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BÉRARD LAKE AREA

NEW QUEBEC

by

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of

BÉRARD LAKE AREA[x]

NEW QUEBEC

by

Jean Bérard

INTRODUCTION

General

The Bérard Lake area, covering approximately 960 square miles of the northern part of the Labrador Trough or Geosyncline, lies some 70 miles west of Fort Chimo. It includes three areas, mapped progressively from south to north by the writer in 1956, 1957, and 1958. They are as follows: the Bones Lake area (longitudes 70°00' - 70°15' and latitudes 58°00' - 58°15': now, Garigùe lake); the Finger Lake area (longitudes 70°00' - 70°15' and latitudes 58°15' - 58°30': now, Bérard lake); and the Leaf Lake area (longitudes 69°45' - 70°15' and latitudes 58°30' - 59°00': now, Feuilles lake). The first and second areas are combined in one map for purposes of this report, the second, or middle, area giving its name to the combined study.

The area straddles the unconformable contact between the Proterozoic rocks of the Labrador Geosyncline and the granitic rocks of the Archean basement. The geosynclinal rocks consist of various sedimentary types, overlain locally by lava flows, with gabbro sills common throughout.

Near the contact, the rocks are flat-lying or nearly so. This is particularly true in the southern part of the area. Towards the east, away from the contact, the dips steepen and folds, overturned to the west, become abundant.

[x]Translated from the French.

Some formations seem to disappear northward, either as a result of non-deposition or of having been cut out by thrust faults. In this report, an attempt is made to solve this problem, and also to establish a geochemical balance between the sedimentary and metasedimentary rocks that possibly could permit correlations between them.

The topography of the Geosyncline differs greatly from that of the Archean basement. The latter is characterized by a gently rolling surface and an irregular drainage pattern, controlled by joints and faults. The Trough, on the other hand, has a very irregular topography. In places, series of hills and valleys, elongated north-south, correspond strictly to underlying hard and soft rocks. Elsewhere, there are mesas, hogbacks, overturned synclines, and many other topographic irregularities of structural or glacial origin. Drainage is to the north, along deep valleys.

Means of Access and Communication

The area is most easily reached by float-plane in summer and by ski-plane in winter. The nearest air-base is at Fort Chimo, which is linked by scheduled flights to Montreal. Fenimore Iron Mines Ltd. started construction of an air-strip south of Feuilles (Leaf) lake in 1954, but did not complete it. Strong winds and high tides make landing and unloading planes quite hazardous on Feuilles lake.

In summer, the area can be quite easily reached in two days by fishing boat from Fort Chimo, via Ungava and Feuilles bays. Feuilles bay can be entered only at high tide; ebb tide causes currents of up to 15 miles an hour at the entrance.

A chain of lakes and rivers extends from north to south through the area. This makes it possible to travel from Feuilles bay to Kaniapiskau river, a distance of 85 miles. Feuilles bay itself may be used by large boats, with the aid of depth charts provided by the Federal Department of Mines and Technical Surveys.

In winter, one may travel freely over the frozen lakes, and even journey to Fort Chimo by dog-sled, snowmobile or tractor. The overland route to Fort Chimo is not practicable in summer, owing to the north-south trend of the lakes. Feuilles lake freezes over irregularly, the ice being continually broken by the tides.

Previous Work

At the end of the last century, A.P. Low (1895), of the Geological Survey of Canada, explored the major rivers of northern Quebec. In 1893, he reached Ungava bay by way of the Kaniapiskau and Koksoak rivers. At that time, he recognized the limits of the "Cambrian" (Proterozoic) formations, and noted iron-bearing rocks, as well as sulphides, among them. In 1896, Low crossed New Quebec from Hudson bay to Ungava bay, by way of Richmond gulf, Eau-Claire lake, Seal lake, and Larch and Koksoak rivers.

The discovery of iron deposits in the southern part of New Quebec drew attention to the whole contact zone on the west side of the Labrador Geosyncline. Between 1945 and 1958, many companies did exploration work and diamond drilling in the Geosyncline. In the present area, Fenimore Iron Mines Ltd. (Consolidated Fenimore Iron Mines Ltd. after January, 1955) took out a mineral exploration license in October, 1947, and delimited important reserves of beneficiating iron ore.

Field Work

The base-maps for the present work were on a scale of 2 inches to the mile and were prepared from aerial photographs. Some field information, such as that on the trend of faults and joints, as well as on lithology and glacial features, was indicated on acetate paper which was placed directly over the photographs. Pace-and-compass traverses were not necessary, because of the ease of locating oneself geographically by use of the photographs. The sparse vegetation made it possible to examine almost all the exposures of rock, which cover about 20% of the area.

Acknowledgments

During the preparation of the present work, which formed the basis for a doctorate thesis, the author received help, very freely and kindly, from many people. Among them, the following must be particularly mentioned:

Dr. F.F. Osborne, thesis director, for many suggestions and untiring aid during the last two years of laboratory studies; Drs. Horace Winchell and Matt Walton, both of Yale University, for many X-ray identifications, and advice on problems of petrology.

During the three seasons of field work, the author was assisted by geologists George Beall and T. Hashimoto, graduate students at McGill University, and P.J. Clarke, graduate student at Queen's University.

Assistance was also rendered by students David Elliott of McGill, Adrien Bisson, Clement Desroches and Achille Leblanc of Université Laval, and Antoine Gagnon and Denis Lalonde of Université de Montréal.

Consolidated Fenimore Iron Mines Ltd. very kindly permitted the use of its camps at Garigue and Feuilles lakes.

Geographic Names

Following is a list of names of some lakes and rivers that have been changed recently by the Quebec Geographical Commission.

Former Name	Present Name
Finger lake	Bérard lake
Bones "	Garigue "
Strain "	Merchère "
Ali "	Gourdon "
Four Bears "	Quatre Ours "
Pig "	Chaperon "
Laura "	Dusay "
Fishhook "	Hameçon "
Larik "	Laric "
Leaf "	Feuilles "
Chioak river	Bérard river
Mannik "	Mannic "
Quel lake	Couteau lake

DESCRIPTION OF THE AREA

Climate

An annual climatic survey, made in 1944-45 by the Canadian Department of Meteorology, gave the following results for the Fort Chimo area:

Table I

(Temp., F.)

Month	Maximal Average	Minimal Average	General Average	Maximum	Minimum
Jan.	-5.0	-20.8	-12.9	35	-50
Feb.	-2.4	-21.1	-11.8	38	-46
Mar.	12.8	- 6.4	3.2	46	-43
Apr.	25.7	6.8	16.2	51	-28
May	40.1	24.7	32.4	88	-2
June	54.5	35.2	44.8	87	18
July	62.8	42.5	52.6	90	29
Aug.	59.2	41.8	50.5	83	29
Sept.	48.3	35.3	41.8	72	23
Oct.	36.5	26.4	31.4	64	5
Nov.	23.6	10.6	17.1	46	-27
Dec.	7.8	7.5	0.2	40	-41

As can be seen from the table, the weather in the area is not particularly severe, and can be compared with that of many Canadian towns. The spring and fall seasons, however, are very short, lasting only a few weeks.

During the summers of 1956 and 1957, July and August were very warm, the maximum temperature being 87° and the minimum 40°. The summer of 1958 was colder and there were brief falls of snow every month.

The lakes are usually free of ice in early July. Owing to strong currents, however, Bérard (Finger), Garigue (Bones) and Merchère (Strain) lakes are open earlier, the north end of Bérard lake normally being free of ice by about June 20th.

The humidity varies widely, particularly in spring and summer. In winter, the vapour pressure drops to zero, owing to low temperatures, but it rises to more than 0.250 inches in summer, thus becoming equivalent to the humidity at Montreal in the months of May and October. Table II gives the vapour pressure, in inches of mercury, for five different localities.

Table II

Month	Montreal	Lake Saint-Jean	Schefferville	Fort Chimo	Frobisher
Jan.	0.050	0.025	0.000	0.000	0.000
April	0.150	0.125	0.100	0.075	0.075
July	0.525	0.425	0.375	0.250	0.175
Oct.	0.240	0.215	0.175	0.150	0.100

The Fort Chimo area has a yearly precipitation which is about half that of the Quebec City region. In summer, the rainfall at Fort Chimo is 1/3 that at Quebec; in the winter, the snowfall is 3/5 that of Quebec. The yearly precipitation of some 15 inches in the Feuilles Bay area permits the consideration of its climate as semi-arid.

The dominant winds are from the east or west in winter, and from the south and southwest in summer.

In summary, the summer (mid-June to mid-September) climate favours health and outdoor work; flies, however, must be reckoned with.

Inhabitants

The only settlement of any importance in the region is Fort Chimo, 70 miles east of the map-area. Many Eskimo families live here, as well as a number of government and company employees. Some Eskimo families lived south of Feuilles lake through the years 1956 to 1958.

Flora

The area, owing to its north-south elongation, straddles two phytogeographic provinces, namely, the forest tundra and the Arctic barrens. The first appears in the sand- and clay-covered floors of the main valleys south of Feuilles bay; the second in many valleys, on the summits of hills, and north of Feuilles lake.

South of Gourdon lake, in the central valley, birch is common and there is some black spruce. These trees are somewhat stunted, being rarely more than 20 feet tall, although their trunk diameters commonly exceed 12 inches. Growth rings are very thin, and the ages of the trees range up to at least 250 years. Exploitation of this lumber is possible only on a small scale. The five Fenimore camps at Garigue lake, for example, were built of local logs.

Vegetation is widespread, the hills being covered with moss and lichen. Shrubs, including some with magnificent iridescent flowers, are present in great variety. The valleys, and the slopes in lee of the wind, or facing the sun, are covered with dwarfed deciduous trees, such as birch, maple and poplar. In the autumn, the Eskimos gather the many varieties of berries which grow in the region. The blueberry, however, is the only type to grow in any abundance.

Fauna

Feuilles lake, with its strong tides and currents, and its fresh or brackish water, is a favourite place for the fisherman or hunter. Seals and white whales abound, particularly at rising tide. Seals go up such rivers as the Bérard (Chioak) Feuilles, and Harveng. Feuilles lake also contains abundant fish, including cod, salmon, char, herring, pike, sturgeon, whitefish and trout. There are at least 44 species of fish, belonging to 21 families, in Ungava bay and the adjacent lakes. Of these, there are 29 marine species, 2 species that go up-river to spawn, and 13 fresh-water species (Dunbar and Hildebrand, 1952).

All of the rivers and fresh-water lakes contain a superabundance of a few species of fish. This is what has made Bérard lake one of the favourite places for fresh-water fishermen in Quebec.

Game is rare in the area, owing to the systematic hunting carried out by the Indians of Fort McKenzie, to the south, and the Eskimos near the coast. During our three summers in the area, however, we saw bear, caribou, lynx, fox, hare, muskrat, lamming, moles, ptarmigan, sparrow-hawks, snowy owls, sea-gulls, Canada geese, and several species of duck. During the summer, thousands of migratory birds nest on the islands of Feuilles lake.

Topography

The general topography of the Labrador Geosyncline and its environs, as described above, applies to the present area. The coexistence of two major topographic types has been noted. One, that of the Archean basement, is characterized by gentle relief, concordance of rounded summit levels, a rectangular drainage system, and the absence of secondary structure and its accompanying pattern on the erosion surface.

The elevation of the surface of the basement rocks ranges between 700 and 1,250 feet above sea-level. All of the summits are rounded, and, as observed from any of the peaks, a mountainous plain extends as far as the eye can see, broken here and there by hills which also have concordant summit levels.

The topography of the Labrador Geosyncline, controlled as it is by structure and by lithology, cannot be reduced to a single type. The strike of the rocks is north, and the dip is gently to the east.

South of Feuilles lake, the valley containing lakes Bérard, Garigue and Merchère is underlain by friable sedimentary rocks. This major valley is the deepest in the region, and drains an area as far up as Larch river. Fifty miles up this valley, the level of the plain barely exceeds 250 feet. This valley is preglacial and served a vast hydrographic network before the glaciers disorganized the drainage.

West of this central valley are mesas, or plateaus, made up of horizontal bands of dolomite or of conglomerate with siliceous cement. The irregular surfaces of the dolomite hills are particularly remarkable.

East of the valley, and north of Feuilles lake, the country is very different. The surface is marked by straight, narrow gabbro hills, aligned parallel to one another. Adjacent to each of the hills is a valley which is underlain by friable sedimentary rocks.

The southern border of Feuilles lake lacks relief, except for some small "islands" of rock that rise above the plain like giant ships.

Hydrography

All the waters of the area drain to Feuilles lake, with fairly large rivers entering each lobe of the lake. The most important are Feuilles, Bérard (Chioak), Harveng, Boyer, Mannic, and Fanfan rivers.

Feuilles river has its source at Minto lake and traverses the northern part of Ungava peninsula for about 170 miles. Near its mouth, the river flows through a 1 1/2-mile-wide canyon, the walls of which rise to about 900 feet where the river cuts the basement complex. The current of the river is very strong and has great carrying power. Tidal action, however, forces it to drop its load of sediment at its mouth, and, at low tide, the river must work its way outward through its own alluvium. It should be noted that spring tides rise as much as 55 feet in Feuilles lake, and that the waters of the rivers are forced back many miles by such tides. Low tides reach 35 feet.

Bérard river drains the central valley. The steep slope between Bérard and Feuilles lakes creates a fast current in this river and, therefore, a heavy discharge. It owes its relatively stable volume to numerous glacial lakes and to the fairly dense vegetation on the flanks of Garigue and Merchère lakes.

Harveng river, which drains into the very large Gerido lake, is really active only when the snow is melting. The reason is that the amount of ground that is free from permafrost within the area drained by the river is very small.

In addition to the main drainage arteries, other rivers run the length of the border zone of the Geosyncline. Although small, these rivers have dissected the rocks and have cut deep valleys near the contact. The result is that the streams that cross the granitic mass and flow into the contact valley are actually in hanging valleys. Falls thus result, some of which are spectacular, as, for example, to the west of Quatre Ours lake.

The drainage on the Archean base is typical of the Canadian Shield. It is in trellis or rectangular patterns, owing to joint systems, shear zones, and gneissic structure.

Lakes, of which there are hundreds of all sizes, cover almost a quarter of the area. Some do not have any drainage, and dry up during the summer; others drain underground.

Physiographic Origins

The long period of erosion that followed the uplift of the Labrador Geosyncline witnessed the wearing down of these rocks to their roots. A very regular drainage system was established, due to differential erosion of several kinds of rocks. Valleys were cut through either friable or soluble rocks, depending upon the predominant type of erosion.

Long before the Pleistocene, the valley of Garigue and Bérard lakes formed the principal drainage trough for waters flowing into Ungava bay. Feuilles river, as well as some streams that empty into the Garigue-Bérard valley, also probably had a preglacial origin. Other valleys, which are now wind gaps, are witness to the existence of an old drainage system parallel to the regional texture.

The Pleistocene ice did not deepen the valleys to any extent. On the contrary, it filled them with debris, as a consequence of moving across the regional structure, and so cut the principal arteries of the earlier drainage system. The new drainage, acting during the thousands of years since the end of continental and alpine glaciation, has not yet succeeded in clearing out the old valleys.

Many V-shaped valleys, some of considerable depth, cut across the geosynclinal border. Some of these may be preglacial, but it is likely that most were carved out more recently, and by torrential action.

GENERAL GEOLOGY

Summary

The Bérard lake area straddles the contact between Archean granitic gneisses and a Proterozoic sedimentary-volcanic sequence intruded by gabbro sills. Near the contact, the Proterozoic rocks are nearly flat-lying, but the dips steepen to the east to form a vast monocline. North of Bérard lake, the sedimentary rocks near the contact have a steeper dip. The significance of this structure will be discussed later in this report.

The stratigraphic sequence is well shown in magnificent, and almost complete, sections. Impure quartzite forms the base, and is followed upward by thin chlorite schists, the Fenimore iron-bearing formation, the Dragon and Chioak formations, the Abner dolomite, the Larch River formation, the lavas and pyroclastic rocks of the Hellancourt formation and, finally, the metamorphic rocks. The intrusion of gabbro sills was the last major geological event prior to regional deformation.

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ARCHEAN ROCKS

General

To the south, the Archean basement rocks occupy a narrow band at the western edge of the present map-area. This band widens near the southern boundary, and then extends, to the north, well within the area. North of Bérard lake, a long fault separates the sedimentary rocks from the basement rocks. Here, the basement rocks have been raised so as to form a huge ridge across the geosyncline. This spur of rock gives Bérard lake its distinctive shape. North of the major fault, the Archean rocks underlie approximately 2/5 of the area mapped. Near Monique lake, another spur of granitic gneiss cuts across the geosyncline for more than 5 miles.

Immediately north of the middle arm of Bérard lake, a window, 2,000 by 1,000 feet in size, exposes the Archean base in the middle of the geosyncline. Some geologists have interpreted similar phenomena as being granitic stocks cutting the sedimentary series. In the present case, however, it is obvious that a part of the basement on which sediments accumulated has been exposed by erosion. Large fractures in the granite mound are filled with quartzite, joints are soldered with dolomite, and unaltered sedimentary rocks are in direct contact with the granite. The dips in the sedimentary rocks immediately surrounding the granite mound outline an asymmetrical conical structure.

South of Merchère lake, the basement gradually loses its thin cover. Here, the sedimentary rocks are almost flat-lying, and their erosion has resulted in an indented contact.

It would be difficult to have a true picture of the geology of the basement without making a detailed study of a large area. The rocks vary greatly, and the various types might belong to one intrusive body, to migmatites, or to inclusions. As most of the varieties were found in the south, the rocks there, despite their restricted occurrence, were given the most attention. Because of this restricted occurrence and the complexity of the problems raised, these rocks can be described only briefly and incompletely. Any petrographic classification, therefore, must be made in only a general way.

The rocks north of Bérard lake appear to belong to a uniform stock covering an area of 250 square miles, or 2/5 of the total area. The granitic gneiss to the south underlies only 35 square miles, or 1/9 of the total area.

The three most common rock types, beginning with the oldest, are: (1) biotite-hornblende gneiss; (2) granodiorite; and (3) pink granite. These rocks are cut by dykes of diabase, pegmatite and aplite.

The gneissosity of these rocks varies greatly, even over short distances, and we have not recorded any preferred orientation for the gneissic rocks as a whole. Nevertheless, the gneissosity of much of the biotite-hornblende gneiss trends north, whereas the weak lineation in much of the granodiorite trends east.

The rocks that are believed to be the oldest in the gneissic complex are grouped together in this report, and age relationships within this group are not discussed. The term "ancient gneiss" includes all the rocks cut by granodiorite or occurring as inclusions.

Ancient Gneiss

Under this title we have included rocks that perhaps belong to different classes and have had special origins, but which also have certain common characteristics. It is difficult to distinguish the very old rocks from those that have been cut by, and enveloped in, younger types.

We have divided the Ancient Gneiss into three principal groups: (1) biotite-actinolite gneiss; (2) biotite-hornblende-plagioclase gneiss; and (3) hornblende-plagioclase gneiss. The second group may be simply a dioritic facies of the granodiorite, but, as relative ages could not be assigned in the field to any of these rocks, all are considered to be integral parts of the Ancient Gneiss.

The biotite-actinolite gneiss is represented only by some small sub-circular masses about 4 miles west of Merchère lake. As this rock breaks down readily under extreme weather conditions, it is generally found, covered with debris, at the bottom of depressions.

The large amount of emerald-green actinolite in the rock gives it its characteristic green colour, and biotite flakes, 2 mm. or more in diameter, give the rock a very scintillating appearance. Quartz, plagioclase and other minerals are also present.

The hornblende-plagioclase gneiss commonly occurs as inclusions in the granodiorite. These inclusions are either isolated and angular and of all dimensions from a few inches to nearly 1,000 feet in diameter, or they are rounded and elongated and partly digested by the enclosing rock. They may be so numerous, as is the case west of Garigue lake, that the rock resembles a veritable intrusive breccia.

North of Bérard lake, the enallogenic inclusions (those similar in appearance to the enclosing rocks) are rare, particularly in the porphyritic granodiorites. At a distance from the shores of Feuilles river, angular inclusions of hornblende-plagioclase gneiss (or amphibolite) contrast strongly with the much lighter-coloured granodiorites. In places where the inclusions reach diameters of some hundreds of feet this contrast may be seen on aerial photographs.

The inclusions, whether classed as gneiss or as amphibolite, constitute a very small part of the basement (Ancient Gneiss). Their contacts with the enclosing rocks are sharp, except for rare nebulous trails of ferromagnesian minerals in the latter.

The rock is black and medium-grained. Hornblende crystals more than 3 mm. long are not rare. Plagioclase crystals are smaller and are masked by hornblende. A petrographic analysis of a representative sample gave the following results:

Hornblende	60%	Microcline	1%
Plagioclase (An_5)	30%	Pyrite	1%
Quartz	4%	Sphene	0.5%
Chlorite	3%	Apatite	tr.
		Zircon	tr.

The rock derives its colour from the ebony-black hornblende. Under the microscope, in natural light, this mineral has a very strong pleochroism, corresponding to the following: Z - yellow; X - dark green; and Y - greenish yellow. The optical angle, 2V, is about 60°. The mineral is more clearly subautomorphic than the plagioclase. It contains idiomorphic inclusions of apatite, chlorite, sphene, and pyrite, as well as globular inclusions of quartz and plagioclase. The maximum size of the crystals is 2 mm., and their average size is 0.5 mm.

The plagioclase is altered to sericite and, in some cases, to epidote, depending on the type of metamorphism and metasomatism that it experienced. Its structure is automorphic, and it contains many inclusions, particularly of quartz, microcline, apatite and sphene.

The microcline is, in places, more abundant than the petrographic analysis given above would indicate. It is interstitial between the hornblende and plagioclase, and seems to fill the irregular spaces that separate these minerals. It contains inclusions of plagioclase, quartz, sphene, and zircon. Quartz is also interstitial between the main constituents of the rock.

It is possible that the elongated crystals of chlorite resulted from the alteration of biotite, rather than of hornblende. They are found as abundantly in the feldspars as in the hornblende itself.

The biotite-hornblende-plagioclase gneiss is another type of Ancient Gneiss that could be called a dioritic gneiss. In contrast to the hornblende-plagioclase gneiss, which is represented mainly by inclusions, this rock seems to form larger masses that are themselves cut by granodiorite. This gneiss is composed essentially of hornblende, with some plagioclase and a little biotite.

A petrographic analysis of a typical sample gave the following results:

Plagioclase (An_{28})	65%	Chlorite	1%
Hornblende	15%	Muscovite	1%
Biotite	5%	Pyrite	tr.
Quartz	5%	Calcite	tr.
Microcline	5%	Epidote	tr.
Apatite	1.5%	Sphene	tr.

The biotite-hornblende-plagioclase gneiss is holocrystalline in texture. The weathered surface displays black spots on a pale grey or greenish grey base. The colours on the fresh surface are the same, though cleaner and sharper. Hornblende is reponsible for the black spots, and plagioclase altered to sericite or epidote gives the rock its grey and green tints.

The texture is allotriomorphic almost throughout, although some thin-sections show a clearly automorphic texture in hornblende at the expense of plagioclase altered to epidote. Veinlets of pink granite are abundant, all parallel to the gneissosity. Gneissic boudinage also occurs, accompanied by lit-par-lit injections of granodioritic material.

The plagioclase of the fresh rock is oligoclase (An_{28}). It is generally altered to sericite, and contains inclusions of quartz, microcline and, more rarely, of biotite, iron oxides and chlorite. The latter minerals result from the disintegration of hornblende. Myrmekitic texture is fairly common in oligoclase crystals, where the exsolution of quartz has formed minute globules.

Red microcline, distributed sparsely throughout the rock, amounts to about 5%. As seen in thin-section, it fills voids between plagioclase and hornblende crystals and contains inclusions of quartz, apatite and sphene.

Hornblende is dark green in thin-section, and contains inclusions of quartz, biotite and iron oxides. It is rarely twinned. Much of the biotite is altered to chlorite.

The biotite-hornblende-plagioclase gneiss is more common than the hornblende-plagioclase gneiss, and constitutes about 10% of the basement rocks.

