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ST-MALGLOIRE AND ROSAIRE - ST-PAMPHILE AREAS, ELECTORAL DISTRICT OF DORCHESTER,
BELLECHASSE, MONTMAGNY AND L'ISLET

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PROVINCE OF QUEBEC, CANADA

Department of Mines

Honourable W.M. COTTINGHAM, Minister

A.-O. DUFRESNE, Deputy Minister

GEOLOGICAL SURVEYS BRANCH

I. W. JONES, Chief

GEOLOGICAL REPORT 76

ST - MAGLOIRE

AND

ROSAIRE - ST - PAMPHILE AREAS

Electoral Districts of

Dorchester, Bellechasse, Montmagny and L'Islet

by

Jacques Béland



QUEBEC

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PRINTER TO HER MAJESTY THE QUEEN

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THE ST. MAGLOIRE AND ROSAIRE-ST. PAMPHILE AREAS

SOUTHERN QUEBEC

by J. Béland

INTRODUCTION

General Statement

The St. Magloire and Rosaire-St. Pamphile areas were mapped by the writer for the Quebec Department of Mines during the summers of 1952 and 1953. In the fall of 1951 attention had been drawn to the area (★) by the discovery of nickel-copper mineralization near St. Fabien de Panet, electoral district of Montmagny. By the spring of 1952 a strip of ground some 40 miles long and a few miles wide extending northeast and southwest of the nickel-copper discovery had been staked and an intensive search for base metals had begun. These developments emphasized the need for a more detailed geological map of the region.

Physiographically the area is in the Appalachian uplands, here dominated by the Notre Dame Mountains. This range in this area rises to 3,000 feet above sea level.

All the consolidated rocks are of Palaeozoic age, ranging from Cambrian to Devonian. Most are sedimentary, but there are some of extrusive and intrusive igneous origin. The sedimentary and volcanic rocks are tightly folded and generally steeply dipping. They reveal a low grade regional metamorphism. One major fault, which possibly extends 28 miles, is of particular interest because it is within a serpentine belt and is looked upon as a favourable structure for the localization of base metals.

Southeast of the serpentine belt and of the major fault is a series of albite diorite sills. The present work has shown that there are indications of base metal and of gold mineralizations associated with these sills. Additional interest is given the region

(★) In this report "the area" refers to the combined areas involved.

by the fact that the serpentine belt is, to the southeast, a major source of asbestos. The nickel-copper mineralization of St. Fabien de Panet is also related to this serpentine.

In consequence of the above, the Quebec Department of Mines undertook regional mapping in the summer of 1952, as well as detailed mapping of the prospect area near St. Fabien de Panet. The latter project was concerned mainly with the operations of Eastern Metals Corporation, Limited.

Location

The area reviewed in this report is roughly 50 miles east of Quebec City. It includes the St. Magloire, St. Pamphile, and eastern half of the Rosaire map-areas of the National Topographic Series - about 750 square miles. It is bounded on the east by the State of Maine and on the north and south by latitudes $47^{\circ}00'$ and $46^{\circ}30'$. On the west, it is bounded by longitudes $70^{\circ}30'$ and $70^{\circ}15'$. Parts of four electoral districts - Dorchester, Bellechasse, Montmagny, and L'Islet - are included in the area.

Access

The principal villages of the area are St. Paul, St. Magloire, St. Fabien, Lac Frontière, and St. Pamphile. These settlements are linked by good gravel roads to the main highway along the south shore of the St. Lawrence. A network of secondary gravel roads within the area permits easy access to any point.

A branch line of the Canadian National Railway crosses the northwestern part of the area, and a branch line of the Quebec Central Railway traverses the southeastern part to reach Lac Frontière.

Previous Work

Geological work in the general region began during the early years of the Geological Survey of Canada. Logan (1850, 1863) (*) and Richardson (1870) reported on the geology of a region bounded northwest by the St. Lawrence, southeast by the State of Maine and extending northeasterly from Chaudière river to about Temiscouata lake. The

(*) See Bibliography at end of report.

rocks in the northwestern part of this region were assigned to the "Quebec group", and considered to be of Cambrian age. Those of the southeastern part were said to be of "Upper Silurian" age. The "Quebec group" had been established near the city of Quebec in the St. Lawrence River valley and later extended to the Appalachian uplands to the south and southeast. Logan considered that the formations of the Quebec group in the uplands were arranged in a syncline, the probable extension of the "Sutton synclinal" that he had previously recognized in the Sutton mountains of Brome county. Selwyn (1878) objected to these views and pointed out that the metamorphic rocks of the Appalachian uplands were not necessarily the metamorphic equivalents of the unaltered sediments of the St. Lawrence River valley, and demonstrated that the so-called Sutton syncline was actually an anticline.

Ells (1888) after remapping most of the area covered by Logan and Richardson, offered an interpretation that somewhat confirmed and elaborated Selwyn's views. Ells held that the Appalachian uplands in that region were traversed by "a great anticlinal of Precambrian schists" bordered northwest and southeast by rocks of Lower Cambrian age. Farther northwest, in the St. Lawrence River valley, was the "Upper Cambrian" Sillery formation, and at the extreme southeast near the State of Maine was "a large basin of Cambro-Silurian rocks". Ells believed that "the lofty ridges of (Precambrian) schists" in the present region were the continuation of the Sutton mountains, including the same rocks and anticlinal structure. The "Lower Cambrian rocks" on the southeast side of the anticline were said to include "volcanics" associated with "serpentine", both of which Ells considered to be extrusive rocks.

In 1913, Dresser, after remapping the northeastern part of the territory covered by Ells and the electoral district of Kamouraska, stated still other divergent views. The rocks mapped by Ells as Precambrian and as Lower Cambrian were lumped into the "L'Islet" formation which, according to Dresser, was a conformable lower phase of the Sillery formation found to the northwest. Both L'Islet and Sillery were considered to be Cambrian. The L'Islet formation occupied a position on the crest of the anticline. On the southeast flank of this fold some rocks correlated with the Sillery were thought to overlie the L'Islet. Farther southeast, unconformably on both L'Islet and Sillery, was the Pohenegamook formation. This formation was believed to be

*Ells apparently used the terms "Upper" and "Lower Cambrian" to separate two formations of Cambrian age, as though separating an upper and lower member of one formation.

Middle Ordovician in age. A conglomerate at the base of the Pohenegamook indicated that an erosional unconformity separated it from the L'Islet and Sillery. Dresser also believed that an orogeny had preceded the deposition of the Pohenegamook. The volcanics and serpentines previously mentioned by Ells were considered to be "diabase, pyroxenite, peridotite and serpentines" which Dresser grouped under the name "Talon formation". These rocks were thought to have been intruded in Devonian time. It is interesting to note that Ells considered the serpentinites, now classed as intrusives, to be extrusive rocks, but that Dresser believed the whole group, including the volcanics, to be of intrusive origin.

MacKay (1921) mapped a small area in the electoral district of Beauce and introduced the new terms "Caldwell" and "Beauceville" to designate two groups of rocks occurring on the southeast side of the Sutton anticline. The Beauceville group is more or less equivalent to Dresser's Pohenegamook formation and the Caldwell is part of the l'Islet. MacKay assumed that the Beauceville was Ordovician and that the Caldwell was Cambrian. Both groups were later extended southwest and northeast - southwest to the Thetford-Black Lake area by Cooke (1937) and northeast to the Etchemin Lake area by Tolman (1936). Cooke and Tolman both classed the schists of the Sutton anticline, named "Bennett schists" by Harvie (1917) and Knox (1917)) as a lower phase of the Caldwell group. The volcanic rocks on the southeast side of the anticline were included in the Caldwell group, and the serpentinites emplaced in both the Caldwell and the Beauceville were said to have been intruded in post-Ordovician time. Cooke, like Dresser, thought that the Caldwell and the Beauceville were separated by an erosional unconformity.

Field Work

The base map used for plotting is an enlargement of a map prepared from aerial photographs by the Surveys and Mapping Branch, Department of Mines and Technical Surveys, Ottawa. The ground was systematically covered by pace and compass traverses spaced one half mile apart. This systematic work was supplemented by an examination of all the outcrops along the roads and in the nearby fields. Aerial photographs were used for direct plotting in open country.

Messrs. R. Blais, W.A. Gorman, R.J. Kruse, H. von Romer and M. Lefebvre during the summer of 1952, and Messrs. L.B. Gillett, G. Beale, Y. Gagnon, R. Marleau and J.P. Rémillard during the summer of 1953, ably acted as assistants. R. Blais in 1952 also logged the core and made other investigations at the Eastern Metals Corporation

property. A report written by him on this property is listed in the bibliography and referred to in the text.

PHYSIOGRAPHY

The central part of the area is traversed by the north-eastern extension of the Sutton Mountains of the Eastern townships, here known as the Notre Dame Mountains (Plate I-A). In the southwestern part of St. Magloire area the range is deeply dissected and shows considerable relief. The highest summits are about 3,000 feet above sea level. To the northeast, in Rosaire-St. Pamphile area, the relief is less but still very pronounced, with the highest hills rising about 1,850 feet above the sea. From the crest of this range the ground slopes more or less gently to the northwest and southeast - northwest to the St. Lawrence lowlands and southeast to the St. John River valley. On the northwest slope gentle hills and broad shallow valleys are characteristic. The southeastern slope on the other hand is broken by narrow belts of moderately high hills made up of rocks relatively more resistant to erosion. One such belt, consisting of steep hills made up of basic volcanic rocks, lies close to the Notre Dame range and nearly crosses the area. Another short series of hills, made up of acidic volcanic rocks, is present in the southwestern part of St. Magloire area (Plate I-B). Farther southeast sills of diorite underlie a series of ridges extending from the southern boundary of St. Magloire area to about St. Fabien. Finally, in the Rosaire-St. Pamphile area hard conglomeratic beds stand out in ridges over a distance of four miles.

The drainage is either northwesterly to St. Lawrence river or southeasterly to St. John river. Near the height of land are a few small lakes. A fairly large lake is found on the southeast slope in Leverrier township (Plate II-A). The main streams are Etchmin and Du Pin rivers, flowing to the St. Lawrence, and Daaquam, Nord Ouest, and Big Black rivers, flowing to the St. John. Along most of their courses these tributaries are graded and occupy wide valleys bordered by gently sloping hills (Plates II-B, III-A, and III-B). At places the rivers have made deep cuts through glacial drift, boulders, and outwash material. Segments of eskers are found in many valleys.

GENERAL GEOLOGY

The sedimentary and volcanic rocks of the area are broadly arranged in five, parallel, northeasterly trending belts, each extending through the area and containing a characteristic assemblage of rocks. These assemblages from northwest to southeast are the Armagh, Rosaire, Caldwell, Beauceville, and St. Juste groups. In

addition, in St. Magloire area and extending into the Rosaire-St. Pamphile area, is a large body of Bennett schists. The Bennett occurs between the Rosaire and Caldwell groups, and is made up largely of metamorphosed Rosaire and Caldwell rocks. Furthermore, within the band of Beauceville rocks, near the south border of the area, are two other narrow zones; one is made up of acidic volcanic rocks, and the other of rocks similar to those of the Caldwell group.

The main structural feature is a broad anticline plunging northeasterly. On the northwest side of this anticline the Armagh and Rosaire groups are tightly folded; on the southeast side, the Caldwell, Beauceville, and St. Juste groups also are tightly folded. The acidic volcanics within the belt formed by the Beauceville group appear to lie unconformably on the Beauceville and the narrow layer of Caldwell within the same belt is presumably a thrust sheet.

