RG 097(A)

SHAWINIGAN AREA, ST-MAURICE, CHAMPLAIN AND LAVIOLETTE COUNTIES

PROVINCE OF QUEBEC, CANADA
DEPARTMENT OF NATURAL RESOURCES
Honourable RENÉ LÉVESQUE, Minister P.-E. AUGER, Deputy Minister

GEOLOGICAL SURVEYS BRANCH
H.W. McGERRIGLE, Chief

GEOLOGICAL REPORT 97

SHAWINIGAN AREA

ST-MAURICE, CHAMPLAIN and LAVIOLETTE COUNTIES

by

JACQUES BÉLAND

QUEBEC
1961

CONTENTS

TABLES

MAPS AND ILLUSTRATIONS

MAPS

FIGURES

PLATES

SHAWINIGAN AREA

CHAMPLAIN, ST. MAURICE, AND LAVIOLETTE COUNTIES

by

Jacques Béland

INTRODUCTION

General Statement

The Shawinigan area is north of the St. Lawrence river about 20 miles north-northwest of Trois-Rivières. It includes the well-known industrial centres of Shawinigan and Grand-Mère, both on St-Maurice river and the sites of hydroelectric power stations.

The area is mainly within the Laurentian uplands but, in the southeast, it overlaps upon the St. Lawrence Lowlands. Thus, for the most part, it is underlain by a complex of Grenville gneisses and paragneisses which have been impregnated and intruded by various Precambrian intrusions. The southeastern part of the area is occupied by clay, sand and gravel which may overlie Paleozoic sedimentary rocks.

Bog iron deposits were mined intermittently in this general area from about 1733 until 1910. Sulphide minerals are scattered throughout the paragneisses and are locally concentrated in shear zones in the anorthosite-gabbro intrusions. Small concentrations of magnetite-ilmenite also occur within one anorthosite-gabbro body.

Location

The area, bounded by latitudes 46°30' and 46°45' and longitudes 72°30' and 73°00', covers about 410 square miles. It includes parts of Caxton and Shawinigan townships and of the seigniory of Cap-de-la-Madeleine in St-Maurice county; parts of Batiscan, Champlain, and Cap-de-la-Madeleine seigniories in Champlain county; and parts of Radnor township and Batiscan seigniory in Laviolette county.

Means of Access

The area is easily accessible by automobile, and all parts of it can be reached from a network of gravel roads. Both the Canadian National and Canadian Pacific railways serve the area.

Previous Work

R.C. McConnell in 1880 (Ells 1898) and A.P. Low in 1891 (Ells 1898) did some reconnaissance work east and west of St. Maurice river for the Geological Surveys of Canada. Ells (1898) authored a map - the Three-Rivers sheet (6,912 square miles) - that includes the Shawinigan area. Most of the Precambrian rocks on this map are shown as one unit called "gneiss and granite". A few thin bands of "crystalline limestone" and some "quartzites" are correlated with Logan's "Grenville series" north of Ottawa river. Ells commented on the relative scarcity of limestone in the Three-Rivers area as compared to the type locality of the Grenville series and suggested that the limestone might have been removed by erosion. He also outlined in the Shawinigan area a mass of "anorthosite", actually a complex of anorthosite - gabbro, and a large elongate "granite" batholith (Hunterstown (1) batholith of this report; map No. 1327). A large mass of granite and granodiorite in the southwestern part of the Shawinigan area possibly joins this batholith. Ells also recognized a gneissic "granite" which was intimately mixed with the grey gneiss or country rock.

Osborne (1936) and Osborne and Lowther (1936) examined a small area about Shawinigan and Grand-Mère to study the petrology of the rocks and determine "the origin and relationships to regional structure of the gently inclined foliation in the Grenville series". The petrological study led to the recognition here of four main types of rocks making up the Grenville series, namely: amphibolitic gneiss, sillimanite paragneiss, crystalline limestones, and meta-quartzites. The amphibolitic gneiss, thought to be derived either from igneous rocks such as diorite or andesite or from sedimentary rocks such as impure limestone or impure sandstone, was said to be at the base of the series and possibly separated from the upper members by an unconformity. From the structural study it was concluded that the sub-horizontal foliation resulted from stresses such as are thought to

---

(1) The name is that of the township found at about the centre of the batholith.

prevail in periods of orogenic deformations and that two such periods might have occurred.

Lunde (1951) mapped an area adjoining the Shawinigan area on the east. The Grenville series as outlined by Lunde was similar to that given by Osborne. An amphibolitic gneiss is overlain by a quartz-biotite-oligoclase (or sodic andesine) paragneiss interbedded with meta-quartzites. Intercalated in this sequence are concordant bodies of fine-grained gneissic granite, more abundant in the upper part of the series.

Work on the Pleistocene geology of the area originated with Chalmers (reported by Ells, 1898) who, among other things, noted "marine terraces" near Maskinongé lake at elevations of 825 and 865 feet above sea-level. Later, Faessler (1948) held that the Champlain sea did not exceed 650 feet in this region. Other Pleistocene work in the area was done by Osborne (1950 and 1951), Lunde (1951) and Bélanger (1952).

Field Work

The mapping leading to this report was done during the field seasons of 1950 and 1951. The base map used was on a scale of one half mile to one inch, and was an enlargement of a map at a scale of one mile to one inch published by the Department of Mines and Technical Surveys, Ottawa.

Systematic pace and compass traverses, spaced one-half mile apart, were run over the hilly and wooded portions of the area. The lowlands were covered by road traverses with a few intervening pace and compass traverses. Aerial photographs were available but were found to be of little use for mapping except in the cleared areas. Photographs were also found useful to determine structural trends and to lay out appropriate traverses.

Elevations of terraces and fossil localities were measured with a Paulin altimeter.

Acknowledgements

Sincere thanks are owed to Professor F.F. Osborne of Université Laval who supervised the field work and also offered many valuable suggestions during the laboratory investigations. Professor

A.F. Buddington and other members of the Department of Geology of Princeton University gave useful advice and guidance during the preparation of this report. The geology of this area was the subject of a Ph. D. thesis presented by the author at Princeton University in 1953. P. Sauvé, R. Smith and A. Deland ably acted as assistants in the field.

PHYSIOGRAPHY

General Features

The Shawinigan area overlaps two physiographic provinces, namely, the Laurentian uplands and the St. Lawrence lowlands (Plate 1A). The southeastern, or lowlands, part of the area is a plain of clay, sand, and gravel filling a wide embayment crossed by the St. Maurice river. The general elevation of this plain is about 450 feet above sea-level. The northwestern part, in the Laurentian uplands, is characterized by rolling hills and stands at a general elevation of 1,000 feet above sea-level. The upland supports a dense growth of hardwood and conifers. The escarpment which commonly marks the boundary between the Laurentian uplands and the St. Lawrence lowlands is here much subdued by the St. Maurice River embayment. West and east of the embayment, the escarpment reappears.

The structure of the underlying rocks somewhat controls the shape of the hills. Gently-dipping gneisses are commonly reflected in steep-flanked, flat-topped hills (Plate IB), and steeply-dipping gneisses in long, narrow, sharp-crested ridges. Some ridges trend parallel to systems of steeply-dipping joints; others, controlled by a steep foliation of the rock, are cut at one or both ends by gorges carved along steep cross-joints.

The St-Maurice River embayment slopes gently to the southeast from an elevation of about 500 feet near the foothills of the uplands to about 400 feet at the mouth of the embayment. At the mouth, a string of low ridges, made up of Pleistocene deposits, bars the entrance.

Minor topographic features include an esker in the southwestern corner of the area and a large kettle hole located near the southern extremity of the esker. The esker follows a valley now largely filled by glacial and marine deposits.

Drainage

Watercourses in the uplands are mostly strings of small lakes spilling into one another or connected by short precipituous streams. In the lowlands, lakes are fewer but larger, and the streams, more mature.

St-Maurice river, which is by far the largest stream in the area (Plate IIA and IIB), crosses the uplands in a relatively straight and deep valley. In the lowlands, it is shallower, more sinuous and broken by several falls and rapids.

Crosby (1932) suggests that the present drainage of the St-Maurice valley differs from that of pre-glacial time. He believes that, originally, the valley was drained by three or more rivers. Moraines and fluvio-glacial deposits left in the wake of the ice sheet checked these rivers and caused the waters to flow through short tributaries into one major river, the present St-Maurice. In the Shawinigan area, the courses of two of the main pre-glacial rivers were traced by Crosby. One river followed the valleys now occupied by Edouard lake (north boundary of the area), La Pêche lake, Perchaude lake and the lower part of Shawinigan river to finally join the present St-Maurice south of the falls at Shawinigan. This channel, between La Pêche lake and the falls at Shawinigan, is now buried under thick deposits of moraines, gravel, sand, and marine clay. The other glacial river, according to Crosby, followed the present course of the St-Maurice from the north boundary of the area to Grandes-Piles but from there ran southeastward to Tortue lake and Des Chutes river. The lower segment of this channel now is also buried under thick glacial, fluvio-glacial, and marine deposits. Thus, the segment of St-Maurice river between Grandes-Piles and Shawinigan would be relatively recent, that is, post-glacial; and certainly the falls at Grand-Mère and Shawinigan, and the tumultuous "rapides des Hêtres" between these two points, indicate immaturity of this lower part of the St. Maurice river.

Deep borings in unconsolidated deposits at Trois-Rivières have shown that buried channels of presumably pre-glacial rivers lie at depths below the present sea-level. This also implies that the land before the last glaciation stood higher than it does now and that it has not as yet been restored to its pre-glacial level.

Tortue lake, the largest lake of the area, occupies a very shallow basin. It is probably a remnant of a once larger body of water which, shortly after the ice began to retreat, may have covered most of the present marshy land north of the string of ridges blocking the entrance of the St. Maurice embayment. The lake has shrunk considerably during historical time and eventually may be reduced to a marsh.

Terraces

Terraces made of glacial deposits or carved in marine clay are present on hillsides in the foothills of the uplands and along St. Maurice river. Along the river, some terraces made up of glacial deposits may be kame terraces, others may have been cut by the river, or by wave action in the Champlain sea. Few of these terraces extend more than a few hundred feet and most are but narrow shelves, considerably subdued by erosion. The best preserved are near Grandes-Piles on both shores of St-Maurice river (Plate III A and B) and near the northern boundary of the area northwest of St-Tite.

Near Grandes-Piles, on the west side of St-Maurice river, the highest terrace, carved in what seems to be marine clay, stands at 490 feet above sea-level. On the east side, the highest terraces, covered by sand and gravel, stand at 545 feet. Northwest of St-Tite, in the foothills of the uplands, terraces, presumably cut by the Champlain sea, stand as high as 600 and 615 feet above sea-level. It may be recalled here that Faessler (1948) proposed 650 feet as the highest elevation reached by the Champlain sea in this region.

GENERAL GEOLOGY

Bedrock exposures are very abundant in the uplands portion of the area and rare in the lowlands. All bedrock exposed is of Precambrian age and consists of various types of gneisses and paragneisses of the "Grenville series" and several varieties of intrusive and metasomatic rocks part of which belong to the Morin series. One outcrop of Palaeozoic rock (Trenton limestone) occurs at Radmor a few hundred feet south of the area. Probably the Palaeozoic rocks extend into the lowlands portion of the area under the thick cover of Pleistocene sediments.

The Grenville series which makes up most of the bedrock includes a pyroxene and/or hornblende - andesine gneiss, a quartz-biotite-sodic andesine paragneiss, a quartz-biotite-microcline paragneiss, crystalline carbonate rocks, locally quite silicated, and meta-quartzites.

The pyroxene and/or hornblende-andesine gneiss is the most widespread unit of the series. It occupies most of the north-western half of the area and is also present here and there in the southeastern half. The bulk of this unit is at the base of the Grenville series as exposed here. The nature of the parent rock that yielded this gneiss is difficult to ascertain but, in the writer's opinion, the bulk of it was probably sedimentary.

Resting on the pyroxene and/or hornblende-andesine gneiss, are found successively: a quartz-biotite-sodic andesine paragneiss and a quartz-biotite-microcline paragneiss, the latter locally characterized by the presence of garnet and more rarely sillimanite. This is the "sillimanite paragneiss" or "sillimanite-garnet paragneiss" mentioned in many descriptions of the Grenville series.

The crystalline, silicated, carbonate rocks and the meta-quartzites are generally found in thin layers within the quartz-biotite-microcline paragneiss and with it make up the upper part of the Grenville series as exposed in the area. Some beds of silicated carbonate rocks and meta-quartzites, however, are also found inter-calated in the basal pyroxene and/or hornblende-andesine gneiss.

In the northern part of the area, the quartz-biotite-microcline paragneiss occurs in a small synclinal structure. Here, it appears to rest directly on the pyroxene and/or hornblende-andesine gneiss without the usually intervening quartz-biotite-sodic andesine paragneiss. However, in many places it is difficult to separate these two facies of paragneiss and in some sections the two facies seem to alternate. There are also some indications at a few places that metasomatism may have caused the replacement of the plagioclase by microcline.

Contacts between the pyroxene and/or hornblende-andesine gneiss and the paragneisses appear to be generally concordant and, at places, gradational. Contacts crossing structural trends, as east of Des Piles lake, may result from faulting, lateral change of facies or crumpling of the softer paragneisses against the more competent pyroxene and/or pyroxene-andesine gneiss. The contrasting lithology of the upper and lower parts of the Grenville series, however, suggests different environments of deposition and that local unconformities, at least, would be normal.

The intrusive and metasomatic rocks have been divided into three groups: 1) intermediate to acidic intrusive and metasomatic rocks found throughout the area in concordant layers or lenses (possibly the oldest igneous rocks of the area); 2) basic, intermediate, and acidic intrusive rocks found in the southwestern part of the area and similar to the Morin intrusive series north of Montreal; 3) a few diabase dykes and sills which, in part, probably represent the last igneous activity in the area.

The intermediate to acidic intrusive and metasomatic rocks, which are the most widespread, are generally fine-grained gneisses of granitic to granodioritic composition, well foliated and locally granulated (mylonitic). A complex interlayering with the country rock and gradational contacts suggest that part of these rocks may be of metasomatic origin. Stringers, veins, dykes, and sills of granite pegmatites generally criss-cross these layered masses. Some of the pegmatites may be related to the second group of intrusives ascribed to the Morin series.