Granodiorite

As already mentioned, the granodiorite cuts the Ancient Gneiss and, in places, produces intrusive breccias. When in large bodies, it is very crystalline and devoid of any apparent structure. However, where injected lit-par-lit into the Ancient Gneiss, it is gneissic. Moreover, a porphyritic variety shows a poorly developed lineation. This is best seen west of Bérard river and north of Feuilles river, where large crystals of microcline are elongated east-west.

The colour of the granodiorite varies from very pale grey to greenish grey, pinkish grey and pink. Each one of almost seventy samples of this rock is different in colour and texture from the others, reflecting differences in composition, grain size, etc.

The principal primary minerals are plagioclase (25-65%), microcline (10-23%), quartz (15-45%), biotite (10-20%), apatite, magnetite, zircon and sphene. The secondary minerals are alteration products of ferromagnesian minerals and plagioclases. The most common are chlorite, calcite, iron oxides, leucoxene, limonite, epidote, muscovite, clay minerals, and pyrite.

Granular texture is common. The rock is generally coarse-grained and, as seen in thin-section, without any preferred orientation. Certain facies are clearly pegmatitic; others are aplitic.

Microfaults are numerous in the granodiorite near the contact with the overlying rocks, particularly where prominent faults are associated with this contact. Quartz grains, showing wavy extinction under the microscope, are present throughout the rock.

The most common granodiorite is pale grey. It contains, apart from quartz, a pale grey and rather dull plagioclase, crystals of biotite, and a small amount of pink microcline. Some specimens contain as much as 20% ferromagnesians, but 5-10% combined biotite, hornblende and chlorite is more usual. Hornblende, if not absent entirely, usually makes up only a small percentage of the rock. Near giant inclusions, however, there may be as much as 10% hornblende. Perhaps the reason for the presence of hornblende in the granodiorite may be found here. In the writer's view, the mineral resulted from the assimilation of amphibolitic inclusions by the granodiorite. The hornblende is generally altered to pennine, a variety of chlorite. Where fresh, however, it is dark green in natural light, and strongly pleochroic.

Much of the plagioclase is altered to sericite, calcite and quartz. Fresh specimens show the exsolution of microcline along fractures and around grains. Inclusions of microcline, quartz, biotite, and zircon were noted. Microcline, quartz, and flakes of biotite and muscovite fill interstices between the plagioclase grains.

North of Bérard lake, a porphyritic rock, made up mainly of white plagioclase and of chlorite, was observed in many places. The plagioclase crystals average 5 mm. in diameter, and constitute about 90% of the rock, the rest being made up of microcline and accessory minerals. This rock seems to be intimately associated with crushed zones, where recrystallization of the deformed granodiorite has apparently taken place. Chlorite surrounds virtually all of the crystals, but is seldom found as inclusions within them. Near the porphyry, the granodiorite is fractured and the plagioclases altered to epidote. The fractures are filled with epidote or quartz, and are elongated sub-parallel to the faults that were observed in the area.

Near Phoques river, 85% of the basement rocks are granodiorite porphyry, 13% amphibolite and 2% diorite or digested amphibolite. The porphyry is generally massive and coarse-grained. In some facies, where a dragging out of the rock has occurred, an augen structure has developed. In general, the rock is composed of pink, Carlsbad-twinned microcline crystals, 1-10 cm. long, dispersed through a granitic matrix of pale green plagioclase, quartz, and a small amount of biotite and hornblende. Where the porphyry is gneissic, an apparent flow structure is associated with the rounded inclusions of amphibolite. Here, all lineations trend close to S.45°E.

Quartz, pegmatite and aplite veins, striking S.45°E., cut the porphyry. Some of the pegmatite is composed of Carlsbad-twinned potassic feldspars, a foot or more long.

Pink Granite

The pink granite is apparently the youngest intrusive of any importance in the basement rocks. It is common in the southwestern part of the area, in the form of lit-par-lit injections in the Ancient Gneiss. Dykes of this granite cut all the basement rocks, and form elongated ridges; one, at least 50 feet wide, could be followed for about 500 feet.

This granite is almost identical with the granodiorite, except that its colour is red or pink. It does not appear to possess any major internal structure. However, some stretching (boudinage structure) can be seen in the enclosing gneissic rocks. The rock is generally quite coarsely granular. It consists mainly of quartz and pink or red microcline. Chlorite and muscovite are present throughout most of the rock, although in very small amounts.

Microcline, characterized by its checkered polysynthetic twinning, makes up about 40% of the rock. It is in xenomorphic crystals around plagioclase, and contains such inclusions as quartz, biotite, chlorite, and mixed plagioclase and quartz.

The quartz, which makes up about 35% of the rock, is generally fractured and has a wavy extinction. Muscovite and biotite (or, more generally, chlorite derived from biotite) appear along the contacts between crystals of plagioclase, microcline and quartz.

The composition of the plagioclase seems to be about An_{15}, but it is ordinarily so altered that it is difficult to resolve the optical properties. Alteration products are sericite, calcite and clay minerals. The most common inclusions are microcline, biotite, zircon, apatite, and sericite.

The red colour of the granite is derived either from disseminated hematite in the altered plagioclase or from the colour of the microcline crystals. The hematite may be intimately associated with alteration products of plagioclase or may occupy fractures in grains of microcline and quartz. It originates either from the oxidation of primary sulphides or from the iron-bearing rocks that formerly covered this part of the basement.

Meta-diabase and Ultrabasic Dykes

The meta-diabase dykes that cut the granodiorite northwest of Bérard lake are actually amphibole-plagioclase gneisses. They differ from Ancient Gneisses of the same type only in occurrence,—they cut the granodiorite, whereas similar rocks in the Ancient Gneiss occur only as inclusions.

One of these meta-diabase dykes was traced for 1,500 feet. It is a few to 20 feet wide, and has very sharp contacts.

North of Canot lake, there are aplite dykes that have the same composition as the rocks they cut. One is 5 feet wide along its observed length of 300 feet.

A single ultrabasic dyke seen north of Bérard lake was followed for several hundreds of feet. The rock is medium-grained, dark green on the fresh surface, pale yellow or pale brown on the weathered surface, and strongly magnetic. It breaks down quite easily, and thus is marked topographically by a long depression.

The principal constituents are antigorite, dolomite, magnetite, and a ferromagnesian pyroxene which is apparently bronzite altered to bastite. The rock was originally a peridotite.

In thin-section, pseudomorphs of bastite replacing bronzite are disseminated in a matrix of tangled small crystals of pale green antigorite. Magnetite forms polygonal networks in the antigorite. These may well be vestiges of original olivine crystals.

PROTEROZOIC ROCKS

General

In the present work, the Proterozoic sedimentary rocks are separated into two groups: metamorphic and non-metamorphic. The latter rocks rarely display stratigraphic or structural complications, and can be divided into very distinct formations. They are easily traced in the field because they are almost continuously exposed and are only rarely interrupted by gabbro sills. The non-metamorphic rocks occur, for the most part, south of Feuilles lake and along the contact with the basement rocks north of the lake.

The metamorphic rocks include gneisses, schists, and other types, all of uncertain stratigraphic position. They are intruded by gabbro sills, and some of the altered rocks resemble hornfels. All are much more recrystallized than other rocks farther to the south which occupy an identical stratigraphic position and which have been classed with the non-metamorphic sedimentary group.

Some of the sedimentary formations, such as the Alison and Fenimore, seem to continue northward, although changed in appearance.

Sedimentary Rocks

Lower Dolomite

In the Larch River area to the south, near the base of the geosynclinal sequence, Auger (1954) and Owens (1955) described a fairly pure dolomite that grades into a dolomitic quartzite toward the base. The latter rock, in turn, rests on slate. This lower dolomite, although thin, seems to be persistent along the western contact of the geosyncline, south of Merchère lake. Here, the dolomite is the youngest geosynclinal formation exposed. It was seen in only three places, all south of the fault that cuts the geosynclinal and basement rocks west of the center of Merchère lake.

In the present area, the lower dolomite is pale to dark grey, buff, green or orange, weathering to green, buff or reddish orange. It lacks the trellis pattern of quartz veins that characterizes the Abner dolomite. It is best exposed about 300 feet west of Merchère lake. Here, the rocks are lightly folded and sheared, and the layers are separated by a graphitic substance resulting from the disintegration of dolomite along surfaces of deformation. The dolomite is in contact with the detrital rocks of the Chioak formation which contains fairly large lenses of the dolomite.

West of Merchère lake, a mass of orange-coloured dolomite rises sharply in the middle of a fault zone and is overlain by the Fenimore formation. As pebbles of the orange-coloured dolomite are present in the Chioak conglomerate, it is evident that this mass belongs to the lower dolomite formation and not to the Abner dolomite.

Alison Quartzite

General - This formation was named by Owens (1952) from the type section around Alison lake. The quartzite, although not exposed in many places, is believed to be present along almost the whole length of the western contact of the Labrador Geosyncline. In places, such as south of Merchère lake, it is hidden under marine conglomerates. In other places, it is cut out by thrust faults or has been eroded away.

The Alison quartzite is probably the equivalent of the Wishart quartzite, a rock described to the south by geologists of the Iron Ore Company of Canada.

Distribution and stratigraphic relations - In the region under study, the Alison quartzite is particularly well exposed around Alison lake, west of Merchère, Chioak, and Dusay lakes, north of Bérard lake, around Rouge bay, north of Arpenteurs bay and north of Chaperon bay. It is almost invariably accompanied by the Fenimore formation, which it immediately underlies. Except for the three occurrences of lower dolomite, this quartzite lies at the base of the Proterozoic sequence.

The thickness of the quartzite ranges from 40 to 150 feet. A 50-foot-thick section, measuring from the granitic gneiss basement to the base of the Fenimore formation, is seen west of Chioak lake. In places, lenses of shale up to a few feet thick alternate with bands of quartzite. Near Phoques river, 1- to 2-inch layers of shale alternate with beds of quartzite which are 1 foot to 4 feet thick. Some geologists have divided the shaly and sandy facies into separate formations. However, there is no apparent reason for such a separation in the present area.

Petrography - The Alison quartzite is hard and resistant to erosion. The colour ranges from black or dark green to pale grey or pale green. Grain size is commonly between 0.25 and 1 mm., but may be as much as 2 mm. The ratio between the two extremes in size is about 1; the writer places it at 9/10.

Near Alison lake, the quartzites are black, olive-green and pale grey. They have a total thickness of about 50 feet, in beds from 1 foot to 3 feet thick. The colour depends on the nature of the cement. In most places, secondary quartz encloses and cements the quartz grains. In some cases, however, the secondary quartz is accompanied by a border of such minerals as chlorite, magnetite, minnesotaite and stilpnomelane. The secondary silica preserves the crystal orientation of the grains it encloses (Plate I-B).

Green quartzites are common to the west of Chioak lake and near Bérard lake. The colour comes from chamosite, which makes up 20% of the rock in places. This mineral is generally in the form of slightly elongated ovoids, and is mixed with the quartz grains.

Around Fabien and Chaperon lakes, the quartzites are more metamorphosed and contain radiated amphiboles, such as grunerite and cummingtonite. The amphiboles are commonly amber yellow, and form rosettes, some of which are quite spectacular.

The following section was mapped north of Phoques river (approximate thicknesses in feet):

Top: Fenimore formation	Feet
Very dark, biotite-sericite schists	20
Dark green, massive quartzite	15
Dark green quartzite; cross-bedded or massive beds	20
Black quartzite and about 45% black shale	1
Dark green, massive quartzite, spotted with siderite	6
Black, shaly quartzite, with a greenish weathered surface; made up of quartzite (65%) and slate (35%)	7
Olive-green quartzite in massive 8- to 12-inch beds	20
Grey quartzite alternating with sheared quartzose slate; boudinage structure.	6
Slate and quartzite in laminated lentils	5
Olive-green and greenish brown quartzite, spotted with siderite crystals	15
Dark green, coarse-grained quartzite, spotted with siderite crystals	1
Olive-green quartzite, spotted with siderite crystals	3
Dark green, massive quartzite	5 - 10
Pale grey, glassy quartzite	10

Base: Masked by overburden, but near an outcrop of granitic gneiss.

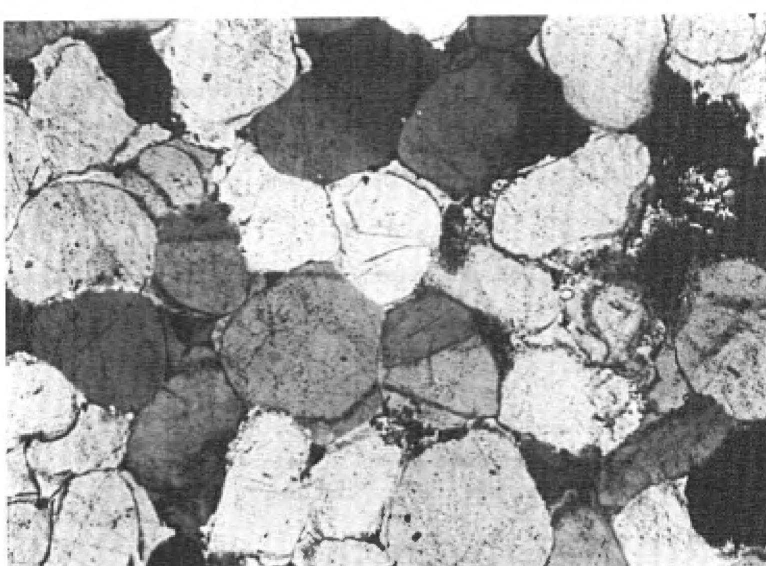
Some quartzites contain up to 5% microcline and traces of altered plagioclase. Except for some grains of chlorite and biotite, allogenic ferromagnesian minerals were not noted. In some specimens the following allogenic constituents are present: fragments of rocks, zircon, muscovite, chert, biotite, chlorite, apatite and shaly micro-grained masses resembling lapilli.

North of Phoques river, about 20 feet of cross-bedded quartzite (Plate I-A) lie in the midst of trapezoidal-shaped or wedge-shaped structures piled one upon another. A few of these structures are 5 to 6 feet long, although the average length is 2 feet.

Ripple-marks were seen in only one place. However, this could be due to the fact that most of the strata examined are in vertical sections, and bedding planes are rarely visible.

PLATE I

A.– Cross-bedding in the Alison quartzite.



B.– Photomicrograph of a specimen of the Alison quartzite from Alison lake. Note the roundness of the grains and the secondary quartz around the grains. The small black dots are magnetite. Crossed nicols, x 120.

The Alison quartzite, owing to its uniformity, massive character, thick beds and even grain, makes an excellent horizon marker. The variables are its colour, which is derived from the intergranular material, and its mineralogy.

In thin-section, the grey quartzite from near Alison lake is seen to be composed of 95% quartz, of which 75% is primary and is made up of original sand grains. These grains are coated with a thin layer of magnetite "dust". The cement is made up of secondary quartz, surrounding the original grains. Accessory minerals present in all sections are plagioclase, microcline, minnesotaite and muscovite.

The black quartzites near Alison lake contain about 10% combined magnetite and hematite, from which the colour is derived. They also contain some shaly material, which indicates a change in the environment of sedimentation.

Near Chioak lake, the quartzite carries abundant chamosite, both as ovoids and as interstitial material. Judging from X-ray and semi-quantitative spectrographic analyses, this variety of chlorite is close to $(Mg_{\frac{1}{4}}Fe)\ 4\ Al\ (Si_5Al)O_{10}(OH)_8$ in composition, giving the following percentages:

MgO	5.95%
FeO	42.30%
Al_2O_3	14.95%
SiO_2	26.35%
H_2O	9.45%

This formula approaches that given by J. Jakob (Table III) for a chamosite from Chamosentze (Déverin, 1945, p. 31); this is not typical, and is a variety with little colour and a low iron content.

The chamosite ovoids are microcrystalline and, under crossed nicols, appear as semi-opaque masses. In natural light, the chamosite is vegetable green when fresh, and brown when weathered. The ovoids accompany grains of quartz, microcline and chert, and have a sphericity with an axial ratio of about 3 to 5. The long axis rarely exceeds 0.3 mm.

TABLE III

Composition of the Chamosites

	J.H. Taylor (1949) Table II, p. 43	A.O. Hayes (1915) p. 59	Jakob, in Déverin (1945)p.31	C17-84 Dept. of Mines Laboratories, Quebec
SiO_2	27.8	22.28	30.07	26.35
Al_2O_3	17.4	25.46	17.26	15.95
FeO	18.5	37.41	37.61	42.30
Fe_2O_3	15.4	0.96	3.66	
MgO	1.8	3.12	1.69	5.95
H_2O+	12.1	10.25	9.01	9.45
H_2O-	4.3			
TiO_2	0.7		0.12	
CaO	0.3	.31		
MnO	trace	.21	0.02	
$(NaK)_2O$			0.60	
Totals	98.3	100.00	100.04	100.00

Some quartzite beds west of Chioak and Bérard lakes contain considerable stilpnomelane. This mineral resembles biotite on fresh surfaces. In thin-section, it is brown and strongly pleochroic; it differs from biotite in that it lacks an uneven surface in the extinction position, and it presents a more flaky appearance. It forms fine needles, arranged in rosettes in many cases. The needles either cut the borders of the grains of quartz or are entangled in the chamositic matrix.

As the degree of metamorphism increases, chamosite disappears and stilpnomelane becomes more abundant. At a still higher degree of metamorphism, such amphiboles as riebeckite, minnesotaite, grunerite and cummingtonite form at the expense of chamosite and stilpnomelane. Quartz recrystallizes,with the new grains having a crenulate outline. In most thin-sections, as well, weak borders of magnetite dust are disorderly superposed on the crystals of quartz, like ghosts of the original grains.

The grunerite observed in the quartzites near Fabien and Chaperon lakes is amber yellow and forms rosettes up to 6 inches in diameter. The rosettes are made of needles radiating from one point and crossing, or replacing completely, the quartz grains.

Origin - A careful study of some 30 thin-sections of basement rocks shows that quartz grains devoid of inclusions of any kind are very rare. Furthermore, about 50% of the quartz crystals in the granitic gneiss and the granodiorite contain one or more inclusions, whereas the quartz grains of the quartzite contain them very rarely. The quartz of the basement rocks has very clear undulatory extinction under the microscope, whereas that of the quartz in the quartzite is more regular; furthermore, the latter lacks the multiple fractures that are present in the quartz of the granitic gneiss.

In general, the facts seem to mitigate against the hypothesis that the quartzite was derived directly from the breakdown of basement rocks, although supporting this hypothesis is the presence of microcline and of traces of plagioclase and chlorite. The pronounced recrystallization indicates that the primary quartz has undergone internal reorganization. In effect, during cementation the quartz grains were bonded by silica, and the fractured and deformed quartz grains took on an orderly internal structure.

In summary, aside from field observations, we can have a good idea of the manner and time of development of the Alison formation from the following main lines of evidence:

1. Uniform lateral distribution.
2. Variable thickness, but commonly within 30-150 feet.
3. Relatively pure; very small amounts of microcline, plagioclase, and chert.
4. Shale and chloritic rocks distributed vertically throughout the formation.
5. Magnetite-bearing shales at the top of the formation.
6. High roundness and sphericity of grains.
7. Cross-bedding; ripple-marks.
8. Sharp vertical variations in colour of beds within a few feet.

These features suggest such conditions and properties as:

1. The presence of first- or second-cycle quartzose sandstone, followed by distribution of the material by marine waves accompanied by the almost total destruction of minerals other than quartz (Kuenen, 1959); or, the material derived from impure sandstone was deposited in a marine, lake, or river environment (Krynine, 1941, and James, 1954).

2. Deposition in shallow water at the wave-affected zone of the basin.

3. Nearness of the coastal environment and the border of the sedimentary basin.

4. Sharp variations in chemical equilibrium, and perhaps in biogenetic conditions, in the interior of the basin.

It would appear from the above that the Alison quartzite resulted from the almost complete decomposition of the original minerals, except for quartz and chert. The absence of any significant plant life would expose the Archean land surface to the action of the weather. It is quite possible that the polished surfaces of grains of quartz result from the action of wind, but the roundness of the grains is very characteristic of abrasion in a humid environment.

It may be concluded that, of all the material removed from the basement rocks by the combined action of wind and water and deposited at the edge of a basin of sedimentation, only quartz and chert and, to some degree, microcline and a little plagioclase and chlorite survived disintegration and decomposition.

The presence of cross-beds indicates shallow water over the epicontinental shelf where deposition took place, with currents parallel to the edge of the geosyncline along which the quartzite accumulated. Such a sedimentary environment is confirmed by the presence of chamosite ovoids, which are indicative of agitated water conditions.

Fenimore Formation

General - Because of its economic importance, the Fenimore formation has received more attention than the others. It has been subjected to vast exploration programs and close studies on the part of company geologists. In the present work, only a general description of the formation is given. Owens (1955) has already described it very completely.

It is probable that the iron-bearing rocks of the western part of the area all belong to the same formation.

The Fenimore formation rests in paraconformity on the Alison and under the Dragon formation. In some places, such as west of Merchère lake, the Fenimore is in unconformable contact with the Chioak formation. In other places, it is absent, either through erosion or non-deposition.

The many promontories of basement rock that project through the Proterozoic probably represent some of the irregularities of the shoreline that served as barriers between basins of sedimentation.

Southwest of Merchère lake, a granitic conglomerate rests directly on the basement, without any intervening younger formation. This is perhaps a record of a marine transgression that accompanied the deposition of younger formations. It is possible that the younger formations were eroded away before the deposition of the Chioak conglomerate. This last hypothesis is based on the fact that there is an abundance of iron-bearing conglomerate and red sandstone within the detrital Chioak formation, west of Merchère lake.

Furthermore, a hiatus of tectonic origin exists in certain places along the contact with the basement. West of Quatre Ours lake, there is a breccia made up of fragments of iron-bearing rocks in a ferrodolomitic cement. This breccia is wedged between a promontory of basement rocks and the bordering detrital rocks of the Dragon formation. Here, the Fenimore formation consists of a tectonic breccia a few feet in thickness (Plate I-A).

Among the principal exposures may be mentioned those to the southwest of Merchère lake, near Alison lake, west of Chioak lake, west of Dusay lake, on either side of the western arm of Bérard lake, west of the north arm of Bérard lake, north of Bérard lake, near Rouge bay, north of Arpenteurs bay, and near Monique, Chaperon, and Fabien lakes. The most economically promising outcrops are those to the west of Chioak lake, and to the west and north of Bérard lake. These will be discussed in the section of the report dealing with economic geology.

The thickness of the Fenimore formation varies considerably. Although absent in places, as mentioned above, it reaches a thickness of close to 120 feet to the west of Chioak lake. To the south, in the Larch River area, Bergeron (1954 a) reports a thickness of 500 feet. In the present map-area, however, it is apparently not more than 150 feet thick.

The contact between the Alison quartzite and the Fenimore formation is gradational. The gradual change in the make-up of the cement of these rocks is apparently due to variations in oxidation-reduction conditions and pH in the sedimentary basin. Although temperature variations, under constant chemical conditions, could also be responsible for these changes, the presence of large amounts of iron oxides and carbonates, alternating with graphite and chamosite, would seem to indicate important changes in pH and in Eh.

Seven types of iron-bearing rocks, with different physical and mineralogical characteristics, have been recognized in the field. These are:

1) Spotted silica
2) Thin- or thick-bedded jaspilite
3) Brown- or blue-weathering carbonate rock
4) Siliceous breccia
5) Hematite- and magnetite-bearing rock
6) Silica- and magnetite-bearing rock
7) Magnetite-bearing shale.

The stratigraphic succession is not fixed and, except for the position of the first and the last units, there may be local changes in order.

Terminology - In order to avoid any ambiguity, some of the terms used will be explained:

1- "Iron-bearing" rocks comprise all of the sedimentary rocks of the Fenimore formation that contain an appreciable amount of iron (10% or more).

2- To differentiate between the sedimentary rocks containing spheroidal forms, the following nomenclature is used:

oölite: rock made up of grains with a layered coating;

ovulites: ellipsoidal grains with a layered coating (Déverin, 1945).

granules: ellipsoidal grains without any internal structure (Pettijohn, 1957).

