudo-anticlinal structure plunging west. The highest outcrop of dunite in this locality occurs on the axis of this structure. Tight folding after consolidation might have produced these relationships; however, there is little evidence within these massive rocks that would substantiate any such intense deformation. It seems more probable that the present attitude of the layering has been brought about by continued movement of the dunitic material in a semi-liquid mass.

Dunite-Peridotite-Pyroxenite Relationships

No contacts of the main body of peridotite and the adjoining pyroxenite were seen. The closest observed outcrops of these two rock types are at the southeast side of Reed hills, where they are separated by 600 feet of drift-covered ground. Although the peridotite in this locality contains local segregations, which give a content of as much as 30 per cent pyroxene, there is no accompanying increase of grain size. Gradations from low pyroxene to low olivine peridotite, in the vicinity of the contact, is noticeably lacking.

The southeast half of the top of Oak hill consists of pyroxenite and some intermingled dunite. In the vicinity of the steep-sided west end of the main ultrabasic outcrop, an area of dunite breccia, in a matrix of pyroxenite, is well exposed. The dunite belt associated with the main body of peridotite lies along the northwest side of Oak hill. At no other locality within the pyroxenite areas were the dunite and pyroxenite found to have such clean-cut relations as those in this breccia, which strongly suggest injection of pyroxenite into previously consolidated brittle dunite.

The relationships described above indicate that the contact between the pyroxenite and peridotite, with its associated dunite, is intrusive, and that the pyroxenite is almost certainly later than the peridotite.

The general relations between the peridotite-dunite and the pyroxenite-dunite bodies suggest that an early injection of ultrabasic magma was cooled sufficiently rapidly to give rise to a remarkably homogeneous, equigranular mixture of olivine and pyroxene, and only allowed limited fractionation to occur. As a result of this rapid cooling, small bodies of dunite remain scattered through the peridotite, and the underlying dunite fraction, exposed along the southeast flank, is small in comparison to the related peridotite mass. Immediately following the consolidation of this earlier injection, there occurred another upward advance of the ultrabasic magma into rocks already hot. Cooling of this magma was sufficiently slow to permit of a more complete segregation of olivine and pyroxene, and resulted in the formation of coarse grained pyroxenite, and a consequently far greater proportion of dunite.

The form of the peridotite-dunite and pyroxenite-dunite bodies has been strongly influenced by the structure of the invaded rocks. The elongation of these bodies conforms to the regional strike and, generally speaking, the strikes of the country rocks around their margins show no evidence of pronounced transgressive tendencies. Drilling at several points along the northwest contact of the peridotite has revealed a northwest dip, and a good deal of interfingering of the intrusive with the quartzite and slate. In the vicinity of the Vimy Ridge mine dips of 15° to 30° prevail; however, the configuration of the contact at this point suggests the presence of a cross fold or drag fold. General relationships point to some crosscutting by the intrusive, where in one place it is in contact with the Caldwell quartzite and in another with the Caldwell lavas; however, it has been shown that these lavas may in places be interbedded with the quartzite (1, p.19), so that such evidence is not conclusive.

The layering, which is present at various places throughout the ultrabasic bodies, has almost everywhere steep attitudes. There is no evidence to show that later folding has accounted for these attitudes, and if it is assumed that the plane of the layering has developed parallel to cooling surfaces, it might be concluded that these intrusive bodies were originally steep sided, and that their tops have been completely removed by erosion. From the evidence, in general, it is inferred that they are not tabular in form, but have probably forced their way up along fold axes in the country rocks, thrusting aside the overlying rocks to some extent, and locally spreading out laterally.

The isolated occurrences to the northwest of the peridotite are composed for the most part of fish-scale serpentine, or have been partly replaced by magnesium carbonate. Identification of the original rock is not easy; however, any identifications that have been made indicate these rocks to be peridotite. They appear to be sill-like, and are no doubt offshoots of the main body to the south. The occurrence 2 miles north of Thetford Mines is the southern extremity of the Pennington sill which has been traced for 15 miles to the northeast. The serpentine immediately west of Caribou mountain appears to have been injected along a narrow band of volcanic rocks.