The rocks of the Morin series differ from those just described in many respects:- they are practically restricted to one massif in the southern part of the area; their contacts are sharp; they are less deformed and less foliated; and, generally, they are much coarser grained. The Morin series, here, includes a gabbroic anorthosite, an anorthositic gabbro, an ilmenite-magnetite gabbro, a pyroxene diorite, a pyroxene-quartz diorite, a pyroxene granodiorite and a coarse porphyritic granite (apparently Pine Hill type). The granite may have batholitic dimensions, for the lobe mapped in the southwestern corner probably extends westerly to the Hunterstown batholith mapped by Ells (1898).

Several mineralogical features of the basic and intermediate facies of the Morin series indicate a sequence differentiated from one magma. The Pine Hill granite may or may not represent the last differentiate of this series of intrusions. The diabase presumably represents an altogether different episode.

The Pleistocene deposits include till, marine clay ("Leda clay"), bouldery gravel, gravel, sand, and silt. The till rests directly on bedrock and, in the southern part of the area, or up to an elevation of about 500 feet above the present sea-level, is overlain by the marine clay. A thin sheet of fine sand generally covers the clay. Locally, ridges of bouldery gravel and delta deposits crop out through the clay. Other gravel and sand deposits presumably overlie the clay. The string of gravel ridges barring the mouth of the St-Maurice River embayment joins northeasterly with the St-Narcisse moraine and presumably marks a major ice-contact deposit.

Recent alluvials are mostly reworked glacial and fluvio-glacial materials removed from the upper reaches of the water-courses. Finely-bedded sand, silt, and clay are also found along the lower segment of St-Maurice river.

TABLE OF FORMATIONS

AGE	FORMATIONS	LITHOLOGY
Recent		Gravel, sand, silt, and bedded clay.
Pleistocene		Gravel, sand, and silt.
		Fossiliferous marine clay (Leda clay) and silt.
		Till, bouldery gravel, gravel, and sand.
Unconformity		
Precambrian		Diabase dykes.
	Morin series (intrusives)	Pine Hill granite. Pyroxene-bearing intermediate rocks: pyroxene diorite, pyroxene-quartz diorite, and pyroxene granodiorite. Anorthosite-gabbro complex: gabbroic anorthosite, anorthositic gabbro and ilmenite-magnetite gabbro.
	Intermediate to acidic intrusive and metasomatic rocks	Granite pegmatites Fine-grained gneissic granite; coarse augen granite. Granodiorite, quartz diorite, and diorite.
	"Grenville series"	Meta-quartzite. Silicated crystalline carbonate rocks. Quartz-biotite-sodic andesine paragneiss and quartz-biotite-microcline paragneiss. Pyroxene and/or hornblende-andesine gneiss possibly in part meta-gabbros.

Description of Formations

Grenville Series

Pyroxene and/or Hornblende-andesine Gneisses

The pyroxene and/or hornblende-andesine gneisses are dark, fine- to coarse-grained, mildly foliated rocks made up essentially of andesine, pyroxene and/or hornblende, with some biotite, quartz, and garnet. The ratio of dark minerals to feldspar and of pyroxene to hornblende varies from place to place. The pyroxene facies is generally more feldspathic than the hornblende facies.

The foliation reflects the mineralogical composition to the extent that facies rich in biotite or hornblende are generally better foliated than those rich in pyroxene or feldspar. The layering generally results from the alternation of layers rich in pyroxene, hornblende, and biotite with layers rich in plagioclase. Granitic veins also, at places, intervene between the layers although such veins are less marked in the pyroxene and/or hornblende-andesine gneisses than in the paragneisses. In the former, the granite has a tendency to be in thick, homogeneous sheets.

The plagioclase varies from An_{25} to An_{45} in the hornblende facies and from An_{35} to An_{55} in the pyroxene facies. It is generally twinned but without the complex twins noted in the plagioclase of the basic igneous rocks. The pyroxene is diopside or augite and hypersthene; the latter two, in about equal amounts, are typical. Rarely, one pyroxene only occurs. Lamellar intergrowths of the orthorhombic and a monoclinic pyroxene and schiller inclusions typical of the intrusive basic rocks of the Morin series are rare in the pyroxene-andesine gneisses. Hornblende is of several varieties and occurs in large isolated grains or in clusters of small grains. In many cases it is accompanied by small crystals of deep red garnet. Biotite is fairly abundant and, at places, such as near the contact of the large northwestern tract of pyroxene and/or hornblende-andesine gneisses with the southeastern belt of paragneisses, it amounts to 30 per cent of the rock (this may mark a gradational facies). Magnetite and pyrite, with some apatite, sphene, and zircon, are accessory. The mineralogical composition of five common facies are given in Table 1, Nos. 1 to 5.

Origin of the pyroxene and/or hornblende-andesine gneiss

A comparison of the mineralogical composition of the biotitic facies (Table 1, Nos.2 and 5) of the pyroxene and/or hornblende-andesine gneiss with that of the quartz-biotite-sodic andesine paragneiss (Table 1, No. 11), which overlies the biotitic gneiss, shows that the calcity of the plagioclase in the biotitic gneiss is intermediate between that of the non-biotitic gneiss and that of the paragneiss. It also shows that the amount of pyroxene and/or hornblende decreases with an increase in the amount of biotite. The quartz also varies sympathetically with the biotite. This sort of transition could possibly be explained by a gradual change in the composition of parent sedimentary rocks.

Another possibility, as pointed out by Osborne (1936), is that the pyroxene and/or hornblende-andesine gneiss ("amphibolites") were derived from basalt or andesite flows. Chemical analyses presented by Osborne (p. 206), and reproduced here in Table 2, Nos. 1, 2 and 3, certainly support this view. However, if these gneisses represent volcanic flows, all the original structures or textures indicative of such rocks have been obliterated.

There are also indications that part of the pyroxene and/or hornblende-andesine gneiss are meta-gabbros or silicated carbonate rocks, as will be seen below.

Meta-gabbros

Sill-like masses of meta-gabbro (Table 1, No. 6) occur within the pyroxene and/or hornblende-andesine gneisses and the paragneisses. Three such bodies were mapped south of La Pêche and Des Piles lakes. One is about 900 feet thick; the thickness of the others could not be measured. None could be traced for more than 500 feet.

The meta-gabbros are dark, medium-grained, granulated rocks. They are more altered than the gabbro of the Morin anorthositic sequence. An ophitic texture is nearly obliterated by granulation of the feldspar and replacement of the pyroxene by hornblende, carbonate, and chlorite (Fig. 3). Some vaguely wedge-shaped aggregates of carbonate and chlorite retain the schiller inclusions and cleavage of pyroxene. Quartz occurs in worm-like masses seemingly replacing the mafic minerals.

These sills of meta-gabbro within or near the pyroxene and/or hornblende-andesine gneiss lead us to think that part of the gneiss could have been derived from such sills. Granulation and recrystallization to a less calcic plagioclase accompanied by uralitization of the pyroxene obviously took place. At a more advanced stage, the near disappearance of the ophitic texture and of the metallic and schiller inclusions, as well as that of the lamellar intergrowth of the pyroxene and the complex twinning of the plagioclase could yield a rock very similar to the pyroxene and/or hornblende - andesine gneiss. However, considering the vast expanse of this gneiss in the area, and the scarcity of the gabbro relics it is difficult to envisage that more than a minor part of the gneiss could have been derived from such basic intrusives.

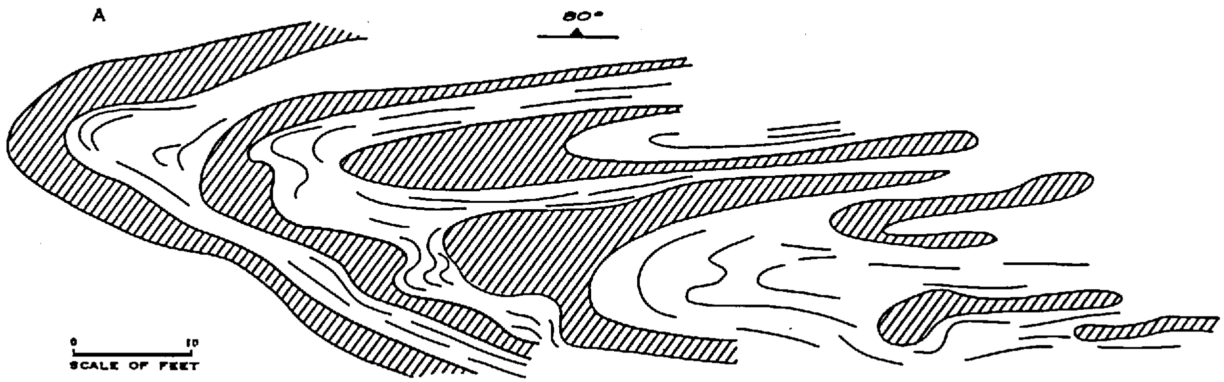
Silicated carbonate rocks

Layers, lenses, and pods of a coarse crystalline carbonate rock, silicated to various degrees, are found intercalated in both the pyroxene and/or hornblende-andesine gneiss and the paragneisses, particularly in the latter. Silication is more marked in the layers interbedded with the pyroxene and/or hornblende-andesine gneiss. The average thickness of carbonate rock layers in the paragneisses is about 20 feet but at a few places there are layers up to 500 feet thick. In the gneiss, the thickness seldom exceeds 10 feet.

Some of the carbonate rock layers have been considerably disrupted and strung out in series of lenticular or irregular masses. Lenses forced into the wall rock in the manner of dykes or apophyses (Fig. 1, B.) are common. Disruption has also led to the formation of "pseudo-conglomerates" made up of rounded or convoluted fragments of wall rock set in a carbonate matrix. The fragments, a fraction of an inch to about 3 feet in diameter, have locally been churned up and polished so that they resemble pebbles and boulders (Plate X A). These breccias, 5 to 10 feet thick, generally grade laterally into normal carbonate rock.

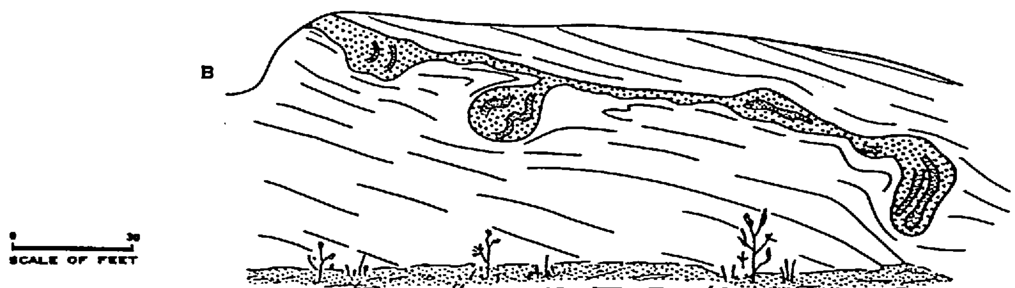
Fairly pure facies show a white, pink, grey, or light brown weathered surface faintly studded with dark silicate grains. The light brown weathering suggests a dolomitic composition. N.L. Wilson (1939) gives two chemical analyses of such carbonate rocks from the Montauban area (30 miles to the northeast) with a ratio of calcium to magnesium carbonate of respectively 3 to 2 and 1 to 1. Wilson believes that a magnesium enrichment has taken place.

FIGURE I



PLAN VIEW

A — Complex folding of paragneiss and quartzite (shaded) interbeds.



SECTION

B — Contorted bed of carbonate rock (stippled) in pyroxene and/or hornblende-andesine gneiss. Narrow bands in carbonate rock are highly silicated.

D.M.Q. [illegible], NO. 1330

Highly silicated facies are generally dark green, granular, disseminated with pyroxene, hornblende, garnet, scapolite, plagioclase, and microcline. Pyroxene, scapolite and plagioclase are the most common silicates. Phlogopite, muscovite, biotite, apatite, zircon, and graphite are accessory. Most highly silicated facies are veined by granite pegmatite, which presumably had something to do with the silication. Pods of very coarse pink calcite that are present locally in the silicated carbonate rock probably resulted from mobilization of the carbonate at the time of silication.

Estimated mineralogical compositions of but slightly silicated carbonate rock and highly silicated facies are given in Table 1, Nos. 7 to 10.

Typical silicate associations include: pyroxene (salite or diopside) and scapolite; plagioclase and garnet; and, more rarely, hornblende and andesine. Some of the highly silicated carbonate rocks with a high content of hornblende and andesine are similar in composition and texture to the hornblende-andesine facies of the pyroxene and/or hornblende-andesine gneiss. It is likely, therefore, that part of this gneiss resulted from silication of carbonate rocks. Thin sections suggest that the change may have been, first, a replacement of the carbonates by scapolite and salite or diopside, and then replacement of these by plagioclase and hornblende. Many scapolite grains are rimmed by, or contain ribbon-like veins of, plagioclase; similarly, hornblende or actinolite often mantle the pyroxenes.

Thus, possible parent rocks of the pyroxene and/or hornblende-andesine gneiss include impure sandstones, volcanic flows, gabbro sills, and carbonate rocks. In the writer's opinion the bulk of this gneiss is more likely to be derived from sandstones and carbonate rocks. Some volcanic flows may have been interbedded with the sandstones.

Paragneisses

The paragneisses include a quartz-biotite-sodic andesine facies and a quartz-biotite-microcline facies. The former appears to underlie the latter for the most part. However, local alternations and lateral gradations,along and across the strike, point to pene-contemporaneous deposition of the two parent rocks in some places.

The paragneisses are found mainly in a broad zone bordering on the south and east the north-central mass of gneiss, and in a southerly plunging synclinorium in the southwestern part of the area. Smaller, isolated occurrences are found within the gneiss.

The paragneisses are typically rusty and are more schistose than the pyroxene and/or hornblende-andesine gneiss. The rust is caused by the weathering of finely disseminated pyrite and pyrrhotite. The stronger schistosity probably results from a higher tenor in biotite. The quartz-biotite-microcline facies is characterized in many places by pink garnet and, in some places, by fibrous sillimanite; hence the frequent usage by previous authors of the term "garnet-sillimanite paragneiss".