Magnetite-bearing shale - Beds of shale, usually quite thin, separate the Alison quartzite from the Fenimore formation. These shales, which alternate with magnetite-bearing quartzites, are commonly iron-bearing, and are therefore included with the Fenimore.

Distribution and thickness - The shale is regularly, but thinly, bedded. West of Chioak lake and north of Bérard lake, where the base of the Fenimore is well exposed, it forms a good horizon marker. Here, although the rock is less than 10 feet thick, it has good lateral distribution. North of Mannic lake, the shale is replaced by a chlorite-garnet schist.

Petrography - The magnetite-bearing shale is dark grey or black on the fresh surface, and brown or grey on the weathered surface, depending upon the carbonate content. It is almost everywhere fine-grained, shaly and quite soft. It is very magnetic, and it is this property that distinguishes these shales from other nearby shales. Differences in colour of individual beds are due to differences in the amount of contained magnetite.

The most common minerals, as noted in thin-section, are: magnetite, quartz, stilpnomelane, chamosite (iron chlorite) and pyrite. Graphite may occur in certain beds. Partial analyses, made by Fenimore Iron Mines, indicate an average grade of 27% iron, 1% manganese and 45% silica.

The metamorphic equivalent of this shale is chlorite-magnetite schist. North of Bérard lake, the rock is dark green and quite schistose. Brown spots, 3 to 4 mm. across, cover almost 20% of the rock's surface. Octahedrons of magnetite, as well as crystals of stilpnomelane, are very much in evidence.

Silica- and magnetite-bearing rock - The iron-bearing rocks containing silica and magnetite outcrop abundantly between the northern arm of Bérard lake and Mannic lake. In some places, this member makes up almost 50% of the Fenimore formation. North of Bérard lake, as well as at Rouge bay, it appears to have an average thickness of 40 feet (Plate II-B). As the extraction of their magnetite content is a relatively simple process, the presence of these rocks determines the economic possibilities of certain deposits.

The silica-magnetite rocks are hard and erosion-resistant. They bear a resemblance to the magnetite-bearing quartzites, especially where made up of thick, massive beds. In most places, lenses or discontinuous layers of chert or siderite alternate with silica-magnetite bands which are between 1 inch and 25 inches thick; the interbeds rarely exceed 4 inches.

The rock is steely blue on both the fresh and weathered surface. The carbonate interbeds weather chocolate-brown; those of chert are pale grey to olive green.

Owing to the local differences within this member, the different types of silica- and magnetite-bearing rocks will be described separately.

PLATE II

A.– Tectonic breccia associated with the Fenimore iron formation to the west of Dragon lake.

B.– Silica- and magnetite-bearing rock, north of Bérard lake. The dark bands and lenses are composed of carbonates.

West of the northern arm of Bérard lake, the basal section of the silica-magnetite member is masked by detrital material. However, the true thickness is about 20 feet.

The rock may be dark grey or black to olive green, with a vitreous and metallic lustre. Its magnetite content is indicated by its weight.

A petrographic analysis of a characteristic sample of the black facies revealed the presence of the following minerals:

Apatite	tr.	Quartz	55%
Hematite	tr.	Siderite	2%
Magnetite	35%	Stilpnomelane	5%
Minnesotaite	tr.	Zircon	tr.
Muscovite	3%		

In thin-section, it can be easily seen that the minerals of the rock have been redistributed and recrystallized. Originally the rock was made up of ovulites and granules of unknown origin. Only "ghosts" of these forms remain, outlined by magnetite dust. The granules have been elongated, twisted and, in places, broken. They are similar in appearance to the spastolites of Pettijohn, under which term are grouped various strongly deformed oölites and spherulites. This deformation, according to Pettijohn, must have been primary, especially if the oölites in question are composed of chamosite. Déverin (1945) wonders whether the chamosite could have been, at one time, in the form of a gel, and whether the ovulites could have been soft balls. Those who reject this hypothesis present the following observation, from an outcrop at Chamosentze, Switzerland:

a) The deformed ovulites, which commonly accompany complete and regularly-shaped grains, and which may serve as nuclei for the formation of later concretions, have the appearance of broken ellipsoids, their edges bevelled off as if by attrition

b) When the ovulites are so numerous that they are touching one another, they remain undeformed and retain their original form.

c) In places, adjoining ovulites have coalesced.

Some authors have taken this as proof that the outer skins of the ovulites were in a gelatinous state at the moment of contact. However, it is difficult to explain the absence of a pad, or buffer, between adjoining grains. According to Pettijohn, solidification could have occurred quite rapidly, upon coalescence of the grains, in the presence of a surplus of chamosite and carbonate.

It would appear from the foregoing that the ovulites were originally chamositic in composition. The transformations that the chamosite ovulites must have undergone remain to be explained. Chamositic granules have been observed in certain horizons of some rocks; magnetite dust cutting recrystallized quartz in others. This leads us to believe that, after diagenesis, iron-rich chlorite was altered, by simple metamorphism, to magnetite dust. With continuing metamorphism the magnetite dust agglomerated into "lumpy" magnetite made up of clusters of crystals seldom over 0.1 mm. in diameter.

These lumps of magnetite may fill the ovulites or may cut completely across them, extending out into the quartz. In some places, the lumpy magnetite intersects two or three ovulites at a time.

The quartz has a granoblastic texture, with very true grain outlines. The lumpy magnetite seems to have been superimposed on networks of intertwined quartz crystals. The quartz crystals range from 0.1 to 0.3 mm. in diameter, and are completely undeformed.

The secondary minerals, consisting mainly of siderite, muscovite and stilpnomelane, are found within the granules or in the interstices between the quartz crystals.

The olive-green facies, which accompanies the black facies described above, is made up of the following:

Hematite	tr.	Minnesotaite	60%
Limonite	tr.	Quartz	10%
Magnetite	25%	Stilpnomelane	5%

The minnesotaite is responsible for the green in the rock. Although individual crystals are not visible to the naked eye, the microscope reveals a foliated mass of needle-like minnesotaite crystals. These crystals range from 0.01 to 0.1 mm. in length; their diameter rarely exceeds 0.005 mm.

The fibrous, green minnesotaite is similar to sericite or talc in appearance. It has a hardness of 1 to 2. In thin-section, it shows strong birefringence, parallel extinction, positive elongation and slight pleochroism.

Two different types of minnesotaite have been observed: one type, which is microcrystalline and forms a uniform structureless mass, makes up almost all of the granules; the other type, along with quartz, makes up the groundmass of the rock.

The granules, visible in thin-section under weak magnification, are oval shaped and undeformed. We have grouped them into three types:

1.- Granules of microcrystalline minnesotaite, without a shell (less than 0.01 mm. in length);

2.- Granules of "lumpy" magnetite;

3.- Granules or ovulites with a shell of lumpy magnetite and a core of microcrystalline minnesotaite.

The granules, or pseudo-ovulites, make up only 50% of the rock and are isolated within the groundmass. Their axial ratios are 4 to 5; the large diameter varies from 0.6 to 1.2 mm.

Quartz is essentially confined to the groundmass, where it is intimately associated with the minnesotaite. It has a granoblastic texture, on which is superposed the indistinct texture of the later minnesotaite needles.

The main accessory minerals are hematite, limonite and stilpnomelane. The last is the most abundant, and is concentrated in the minnesotaite-poor sections of the rock.

The minnesotaite is the characteristic mineral of the carbonate member of the Fenimore iron formation. In the case described above, it is possible that the green magnetite-bearing rock is part of a lens of iron carbonate in the midst of the silica-magnetite rock. Another possibility is that the minnesotaite was derived from the metamorphism of greenalite.

<u>North of Bérard lake,</u> diamond drilling has indicated from 40 to 90 feet of silica-magnetite rock. The average thickness is about 50 feet, and the member lies above the magnetic shale and beneath the hematite-magnetite-bearing rock.

The individual beds of this member range from a few inches to several feet thick. The thinner beds, which are rich in magnetite, in places alternate with bands of granular white silica from 1/16 to 1/4 inch thick. The massive beds, on the other hand, are rich in silica and contain disseminated magnetite. Diamond drilling has revealed, at different horizons, lenses of saccharoidal pink silica, specular hematite, massive magnetite, yellow spotted carbonate, jaspilite and shale, as well as veins of pyrite and quartz. Systematic sampling carried out near Phoques river has uncovered narrow beds of pale yellow quartzite in the midst of the iron-bearing rocks. This quartzite contains only traces of iron minerals, and its presence is, therefore, difficult to explain.

In thin-section, this facies of the silica-magnetite member is seen to be completely recrystallized. Although minnesotaite is abundant in equivalent rocks to the south, its place is taken by biotite and chlorite in these rocks. The quartz is well crystallized and possesses a granoblastic outline. The other minerals are automorphic and are disseminated through a network of quartz grains.

The granules or pseudo-ovulites are rare, and, where present, are represented only by an outline of magnetite dust. More commonly, however, ovoidal clots of tiny magnetite octahedrons have completely replaced the original ovulites. These randomly-distributed clots make up 30-50% of the rock. In some thin-sections, no granules at all were observed. Here, the quartz grains are powdered with magnetite dust.

The main accessory minerals are stilpnomelane, siderite and hematite.

<u>North of Chaperon lake</u>, the silica-magnetite rocks have undergone such severe metamorphism that positive identification is difficult. One rock type, however, was identified by its general appearance and its position relative to the iron carbonates. It is made up mainly of magnetite and silica, but is interstratified with carbonate bands. The following is the mineralogical make-up of the two adjacent rock types.

Carbonate band:	Albite	2%
	Magnetite	9%
	Quartz	9%
	Siderite	80%
	Stilpnomelane	tr.
Oxide band:	Albite	tr.
	Chlorite	tr.
	Magnetite	45%
	Quartz	26%
	Siderite	28%
	Stilpnomelane	1%

The carbonate bands make up 25% of the rock and range from 0.5 to 3 inches in thickness. The constituent minerals, which are quartz, albite, and magnetite, are dispersed through the groundmass of the rock and show a preferred orientation of optic axes. The albite displays two types of twinning,-albite and Carlsbad.

The oxide bands have a maximum thickness of 12 inches. They do not show any primary structure. The rock is black, with a metallic lustre. The principal minerals are magnetite, siderite and quartz in crystals seldom more than 0.5 mm. across. They are well crystallized and form a uniform granoblastic mass.

Hematite- and magnetite-bearing rock - This type of iron-bearing rock, as it differs from the previously described type only by the presence of hematite, is often difficult to distinguish in the field. In places where specular hematite is abundant, however, the rock has a strikingly micaceous appearance.

Distribution and thickness - The hematite-magnetite rock is present throughout the area, from south of Merchère lake to Bérard lake. Although its thickness and stratigraphic position vary from place to place, its general characteristics remain the same. West of Dusay lake, the member is some 20 feet thick. West of Chioak lake, as well as north of Bérard lake, it is 15 to 30 feet thick. At Arpenteurs bay, and north of Mannic lake, the thickness could not be estimated, owing to complexity of structure; it appears, however, to be 10 to 15 feet thick.

Petrography - As the lithology of this member varies considerably from place to place the different facies will be described according to their geographic location.

Southwest of Merchère lake, as well as west of Merchère and Garique lakes, the hematite-magnetite rock is represented only by a few thin, massive beds, containing lenses of grey or olive-green chert. Fine-grained magnetite predominates in the metallic beds; quartz, hematite and minor chert make up the rest of the rock.

West of Dusay lake, the Fenimore and Alison formations are inextricably involved in a chaotic structure. Here, a series of strike faults, as well as some thrust faults inclined to the west, are responsible for the complex structure and for reversals in the stratigraphic sequence.

A sample taken at random revealed the following mineralogical composition:

Hematite	35%
Magnetite	7%
Quartz	45%
Riebeckite	10%
Siderite	2%
Stilpnomelane	1%

Under the influence of certain factors, such as the presence of water, automorphic crystals of riebeckite formed at the expense of pre-existing silicates, such as chamosite and minnesotaite. Leith (1903) reports similar examples in which amphiboles were formed from greenalite or from minnesotaite, either in strongly folded beds or near gabbro sills. The riebeckite crystals are visible to the naked eye and have a steel-blue colour. Some rod-like crystals are nearly 1 inch long and 1/4 inch wide. Under the microscope, the riebeckite is distinguished by strong pleochroism - going from Prussian blue to light yellow, pink and orange. The elongation is negative; $X/C = 5^{o}$; the dispersion is strong; the birefringence is yellow, pink, blue and purple; and 2V = approximately 60^{o}.

The quartz forms a network of crystals with a granoblastic texture. The grains average 0.2 mm. in diameter. The magnetite within the rock takes two forms: a) dust disseminated through the quartz; and b) fairly well formed lumpy granules. The granules have several shapes, from perfectly oval to quite irregular. The majority, however, are made up of agglomerated magnetite crystals, with a core which corresponds to the original granules.

On a polished surface, the hematite is seen to be intimately mixed with the magnetite. The mineral contacts are quite irregular.

West of Chioak lake, the Fenimore formation is represented by the hematite-magnetite member. This member, which outcrops on a cliff, is about 30 feet thick. It is made up of thin beds, containing bands of both carbonate and chert. The rock is black and compact and has a metallic lustre. It breaks easily under the hammer, splitting into slabs with an average thickness of 1 inch.

The average mineralogical composition of the metallic beds is as follows:

Apatite	tr.	Magnetite	30%
Chlorite	2%	Minnesotaite	2%
Chert	4%	Quartz	30%
Greenalite	3%	Siderite	4%
Hematite	17%	Stilpnomelane	8%

The above analysis takes in the chert and carbonate bands intercalated within the hematite-magnetite rocks. The chert interbeds, rarely more than 1 inch thick, are made up of microcrystalline quartz which is powdered with hematite dust and contains octahedrons of magnetite, rhombohedrons of siderite and needles of minnesotaite. The carbonate bands are made up of cryptocrystalline siderite, which, owing to the presence of hematite or goethite dust, magnetite octahedrons, and interstitial microcrystalline quartz, is almost opaque.

In places, the magnetite-bearing rock contains granules ranging from 0.1 to 1 mm. in diameter. These granules take the following forms:

a) Granules of lumpy magnetite.
b) Granules or ovulites with a shell of lumpy magnetite and a core of minnesotaite, siderite or microcrystalline quartz.
c) Granules made up mainly of microcrystalline quartz, minnesotaite or siderite.
d) Granules of microcrystalline quartz, spotted with polygonal aggregates between 0.005 and 0.01 mm. in diameter of hematite dust.
e) Granules of minnesotaite rimmed with tiny polygons of hematite dust.
f) Granules of chert rimmed with minnesotaite.

Varieties "a" and "b" are the most common. They cut the other types of granules, and are apparently the latest to have been formed.

From this, it can be reasoned that the original granules were altered during diagenesis, and that gradually the iron-bearing minerals formed new granules which, in some cases, cut across the outlines of the existing ovulites.

North of Bérard lake, beds of hematite-magnetite rock, 2 to 25 inches thick, alternate with lenticular beds of carbonate up to 4 inches thick. Here, the member has a total thickness of 20 feet. It overlies the magnetite-silica member and is covered by beds of interbedded carbonate and chert. The rock is grey-blue, with a metallic lustre. Certain facies resemble black quartzite.

Under the microscope, the rock displays a fairly advanced stage of crystallization. The quartz has a granoblastic texture, on which are superposed aggregates of magnetite and hematite crystals. These aggregates resemble deformed secondary granules, but they do not show any trace of the primary granules described above. The hematite grains range from 0.003 to 0.01 mm. in diameter; the magnetite grains, from 0.03 to 0.1 mm.

PLATE III

A.– Iron-bearing, carbonate-chert rock; dark blue on the weathered surface. Note the roughness of the surface, owing to the veinlets of chert and granular silica. North of Bérard lake.

B.– Contact between the Dragon formation (black) and the Chioak formation (light grey). Note the occurrence of black microsandstone at the base of the Chioak formation. Looking south, near Dragon lake.

Diamond drilling through this member intersected bands of specularite, 1/8 to nearly 2 inches thick, beds of spotted silica, beds of oölitic hematite, a little cubic pyrite, and magnetitic chlorite shales ranging from 1 foot to 3 feet thick. In one place, a 5-foot-thick bed of fibrous cummingtonite was mapped. This variety of cummingtonite, making up more than 95% of the rock, is composed of radiating fibres and is extremely difficult to break with the hammer. It is greenish grey on the fresh surface and brick-red on the weathered surface.

A few specimens contain biotite, partly altered to chlorite, as well as muscovite and siderite. The carbonate interbeds are very similar to the carbonates that will be discussed later in the report.

<u>North of Arpenteurs bay</u>, where the Fenimore formation was most severely deformed, the amphiboles and feldspars that it contains give evidence of a fairly high degree of metamorphism. Here, these steel-grey rocks display a schistosity resulting from the development of lamellae of specularite. Chert-rich beds alternate with iron-rich beds.

As seen in thin-section, the iron-bearing rocks are well crystallized. They are made up of the following minerals:

Hematite	6%	Quartz	40%
Magnetite	29%	Riebeckite	10%
Microcline	4%	Stilpnomelane	10%
Plagioclase	1%		

The matrix of the rock is made up of granoblastic quartz, 0.05 to 0.1 mm. in diameter, each grain coated with well crystallized stilpnomelane. The magnetite breaks down into grains of a similar size and, following the outline of the quartz, may develop into "ghost" crystals. The hematite forms a coarse dust, distributed through such minerals as quartz, feldspar and riebeckite.

Two types of microcline are present: a) individual grains, probably of detrital origin; b) secondary growths around the original microcline grains and between the grains of quartz. The latter type acts as a cement between the quartz grains in the same manner as the stilpnomelane. The microcline grains, some of which display a characteristic checkered polysynthetic twinning, commonly contain very small grains of iron oxide and inclusions of quartz.

The riebeckite forms acicular crystals, seldom much over 3 mm. in length, aligned parallel to the schistosity of the rock. Its optical properties are the same as the riebeckite in the rocks at Dusay lake, described above.

North of Mannic lake, the hematite- and magnetite-bearing rocks are completely recrystallized. They are steel-blue and have a metallic ring when struck. They contain several lenses of chert and carbonate, metamorphosed to spotted silica and fibrous amphibole. The principal minerals of the rock are:

Biotite	tr.	Muscovite	tr.
Cummingtonite	30%	Quartz	40%
Hematite	14%	Siderite	1%
Magnetite	15%	Stilpnomelane	tr.

The cummingtonite crystals range from 1 to 10 mm. in length and from 1/4 to 3 mm. in width. They are randomly oriented, and are set in a matrix of granoblastic quartz, spotted with crystals of magnetite and hematite. The cummingtonite crystals enclose globules of quartz, occasionally in some abundance.

Siliceous breccias - Tectonic breccias and intraformational breccias are included within the Fenimore formation. The first type, because of its unusual origin, will be discussed in the chapter on structural geology.

The breccias occur throughout the Fenimore formation, but are most common in association with narrow bands of chert. Chert or, more rarely, microcrystalline silica with or without siderite, makes up the fragments of all the breccias. The different types of breccias can therefore be distinguished only by the nature of the cement. The most common types of cement are composed of: a) ovulitic ferrodolomite (or siderite); b) microcrystalline silica; c) ovulitic ferrodolomite with microcrystalline silica; and d) hematite or goethite.

A breccia consisting of fragments of chert in a matrix of ovulitic siderite was mapped at several places. The fragments, the majority of which are sub-angular, range from sand-grain size to blocks 10 inches long by 3 to 4 inches across. The petrographic analysis of a sample containing the smaller sizes of fragments gave the following results:

Cement	(85%)	Calcite	1%
		Magnetite	1%
		Quartz	
		a) microcrystalline	2%
		b) granular	6%
		Siderite	75%
		Stilpnomelane	15%

Fragments	(15%)	Chert	80%
		Minnesotaite	5%
		Siderite	13%
		Stilpnomelane	2%

A breccia of microcrystalline silica forms quite thick layers north of Bérard lake and at Rouge bay. The total thickness of this breccia is about 15 feet. It is made up of elongated fragments, 1/2 inch to 10 inches long and 1/8 to 3/4 inch across.

Breccias in which the cement is composed of both ovulitic siderite (or ferrodolomite) and microcrystalline silica almost everywhere accompany the two types of breccia described above. This type of cement probably represents an intermediate stage between the other two.

A petrographic analysis of a sample of this rock, taken from west of Chioak lake, gave the following results:

Cement	(65%)	Calcite	tr. - 1%
		Ovulitic fragments	1%
		Magnetite	20%
		Minnesotaite	1%
		Quartz	
		a) granular	2%
		b) microcrystalline	40%
		Siderite	30%
		Stilpnomelane	5%
Fragments	(35%)	Chert	80%
		Magnetite	2%
		Minnesotaite	5%
		Siderite	10%
		Stilpnomelane	3%

The chert fragments contain very small ovoid granules, rarely more than 0.1 mm. long, their presence revealed by a concentration of minnésotaite. The edges of the fragments are rich in stilpnomelane and secondary magnetite; their interiors consist only of needles of minnesotaite and rhombohedrons of siderite.

The matrix of the rock is composed of ovulites, from 0.3 to 1.0 mm. in diameter, with a concentric structure. The ovulites, in turn, are set in a cement of microcrystalline quartz. Fifteen different types of ovulites were noted in a single section. The principal types are as follows: a) "phantom" ovulites, consisting of chert with a border of stilpnomelane;

b) granules of magnetite; c) granules of stilpnomelane surrounded by magnetite; d) ovulites with a quartz center and a border of magnetite or of siderite with hematite and stilpnomelane; e) granules of pure siderite; f) ovulites which are completely isolated within a quartz crystal and which are outlined by a thin border of minnesotaite.

The breccias with a hematite-goethite cement are quite rare, and, within the map-area, are restricted to a locality west of Garigue lake. Here, fragments of an argillaceous rock are cemented by brick-red limonite.

The breccias described above, with the attrition of the fragments and the presence of ovulites and fragments of oölites, are evidence of minor interruptions (diastems) in the deposition of the iron-bearing rocks.

Carbonate facies - The carbonate facies, which makes up about half, by volume, of the Fenimore formation, is the most spectacular horizon owing to its distinctive steel-blue or chocolate-brown weathered surface (Plate III A). It is found mainly at the top of the formation, above the spotted silica.

Distribution and thickness - This horizon is present wherever iron-bearing rocks are found. The best exposures are west of Chioak lake, where multi-coloured carbonate rocks can be followed for 5 miles, and, the total thickness of the member is about 25 feet. North of Bérard lake, diamond drilling has intersected about 12 feet of carbonates interstratified with chert.

Petrography - Whether blue or brown on the weathered surface, the rocks of the carbonate facies are quite similar in composition. The only important variable is the amount of manganese and other oxide fractions which help colour the rocks. The average composition of twenty representative samples, taken from the main outcrops, is as follows:

Biotite	tr.	Hematite	0.5%
Calcite	0.5%	Limonite	5%
Chert	tr.	Magnetite	9%
Chlorite	2%	Minnesotaite	1%
Ferrodolomite	5%	Quartz	15%
Greenalite	2%	Siderite	45%
Grunerite - cummingtonite	8%	Stilpnomelane	6%

Minor variations in mineralogy, especially as regards the carbonate minerals, can cause sharp colour variations in the rock. These differences in colour, as observed on the weathered surface, result in a differentiation of the carbonate facies. As this differentiation corresponds to climatic conditions in the area, however, it is of local significance only.

The iron-bearing carbonate rocks with a chocolate-brown weathered surface are the most abundant. They are almost everywhere accompanied by beds of chert of variable thickness. In places, the chert is extremely abundant and the carbonate rock is confined to lenses.

The carbonate rocks with a steel-blue weathered surface appear at several horizons throughout the brown carbonates. They contain beds, lenses or nodules of chert. The nodules are from 6 to 14 inches long and 4 to 10 inches across. In certain horizons, some of these nodules display fractures or septaria. Minute septaria in ovulites were seen in thin-sections.

According to Pettijohn (1957), these structures are due to the development of gels from soils in an aqueous environment, followed by the formation of a crust around the gel, with subsequent dehydration of the interior and the development of shrinkage fractures. Finally, the fractures were filled with the available minerals, such as quartz, calcite, and ferrodolomite.