In age, the Rosaire, Armagh and Caldwell groups are here tentatively considered to be Cambrian. The Armagh and Caldwell have many lithologic similarities and may be contemporaneous. Observations made in an adjacent area (Béland, 1955) indicate that the Rosaire and Armagh are conformable. The Beauceville group possibly is separated from the Caldwell by an erosional unconformity; it is considered to be Ordovician in age. The acidic volcanics lying unconformably on the Beauceville are probably Silurian or Devonian. The St. Juste group is thought to be Devonian (Gorman, 1954).

The intrusive rocks are divided into three groups. A first group includes serpentinites, diorites, granodiorites, syenites and granites, all closely associated and emplaced in the Bennett, Caldwell, and Beauceville groups. The serpentinites are the most abundant, and are seemingly the earliest, of these intrusions. They occur as long tabular masses mostly confined to a narrow belt at the contact of the Caldwell and Beauceville groups. The diorites, granodiorites, syenites and granites are in small stocks or dykes cutting the serpentinites; they probably were emplaced shortly after the serpentinites. This period of igneous activity is tentatively placed toward the end of the Ordovician time.

A second group is made up of a few sills of gabbro, emplaced like the serpentinites in the Bennett and the Caldwell. These gabbros may be related to the serpentinite series but because of uncertainty are treated separately.

The third group includes sills of albite diorite emplaced in the Beauceville, and is thought to be post-Silurian. The

albite diorite and the serpentinites are economically important because of their relations to some small metallic deposits in the area.

Recent stream accumulations and glacial drift including moraines, kames, eskers, and outwash alluvions are abundant in the region, particularly in some of the broad valleys.

The stratigraphic succession outlined above is summarized in the following table of formations.

Table of Formations

System	Rock Unit	Lithology
Quaternary	Recent	Stream deposits; morainic material, eskers, kames, outwash
	Pleistocene	
Devonian	St. Juste group	Grey and black sandstones; grey and black slates
Post-Silurian?	intrusives	Albite diorites
Silurian or Devonian		Acidic volcanic rocks
Post-Ordovician?	intrusives	Serpentinites, diorites, granodiorites, syenites and granites; gabbros
Ordovician	Beauceville group	Black, grey, green, and red slates; green and grey impure sandstones; green and grey siltstones; cherts; limestones; basic volcanic rocks; tuffs; conglomerates
Cambrian	Caldwell group	Green, red and grey impure sandstones; green, red and grey slates; white quartzites; basic volcanic rocks
	Rosaire group	White and grey quartzites; grey siltstones; black and grey phyllitic slates; calcareous quartzites; siltstones and slates
	Armagh group	Green, red and grey impure sandstones; green, red and grey slates; white quartzites
	Bennett group	Quartz-mica-chlorite schists; schistose quartzites; black, red and green phyllites; green and red phyllitic impure sandstones; limestone

Cambrian

Bennett Group

The Bennett group underlies a belt as much as ten miles wide in the southern half of the area. Toward the northeast the belt narrows rapidly, apparently plunging out on the axis of the Sutton Mountains anticline. It disappears in an open arc in Patton township close to the Montmagny-L'Islet County line.

Although the rocks of this group are shown as a separate map unit they appear to be metamorphic phases of the bordering Rosaire and Caldwell groups. Toward the northwest the Bennett is composed largely of black, grey, and green quartz-mica-chlorite schists and white, grey, and black schistose quartzites^{*}. These schists and quartzites grade along and across the strike into slates and quartzites typical of the Rosaire group. In Patton township a sequence from black schists to black phyllites to black slates may be followed. Here also, slightly micaceous and schistose quartzites pass gradually into typical Rosaire types, - massive granular quartzites in which the matrix is but slightly recrystallized and the original clastic grains of quartz are easily discernible.

The schists in the southeastern part of the belt are mainly coarse-grained, green or red phyllitic sandstones interbedded with green or red quartz-mica-chlorite schists or phyllites. These rocks are Caldwell types, except for metamorphic effects. Thus, the boundary between the Bennett and Caldwell groups is more or less the limit between two metamorphic grades of the same assemblage of rocks.

Near the west border of the area, along the road separating ranges IV and V of Patton township, a lens of phyllitic sandstones and slates that possibly belongs to the Armagh group is intercalated in the Rosaire schists. Other lenses of Armagh may also occur to the southwest within the schist belt but, if so, the high grade of metamorphism has prevented their detection.

A grey limestone is apparently intercalated in the schists, about one half mile southwest of St. Philéon. This limestone, however, shows no sign of recrystallization and it is lithologically

^{*}The term "quartzite" in this report refers to a sandstone in which quartz is the predominant clastic constituent regardless of the metamorphic grade of the rock and the nature of its cement.

different from limestone found in small amounts in the Rosaire belt to the northeast.

The quartz-mica-chlorite schists, commonly found in the northwestern part of the schists belt, have the composition given in Table 1.

Table 1.-Composition of the Bennett Quartz-mica-chlorite Schists

	<u>Per Cent</u> [*]
Quartz	86
Feldspar	3
Mica and chlorite	7
Epidote and zoisite	2
Carbonate	<u>2</u>
	100

The schistose structure is given by thin folia of micas and chlorites. The quartz grains (about 0.2 mm. in diameter), usually drawn out, are arranged in folia parallel to those of micas and chlorite. In part, however, the quartz grains show a mosaic texture with sutured contacts or slight peripheral granulations. The feldspar grains seem to have been rotated so that the twin plane makes an angle of about 45° with the plane of schistosity. Carbonate is secondary and replaces some of the quartz and feldspar grains. Here and there the carbonate occurs with quartz in thin veins parallel to the schistosity. Zircon, apatite, garnet, iron sulphides and oxides are found in small amounts. Garnet rarely exceeds one per cent of the rock.

Some of the black schists are graphitic and others are biotitic. Locally they contain disseminated cubes of pyrite. Some layers of green schists show porphyroblasts of chlorite the largest of which are about one-quarter of an inch in diameter. The phylitic sandstones, found in the southeastern part of the schist belt, commonly show a gneissic structure, seemingly a result of deformation. In such facies the coarse clastic material has a tendency to be segregated from the fine silty matrix.

^{*}Quartz-mica-chlorite schists.- Average of 5 estimates. The feldspar is plagioclase and the micas are muscovite with some brown biotite; chlorite predominates among the micaceous minerals.

The schists and schistose quartzites of the Bennett group form a broad anticlinal structure which fades out northeasterly into a series of isoclinal folds made up of Rosaire, Armagh and Caldwell rocks. The schists in the northwestern part of the Bennett belt are largely metamorphosed Rosaire and in the southeastern part they are seemingly metamorphosed Caldwell. It is to be concluded, therefore, that the Bennett is not truly a formation in the strict sense of the term but a group of metamorphosed rocks that belong to the Rosaire, Armagh and Caldwell groups. Therefore, the Bennett cannot be Precambrian as was thought by Ellis (1888); it must be of the same age as the parent rocks, that is, Cambrian. Cooke (1937) and Tolman (1936) interpreted the Bennett as a lower phase of the Caldwell. This view possibly is correct for the schists that border the Caldwell belt, but it cannot be extended to include all the Bennett group. Actually it is uncertain to what part of the Caldwell group, lower or upper, the metamorphosed Caldwell (Bennett) may belong. Much more work will have to be done before a true stratigraphic column of the Caldwell group can be established. It may be noted here that the anticlinal structure in the Bennett is shown by schistosity; bedding generally is not clear and may not be parallel. At places it seems that a gently dipping schistosity has been superimposed on steeply dipping beds arranged in tight folds such as found in the Rosaire and Caldwell groups to the northwest and southeast. If such is the case the metamorphosed Caldwell may not be stratigraphically lower than the non-metamorphosed.

More recent work by Cooke (1954) in the Eastern Townships has indicated that in the Orford, Richmond and Warwick areas the "Bennett schists" of the Sutton anticline are metamorphosed facies of formations of the Oak Hill series. The Oak Hill series, as established by Clark (1934) in the Sutton area, is of Lower Cambrian age and made up at the base of the Tibbitt Hill lavas (basic lavas) followed successively by the Call Mill slate, Pinnacle greywacke, White Brook dolomite, West Sutton slate, Gilman Formation (mostly quartzites), Dunham dolomite, Oak Hill slate, Scottsmore quartzite and Sweetsburg slate. From the Sutton area to the Warwick area, that is from southwest to northeast, it is found that the Oak Hill series offers many changes; some formations thin out, disappear, or show marked lithologic modifications. In Richmond area a new formation, the "Melbourne limestone", has been recognized by Cooke at the top of the series. On the southeast the metamorphosed Oak Hill series is bounded by the Caldwell group, from which it is said to be separated by the "Caldwell thrust".

If this thrust be excepted, the Bennett group of the present area (central and northwestern part of the Sutton anticline)

structurally and stratigraphically occupies to a certain extent a position similar to that of the "Bennett schists" (metamorphosed Oak Hill series) of the Eastern Townships. The question therefore may be raised as to whether the Rosaire group which seemingly occupies most of the Sutton anticline in the present area may be correlated to the Oak Hill series. A comparison of the two sequences, however, shows lithologic dissimilarities; the Rosaire group, described below, does not include any basic lavas or dolomite; also, limestones are rare and, where found, are intimately mixed with the slates. Therefore, unless there be considerable change of facies, on a purely lithologic basis, this correlation remains dubious although not impossible.

Armagh Group

"Armagh group" is a new term. It is introduced here to designate an assemblage of impure, green, red, and grey sandstones interbedded with green, red, and grey slates and some white siltstones. The sandstones generally are gritty and show graded bedding. In many beds small pebble conglomerates at the base pass gradually into fine-grained sandstones or siltstones towards the top. Other beds contain large fragments of green, red, and grey slates set in a sandy matrix. In many gritty beds the coarse material is blue quartz and pink feldspar. Other beds contain calcareous lenses made up of sandy material cemented by carbonate. Here and there deformed sandstones show faint gneissic structures, as though the coarse clastic material had been segregated from the fine-grained groundmass.

Typical sections of the Armagh group consist of sandstone beds 3 to 15 feet thick in which are intercalated slate beds 1 to 3 feet thick and siltstones beds less than an inch thick. Rarely, thicknesses of a hundred feet or more of green, red, and grey slates are encountered.

The sandstones as shown in Table 2 are largely quartz and feldspar with a moderate amount of argillaceous material and some micaceous minerals. The quartz and feldspar grains average about 0.5 mm. in diameter. The micaceous minerals, mostly white mica and chlorite, are in tiny flakes and probably result from a recrystallization of the argillaceous paste. The proportion of shaly material to quartz and feldspar remains about constant in all samples examined, but the proportion of quartz and feldspar varies. Accordingly two types of sandstones, here called greywacke and quartzite, have been distinguished (Table 2) The greywacke type is the most common and is the principal constituent of the Armagh group.

In some places rock fragments make up as much as 10 per cent of the greywacke. Size sorting and roundness are generally poor in both the quartzite and the greywacke. In highly deformed beds the quartz is partly recrystallized, and green or brown biotite appears in the groundmass. Other common metamorphic minerals in these beds are chlorite, muscovite and epidote. Carbonate is in irregular patches, or in veinlets.