Migmatization, generally of the "lit-par-lit" injection type, is quite widespread.

Estimated mineralogical compositions of the two types of paragneisses are given in Table 1, Nos. 11 and 12, and two chemical analyses presented by Osborne (1936) are reproduced in Table 2, Nos. 4 and 5.

Thin sections show that the paragneisses are considerably deformed. Much of the quartz is drawn-out in lenses or lamellae. The feldspars are granulated and commonly intergrown with quartz along the edges of the grains. The potassic feldspar, generally microcline and perthitic microcline, appears to be largely in the form of broken porphyroblasts. The amount of exsolved material in the perthite commonly increases with the degree of shearing as though strain had favoured exsolution. Garnet is found in large eye-shaped poikiloblasts, criss-crossed by fractures. Sillimanite is in acicular prisms cluttered into sheaves or strung out along foliation planes. Concentrations of sillimanite are common alongside granitic veins and also within the veins themselves.

Apatite, zircon, and sphene occur in small amounts. Some of the quartz-biotite-microcline paragneiss contains small quantities of muscovite and graphite.

Meta-quartzite

Layers of meta-quartzite, seldom more than 10 feet thick but ranging up to 500 feet, are found interbedded with the paragneisses and, more rarely, with the pyroxene and/or hornblende-andesine gneiss. Most of the meta-quartzites, like the carbonates, are found within the quartz-biotite-microcline paragneiss in the upper part of the Grenville Series. The thickest beds observed were within the tightly-folded synclinorium in the southern part of the area. Thin-bedded successions of quartzite and paragneiss are also present here.

Thin sections show that the meta-quartzites, like the paragneisses, are much deformed. The quartz is entirely recrystallized, and much of it is drawn out into thin lamellae. A faint reddish colour is given here and there by thin films of ferric oxides deposited in minute cracks or around the grains. Deformation, however, is less pronounced in the small synclinal structure located near the northern boundary of the area. Here a faint bedding is given by bands in shades of grey, white, and buff and some granular texture has been preserved.

Rare beds of meta-quartzite may be garnetiferous or feldspathic or micaceous. Garnetiferous beds, within the southern synclinorium, are strikingly studded with very large porphyroblasts of red and pink garnets. Feldspathic beds carry a potassic feldspar, white or pink, often cluttered into coarse porphyroblastic aggregates. Where the feldspar is associated with glassy quartz, the meta-quartzite much resembles a quartzose granite pegmatite. Micaceous varieties, carrying either biotite or muscovite, often show a faint compositional layering which may represent original bedding or a tectonic unmixing of the mineral components brought about by deformation.

Nodules 2 to 3 feet long, made up of calc-silicates such as diopside and epidote, probably were originally carbonate nodules deposited with the quartz. Some of these nodules are disseminated with tiny flakes of graphite. Graphite and epidote may occur concentrated in thin beds. Small amounts of apatite, zircon, sphene, and pyrite were observed in the thin sections.

An average mineralogical composition of several relatively pure meta-quartzite beds is presented in Table 1, No. 13.

INTERMEDIATE TO ACIDIC INTRUSIVE AND METASOMATIC ROCKS

This group of igneous rocks includes highly deformed gneisses found throughout the area as tabular concordant bodies with gradational contacts (this is in marked contrast with the well circumscribed intrusive masses of the Morin series). It also includes granite pegmatites, in lit-par-lit veins and in thick sills or dykes. Most of the sheets or concordant bodies have the composition of granite, and are fine-grained. A few show a coarse augen structure. Some sheets and a few small stocks have, at least locally, a dioritic composition.

Diorite, quartz diorite, and granodiorite

These intermediate rocks occur in small, ill-defined, elongated stocks and in sills 10 to 25 feet thick. In some sills they grade laterally or transversely into granite.

Some greenish, medium-grained, massive bodies of diorite and quartz diorite contain pyroxene and may be related to the pyroxene-bearing intermediate rocks of the Morin series. However, the plagioclase does not show the complex twinning, nor the pyroxene the schiller inclusions and the lamellar intergrowths, typical of the Morin intrusive rocks. The pyroxene and plagioclase are much more like those observed in the pyroxene and/or hornblende-andesine gneiss. A peculiar facies, which may be termed a leuco-quartz diorite, is practically made up of anhedral plagioclase and quartz in about equal amounts. The texture and general appearance are those of an igneous rock. Accessory minerals include zircon, apatite, muscovite, hornblende, and epidote.

Estimated mineralogical compositions of these rocks are presented in Table 1, Nos. 14 to 17.

Fine-grained gneissic granite

The fine-grained gneissic granite generally occurs as thick sheets within the paragneisses or as small elongate stocks within the pyroxene and/or hornblende-andesine gneiss. Several large sheets within the paragneisses branch off from a north-northeasterly trending band traversed longitudinally by a major fault. At the fault the granite is mylonitized and brecciated. This structural arrangement suggests that the fault may have provided a channel along which the granite welled up and that later reactivation of the fault led to brecciation and granulation of the emplaced granite.

The thick sheets of gneissic granite intercalated in the paragneisses or the stocks penetrating the pyroxene and/or hornblende-andesine gneiss are not homogeneous bodies. Most merge into the country rock through zones of mixed gneiss and also contain screens or lenses of metasomatized and veined country rock. Metasomatized zones are often characterized by large porphyroblasts of potassic feldspar and quartz.

The granite is typically pink or grey; rarely, it is slightly greenish. The grey facies usually owes its colour to a predominance of oligoclase over potassic feldspar; the latter feldspar is more characteristic of the pink facies. Foliation results from segregation of the dark minerals (biotite with subordinate hornblende) from the felsic elements. The latter are usually granulated and drawn out. Much of the quartz is in recrystallized lamellae. In the sheets intermixed with the paragneisses streaks of garnet and sillimanite parallel the foliation.

The potassic feldspar is mostly perthitic microcline. The exsolved material, which commonly makes up as much as 50 per cent of the mineral grains, occurs in blebs and dots or, rarely, forms continuous rims around the grains. Small amounts of muscovite, epidote, zircon, apatite, and sphene are accessory.

Mineralogical compositions are given in Table 1, Nos. 18 and 19.

Coarse augen gneissic granite

At places in the paragneiss belt, such as south of Des Piles and Truite (No. 1) lakes, the rock is a coarse, augen, gneissic granite. This granite is characterized by very closely-packed, eye-shaped aggregates of potassic feldspar and quartz set in a fine-grained foliated matrix of biotite with some hornblende. Many contacts with the paragneisses are through transition zones showing only scattered porphyroblasts of potassic feldspar and quartz disseminated in the paragneiss. This coarse augen granite probably developed by replacement of the paragneiss.

The mineralogical composition of this rock is given in Table 1, No. 20.

Granite pegmatites

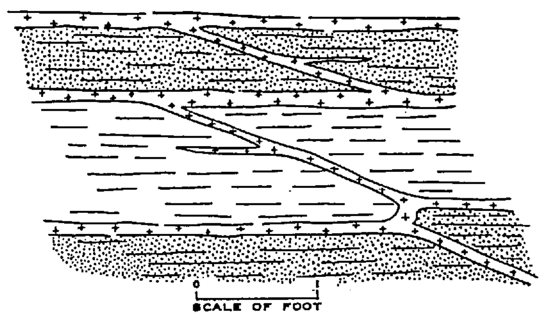
Veins, irregular pods, lenses, sills, and dykes of granite pegmatite are found throughout the area; they are generally associated with the concordant bodies of granite but are also near the more acidic facies of the Morin series. Sills and dykes up to 25 feet thick were noted. The veins usually follow the structure in a lit-par-lit fashion and are at places interconnected by feeders (Fig. 2 A and B). Other veins form irregular networks. Emplacement seems to have taken place through forceful intrusion (Plates 9 B and 10 B) and replacement of the country rock (Plates IX A and Fig. 2 A). Fig. 2 C illustrates partial replacement of the wall rock and two ages of granite pegmatite.

Successive stages of emplacement is also shown by the different degrees of deformation shown by certain groups of dykes or sills. Some practically undeformed dykes clearly transgress highly deformed (gneissic) sills and dykes. These late dykes are particularly abundant in the southern part of the area and here may represent a late phase of the Morin series (Pine Hill granite).

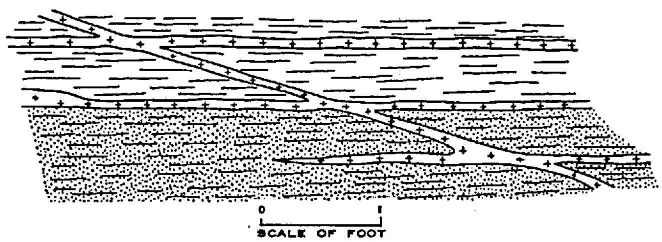
The typical granite pegmatite is pink or grey, rarely greenish, and is made up of extremely coarse crystals of quartz and potassic feldspar and a variable amount of plagioclase feldspar. Mafic elements include biotite, hornblende and, more rarely, pyroxene. The composition of the most common facies is given in Table 1, No. 21. In some thick dykes, tabular crystals of pink feldspar up to a foot long and euhedral books of biotite, 2 to 3 inches across, were observed.

FIGURE 2

A

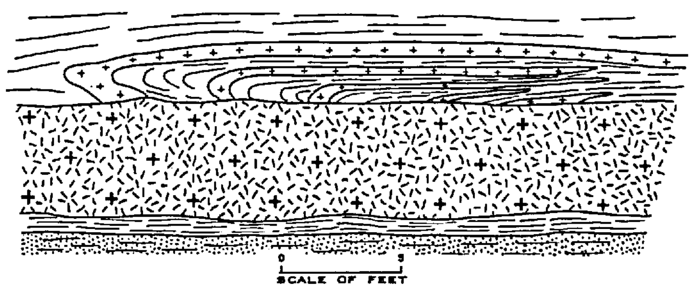


B



A & B — Sectional views of veined gneisses showing lit-par-lit veins with interconnecting feeders.

C



C — Sectional view showing a sill of coarse granite pegmatite truncating (replacing?) a veined gneiss.

D.M.Q. 1960, NO. 1331

The mineralogical composition of the pegmatites varies to some extent with the country rock in which the pegmatites are emplaced. For instance, pyroxene and hornblende and a caicic plagioclase generally characterize the pegmatites found in the pyroxene and/or hornblende-andesine gneiss. Some of these pegmatites carry tablets of hornblende 10 to 12 inches long and 6 to 8 inches thick. Similarly, pegmatites associated with the paragneisses have a tendency to be more quartzose and more potassic. They are occasionally garnetiferous and, rarely, contain some sillimanite. Some dykes of pegmatites emplaced in silicated carbonate rocks contain large crystals of salite, a calcic pyroxene characteristic of the carbonate rocks. Small amounts of zircon, apatite, sphene, muscovite, zoisite, and tourmaline were noted in several thin sections of the pegmatites.

MORIN SERIES

The Morin intrusive series includes an anorthosite-gabbro complex, several types of intermediate pyroxene-bearing rocks and a coarse porphyritic granite correlated with the Pine Hill member of the series. The anorthosite-gabbro complex with the pyroxene-bearing rocks much resemble anorthosite-charnockite series found elsewhere in high-grade metamorphic terranes. Several mineralogical features suggest that the sequence here may be derived from one magma. The genetic relationships of the porphyritic granite (Pine Hill) to this magma are less certain. Intrusive relationships indicate that the emplacement of the granite followed that of the anorthosite-charnockite sequence, but it is not clear whether or not the granite is connected with that sequence.

The rocks of the Morin series are practically all concentrated in one massif in the southern part of the area. Small, isolated, tabular, satellitic bodies occur at Shawinigan where they cause the falls, and in the northeastern corner of the area, near St. Tite.

The anorthosite-gabbro complex occurs as a down-buckled, southerly-plunging (25 degrees) tabular body in the southern part of the area, and as a steeply dipping lobe open westerly near the western boundary of the area. The composition of most of this complex varies from gabbroic anorthosite (1) to gabbro. Gradation to a rock having

(1) Buddington's (1939) classification:

anorthosite	0-10%	mafic	minerals
gabbroic anorthosite	10-22 1/2%	"	"
anorthositic gabbro	22 1/2-35%	"	"
gabbro	35-65%	"	"

the composition of a pyroxene diorite takes place at the western edge of the U-shaped body, and lenses of gabbro rich in ilmenite and magnetite are found in the upper part of the western limb of this same mass.

Gabbroic anorthosite and anorthositic gabbro

Gabbroic anorthosite and anorthositic gabbro are somewhat intermixed in both the U-shaped mass and the lobe. However, gabbroic anorthosite is definitely prevalent at the nose of the U-shaped mass and may represent here an early differentiate accumulated at the base of the tabular body. Ilmenite-magnetite rich gabbro lenses stretched out along one horizon at the west limb of this same body also point to a layered structure.

Both the gabbroic anorthosite and anorthositic gabbro are generally very coarse, dark rocks made up of interwoven laths of plagioclase feldspar, varying from calcic andesine to labradorite, and a subordinate amount of pyroxene. In some very coarse facies, as in the gabbroic anorthosite at the nose of the U-shaped mass, the laths are about one inch long. Some mafic facies show an ophitic to sub-ophitic texture. The pyroxene is dark brown or black and in large grains or in aggregates of small grains filling wedge-shaped interstices. Nos. 22 and 23, Table 1, give the mineralogical compositions of two common facies of these rocks.

Under the microscope, the plagioclase shows simple and complex twinnings and is loaded with tiny rod-shaped exsolutes made up of magnetite, ilmenite, and hematite. These rods are aligned in rows or scattered throughout the feldspar grains without any clear geometrical pattern. Bending of twin lamellae and peripheral granulation of the grains point to straining either during or after crystallization of the anorthosite-gabbro – more likely after.

The pyroxene (hypersthene and augite) contains tiny inclusions like those of the plagioclase and also thin schiller blades. Many large crystals have a lamellar structure oriented parallel to the optic plane.