South of Bérard lake, the carbonate rocks are made up almost entirely of ovulites with a layered shell structure which, in places, persists right to the core. In natural light, the concentric layers of the ovulites are opaque and appear to be made up of hematite and goethite dust. Crystals of quartz and secondary ferrodolomite may cut and replace one ovulite or several ovulites at a time. Twin ovulites are widespread; at least two or three ovulites may be held together and enveloped by a layered shell of the same type as the shell of the ovulites themselves. Some ovulites display what appear to be sporules inside their innermost shell; however, these are simply aggregates of magnetite dust in the process of recrystallization.

North of Bérard lake, ovulites are rare and the iron-bearing carbonate rocks contain granules of magnetite, siderite and minnesotaite or grunerite. This would indicate an increase in degree of metamorphism.

The reagents $Cu(NO_3)_2$ (Rodgers, 1940) and $K_3Fe(CN)_6$ (Henbest, 1931, p.362) were used to identify several carbonate minerals, such as siderite and ferrodolomite. Owing to the extremely fast reaction of potassium ferrocyanide, however, it is difficult to determine whether the rock contains much or little iron, but certain criteria allow us to suspect that one carbonate or the other is present. Traces of calcite were noted in certain veinlets, as well as crystals of rhodochrosite.

Owens (1955) reports the chemical composition of an almost pure iron carbonate as follows:

Iron	36.4%
Manganese	2.8%
Magnesium	4.2%
Silica	2.75%
Calcium	0.75%

We believe, although only on indirect evidence, that ferrodolomite is the predominant carbonate mineral. Two types of iron carbonate are present,- one dark brown and the other a pale yellow. When heated to incandescence, the residue of the former was strongly attracted by a magnet, whereas the latter was only slightly. Another test involved covering a polished surface of the two minerals with potassium ferrocyanide; the brown (or sideritic) carbonate was unaffected, whereas the ferrodolomite gave a blue coloration. The reason is that the ferrodolomite is attacked by the acid of the solution, thus permitting the ferrocyanide to react with the surface. Once the presence of the two iron carbonates in the vein material was determined, the same procedures were repeated with the sedimentary carbonates.

The secondary iron silicates, such as minnesotaite, stilpnomelane, grunerite-cummingtonite and possibly chlorite, were derived, through metamorphism, from pre-existing silicate minerals such as greenalite and chamosite.

The interbeds of chert amongst the iron-bearing rocks are of interest. Some contain sparsely distributed ovulites of quartz, covered with a film of hematite dust. Microgranules make up the groundmass of several of the chert lenses. They are barely visible in natural light, and, under crossed nicols, their structure is masked by microgranular quartz. The microgranules are 0.01 mm. in diameter and are very pale green. Other chert beds are made up of crystalline quartz with, in places, a tenuous skin of magnetite dust. Minnesotaite is almost everywhere present in the chert. Traces of magnetite, siderite and stilpnomelane have also been observed.

North of Feuilles lake, the iron-bearing carbonate rocks are dissected by fractures filled with quartz, carbonates and fibrous grunerite. The fibres of the latter mineral are up to 6 inches long and, in places, make up about 2% of the rock.

Thin- or thick-bedded jaspilites - Jaspilites are represented within the area by only a few thin beds west of Merchère and Chioak lakes, as well as at Rouge bay. This member, although different in appearance, may simply be a facies of the magnetite-hematite-bearing rocks. It is composed of beds of massive jasper alternating with lentils of hematite and magnetite, of beds of oölitic jasper, magnetite and hematite, or of bands of jasper with accompanying specularite.

West of Chioak lake, the rock is massive and homogeneous. It is made up of small grains of brick-red jasper, crystals of carbonate, and magnetite.

Several types of granules can be distinguished under the microscope. The most common are made up:

1) completely of jasper, or of microcrystalline quartz containing hematite dust;
2) of siderite;
3) of randomly oriented flakes of chlorite, containing some siderite;
4) of chert replacing at least half of the ovulite;
5) of polygons composed of hematite dust, with or without a nucleus of magnetite;
6) of a coating of siderite around massive jasper or jasper with a polygonal core;
7) of siderite "powdered" with hematite dust;
8) of siderite with some minnesotaite;
9) of chert with some hematite and minnesotaite.

Some of the ovulites display septaria; others are twinned. Their long diameters range from 0.5 to 1.0 mm; the axial ratio is 4 to 5.

Spotted silica - Spotted silica forms the uppermost member of the Fenimore formation. It is present wherever the Fenimore occurs, from Merchère to Fabien lakes. Its thickness, varying only slightly from place to place, is rarely over 25 feet; drilling north of Bérard lake, however, intersected up to 50 feet of it. The distinctive spotted appearance of this rock, as well as its resistance to erosion, makes it a good horizon marker.

The spotted silica commonly displays a characteristic saccharoidal texture. The grain size ranges from 0.01 to 0.5 mm. The rock is usually pale yellow or cream coloured, although it may be brown or grey in places. The spherical brown spots, 2 to 4 mm. in diameter, are due to concretions of siderite.

The average mineralogical composition of a number of specimens taken south of Bérard lake is as follows:

Chert	4%	Minnesotaite	tr.
Graphite	1%	Quartz	90%
Limonite	2%	Siderite	3%

In places, the rock exhibits "ghosts" of a granular structure, outlined by aggregates of well crystallized quartz within the microgranular quartz. The outlined granules are about 0.5 mm. long, the individual quartz grains being 0.03 to 0.2 mm. in diameter.

Graphite forms small spots with a soot-like appearance. North of Bérard lake, the spotted silica member gives evidence of appreciable metamorphism, and the siderite concretions are very large and more numerous. Minerals such as cummingtonite have been developed at the expense of pre-existing silicates. The quartz has a marked saccharoidal texture and, under the microscope, the rock looks like the sections of a honeycomb. The crystals of quartz are separated from one another by coatings of magnetite.

Origin of the Fenimore formation - It is not the writer's intention to bring up again the controversy over the origin of the iron-bearing formations. As this subject has been dealt with adequately by several authors, this report will only summarize the most recent work, especially as it concerns the particular features of the iron-bearing rocks of the present map-area.

The banded iron-bearing rocks of the Precambrian present the following problems: 1) What was the nature of the Precambrian atmosphere? 2) Whence came the principal constituents of the iron formations? 3) What was the mechanism of transport, and how were the other transported materials removed from the site of deposition? 4) In what environment, and by what agents, did precipitation take place?

Erosion and transport - The principles that governed the erosion and transport of the material of the iron-bearing rocks also governed their deposition. One should, therefore, consider the basic physicochemical conditions. To this end, the evolution of the different concepts is reviewed, and an effort made to apply the hypothesis that best suits the facts.

The hypothesis of the volcanic origin of the iron and silica, as postulated by Van Hise and Leith (1911) and Moore (in Moore and Maynard, 1929), and upheld by Chatsky, Niggli, and Schneiderhonn, has received new support from Bouladon, Jourasky, Colson (1955) and Oftedahl (1958). Although this may be kept as a working hypothesis, it does not seem to explain all of the features of the iron-bearing rocks.

Tanton (1950, 1951) explains the origin of the jaspilites and the other iron-bearing rocks of the Lake Superior region by the differentiation of an acidic iron-rich magma. He believes that the alternating chert and hematite bands formed during the cooling of the lava flows, and that the oölitic structures originated from tiny globules which separated from the main liquid mass.

In the region under study, however, this hypothesis does not explain such things as the grains of detrital quartz and microcline in the midst of the iron-bearing rocks, nor does it account for the cross-bedding observed at certain horizons.

Gruner (1922), James (1954), Krumbein and Garrels (1952), Huber (1958), Hough (1958), and others consider that the sedimentary material was derived by erosion from nearby continental masses. This offers a better explanation for the world-wide occurrence of iron-bearing rocks than does any of the above hypotheses, especially in view of the absence of volcanic rocks or signs of volcanic emanations.

Zobell (1946) and Mason (1949) established the physicochemical basis for marine sedimentation. Pourbaix (1949), Castaño and Garrels (1950) suggested the physicochemical conditions that would be necessary for the formation of iron-bearing sedimentary rocks. Following this, Krumbein and Garrels established stability diagrams for hematite, siderite and pyrite in the normal marine system. Huber and Garrels (1953), Deltombe and Pourbaix (1954), James (1954) and Huber (1958), through their new observations, later improved on these stability diagrams.

The small amount of clastic material in the sedimentary iron-bearing rocks suggests a selective mechanism of transport by dissolution or colloidal suspension.

The basement rocks contain the following minerals in descending order of abundance: SiO_2(65%), Al_2O_3(15%), CaO, K_2O, Na_2O, Fe_2O_3, MgO, etc. As the iron-bearing rocks contain only small amounts of alumina and alkalis, a dissolution or selective transportation of these minerals must have occurred. The alkaline elements are very soluble and present no problem. However, alumina (an amphoteric substance) is subject to complex chemical laws. It may act either as a base or as an acid compound, depending on the degree of acidity of the surrounding environment. Alumina goes into solution with a pH of 4 and a pH of 9, and its solubility is considerably reduced between these limits (Correns, 1949). Silica and alumina could act together to form clay minerals, or they could coagulate to form hydrosols.

The transport of iron depends mainly on the oxidation potential and the degree of acidity of the environment. If transport took place in soft water, disturbed and well aerated, the oxidation potential would be about 0.25 to 0.30 and the pH would not be greater than 5.0 or 6.0. Under these conditions, the iron content would be weak.

In stagnant water, the oxidation potential is greatly diminished and the amount of iron in solution is considerably increased. The maximum amount of iron is carried by waters bearing considerable organic material and flowing over carbonate-poor rocks (Huber and Garrels, 1953).

The solubility of the silica increases with the pH. It may form a true solution if in small concentrations. With the slightest increase in silica content, however, a colloid would form.

Deposition - The work of Alexandrov (1955) on the relative solubility of Fe_2O_3 and SiO_2, at different temperatures and pH values, forms the basis of an interesting hypothesis on the origin of the banded iron-bearing rocks. His work shows that changes in temperature and pH could bring about the selective dissolution of either silica or iron, if the Precambrian, with the small amount of vegetation that it was apparently able to support, could produce enough humic acid solutions to dissolve and transport predominant amounts of, respectively, silica during the hot season and iron oxide during the cold season.

Silica can be precipitated by organic as well as by inorganic means. Certain plancton and diatoms are known to assimilate silica and carry it to the bottoms of lakes to form deposits which may be quite large. Nevertheless, as there is no certain proof of the presence of organisms of this type in the Precambrian, inorganic precipitation can be considered to be the most likely process. Krauskopf (1956) has indicated that, although the solubility of amorphous silica is only slightly affected by changes in pH from 0 to 9, it increases appreciably when the pH is greater than 9.

Siever (1957) tried to determine the amount and effect of silica in the various sedimentary cycles. This author believes that the concentration of silica in the Precambrian surface waters was greater than that prevalent today. The extreme weathering of the granitic rocks, brought about by the action of rain-water and of large amounts of CO_2 in solution (Rubey, 1951), could have added a considerable quantity of silica to the run-off waters and could also have saturated the oceans in $Si(OH)_4$. With the addition of more silica to this saturated environment, the amorphous silica could have been precipitated by simple coagulation.

If Siever's hypothesis is combined with that of Alexandrov, we can envisage a relatively simple mechanism whereby silica could be precipitated in a fairly rhythmic cycle throughout the year and iron precipitated mainly during the cold season. This would explain the banding of the iron-bearing rocks.

Conclusions - The Fenimore formation is composed almost entirely of chemically deposited sediments, separating an underlying quartzite from an overlying banded siltstone. It is made up, successively, of sulphide, oxide, and carbonate facies.

The sulphide facies is represented by the magnetic shales and by the shale that forms a transition between the quartzite and the main sequence of iron-bearing rocks. The oxide facies is made up of hematite-magnetite rock, silica-magnetite rock and jaspilite. The carbonate facies, at the top of the formation, contains beds that could be classified as part of a silicate facies. It is difficult, however, to determine whether this is a sedimentary or a metamorphic facies.

The relationship of the Fenimore formation to the development of the Labrador Geosyncline - Students of Precambrian iron formations always remark on the degree of geomorphologic maturity of the old land surfaces on which the formations accumulated. North of Roberts lake, isolated remnants of quartzite and iron-bearing rocks fill depressions in the Archean basement, thus revealing irregularities in the existing terrain. Despite these minor irregularities, however, the iron-bearing rocks were deposited, without interruption, in a closed basin. It matters little whether the basin was the intercontinental geosynclinal type of Haug (1900) or whether it formed behind some structural barrier. The essential conditions for the accumulation of iron-bearing sediments included a high concentration of the constituents and abnormal oxidation-reduction conditions at the bottom of the basin.

The configuration of the basin, the climatic conditions, and the nature of the adjacent rocks, all had an influence on the deposition of the chemical sediments. For example, in places where spurs of basement rock projected into the basin sedimentation would not have occurred except around the borders of the promontories in deeper water. This apparently occurred south of Merchère lake, where an "island" of basement rock, covered with red sandstone, lies in the midst of the iron-bearing rocks.

The presence of interformational breccias indicates interruptions in sedimentation, followed by erosion. As these breccias occur within different facies, we can postulate that, within the main basin, there existed closed basins where different types of sediments accumulated. This would also explain abrupt variations and alternating positions amongst the various facies.

Mechanism of sedimentation - It is not necessary to discuss the nature and extent of the water in the sedimentary basin. Nevertheless, different phenomena, such as twinned ovulites, septaria, broken ovulites, breccias, cross-bedding (Bergeron, 1954a; Perrault, 1955), etc., lead us to believe that the basin was unstable and not very deep. This being the case, it seems likely that the water was soft or slightly brackish, and that it was susceptible to temperature variations.

The granules that are present throughout the Fenimore formation were formed under identical conditions, namely: (1) rapid deposition from colloidally precipitated gels; (2) a weak tendency to crystallization, owing to the colloidal character of the silica, the ferrous or ferric organic compounds, and the hydroxides; and (3) the virtual absence of fragments that could have served as nuclei during the formation of the ovulites (Gruner, 1922).

On the other hand, the ovulites have a layered shell and are commonly without a core. De la Bèche (1851) believed that they formed by chemical accretion in a turbulent environment. This explanation is the most reasonable in the light of the sedimentary conditions and the presence of twinned ovulites.

The silica may be made up of minute granules or may contain isolated ovulites within the matrix.

Siever's hypothesis, which states that the waters were silica-saturated, is interesting in that it explains why the Precambrian iron-bearing rocks contain banded silica. The minute granules were derived, without doubt, from the coagulation of the silica in a saturated environment. The presence of ovulites immersed in a siliceous matrix also corroborates this hypothesis.

<u>Summary</u> - As it is impossible to determine the physico-chemical conditions of sedimentation by direct means, a working hypothesis must be used. The iron, in its four principal mineral facies, was submitted to the normal Eh and pH conditions of soft or slightly saline water. The climate must have been quite hot, perhaps tropical and humid, enabling the silica and the iron to be washed from the granitic surface, with the alumina being left behind. In some places, the sedimentary basin was deep enough to permit a density layering of the water in the summer and a complete circulation of water in the winter. Here, the deposition of silica was followed by the deposition of iron (Hough, 1958). In other places, where the basin was not so deep, different types of material, representing changes in weather conditions, accumulated (Alexandrov, 1955; Sakamoto, 1950).

<u>Diagenesis and metamorphism</u> - Many of the changes in the iron-bearing rocks took place during or shortly after deposition. In places, quartz is replaced by completely recrystallized iron oxides and iron silicates. Granules of magnetite are, in the same way, formed from magnetite dust. Recrystallized carbonates and pyrite also replace pre-existing minerals.

The transition from diagenesis to actual metamorphism is gradational. Minerals such as greenalite and cummingtonite formed from primary silicates such as stilpnomelane, minnesotaite, greenalite, and iron chlorite. Coarse-grained quartz is derived from chert and from micro-crystalline quartz by means of internal reorganization. In the same way, the magnetite crystallizes in octahedrons and the siderite in rhombohedrons, with the disappearance of the ovulites and granules. The hematite is changed to specularite.

<u>Dragon Formation</u>

<u>General</u> - The author (1958) proposed this new formation name in order to designate the sequence of detrital rocks that separates the Fenimore formation from the overlying Chioak formation. Although geologists of Fenimore Iron Mines had considered this sequence of rocks to be a member of the Chioak formation, its separation is justified by the stratigraphy, mineralogy and structural features of the rocks.

<u>Description</u> - The Dragon formation is essentially a "rhythmite",- i.e., a formation formed by rhythmic sedimentation. It is made up of beds of light grey siltstone, from 1 cm. to 10 cm. thick, alternating with beds of a very friable, black shale 0.5-20 mm. thick. The total thickness of these rhythmites, as exposed west of Chioak lake, is 115 feet (Plate III-B).

The rocks of this formation are dark, especially if compared with the overlying Chioak sandstone (Plate III-B), and break easily along shaly bedding planes into thin slabs.

They are well exposed along the western border of the southern part of the area, extending 6 miles north of Quatre Ours lake. The striking outcrops in the vicinity of Dragon lake account for the name of the formation.

These rocks differ in mineralogy from those of the Chioak formation. They are richer in graphite and contain stilpnomelane, anthraxolite, disseminated pyrite, and considerable chamosite or iron chlorite.

A petrographic analysis of representative samples of the Dragon formation gave the following results:

Quartz	30%	Graphite	tr.-5%
Chert fragments	20%	Pyrite	1%
Chamosite)	20%	Stilpnomelane	1%
Argillite	10%	Magnetite	1%
Microcline	5%	Epidote	tr.
Biotite	5%	Limonite	tr.
Plagioclase	3%	Apatite	tr.
Carbonates	2%	Sericite	tr.
		Anthraxolite	tr.

Chamosite, graphite and carbonates make up the cement. In some cases, the rock is silicified and, when hit with a hammer, breaks with a conchoidal fracture and gives off a sound similar to breaking porcelain.

Thick beds and coarse grains are a feature of the upper part of the formation, and some of the beds have the appearance of true quartzites, spotted with crystals of siderite. At the top there is evidence of oscillatory sedimentation, with five or six repetitions of alternating shale and arkose beds (Plate IV-A). The sandstone beds contain angular pieces of shale detached from the underlying layer. Each bed is 1 foot to 3 feet thick. These beds mark the boundary between the Dragon and the Chioak formations. Thus, there is a pseudo-discordance between the two formations, representing a local interruption in sedimentation, accompanied by erosion of the shales already formed.

Thin-sections of the siltstone show very angular microcline grains, as well as chert and plagioclase fragments, commonly enveloped in chamosite. Some of the rocks contain ovulites of chamosite surrounded by a secondary coating of this mineral. The chamosite is responsible for the green colour of the rock. According to both X-ray and semi-quantitative spectrographic analysis, the chamosite, or iron chlorite, corresponds to the formula: $(Mg_{\frac{1}{4}}Fe'')_4Al(Si_3Al)O_{10}(OH)_8$.

Folds, a few feet across, were noted beneath the massive beds of Chioak sandstone. Near the north shore of Quatre Ours lake, the siltstones of the Dragon formation do not display any angular unconformity with the overlying beds of sandstone. On the contrary, it appears that the argillaceous beds behaved in a plastic manner, whereas the more rigid marker beds escaped any deformation.

The Dragon formation, in general, is nearly horizontal. In places, it displays slip planes, "trails" of anthraxolite and tiny cleavage fractures in the shaly layers of the rock. The slip planes generally lie perpendicular to the fold axes. Some of them are accompanied by grooves resulting from the sliding of the rigid beds over the plastic beds.

<u>Origin</u> - In view of the angular nature of the grains, which average 0.06 mm. across, deposition could have taken place either in water or in air. The rhythmic layering of the sedimentary rocks, however, offers proof that deposition was effected under water. The alternation of chloritic beds with detrital quartz-microcline beds indicates that the transportation of the material was controlled mainly by seasonal factors.

Chioak Formation

<u>General</u> - The word Chioak is derived from the Eskimo word "Siogha'luk", which means "coarse sand". The Chioak formation, composed almost entirely of detrital material, is made up of several fairly distinct members, such as iron-bearing conglomerate, conglomerate with granite fragments, various sandstones, and black or red pelitic rocks. Rapid facies changes make it impossible to establish horizon markers. Variations in a horizontal direction are of a granular nature; vertical changes are compositional. For this reason, the rocks will be described under two lithologic classifications—based either on grain size or on the nature of the cement.

<u>Distribution and thickness</u> - The Chioak formation underlies a large area to the west of the central valley, extending from the southern border of the region to Bérard lake. North of Bérard lake, thin but persistent bands of sandstone and siltstone separate the Fenimore formation from the Abner dolomite.

North of Feuilles lake, the Chioak formation is inconsistent and is seldom more than 50 feet thick. Here, the iron-bearing formation and the gabbros lie very close together. Nevertheless, it is possible that, in this sector, slates, chloritic and other schists, and metadolomites intercalated with argillaceous beds belong to the Chioak formation.

South of Chioak lake, on the other hand, the beds of conglomerate and sandstone are 600 to 800 feet thick. Changes in thickness, however, occur as rapidly as changes in facies.

In the southern part of the area, the Chioak formation lies unconformably on both the basement rocks and the Alison formation. It lies unconformably on the iron-bearing rocks to the west of Garigue lake, and near Bérard lake. West of Chioak lake, however, it is in pseudo-discordance with the Dragon formation. Here, structural conditions deepened the basin of sedimentation, whereas in other localities the same conditions produced "shoals" within the basin. This will be discussed in the chapter on structure.

There is a pseudo-discordance between the top of the Chioak formation and the overlying Abner formation. The change from detrital rocks to chemically precipitated sediments is gradual and, north of Merchère lake, all of the intermediate facies between an iron-bearing conglomerate and a massive dolomite are observed.

Petrography - The detrital rocks can be divided, according to their grain size, into conglomerates, sandstones and pelitic rocks. Superposed upon this, however, is a mineralogic classification, based on the nature of both the grains and the cement.

Conglomerates - The conglomerates are represented by three main types,— arkosic conglomerate, iron-bearing conglomerate and cherty conglomerate. There are also several sub-types, formed of mixtures, in varying proportions, of the principal constituents.

Arkosic conglomerate with granite fragments - This rock is observed mainly to the southwest and west of Merchère lake. In places, it is truly arkosic. Some of the contained fragments are more than 3 feet across. The nature of the cement is quite variable, but calcite and argillaceous minerals are the most common.

This conglomerate is commonly interbedded with a feldspathic sandstone of equivalent composition. In a few places, angular blocks of granite are isolated in a matrix of arkosic sandstone. These blocks appear to have been transported by torrential waters and dropped helter-skelter along with other accompanying material. Farther to the north, this conglomerate grades into cherty conglomerate and iron-bearing conglomerate.

South of Merchère lake, the arkosic conglomerate is a truly basal conglomerate. This is the result of erosion and disintegration "in situ" of basement granite.

Iron-bearing conglomerate - Local deformations caused fracturing and folding in the iron formation, the Alison quartzite and in the other formations, such as the lower dolomite and underlying schists, which were built up in a regressive marine environment. This deformation resulted in the development of a mixed rock, such as the iron-bearing conglomerate - a product of marine erosion of the underlying formations. This conglomerate is probably a facies of the granitic conglomerate farther to the south and of the type of conglomerate to the north that contains grey or black chert. The iron-bearing conglomerate outcrops mainly west of Merchère lake, north of the fault cutting the basement rocks and the overlying sedimentary rocks of that district. Here, the conglomerate, forming thick and resistant beds, has a total thickness of between 50 and 150 feet.

The fragments consist essentially of the following:

Type	Origin
White quartz Granitic gneiss	Basement
Orange dolomite	Lower dolomite
Grey siltstone Slate and shale	Shale underlying the lower dolomite (not observed within the area)
Quartzite	Alison quartzite
Jasper Iron-bearing rocks Black jasper	Fenimore formation
Siltstone Shale	Dragon formation
Red conglomeratic sandstone	Lower Chioak formation

All of the above-listed fragments are usually quite well rounded, with polished surfaces. They are strongly cemented by secondary quartz, ferrodolomite and hematite. The matrix is a red arkosic sandstone, rich in iron oxide.