Table 2.-Composition of the Armagh Sandstones

	<u>Per Cent</u> [*]	<u>Per Cent</u> ^{**}
Quartz	56	77
Feldspar	22	8
Micas, chlorite, and clay minerals	17	15
Carbonate	3	-
Rock fragments	<u>2</u>	<u>-</u>
	100	100

Zircon, hematite and chromite occur in small amounts. Hematite is particular to the red beds to which it gives the red colour. In some of these beds it amounts to 2 per cent of the rock. Chromite was found in but one sample, taken within the lenticle that follows the boundary of ranges V and VI in Arago township. This chromite, seemingly of clastic origin, is very much like the chromite found in the serpentinite bodies. If it actually came from the serpentinites (which are believed to have been emplaced in post-Ordovician time), it would mean either that the lenticle yielding the sample is not Armagh or that the Armagh is younger than is assumed here.

The rocks of the Armagh group in this area bear a strong resemblance to the rocks exposed at Charny and between Sillery and Cap Rouge, where the term "Sillery formation" was originally applied. In the uplands, however, are numerous beds of red sandstones which find no equivalent near Quebec. For this reason, and because the term "Sillery" has been used to designate rocks of various lithological characters and of different ages, it has been thought preferable to introduce the new name Armagh for the Sillery-like rocks of

^{*}Greywacke.- Average of 5 estimates. The feldspar is mostly plagioclase with some perthite, microcline and orthoclase. The micas are muscovite and biotite. The rock fragments include granite, pegmatitic granite, acidic porphyritic volcanics, chert and slate.

^{**}Quartzite.- Estimate. The feldspar is mostly plagioclase; some is potassic.

the uplands. The new term is derived from the village of Armagh, electoral district of Bellechasse, where particularly good exposures of the rocks concerned can be seen. Much work, however, will be needed before a complete stratigraphic sequence of these rocks and their relations to the original "Sillery" can be established.

The age relationships of the Armagh, Rosaire and Caldwell are also obscure. There is some indication in the Ste. Perpétue area (Béland, 1955), adjacent to the northeast that the Armagh is older than the Rosaire. On the other hand, the anticline that traverses the belt of Bennett schists in the St. Magloire area, if not a foliation dome, suggests that the Armagh is younger than the Rosaire and contemporaneous with the Caldwell. Actually the Armagh and Caldwell bear strong lithological resemblances.

Rosaire Group

The term "Rosaire" derives from the small village, Notre-Dame du Rosaire, electoral district of Montmagny, where the rocks included in the Rosaire group are particularly well exposed. These rocks include white, grey, black, and buff quartzites interbedded with black, grey, or green slates, and grey or white siltstones. The quartzites, siltstones and slates are at places slightly limy and in the slates calcareous beds occasionally alternate with non-calcareous beds. The quartzites are apparently the predominant member of the group and generally occur in series of beds 5 to 50 feet thick (Plate IV-A). The intercalated slates seldom exceed 5 feet in thickness although zones 200 feet or more thick are encountered. The beds of calcareous slates are generally but a few inches thick (Plate IV-B).

The quartzites commonly show a faint and thin layering that resembles bedding. In places they contain small pellets of shales and, rarely, disseminated cubes of pyrite. As may be seen in Table 3 they are made up largely of quartz with moderate amounts of feldspar, argillaceous material, and carbonate. Stockworks of quartz veins are common (Plate V-A).

Table 3.-Composition of the Rosaire Quartzites

	<u>Per Cent</u> ¹	<u>Per Cent</u> ²	<u>Per Cent</u> ³
Quartz	90	58	60
Feldspar	1	20	1
Chlorite, micas and clay minerals	5	15	4
Carbonate	3	7	35
Carbonaceous matter	1	-	-
	<hr/>	<hr/>	<hr/>
	100	100	100

¹Quartzites.- Average of 7 estimates.

²Feldspathic quartzites.- Estimate. The feldspar is mostly albite and oligoclase with some microcline and perthite.

³Calcareous quartzites.- Estimate.

The quartz grains in most of the quartzites have a diameter of about 0.3 mm., and are well rounded and sorted. The matrix is generally silty and slightly argillaceous or calcareous. In highly deformed facies the quartz grains show a mosaic texture with sutured contacts and the argillaceous paste is recrystallized to micas and chlorite. The carbonate is largely secondary and probably related to the numerous quartz and carbonate veins found in these rocks. The dark quartzite seemingly takes its colour from thin films of carbonaceous matter coating the sand grains. Clastic biotite, epidote, tourmaline, apatite, zircon, and iron sulphides and oxides are found in small amounts.

The siltstones associated with the quartzites and slates are generally thin-bedded and, rarely, cross-bedded. They seem to have a composition much like that of the quartzites. The slates generally show a good slaty cleavage. Some are arenaceous and the black slates are at places graphitic.

The Rosaire group, with its quartzites, thin-bedded siltstones, and slates, constitutes an assemblage that presumably accumulated in a shallow, relatively stable basin where the material deposited could be efficiently reworked and sorted out either by wave or current action. The Rosaire group in that respect differs considerably from the associated and also Cambrian Caldwell and Armagh groups. These two last groups are made up largely of impure gritty sandstones seemingly deposited in a deep and unstable basin or some other environment where deposition was rapid and sorting inefficient.

The l'Islet formation of Dresser (1913) more or less includes both the Rosaire and the Caldwell groups as here distinguished.

Caldwell Group

In the southern part of the area, the Armagh and Rosaire groups are on the northwestern side, and the Caldwell on the southeastern side of the Bennett Schists group. In the northern part, however, the Caldwell and Armagh-Rosaire come into contact. The Caldwell in the southern quarter of the area is two miles wide and in the northern three-quarters, four and a half miles. It is made up of rocks very similar to those of the Armagh group. It includes green, red, and grey impure sandstones, green, red, and grey slates, and some white, pure quartzites. It also includes greenstones. The latter are not found in the Armagh group within the area but do occur in this group west of the St. Magloire area near St. Gervais, St. Lazare and St. Anselme.

Like those of the Armagh the sandstones and slates of the Caldwell group occur in alternate beds. Typical sections show sandstone beds 2 to 5 feet thick alternating with beds of slate 2 to 10 inches thick. Some beds of sandstone are graded and others are even-grained. The even-grained beds are generally thicker than the graded ones, ranging up to 100 feet. The graded beds in places show gradations from impure argillaceous sandstones to pure quartzose sandstones. Rarely, gritty beds contain lenses of gravel interfingering with sand. A few beds show at their base small channels filled with gravel. Many beds contain angular fragments of slates, some of which are as much as one foot long. Clastic pink feldspar and blue quartz such as noted in the Armagh sandstones, are quite common here also. Close to the Bennett schist belt many sandstone beds show a marked gneissosity (Plate V-B). This structure, which results from deformation, is parallel to the schistosity but oblique, in part, to the bedding.

The Caldwell sandstones may be divided into three types on the basis of composition: greywackes, subgreywackes and quartzites (see Table 4). Of these three types the greywackes and subgreywackes are the most common and, with the greenstones, make up most of the Caldwell group in this area. The average grain size of these sandstones is about 0.5 mm. Size sorting and roundness are poor. The greywackes and subgreywackes contain scattered large fragments

of slates and numerous small fragments 1 to 2 mm. across of acidic volcanic rocks, granites, pegmatitic granites, vein quartz, siltstones, chert, and quartzites. Some greywackes, largely made up of clastic grains of potash feldspar, contain also numerous fragments of granites which indicate that the source area of at least part of the Caldwell sediments was a granitic terrane much like those found on the north shore of St. Lawrence river.

Table 4.- Composition of the Caldwell Sandstones

	<u>Per Cent</u> ¹	<u>Per Cent</u> ²	<u>Per Cent</u> ³
Quartz	52	57	79
Feldspar	24	8	8
Chlorite, micas and clay minerals	21	33	10
Epidote	1	1	1
Carbonate	2	1	2
	<u>100</u>	<u>100</u>	<u>100</u>

¹Greywackes.- Average of eleven estimates. The feldspar is mostly plagioclase (An₅ to An₃₅) with some microcline, perthite and orthoclase.

²Subgreywackes.-Average of four estimates. The feldspar is mostly oligoclase with some microcline and perthite.

³Quartzites.- Average of four estimates. The feldspar is mostly oligoclase with some perthite.

The slates of the Caldwell group are predominantly red. They are made up of very fine quartz and feldspar and abundant clay material. The red beds contain finely divided hematite. Red beds alternate with green beds or, at places, are separated by very thin layers of white, quartzose siltstones.

The volcanics (greenstones) are black, green, or purplish. Some thick layers are coarse-grained in part, but generally the rock is very fine-grained. Breccias and agglomerates are common. The fine-grained facies may be alternately pillowed and massive. The pillows are one to three feet long and are rimmed by vein material made up of quartz carbonate, epidote, and some hematite. Some flows also show amygdules of quartz carbonate and chlorite. Some highly altered layers are spotted white and brown. Others are criss-crossed by veins of quartz, epidote, chlorite, carbonate, and hematite.

Most of the material collected was too altered for precise determination of the original composition but some coarse-grained

specimens gave the following: about 55 per cent plagioclase feldspar varying from An_{24} to An_{32} , about 40 per cent augite and 1 to 5 per cent quartz. It would seem therefore that these greenstones are akin to spilites (soda-rich volcanics). Many specimens show a faint ophitic texture. The feldspar is in slender laths 0.5 to 1 mm. long. The pyroxene is in stubby grains 0.5 to 2.5 mm. across. Wedges of quartz and micropegmatite fill the interstices. The degree of alteration varies from place to place. The feldspar laths are largely replaced by sericite, chlorite, quartz and carbonate; the pyroxenes by chlorite, carbonate, epidote, actinolite and rarely hornblende. A very fine-grained facies is a felt-like aggregate of feldspar and actinolite with small irregular masses of quartz, carbonate, chlorite and epidote and with finely disseminated magnetite. The white and brown spots in the greenstone are made up of a greyish clay mineral and coarse epidote. In most of the highly altered greenstones quartz amounts to about 5 per cent, carbonate to 15 per cent, epidote to 30 per cent, actinolite and chlorite to 45 per cent. Zoisite, sericite, ferristilpnomelane, iron sulphides, iron oxides and leucoxene are also found in small amounts.

Within the area underlain by Beauceville rocks is a narrow band of impure sandstones and some basic volcanics similar to those found in the Caldwell group. For this reason these rocks are here considered to be Caldwell. This presumed Caldwell could represent the roots of an anticline or indicate that a slice of Caldwell has been thrust into the Beauceville. A sequence of beds at the northeast end of a large outcrop adjoining the south boundary of the area suggests that the narrow band has a synclinal structure; therefore, it seems more likely that the band is a thrust slice.

The sedimentary and volcanic rocks that make up the Caldwell group are to a large extent typical of rocks generally thought to have accumulated in a deep marine basin where sedimentation was rapid and little reworking and sorting could take place. In that respect the Caldwell group, like the Armagh, differs from the Rosaire group as was pointed out above.

Although the Caldwell group has not been precisely dated it is generally considered to be of Cambrian age. Dresser (1913) and Cooke (1937) have held that the Caldwell was separated by an erosional unconformity from a group of rocks to the southeast named Pohenegamook by Dresser, and apparently the equivalent of the Beauceville of MacKay (1921). "Beauceville" is now the accepted term. According to Dresser and Cooke the erosional unconformity between Beauceville and Caldwell is indicated by conglomerate beds at the base of the Beauceville; the conglomerates being said to be made up

of material largely derived from the Caldwell. The unconformity was believed to be sufficiently important to mark a separation between Ordovician (Pohenegamook-Beauceville) and Cambrian (Caldwell). Also, Dresser inferred that folding and general uplift preceded this period of erosion.

The writer is not familiar with the conglomerates in the Thetford region (Cooke, 1937), and these may well merit the stratigraphic importance attached to them. However, as pointed out below in the discussion of the Beauceville group, the reported implications attached to the conglomerates in the present area (inclusive at least of some of those seen by Dresser) are open to question.