Gabbro

The gabbro ranges in texture from very coarse to very fine grained, and in many instances both coarse and fine grained material are intermixed. The rock is normally dark green, flecked with white; however, the more dioritic facies, such as that found in the vicinity of Mount Louise, are greenish grey.

The general distribution of the gabbro suggests a close association with the pyroxenite, and gradational contacts have been observed between the two. Such contacts are well displayed on the top of Bengel mountain and on the northeast end of Adstock mountain. Furthermore, a gabbro dyke cuts the pyroxenite on Bengel hill.

On the other hand, apophyses of pyroxenite may be seen to extend short distances into the gabbro near the east end of East lake, but these are highly serpentinized and appear to be severely deformed. It seems probable that the pyroxenite, in such cases, was 'injected' after consolidation and serpentinization. At most of the contacts between gabbro and ultrabasic rock, the latter is generally completely serpentinized and both rocks are severely sheared.

The weight of evidence points to the gabbro being closely associated with the ultrabasic rocks, particularly the pyroxenite. The sequence of dunite, pyroxenite and gabbro in the rocks of Bisby ridge strongly suggests a derivation through gravitational differentiation. The gabbro is thus either contemporaneous with or slightly younger than the pyroxenite.

Acid Intrusives

Granite, and probably monzonite, occur, for the most part, as small irregular shaped intrusive bodies in the gabbro and the ultrabasic rocks. No gradational contacts were observed. The more quartz-rich varieties appear to be confined to the gabbro and pyroxenite. Bodies of leucocratic granite are numerous in the Reed hills and Granite hill areas of the peridotite, whereas the acid bodies, situated along the northwest side, are generally quartz-lean, feldspathic rocks, composed chiefly of orthoclase and plagioclase. Most of the occurrence include coarse grained, fine grained, porphyritic, and pegmatitic facies.

Only a thorough petrographic study will permit a proper classification of the acid intrusives to be made.

Amphibolite

The rock is composed essentially of green hornblende accompanied by variable amounts of epidote; in some places quartz is present. The texture ranges from nearly aphanitic to coarse grained, and the rock is either massive or delicately banded. In one locality, by reason of its texture and structure, it was mistaken, in the field, for a basic lava. Sharp contacts have been observed with the peridotite, and with the Caldwell quartzite and schist; however, gradational contacts are more common.

The attitude of the layering in the banded variety of amphibolite conforms with the attitude of the bedding in the adjoining Caldwell rocks. It is possible that some of the amphibolite may have been derived from basic tuffs, but, in view of its gradation into the Caldwell quartzite and schist, it is evident that a part, at least, have been derived from these rocks.

Serpentinization and Related Alteration

The extensive serpentinization of the dunite has already been mentioned in the description of this rock type, and it is generally evident that the olivine of the olivine-rich and pyroxene-rich peridotites is more thoroughly serpentinized than the pyroxene. The main mass of the peridotite may be said to be from 40 to 70 per cent serpentinized throughout, whereas in the pyroxenite areas the degree of development of serpentine has been largely dependent on the relative abundance of olivine. Widespread serpentinization of this nature appears to have pervaded the entire peridotite mass and much of the pyroxenite, and seems to bear no relation to the structure.

Complete serpentinization within the peridotite, and to some extent within the pyroxenite, appears to be confined to certain zones. Wherever the contacts between the country rocks and the peridotite have been exposed, serpentinization is seen to be complete to a distance of at least 1,000 feet from the contact. Complete serpentinization in the vicinity of granite intrusives is normal, and, in some cases, extends to 100 feet from their contacts. Completely serpentinized peridotite, unrelated to any contact or large body of granite, is revealed by drilling and by scattered outcrops as extending southwest from Thetford Mines. These and other minor zones of serpentinization are associated with fairly severe fracturing, which appears to have resulted from adjustments within and along the contacts of the peridotite. Relationships such as these indicate a late stage of serpentinization that has been localized by structural controls.