The upper part of this member grades into a red dolomitic conglomerate and into a green dolomite containing isolated pebbles of jasper and an iron-bearing rock.

Cherty conglomerate - This is the most extensive and thickest of the conglomerates. It outcrops almost continuously along the contact with the basement rocks, from Alison lake to north of Bérard lake. The rock is well solidified and contains pebbles and boulders of grey or black chert in an arkosic matrix. Other pebbles and boulders observed in the conglomerate are made up of quartz, quartzite, granite, various types of gneiss, shale (Dragon formation) and jasper. The fragments range from 1 to 30 cm. in diameter.

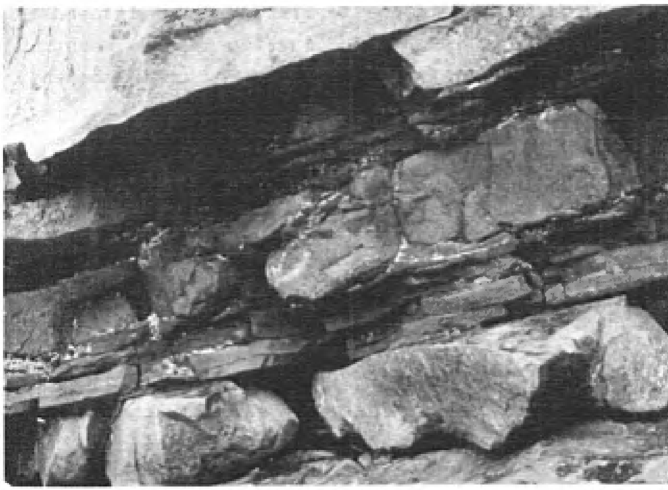
The cement is composed of silica, chert, ferrodolomite, argillite, or authigenic chlorite. Where the rock has a siliceous cement, it is very hard and difficult to break. The joint planes of this rock display a very smooth, uniform surface, with the chert pebbles breaking cleanly across (Plate IV-B). Where the cement is dolomitic, on the other hand, the rock erodes quite rapidly, releasing the fragments. Erratic boulders of dolomite-cemented cherty conglomerate bear witness to this (Plate V-A). In fact, blocks 4 to 6 feet in diameter have been weathered out to form disintegration cones or disintegration towers.

The matrix and cement of this conglomerate will be described at more length in the section on the sandstone facies.

Sandstones - The Chioak is essentially a sandy formation, with minor conglomerate and shale facies. The basic colour of the rock is derived from the cement, which may be hematite, goethite, ferrodolomite, calcite, chert, authigenic chlorite, or a combination of these constituents mixed with argillite, allogenic chlorite, rock dust or granitic material. The larger constituents may also influence the colour of the rock, especially on the fresh surface.

The origin of the sandstone is revealed by its present position, the nature of its larger constituents and the type of source rock. For instance, the pink or red sandstones southwest of the area are made up of pink or red microcline derived from the adjacent pink granite, and the black or grey sandstones result from the simultaneous breakdown of grey granodiorite, iron formation and Alison quartzite. As the sandstones directly reflect the nature of the rocks from which they were derived, they cannot be rigidly classified. The different types of sandstone correspond to facies changes that are due to the composition of the parent rocks and, above all, to the environment of deposition.

PLATE IV



A.— Interbedding of grey sandstone and black siltstone at the top of the Dragon formation. Note the fragments of siltstone in sandstone in the center of the photo.

B.— Joint plane through a conglomerate containing black chert fragments.

In this report, the term "sandstone" is used to signify a detrital rock made up of grains of sand enveloped in a cement. As the diversity of the sandstones depends on the nature of the cement, the following types can be distinguished:

a) sandstones with a pelitic cement, including the pink sandstones and the grey or black sandstones;

b) sandstones with a ferrodolomitic cement;

c) sandstones with a ferruginous cement;

d) sandstones with a siliceous cement.

Sandstones with a pelitic cement - The grains and the cement of this type of sandstone were deposited simultaneously. These rocks apparently formed when a thick cover of residual rocks was suddenly disturbed by erosion and swept unsorted into neighbouring sedimentary basins.

Pink sandstone - This rock is the sandy equivalent of the granitic conglomerate described earlier in this report. It has apparently been derived from the disintegration of the pink granite observed to the southwest of the area.

The pink sandstone outcrops over an area of about 5 square miles to the southwest of Merchère lake. In places, it is in direct contact with the granite gneiss. Elsewhere, it lies in pseudo-discordance upon the iron-bearing formation.

This member is not always observed in the same stratigraphic position. This is apparently due to rapid facies changes resulting from variations in the conditions of sedimentation. At the north end of Merchère lake, for example, the pink sandstone lies above the black sandstone and below the red sandstone and iron-bearing conglomerate. Farther to the south, however, it either overlies or is interbedded with the red sandstone.

The pink sandstone, which is composed essentially of feldspars and quartz, corresponds to an arkose in composition. Clay minerals and other minor constituents make up about 15% of the rock.

The petrographic analysis of a typical sample gave the following results:

Microcline-perthite	40%	Pyrite	1%
Quartz	30%	Chlorite	1%
Sericite	10%	Hematite	tr.
Plagioclase	5%	Biotite	tr.
Calcite	5%	Epidote	tr.
Chert	2%	Apatite	tr.

PLATE V

A.— Erosion surface of cherty conglomerate with a ferrodolomitic cement.

B.— Red sandstone (black) and pale pink arkose of the Chioak formation, west of Merchère lake. Deposition break (diastem) at the point indicated by the hammer.

Sericite, accompanied by calcite and chlorite, forms the cement of the rock.

In places, the pink sandstone is so well cemented that it bears a remarkable resemblance to the granite from which it was derived. The grains are interlocked perfectly, as if they had crystallized "in situ". The narrow interstices are filled with clay minerals and minor carbonates.

Minor deposition breaks (diastems) and cross-bedding are quite common.

Black sandstone - This rock, which is especially common to the west of Garigue, Gourdon, and Bérard lakes, is interbedded with black shales. The individual beds range from 1 foot to 4 feet in thickness. The rock reflects the abundance of diorites in the nearby basement rocks, as well as the existence of black chert in the iron formation.

The black sandstones fall within the same stratigraphic sequence as the arkoses described above and the light grey sandstones which will be described later in the report. Based on their mineral content of feldspar, quartz, rock fragments and chert, the term sub-greywacke could be applied to these rocks.

The black sandstones were derived from the disintegration of dioritic rocks, and the nearby pink sandstones were derived from pink granite. Although both were formed in the same basin and under the same conditions of weathering and climate, they differ considerably in appearance.

The black sandstone, which includes a conglomerate facies with abundant well-rounded black chert pebbles, is commonly massive and very resistant. It is composed mainly of microcline, perthite, quartz, plagioclase, hematite, chert, and clay minerals. The dark colour of the rock is derived from the iron oxide associated with the chlorite and the clay minerals. Some samples contain graphite. Petrographic analyses of a large number of samples gave the following average:

Clay minerals	5%	Leucoxene	tr.
Biotite	tr.	Magnetite	tr.-1%
Chert	5%	Microcline-perthite	35%
Chlorite	5%	Plagioclase	2%
Epidote	tr.	Pyrite	tr.
Ferrodolomite	3%	Quartz	40%
Rock fragments	2%	Sphene	tr.
Goethite	1%	Stilpnomelane	tr.
Graphite	tr.	Tourmaline	tr.
Garnet	tr.	Zircon	tr.

The grains of the sandy facies are sub-angular to rounded; those of the shaly facies are angular. The roundness of the grains increases with size. Where sub-angular, they are so closely crowded together that there is almost no interstitial clay or rock powder.

The matrix of the coarse-grained black sandstone is composed of small angular grains of the same composition as the interbedded siltstone. The cement is made up of secondary chert, ferrodolomite, clay minerals and quartz.

Authigenic chlorite accompanies the black sandstone almost everywhere, commonly forming true ovulites. In places, chlorite, accompanied by ferrodolomite, replaces the microcline and quartz grains, resulting in an interlocking texture.

Accessory minerals such as zircon, garnet, tourmaline, sphene, leucoxene, epidote, and biotite are common, especially as inclusions in the grains of quartz and feldspar.

Microcline is the most abundant and best preserved of the feldspars. Its outlines can be revealed, and its importance evaluated, by colouring with sodium cobaltinitrate. The plagioclase alters to sericite, and only the larger fragments show albite twinning.

With the exception of a few crystals of biotite and chlorite sheltered within the rock fragments, allogenic ferromagnesian minerals were not observed in the thin-sections.

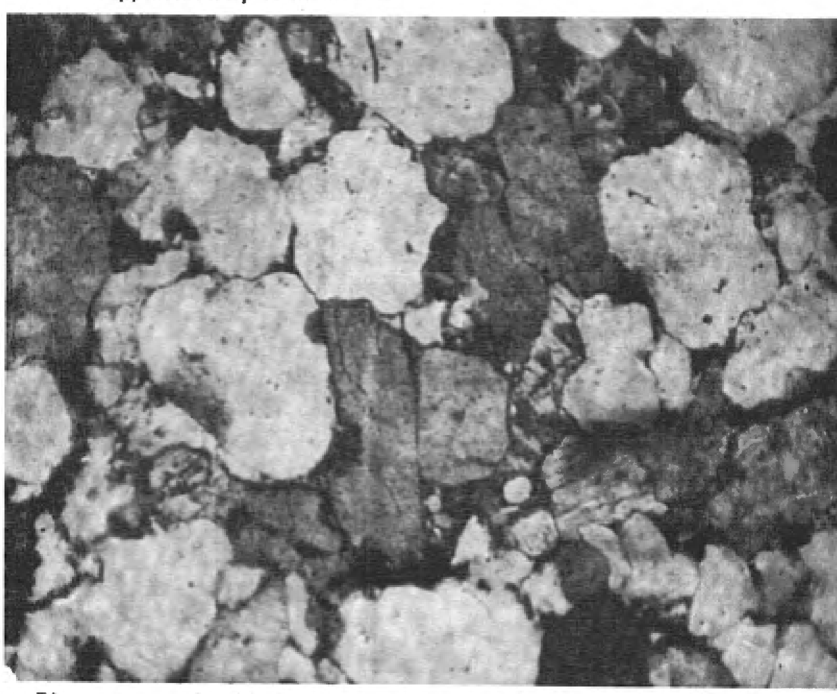
Pyrite and graphite were noted in several fine-grained specimens. Pyrite forms cubes which have grown at the expense of the secondary minerals. The graphite is usually present as tiny flakes disseminated through the rock. In a few places, however, concentrations of the mineral can be observed in shear zones.

<u>Light grey sandstone</u> - This feldspathic sandstone is purer and better consolidated than the black sandstone (Plate VI-B). It is well exposed to the west of Chioak lake, where it forms massive beds from 1 foot to 6 feet thick that do not show any internal structure.

The rock is hard, tough and erosion-resistant. The exposed bedding surfaces are marked with several types of well-preserved glacial striae and grooves (Plate VIII-B).

PLATE VI

A.— Siltstone of the Chioak formation east of Bras du Milieu, Bérard lake. Note the bedding which can be traced from the southwest to the northeast corner of the photo, and the cleavage which lies approximately north-south.



B.— Photomicrograph of light grey sandstone of the Chioak formation. Note the compaction of the rock, which, at first glance, resembles a granite. Dark grey microcline and quartz. Natural light, x 80.

The essential minerals, quartz and feldspar, make up 90% of the rock.

In hand-specimen, this rock bears a strange resemblance to the grey granodiorite from which it is probably derived. The only difference is that, with the exception of flakes of chlorite, ferromagnesian minerals are absent.

Analysis of a typical sample showed:

Microcline-perthite	45%	Quartz	35%
Plagioclase	10%	Sericite	5%
Chert	3%	Chlorite	2%
Iron oxides	tr.		

Sandstone with ferrodolomitic cement - This sandstone is easily distinguished in the field by its rough, brown weathered surface. The rock is easily eroded, and the liberated grains accumulate in depressions of the rock's surface. This phenomenon is quite marked and allows the constituents of the rock to be easily examined.

The ferrodolomite-cemented sandstone can be observed, as bands 2 to 3 feet thick, at different horizons within both the black and grey sandstones. West of Chioak lake, where the sandstone is abundant, it forms thick and very friable beds at the top of the Chioak formation. It is also associated with conglomerates that have a similar cement.

The rock is generally dark grey or black on the fresh surface. The pale to dark brown weathered surface is very characteristic. The composition varies considerably, especially as regards the relative proportions of the detrital material and cement. Some bands contain almost 85% carbonates and could be considered as simple arenaceous ferrodolomites.

Analysis of a thin-section of the most widespread type of ferrodolomite-cemented sandstone gave the following results:

Ferrodolomite	40%	Quartz	30%
Microcline	15%	Plagioclase	6%
Chert	6%	Chlorite	1%
Magnetite	1%	Sericite	1%

Ordinarily, the grains are completely isolated in the carbonate matrix and only rarely touch. They are well rounded, with a sphericity near one. The ferrodolomite is automorphic, the diameter of the crystals ranging between 0.2 and 0.4 mm.

Sandstone with ferruginous cement - This type of sandstone is abundant only to the southwest and west of Merchère lake. Here, it alternates with the pink sandstone and arkosic conglomerate. The only distinguishing features of this rock are its brick-red colour and its content of goethite, hematite and red jasper. The red colour is derived from the abundance of disseminated iron oxides which are intimately associated with the clay minerals of the rock.

The composition of this sandstone is similar to that of the pink sandstone with which it is associated. The slight colour difference is due to the physicochemical conditions of the sedimentary basin and perhaps to changes in climate.

Cross-bedding is common. At one locality west of Merchère lake, cross-bedded red sandstone rests paraconformably on cross-bedded pink sandstone. This clearly indicates a difference in the conditions of sedimentation of the two sandstones, marked by a short time lapse during which a diastem was produced.

Sandstone with siliceous cement - This type of sandstone is quite rare and does not form continuous beds. It is found at any horizon where chert and secondary quartz make up the cement of the rock.

In places, a very quartz-rich sandstone may be cemented by quartz and chert. This produces a homogeneous, erosion-resistant rock resembling the black sandstone with which it is commonly associated.

Shales - The red, green, black and grey shales, observed as fairly thick beds in almost every horizon of the Chioak formation, comprise the microgranular facies of the sandstones and conglomerates just described. A few miles east of the contact, shale is much more abundant than sandstone.

The peninsula that separates the eastern and central arms of Bérard lake is underlain almost entirely by shale, siltstone and a small amount of sandstone. All of these rocks are dark grey to black. Except for their content of clay minerals, the shales are mineralogically similar to their corresponding sandstones. West of Garigue lake, the Chioak is separated from the Abner dolomite by bands of shale that grade as sharply into the sandstones as into the dolomite.

Detrital grains of quartz, microcline, and chert, quite angular in shape, make up 10-50% of the rock. Illite and chlorite are the main constituents of the matrix. These minerals, which cannot be distinguished under the microscope, were detected by X-ray diffraction methods.

Some of the black shales are rich in magnetite; others contain abundant graphite and disseminated pyrite. Well-sorted sediments are quite common at certain horizons within the black shale.

The red shales, which are rich in goethite, constitute the pelitic facies of the ferruginous sandstone.

Structure and texture - The Chioak formation generally displays only minor folding. Near the contact with the basement rocks, the beds of conglomerate and sandstone dip at a maximum of 5° to 10° toward the east (Plate VII-A). Such a dip would correspond with the initial angle of repose of mixed coarse sediments. Away from the contact, the dips increase slightly and the rocks are more strongly folded.

West of Chioak lake, the sandstone beds dip at 10° to 15° to the east, but are unfolded. The first open anticlinal and synclinal folds appear east of the lake (Plate VII-B). This folding, which affects the pelitic facies of the formation more than the sandstones or conglomerates, gradually becomes more accentuated farther to the east.

In places where sandstone beds alternate with shale, broken cleavage fractures were noted at the contacts between the beds. The shales reveal evidence of even the slightest external forces that have been applied to the rocks. Cleavage fractures are well developed (Plate VI-A).

The joints and faults that cut the Chioak formation will be discussed in the chapter on tectonics. Internal structures are represented by some cross-bedding, reworked sediments and "cut-and-fill" forms.

Origin - The geomorphologic conditions of the Lower Precambrian differed but little from those of the present day. South of Merchère lake, the ancient surface has been gradually revealed by the erosion of the overlying Proterozoic rocks. The surface is regular and resembles the present surface of the Precambrian Shield.

The evidence of deformation near the base of the formation indicates the tectonic activity that began with the deposition of Chioak sediments. Faulting isolated certain sedimentary basins, causing a considerable accumulation of detrital material on the down-side, possibly at the fault. This would explain the presence of blocks of arkosic conglomerate in the upper beds of the Chioak formation. These blocks were apparently derived from the base of the formation.

PLATE VII

A.– Beds of Chioak sandstone to the west of Chioak lake. Dip is 5° to the east.

B.– Anticline in the Chioak sandstone to the east of Chioak lake. The man in the center gives an idea of the thickness of the beds.

All of the sedimentary rocks directly reflect the nature of the basement rocks or the older sediments from which they were derived. Mechanical disintegration was responsible for the granularity and, indirectly, for the transport of the particles.

The writer believes that, during deposition, the climate of the region was tropical and humid. This is based on the following observations: a) admitting that the conditions of chemical weathering were the same as at present, the disintegration, transport and deposition of the material must have been accomplished quite rapidly; b) the presence of cross-bedding, reworked sediments, "cut-and-fill" structures and angular blocks isolated within the sandstone proves that deposition was quite rapid; c) the red sandstones are of primary origin, are interbedded with unaltered arkoses, and form, with these latter rocks, deltaic deposits where oxidation-reduction conditions were quite variable; d) ferrodolomitic cement could not have formed under cold humid climatic conditions, because, as noted earlier, rocks cemented by this material disintegrate rapidly under the action of a cold rainfall; e) the presence of dolomite and of chemically precipitated iron-bearing rocks indicate a hot or, at least, a variable climate.

The conglomerates and sandstones resulted from the disintegration of the adjacent rocks. The materials were transported by wind and by water, and were distributed by wave and current action in the sedimentary basin. Material from the granodioritic basement rocks was transported rapidly to the basin, and the sandy grains were distributed according to their granularity. This resulted in a gradual facies change from west to east, — conglomerate near the basement contact, with sandstone and then shale farther away.

The presence of rounded boulders in the Chioak formation indicates that water was the main transporting agent. The only other possibility is that the boulders were further rounded by wave action, or, as suggested by Owens in 1955, by glacial action.

Isolated angular fragments in the cross-bedded sandstone leads to the belief that part of the materials was tumbled about and that sliding of the unconsolidated material occurred at certain places.

Near Chioak lake, the absence of internal structure in the sandstone indicates that deep currents reworked the sands, washing the fine material into deeper water.

The compaction of the grains was undoubtedly responsible for the preservation of the easily weathered minerals. The solidification of the red sandstone and arkoses, as judged by the preservation of delicate textures, must have taken place quite rapidly.

Metamorphism - East of the northern arm of Bérard lake, the shales have been transformed into chloritic schists. Farther to the north, the Chioak formation is represented by chlorite-biotite schists.

The clay minerals, such as chlorite and illite, were recrystallized and metamorphosed into chlorite and biotite. The parallel orientation of the micaceous minerals gives the rock a strongly schistose structure.

The Chioak formation could not be positively identified north of Feuilles lake. In the chapter on metamorphic rocks, however, rocks that are similar in some respects to those of this formation will be described.

Abner Dolomite

General - The Abner dolomite lies conformably above the Chioak formation. It extends the length of the area as far north as Feuilles lake, where it seems to disappear. It follows the central valley quite closely, forming imposing mesas near Abner, Garigue, and Gourdon lakes.

A short distance south of Rouge bay, there is a small outcrop of dolomite that is quite characteristic of the formation. Other dolomites farther north have been classed separately from the Abner because of lack of correlating evidence.

Distribution and thickness - West of both Garigue and Abner lakes, three large mesas of dolomite rise some 200 feet above the general surface. These hills, which are joined by continuous outcrop, are easily distinguished from a considerable distance on the ground or from high in the air.

In the vicinity of Bérard lake, the dolomite crops out east of the valley, close to the gabbro sills. Here it is thinner and more deformed.

The last important outcrop of Abner dolomite lies midway between Bérard lake and Rouge bay. A few miles farther north, a very small exposure is caught between chloritic schists and a gabbro sill.

The formation is 100 to 400 feet thick. Individual beds range between 6 inches and 6 feet thick, and generally are thicker at the base and thinner towards the top of the formation; the average thickness is about 1 foot.

The contact of the Abner dolomite with the Larch River formation, as seen in a few places east of Merchère lake, is a zone of thinly interbedded dolomite and shale, each rock type being repeated five or six times and each bed having quite sharp contacts.

In some places, the contact between the Abner dolomite and the underlying Chioak sandstone is gradational, with the rocks grading upwards from sandstone through dolomitic sandstone and sandy dolomite to pure dolomite. Elsewhere, the contact is oscillatory and sandstone alternates with dolomite.

Petrography - The weathered surface of the Abner dolomite is generally chamois-coloured, although it becomes darker with increasing iron content. On the fresh surface, the colours are highly variable, the most common being light grey, dark grey, cream, yellow, chamois, brown, green, pink, red, and orange. Systematic sampling west of Gourdon lake revealed eight distinct colours in a thickness of less than 50 feet. Some specimens showed colour variations within a few inches and, in places, within a few millimeters.

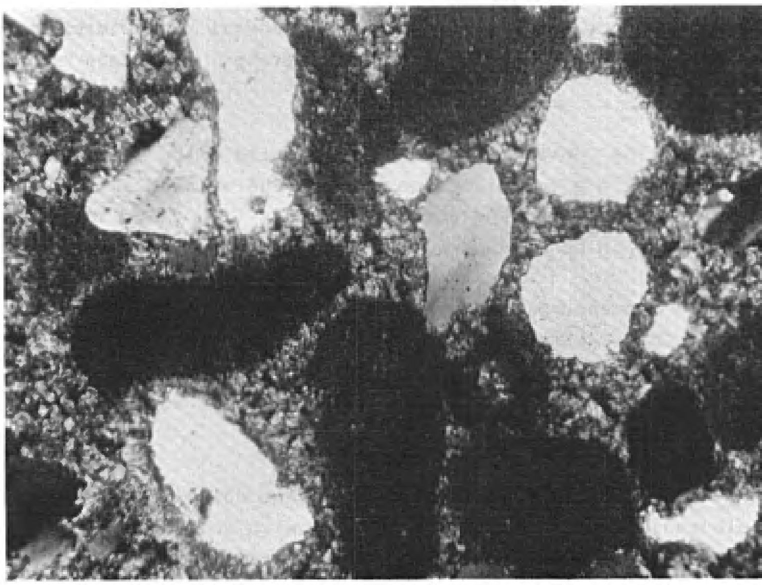
The colouration of the dolomite is a complex problem. It is determined, in some cases, by such accessory minerals as graphite, magnetite, hematite, chlorite, etc., in others, by such trace materials as the oxides of iron, chromium and manganese, camouflaged in the crystalline matrix of the dolomite.

The Abner dolomite is commonly microgranular and relatively pure, although some beds, the weathered surfaces of which are rough, contain considerable sand and silt.

Networks of quartz veins cut the rock in all directions, and produce a checkered weathered surface which is quite characteristic of the formation.

In thin-section, the dolomite is holocrystalline, the diameter of the grains varying between 0.05 and 0.4 mm. Where granules are present, however, they are made up of cryptocrystalline dolomite.

PLATE VIII



A.– Photomicrograph of sandy Abner dolomite, containing colloform granules (black). The sand grains are irregular and frosted. Natural light, x 160 ±.

B.– Same as A, showing one granule (black), and quartz grains (pale grey). The matrix is dolomite. Natural light, x 700 ±.

Although ovulites were not observed in the writer's thin-sections, Owens (1955) noted some in thicker sections. He remarked that they were hard to distinguish because of the very pale dust that enclosed them.