Ordovician

Beauceville Group

The Beauceville group in the present area is made up mostly of slates and impure sandstones with some siltstones, cherts, limestones, basic volcanics and lithic tuffs. In the northeastern (Rosaire-St. Pamphile) part of the area, at the contact of the Caldwell and Beauceville, conglomeratic beds are associated with sandstones and slates similar to those of the Beauceville group. These are the conglomerate beds thought by Dresser (1913) to represent the base of the Beauceville (Pohenegamook) group and to indicate an erosional unconformity between the Beauceville and Caldwell groups.

The conglomerates and the interbedded sandstones and slates are found over an area about 14 miles long and at places nearly a mile wide (see map). The fragments in the conglomerates are of various sizes and compositions: white and grey quartzites up to 12 feet in diameter; green, impure sandstones up to about 5 feet in diameter; numerous small pebbles of black, grey, green and, rarely, red slates; and a few small pebbles of grey siltstones. Size sorting among the fragments is very poor, and those that were but slightly, or not, affected by the subsequent foldings are angular or subangular. The fragments may be either closely packed or loosely scattered in a sandy or slaty matrix (Plates VI-A and VI-B). At many places conglomeratic beds pass gradually across their strikes to sandstones or slates much like the material that makes up the matrix.

The fragments of white and grey quartzites and those of grey siltstones (some of which are calcareous) are lithologically identical to rocks of the Rosaire group. Similarly the green impure

sandstones and green and red slates are identical to rocks of the Caldwell or Armagh group. It would seem, therefore, that a large part of the material that makes up the conglomerates had its source area to the northwest. This material could very well have been deposited on an eroded surface established after the deposition, folding and uplifting of the Rosaire, Caldwell and Armagh groups so as to form the base of the Beauceville group, as is suggested by Dresser. However, it is rather peculiar that basic volcanics which are very abundant in the Caldwell group, are not encountered in the conglomerates. Also, most of the small slate pebbles, which amount to a large part of the conglomeratic material, bear a stronger resemblance to Beauceville slates than to those found in the Rosaire, Caldwell, or Armagh groups. Furthermore, in the southwestern part of the conglomeratic band, top determinations of the interbedded sandstones indicate that the Beauceville slate and sandstones southeast of the conglomerates are more likely to be below rather than above the conglomerates. Some 30 miles to the southwest in the Ste. Justine area similar conglomerates also are located near the Caldwell-Beauceville contact. Structural evidences persuaded Gorman (1954) that these conglomerates are younger than the Beauceville, and possibly of Devonian age. Whether the conglomerates of the present area are at the base of the Beauceville and so indicate a Caldwell-Beauceville unconformity, or whether they indicate a post-Beauceville unconformity, still remains doubtful.

By far the most common rocks of the Beauceville group are sandstones and slates. Many sections show beds of green and grey sandstones 2 to 5 feet thick alternating with thin beds of black, grey, green and, rarely, red slates. Other sections show thick layers of slates with thin interbeds of sandstones. Commonly, thin or thick beds of grey or green siltstones and black chert are associated with the sandstones and slates. Some chert beds are as much as 100 feet thick. Many sandstone beds are even-grained; others show a marked graded bedding. The base of the graded beds generally is conglomeratic, made up of coarse grains of quartz and feldspar and numerous large fragments of volcanic rocks, chert and black slates. This coarse phase generally passes upwards into a fine-grained, shaly sandstone.

As indicated in Table 5, the average Beauceville sandstone is a feldspathic quartzite with a rather large percentage of rock fragments. The average grain size of the quartz and feldspar clastics is about 0.5 mm. and that of the rock fragments about 1 mm. Most fragments are of acidic volcanic rocks, basic igneous rocks, granite, siltstones, slates, sandstones and chert. Sorting and roundness is generally poor. Part of the argillaceous fraction is

recrystallized to white micas and chlorites. Recrystallization, however, is less marked than in the Caldwell sandstones, probably because the Beauceville group is farther away from the Bennett schist belt. The carbonate is largely secondary. Pyroxene, hornblende, biotite, zircon and iron oxides and sulphides are found in small amounts.

Table 5.- Composition of the Beauceville Sandstones

	<u>Per Cent</u> [*]
Quartz	58
Feldspar	16
Micas, chlorite and clay minerals ...	12
Epidote	1
Carbonate	3
Rock fragments	10
	<hr style="width: 10%; margin-left: auto; margin-right: 0;"/> 100

^{*}Feldspathic quartzite.- Average of five estimates. The feldspar is mostly plagioclase with some microcline and orthoclase.

The Beauceville slates are black, grey, green, and red. Red slates are generally in thin beds, except in the area between Frontière lake and Bernatchez where they occur in thick beds. Most slates found in the Beauceville group are made up of very fine quartz, feldspar, and clayey material; the last being in part recrystallized to micas and chlorite. Some of the grey slates are calcareous or contain carbonate lenses. All slates show a neat cleavage.

The siltstones interbedded with the slates and sandstones are made up of clastic grains of quartz and feldspar and variable amounts of clay and micaceous minerals. Some beds are soft; others are very hard. A common variety is a pale green chert-like rock made up mostly of quartz with some feldspar and finely divided epidote; chlorite, white micas and clay minerals also occur in small amounts. This variety is spotted in places with white dots made up of a clay mineral and zoisite.

Limestone, in the Beauceville group, has been found only on St. Roch river in Dionne township. Here a few beds of pure to arenaceous limestone 1 to 3 feet thick are intercalated in grey calcareous slates.

The Beauceville group also includes small amounts of basic volcanics, and lithic tuffs. The basic volcanics resemble those of the Caldwell group. They are pillowed or massive, amygdaloidal, and

considerably altered. In lots 5 and 6, range II, Bellechasse township, is an aggregate of large fragments of greenstones, dark coloured igneous rocks, pumice, chert and slate in a slaty matrix. This could be a volcanic or an explosive breccia.

Lithic tuffs within the Beauceville group have been found in Leverrier township near the boundary between Quebec and the State of Maine. These tuffs have a rugged and rusty weathered surface and are made up of small angular fragments of acidic and intermediate volcanic rocks, angular crystals of quartz, feldspar and pyroxene in a siliceous and micaceous matrix. Rarely, fragments of sedimentary rocks are also found. The texture of these rocks is generally obscured by a marked alteration to chlorite, epidote and carbonate.

The rocks that make up the Beauceville group in the present area are to a large extent very similar to those found at the type locality at Beauceville in the Chaudière River valley. It may be noted here that Mackay (1921), who introduced the name Beauceville, had mapped as volcanics many rock exposures now considered to be sandstones, slates, and tuffs. Gorman (1955) describes the Beauceville group in the St. Georges-St. Zacharie area as made up mostly of grey, medium- to coarse-grained impure sandstones and black, grey and green slates with small amounts of acidic tuffs, albite rhyolite and conglomerate. Gorman^{*} also believes that the age of the group is Middle Ordovician, judging by graptolites found in Beauceville slates in the Ste. Justine area.

The Beauceville of the present area is continuous along the strike to Gorman's fossil locality in the Ste. Justine area immediately to the south and, hence, may be presumed to be of the same age.

Frontière Group

The Frontière group (new name) is not as well defined as the other groups in the area. It is distinguished on the St. Margloire map as the southeastern half of the Beauceville group. It was not separated from the Beauceville in the areas to the southwest (Gorman: Ste. Justine, St. Georges-St. Zacharie areas) although it can be distinguished there with some difficulty.

^{*}Gorman, W.A., Personal communication.

In St. Magloire area the Frontière group is composed of three units, namely, impure sandstones, slates, and basic volcanics. The first two constitute 98 per cent of the group and are particularly well exposed near Lac-Frontière. Separation from the Beauceville is based not so much on the rocks seen as on those that appear to be lacking. The grey and green impure sandstones, the black and grey slates, and the altered basic volcanics (greenstones) are like Beauceville types. However, other types characteristic of the Beauceville assemblage are missing; these include hard siltstones, cherts, and green and red slates. Also, the rocks of the Beauceville and Frontière are arranged in different patterns. In the Beauceville the sandstones and slates alternate throughout, whereas in the Frontière the sandstones are largely confined to one zone bordering on the Beauceville and the slates to another and overlying zone. This suggests that the Beauceville and Frontière could have been deposited in different environments and possibly at different times. However, it may indicate only a change of environment without appreciable difference in time.

The sandstones are commonly gritty, contain large fragments of slates, and show graded bedding. Graded beds generally have a conglomeratic base. Limy nodules and lenses are found in many beds. As may be seen in Table 6 the sandstones are quartzose, feldspathic, somewhat argillaceous, and contain small amounts of rock fragments.

Table 6.- Composition of the Frontière Sandstones

	<u>Per Cent</u> ¹	<u>Per Cent</u> ²
Quartz	54	78
Feldspar	23	7
Chlorite, micas and clay minerals	12	8
Epidote	4	6
Carbonate	2	1
Rock fragments	5	-
	<hr/> 100	<hr/> 100

¹Feldspathic quartzites.- Average of five estimates. The feldspar is mostly oligoclase with some microcline.

²Quartzites.- Estimate

The clastic grains of quartz and feldspar have an average diameter of about 0.4 mm. and the rock fragments about 1.5 mm. The latter include basic, intermediate and acidic volcanics, granite, pegmatitic granite, quartz veins, quartzites, impure sandstones, siltstones, slate and limestone. Size sorting and roundness are not

marked. The matrix is silty, argillaceous, and partly recrystallized to micas, chlorite and epidote. Clastic micas occur in small amounts. The carbonate is secondary. Hypersthene, sphene, tourmaline, zircon, and iron minerals are found in small amounts. A few grains of clastic chromite were noted in samples collected near Frontière lake.

The chromite is particularly noteworthy because chromite-bearing serpentinites intrude the Beauceville, Caldwell and Bennett groups to the northwest. Since this chromite is clastic and may have been derived from the serpentinites it may be inferred that the Frontière and Beauceville are separated by an erosional unconformity. And since the Beauceville is probably Middle-Ordovician and the serpentinites are here assumed to have been emplaced toward or at the end of the Ordovician, it may also be inferred that the Frontière group is Silurian or Devonian. If post-Taconic, it is certainly pre-Acadian because it is as much folded as the Beauceville.

Silurian or Devonian

Acidic Volcanic Rocks

Within the area underlain by the Beauceville group, in Ware and Roux townships, is a half-mile wide strip of acidic volcanic rock. This extends some three miles southwest into the Ste. Justine area. The rock is black or greenish on fresh surfaces and weathers white or rusty. It is generally massive and glassy and has amygdules of carbonate and chlorite. At some places it consists of angular fragments cemented by a matrix which seems to be of the same composition as the fragments. Some schistose and micaceous facies are also present. The rock is generally very altered. Under the microscope irregular small masses of quartz, part of which seems to be secondary, are common. Another constituent is a sodic plagioclase in slender phenocrysts largely altered to sericite, clay minerals, chlorite and epidote. Apatite, zircon and iron oxides occur in small amounts. Part of the broken facies shows fragments of various types of acidic volcanics and rarely small fragments of sedimentary rocks. Some of the latter may be lithic tuffs interbedded with the volcanic flow. They closely resemble those found intercalated in the Beauceville sequence in Leverrier township.

The abrupt ending of the volcanic layer at its northeastern end and indications of a structural unconformity in the Ste. Justine area* suggest that the acidic volcanics and tuffs of Ware

*Gorman, W.A., Personal communication.

and Roux townships do not belong to the Beauceville group. In Ste. Justine area they appear to lie unconformably on the Beauceville. They are, therefore, presumably post-Middle Ordovician. And since they are folded they must be pre-Acadian. Thus, they are considered here to be Silurian or Devonian.