The anorthosite-gabbro in some thin sections shows small interstitial granophyric intergrowths of quartz and potassic feldspar. This material never exceeds 1 or 2 per cent of the rock. Thin and discontinuous fringes of biotite occasionally rim the pyroxene. Apatite and zircon are found in small amounts.

Meta-gabbro

The anorthosite-gabbro complex, near its contact with the Pine Hill granite, shows signs of a marked alteration characterized by the breaking down of the pyroxene into hornblende. Strain is also indicated by granulation of the feldspar laths. In the gabbroic facies some obliteration of the ophitic texture can be seen.

The first step of this alteration seems to have been a rounding of the mineral grains by formation of hornblende around the pyroxene wedges or angular aggregates (Plate XI), and peripheral granulation of the feldspar laths. At more advanced stages anhedral hornblende is scattered in a mosaic of plagioclase and the rock shows a faint gneissic structure. No. 24, Table 1, is an estimated mineral composition of a partly altered anorthositic gabbro. The anorthite content of the feldspar has apparently remained unchanged through the alteration.

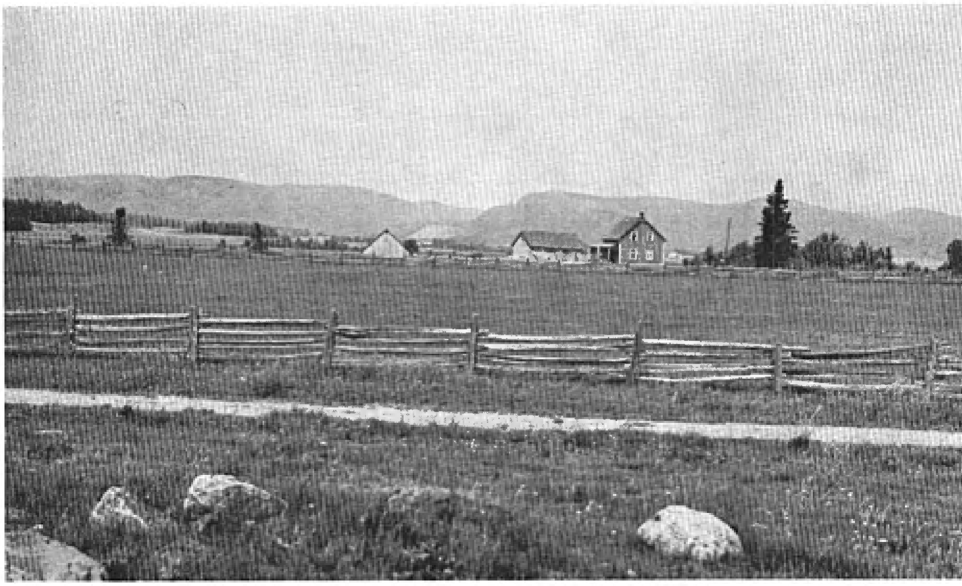
Gabbro inclusions

The anorthosite-gabbro complex at several places contains inclusions up to 25 feet across made up of a fine-grained gabbro. An estimated mineralogical composition is given in Table 1, No. 26. Some inclusions are angular and blocky whereas others are lenticular and drawn out. They may represent gabbroized fragments ripped off from the walls or blocks of an earlier chilled facies floated up by the magma.

Ilmenite-magnetite gabbro

The ilmenite-magnetite gabbro, found in lenses in the upper part of the west limb of the down-buckled sheet, is a very dark, medium-grained, faintly banded rock. Banding results from a vague separation of the felsic elements from the pyroxene and ore minerals. In the dark bands some segregation of the pyroxene from the ore is also noticeable. Average tenor in ore is 25 per cent, with local concentrations reaching up to 80 per cent. Thin sections show that the rock is at places considerably granulated. In but slightly granulated specimens the pyroxene and plagioclase have both a tendency to be idiomorphic and thus must have crystallized contemporaneously. Ore is in irregular aggregates with a tendency to be interstitial, (Fig. 3 B). An estimated mineralogical composition is given in Table 1, No. 25.

PLATE I



A — Laurentian foothills viewed from the Lowlands.

B — Steep-flanked, flat-topped hill in the Uplands.

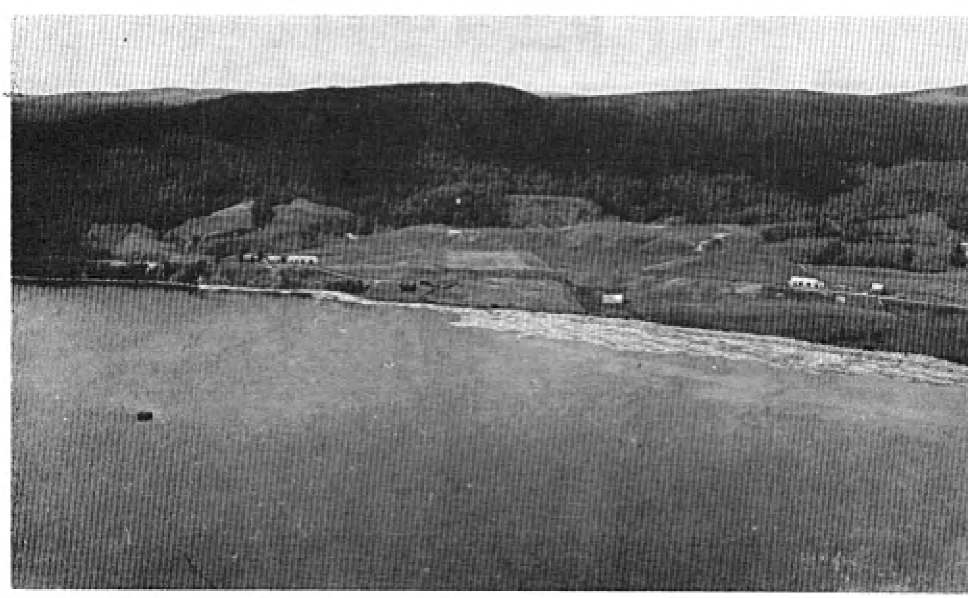
PLATE II

A — St-Maurice river. North of Grandes-Piles.

B — St-Maurice river. North of Grandes-Piles.

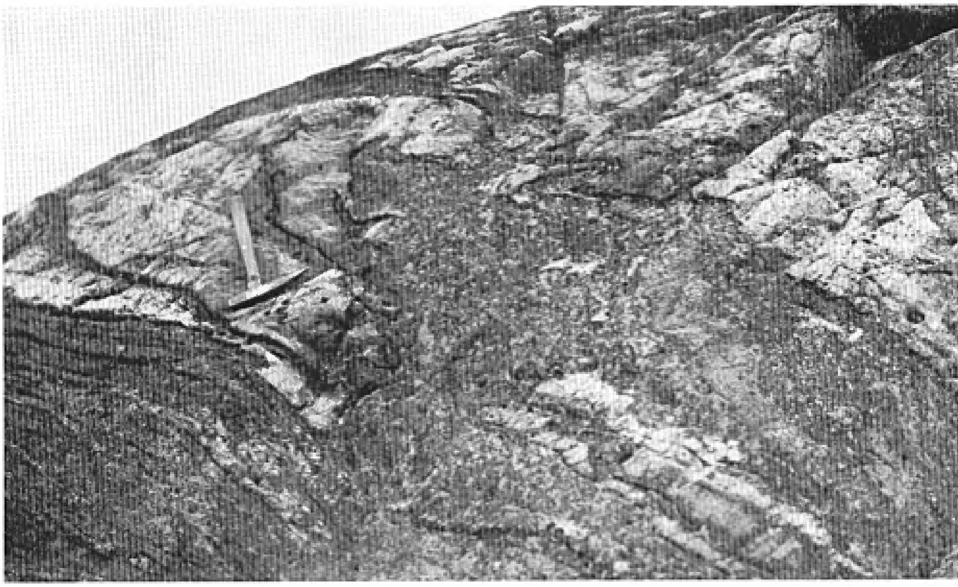
PLATE III

A — Terraces on west shore of St-Maurice river near St-Jean-des-Piles.



B — Terraces on west shore of St-Maurice river near St-Jean-des-Piles.

PLATE IV



A — Tightly folded bed of meta-quartzite in a steeply dipping sequence of paragneisses and meta-quartzite. The inner core of paragneiss has been forced through the limb of the fold in the manner of a dyke (lower centre).

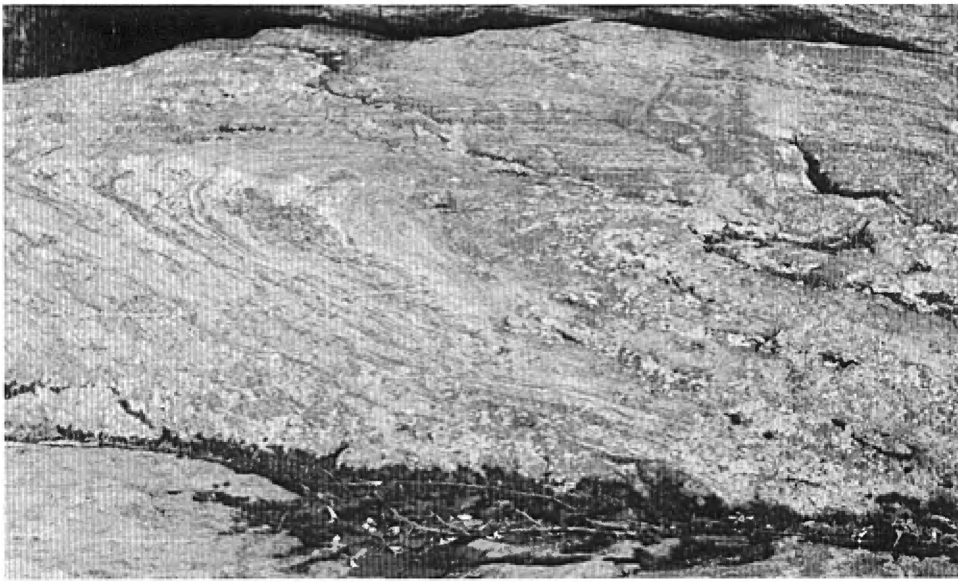
B — Tightly folded bed of meta-quartzite in a steeply dipping sequence of paragneisses and meta-quartzite.

PLATE V

A — Sectional view of a tight recumbent fold in area of gently inclined gneissosity. East shore of St-Maurice river, near Grandes-Piles.

B — Sectional view of a tight recumbent fold in area of gently inclined gneissosity, near St-Tite.

PLATE VI



A — Sectional view of a tight recumbent fold in paragneiss, in area of nearly flat-lying gneissosity. At the falls of Grand'Mère.

B — Sectional view of a tight recumbent fold in paragneiss, in area of nearly flat-lying gneissosity. At the falls of Grand'Mère.

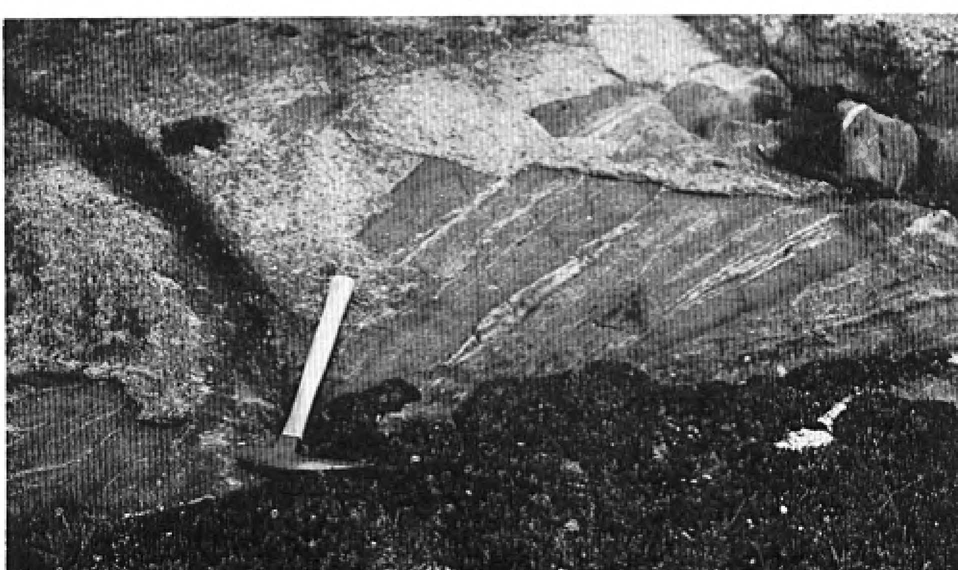
PLATE VII

A — Sectional view of a tight recumbent fold in area of nearly flat-lying gneissosity near St-Boniface. The fold involves pegmatite sills and carbonate rock beds (etched out).

B — Contorted bed of meta-quartzite in nearly flat-lying paragneiss. The bed has been ruptured and dragged into an annular structure.

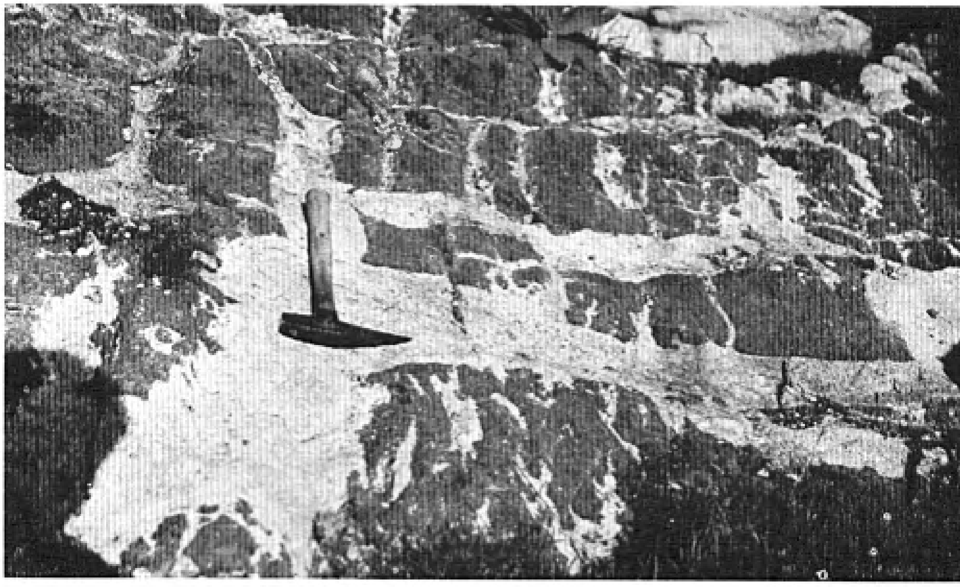
PLATE VIII

A — Linear structure in veined paragneiss. The lineation is nearly horizontal and parallel to the hammer handle.