Nevertheless, many granules and irregular concretionary masses were seen in the sandy facies of the dolomite. The granules are oval-shaped, and a little stretched and deformed; their long axes range from 0.25 to 1.0 mm. in length. They can be easily seen in thin-section, owing to their relative opacity which results from the cryptocrystalline structure of the dolomite and, possibly, the presence of disseminated dust (Plate VIII, A and B).

The dolomite, which makes up most of the rock, is slightly ferruginous. Chemical analysis of several samples has revealed the presence of calcite, dolomite, and ferrodolomite. Calcite is common as minute veinlets, and is also present in the metamorphosed dolomites. Ferrodolomite is more common, but much of it is secondary. All of the intermediate stages between ferrodolomite and dolomite were noted in this formation. Many samples, when exposed to the action of potassium ferricyanide, gave all the blue tints from pale blue to Prussian blue, depending on the iron content.

In the middle of the Abner formation, west of Abner lake, there is an erosion surface which is accompanied by an intraformational breccia. This breccia is made up of angular fragments of dolomite in a sandy ferrodolomitic matrix. In some places, the irregular surface of the breccia is covered by cross-bedded dolomitic sandstone, the sand grains ranging from 0.1 to 0.8 mm. in diameter. A petrographic analysis of the sandstone showed 55% quartz, 40% dolomite and 5% microcline.

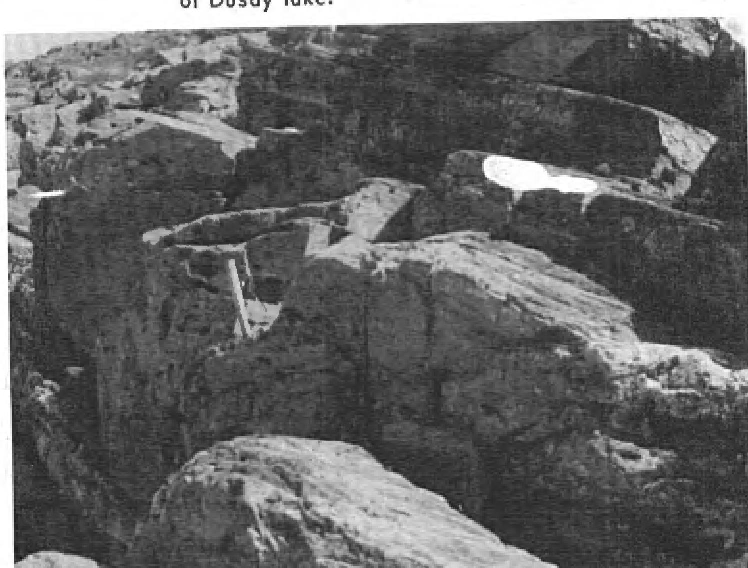
Analyses of many other sandy beds, from different horizons within the Abner formation, gave the following averages:

Dolomite	30 - 45%	Quartz	20 - 35%
Ferrodolomite	5 - 10%	Microcline	2 - 6%
Chert	2%	Calcite	tr. - 1%
Apatite	tr.	Zircon	tr.
Stilpnomelane	tr.		

West of Gourdon lake, a colony of algae, or algal-like structures of the _Colloenia_ type, covers an area of 200 square feet (Plate IX-A). These concretion-like forms range from 1 inch to 12 inches in diameter; the most common are 4 inches or less. They consist of conical or concentric leaves of quartz, separated from one another by dolomite.

PLATE IX

A.– Probable biogenic structures of the Colloenia type in the Abner dolomite west of Dusay lake.



B.– Larch River sandstone and siltstone, east of Merchère lake, showing calcareous concretions with long axes parallel to the strike of the cleavage.

Another concretionary form is revealed by a weathered surface consisting of cylindrical shapes, 1 inch to 4 inches long and 1/8 inch wide, piled one on the other and separated by thin bands of siltstone. The siltstone is made up of quartz and microcline, cemented by dolomite. In three dimensions, the concretions appear as flattened biscuits piled on each other in a somewhat disorderly fashion. They are made up of 99% cryptocrystalline ferruginous dolomite, with traces of microcline, magnetite, and quartz.

Massive, clear grey chert, in beds 6 inches to more than 3 feet thick, is associated with the dolomite beds. Massive pyrite occurs here and there in the chert, and, where it has been dissolved, the chert has a spongy appearance.

Structure and texture - Although, in the southern part of the area, major folds and faults are very rare in the Abner formation, there are numerous microfaults and microfolds. Microfaults may be recognized in the field by a displacement of the quartz veinlets that fill them. They are, however, particularly apparent in thin-sections treated with potassium ferricyanide.

Deformation is progressively more evident to the north, and, near Gourdon and Dusay lakes, the dolomite is strongly contorted and is cut by multiple faults.

Two joint systems, one trending north and the other N.60°E., cut the dolomite west of Garigue lake. These systems are easily visible from the air, because the rock, in places, is so well fractured that outcrops seem to be made up of closely spaced individual blocks.

The principal structural features inherent to the rock are inter- and intraformational breccias, cross-bedding and diastems.

Origin - The question of the origin of the Abner dolomite raises the triple question of the origin of the dolomite itself, the chert bands, and the quartz veinlets. The facts given above do not support either the primary or the secondary theory of the origin of dolomite.

The presence of cross-bedding, intraformational breccias, algal structures and concretions mitigate against the former existence of a deep basin. Indeed, the absence of muds would seem to indicate that the water was clear and shallow, and that the detrital material was brought to the basin of sedimentation by wind or water action.

The very angular and uniformly fine sand might well be wind-blown, with the larger, rounded grains having been transported by water. This detrital material is partly replaced by dolomite, as indicated by the irregular surface of the grains (Plate VIII-B). This feature of dolomite replacing quartz is important because it explains indirectly the origin of the quartz veins.

The chert bands interbedded with the dolomite are sedimentary in origin, and may be explained by one of two opposing theories. Tarr (1926) advocated the theory of primary precipitation of silica, whereas Van Tuyl (1916) advocated the theory of penecontemporaneous replacement (diagenesis). The second theory seems to apply best in the present map-area.

Recrystallization of the chert bands to holocrystalline quartz, and the partial dolomitization of quartz grains, whether eolian or not, indicates a possible source for the quartz in the multiple veinlets that cut the dolomite in all directions.

Microfolds and microfaults definitely show that the rock has undergone deformation. This deformation caused a migration of silica, thus resulting in the network of quartz and calcite veinlets observed along fractures and folded layers.

The undulating extinction of the quartz grains is evidence of strong deformation of the rock, as are the elongated and broken ovulites. Such phenomena could, in large part, have only been produced after lithification of the rock under pressure and in the presence of abundant connate water.

Silica is quite soluble under the above conditions, and it was apparently because of this feature that the silica migrated during deformation of the rock. When fracturing occurred, decompression reduced the solubility of the silica and caused its deposition in the newly formed openings.

Metamorphism - The changes that affected the Abner dolomite after lithification were many and varied. In addition to recrystallization of the dolomite and of the chert, quartz veins, and such minerals as sericite, fuchsite, and tremolite-actinolite, developed.

Sericite and fuchsite (green muscovite) were observed in the dolomite north of Bérard lake, where they formed along shear zones in folded strata. In some places, fuchsite makes up about 5% of the rock, and the crystals, many of which are twisted, are easily visible to the naked eye.

Near Rouge bay, the dolomite contains bands of pale green actinolite, made up of thin needles aligned in the same plane. This rock contains as much calcite as dolomite, as is shown by tests with copper nitrate.

Larch River Formation

General - The Larch River formation lies in paraconformity on the Abner dolomite. It consists of a thick sequence of siltstone and shale, with interbeds of dolomite. The formation thins near Dusay lake, and cannot be traced farther to the north.

The formation was named by Bergeron (1954 a), who found it to be more than 15 miles wide along Larch river. Here, it is made up of grey or dark green argillite and siltstone, with some interbeds of red siltstone and black slate (Fahrig, 1955). The rocks generally display considerable deformation.

It is possible that this formation is a repetition of the microgranular facies of the Chioak formation. It may also be a facies of the Chioak that has been thrown into its present position by faulting or folding, and thus has the appearance of overlying the main Chioak formation.

The schists and slates east of Gourdon and Dusay lakes are considerably deformed and broken by open folding and thrust faulting. A half-mile east of Gourdon lake, the slates are broken and form a 20-foot-wide tectonic breccia. Here, angular fragments of graphitic schist and black and grey slate, ranging in size from 1/10 inch to 3 inches, are distributed haphazardly in a very porous, limonitic, shaly matrix. The weathered surface of the breccia is covered by a thick layer of shaly, graphitic dust.

Judging from the presence of tectonic breccias of this nature, a thrust fault would seem to be the principal cause of the thinning of the exposed part of the Larch River formation near Dusay lake and even farther north.

Distribution and thickness - From Larch river, 30 miles south of the present area, to Dusay lake, the Larch River formation covers a triangular area with an apex near Dusay lake. It is about 6 miles wide east of Merchère lake, and it steadily narrows northward in accordance with the closing in of the lavas and gabbros on the Abner dolomite. The Larch River cannot be followed north of Dusay lake, owing to its restricted importance and the number of faults that mask its identity. In this northern part of the area, the chloritic schists overlying the Abner dolomite could be genetically related to the Larch River formation, but lithologic and stratigraphic methods of correlation cannot be used. The chloritic schists are described in the section on metamorphic rocks.

On the eastern shore of Merchère lake, the Larch River is at least 150 feet thick; east of Gourdon lake, it is 25 feet thick. It is impossible to measure the true total thickness of the formation because of the many folds and the longitudinal faults which, in places, double the thickness of the beds.

Petrography - The Larch River formation includes many rock types as a result of sedimentary and metamorphic facies changes. The most common rocks are shales and siltstones, and the corresponding metamorphic facies, — namely, slates, phyllites, and, more rarely, chlorite schists.

The rocks generally range from dark to light green in colour, although they may show any shade from pale grey to black. The grain size also varies widely. In places beds of coarse sandstone alternate with siltstone and shale, although the latter two types are the more abundant.

Dolomitic bands interstratified with the shales make structural interpretations rather difficult in places, and, where thicker beds are present, the contact between the Abner and the Larch River formations is not easy to establish. Such is the case east of Garigue lake, where the two formations are interbedded. Where the dolomite interbeds are of sufficient importance they have been mapped as Abner, regardless of their stratigraphic position.

The green rocks of the Larch River formation strongly resemble cryptocrystalline lavas. They can be distinguished, however, by the presence of sandy beds, calcareous concretions, dolomite and red sandstone beds, graphitic schists, and black slates, as well as by the absence of such volcanic features as vesicles, spherulites and pillow structures.

The following list gives a compilation of the average mineralogical composition of 18 representative samples. Thin-section study was combined with the diffraction method of X-ray analysis. The technique used to identify each of the minerals is indicated in the following list.

Apatite	tr.	(Microscope)
Calcite-dolomite	tr. - 15%	(Acids and chemical reagents)
Chert	1 - 3%	(Microscope)
Chlorite	5 - 25%	(X-ray; microscope)
Epidote	0 - 10%	(X-ray; microscope)
Graphite	tr. - 60%	(Oven; microscope)
Illite	10 - 40%	(X-ray)
Kaolin	tr. - 10%	(Microscope)
Microcline	tr. - 35%	(Sodium cobaltinitrate)
Iron Oxides	1 - 3%	(Microscope; magnet)
Plagioclase	10 - 35%	(X-ray; microscope)
Pyrite	tr. - 5%	(Binocular)
Quartz	25 - 60%	(X-ray; microscope)
Sericite	minus 1%	(Microscope)
Sphene	tr.	(Microscope)
Stilpnomelane	tr.	(Microscope)
Zircon	tr.	(Microscope)

Only 3 or 4 of the dominant constituents of the rock registered satisfactory X-ray diffraction patterns, and the physicists of the Quebec Department of Mines determined the relative abundance of the minerals from the density of their characteristic lines.

Quartz, the principal constituent of the rock, is present as fine, very angular grains from 0.01 to 0.1 mm. in diameter. The sandy facies includes a few larger and more rounded quartz grains. Some of the quartz contains inclusions of apatite, zircon and stilpnomelane.

Quartz veins are very abundant, and quartz and calcite veinlets from 0.05 to 0.2 mm. wide cut the rock in all directions.

The matrix is composed of such clay minerals as illite, kaolin, sericite, talc and chlorite, accompanied, in places, by graphite or carbonate. These minerals are commonly oriented in one plane, as is indicated by simultaneous extinctions under crossed nicols. It is therefore evident that some of the shales and siltstones have been altered to semi-schists. Orientation of recrystallized particles of clay size could scarcely take place without the action of very appreciable metamorphism. Only diagenesis and loading would be sufficient to explain the orientation of detrital tabular or prismatic grains as well as recrystallized clay minerals.

Plagioclase grains are well preserved in the rock, and are less altered than in much of the Chioak siltstone. Although the plagioclase content given in Table XV is perhaps too high, there is so much present that it raises serious problems, and the possibility of volcanic material having been added to this sedimentary rock must not be overlooked. The presence of microcline and detrital quartz marks the rock as a pelite, but volcanic contributions may be responsible for some of the plagioclase, chlorite, and epidote.

Graphite is an important constituent in places. It is very fine-grained, and is concentrated in some shaly or dolomitic beds. In one bed, a gradual passage from pure dolomite at the base to graphitic dolomite at the top was noted. Graphite also accompanies the slates and black shales. It is easily visible where it rests free on the weathered surfaces of these rocks.

South of Merchère lake, massive black chert covers some 500 square feet and is in contact with the folded and probably faulted slates. The chert appears to be a silicified part of the black shales.

Disseminated pyrite accompanies the graphitic rocks almost everywhere. Where the rocks have been slightly metamorphosed, the pyrite is in perfect cubes pushing against the enclosing walls.

The most common of the many types of carbonates are dolomite and ferrodolomite. Calcite is less widespread, except in veinlets and in the form of oval concretions.

Structure and texture - Fracture cleavages and drag folds are ubiquitous. In some slates, the fracture cleavage is in places parallel to, and in places discordant with, the bedding.

East of Merchère lake, the slates yield large, thin slabs. Here as well, the sandy beds contain ellipsoidal concretions that lie parallel to the cleavage of the adjacent slates (Plate IX-B). The concretions are 1 foot to 2 1/2 feet long and 4 to 12 inches wide.

Origin - The Larch River formation, as a whole, is the product of normal, marine sedimentation.

Hellancourt Formation

The volcanic rocks outcropping in the present area represent the continuation of the Hellancourt volcanic formation described by Sauvé and Bergeron (1964) from the Gerido-Thévenet area.

<u>Distribution and thickness</u> - The Hellancourt formation forms a band averaging 1 mile in width and extending in a general northerly direction for 22 miles along the eastern edge of the area. Lavas make up 95% of the formation, the remainder being pyroclastic rocks with some sedimentary layers.

The formation is estimated to be at least 5,000 feet thick. This estimate, however, does not allow for thrust faults nor for overturned folds.

<u>Petrography</u> - About 70% of the lavas display pillow structures. The pillows generally range from 6 inches to 4 feet in length, although some are at least 6 feet long. Their rims or crusts, which result from fast cooling of the flows, are made up mainly of chlorite, actinolite, quartz, plagioclase and talc. The crusts, 1 to 3 cm. thick, are dark green in the middle and generally pale greenish grey toward the outside.

An X-ray examination of the crusts gave the following results:

External part	Chlorite	62%
	Actinolite	31%
	Quartz	7%
Central part	Chlorite	24%
	Actinolite	16%
	Quartz	15%
	Plagioclase	40%
	Talc	5%

The percentages were calculated from estimates of the intensity of the diffraction lines; (determinations were made by the Laboratories of the Quebec Department of Mines).

Flattened, horizontal vesicles, 1 to 10 cm. in diameter, are particularly common at the top of the pillows. According to Sauvé (1957), who made a special study of the basaltic flows in an adjacent area, vesicles are very common, representing more than half the volume of some pillows.

Vesicles indicate the tops and the positions of the lava flows. The reason is that they form and tend to accumulate near the tops of flows when the rock is still fluid.

Although the pillow lavas and the less common massive lavas grade into one another within short distances, no sharp contacts were noted. Some of the massive lavas have an internal structure that resembles rude layering or "stretched-out" zones. This is actually flow structure resulting from successive and more or less differentiated flows.

The massive flows, lacking the characteristic structures of lavas, are often mistaken for medium-grained diabase sills. In some cases, the centers of thick flows are so crystalline that they resemble the diabase sills that occur farther east or even among the lava flows themselves.

Both the pillowed and the massive lavas have the same general composition, differing only in their degree of granularity.

Porphyritic lavas occur in the midst of some massive flows. The phenocrysts are white plagioclase crystals, 1/4 inch to 2 inches long, and are so widely scattered in the green, aphanitic matrix that they make up only 2-4% of the rock. Like the plagioclases in the other rocks, these phenocrysts are altered to albite and clinozoisite.

The principal minerals of the lavas are actinolite, chlorite and clinozoisite, with albite, quartz, pyrite, iron oxides, calcite and talc in smaller quantities. The rock is altered throughout, and original minerals are rarely preserved.

Under the microscope, the characteristic basaltic texture, with plagioclase crystals lying among ferromagnesian minerals, is apparent. The plagioclases have been replaced by a semi-opaque aggregate made up of microcrystalline albite, clinozoisite and calcite. In spite of the good preservation of original structures in the plagioclases, intact crystals were not observed.

Emerald-green actinolite, pseudomorphic after original pyroxenes, is the predominant ferromagnesian mineral in the lavas. In one thin-section, a trace of pyroxene, believed to be augite, was seen. The actinolite, forming rod-like crystals, is very pale green in natural light and very weakly pleochroic.

Chlorite is everywhere present in the lavas, occurring within, as well as on the exterior of, the other minerals. It is derived from the alteration of original ferromagnesians, and also from the partial alteration of actinolite, the borders of which are replaced in many cases. The most common variety is pale green in natural light and has a dark blue birefringence.

The most common accessory minerals are leucoxene (pseudomorphic after sphene), quartz (secondary or primary) and calcite (an alteration product). Also common are apatite, epidote, magnetite, pyrrhotite, pyrite, and chalcopyrite.

Pyroclastic rocks - Although pyroclastic rocks were not positively identified among the lavas, many factors suggest that rocks resembling tuffs are interstratified with the siltstones and chloritic schists. The tuff-like rocks are pale grey or greenish grey, and contain fragments of darker material that resemble slates.

Structure and texture - The Hellancourt formation is made up of many lava flows, which, in general, dip east at 35^{o} - 60^{o}, although some have a dip of 80^{o}. Pillow structures show that the lavas, in almost all cases, lie in their normal positions.

Some flows have a well developed prismatic structure, the 5- or 6-sided columns or prisms being 2-3 feet in diameter, regular, and exactly juxtaposed. As the prisms are perpendicular to the original cooling surfaces they are vertical in the flows, but, in the sills, lie perpendicular to the contacts, regardless of the present orientation of the latter.

In addition to the prismatic columnar joints, the lavas also feature columnar joints that are rectangular or square in section. Such false columns commonly accompany the "organ-pipe" structure observed in the lower layers of lava flows.

The false columns are evidence of a descending, cooling current from the surface of the flow. True columns, on the other hand, owe their origin to the much more regular rising of warm isotherms from the base (Jung, 1958). The false columns seen here probably originated during regional deformation rather than during the cooling of the lava.

Upper schists and sandstones - The description of these rocks is given in the section on metamorphic rocks.

Metamorphic Rocks

Introduction

The reasons for describing the metamorphic rocks in a separate section are outlined in the section dealing with Proterozoic rocks. Many uncertainties of stratigraphic and structural position, in addition to variations in the degree and type of metamorphism, raise difficult problems.

As is shown on the accompanying map, difficulties arise where the lava flows disappear near Dusay lake. Also, metasedimentary rocks become important near Feuilles lake, where they cover a large area.

Southeast of Bérard lake, four types of very characteristic sedimentary rocks are interstratified at different levels with gabbro sills:

a) shales, slates, phyllites, chlorite schists, hornfels;

b) feldspathic sandstones (yellow, black, red);

c) iron-bearing rocks;

d) dolomites.

These rocks are only slightly metamorphosed, the only metamorphism of importance being at the contacts with gabbro sills. As these rocks are rare and poorly represented in the field, they have been placed by the writer with the appropriate metamorphic rocks on the basis of stratigraphic position.

The principal types of metamorphic rocks of the area belong to the following sequences:

1. Pelitic and arenaceous sequence:

    a) mica schists, slates, phyllites, chlorite schists;

    b) quartzite;

    c) various sandstones.

2. Carbonate sequence:

    a) meta-dolomite;

    b) calc-pelites and calc-arenites;

    c) iron-bearing rocks.

3. Plutonic sequence (to be discussed in a later section of the report).

Outcrops of metasedimentary rocks are particularly common around Feuilles lake. In many places, the bedrock is completely stripped of loose material. However, the valleys that empty into the bays of Feuilles lake are entirely filled with fluvioglacial debris and the bedrock is concealed, thus complicating efforts to provide structural and stratigraphic interpretations.

It is difficult to evaluate the thicknesses of the pelitic and carbonate sequences of the metamorphic series, because of the many gabbro sills that more than double the total thicknesses of these sequences, and also because of the various types of deformation that have affected the rocks. As one approximation, it is thought that the sedimentary rocks lying under the sill west of Refuges bay are about 3,000 feet thick, and a similar thickness probably overlies the sill.

Petrography

The sequences, pelitic and arenaceous on the one hand, and calcareous on the other, include all of the metamorphic rocks of the area. They are made up of stratified assemblages, of variable thicknesses, representing old sedimentary series that were recrystallized in the depths of the Labrador Geosyncline. In the present chapter, the metamorphic series is described in the same way as the sedimentary series, except that the special characteristics of regionally metamorphosed rocks, such as foliation and recrystallization, are added to the stratigraphic characteristics.

Pelitic and Arenaceous Sequence

The great diversity of mineralogical associations in the micaceous and sandy schists results from variations in sedimentary facies and in metamorphic conditions. In classifying such rocks, the writer places both contact and regionally metamorphosed rocks, and even granular rocks, in the same facies. Nevertheless, when feasible, the contact metamorphic facies is distinguished by means of field relationships as well as mineralogic associations.

Phyllites, chlorite schists, mica schists and gneisses - The principal mineralogical assemblages of this pelitic and arenaceous sequence belong to the greenschist facies. These rocks occur at different stratigraphic levels, but are particularly well represented at the base of the gabbro sills that overlie the Abner dolomite south of Feuilles lake.

The schists are green, grey or black, depending on the predominance of chlorite, sericite or biotite, and are fine- to medium-grained. Foliation is well developed. In addition to stratification, these rocks have a schistosity which is more and more marked as the micaceous content increases.

The bedding is revealed, despite metamorphism and deformation, by an alternation of thin layers of quartzo-feldspathic sandstone with pelites.

Microscopic analysis shows that three greenschist sub-facies are represented here. The most common mineralogic assemblages are:

Quartz-chlorite-sericite-(albite)
Quartz-chlorite-sericite-biotite-(albite)
Quartz-biotite-(chlorite)-sericite-(albite)
Quartz-biotite-(chlorite)-microcline-albite-(epidote)
Quartz-biotite-chlorite-albite-epidote

The order of listing has no quantitative implication here, in view of the many variations from one rock to another.

In addition to the essential minerals listed above, the schists contain many accessory minerals, such as apatite, stilpnomelane, tourmaline, cordierite, calcite, zircon, graphite, pyrite, magnetite, and sphene.

Quartz, the dominant mineral, has a characteristic granoblastic texture, owing to the presence of non-oriented, isometric grains, 0.05 to 1.5 mm. in diameter.

As is indicated by their strongly indented structure, the detrital quartz grains have been "welded" together. The borders of the grains are not preserved, except where the grains are isolated in a chloritic or sericitic matrix; in such cases, the border reveals the arenaceous nature of the rock.

Some of the quartz grains carry inclusions of chlorite, sericite, apatite, zircon and microcline. Generally, however, they are clear, lack inclusions, and have an undulatory extinction. This permits the recognition of two processes which, depending on circumstances, tend to replace each other: one, the crushing of original minerals, is physical and destructive; the other, the appearance of new minerals, involves chemical and constructive action.