Devonian

St. Juste Group

The term "St. Juste group" is introduced to designate an assemblage of black slates and black and grey sandstones exposed in the vicinity of St. Juste in the southeastern part of St. Magloire area. As shown in Table 7 the sandstones are quartzose. The average grain size is about 0.2 mm. Some beds contain many fragments of volcanic rocks, siltstones and slates. The clastics are subrounded and poorly sorted. The matrix is clayey, but slightly recrystallized to micas and chlorite. In that respect it is much less recrystallized than the matrix of the Beauceville (and Frontière) sandstones, possibly because it has not been as much deformed. Epidote is very rare. Carbonate is not abundant and largely secondary. Zircon and iron minerals are found in small amounts.

This group of rocks has been traced southwest by Gorman (1954; 1955) across the Ste. Justine area to the St. Georges-St. Zacharie area in the Chaudière River basin. In the St. Georges-St. Zacharie area the St. Juste group (Gorman, 1955) unconformably overlies rocks considered to be Beauceville. It contains fossils indicative of a Devonian age. Other fossils at a few localities in the Ste. Justine area also point to a Devonian age for the St. Juste group. As mentioned above the relationships of the Frontière group to the Beauceville and St. Juste in the Ste. Justine and St. Georges-St. Zacharie areas are still not clear. If present at all the Frontière would have to terminate abruptly northeast of the St. Georges-St. Zacharie area.

Table 7.- Composition of the St. Juste Sandstones

	<u>Per Cent</u> [*]
Quartz	72
Feldspar	7
Chlorite, micas and clay minerals..	19
Carbonate	2
	<hr/>
	100

^{*}Quartzites.- Average of three estimates. The feldspar is mostly plagioclase with some microcline.

Plate I



A - Notre-Dame range seen from St-Magloire — St-Philémon road.



B - Ridge of acidic volcanic rocks three and a half miles southwest of St-Magloire.

Plate II

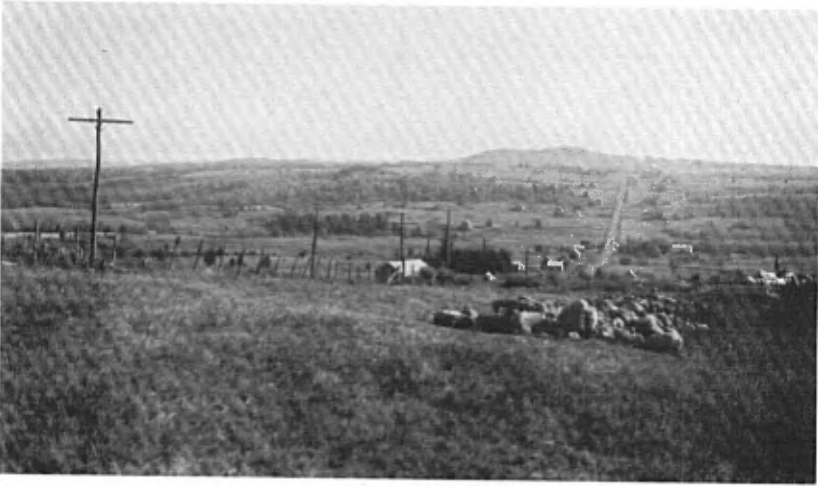


A - Leverrier lake, from high ground to the north.



B - Broad valley crossing the St-Marcel — Ste-Apolline road.

Plate III



A - Black river valley seen from the St-Adalbert — St-Pamphile road.



B - Black river valley north of St-Adalbert — St-Pamphile road.

Plate IV



A - Beds of Rosaire quartzite; lot 26, range I, Talon township.

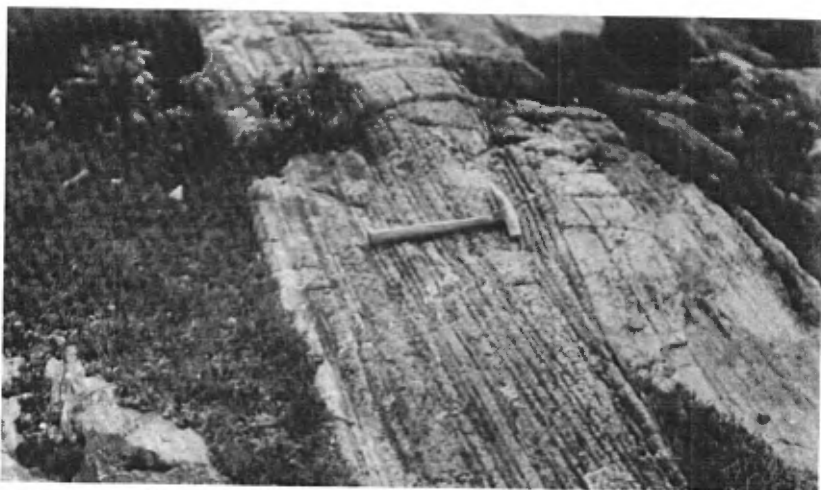


B - Rosaire black phyllites with thin limy interbeds; lot 20, range IV, Arago township.

Plate V



A - Rosaire quartzite with quartz veins; lot 26, range I, Talon township.



B - Banded, graded bed of Caldwell sandstone; lot 3, range IV, Dionne township.

Plate VI



A - Conglomerate bed one mile southwest of St-Adalbert .

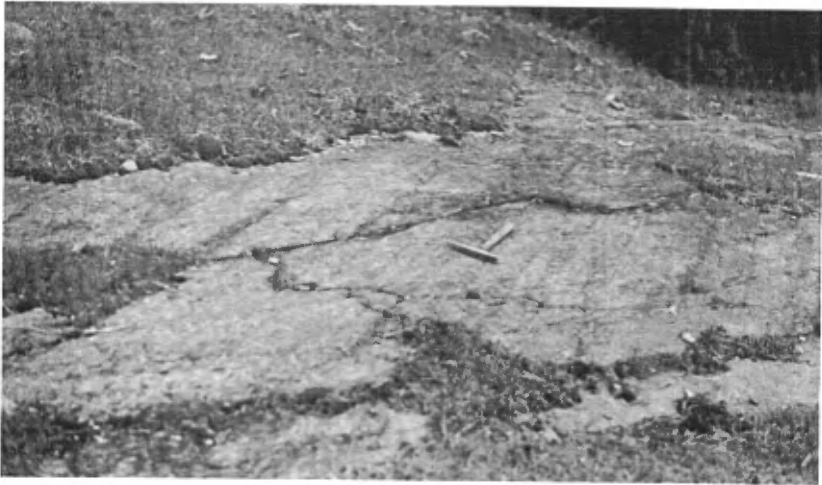


B - Conglomerate bed one mile southwest of Black river .

Plate VII



A - Cross-section of an esker near Black river, Talon township.



B - Glacial striae, on soft slates at St-Adalbert.

Intrusive Rocks

The intrusive rocks of the area may be divided into three groups. One group includes large and small, generally tabular, bodies of serpentinites intruded by dykes and small stocks of diorite, granodiorite, granite and syenite. Most of the serpentinites belong to the serpentine belt that extends, in Quebec, from the state of Vermont to l'Islet county. A second group consists of sills and dykes of gabbros probably related to the serpentinite series. The third group includes sills of albite diorites found in a zone which extends from the vicinity of St. Pamphile in l'Islet county to the south boundary of the area and southwest of the area to the Chaudière River basin. Almost all these sills are contained in rocks of the Beauceville group.

Serpentinite and Associated Rocks

Most, and the largest, of the serpentinite bodies are found in a narrow belt that follows the contact of the Caldwell and Beauceville groups. This suggests that the contact zone itself is a zone of weakness, a suggestion that is further supported by marked shearing in both Caldwell and Beauceville as the contact is approached. Some bodies also occur away from this contact in the Caldwell group and in the Bennett schists. A large circular magnetic anomaly at the northeast end of the Bennett belt indicates that a large body of basic rock, possibly serpentinite, may lie here below the sedimentary rocks. The gradient of the anomaly suggests a depth of some 6,000 feet. The two largest known bodies of serpentinite in the region are respectively in Rolette and Talon townships. The Rolette body intrudes slates, sandstones and chert which, at the southwest end of the serpentinite body, are mineralized with nickel and copper sulphides. This mineralization is further discussed in the section dealing with the economic geology. Aside from these two bodies of serpentinite another fairly large mass is found in Roux township and several small bodies occur in Leverrier, Talon, Roux and Standon townships.

The serpentinite is black, dark grey or green on fresh surfaces, and weathers to a rusty brown. Rare coarse pyroxene crystals, largely altered to bastite, indicate that at least part of the serpentinite is altered peridotite. The rock is now almost completely altered to scaly serpentine minerals, largely antigorite. At places it is considerably carbonated. Asbestos is rare and in thin veins. Finely divided magnetite generally amounts to 2 or 3 per cent of the rock. Rarely, thin layers of disseminated chromite were noted. The rock is broken into angular blocks separated by slip planes coated by coarse fibres of "slip-serpentine". Thin discontinuous layers of talc schists parallel to the schistosity of the surrounding sedimentary rocks were noted in the Rolette body of serpentinite.

Within the largest bodies of serpentinite are small stocks of diorite, granodiorite and granite, and dykes of granodiorite, aplite and syenite. Serpentinization is seemingly more advanced along the contacts of some of these late intrusives, although it is doubtful that all the serpentine is directly related to them. In one small stock of diorite, andesine (An_{32}) amounts to 60 per cent, hornblende 37 per cent, and chlorite and epidote 3 per cent. This diorite differs from the albite diorites found in the Beauceville slates in that it contains a more calcic plagioclase and the predominant mafic mineral is hornblende instead of augite. From this it is concluded that the albite diorites probably do not belong to the serpentinite series.

Gabbro

A few sills and dykes of gabbro, some of which are considerably altered, occur near the serpentinite bodies. One dyke, emplaced in Bennett schists in range XII of Standon township, is about 150 feet thick. Some fairly thick sills, one near Moose river in range IV of Rolette township and two in range V of Roux township, are emplaced in Caldwell rocks. One of these sills is made up of clusters of coarse pyroxene in a fine-grained groundmass of chlorite, epidote and altered feldspar. All these gabbros are probably related to the serpentinite series although this relationship could not be definitely established.

Albite Diorite

Albite diorites, mostly in sills one to 50 feet thick, are found in the southern part of the area (St. Magloire) in a band that extends from near St. Fabien to and beyond the southern boundary of the area. Apart from this band, a small stock, one mile east of Gravier lake (Roux township) seems to intrude acidic volcanic rocks of presumed Silurian or Devonian age. Also, two sills intrude Beauceville rocks; one is 2 miles southwest of St. Pamphile, and the other is 2 1/2 miles southwest of Ste. Lucie. And finally, near Frontière lake, a sill is emplaced in the Frontière group. If the Frontière group is Silurian and the acidic volcanics Silurian or Devonian then the albite diorite intrusions must be post-Silurian in age. Lack of granulation in the albite diorites suggests that they are at least post-Taconic.

The albite diorite is black or green on fresh surfaces, generally rusty-weathering, fine- to coarse-grained, and in part porphyritic. The porphyritic facies shows white phenocrysts of feldspar. Some of the fine-grained facies is like basalt and commonly contains amygdules of quartz, carbonate, and chlorite. The coarse-grained

facies generally shows a marked diabasic texture. Disseminated small nests of iron sulphides are common. The rock, although generally massive, is well foliated in places, particularly in the southeastern part of the main belt in the St. Magloire area. It is also much fractured and jointed. Cross and longitudinal joints are particularly well marked.