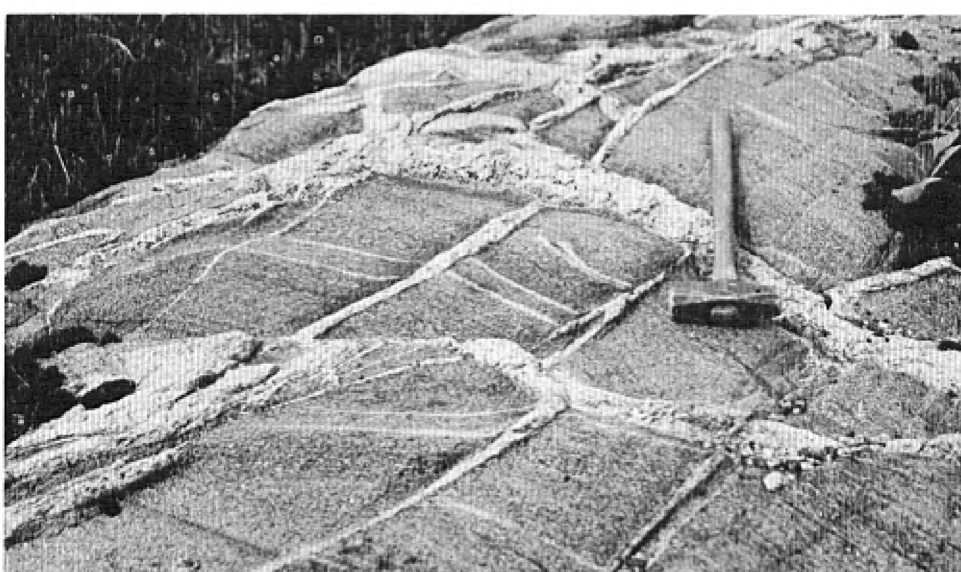


B — Granite pegmatite (light grey) intruding brecciated mafic gneiss (dark grey).

PLATE IX



A — Granite pegmatite (white) veining and replacing mafic gneiss (dark grey).

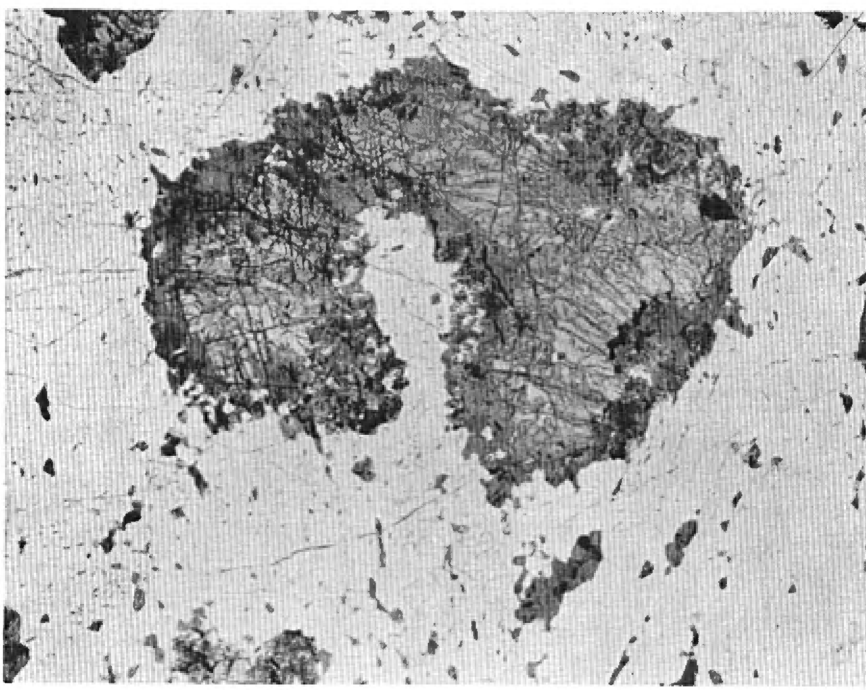


B — Brecciated mafic gneiss (grey) veined by granite pegmatite (white). The blocks have been offset at places.

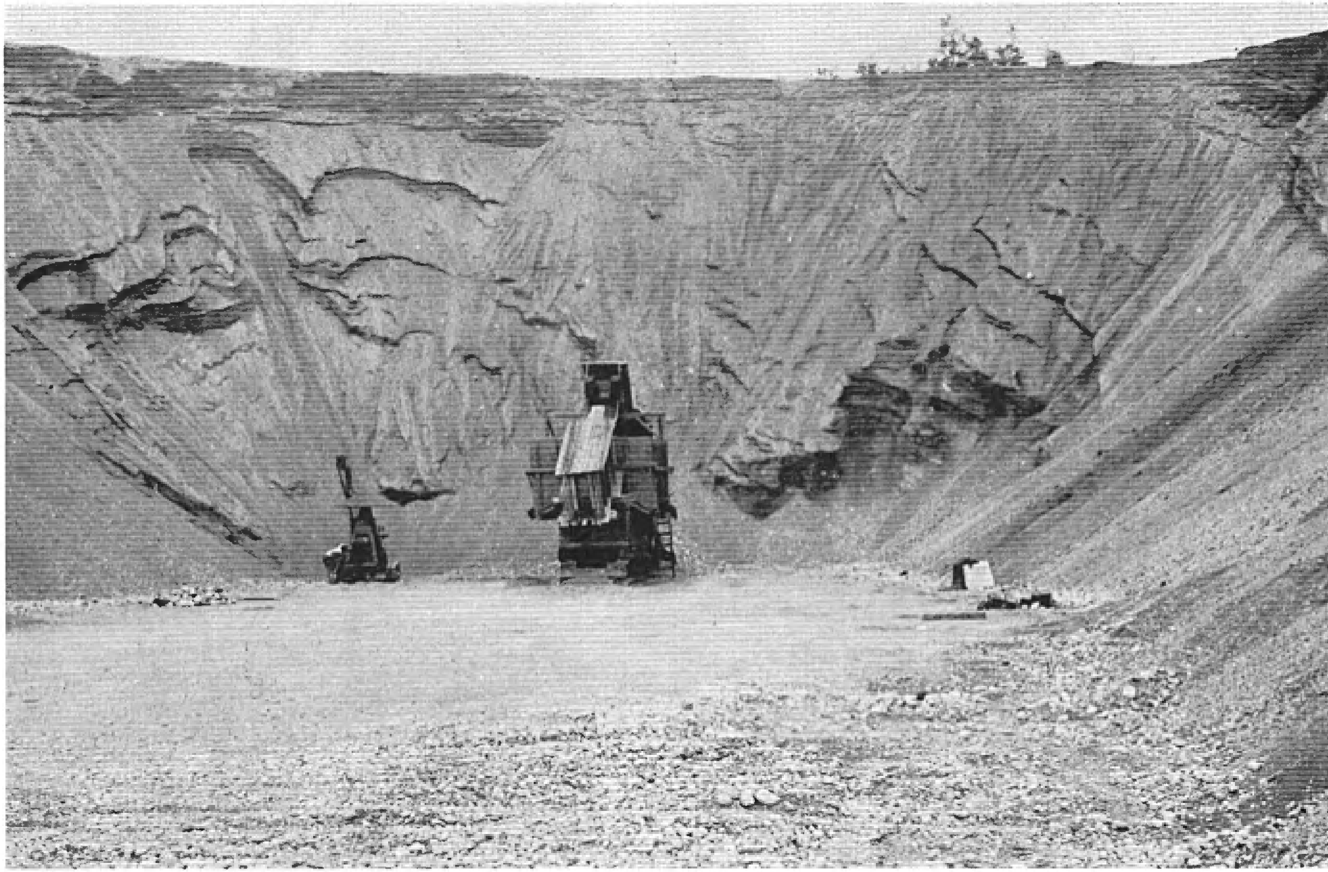
PLATE X

Pseudo-conglomerate. Fragments of silicated carbonate rock, pegmatite, and mafic gneiss in a carbonate matrix.

PLATE XI



Microphotograph of an altered ophitic gabbro. At centre is a pyroxene aggregate (grey) rimmed by hornblende (dark grey) in partly granulated plagioclase feldspar (white).



Gravel deposit showing a deltaic structure on the north flank of Mt. Carmel. The fore-set beds dip to the north.

PLATE XII

A remarkable feature of the ilmenite-magnetite gabbro is the abundance of exsolved material (tiny rods of ilmenite, magnetite and hematite) in the plagioclase and the pyroxene (hypersthene and augite). The hypersthene shows a marked pleochroism, presumably because a relatively high content of iron or titanium. Some pyroxene grains are rimmed by hornblende and biotite both rarely associated with ilmenite and magnetite. Hornblende and biotite also rim some ore grains.

Pyroxene-bearing Intermediate Rocks

Pyroxene diorite

Irregular small masses of a dark, fine-grained pyroxene diorite are found within the western portion of the west limb of the U-shaped body of anorthosite-gabbro and also at a few places within the east limb. An estimated mineralogical composition is given in Table 1, No. 27. Contacts with the anorthosite-gabbro in which the pyroxene diorite is emplaced may be sharp or gradational. In the western limb, the pyroxene diorite grades into pyroxene granodiorite through a zone with disseminated large porphyroblasts of biotite and potassic feldspar. This potassium enrichment is probably related to the emplacement of the pyroxenic granodiorite, also part of the Morin sequence. Booklets and poikilitic aggregates of biotite, disseminated practically throughout the pyroxene diorite, may also be related to this granodiorite emplacement.

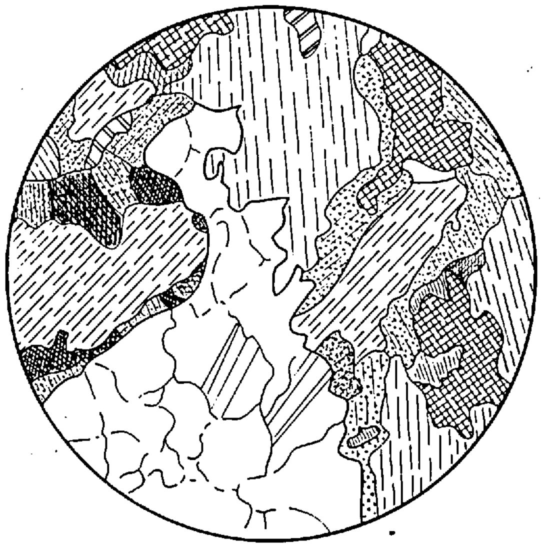
Pyroxene-quartz diorite dykes

Dykes, 4 to 6 inches thick, made up of a fine-grained quartz diorite with a small amount of hypersthene (Table 1, No. 22) cut the anorthosite-gabbro complex at a few places. Along some dykes, concentrations of carbonate, ilmenite, and magnetite spread out into the anorthosite-gabbro.

Pyroxene granodiorite

Pyroxene granodiorite (mangerite) occurs in small irregular bodies grading into Pine Hill granite in the southwestern part of the area near Des Isle and Fer-à-Cheval lakes, and as sheet-like concordant bodies, at and south of Shawinigan and near St-Tite (northeast corner of the area). At Shawinigan, several sills, separated by screens or lenses of granitized paragneisses, carbonate

FIGURE 3



A

A - Rims of hornblende (stippled) around pyroxene (dashed) in a meta-gabbro. (Sill south of Des Piles Lake.) X 17

B

B - Rims of hornblende (stippled) around ore (black) and pyroxene (dashed) in an ilmenite-magnetite gabbro. X 27 rock, meta-quartzite, and hornblende-andesine gneiss, can be recognized. Near St-Tite, layers or lenses of fine-grained granite are intercalated in the pyroxene granodiorite. Gradations to a hornblendic Pine Hill granite are also apparent in the St-Tite sills.

The pyroxene granodiorite is generally very coarse-grained, porphyritic, and quite massive. The sills at Shawinigan and near St-Tite, however, have a tendency to be gneissic. Here many of the feldspar phenocrysts are augen-shaped and, at Shawinigan, alternations of pink and greenish augen characterize part of the rock. Osborne (1936) notes that the pink and green layers here have about the same chemical compositions (Table 2, Nos. 11 and 12).

Thin sections show that the pyroxene granodiorite is made up of large crystals of potassic feldspar, generally perthitic, and plagioclase (sodic andesine) set in a matrix of quartz, pyroxene, hornblende, and biotite. An estimated mineralogical composition is given in Table 1, No. 29. In gneissic facies the feldspar grains are granulated and drawn out, and the quartz is in foliae. Large rosettes, made up of poikilitic flakes of biotite, are rare.

The pyroxene in the least deformed facies has a tendency to be idiomorphic and contains schiller inclusions like the pyroxene of the anorthosite-gabbro complex. Plagioclase also shows the same complex twinning observed in the anorthosite-gabbro.

Accessories include garnet, zircon, apatite, muscovite and sphene.

Pine Hill Granite

A coarse porphyritic granite present here is similar to the Pine Hill granite that is associated with anorthosite-gabbro and pyroxenic intermediate rocks north of Montreal and north of the Ottawa river. The main occurrence is in the southwest corner of the area and consists of a lobe-shaped body bordered to the east by the anorthosite-gabbro complex. The lobe presumably extends southwesterly outside the area and joins with the Hunterstown batholith mapped by Ells (1898). Satellitic tabular bodies are also found within the U-shaped southern mass of anorthosite-gabbro, at Shawinigan, and near St-Tite. Near St. Tite the granite is locally very hornblendic. Estimated mineralogical compositions of both facies are given in Table 1, Nos. 30 and 31.