Carbonate alteration of the ultrabasic rocks has been extensive in some localities, and has resulted in replacement by iron-bearing magnesium carbonate, usually accompanied by talc. In the saddle between Brousseau and Bengel hills, the rock, which is presumed to have been dunite, has been converted to carbonate and talc over an exposed area of 1,000 by 600 feet. Similar alteration was observed in the dunite area west of Oak hill. In the vicinity of Thetford Mines, a broad zone of replacement occurs along the irregular contact to the east, and another zone can be identified with the southwest shatter-zone situated along the southeast side of the pits, and revealed by drilling to extend to beyond 1,500 feet in depth. Beneath the middle of the north-south part of the main body of Black lake a zone of massive carbonate and talc, in association with granite, has been revealed by diamond drilling.

STRUCTURAL GEOLOGY

The Caldwell rocks occupy the southwest limb of a major anticlinal structure, the axis of which passes just east of Trout lake and trends generally northeast. A band of graphitic schist displays remarkable thickening at the nose of the fold, testifying to the extent of deformation by flowage within the schist area.

Another anticline is marked by the presence of quartzite between the two major belts of intrusive rocks. The rather intricate relations between quartzite and volcanic rocks to the east of Thetford Mines is revealed by the extensive core drilling carried out in this area, and indicates the presence of a synclinal structure. A minor anticline appears in the Caldwell rocks immediately southwest of Thetford Mines.

Much of the folding of the Caldwell rocks was apparently accomplished during the Precambrian, as evidenced by the breccia of the Coleraine group which lies, with possible angular unconformity, beneath the late Ordovician Beauceville slate. Metamorphism is more accentuated in the vicinity of the Trout lake anticlinal axis, and it seems probable that the rocks here were composed of a much higher proportion of shale than the adjoining arenaceous rocks to the southeast, which gave rise to the quartzites. As a result of this initial distribution, stress relief tended to be concentrated along the belt of weaker rocks. Although there is no evidence of faulting associated with the earliest folding, it may be assumed to have taken place in view of the intensity of the dynamic metamorphism, which has been shown to have occured at this time.

Following the accumulation of the Coleraine and Beauceville measures, late Ordovician folding took place along axes similar to those established in Precambrian time and was accompanied by successive intrusions of ultrabasic magma. The granite and associated acid intrusives show extreme irregularity of shape and distribution, and probably reached their present positions during an early stage of adjustments in the host rocks. Continuation, or renewal, of the folding, after the emplacement and consolidation of these various rocks, resulted in a further series of adjustments within the ultrabasic rocks, particularly along the northwest contact of the peridotite. Individual fault faces in the mine workings display widely differing directions of movement on successive serpentine laminations, and it is probable that these movements involved only minor displacements. Nevertheless, shattering of the rocks over broad zones was achieved by this churning effect. The pronounced schistosity of the serpentine immediately adjacent to most granite contacts, within these

zones of adjustment, indicates that these relatively competent bodies have served as buttresses which have, for the most part, withstood deformation. Some shearing, and a little brecciation of these acid rocks has been noted. Serpentinization followed the granite injection and persisted throughout the later stage of adjustment, causing complete replacement of the rock mass within and adjoining the shatter zones.

The abrupt irregularities in the trend of the intrusive contacts of the gabbro and pyroxenite northwest of East lake, of the granite of Reed hills, and of the peridotite west of Thetford Mines, have been interpreted as indicating the presence of northwest-striking cross faults. These and other minor post-asbestos faults, which appear in the mine workings, may be attributed to the Devonian, or to a later period of deformation.