In the main belt the albite diorites are in slates, siltstones, sandstones and cherts, which commonly form but thin screens between the sills. Baked slates and chilled margins of the diorites were noted at some contacts. Commonly the slates near the diorites are rusty from disseminated iron sulphides or have been enriched in carbonate or silica. Micaceous and chloritic slates have also been noted. Some of the carbonated slates contain very coarse porphyroblasts of carbonate, whereas others are replaced by finely divided material. Many samples of altered slate have been found to contain as much as 50 per cent carbonate and 15 per cent chlorite partly intergrown with biotite. Apatite is also found in small amounts. Along some contacts both the diorite and the wall rock contain small concentrations of iron, copper and zinc sulphides. These are further discussed in the section dealing with economic geology.

The sills and the wall-rock contain numerous veins of quartz and carbonate. Some veins also contain tremolite, chlorite, epidote and, rarely, albite. The veins generally follow the joints or are arranged in stockworks. In the southeastern part of the main belt an arsenopyrite and gold mineralization is seemingly related to these quartz and carbonate veins.

Under the microscope, the albite diorites are made up mostly of albite and augite largely altered to carbonate, chlorite, epidote and quartz. The porphyritic facies contains sericitized phenocrysts of albite, 1 to 2 mm. long, disseminated in a fine-grained felt of albite and augite crystals. Other facies contain aggregates of coarse pyroxene surrounded by slender laths of albite. In still other facies the albite and augite are equally well developed and of the same grain size. The feldspar commonly shows signs of straining but is not granulated. The pyroxene is generally fresher than the feldspar but still largely altered to actinolite, hornblende, stilpnomelane and leucoxene. Sulphides are disseminated in small stringers or in large aggregates of small grains. The alteration products: chlorite, carbonate, epidote and quartz, occur in irregular masses. Part of the quartz is seemingly primary but a large amount is secondary.

In some ophitic facies small wedges of micropegmatite fill interstices. Ilmenite, leucoxene, sphene, zircon and apatite are found in small amounts.

The main belt of albite diorite sills (St. Magloire area) may be divided into two zones on the bases of different compositions and structures. The dividing line, parallel to the range lines, passes through the middle of ranges II of both Panet and Bellechasse townships. To the northwest zone may be added the small stock that occurs about one mile east of Gravier lake and the two sills found respectively southwest of Ste. Lucie and southwest of St. Pamphile. The albite diorites in the northwest zone differ from those of the southeast zone principally because of a lower tenor in quartz and mafic minerals and a more calcic albite. Besides, the northwest zone is seemingly characterized by a copper and zinc mineralization and the southeast zone by a gold-arsenopyrite mineralization. This is further discussed in the section dealing with the economic geology. It is not clear whether the difference in composition of the albite diorites in the northwest and the southeast zones indicates different magmatic phases or different alterations. In both zones the rock is considerably altered, but it is definitely more so in the southeast zone. Some of the albite diorite in this zone contains as much as 50 per cent carbonate or 50 per cent chlorite and biotite. The rock also contains more sulphides, these being generally proportional to the amount of carbonate and chlorite. This larger proportion of alteration minerals may be related to the obviously more severe deformation. Other features, however, such as a different tenor in primary quartz and mafic minerals and the different composition of the albite (see Table 8), point to a magmatic differentiation. In the northwest zone the albite has an anorthite content of about An_{10} and in the southeast zone of about An_5 . To this may be added the presence of interstitial micropegmatitic intergrowths of potash feldspar and quartz in the albite diorites of the southeast zone. These diorites also contain a small amount of apatite.

Table 8.- Composition of Albite Diorite

	<u>Per Cent</u> ¹	<u>Per Cent</u> ²
Quartz	3	7
Albite	53	52
Mafic constituents	41	29
Carbonate	1	7
Epidote-zoisite	1	1
Iron ore	1	2
Micropegmatite	-	2
	<hr/>	<hr/>
	100	100

¹Albite diorite of northwest zone.- Average of twelve estimates. The mafic constituents are mostly augite and chlorites with some actinolite, biotite and ferristilpnomelane (ferric iron-rich chlorite).

²Albite diorite of southeast zone.- Average of eight estimates. The mafic constituents are mostly chlorites with some actinolite and biotite.

It seems possible, therefore, that the different compositions and metallic mineralizations in the northwest and southeast zones result from magmatic differentiation, although because of the high degree of alteration of the rocks this cannot be firmly established.

Pleistocene and Recent

Recent deposits are mostly fluvial accumulations along the present watercourses. Pleistocene deposits include morainic material, and kames, eskers and other stream accumulations of glacial origin.

The morainic material is particularly abundant on the flanks of the hills and generally consist of boulders in a matrix of gravel, sand and clay. Most of the boulders are angular and have been quarried from the local bedrock. Others are subangular and have been carried for some distance. The few of Precambrian granite gneisses are well rounded. Quarrying seems to have been particularly effective in the northwestern part of the area in the belt of Armagh rocks. Here vast stretches of ground are littered with angular fragments of Armagh sandstones.

Most boulders seem to have been carried southerly, although some must have been moved northerly. For instance, huge blocks of Caldwell greenstone, as well as boulders of Beauceville chert, occur several miles north of their source areas. Other glacial features, however, such as chatter marks, roches moutonnées, and boulder trains south of some roches moutonnées, point to a southerly movement of the ice. Glacial alterations are common and particularly marked on outcrops of slates (Plate VII-B). Over most of the southern part of the area (St. Magloire) the trend of the glacial striae is about S.10°E. Over the northern part (Rosaire-St. Pamphile) several trends were noted. In the northwestern part of this area the trend is about S.45°E., in the northeastern part about S.10°E., and in the southern and southwestern parts about north-south. In the southwestern part a second set of striae trends about N.80°E. This second set probably represents but a local movement of the ice, possibly a mass of ice descending easterly from the high ground of the Notre Dame range to the west.

Many valleys and other depressions in the region are filled with thick stratified sheets of gravel and sand presumably accumulated by glacial streams. With these deposits are also conical hills, probably kames, made up of boulders and gravel. Overlying the

thick sheets of gravel and sand are also segments of eskers made up of boulders, gravel and sand. These eskers are 10 to 50 feet high, 100 to 300 feet wide at the base, and have a triangular cross section (Plate VII-A). At most places the segments are short but some, generally meandering, can be traced over distances of 3 to 6 miles. Some terminate with a fan-shaped mound of gravel and sand which is seemingly a deltaic deposit accumulated in a glacial lake. Other eskers are bordered by ridges or irregular mounds of gravel and sand pocked with kettle holes.

STRUCTURE

Folding

The main structural feature of the Appalachian uplands in this region is a broad anticline commonly referred to as the Sutton anticline. This anticline, originally identified in the Sutton mountains of Brome county, is known to extend into the present area. Here, in the Bennett schist, it traverses the St. Magloire area and fades out into tightly folded rocks of the Rosaire group in the Rosaire-St. Pamphile area to the north. The anticlinal structure is a broad arch plunging about 15° northeasterly over most of the St. Magloire area. Near the west boundary of that area it plunges about 10° southwesterly. The crest of this anticline is quite irregular and, here and there, it rolls into a series of minor folds. This anticlinal structure actually is based on schistosity and may not necessarily be that of the bedding. In the northeastern part of the anticline for instance, where the Bennett schists pass gradually to phyllites and then to slates and quartzites of the Rosaire group, it appears that the anticline fades out into a series of tight folds of small amplitude. At many places within this gradational zone near the crest of the anticline there are two schistositities. One is gently dipping like that found in the Bennett schists farther southwest, and the other is steeply inclined like that found in the Rosaire rocks farther northeast. In the southwestern part of the anticline the bedding is generally obscured by the schistosity and the high degree of contortion and disruption of the rock. At a few places near the crest of the anticline some steeply inclined beds are disrupted along gently-dipping planes of schistosity. Away from the crest the beds, where recognized, are parallel to the schistosity. Drag folds with amplitudes of one to five feet were observed at several places on the flanks and near the crest of the anticline. Most of such folds seem to indicate a downward displacement of the upper beds. This is the opposite of what would be expected if the anticline had been formed by flexure. Actually these drag folds suggest flowage

under vertical stresses rather than folding under tangential stresses. Thus, it is not clear whether the Sutton anticline is truly a fold. It could be a foliation (schistosity) dome superimposed on a series of isoclinal folds such as appear to be present northwest and southeast of the anticline.

Some support to this interpretation may be found in the Richmond area (Cooke, 1954) of the Eastern Townships, also traversed by the "Sutton anticline". Here the structure appears to be a schistosity anticline superimposed on a synclinal structure and bounded northwest and southeast by thrust faults. As in the present area the schistosity on the northwest limb of the anticline dips about 45° northwest and on the southeast limb about 60° southeast. At the crest it forms an arch. Drag folds of the schistosity planes on both limbs, however, point to a downward movement of the lower layers. This and other features have led Cooke to consider that the schistosity arch was the result of shearing consequent upon movements along the two bordering faults, the southeastern block being thrust over the central block along a southeasterly-dipping fault while the central block itself was thrust under the northwestern block along a northwest-dipping fault. Although this particular interpretation may not be valid in the present area, there is a good possibility that the "Sutton anticline" in the two areas is not a flexure fold.

Somewhat similar structures have been found also in Central Vermont east of the Green Mountains anticlinorium (southern extension of the Sutton anticline). Here, according to White and Jahns (1950), are elongate "cleavage domes" several miles in length in which a secondary "slip-cleavage" forms an arch superimposed on a primary flow cleavage. Minor folds related to the slip cleavage point to a downward movement of the upper layers of the arched structure. It is thought that there was first a folding into a series of synclines and anticlines which led to the development of the primary flow cleavage; later this was followed by a second deformation during which slipping and arching resulted from an upward welling of the central part of the dome. Such upwelling is tentatively attributed to the rise of a granite mass (or migmatite front) or of a plastic core in a manner similar to the diapiric emplacement of a salt plug.

Northwest and northeast of the Sutton anticline in the present area the Rosaire and Armagh groups apparently are arranged in isoclinal folds with axes about parallel to that of the anticline. Immediately northwest of the anticline the Rosaire beds dip between 50° and 70° northwest, which suggests a steep overturn to the southeast. In the Armagh northwest of the Rosaire the folds are steeply overturned to the northwest. Lenses of Armagh within the

Rosaire northeast of the anticline indicate, however, that the Rosaire and Armagh were deformed together into a series of tight folds.

Southeast of the Bennett schists and the Rosaire group, the Caldwell is tightly folded with the axes steeply overturned to the northwest near the Sutton anticline and about vertical farther southeast. The trend of the folds is somewhat oblique to the general direction of the Caldwell band; furthermore, the folds abruptly end at the Caldwell-Beauceville contact as though truncated here by a fault.

The Beauceville group, like the Caldwell, is tightly folded and the axes of the folds are about parallel to the trend of the belt in which the Beauceville is found. Emplaced in these folds are conformable sills of albite diorite.

The St. Juste group to the southeast seemingly is in isoclinal folds that trend about parallel to those of the Beauceville. The St. Juste, at many of its exposures, appears to have been less deformed than the other groups.

The structure of the conglomerate zone found in the vicinity of St. Adalbert at the Caldwell-Beauceville contact is difficult to interpret. The attitude of the conglomerate beds and top determinations of associated sandstone beds indicate that the assemblage is tightly folded like the Beauceville and Caldwell. In the southwestern part of the zone, the conglomerates appear to overlie the Beauceville but in the northeastern part they seem to be at the base of the Beauceville group. In the Ste. Justine area a similar conglomeratic complex also at the Caldwell-Beauceville contact is considered by Gorman (1954) to overlie the Beauceville and to be Devonian in age.