Much of the Pine Hill granite resembles in general appearance the pyroxene granodiorite previously described. It is porphyritic, greenish or pink, massive or faintly gneissic. The hornblendic facies, however, has a slightly finer grain and is rarely porphyritic. In the porphyritic facies the phenocrysts are potassic feldspar and, rarely, plagioclase. The mafic minerals are usually biotite with some hornblende. Apatite, zircon, sphene, epidote, muscovite, and garnet are found in small amounts.

The contact of the Pine Hill granite with the anorthosite-gabbro of both the small body north of Souris lake and the larger U-shaped body to the southeast is generally concordant. It seems to follow a foliation, faint in the anorthosite-gabbro and marked in the granite. Blocks of anorthosite-gabbro incorporated in the granite, a few dykes of granite cutting the anorthosite-gabbro, and disseminated porphyroblasts of potassic feldspar and quartz within the anorthosite-gabbro near the contact show that the granite is younger.

The foliation within the Pine Hill granite, whether at the border zone of the main body or within the satellitic bodies, is never as marked as that observed within the fine-grained gneissic granite previously described. Interlayering with granitized country rock is also absent. The contacts are sharp except for occasional narrow zones of migmatite disseminated with large porphyroblasts of potassic feldspar and quartz. Contacts of the Pine Hill granite with the fine-grained gneissic granite, such as east of Fer-à-Cheval lake (southwest corner of the area) and northwest of St-Tite, are generally marked by a rapid change in grain size and general appearance of the rock. These two granites were, therefore, probably emplaced under different conditions, at different periods.

<u>Differentiation within the Morin series</u>.

Several mineralogical features of the basic and intermediate rocks of the Morin intrusive series point to a differentiation from one magma. Genetic relationships of the Pine Hill granite to this assemblage are more difficult to establish.

The consanguinity of all the basic and intermediate rocks of the Morin series is suggested by the presence of the same metallic inclusions (ilmenite, magnetite, and hematite) in both the plagioclase and the pyroxene. Also, the pyroxene invariably shows schiller inclusions. Within the anorthosite-gabbro layered complex of the southern part of the area the concentration of metallic inclusions increases upward and culminates at the ilmenite-magnetite gabbro horizon.

Differentiation is further indicated by the variation of the proportion of mafic to feldspathic elements. The pyroxene to plagioclase ratio increases upward; the very bottom layer is gabbroic anorthosite followed by anorthositic gabbro and, near the top, gabbro. This increase in mafic elements is accompanied by a general reduction in grain size and a slight reduction in the calcity of the plagioclase. The sequence of events seems to have been as follows:- First, at the gabbroic anorthosite stage, large laths of plagioclase, about An_{50}, formed a mat-like aggregate on the floor. Hypersthene wedges between the laths of plagioclase show that some pyroxene also crystallized at about the same time. Subsequently, at the anorthositic gabbro stage, the proportion of pyroxene considerably increased and both augite and hypersthene crystallized. Augite is found in small irregular lumps at the periphery of the large idiomorphic hypersthene grains or as fine aggregates wedged in between the coarse hypersthene stubs. Both hypersthene and plagioclase had, then, a tendency to be idiomorphic and the calcity of the plagioclase seems to have but slightly decreased. At the gabbro stage (ilmenite-magnetite gabbro) augite, hypersthene, and plagioclase formed in about equidimensional grains, for the rock shows a mosaic texture. The proportion of augite to the total pyroxene passes from 25 per cent in the anorthositic gabbro to 65 per cent in the gabbro, and the anorthite content of the plagioclase in the gabbro is about An_{40-45}. Ilmenite and magnetite, which in earlier facies had been held up in solution in the pyroxene and plagioclase to appear later as exsolutes, show up in the gabbro as discrete grains, that is, as a primary phase just like the pyroxene and the plagioclase. Minor amounts of hornblende and biotite which are seen rimming the pyroxene of the gabbro may have ended the reaction series. These two minerals, however, may be secondary and due to subsequent metamorphism.

The next episode of this differentiation process was apparently the emplacement of the pyroxene diorite followed by the pyroxene granodiorite, both of which occur close to the anorthosite-gabbro complex and share common mineralogical features. The plagioclase and the pyroxene again contain the metallic inclusions, and the pyroxene, the schiller inclusions, noted in the anorthosite-gabbro sequence. The pyroxenes are hypersthene and augite and, in the pyroxene diorite, occur in about the same proportion as in the gabbro. The plagioclase in the diorite and granodiorite shows an anorthite content of about An_{35} as compared to An_{40-45} in the gabbro.

The presence of pyroxene, somewhat unusual in intrusive rocks of intermediate composition, suggests that the high temperatures that prevailed during the emplacement of the anorthosite-gabbro sequence must have persisted also during the intrusion of the intermediate facies.

The Pine Hill granite could possibly represent the last term of the differentiation but the lack of common mineralogical features with the other intrusions and the large volume of the granite as compared to that of the basic and intermediate facies render such a correlation hazardous.

DIABASE DYKES

A few diabase dykes, less than 10 feet thick, and traceable only short distances, cut the pyroxene and/or hornblende-andesine gneiss, the paragneisses, and the basic and intermediate rocks of the Morin series. Most of these dykes are somewhat deformed and disrupted, whereas a few apparently post-date all periods of deformation. The dykes show no definite pattern or simple relationship to the structural trends as is observed in some other parts of the Grenville sub-province. Directions here are erratic.

The rock is grey to black, fine-grained, and equigranular. An estimated mineralogical composition is given in Table 1, No. 32. Thin sections of the least deformed dykes show a mosaic of hypidiomorphic pyroxene and anhedral plagioclase. Scattered grains of zircon and apatite occur as accessories.

PLEISTOCENE AND RECENT DEPOSITS

Till, bouldery gravel, gravel, marine clay, eskers, sand and silt make up the Pleistocene deposits of the area. Recent accumulations include alluvions along water courses, taluses at the foot of the steeper slopes, and soil resulting from mechanical or chemical desintegration.

Till

Till resting on bedrock was seen in a few roadcuts. In valleys, the maximum thickness observed was 15 feet; on the hill slopes, it does not exceed a foot or two. The till is generally made up of subrounded fragments of Precambrian rocks of various sizes set in a matrix of gravel, sand, and a material resembling clay.

Deposits of washed till made up of rounded boulders mixed with gravel or sand occur in the northeast corner of the area near Cossetteville in a series of low ridges, 50 to 300 feet wide and up to 1/2 mile long. The deposits presumably underlie the marine clay by which they are surrounded. Deltaic gravel deposits within the clay belt, near the foothills of the Laurentian uplands, are probably fluvio-glacial deposits.

Marine (Leda) clay.

Marine clay is spread over wide tracts in much of the Lowlands portion of the area. It is generally massive but with thin sandy partings in some places, bluish grey, and almost free of pebbles. Shell fossils occur in small pockets at various horizons. Some of the fossils collected during our fieldwork were identified by Mr. René Bureau of Université Laval as follows:

Lamellibranchiata:

Macoma groënlandica
Saxicava rugosa
Mya truncata
Mya arenaria
Mytilus edulis
Yoldia (?)

Crustacea:

Balanus

The most common species are *Macoma groënlandica* and *Saxicava rugosa*. All species appear in the list given by Dawson (1893) in his work on the "Leda clay" of the island of Montreal.

The highest fossil locality recorded is near Grandes-Piles, on St-Maurice river, at 480 feet above sea level; the lowest is near Shawinigan, on the shore of St-Maurice river, at 132 feet.

Eskers

A narrow sinuous esker made up of sand, gravel, and well worn pebbles follows the Bellemare and Vert Lakes valley for 2 1/2 miles in the southwest corner of the area. The ridge, in its northern part, trends southeasterly and, in its southern part, southwesterly. At the south tip of Vert lake, near the esker, is a large kettle hole sunk in a thick sheet of presumably fluvio-glacial material. This valley, now feebly drained by a string of lakes, may have been one of the major drainages of the area before glaciation.

Gravel deposits

Many thick gravel deposits made up of stratified glacial material are encountered in the Lowlands, and in the foothills. The low range of hills at the mouth of the St-Maurice River embayment is also largely made of gravel interbedded with sand.

Most of these deposits show a deltaic structure. Those in the foothills and within the Lowlands near the foothills, have foreset beds dipping south or southeast whereas those at the mouth of the embayment have foreset beds dipping about 35 degrees north (Plate XII).

The hills at the mouth of the St-Maurice River embayment include Charette hill south of the present area and Mont Carmel along the southern boundary. Mont Carmel, 2 1/4 miles long and 1/2 mile wide, has an elevation of 225 feet above the plain level. Northeasterly it joins with the St-Narcisse moraine which, according to Lunde (1951), has a core of a very coarse bouldery gravel overlain on its northwest flank by gravel, sand and silt. Northwest of the moraine is a wide tract of marine clay.

Mont Carmel near its top is also quite bouldery but apparently less so than the St-Narcisse moraine. The deltaic structure on the northwest flank was probably formed during the Champlain sea invasion as the morainic ridge was being cut down by the advancing sea. Regression of the sea has left on the flanks of the hill a series of terraces easily detected on aerial photographs.

Sand and silt

A thin layer of sand and silt covers much of the clay belt in the Lowlands. The sand shows some cross-bedding. This nappe of coarse material overlying the clay was probably spread out as the Champlain sea retreated to the St. Lawrence estuary. The water may have been then fresh or brackish because no fossils were found in this material.

STRUCTURAL GEOLOGY

Foliation and bedding

The pyroxene and/or hornblende andesine gneiss and the paragneiss of the area show a marked foliation. This is given mainly by compositional or textural layers which commonly are emphasized by a general parallelism of the platy minerals. Other elements of the foliation include: lit-par-lit injections of granitic material, flat discs of quartz, thin bands of carbonates, and eye-shaped aggregates of granulated feldspathic porphyroblasts.

Some of this banded structure probably reflects an original bedding but because of a high degree of recrystallization and a severe deformation this is very difficult to ascertain. The planar structure could just as well reflect a schistosity that originally transgressed the bedding. Also, compositional layering could have been in part brought about by some method of mechanical sorting, such as segregation of more plastic minerals along adjustment planes, while the rocks were being deformed. Solution of certain minerals at points of pressure and redeposition at points of lower pressure could have caused some of this structure.

Reliable bedding indicators are given, however, by the meta-quartzite beds and to some extent by the silicated carbonate beds; the latter are less reliable because of their propensity to flowage, as exemplified in Fig. 1 B. The meta-quartzite beds as well as the least deformed carbonate layers parallel the foliation of the adjacent gneiss or paragneiss throughout this area. Thus, it has been assumed that the foliation within both the gneiss and the paragneiss could substitute for the bedding.

Lineation

Both the gneiss and the paragneiss show linear structures resulting from a mild corrugation of the foliation or bedding planes, drag folds, minor folds, rodding (in the carbonate rocks), fluting (Plate VIII A), and elongated ellipsoids of quartz and feldspar (in the migmatites). Lineation is also given in hornblendic or biotitic facies by an alignment of the mafic minerals on the foliation planes. It appears that all these lineations are b-lineations, that is, are parallel to fold axes.

It can be seen on the accompanying tectonic map that the attitude of the lineation varies from one portion of the area to another but, nevertheless, reflects over each portion a general structural trend. This is well exemplified in the north central part of the area where the lineation (averaged in the circle) coincides with the axis of a complex basin-like structure outlined by the foliation. Elsewhere, also, the lineation is much more consistent in direction than the foliation and more or less conforms to the general structural trends. Southwest and northwest of Grand-Mère, for instance, the lineation is about perpendicular to the foliation but concordant with the general structural trend of the central portion of the area. It indicates a southeasterly plunge of the structure.

West and northeast of Shawinigan, in the southern part of the area, the trend of the lineation coincides roughly with that of the foliation and like the foliation outlines two distinct structural belts; one trending northerly and the other, northeasterly. The lineation shows that one belt plunges southerly and the other southwesterly. The abrupt change of trend at the boundary of these two belts is also found elsewhere in the area. Deformation presumably took place at a tectonic level where rocks yielded easily and stresses could be exerted simultaneously or successively from different directions. Abrupt changes such as are exemplified in the northwestern part of the area are otherwise difficult to explain. The truncations west of La Pêche lake and near Shawinigan, however, may in part be explained by faulting.

Folds

Both the pyroxene and/or hornblende-andesine gneiss and the paragneisses over much of the area appear to be in gentle rolls, with dips varying from about 10 to 30 degrees. In the southern part of the area, within the paragneiss belt, the foliation, bedding, and lineation indicate a tightly folded synclinorium pitching southerly about 25 degrees. The U-shaped complex of anorthosite-gabbro located in this synclinorium is presumably a downbuckled sheet plunging southerly like the synclinorium. To the west, north, and east, the tightly folded synclinorium merges gradually with the nearly flat structures prevailing over most of the rest of the area.

Near the northern boundary, west of St. Maurice river, a syncline in paragneisses, meta-quartzite, and carbonate rock trends about parallel to the synclinorium of the southern part of the area but with much gentler dips. Preservation of the paragneisses here, as in the southern part of the area, is apparently due to a down-folding into the pyroxene and/or hornblende-andesine gneiss.

The tight folding within the southerly pitching synclinorium may be accounted for by a vice-like movement resulting from the down-folding of the anorthosite-gabbro sheet.

The paragneiss obviously offered less resistance to deformation than the more massive pyroxene and/or hornblende-andesine gneiss or the anorthosite-gabbro. The crumpling of the paragneiss against the anorthosite-gabbro, as can be deduced from the abrupt truncation of the foliation at the nose of the U-shaped body of anorthosite-gabbro, illustrates the difference in competency.

The plasticity obtained by the paragneiss at the time these rocks were deformed is also well shown by the disruption and complex folding of meta-quartzite beds intercalated in the paragneiss in the southern part of the area (Plate 4A and 4B, and Fig. 1 A). At one place, for instance, the paragneiss has been forced through a quartzite bed in the manner of a dyke (Plate 4 A). Such structures could not have developed without considerable flowage of the paragneiss.