ECONOMIC GEOLOGY

Asbestos

Asbestos was discovered in the area in 1876 and production, which commenced on a small scale in 1878, has continued to grow ever since, although there have been brief periods during which a decline was recorded. In 1952, there were 9 producing mines in the area. The larger asbestos deposits of the region are divided, for purposes of description, into 5 groups.

Pennington Group

The Pennington group in the northern part of the area, includes the deposits in the Pennington sill. The mines in this group of deposits are the Federal, Pennington and Flintkote.

Federal Mine

The Federal mine is in lots 9 and 10, range V, Thetford township, the property of Asbestos Corporation Limited. The pit has a length of 1,700 feet and a width of 200 feet. The property has not been operated since 1927.

Pennington Mine

The Pennington mine, the property of Asbestos Corporation Limited, has not been operated since 1923. The pit, which extends over a length of 700 feet and a width of 300 feet, is situated in lots 16 and 17, range IV, Thetford township. The Pennington sill at this point has an apparent width of 600 feet and a steep dip to the southeast. The footwall side of the sill is heavily sheared.

Flintkote Mine

The Flintkote mine, owned by Flintkote Mines Limited, is the only operating mine in the Pennington group. It is situated in lots 18 and 19,

range IV, Thetford township. Lot 18 is owned by Flintkote Mines Limited, and lot 19 is leased by them from Asbestos Corporation Limited. Here the Pennington sill has a width of 150 feet and dips 50° to 70° southeast. Open pit operations commenced in 1946 and by the end of 1952 the pit had reached a depth of 150 feet. The length of the pit is 1,700 feet and the maximum width 300 feet. The Flintkote mill has a capacity of 1,500 tons per day.

Thetford Mines Group

The deposits of this group are at Thetford Mines. They extend over a length of 5,500 feet and a width of 2,000 feet, the long axis trending generally northeast. The mines in this group of deposits, from north to south, are the King, Bell, Johnson, Bennett-Martin and Beaver. A zone of severely shattered ground, which dips steeply northwest, lies immediately southeast of the asbestos-bearing zone and parallel to it. Serpentinization is complete in this shattered ground and below the 300 foot horizon in the ore zone. Associated with the zone of shattering there is extensive replacement by iron-bearing magnesium carbonate, and talc. A zone of massive carbonate, bounded on either side by a mixture of carbonate and talc, was intersected by drill holes and by underground workings in the Johnson mine. Its tabular form suggests a controlling structural feature of similar form. Its proximity to the asbestos deposits suggests that there is some genetic connection between the two.

Subsidiary shatter zones, up to 100 feet wide, generally with steep dips, cut the asbestos orebodies. Associated with the shatter zones are irregular shaped feldspathic bodies. One of these shatter zones was traced along the southeast side of the deposit, in the King and Johnson mines, for a distance of 2,000 feet and a depth of 1,000 feet. Another forms the northwest side of the Bennett-Martin pit. Its probable northeastward extension has been traced through the Bell pit; small scattered occurrences of asbestos to the southwest indicate its continuation in this direction for an additional 2,000 feet.

The King, Bell, Johnson and Bennett-Martin mines are all in the same deposit, which is the largest, deepest and richest deposit in the area, and has been the source of a large proportion of the total asbestos production of the district. It has a length of 3,300 feet and a width of 1400 feet. Underground workings in this deposit extend to a depth of 1,100 feet. Diamond drilling to a depth of 1,500 feet has proved that the asbestos-bearing ground is continuous to that depth, with no indication that the bottom of the orebody has been reached.

King Mine

The King mine is the property of Asbestos Corporation Limited. It is situated in lot 26, range V, and lot 26, range VI, Thetford township. The King mine was operated as an open pit from 1878 to 1930, during which time the excavation attained a length of 1,000 feet, a maximum width of 700 feet and a depth of 400 feet. Since 1930, underground mining methods have been employed. The mill at the King mine has a capacity of 3,500 tons per day.