Faulting

Many structural features point to a faulted contact between the Caldwell and Beauceville groups. As mentioned above, most of the serpentinite bodies occur along this contact as though emplaced along a zone of weakness. Also, the folds in the Caldwell belt terminate abruptly at the Caldwell-Beauceville contact, and both the Caldwell and Beauceville rocks are severely sheared along the contact zone. The shearing is particularly marked in St. Magloire area. In Rosaire-St. Pamphile area it is pronounced only near the south boundary, where several parallel shear zones occur within the Caldwell. The sheared rocks are very schistose and the schistosity is everywhere steep.

Another shear zone is found in Talon township south of Talon lake. At the south tip of the lake it is marked by a narrow gorge oriented north-south. Farther south, the shear zone swings to the southwest and possibly merges with the Caldwell-Beauceville fault. In view of the above evidences it is possible that the Beauceville and Caldwell are bounded by a high angle fault along which the Beauceville has been thrust against the Caldwell. This thrusting might have accompanied the folding, and both would have been effected by orogenic pressure directed northwesterly.

A cross-fault with an apparent horizontal displacement of about a quarter mile was noted within the Caldwell belt near the boundary of Roux and Rolette townships. Another cross-fault apparently has offset the Caldwell-Beauceville contact in the northeastern part of Rosaire-St. Pamphile area. Such cross-faults could have developed while the Beauceville was being thrust against the Caldwell.

ECONOMIC GEOLOGY

Before 1951, there was little interest in the present area from the point of view of economic geology. A few prospects of asbestos had been summarily investigated, and that was all. However, in the autumn of 1951, after the discovery of nickel-copper ore near St. Fabien de Panet, the southern part of the area became the scene of an intensive search for mineral deposits. Since 1951 several mining companies and individuals have done some detailed geological mapping, geophysical work, and diamond drilling. Most of the work has been aimed at investigating three main geological features: the break between the Caldwell and Beauceville groups, the serpentinite intrusive bodies and the sills of albite diorite. Interest in the serpentinite bodies resulted from the nickel-copper ore being near a large mass of serpentinite. Interest in the albite diorite sills to the southeast was aroused when, subsequently, small concentrations of copper and zinc sulphides and free gold were disclosed in and near some of them.

The gold is in quartz veins and quartzose albite diorites that seemingly are restricted to the southeastern part of the albite diorite complex. Somewhat in contrast, the occurrences of copper and zinc minerals are principally in the northwestern, and slightly more basic, part of the complex.

Base Metals

Eastern Metals Corporation, Limited

Eastern Metals Corporation (recently taken over by Mogul Mining Corporation) is developing a nickel-copper deposit about two miles west of St. Fabien de Panet. The deposit is located in lots 21 and 22, range VI, Rolette township. The property of this company includes lots 16-24, range IV; lots 12-29, range V; lots 12-30, range VI; and lots 14-31, range VII; all in Rolette township.

History.- The deposit was discovered in 1949 by Theodore Belanger of St. Fabien, who was attracted by gossan at the site of what is now known as the North or Nickel zone. Consolidated Mining and Smelting Company of Canada optioned Belanger's claims and drilled three holes. These holes did not yield encouraging results. In 1951 Ascot Metals Corporation, Limited, bought the mineral rights from Mr. Belanger and founded the subsidiary Eastern Metals Corporation to develop the deposit.

Operations.- Surface operations to date have included detailed geological mapping, magnetic and electric (self potential) geophysical surveys, and diamond drilling. A total of 58,799 feet had been drilled from the surface up to March 4, 1955.

Underground operations included the sinking of a three-compartment shaft to 740 feet. Five levels were established at the respective depths of 160, 303, 450, 560, and 703 feet from the surface. Cross-cuts join the shaft to the North ore zone at each level, and to the South ore zone at levels 1 and 2. Cross-cuts join the North and South ore zones at levels 3 and 5 without passing through the shaft. Other exploration cross-cuts also have been put in. The North ore zone has been explored at levels 1, 2, 3, and 5 by drifts with lengths respectively of 740, 520, 470 and 1,400 feet. Drifts in or near the South ore zone at levels 1, 2, and 3 have respective lengths of 650, 850, and 750 feet. A drift was being driven in the North ore zone at the 4th level, and drifts and cross-cuts to explore lenses of copper mineralization at higher levels were being driven in the summer of 1955. Underground operations up to March 11, 1955, also included over 300 diamond drill holes with a footage totalling 31,979.

Geology.- The deposit is at the southwest end of an elongate body of serpentinite cut by granodiorite dykes and emplaced in Beauceville sedimentaries. At the contact are altered rocks

derived from both the serpentinite and the sedimentaries. The ore is in these altered rocks.

Beauceville.- The Beauceville here is mainly slates - black, grey, green, and red - with interbeds of green and grey quartzose siltstones, grey argillaceous sandstones, and chert. The slates are generally phyllitic in the contact zone. There are also a few zones of black, graphitic slate. Anomalies detected by electric geophysical survey correspond to some of these zones.

Serpentinite.- The serpentinite body, at the surface, is 7,000 feet long and up to 2,000 feet wide. It is a black to bluish green rock composed mainly of antigorite. The presence of some pseudomorphs after pyroxene indicate that the original rock was a coarsely crystalline peridotite. Small amounts of chromite and magnetite are present. The chromite is in small scattered grains or, rarely, is in thin layers. One drill hole gave 22 per cent chromite over a few feet. A few stringers of cross-fibre asbestos 1/32- to 1/8-inch long were noted. Isolated grains and small stringers of pyrrhotite, pyrite and, rarely, millerite occur. The millerite is generally found on slip surfaces near the ore deposit. Carbonates, mostly dolomite, occur in veins and in irregular small spots. Near the contact with the Caldwell volcanics on the north the serpentinite is locally enriched with hematite and tinted red.

Granodiorite.- Granodiorite dykes crop out but at one place on the mine property although several dykes have been intersected in drill holes. They vary from 20 to 50 feet wide. Their strike is about parallel to the long axis of the serpentinite body, and their dip is vertical. The rock is greenish, hard, massive and medium-grained. It is made up of quartz (30 per cent), oligoclase (45 per cent), orthoclase (8 per cent), chlorite (11 per cent), and small amounts of iron oxides, leucoxene, rutile and apatite. The chlorite, being pseudomorphous after hornblende, suggests considerable alteration after the emplacement of the dykes. The serpentinite near the granodiorite dykes contains some phlogopite. Streaks of massive chalcopyrite also occur near the contacts of some of the dykes. However, as pointed out below, the bulk of the copper ore here probably is not related to the dykes. Stocks and dykes of less altered granodiorite cut another mass of serpentinite four miles to the northwest of the Eastern Metals property.

Altered Rocks.- The altered rocks are restricted to the southwest end of the serpentinite body. There they form a zone 20 to 80 feet wide along the serpentinite-Beauceville contact. A few tongues of altered rock extend into the serpentinite. The

altered rocks derive mainly from Beauceville slates but, in part, as evidenced by grains of chromite, from the serpentinite.

The altered rocks include several varieties. A common type is a dark grey, dense, cherty and evidently silicified rock. This has been mistaken for a rhyolite or for a quartzite by some observers. However, as it grades into less altered facies, and wraps around the southwest end of the serpentinite body, it may be assumed to be of metasomatic origin. Further evidence of such origin is given by carbonatation close to the serpentinite. Here we find disseminated or coarsely crystalline dolomite and calcite. Close to the serpentinite the silicified and carbonated rocks are also bordered locally by irregular lenses of talc and talc-chlorite schist presumably deriving from the serpentinite. One such lens is shown on the accompanying map of Eastern Metals property.

A common sequence in the altered zone is, from the serpentinite outwards, - talc schist, dolomite-rich rock, silicified rock, partly silicified chloritic phyllite, slate.

Veins of carbonates and of white and glassy quartz are common. Presumably these veins represent a second introduction of silica and carbonate, following brecciation of the altered rocks.

Structure.- The serpentinite body trends about N.25°E., parallel to the fold axes in the Beauceville which is the host formation. It seems likely that this ultra-basic mass, like the others along the Caldwell-Beauceville contact, was emplaced along a high-angle thrust fault, or some zone of weakness, that developed during the folding of the Caldwell and Beauceville. The thrust appears to be located immediately north of the serpentinite body.

There is a complex interfingering of serpentinite and Beauceville sedimentaries at the southwest end of the serpentinite mass. Two large tongues of serpentinite form a broad embayment open to the southwest in which are three other small tongues of the same rock. The ore is found at the contact of these tongues with the sedimentaries, and partly within the tongues. The tongues are more or less parallel to the axial planes of the isoclinal folds within the Beauceville belt. They plunge about 45° southwest. All, except the large tongue on the southeast side, dip steeply southeast or are vertical. The large tongue dips 45° northwest on its northwest side and steeply southeast on its southeast side. The fingers of slate in the embayment suggest roof pendants, thinning at depth and

plunging southwest at about 45° . Roof pendants of basic volcanic rocks, nearly vertical, occur to the northeast.

Secondary movements apparently along the thrust fault to the north affected the mineralized area. The serpentinite and the Caldwell volcanics, in contact here, are sheared and numerous slip planes and breccia zones are present in the serpentinite. Similar slip planes also occur in the sedimentary rocks within the embayment. The slates are sheared and phyllitic and the zone of altered rocks is brecciated. It is probable that the granodiorite dykes, all of which are essentially parallel and have a vertical dip, were emplaced in a series of parallel faults subsidiary to the main thrust fault. It may be that the interfingering of serpentinite and Beauceville sedimentaries is the result of slicing, and that the sedimentary fingers are not roof pendants as suggested above. However, the underground workings apparently have not yet disclosed any evidence of such faulting.

It is also possible that the altered rocks formed along a zone of minor slippage and brecciation resulting from orogenic stresses on rocks of different competency. In any event, there are evidences of dislocation within the embayment of sedimentary rocks at the southwest end of the serpentinite body. Also, detailed studies of the two main ore zones show that repeated deformations during the course of the mineralization did take place.

The Deposits.- The nickel and copper ores of the deposits is confined to the zone of altered rocks. It occurs principally in two zones, about 400 feet apart on the surface, and referred to as the North and the South zones (see map of Eastern Metals property). Other, minor zones occur near these two principal ones.

The North (or nickel) zone is about 180 feet north of the shaft. It trends $N.25^{\circ}E.$, dips vertically, and plunges 45° to the southwest. It follows the northernmost of the three small tongues of serpentinite described above. At the surface, this zone is 800 feet long and has an average width of 50 feet. It is reported to extend to 525 feet depth. Information given by the company in June 1955 provides the following measurements and tonnage estimates:

<u>Level</u>	<u>Length</u> (Average in feet)	<u>Width</u> (Average in feet)	<u>Height</u> (In feet)	<u>Tonnage</u>	<u>Tenor</u> Ni (Per cent)
0 to 1	465	28	120	130,000 proved	0.96
1 to 2	460	18.7	143	103,000 "	0.98
2 to 3	392	14.9	147	71,500 "	1.16
3 to 4	200	7.7	100	<u>12,830</u> probable	<u>1.87</u>
				317,330 Total	1.05 Average

Most of the ore is in the silicified and carbonated slates; a little is in the altered serpentinite. The grade is variable. Some sections 4 to 5 feet long have tenors up to 12 per cent nickel and 30 per cent zinc. In general the ore is found in irregular pockets and lenses. The best ore is reported to be in the centre of the zone, where the overall grade is about 1 per cent nickel, 1 to 2 per cent zinc, and a little copper.