The dual activity of cataclasis and recrystallization is evident from micaceous minerals lying parallel to the foliation or perpendicular to it.

Muscovite abounds in all of the rocks of the greenschist facies. As small flakes, 0.005 to 0.1 mm. in diameter, the mineral is associated, in many places intimately, with chlorite and biotite. In places, also, flakes of muscovite alternate with the chlorite or biotite.

The lepidoblastic texture of the muscovite resulted from recrystallization of sericite during deformation and metamorphism. This secondary muscovite rarely contains inclusions, is usually colourless in thin-section, and is strongly birefringent. Some is tinted pale green, but pleochroism is absent.

The texture of the biotite is lepidoblastic in some schists and porphyroblastic in others. In the former case, the flakes of biotite lie flat in the undulating schistosity planes, and their extinction is parallel to the schistosity.

The chunky biotite porphyroblasts, 0.5 to 3 mm. in diameter, give the rock a spotted appearance. Their basal cleavage (001) is perpendicular to the plane of schistosity, and the X axis may be elongated in any direction in this plane. All of the porphyroblasts are spotted with spherical inclusions of quartz and with small crystals of radioactive zircon surrounded by pleochroic halos. The quartz globules and the halos have an average diameter of 0.05 mm. (Plate X-B). The biotite, dark brown and strongly pleochroic, is identical in both of the textural varieties.

As with the biotite, the chlorite may be porphyroblastic or lepidoblastic in texture. The rare chlorite porphyroblasts accompany those of biotite. They carry abundant zircons surrounded by pleochroic halos, as well as globules of quartz, exactly as in the biotite.

With rare exceptions, albite accompanies the mica schists. Its molecular anorthite content is low in all cases, ranging between An_3 and An_7. Both the albite and the intimately associated quartz are granoblastic in texture. Crystals are 0.3 to 1.5 mm. in diameter, the size depending on the degree of recrystallization. Here and there, albite porphyroblasts, 1.5 to 2 mm. across, give an augen appearance to the rock.

The content of microcline (detected by chemical reagents) in the rock averages 1%; it may be absent, as in the pelitic schists, or it may make up nearly 5% of the rock, as in the quartzo-feldspathic schists.

Epidote is generally rare, although the schists west of Profonde and Sèche bays contain 10-20% of the mineral in some zones. The crystals are elongated prisms which range from 0.05 mm. to 1.5 mm. or even more in size, and are colourless but highly refringent and birefringent. Some of the epidote crystals enclose a brownish core surrounded by a pale brown halo. The cores are probably metamict allanite - in other words, allanite changed to a dark brown, opaque material by internal reorganization caused by radioactive thorium contained in the allanite. Such metamictization probably was identical with that which affected the biotite and chlorite.

PLATE X

A.– Photomicrograph of biotite schist containing albite, quartz and epidote. Crossed nicols, × 80.

B.– Photomicrograph of grunerite schist in contact with a gabbro sill. Note the pleochroic halos in the grunerite. Natural light, × 80.

Black, iron-rich tourmaline is in triangular crystals that tend to be needle-like. This mineral is generally rare, but, in some zones near gabbro sills, it makes up as much as 10% of the rock. It has a dark blue or mauve birefringence.

Calcite and dolomite are largely recrystallized, and have a mosaic or interstitial texture. The calcite commonly forms veins and fills interstices, whereas much of the dolomite is in perfect rhombohedra. Such dolomite porphyroblasts average 1/4 inch in diameter, but may be as much as 1 inch across.

Stilpnomelane, pyrite, sphene, apatite and iron-bearing minerals make up a very small part of the rock.

The mineralogical assemblages just described apply to the schists that formed through regional metamorphism. Similar pelitic and quartzo-feldspathic rocks, exposed to contact metamorphism against gabbro sills, are described below.

In addition to the minerals mentioned above, the spotted schists and hornfels contain appreciable quantities of garnet, actinolite, grunerite-cummingtonite, ferro-stilpnomelane and stilpnomelane.

Much of the actinolite contains inclusions of radioactive minerals surrounded by doubly concentric halos. The interior parts of the halos are dark brown and are surrounded by perfectly circular pale brown coronas. The interiors are from 0.01 to 0.05 mm. in diameter; the outer rings, from 0.03 to 0.07 mm.

The biotite and chlorite also carry abundant pleochroic halos. The garnets are very irregular in shape and have a poikiloblastic texture,— that is, they enclose other automorphic or xenomorphic minerals. Some crystals contain so many inclusions of xenomorphic quartz that the garnet appears to be intergranular between the quartz grains and has almost disappeared.

Quartzites - A north-striking band of meta-quartzite, some 150 feet thick, lies west of Sèche and Baleine bays. It is in massive beds 6 inches to 4 feet thick, and is white, grey, or pale yellow when fresh. It is white-weathering almost wherever exposed.

The average mineralogical composition is:

Apatite	tr.	Phlogopite	1%
Biotite	3%	Plagioclase	7%
Calcite	3%	Pyrite	1%
Chlorite	2%	Quartz	75%
Dolomite	2%	Stilpnomelane	tr.
Muscovite	5%	Tourmaline	tr.
		Zircon	tr.

The metamorphic quartzites show sericite replacing microcline, and contain biotite, authigenic tourmaline, and fresh plagioclase. These criteria distinguish them from the sedimentary quartzites.

The quartz has a very much indented, granoblastic texture, and carries rare inclusions of chlorite, sericite, biotite, zircon and plagioclase. The extinction is wavy.

Albite (An_{5-10}) is intimately associated with quartz and is also granoblastic in texture. It shows repeated albite twinning. Some of the grains have a sieve texture (a variety of poikiloblastic texture), and carry innumerable, small, spherical inclusions of quartz.

Biotite, chlorite and muscovite lie in the bedding planes between the grains of quartz. Calcite and dolomite serve as the cement in some carbonate-rich facies, and there is a gradual passage from pure quartzites to the calcareous pelitic rocks that are described later in the report.

Various Sandstones - Under this heading are grouped the sandstones near Laric and Lachance lakes which appear in exposures hundreds of feet long. They are not seen elsewhere in the area.

Black feldspathic sandstone, some 30 feet thick, outcrops about a mile north of Couteau lake. Here, it forms resistant interbeds in micaceous schists and black slates. Veins of white quartz cut the rock in all directions.

The dark colour is caused by magnetite dust which covers most of the grains. Microcline and quartz are the main constituents, and their detrital nature is well preserved; the grains are well rounded and range in size from 0.5 to 3 mm. The matrix is chloritic-sericitic.

The approximate mineralogical composition is as follows:

Quartz	55%	Plagioclase	3%
Microcline and micropherthite	20%	Epidote	1%
Chlorite	8%	Magnetite	1%
Sericite	7%	Apatite	tr.
Calcite	4%	Sphene	tr.

The deformation of the grains and the stretched borders that surround them give an indication of the mechanical deformation that the rocks have experienced.

A pale yellow feldspathic sandstone, about 50 feet thick, outcrops for 300 feet along the shore of Lachance lake. It is very hard and erosion-resistant, and is almost an orthoquartzite. It is cut in all directions by numerous veins of quartz.

The detrital grains that make up this rock are well rounded and range from 0.1 to 3.0 mm. in diameter. Secondary quartz, as well as calcite and sericite, forms the cement. The average mineralogical composition of the rock is as follows.

Quartz	75%	Magnetite	tr.
Microcline	15%	Limonite	tr.
Sericite	5%	Pyrite	tr.
Calcite	3%	Apatite	tr.
		Chlorite	tr.
Chert and slate fragments	1%	Zircon	tr.

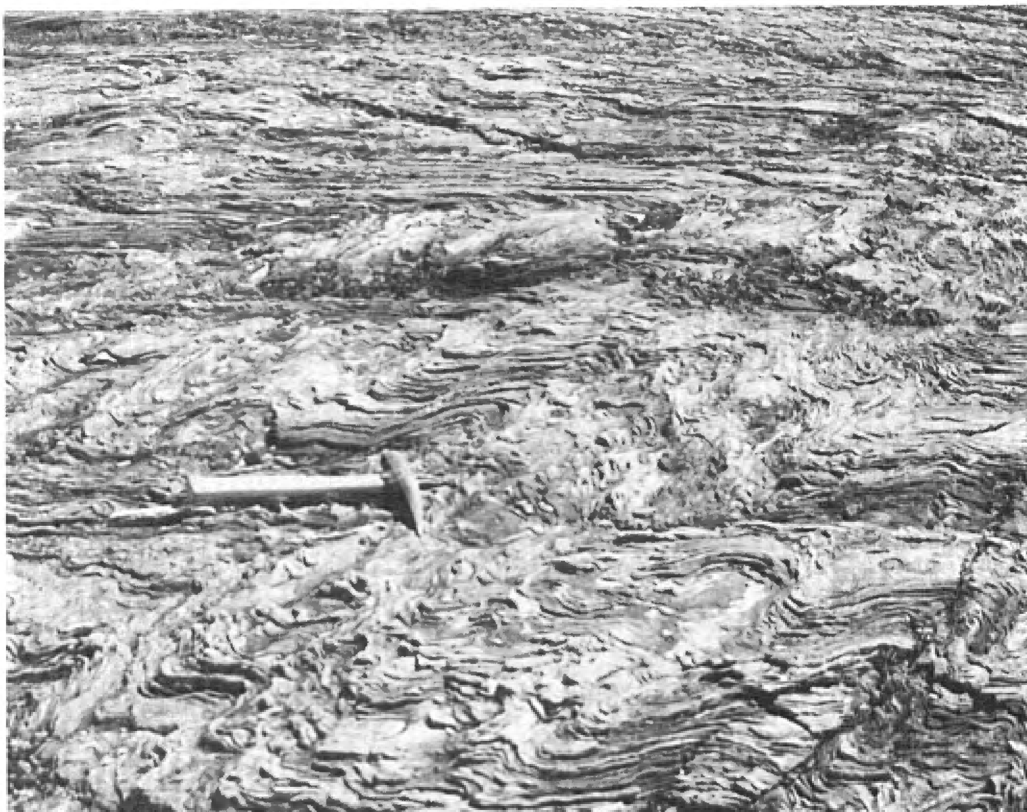
<u>Carbonate Sequence</u>

The carbonate horizons are easily recognized in the field by their pale yellow weathered surfaces. Exceptions were noted in the tidal zones around Feuilles lake, where the colour of the weathered surface is not diagnostic. Identification is consequently more difficult here, particularly where sandy carbonates alternate with quartzo-feldspathic schists.

The carbonates may be divided into three main classes: meta-dolomites, calcareous pelites and arenites, and iron-bearing rocks of very limited importance. The first two are so intimately associated that it is difficult, and in places impossible, to separate them into distinct units.

7

PLATE XI



Folded meta-dolomite of the metamorphic series, west of Sèche bay.

Meta-dolomite - Meta-dolomites are common south and west of Sèche bay, west of Profonde bay, north of Feuilles bay, and along Boyer river. The rock is strongly foliated, rarely massive, and is strongly folded almost throughout (Plate XI). The foliation was caused by the folding, and is evidenced by a multitude of parallel veinlets of quartz.

The thickness of the rock is difficult to determine because of the deformation it has undergone. East of Arpenteurs bay, however, the carbonate assemblage, consisting of meta-dolomite and dolomitic schists, is at least 600 feet thick.

The principal mineralogic assemblages of the meta-dolomites are:

Dolomite-quartz-muscovite (or phlogopite)
Dolomite-quartz-talc-calcite-(albite)
Tremolite-dolomite-talc-(muscovite-calcite)
Tremolite-dolomite-calcite

Some slightly metamorphosed horizons contain up to 95% dolomite. This mineral, crystallized in a mosaic form, is very fine-grained, in contrast to the always coarse-grained Abner dolomite. The crystals rarely are more than 0.05 mm. in diameter, except in veinlets, and they have a sugary appearance in thin-section.

Calcite (determined with the help of copper nitrate) is associated almost everywhere with the dolomite. It also is fine-grained, except in veinlets.

Quartz is important in some of the rocks, and the proportion of quartz to carbonate forms the basis for the separation of quartzose dolomites from calc-arenites, as described below.

In places, the dolomites carry an appreciable quantity of quartz as accretions or as veins lying parallel to the schistosity. Such quartz is metamorphic in origin, and is derived from the rearrangement of primary quartz along tension planes that correspond with the schistosity. Almost all of it is clear and devoid of multiple inclusions. A wavy extinction was noted in some cases.

Where the dolomitic carbonates have been somewhat metamorphosed, whether by heat from a gabbro sill or by regional deformation, the dolomite and accompanying quartz have combined to form tremolite. The fibrous tremolite gives the rock a velvety appearance. In thin-section, randomly arranged needle-like crystals form a schistose background for phlogopite, quartz and albite. Rocks that contain nearly 95% tremolite (the rest being calcite and dolomite) form thick beds east of Arpenteurs bay.

Talc accounts for part of the magnesium content of the meta-dolomites, and is an important part of the rock where it is associated with tremolite or with quartzose dolomite. It is most common in contact zones with gabbro sills.

Muscovite appears on the schistosity planes, giving them a shiny appearance. Biotite and phlogopite occur most commonly in the well crystallized marbles. Phlogopite, particularly, is associated with talc and tremolite in the form of completely crystalline masses.

The rare meta-dolomites that carry albite are close to intrusive rocks, and could well have received, through metasomatism, important contributions from the intrusive bodies. In fact, alkaline metasomatism could have played an important role, as will be shown in the description of the contact meta-dolomites. The albite is not twinned, and carries an appreciable quantity of various inclusions.

Traces of chlorite, magnetite, zircon, pyrite, and limonite accompany most of the meta-dolomites.

The regionally metamorphosed rocks have been described above; identical rocks that have undergone contact metamorphism are described below.

The granoblastic texture of the dolomitic marbles and the felted texture of the tremolite marbles are superposed on the spotted contact schists, and the zoisite porphyroblasts are partly replaced by tremolite. In addition to the minerals mentioned above, the contact meta-dolomites contain diopside, microcline, zoisite and actinolite. The last two minerals are in porphyroblasts 1/4 inch to more than 1 inch long.

Diopside is rare, and was generally altered to tremolite during regional metamorphism. Interstitial microcline is present in amounts up to 20% in some rocks rich in tremolite, diopside, dolomite and quartz. These rocks also contain veinlets of microcline, similar to those of quartz and calcite.

It is believed that alkaline metasomatism was responsible for the transfer of potassium and sodium. At the contacts with gabbro sills, in fact, the residual solutions of basic magmas were, in many cases, sufficiently rich is sodium and potassium to enrich the adjacent rocks with these elements (Turner and Verhoogen, 1951, p. 487). Another very convincing argument (apart from the number of microcline veinlets that cut both the gabbros and the adjacent sedimentary rocks) comes from the presence of tectonic breccias accompanying the sills. These breccias are cemented by pink microcline and a small amount of quartz.

Even albite was observed in the meta-dolomites. The sodium was probably introduced into the rock in the same manner as was the potassium.

Some thin layers are made up almost entirely of zoisite porphyroblasts oriented in the bedding plane, whereas in others the porphyroblasts do not show any preferred orientation and are isolated in the matrix of the rock.

Calcareous pelites and arenites - Under this heading are included dolomitic rocks containing some detrital material. Although such rocks do not belong to definite horizons, they are particularly common south and east of Sèche bay, on the islands in Feuilles lake, and in the vicinity of Refuges bay. They weather pale grey to buff, depending on the content of carbonates and on the degree of metamorphism.

The main constituents of the dolomitic schists are dolomite, quartz, tremolite, calcite, microcline, biotite, muscovite, and epidote. Accessory minerals include allanite, zircon, iron oxides, chlorite and apatite. The dolomite and calcite are finely granular, and show a strongly indented granoblastic texture.

Quartz is in sandy beds that alternate with pelitic or dolomitic beds. Much of the mineral is contained in lentils lying in the schistosity planes. These planes, which in places coincide with the axes of minute folds in the schists, consequently may be either transverse or parallel to the bedding. In the more massive beds, the texture of the quartz is granoblastic. The grain size is variable, but is rarely more than 1.5 mm. The quartz is not fractured, and generally has a weakly undulating extinction.

The biotite, muscovite and microcline of these rocks are identical to those of the mica schists described above.

Epidote, clinozoisite and allanite are common in all of the thin-sections examined. Allanite forms the central core of the epidote or clinozoisite. This dark brown core results from metamictization, owing to the radioactivity of the thorium in the allanite.

Epidote forms small, stocky, euhedral prisms. In fractured crystals, both the fractures and the edges of the crystal are outlined in brown. These brownish outlines leave the metamict allanite core and converge toward the exterior as if a part of the radioactive element had moved outward along fractures already present. Apparently the increase in pressure within the crystal, owing to radioactive disintegration, was able to fracture the crystal outward from the core, thus allowing part of the disintegration products to escape.

Clinozoisite resembles the epidote in natural light, but its birefringence is clearly weaker and, further, it is twinned along the (100) plane. In addition to allanite the clinozoisite carries inclusions of calcite, quartz, and microcline.

Iron-bearing rocks - Two outcrops of iron-bearing carbonate rocks were seen near Laric lake. They are composed mainly of ferrodolomite and stilpnomelane. Some beds carry chert and iron oxides; others carry stilpnomelane and chert accompanied by a little carbonate and some silicates. The silicates are so finely crystallized and so closely associated with stilpnomelane that they could not be positively identified. Nevertheless, tremolite and a small amount of pyroxene are believed to be present.

Structure and Texture

The schistose cleavage ("s" plane) is particularly well developed in the pelites and meta-dolomites. In the pelites, especially, foliation surfaces carry striae oriented in the same direction as the foliation. In profile, they appear partly as small waves with rounded summits, partly as angular tooth-like projections. All of the crests are inclined in the same direction.

The general direction of movement,—that is, the direction in the schistosity plane that is perpendicular to the lineation, corresponds to the "a" axis. The lineation corresponds to the "b" axis, and the "c" axis is perpendicular to the schistosity.

In addition to the "b" lineation, some samples have an "a" lineation (Cloos) corresponding to the elongation of crystals in the schistosity plane.

In places, the schistosity is complicated by a secondary fracture cleavage that is dependent upon the foldings of the "b" lineation. The fractures, which are rather poorly developed, join the crests of the folds and correspond to the fold axis of each. The fracture plan does not correspond to the "c" axis but, instead, cuts it at an angle of a few degrees.

Fracture cleavage affects the sandy metasedimentary rocks particularly, and these break readily into 1/8- to 3/4-inch-thick plates which may be as much as 20 to 30 square feet in area. This cleavage may cut, or be parallel to, the bedding, and it is evident that it cuts the primary structure which consists of gently curving closed folds.

Schistosity and fracture cleavages, for the most part, strike S.15°E. and dip east. The only exceptions to this general rule relate to the rocks in the structural basins near Refuge and Profonde bays.

The pelitic sequences, both arenaceous and calcareous, have all been folded. The folds, however, are upright, and thus the true stratigraphic sequence is still apparent. These folds also dip eastward, although this feature is generally obliterated by fracture cleavage.

Southeast of Sèche bay, the metamorphic rocks are largely involved in a complex structure that consists of sedimentary layers and diverse sills. The tops of the folds are cut by thrust faults which preserve the general character of the structure as far as strike and dip are concerned.

Correlation

Certain horizons, such as the schists and meta-dolomites, lend themselves to comparison with sedimentary formations farther west. The biotite schists and chloritic schists, of pelitic or sandy origin, have many features in common with the chloritic schists of the Larch River and Chioak formations.

When one follows the Abner formation northward, it is readily traced to Rouge bay, where it is represented by a small outcrop about 50 feet thick. Here, the dolomite is in contact with a thin gabbro sill.

North of Feuilles lake, bands of foliated dolomite totalling 500 feet in thickness overlie graphitic and chloritic schists and underlie dolomitic and chloritic schists, the whole being topped by a thick gabbro sill.

The two types of dolomite are compared in the following table in terms of megascopic and microscopic characteristics:

Table IV

Abner dolomite	Metamorphic meta-dolomite
Colour of weathered surface	
buff, brown, pale yellow	pale green, buff, rusty
Colour of fresh surface	
white, black, grey, rose, yellow	grey, black, pale green (common)
Appearance	
massive, devoid of structure; quartz veins trending in all directions	schistose; abundant quartz veins parallel to the schistosity
Mineralogy	
dolomite (90%), quartz, calcite (tr.)	dolomite (60%), tremolite, quartz, sericite, talc, calcite
Detrital material	
trace	abundant
Bedding	
visible almost everywhere in spite of folds and plastic deformation	probably parallel to schistosity, but impossible to determine except where sandy beds are present
Deformation	
none or very weak	weak to very strong; folded beds
Granularity	
large allomorphic crystals of twinned dolomite	small granoblastic crystals of dolomite, rarely twinned
Stratigraphic position	
overlies the detrital Chioak formation and underlies detrital rocks (chloritic or phyllitic schists)	overlies and underlies chloritic schists

From the above comparisons, it appears that the two dolomites are very different, one being metamorphosed and the other showing no evidence of major recrystallization. The distinguishing characteristics may be explained in one of two ways:-

1) the two dolomites could belong to two distinct formations;

2) they could belong to the same stratigraphic unit, in which case they must have been deposited in different environments and at different depths.

In the light of present knowledge, including petrographic and structural data, it is thought that the Abner dolomite and the meta-dolomite belong to different horizons, and that the latter was brought to its present position by deformation and by thrust faulting over younger rocks.

Gabbro

General

Gabbro sills are numerous in the sedimentary rocks of the Labrador Trough, and are the only intrusions of any importance at the latitude of Fort Chimo. They are thickest in the center of the Trough, where they constitute 20% of the bedrock. Most of the sills are many miles long and die out very gradually. The intrusive relations of the gabbro are shown by the following features:

1) they push up, disturb and dislocate the overlying beds;
2) they include transported fragments of adjacent beds;
3) they subdivide to produce thinner sills and to surround lenses of sedimentary rocks;
4) they generally conform to the walls and roof of the enclosing rocks, but cut across these in places to form oblique dykes and apophyses;
5) around the sills and apophyses have developed - a) a fine-grained chilled texture, and b) contact metamorphic aureoles, a few millimeters or centimeters thick, in the enclosing rock;
6) the rock is holocrystalline at the center, and the upper parts of the dykes include pegmatitic lentils;
7) many thick sills display the effects of magmatic differentiation.

Distribution and Thickness

In the southern part of the area, the gabbro sills occupy only a narrow, arc-like band along the eastern border. However, in the northern half, the gabbros are more abundant and cut almost a third of the surface of the Trough.

At the latitude of Merchère lake, the gabbros are 8 miles from the basement rocks, but they gradually approach to 1/3 of a mile near Boyer river.

The individual sills vary considerably in thickness, some being only a few feet thick and others being 2,000 feet or more. The thickest (1,000-2,000 feet) are located north of Refuges bay and east of Larch lake. Sauvé (1957) records thicknesses of up to 3,500 feet. In general, however, the sills are 50 to 300 feet thick. The sills on the islands in.Feuilles lake are 5 to 25 feet thick. They are uniform in composition and lack noteworthy structures.

Description

The colour of the gabbros varies greatly, from black or dark green to pale grey or pale green, and depends on the degree of metamorphism, the composition and the grain characteristics.

The thickest dykes are well stratified or banded as a result of magmatic differentiation. The gabbro east of Lachance lake consists of alternating layers of different compositions, and is beautifully banded. On the weathered surface, brown bands, 2 to 4 feet thick, alternate with thicker, dark green bands. The brown bands are divided longitudinally into two symmetrical parts by a quartz-filled fissure. On each side of the fissure is a band of gabbro rich in blue quartz. This, in turn, is bordered by a gabbro band marked by many longitudinal fissures. The dark green bands are massive, low in quartz, and lacking in gross structures.

In addition to this spectacular banding, the thick sills possess an indistinct banding that can be seen only from a distance. This denotes a gradual change in composition with, here and there, transition bands that are more apparent. These bands result from enrichment in feldspar or feldspar and quartz at the tops of the sills, and enrichment in ferromagnesian minerals at the base.