Bell Mine

The Bell mine is in the east corner of lot 27, range V, Thetford township, adjoining the King mine to the northeast and the Johnson mine to the southeast. It was operated by open pit methods from 1880 until 1951, when underground mining was commenced. The property is owned by Bell Asbestos Mines Limited. The mill capacity is 1,600 tons per day.

Johnson Mine

The Johnson mine is in the north corner of lot 27, range VI, Thetford township. It has common boundaries with the King mine to the northeast and the Bell mine to the northwest. Mining, on a very small scale, was started in 1876. The first shipment of asbestos fibre was made in 1878. Open pit mining methods were employed from 1876 to 1940. Since 1940 the mine has been operated by underground methods. The capacity of the mill is 3,000 tons per day. The property is owned by the Johnson's Company Limited. This company, incorporated in 1885, is the oldest asbestos mining company in the province.

Bennett-Martin Mine

The Bennett-Martin open pit is in lots 27 and 28, range V, Thetford township. The asbestos-bearing rock on this property does not extend beyond a depth of 300 feet. The property is owned by Asbestos Corporation Limited. Ore from this mine is treated at the Beaver mill.

Beaver Mine

The beaver mine is situated in lot 28, range VI, Thetford township, and lots 31 and 32, range C, Coleraine township. It is owned by Asbestos Corporation Limited. Open pit mining methods are employed. The deposit has a length of 2,400 feet and a maximum width of 900 feet and extends to a depth of 300 feet. It is separated from the deposit in which the King, Bell, Johnson and Bennett-Martin mines are operating by a belt of barren rock consisting in part of dunite which contains minor amounts of slip fibre. At its southeast end the deposit is bounded on either side by schistose zones which converge downward. The movements in these zones have shattered the rock, converting part of it into typical "fish scale". The Beaver mill, which also treats ore from the Bennett-Martin mine, has a capacity of 3,200 tons per day.

Reed, Murphy and Quarry Hills Group

The deposits of this group lie in a belt along the northwest side of Reed, Murphy and Quarry hills, near the town of Black Lake. The general trend of the belt is northeast, parallel to the contact of the peridotite with the Caldwell volcanics. The peridotite between the asbestos deposits and the Caldwell volcanics has been revealed by drilling to be completely serpentinized and severely shattered. Large, discontinuous bodies of granite, up to 300 feet in width, occupy an irregular zone which marks, roughly, the southeast margin of the deposits. The apparent fault zone to the northeast, and the granite to the southeast, seem to have been the main influences in localizing the deposits.

The mines in this group of deposits are, from north to south, the Maple Leaf, Reed, Southwark, Union, Johnson and British Canadian.

Maple Leaf Mine

The Maple Leaf mine is in lot 29, range A, Coleraine township. It is owned by Asbestos Corporation Limited. The open pit, which is now idle, has a length of 800 feet and a width of 450 feet. The asbestos-bearing rock occurs at the contact of the Reed Hills granite.

Reed Mine

The Reed mine is in lot 27, range A, Coleraine township, 2,000 feet southeast of the Maple Leaf pit. It was operated by open pit methods, but is at present inactive. The Reed deposit is situated in an embayment of the main body of the Reed Bills granite. The property is owned by Asbestos Corporation Limited.

Southwark Mine

The Southwark mine is in lot 27, range B, Coleraine township. The main open pit is 2,800 feet south of the Maple Leaf pit. It is situated in an embayment of the main body of the Reed Hills granite. The property is owned by Asbestos Corporation Limited. Recent diamond drilling between the Maple Leaf and Southwark mines has shown the asbestos-bearing rock to be continuous between the two, giving the deposit an overall length of 3,200 feet, a maximum width of 1,000 feet and a depth of 300 feet.