Another type of structure noted within the paragneisses and nearly absent in the pyroxene and/or hornblende-andesine gneiss is recumbent folding. It is found within the area of gently dipping structures and consists of noses of folds whose limbs merge gradually with these structures. (Plates V, VI and VII A). Such folds are well exposed at various places on the east shore of St-Maurice river from Grand'Mère to the north boundary of the area, near Truite (No. 1) and Des Piles lakes, St-Boniface, Glenada and St-Tite. Folds within the pyroxene and/or hornblende-andesine gneiss generally involve beds of carbonate rocks.

The amplitude of the folds varies from 10 to 25 feet; the axial planes as stated above are parallel to the foliation and the fold axes coincide more or less with the trend of the lineation of the portion of the area in which the folds occur. Most folds are overturned to the north or northeast.

The significance of these folds is not clear. They may be drags along sub-horizontal shearing planes developed within the flat-lying gneiss and paragneisses or relics of recumbent folds of large amplitude obliterated by sub-horizontal shearing. The relatively small amplitudes of the folds suggest drags.

Faults

Two major normal faults running in a northeasterly direction are found in the area. One crosses the northwestern part of the area from Souris lake to Isale lake and extends north and south of the area. The other extends from Shawinigan to the southern boundary of the area and beyond.

The northwestern fault is bordered on the west, from Souris lake to the Shawinigan River valley, by a high escarpment that presumably resulted from the rapid erosion of the paragneisses brought down along the fault. North of the Shawinigan River valley to the northern boundary of the area the fault follows a deep narrow valley occupied by streams and finger lakes. Outcrops in this valley reveal a zone of sheared, brecciated, and granulated granite, 1/2 to 3/4 miles wide. Slightly north of Shawinigan river the southeastern paragneisses end abruptly against the fault.

The major fault extending southwesterly from Shawinigan marks approximately the boundary between the Lowlands and the foothills of the Laurentian uplands on the west side of the St-Maurice River embayment. Southwest of St-Boniface it is bordered on the northwest by an escarpment. The fault extends far into the Lowlands, and several tens of miles southwest of the present area it brings into contact Potsdam and Trenton beds (Clark, 1956). The younger beds are on the southeast side of the fault. Faulting of Trenton beds indicates that the fault must be post-middle Ordovician.

These two normal faults running through the area are actually part of a system of en echelon faults which, between Montreal and Quebec, mark the boundary between the Laurentians and the Lowlands.

A small normal fault, probably just a local slump, can be traced a few tens of feet on the east shore of St. Maurice river, 3 miles north of Grandes-Piles. The fault trends east with the south side downthrown. On the north side, two nearly flat sheets of gneissic granite, much granulated at the fault, are curved downwards and taper off against the fault plane.

Shears

Shears are prominent along the contacts of the anorthosite-gabbro bodies especially on the east side of both prongs of the U-shaped sheet. A shear zone extends all along the east contact of the west prong and shears are observed at many places on the east side of the east prong particularly near the southern tip. At these contacts, both the anorthosite-gabbro and the paragneiss are foliated and granulated.

Shears are also conspicuous on the north side of the small lobe of anorthosite-gabbro located at the west boundary of the area. Another shear zone apparently crosses the lobe in an east-west direction along a deep narrow valley. The road traversing the lobe runs along this valley.

Joints

Joints are common in all the consolidated rocks of the area although less so in the anorthosite-gabbro. Many joint faces show striae, slickensides or mirrors indicative of minor displacement along the joint planes. Vein material also points to circulation of solutions along some of the joints.

The best developed joints seem to fall into three systems. One system is nearly horizontal, and probably could be attributed to release of tension following erosional unloading. At the normal fault on St-Maurice river, 3 miles north of Grandes Piles, horizontal joints run through the fault without any offsetting and thus post-date the faulting.

The two other systems include steeply inclined joints running 1) parallel to the lineation and 2) perpendicularly to it. Those parallel to the lineation are usually referred to as longitudinal joints and those perpendicular, as cross-joints. Both types are shown on the tectonic map. Osborne and Lowther (1936) express the opinion that these joints resulted from the same stresses that induced the foliation and the lineation. Undoubtedly the oriented structure shown by the foliation and lineation have exerted some influence on the directions of joints, but the fracturing could have taken place later during subsequent warping or uplifting of these terrains, or possibly with the normal faulting that affected the area in, presumably, post-middle Ordovician time. As is shown on the tectonic map one system of vertical joints (or steeply dipping; shown in the circles) is about parallel to the direction of normal faulting.

ECONOMIC GEOLOGY

Pegmatite

Dykes and sills of coarse pegmatite are found throughout the area. Most are made up of the common constituents and accessories of granite with some hydromafic minerals and, occasionally, a small amount of tourmaline, magnetite, ilmenite, and hematite.

Tests for radioactive minerals on many samples collected failed to give any significant results.

Lots 30-31, range 1, and lots 29-30, range II, Mekinac township. In December 1952, a 6-inch vein of pegmatite containing a few crystals of radioactive monazite was found near St-Joseph-de Mekinac, 15 miles north of the north boundary of the area. Assays made at the laboratory of the Quebec Department of Mines indicated tenors of 0.06 to 0.34 U_3O_8. An interesting aspect of this discovery is that a local industry, Shawinigan Chemicals, at Shawinigan, imports monazite to manufacture products in which the monazite rare earths enter. The quantity of monazite at the prospect, however, is extremely small.

Sulphides

Rusty paragneiss

Disseminated pyrite and pyrrhotite and, rarely, some grains of sphalerite and galena are found in the rusty weathering paragneiss but no marked concentration was anywhere observed.

Block C Shawinigan twp. Near Shawinigan, at the falls, below the dam west of the largest island, in a sill of coarse Pine Hill granite, a mildly mineralized zone 10-15 feet wide extends for 100 feet. The zone follows a system of closely-spaced vertical cross-joints. The granite along the joints is chloritized and is veined by coarsely crystalline calcite and some sulphides. The veins are vuggy and at places crustiform. Vugs are partly filled with coarse idiomorphic calcite and sulphides. The sulphides are mostly pyrite, pyrrhotite, and marcasite with lesser amounts of sphalerite and galena. The zone dies out within the limits of the exposure and tenors in zinc and lead are very low.

Lot 21, R. II, and lot 38, R. V, at Shawinigan twp. and lot 14, R. XI of Caxton twp. Within the U-shaped body of anorthosite-gabbro and within the small lobe of similar rock at the western boundary of the area a few sheared zones contain some small pockets heavily mineralized with sulphides. Two zones particularly noteworthy occur along the east contacts of both the east and west limbs of the U-shaped body and another one seemingly follows the road that crosses the western lobe located at the west boundary of the area.

The sulphides are mostly pyrite and pyrrhotite with small amounts of chalcopyrite. Assays also reveal the presence of nickel and cobalt. Three assays of grab samples collected follow:-

1) lot 21, R. II, Shawinigan township, at the southeast tip of the east limb of the U-shaped body, near the Canadian National Railway;

2) lot 38, R. V, Shawinigan township, at the north tip of the largest lens of ilmenite-magnetite gabbro;

3) lot 14, R. XI, Caxton township, at 0.2 miles north of the road that crosses the western lobe and 0.65 miles east of the west boundary of the area;

	Copper %	Nickel %	Cobalt %
1)	0.04	0.06	----
2)	0.03	0.16	----
3)	0.08	0.31	0.10

Lots 11 to 14, ranges XI and XII, Caxton township. From 1953 to 1956, Shawinigan Nickel Corporation and individuals did some prospecting in search of nickel in these lots and the surrounding district. The sector investigated coincides with the central and southern parts of the small lobe of anorthosite located at the west boundary of the area. The work done included a magnetometer survey of the sector and about 5,000 feet of diamond drilling divided among 25 holes varying in depths from about 100 to 600 feet.

The rocks intersected by the holes included various facies of the anorthosite-gabbro complex and, in a few holes, some acidic rocks. From several holes short mineralized sections were reported with tenors of nickel and copper varying from traces to about 1 per cent. The mineralization was apparently very erratic.

Ilmenite-magnetite

Lots 33 to 38, R. V, lots 24 and 25 and 27 to 32, R. VI, and lots 22 and 23, R. VII, of Shawinigan twp. The southernmost lens of ilmenite-magnetite gabbro within the west limb of the U-shaped body of anorthosite-gabbro, on lot 22 and 23, R. VII, Shawinigan township, near the village of St-Boniface, was exploited years ago for its iron content. More recently it has been investigated for its titanium content.

The site is known as the Grondin mine (Dulieux, 1913). It was first exploited in 1878. A blast furnace, the ruins of which can still be seen today, was erected near Machiche creek and ore was taken from a small open pit in a lens of nearly massive ore. Erratic blocks of ore collected from the surrounding hills were also fed to the furnace. Operations had to be abandoned because of difficulties in smelting the ore, presumably because of its high tenor of titanium. It has been estimated that about 150 tons of ore was taken out of the pit.

In 1950, Chavigny Gold Mines, interested in the titanium content of the ore, put down a few shallow diamond drill holes near the old pit and stripped some showings north of the pit. The results apparently were not encouraging because the work was suspended after a few months.

Two other lenses of gabbro rich in ilmenite and magnetite occur north of the Grondin mine. One is on lots 24 and 25, R. VI, Shawinigan township, and the other crosses lots 33 to 38 of R. V, and lots 27 to 32 of R. VI, of the same township. The lenses parallel the border of the anorthosite-gabbro and dip very steeply. The ore here seems to be of lower grade than that found at the Grondin mine (Table 1, No. 25; Table 3). The amount of magnetite and ilmenite combined in these northern lenses runs 20-25 per cent (volume), whereas the combined Grondin ore contains about 60 per cent (weight).

The massive ore at Grondin mine is found in irregular pods and in layers 6 to 10 inches thick alternating with a magnetite-ilmenite gabbro. A dip needle survey made by Waddington (1942) over an area of about 0.4 square mile around the mine suggests that this gabbro occurs in several elongate pockets some 200 to 300 feet long and 30 to 50 feet wide. The amount of massive ore in these pockets of gabbro is not known.

Polished sections of massive ore show that the magnetite and ilmenite are generally in separate, anhedral, and homogeneous grains, 0.5 to 2 mm. across. In some grains, magnetite and ilmenite adjoin along a sharp, straight line. Some ilmenite grains are twinned. Others contain rare fine blades or dots of hematite.

Very small amounts of pyrite, pyrrhotite, marcasite and chalcopyrite are disseminated in the ore.

Lake and bog iron ore

Bog iron deposits in the lower part of the St. Maurice River valley were known to the early settlers of the New France colony. Historical accounts mention that in 1663 a report about these deposits by Pierre Brochu was submitted to King Louis XIV. It seems that the first exploitation of the deposits was undertaken around 1733 by François Poulin, sieur de Francheville, proprietor of the Seigneurie de St. Maurice. The furnace known as "Les Forges de St. Maurice" was located on St. Maurice river at a place now known as Les Vieilles Forges about 6 miles north of Trois Rivières. Under different ownerships this furnace operated at intervals till about 1883.

In 1860 another furnace, Les Forges de Radnor, was built at Radnor; it ceased to operate about 1910. A smaller installation known as "Les Petites Forges" on Mekinac-du-Sud river near the mouth of Truite (No. 2) lake also existed about the same time.

The ore treated at Radnor and Les Petites Forges came largely from the Shawinigan map-area, from two bog iron fields and one lake deposit. One of the fields is at the headwaters of Black creek, between Hérouxville and the Canadian Pacific Railway, and the other is about a mile northwest of Radnor, between the Canadian Pacific Railway and the road to St. Narcisse Station. The lake deposit is in Tortue lake. It seems that the Black Creek field supplied Les Petites Forges, whereas the ore treated at the Radnor Forges came mostly from Tortue lake and in smaller amounts from the Radnor ore field.

No exact information could be obtained as to the production of these furnaces except that Radnor Forges about 1865 was producing some 2,000 tons of pig iron per year from 4,000 to 5,000 tons of ore. At the bog iron fields the ore was broken up with picks, washed and shoveled into horse-drawn carts to be transported to the furnaces. At Tortue lake, a dredge was used and transportation, at the beginning of the operations, was by cart and, later, by railway. The ore at the furnaces was reduced with maplewood charcoal activated by air supplied by a blower driven by a water-wheel.

The iron field at the headwaters of Black creek, judging from the excavations now to be seen, must have covered an area of about one square mile. The ore appears to have been in rusty sand very near surface in "runs" 1 to 2 feet deep, 10 to 15 feet wide and 200 to 300 feet long, along shallow, marshy and sinuous depressions. The Radnor field, located on the southeast flank of Mt. Carmel, may have been about one mile wide and 3 to 4 miles long. Here, also, the ore is in rusty sand and near surface, but the ground is less swampy.

Ore can still be found over both fields. It is in spongy, rusty masses, black and shiny on fresh fractures. It has been appropriately described as a dried up mixture of hydrous ferric oxides darkened by organic matter and a little manganese.

The Tortue Lake deposit, the most productive of all, covered most of the bottom of the lake and extended on the beaches. Near the outlet of the lake it is said to have had a thickness of 6 feet, and older reports mention that this part of the lake again yielded ore 8 to 10 years after it had been completely mined out.

The lake ore is somewhat different from that of the fields. It consists of small flat concretions made up of concentric layers of black shiny ore gathered around cores of sand, silt or clay.

The pig iron made from the lake ore is said to have been much in demand. Part of it was shipped to England to be processed and cast into locomotive wheels which were found to be of a very high quality and of long durability.

Chemical analyses of both the lake and the bog ores are presented in Table 4.

The source material of both the bog and the lake deposits may have been the iron oxides staining the sand found over most of the lowland portion of the area. A field like the one at the headwaters of Black creek may have resulted from stagnation of ferruginous waters in flat marshy ground. During dry periods the marsh is reduced to a system of shallow and sinuous channels and iron compounds probably precipitate in the porous sand. At Radnor, accumulation may have resulted from the precipitation of iron salts from ferruginous water seeping out at the foot of Mt. Carmel at the clay-sand interface. At Tortue lake, deposition is favoured by a high rate of evaporation resulting from the shallowness of the lake. The lake actually has shrunk considerably in historic time. It seems, also, that the lake receives a rich supply of iron compounds from the incoming streams, judging from the yellow and reddish colours of these streams. Upon evaporation the precipitates presumably collect around sand, silt or clay pellets and build up into concretions which, under the weight of the accumulating sediments, collapse, dehydrate, and harden into flat massive discs.