The nickel and zinc minerals are found in irregular aggregates and in stringers usually emplaced in brecciated masses of fine-grained pyrite. The nickel minerals are millerite, with some violarite and a little gersdorffite. The zinc mineral is sphalerite.

The metallic minerals so far identified in this zone include^{*}:

Pyrite. Generally in fine-grained brecciated masses veined by nickel and zinc sulphides. Quartz and calcite veins also cut these masses and carry other and later pyrite in small quantities.

Millerite. Generally in narrow seams of clayey material presumably derived from altered slates. It occurs in aggregates of large crystals with good cleavage; some of the crystals are as much as two inches long. This occurrence is unusual for millerite generally is found in slender, hair-like crystals or in very small masses replacing other minerals; it rarely occurs in large concentrations.

Gersdorffite. Occurs in aggregates and small blebs within the silica-carbonate gangue, and occasionally borders the millerite.

Violarite. Results from the alteration of millerite and of gersdorffite.

^{*}Information from Blais (1952) and Pollock (1955).

Sphalerite. Occurs as irregular stringers within the brecciated masses of pyrite.

Marcasite. Encrusts the brecciated pyrite and shows a colloform structure.

Pyrrhotite. Occurs on many slip surfaces in serpentinite^{*}.

The South (or Copper) zone is 310 feet south of the shaft. It lies along the northwest flank of the large southeastern tongue of serpentinite. Like the North zone it strikes N.25°E. and plunges 45° southwest, but its dip is 45° northwest instead of vertical. At the surface the South zone is about 1,500 feet long and 10 to 50 feet wide. As in the North zone, most of the ore is in silicified and carbonated slates with some in altered serpentinite.

Cross sections of the two zones and electric readings suggest a merging of two zones towards the southwest at a depth of about 700 feet. However, the different assemblages of ore minerals in the two zones suggest that the zones remain separate at depth.

The South zone has not been extensively explored as yet; but the ore appears to be distributed in irregular lentils generally parallel to the zone as a whole. Early drilling indicated an overall grade for this zone of about 1.5 per cent copper, 0.30 per cent zinc, and 0.20 per cent nickel. The ore is in veins and aggregates of chalcopyrite emplaced in brecciated masses of fine-grained pyrite like that of the North zone.

Lentil No. 1 is 150 feet long and up to 70 feet wide on the first level. On the second level it is 50 feet long and about 40 feet wide. It reaches from 40 feet below the surface to the second level, or a vertical distance of about 260 feet. On the first level this lentil is located in a drift some 450 feet southwest of the cross-cut leading to the shaft.

Lentil No. 2 is located on the second level under Lentil No. 1 and some 150 feet to the southeast. It is 200 feet long and 20 to 70 feet wide. The downward extent of this lentil has not yet been determined.

Diamond drilling has shown the presence of other lentils which, however, are not yet well defined.

^{*}Note: Other secondary minerals reported (Faessler, 1953) from the Eastern Metals property include hisingerite, allophane, lutecite, and cyanotrichite.

The metallic minerals of this zone include^{*}:

Pyrite. As in the North zone the bulk of the pyrite is in fine-grained, brecciated masses replacing the silica-carbonate rock. It is veined by chalcopyrite. Primary pyrite occurs also in some beds of altered, black, graphitic slates.

Chalcopyrite. The main ore mineral. It forms veins and replacements in the silica-carbonate rock and the pyrite.

Chalcocite and bornite. Present in small amounts; seemingly results from alteration of the chalcopyrite.

Malachite. Seen on surface showings only.

Native copper. Thin scales were noted on some slip surfaces both underground and on surface.

Sphalerite. Occurs in small masses associated with the chalcopyrite; may contain traces of cadmium judging from X-ray fluorescence tests.

Galena. Occurs in minute grains in chalcopyrite and sphalerite.

Arsenopyrite. One small grain, being replaced by chalcopyrite, was noted.

Three other ore zones, all small, have been found in the embayment. One is 75 feet north of the North zone and the other two are between the North and South zones. They are parallel to the two main zones and have a vertical dip. Judging from their mineral assemblages and their low tenor in nickel and zinc they are related to the North zone.

Paragenesis. The peridotite body was emplaced in the Beauceville sedimentaries along a zone of weakness or actual fault. Later movements along this zone caused minor fracturing, brecciation and slipping within the peridotite and the surrounding rocks. This deformation probably was more marked at the southwestern end of the peridotite body. Thus, better channels were made available there for solutions rich in silica, carbonate and iron to migrate upwards and form zones of altered rocks. Structural features probably determined the position of the zones.

^{*}Information from Blais (1952) and Pollock (1955).

Later, a reactivation of the fault zone caused brecciation of the zones of altered rocks followed by a second surge of silica-carbonate solutions. This was the stage when the ore zones probably took on their distinctive characters - nickel ore predominating in the North zone and copper ore in the South zone. The mineralization apparently was mesothermal - taking place at moderate depth and moderate temperature.

Later still, meteoric waters seeping downward led to supergene alteration - the millerite and gersdorffite (Pollock, 1955) being partly replaced by violarite in the North zone, and the chalcopryrite by bornite, chalcocite, and native copper in the South zone.

The assemblage of nickel minerals in the North zone is somewhat unusual. In most other nickel deposits bordering on ultrabasics the ore minerals are pentlandite and nickeliferous pyrrhotite - occasionally altered to violarite and millerite. Here, however, pentlandite and nickeliferous pyrrhotite are absent. Also, most such other deposits are magmatic in origin whereas the present is apparently hydrothermal.

Lot 46, Range I, Bellechasse Township

The discovery of several large erratics heavily mineralized with copper and zinc sulphides on lot 46, range I, Bellechasse township, led to drilling by Mr. H. Champagne and, later, by Panet Metals Corp. The drilling disclosed, under a heavy burden of gravel and sand, vertical lenses of zinc and copper ore. The ore is in slates in which are emplaced sills of albite diorite. One ore lens is reported to be about 300 feet long and 5 feet thick, and another, to be about 500 feet long and 10 feet thick. The ore has largely replaced altered slates and consists of fine-grained pyrite, pyrrhotite, sphalerite, chalcopryrite and galena. Reported assays indicate tenors of 2 to 4 per cent zinc, about 0.5 per cent lead and 0.5 per cent copper.

Ranges I and II, Bellechasse and Panet Townships

At many places within the complex of albite diorite sills, most of which are in ranges I and II of Bellechasse and Panet townships, small concentrations of metallic sulphides largely pyrite and pyrrhotite have been found. Along the road that follows the range I-II line, the slates bordering the sills are at several places rusty and contain disseminated iron sulphides, carbonate, and fine silica. Assays of grab samples of altered slates indicated low tenors in copper and nickel on lot 23 of range I and lot 15 of range

II in Bellechasse township; in copper on lot 19 of range II in Bellechasse township, and lots 40 and 41 of range II in Panet township; and in zinc on lot 40 of range I in Panet township.

Lot 22, Range IX and Lot 39, Range V, Talon Township

On lot 22 of range IX in Talon township a grab sample of a rusty chert-like siltstone (Beauceville group) has indicated a low tenor in copper. On lot 39 of range V a rusty and highly sheared sandstone (Caldwell group) contains small concentrations of pyrite, pyrrhotite and chalcopyrite, assaying low in zinc, nickel, and copper. This mineralized rock is in a shear zone near, and parallel to, the Caldwell-Beauceville contact.

Lot 35, Range VI, Leverrier Township

On lot 35 of range VI, Leverrier township, near a small mass of serpentinite, rusty phyllitic slates contain a low tenor in copper and lead.

Gold

Lot 10, Range II, and Lot 11, Range III, Bellechasse Township

In 1952 gold-bearing veins of milky quartz were discovered on lot 10 of range II and lot 11 of range III in Bellechasse township. The veins on lot 10 occur about 150 feet northwest of the boundary between ranges II and III and those on lot 11 are about 250 feet southeast of the same boundary. The two occurrences seemingly belong to one mineralized zone trending northeasterly or more or less parallel to the regional structure. Geological mapping, geophysical work, trenching and drilling done by N.A. Timmins (1938) Ltd. on lot 11, in 1952 and 1953, and by A.E. Rosen on lot 10, in 1952, indicate that the zone is nearly vertical and 20 to 50 feet wide. It has been traced for about 500 feet on lot 10 and for about the same distance on lot 11.

The quartz veins parallel sills of quartzose albite diorite emplaced in slates, chert, and sandstones of the Beauceville group. The veins vary in width from one to 20 feet, and have ill-defined contacts. Trenching and drilling indicate that some of the veins are vertical and that others are rolling or very irregular. Some seemingly pinch out in short distances. Everywhere in the mineralized zone the wall rock, and particularly the albite diorite, is considerably altered and enriched in silica, carbonate and chlorite.

The slates are markedly phyllitic and the diorite is moderately schistose. Most of the gold seems to be in the quartz veins, where at places it is free, but some also occurs in the diorite where it is commonly associated with arsenopyrite, sphalerite, galena and chalcopyrite. Reported assays of grab samples of vein quartz have indicated tenors approximating one ounce per ton. The top soil, near the mineralized zone contains particles of gold, which leads to the speculation that some of the Chaudière River basin placer gold may have originated from this area.

Lot 31, Range III, Bellechasse Township

On lot 31, range III, Bellechasse township, about five miles southwest of the mineralized zone just described, other auriferous quartz veins also are associated with quartzose albite diorite sills emplaced in slates, chert and sandstones of the Beauceville group. No free gold was seen here but assays of grab samples of the quartz veins indicate low tenors in gold.

It can be inferred from the two occurrences of gold described above that the southeastern part of the albite diorite complex is favourable ground for gold prospection.

Asbestos

Lots 20 and 21, Range V, Talon Township

On lots 20 and 21 of range V, Talon township, about 500 feet northwest of the boundary between ranges V and VI, is a showing of asbestos known as the Bolduc prospect. The showing is in a large mass of serpentized peridotite much like the serpentinite normal to the region. Several pits and trenches have been cut in the side of a ridge and in one trench a three-foot dyke of syenite cutting the serpentinite can be seen. Near this dyke and in the other trenches and pits are some thin veinlets of cross fibre asbestos.

Lots 8, 9 and 10, Range VI, Talon Township

On lots 8, 9 and 10 of range VI, Talon township, about 800 feet southeast of the range V-VI line, is another showing of asbestos referred to in older reports (Denis, 1930) as the Breton prospect. The showing is in a large mass of serpentized peridotite similar to that found on lots 20 and 21 of range V. Actually these two masses may be parts of one large body. Old mine workings at the showing consist of a shaft some 25 feet deep at the bottom of

which is a tunnel about 25 feet long. Near the shaft are several trenches and pits. Years ago some drilling was done by Johnson's Company Limited. The underground works are now flooded but in the trenches and pits veinlets of cross-fibre asbestos up to one-quarter of an inch thick can be seen.

Limestone

On lot 15 of range VI, Dionne township, limestone beds are intercalated in calcareous slates of the Beauceville group. If in sufficient quantity this limestone possibly could be used for the soil conditioning that is much needed in this region. Pure limestone, however, may be rare. Most of the beds exposed are sandy and contain fragments of slates or siltstones.

Silica

The Rosaire quartzite, particularly abundant in the Rosaire-St. Pamphile area, might be used as a source of silica although pure beds are rare. Most beds contain an appreciable amount of argillaceous or organic matter and many others are iron-stained.

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