Union Mine

The Union mine is in lots 27 and 28, range B, Coleraine township, high up on the northwest side of Murphy hill. The property is owned by Asbestos Corporation Limited. The open pits, now idle, cover an area 1,300 feet long by 600 feet wide. Dunite bodies, comparable in size to the pits themselves, occur in and adjacent to the pits, which are bounded on the northwest by a body of granite. The asbestos occurs in partly serpentinized peridotite and, to a minor extent, in the associated serpentinized dunite. The deposit extends to a depth of 300 feet.

Johnson Mine

The Johnson mine, in lots 30 and 31, range B, Coleraine township, is owned by Johnson's Company Limited and is operated by open pit methods. The mill has a capacity of 800 tons per day. A new mill, now under construction, will have a capacity of 4,000 tons per day.

The Johnson and British Canadian mines (see below) are in the same deposit, which has a length of 5,000 feet and a maximum width of 2,000 feet. The rock of the ore zone is, for the most part, only partially serpentinized.

British-Canadian Mine

The British-Canadian mine is in the same deposit as the Johnson mine (see below). It occupies parts of block A and lot 32, range B, Coleraine township, and lot 28, range VI, Ireland township. It is owned by Asbestos Corporation Limited and is operated by open pit methods. The mill has a capacity of 6,000 tons per day.

Black Lake Group

The deposits of this group lie under, and adjacent to, Black lake. Most of the asbestos fibre is associated with partially altered peridotite. Dunite bodies, having dimensions of as much as 200 feet, are common. Some of these are host to asbestos. Syenite bodies are scarce within the asbestos-bearing zones, but both granite and syenite are present as fair sized bodies beyond their limits, particularly west of the deposits, where they are accompanied by extensive steatitization. The mines in this group of deposits are the United Asbestos and the Edith.

United Asbestos Mine

United Asbestos Corporation Limited holds mining concession No. 373 which comprises parts of block A, Ireland township, and block D, Coleraine township. In February, 1950, a three-compartment vertical shaft was collared in lot 28, range V, Ireland township, on the east side of Black Lake. The shaft was completed to a depth of 556 feet in 1951 and lateral work is now being done on the 260-foot and 540-foot levels.

Intersections along the drives on these two levels, coupled with diamond drill hole data, indicate the presence of a pipe-like asbestos-bearing zone immediately south of the shaft. This zone rakes north at about 35°. It has a thickness of 100 feet, an east-west width of 200 feet and a length, measured down the rake, of about 900 feet.

Intersections in drives and diamond drill holes farther to the south suggest the presence of a north-south zone possibly 500 feet by 1,000 feet, with a vertical range of 450 feet. The rake of the footwall conforms closely to that of the pipe-like zone to the north.

A zone made up of numerous apparently isolated pockets of asbestos, in partly serpentinized peridotite, extends south- southeast from the vicinity of the shaft for about 1 mile. This zone, which attains a maximum width near its centre of 1,200 feet, is exposed in a number of small prospect pits and was intersected by several diamond drill holes and by the mine workings beneath the eastern part of the lake.

In the vicinity of the island in Black lake diamond drilling has outlined a zone of asbestos-bearing rock 70 to 150 feet thick immediately beneath what is apparently a tabular body of granite which dips gently to the north.

Edith Mine

The Edith mine open pit is in lot 28, range IV, Ireland township. The property is owned by Asbestos Corporation Limited. The pit is at the south end of a large acid intrusive body situated to the west of Black lake. Diamond drilling in the vicinity of the pit has outlined a zone of asbestos-bearing rock adjacent to the intrusive contact.

Vimy Ridge Group

The deposits of this group are situated in Ireland township on the north slope of Caribou mountain, adjacent to the contact of the peridotite with the Caldwell quartzite. There are three distinct deposits in the Vimy Ridge zone: the Normandie orebody at the northeast end, the main Vimy Ridge orebody in the centre, and the "C" group at the southwest end. They form a northeasterly-trending zone with a length of 4,600 feet and a maximum width of 1,500 feet. The vertical range of the deposits is of the order of 1,200 feet.