Table 1

Estimated Modal Analyses

A.- Pyroxene and/or hornblende-andesine gneiss and meta-gabbro

	1	2	3	4	5	6
	Vol. %	Vol. %	Vol. %	Vol. %	Vol. %	Vol. %
Quartz	1	3	tr	5	3	--
Plagioclase	49(An_{35})	51(An_{33})	47(An_{39})	54(An_{41})	60(An_{34})	45(An_{38})
K - feldspar	tr	tr	tr	tr	2	--
Pyroxene	3	tr	14	25	14	20
Hornblende	41	30	35	8	--	20
Biotite	3	14	1	3	20	8
Opaques	3	2	2	4	1	2
Garnet	tr	tr	1	1	--	--
Apatite	--	--	--	--	--	5
	100	100	100	100	100	100

1.- Hornblende-andesine gneiss.
2.- Biotite-hornblende-andesine gneiss.
3.- Pyroxene-hornblende-andesine gneiss.
4.- Pyroxene-andesine gneiss.
5.- Biotite-pyroxene-andesine gneiss.
6.- Meta-gabbro (sill south of Des Piles lake).

B.- Silicated carbonate rock

	7 Vol. %	8 Vol. %	9 Vol. %	10 Vol. %
Carbonate	73	4	--	--
Quartz	4	9	2	11
Plagioclase	4 (An_{34})	18(An_{38})	26(An_{43})	35(An_{73}?)
K-feldspar	--	4	12	--
Scapolite	11	30	--	8
Pyroxene	7	30	8	7
Hornblende	--	tr	40	--
Actinolite	1	--	--	--
Sphene	tr	3	--	3
Garnet	--	--	--	35
Opaques	--	2	9	1
Accessories	--	--	3	--
	100	100	100	100

7.- Slightly silicated carbonate rock. The pyroxene is salite (iron-rich diopside) and diopside.

8.- Pyroxene-sapolite facies. The pyroxene is mostly salite with rare diopside.

9.- Hornblende-andesine facies. The pyroxene is diopside.

10.- Plagioclase-garnet facies. The pyroxene is salite and the garnet, grossularite-andradite.

C.- Paragneisses and meta-quartzite

	11 Vol. %	12 Vol. %	13 Vol. %
Quartz	22	30	81
Plagioclase	48(An_{31})	17(An_{30})	6
K-feldspar	4	28	3
Pyroxene	2	--	--
Hornblende	2	--	1
Biotite	20	12	7
Opaques	2	tr	--
Garnet	tr	9	2
Sillimanite	--	4	--
Epidote	--	--	tr
Graphite	--	tr	1
	100	100	101

11.- Quartz-biotite-sodic andesine paragneiss.
12.- Quartz-biotite-microcline paragneiss. The potassic feldspar is microcline, microcline-perthite, and perthite.
13.- Meta-quartzite.

D.- <u>Intermediate to acidic intrusive and metasomatic rocks and granite pegmatite</u>

	14 Vol.%	15 Vol.%	16 Vol.%	17 Vol.%	18 Vol.%	19 Vol.%	20 Vol.%	21 Vol.%
Quartz	5	21	30	47	25	35	30	34
K-feldspar	4	--	28	--	10	54	50	60
Plagioclase	73(An_{29})	63(An_{30})	35(oligo)	53(An_{32})	56(An_{28})	4(An_{23})		4(An_{15})
Pyroxene	15	9	--	tr	--	--	--	--
Hornblende	--	--	--	--	--	--	5	1
Biotite	2	7	5	--	9	5	12	1
Opaques	1	1	2	--	--	1	3	--
	100	100	100	100	100	99	100	100

14.- Diorite. The pyroxene is hypersthene and augite in equal amounts.
15.- Quartz diorite. The pyroxene is hypersthene and augite in equal amounts.
16.- Granodiorite.
17.- Leuco-quartz diorite.
18.- Fine-grained, gneissic oligoclase granite. The potassic feldspar is mostly microcline.
19.- Fine-grained, gneissic microcline granite. The potassic feldspar is microcline and perthite.
20.- Coarse augen granite. South of Des Piles and Truite (No. 1) lakes. The potassic feldspar is microcline, microcline-perthite, and perthite.
21.- Granite pegmatite. The potassic feldspar is mostly microcline with some perthite.

E.- Morin series and Diabase

	22 Vol.%	23 Vol.%	24 Vol.%	25 Vol.%	26 Vol.%
Plagioclase	80(An_{50})	59(An_{48})	50(An_{51})	28(An_{43})	50(An_{42})
Hypersthene	15	21	13	15	4
Augite	5	12	--	27	10
Hornblende	--	--	23	7	15
Biotite	--	5	5	1	14
Opaques	--	3	3	22	7
Quartz	--	tr	5	--	--
K-feldspar	--	tr	--	--	--
Apatite	--	tr	1	--	--
	100	100	100	100	100

22.- Gabbroic anorthosite.
23.- Anorthositic gabbro.
24.- Altered anorthositic gabbro.
25.- Ilmenite-magnetite gabbro. High concentrations of ilmenite and magnetite are found at Grondin mine (see Table 3)
26.- Inclusions of gabbro in the anorthositic gabbro.

E.- Morin series and Diabase

	27 Vol.%	28 Vol.%	29 Vol.%	30 Vol.%	31 Vol.%	32 Vol.%
Quartz	tr	30	15	23	10	--
K-feldspar	tr	--	13	49	59	tr
Plagioclase	52(An_{37})	50(An_{40})	55(An_{34})	9 (An_{26})	10(oligo)	55
Hypersthene	5	tr		--	--	14
Augite	16	--	5	--	--	14
Hornblende	--	--	3	7	14	--
Biotite	19	15	3	8	4	9
Opaques	6	5	tr	3	--	8
Apatite	2	--	--	--	--	--
Chlorite	--	--	5	2	--	--
Accessories	--	--	1	--	3	--
	100	100	100	100	100	100

27.- Pyroxene diorite.
28.- Quartz diorite. Thin dykes cutting the anorthosite-gabbro complex.
29.- Pyroxene granodiorite. The pyroxene is hypersthene and augite and the potassic feldspar is microcline, microcline-perthite, and perthite.
30.- Pine Hill granite. The potassic feldspar is mostly microcline.
31.- Pine Hill hornblende granite. Near St-Tite. The potassic feldspar is microcline and perthite.
32.- Diabase dykes.

Table 2

Chemical Analyses (1)

A.- Amphibolites and paragneisses

	I	II	III	IV	V	VI	VII
	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %
SiO_2	55.70	59.59	49.06	70.55	64.10	55.80	51.20
TiO_2	.90	.77	1.36	1.80	.85	2.00	2.95
Al_2O_3	15.50	17.31	15.70	13.83	17.50	16.48	16.08
Fe_2O_3	2.95	3.33	5.38	.88	.72	.67	.90
FeO	6.14	3.13	6.37	8.38	7.91	5.95	11.26
MnO	.05	.18	.31	.05	nil	tr	.08
MgO	5.21	2.75	6.17	1.30	1.50	4.31	5.96
CaO	6.90	5.80	8.95	1.00	1.60	4.30	1.60
Na_2O	3.43	3.58	3.11	.42	1.22	3.71	.96
K_2O	1.78	2.04	1.52	1.32	3.49	5.66	6.90
H_2O - 105°C	.30	1.26	1.62	nil	.30	.30	.40
H_2O + 105°C	.60			.60	.85	.70	1.50
CO_2	nil	--	--	nil	nil	nil	nil
P_2O_5	.35	.26	.45	tr	tr	.15	.10
	99.81	100.00	100.00	100.13	100.04	100.03	99.89

I.- Specimen No. 2.- Amphibolite. W.H. Herdsman, analyst.
II.- Daly's average of 87 andesites.
III.- Daly's average of 198 basalts
IV.- Specimen No. 38.- Sillimanite gneiss with very little injected pegmatitic material. W.H. Herdsman, analyst.

(1) Reproduced from Osborne (1936) p. 206 and p. 213.

V.- Specimen No. 35.- Sillimanite gneiss with injections of pegmatitic material. W.H. Herdsman, analyst.

VI.- Specimen No. 115.- Biotite hornfels. W.H. Herdsman, analyst.

VII.- Specimen No. 110.- Schliere in granulite. W.H. Herdsman, analyst.

Table 2 (cont'd.)

B.- Granite gneiss, gabbro, and pyroxene granodiorite (granulite)

	VIII	IX	X	XI	XII	XIII
	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %	Wt. %
SiO_2	72.40	71.69	46.70	66.50	65.40	68.65
TiO_2	.30	-	2.60	.82	.75	.45
Al_2O_3	14.03	14.84	17.85	14.24	15.66	15.47
Fe_2O_3	.26	-	4.54	.93	.62	.40
FeO	2.14	1.25	8.85	4.28	4.19	2.79
MnO	nil	tr	.18	tr	.08	nil
MgO	.18	.37	4.16	1.23	1.26	.36
CaO	1.20	1.03	8.95	3.60	3.10	3.00
Na_2O	2.63	3.13	2.96	2.68	2.86	2.49
K_2O	6.32	7.09	1.06	4.22	4.87	5.31
H_2O - 105°C	.10	.10	.10	.20	.10	.05
H_2O + 105°C	.40	.49	.25	.80	.90	.90
CO_2	nil	-	nil	nil	nil	nil
P_2O_5	.14	-	1.54	.42	.30	.13
	100.10	99.99	99.74	99.92	100.09	100.00

VIII.- Specimen No. 9.- Red granite gneiss, W.H. Herdsman analyst.

IX.- "Granitite gneiss", Kipawa Lake, Pontiac County, Quebec. (Geol. Sur. Can., Ann. Rpt. 9, pt.R, 1898, p. 18).

X.- Specimen No. 144.- Border facies of gabbro. W.H. Herdsman analyst.

XI.- Specimen No. 81.- Granulite with red feldspar augen. W.H. Herdsman, analyst.

XII.- Specimen No. 83.- (Same locality as No. 81) - Granulite with green feldspar augen. W.H. Herdsman, analyst.

XIII.- Specimen No. 132.- Granulite with garnets. W.H. Herdsman, analyst.

Table 3

Analyses of ilmenite-magnetite ore of Grondin mine

	1	2
	Wt.%	Wt.%
Ilmenite	9	23
Magnetite	16	36
Silicates	75	41
	100	100
magn./ilmen. ratio	1.8	1.6
TiO_2	5	12
Fe	14	36

1.- Lean gabbro. Modal analysis is average of 4 recalculated chemical analyses.

2.- Ore. Modal analysis is average of 7 recalculated chemical analyses. Small amounts of hematite and pyrite have been neglected.

Table 4

Chemical analyses of bog and lake iron ores

	1	2
	Wt.%	Wt.%
Fe_2O_3	60.74	70.04
MnO	1.18	1.78
Al_2O_3	2.59	2.20
CO_2	3.47	0.32
MgO	0.93	0.27
P_2O_5	0.64	0.76
SO_2	0.19	0.23
SiO_2	13.94	7.84
Loss on ignition	16.49	16.34
	100.22	99.78
Fe	42.52	49.05
P	0.30	0.33
S	0.08	0.09

1.- Bog ore. Radnor field. J.T. Donald, analyst.

2.- Lake ore. Tortue lake. J.T. Donald, analyst.

REFERENCES

BELANGER, M. (1952) Quelques aspects de la morphologie des terrains supérieurs des basses terres du St-Laurent. An. Can. Franc. Adv. Sci., 1952, (abstract).

BUDDINGTON, A.F. (1939) Adirondack igneous rocks and their metamorphism. Geol. Soc. Am., Mem. 7.

CLARK, T.H. (1956) Oil and Gas in the St. Lawrence Lowland of Quebec. Can. Inst. Min. and Met., Trans., Vol. LIX; pp. 278-282.

CROSBY, I.B. (1932) Drainage changes and their causes in the St. Maurice valley, Quebec. Jour. Geol., vol. 40, pp. 140-153.

DAWSON, Sir J.W. (1893) The Canadian Ice Age. Montreal.

DULIEUX, P.E. (1913) Les minerais de fer de la Province de Québec. Rapp. du Serv. des Mines, Québec, 1915, pp. 96-101.

ELLS, R.W. (1898) Geology of the Three Rivers Sheet. Geol. Surv. Canada, Ann. Rept., pt. J., vol. XI.

FAESSLER, C. (1948) L'extension maximum de la mer Champlain au nord du St-Laurent, de Trois-Rivières à Moisie. Rapp. de la Soc. Provancher d'Histoire Naturelle du Canada, 1947.

LUNDE, M. (1951) Geology of the Grondines Map-Area, Precambrian Section. In Clark, T.H., and Lunde, M., Que. Dep't. Mines, P.R. No. 237.

OSBORNE, F.F. (1933) Some Commercial Granites of Quebec. Que. Bur. Mines, Ann. Rept., 1932, Pt. E.

OSBORNE, F.F. (1936) Petrology of the Shawinigan Falls District. Geol. Soc. Am. Bull., vol. 47, pp. 197-228.

OSBORNE, F.F. and LOWTHER, C.K. (1936) Petrotectonics at Shawinigan Falls, Quebec, Geol. Soc. Am. Bull, vol. 47, pp. 1343-1370.

OSBORNE, F.F. (1950) Ventifacts at Mont Carmel, Quebec. Roy. Soc. Canada Trans., vol. XLIV, sect. IV, pp. 41-49.

OSBORNE, F.F. (1951) Parc des Laurentides Ice Cap and the Quebec Sea. Naturaliste Canadien, 78, pp. 221-251.

WADDINGTON, G.W. (1942) Report on a magnetite deposit in the parish of St. Boniface, Quebec. (MSS.Que.Dep. Natural Resources).

WILSON, N.L. (1939) An investigation of the metamorphism of the Orijarvi type with special reference to the Zn-Pb deposit at Montauban-les-Mines, Quebec. Ph. D. thesis, McGill University, Montreal.

ALPHABETICAL INDEX