A zone of shattered and completely serpentinized peridotite, trending roughly parallel to the major axis of the ore zone, has been proved by drilling to extend from the northwest end of Black lake to the Vimy Ridge mine. Its continuation to the southwest of the mine is marked by a pronounced valley which lies along the steep northwest end of Caribou mountain.

Normandie Orebody

The newly discovered Normandie orebody, which lies in lots 24 and 25, range III, and lots 24 and 25, range IV, Ireland township, has a length of 1,800 feet and a width of 1,000 feet. It pitches northward beneath the Caldwell quartzite. As in the main Vimy Ridge orebody, ribbon veining and low dips are prevalent. The property is owned by Asbestos Corporation Limited.

Vimy Ridge Mine

The Vimy Ridge mine is owned and operated by Asbestos Corporation Limited. Open pit mining methods are employed. The mill has a capacity of 2,400 tons per day. The main pit is in lots 24 and 25, range III, Ireland township. The orebody has a length of 1,500 feet, a maximum width of 1,500 feet, and a vertical range of about 600 feet. It is separated from the Normandie orebody by 400 feet of barren ground. The asbestos occurs as thin, closely spaced parallel veins in partly serpentinized peridotite. The veins dip 20° to 30° northeast. Apparently they are subsidiary to a system of steep-dipping faults that strike generally north. Ribbon veining is common, these veins having in general the same attitude as those of the main vein system.

"C" Group

The "C" group is a pocket of asbestos-bearing ground in lot 25, range III, Ireland township, having a horizontal diameter of 400 feet and a depth of 100 feet. It is separated from the main Vimy Ridge orebody by 1,200 feet of practically barren ground.

Other Occurrences

Belmina Mine

Asbestos is found at various points around the margin of the peridotite of Belmina ridge, in Wolfestown township. The deposit in the pit at the south end of the ridge is accompanied by a pronounced fracture zone which cuts across the east side of the pit. The zone strikes N. 45° E. and dips 80° southeast. Some cobbed asbestos was shipped from the Belmina mine in 1920. The property is now owned by Asbestos Corporation Limited.

Continental Mine

The Continental mine is situated in block B, Coleraine township, about 1½ miles northwest of the village of Coleraine, on the road leading to the Vimy Ridge mine. It was operated for a brief period in 1951-52 by the Continental Asbestos Company Ltd. The mill has a capacity of 750 tons per day. The deposit is in peridotite, close to its contact with the acid volcanic rocks of the Coleraine group.

Pontbriand Mine

The Pontbriand property is situated in lot 15, range IV, Thetford township. It is owned by Bell Asbestos Mines Limited. During 1947 the company carried out a programme of diamond drilling which outlined an orebody 2,000 feet long by 800 feet wide, estimated to contain 25,000,000 tons of asbestos-bearing rock of commercial grade.

Windsor Mine

In March, 1953, the Provincial Asbestos Company Limited reopened the Windsor mine which is situated at the north end of Bengel hill in Coleraine township. The pit is in dunite, near its contact with the overlying pyroxenite of Bengel hill. The rock in the area of the pit is intensely fractured and generally highly slickensided and contains a moderate amount of slip fiber.

General Relationships

Asbestos occurrences of economic value, with only a few minor exceptions, are situated near contacts. These are preferably the contacts of the peridotite with the country rocks, and the contacts between granite and peridotite. The major deposits are associated with fracture zones which are accompanied by intense serpentinization. Most of the adjustment within the peridotite, which resulted from continued uplift and folding in this region subsequent to the ultrabasic intrusion, has been localized along the northwest margin, or along that margin adjacent to the schist belt, within which most of the regional deformation has apparently been concentrated since the earliest period of folding in this part of the crust. The resultant shatter zones in the peridotite appear to be the channels through which the serpentinizing solutions have risen. Wherever the walls could be forced open, and the conditions of temperature were favorable, these solutions have spread out into

the adjacent fractured rocks to form the fibrous serpentine veins. The comparatively impervious bodies of acid rock have assisted, not only in providing the right structural conditions in their vicinity, but have served also as traps for the circulating solutions. In view of the wall-rock reaction involved, conditions which have permitted stagnation of the solutions would seem to be a prerequisite to chrysotile vein formation.

Asbestos vein-formation has shown a preference for the partly serpentinized, and comparatively brittle, peridotite. The dunite, which is considered to have been completely serpentinized at a very early stage, is normally host to many minute slip-fibre veins, and to narrow, discontinuous, lenticular cross-fibre veins, in comparison to the stronger veining to be found in the adjoining peridotite. This selectivity is thought to be due largely to the difference in behaviour of these two rock types when subjected to stress. In a number of localities, the presence of dunite bodies, which are comparable in size to the asbestos deposit immediately adjacent to them, suggests that the dunite may have played an important part in localizing the deposit. The tendency of a pocket of serpentinized dunite to yield plastically under stress has probably been accompanied by crackling of the surrounding more competent peridotite. This relationship is suggested by the association of dunite and asbestos-bearing peridotite in many of the small isolated deposits, as well as in some of the larger deposits such as the Union orebody.

Chromite

Chromite is found as an accessory mineral in the dunite and peridotite. All of the deposits occur in dunite, and the majority of these are found within the larger dunite masses, although a few are found associated with the dunite pockets scattered through the peridotite. Appreciable quantities of chromite were recovered from the Union pits on Murphy hill, and from a small body of dunite adjacent to the southeast side of the Beaver pit in Thetford Mines.

The chromite bodies of economic value occur, for the most part, as segregations in the dunite, and many of them display a layered structure and lenticular form. Some of this chromite appears to have been emplaced after consolidation of the host rock. The fact that it is found entirely within the dunite would suggest that any transfer has been of a very local nature. In the Montreal chrome pit, situated to the northeast of the Diamond hills in range II, Coleraine township, near the contact of the dunite with the volcanic rocks of the Coleraine group, a mixture of dunite and pyroxenite are present. There is some indication that the chromite occurs in a pyroxenite host, but due to the schistose nature of these rocks, and their intimate association at this locality, it is difficult to establish the exact relationships.

The distribution of the chromite concentrations does not appear to follow any particular pattern.

Other Minerals

Chalcopyrite, pyrite, and pyrrhotite occur in association with the basic Coleraine volcanic rocks to the northwest of East lake. One such occurence, immediately south of the tongue of slate to the east of Belmina ridge, appears to be associated with a brecciated flow. It is possible that this mineralization is related to the intrusion of gabbro in this vicinity.

Vermiculite is found at the east end of the Continental pit (p. 21) over an area about 100 feet square, in an irregular network of veins up to 6 inches wide. The mineral occurs in flakes up to 1 centimetre in size, and appears to be of good quality.

Biotite is a common alteration product associated with the acid intrusives found in the asbestos mines. Many small dikes and the narrow fringes of larger intrusive bodies are composed almost entirely of biotite. It is thought that hydrothermal alteration of biotite-rich dikes has given rise to the vermiculite.

Iron-bearing magnesite, and material sufficiently low in carbonate and high in talc to be called soapstone, occur as alteration products of the serpentinized ultrabasic rocks. The more important occurrences are found to the southeast and east of the Thetford pits, to the west of the underground workings beneath Black lake, and in the saddle between Bengel and Brousseau hills. It is probable that this type of alteration is much more widespread than is indicated by the few observed occurrences, for these generally occupy low ground, or are buried beneath overburden, and their presence is only disclosed by drilling or by underground work. The association of this type of alteration with certain of the asbestos deposits suggests that it is closely related to the secondary serpentinization, and formation of fibrous serpentine.

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