The sills are composed of holocrystalline rocks, being medium to coarse in the centers and finely crystalline even at the chilled borders. The thicker sills enclose lentils of pegmatitic gabbro and porphyritic gabbro in their upper parts.

North of Refuges bay, the gabbros carry inclusions, 1 foot to 25 feet in diameter, which were probably torn from overlying sedimentary roof rocks at the time of injection.

No feeder channel related to a thick sill was noted, but some dykelets that supplied very small sills were observed.

South of Sèche bay, an ultrabasic dyke cuts a thick gabbro sill. This, along with the presence of gabbroic pegmatites, was the only indication of residual magmatic activity.

Veins of quartz and epidote cut the upper parts of deformed sills in all directions. East of Rouge bay, the gabbro encloses masses of milky quartz covering many hundreds of square feet. North of Feuilles Lake, there are irregular masses of calcite and white quartz in the meta-gabbros.

Petrography

Following a detailed study of gabbros outcropping some miles east of the present area, Sauvé (1957) recognized seven related rock types, namely:

a) meta-diabase, meta-gabbro
b) anorthositic gabbro
c) ultramafic gabbro
d) pegmatitic gabbro
e) transition rocks, quartzose diorite, granophyre
f) dykes and veins
g) spotted gabbro

All of the basic sills in the Feuilles Lake area experienced regional metamorphism, and, because of this, the original mineralogic composition of the gabbro was changed. Where metamorphism was weakest (greenschist facies), saussuritization of the plagioclases and uralitization of the pyroxenes produced epidiorites made up of albite-epidote-actinolite. Under more intense metamorphism, the albite-hornblende-garnet assemblages were formed; these are equivalent to the epidote-amphibolite facies of Turner.

Epidiorite (meta-gabbro) - In the interior of the thick sills, the composition of the epidiorites varies owing to the settling of heavy minerals and the rising of lighter ones. Thus, gabbro rich in ferromagnesians is found at the base, anorthositic gabbro in the middle, and quartzose gabbro at the top. Much of the upper part is cut in all directions by lentils of pegmatitic gabbro.

Greenschist facies - The rock is pale grey or dark green, depending upon the proportions of pale grey plagioclase and bottle green actinolite. It is generally well crystallized, and the ophitic texture is perfectly preserved. Both the ophitic and the intergranular textures consist of rectangular crystals of saussuritized plagioclase enveloped in laths of uralitized pyroxene (Plate XII-A).

The average mineralogic composition of the epidiorites is as follows:

	%		%
Actinolite	25-55	Iron oxides	tr.-5
Albite a) microcrystalline	0-10	Pyroxene	0-tr.
b) eucrystalline	0-30	Quartz	1-15
Apatite	0-tr.	Rutile	0-tr.
Calcite	1-5	Serpentine?	0-1
Chlorite	5-25	Stilpnomelane	0-tr.
Epidote (and clinozoisite)	1-20	Sulphides	tr.-3
Leucoxene	1-3.	Talc	tr.-2
Microcline	0-tr.		

The original plagioclases of the gabbro have been altered to clinozoisite, albite, chlorite, quartz, and calcite. The albite pseudomorphs contain about 3% of the anorthite molecule. Where the rock is microcrystalline, albite and clinozoisite constitute semi-opaque aggregates within saussuritized plagioclase. In places, the eucrystalline albite transgresses the boundaries of the old plagioclase crystals, thus showing a more advanced reorganization and recrystallization.

Microcline, in places, forms minute veinlets as well as small interstitial globules in the quartzose epidiorites. The microcline was detected from its reaction to sodium cobaltinitrate after treatment with hydrofluoric acid.

Actinolite is the principal mineral of the greenschist facies of the epidiorites. It is in the form of crystals that may be either elongated or squat and that, in some cases, are twinned. In general, the actinolite is very pale green or colourless, and is weakly pleochroic in pale yellow and greenish yellow tints. It is derived from the uralitization of pyroxenes. An analysis of twenty thin-sections of gabbro revealed only two small crystals of pyroxene which resemble augite.

Chlorite is common, and is generally associated with actinolite. It may form irregular masses within actinolite crystals, or may surround them and thus form a border to the delicate acicular texture of the fibrous actinolite. The chlorite is pale to dark green, and in places is brown at the edges. The colourless variety shows rare pale green pleochroism; the pleochroism increases with an increase in green colouration.

A variety of chlorite with Prussian blue interference is probably penninite. Another variety, resembling glauconite in many respects, is found in recrystallized quartzose gabbros. It has a small, coiled, wormlike form.

Clinozoisite, in small grey crystals, is abundant. It is found only within rectangular forms that represent calcic plagioclase. The mineral is not easy to recognize, owing to its limited size and semi-opacity.

Elongated prisms of epidote within veinlets are commonly visible to the naked eye. They also accompany the clinozoisite and, in places, seem to replace the latter mineral. The strong birefringence of epidote readily distinguishes it from clinozoisite.

Primary, blue, translucent quartz is abundant in the upper parts of the gabbro sills. It fills interstices between actinolite crystals or forms irregular globules. Veins of white quartz, in places accompanied by calcite and epidote, cut the gabbro sills in all directions.

Ilmenite, partly replaced by leucoxene, is abundant in the ferromagnesian-rich facies.

Calcite commonly accompanies clinozoisite and albite in the saussuritized plagioclases.

Apatite, sulphides, talc, serpentine? and rutile may be observed here and there. Such sulphides as pyrite, chalcopyrite and pyrrhotite are common and can usually be seen with the naked eye. The presence of talc was revealed by X-ray analysis.

Epidote-amphibolite facies - This facies term is used in the present work to indicate the substitution of pleochroic hornblende for actinolite and to designate the albite-hornblende-epidote and albite-hornblende-garnet sub-facies (Turner, 1948).

If one attempts to separate the two main gabbro facies by an isograd, such a line would extend from Sèche bay to Arpenteurs bay. The greenschist facies would lie to the south of the line; the albite-amphibolite facies to the north.

The rocks of the albite-amphibolite facies are well crystallized, and the original structure of the gabbro is obliterated. The automorphic structure of the hornblende, and the recrystallization of quartz, albite and epidote, are responsible for this complete change of internal structure (Plate XII-B).

The albite-epidote-hornblende-quartz sub-facies is characterized by an allomorphic, sodic plagioclase, by dark green, polychroic, automorphic and prismatic hornblende, and by abundant small crystals of epidote isolated within a matrix of quartz.

The albite-hornblende-garnet-quartz sub-facies is identical to the above sub-facies except that it contains much garnet and little or no epidote. The garnet (probably almandine) carries inclusions of quartz, pyrite and chlorite. It is tinted brown by iron oxides at the borders and along fractures.

Biotite is an important constituent of some rocks. It is present as tiny flakes within other minerals, or is found in interstices in quartz.

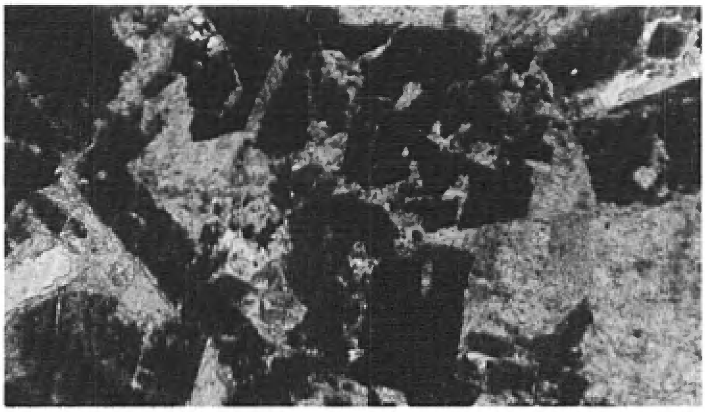
The hornblende carries inclusions of biotite, zircon, magnetite and quartz, and also forms pleochroic halos around some zircon crystals.

Almost all of the ferromagnesian-rich gabbros contain some magnetite.

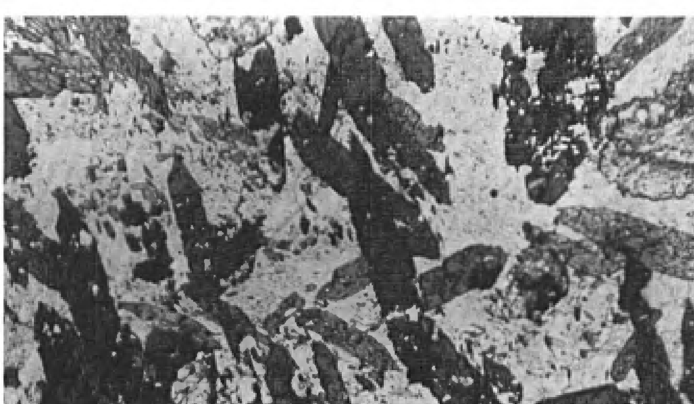
Amphibolite facies - In the neighbourhood of Boyer river, it would be possible to draw another isograd to separate the epidote-amphibolite facies from the amphibolite facies. This arbitrary separation is based solely on the appearance of oligoclase-andesine, which results from a partial reaction of albite with epidote.

The plagioclase (An_{28}) is clear and well crystallized. The hornblende is the same as that of the epidote-amphibolite facies. A little epidote, better crystallized than in other facies, accompanies the oligoclase. Sphene and iron oxides are abundant.

PLATE XII



A.— Photomicrograph of meta-gabbro. Pyrrhotite (black), plagioclase altered to albite and clinozoisite (dark grey), actinolite (pale grey), and quartz (white). Natural light, × 80.



B.— Photomicrograph of meta-gabbro. Hornblende, albite, quartz, garnet, and a little epidote. Natural light, × 80.

Ultramafic and anorthositic meta-gabbros - The foregoing section has described the intermediate gabbros of the area. Ultramafic and anorthositic varieties are also present, and a probable concentration of olivine at the base of a thick gabbro sill near Luc lake is particularly noteworthy. In thin-section, a multitude of little globules can be seen within actinolite crystals. The globules are clear, and their borders are marked by a corona of cryptocrystalline dust. Judging from the shape of the globules, and the presence of rare brown hornblende crystals, the rock was rich in olivine before being altered. As this rock was seen only at one place, it must be considered as a somewhat exceptional type.

Pegmatitic gabbro - Lenses and shapeless masses of pegmatitic gabbro occur near the summits of thick gabbro sills. The contacts between the pegmatite and the enclosing gabbro are very clear, and the passage from one type to the other takes place within a few centimeters. The pegmatites have the same composition as the enclosing rock; the only difference is in the size of the crystals. Some of the actinolite and hornblende crystals are as much as 8 inches long. Blue quartz fills the interstices between the plagioclases and amphiboles.

Spotted gabbro - Two quite distinct types of spotted gabbro are present. The more common type owes its texture to phenocrysts of plagioclase or to aggregates of plagioclase crystals ranging from 1/4 inch to 8 inches in length and from 1/8 inch to 3 inches in width.

The phenocrysts are milky white or pale grey on the weathered surface and stand out spectacularly from the matrix. The edges of the crystals are slightly rounded, and contacts with the matrix are very clear. In deformed sills, phenocrysts 3 to 6 inches long are stretched, broken and twisted in a fine-grained gabbroic matrix.

In the present area, porphyritic gabbros make up only a very small part of the thickest sills. Phenocrysts make up 15 - 40% of these rocks, whereas most of the gabbros generally contain less than 20%.

The phenocrysts are saussuritized, and are composed of clinozoisite and albite enclosing a little actinolite or hornblende, quartz and chlorite. A corona, 2 to 3 mm. thick, of well crystallized albite surrounds all of the phenocrysts in the thin-sections examined by the author.

The second type of spotted gabbro was seen only west of Laric lake. It occurs in the upper half of a thick sill, and is very much restricted laterally. The spots are oval aggregates of pale minerals, the aggregates being 3 to 12 inches long and making up about 5% of the rock. They are composed of quartz (55%), albite (35%), chlorite, a little biotite, talc (or sericite), sphene, leucoxene, and calcite.

Structure and Texture

In most cases, the gabbro sills lie parallel to the stratification of the enclosing rocks. Contacts are very clean and are easily recognized in the field. In fact, as most sills dip gently east, the walls are exposed along the steep west-facing slopes. In such places, the somewhat metamorphosed sedimentary rocks may be seen in contact with the chilled border of the gabbro.

Pseudo-bedding is an important and very characteristic feature. It owes its origin either to magmatic differentiation or to multiple injection. We believe that some of the "bedding" that displays sharp contacts was derived from multiple injections, whereas those gabbros with gradual variations in composition were derived, "in situ", by magmatic differentiation owing to gravity.

The inclusions observed in great numbers north of Luc lake were derived from the sedimantary rocks of the roof or enclosing wall, either by plucking or by collapse. These rocks, which were dolomitic arenites and massive dolomites, were transformed by metamorphism to a pale green talcose dolomite.

Prisms or rectangular columns are very common in thick gabbro sills. Such joint blocks are identical to those observed in the lavas and described in a preceding section of this report.

The gabbros were deformed during regional folding. Thrust faults at the base of sills, as well as transverse faults and shear zones, are widespread. The shear zones are almost all accompanied by massive sulphides such as pyrite, pyrrhotite and chalcopyrite.

A tectonic breccia at the base of a sill east of Lachance lake consists of fragments of gabbro surrounded by coronas, about 2 mm. thick, of pink microcline. The matrix is composed of calcite, sphalerite and quartz.

PLEISTOCENE

Erosion and Transportation

Many small features indicate that continental ice moved north-northeast over the area. These indications include glacial striae and grooves, polished surfaces, and friction cracks.

About one hundred glacial striae or sets of striae trend N.30°E. Some of these are 1 to 2 cm. deep, 10 to 15 m. long, and semi-circular in section. The northwest flanks of some hills are marked by striae and grooves; these are particularly common on the steep faces of lavas and gabbros. In general, the striae are abundant on rocks that are hard, resistant to erosion, and have flat or gently sloping surfaces. In particular, the Chioak sandstone west of Chioak lake is marked by well formed, parallel striae (Plate XIII-A), accompanied by friction cracks (to be described below).

Other glacial striae trend between N.15°E. and N.60°W., but it was not possible to date these features relative to those described above. Some definitely cut the N.30°E. set; others seem to be cut by the latter.

Even though the striae indicate the trend of movement of the glaciers, they do not, in all cases, give the true direction of movement. A statistical study of many striae suggests that most of them, although they terminate almost imperceptibly, point to the north, — that is, they give the true direction of movement of the ice. These observations are in accord with the general theory, but it should be noted that they were recorded on surfaces that were essentially flat.

The best indicators of the true direction of movement of glacial ice are friction cracks. Harris (1943) and Flint (1955) described and classified these as follows (Figure 1):

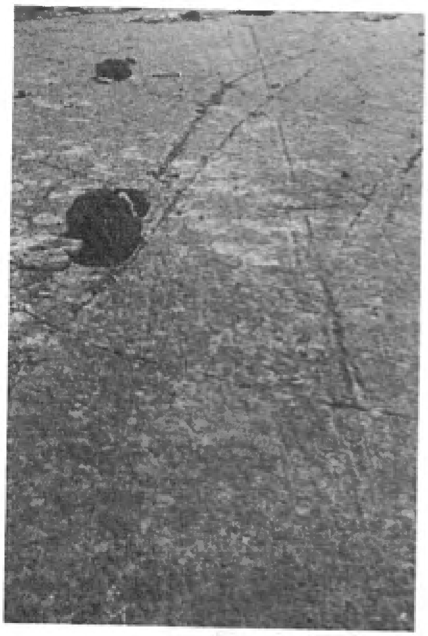
a) Crescentic gouges are concave upstream and consist of two fractures from between which the rock has been removed.

b) Lunate fractures resemble the above except that they are concave downstream.

c) Crescentic fractures are concave downstream and consist of a single fracture only, without removal of any rock.

d) Chatter-marks occur only within larger grooves, are concave downstream or not concave at all, are made by the removal of a chip of rock, and possess no fracture that extends deeper than the scar left by the removal of the chip.

PLATE XIII



A.– Glacial striae trending N. 35° E. on beds of Chioak sandstone.

B.– Crescentic glacial fractures.

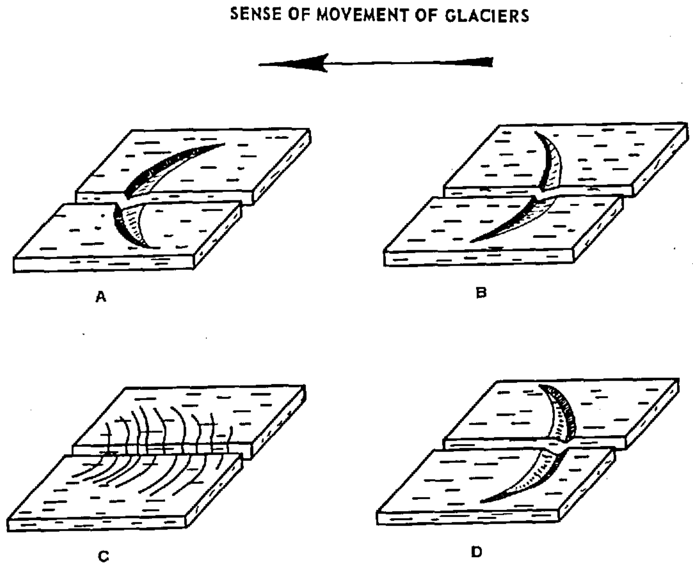


Figure 1.- Schematic drawings of friction cracks caused by the movement of glaciers over polished rock surfaces. (After R.F. Flint, 1955; S.E. Harris, 1943).

a) Crescentic gouge

b) Lunate fracture

c) Crescentic fractures

d) Another type of lunate fracture found in the present area (identical with "a", but indicating opposite movement).

All such fractures are very common in the area, but particularly so on the Chioak sandstone west of Chioak lake (Plate XIV). Lunate fractures, 1 cm. to more than 1 m. long, and 1 to 3 cm. deep, are not rare. Crescentic gouges opening upstream have the following approximate dimensions: 2 - 5 cm. deep at the bottom of the concave part and from 2 cm. to 1 m. or more long. These lines of evidence, as well as the transportation of boulders, show that the main ice movement was in a N.30°E. direction.

A very large number of drumlins cover the Archean basement rocks in the western part of the area. They are in individual groups of twenty or thirty, and range in size from 1/4 to 1 mile long and from 300 to 500 feet wide. They are made up almost entirely of debris from the local rocky hills.

East of the north end of Bérard lake, spectacular crag-and-tail structures are elongated in a N.30°E direction. One that is 3 miles long has a steep rock exposure at its south end, followed northward by a long tail of detrital material. This also indicates a N.30°E. movement of the glaciers.

Giant, parallel gouges, 100 to 300 feet wide, are elongated N.30°E. in the area west of Sèche bay (Plate XV-B). These extend over a width of 3 miles and a length of 10 miles. They are developed in detrital material for the most part, although some are in well-jointed rock.

Deposition

Two major classes of glacial deposits are present in the area, — namely, tills and stratified deposits. The tills, which were left behind in great disorder, cover a large part of the granitic plateau. Composed of loose material of all sizes, they have a predominance of boulders and sand, and clay is rare. In some places, later washing by glacial melt waters modified the original composition of the tills so that only concentrations of pebbles were left. Some of these, however, cover large areas.

Erratics are found throughout the area, and some huge ones are perched on the tops of gabbro and lava hills.

The morainic deposits of the area belong to three categories: ground, lateral, and frontal moraines. Ground moraine cover the bottoms of valleys in particular. Debris litters the valley floors from one side to the other. This almost invariably produces long, narrow,

PLATE XIV

A.– Crescentic fractures of glacial origin in the Chioak sandstone. The direction of ice movement is indicated by the head of the hammer.

B.– Crescentic gouges and glacial striae.

shallow lakes, many of which drain through the loose soil. This type of moraine is particularly common in valleys between gabbro sills in the eastern part of the area, as well as in the western valley, near the contact with the basement, and in the valley of Merchère, Garigue and Bérard lakes.

The lateral moraines of the area offer little that is unusual in themselves, but, thanks to marine erosion marks and terraces cut in them, they bear witness to important geological events. West of a large bend in Bérard lake, morainic deposits are perched some 300 feet above the level of the lake. These deposits seem to be lateral moraines, but could also be kame terraces. They are almost continuous, although interrupted here and there by rock exposures.

On the rocky flanks on each side of Feuille river, deposits of glacial detritus are perched at identical altitudes. The deposits have an even surface that slopes gently toward the valley. Three marine erosion shelves, cut at different elevations, extend parallel to the valley. It seems evident that the deposits are lateral moraines, but it is possible that, at some places, they are covered by kame terraces.

Two hypotheses are offered to explain the slope of these morainic deposits: 1) the lateral moraines may have slumped somewhat with the melting of the valley glacier with which they were in contact; or 2) marine action, which cut the terraces, could have redistributed the material and moved a good quantity of it to lower ground, thus giving a gentle slope to the erosion surface.

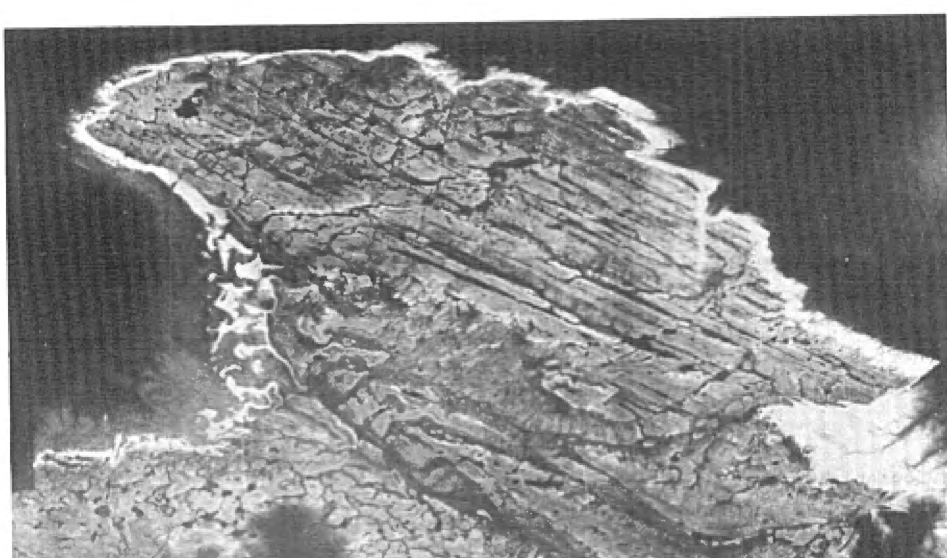
The valley southwest of Garigue lake is covered with ground moraine, with somewhat deteriorated lateral moraines and with a magnificent frontal moraine. The frontal moraine extends some 2,000 feet across the valley, is about 50 feet wide and 20 feet high, and is made up mainly of pebbles and boulders. It is arc-shaped, the concave side facing up the valley. The inner part of the arc is marked by a multitude of small glacial basins rarely more than 50 feet across (Plate XV-A).

The stratified glacial deposits of the area are interesting in their variety and distribution. They may be divided into two main groups: fluvioglacial and ice-contact deposits.

The main valleys carry very thick (up to 100 feet or more) fluvioglacial deposits made up of various materials, including clay, sand, pebbles, cobbles and boulders. In places, sand and boulders dominate; elsewhere, all of the fine material has been carried away by streams.

PLATE XV

A.– Frontal moraine and glacial lakes. Garigue lake is in the distance. Looking northeast.



B.– Aerial photograph showing giant glacial grooves in detrital material and in bedrock, east of Sèche bay. (R.C.A.F. photo).

Some thirty kames were noted, almost all around Merchère lake (Plate XVII-B). Some rise as much as 100 feet above the surrounding plain.

A somewhat flattened esker extends for several miles from the center of the southern part of Garigue lake. It appears to have been modified by water action when the lake was at a higher level.

Northwest of Mannic lake, an esker, 7 or more miles long, extends east-west. It is composed mainly of fine material, sand and pebbles. It is very regular, and easily traced throughout its length despite the presence of gaps made by streams cutting across it.

Most of the shore of Garigue lake and some of the shore of Merchère lake consist of a kame terrace, or a pseudokame terrace, resembling an esker. The deposit is about 15 feet high and 50 feet wide. One side of the kame terrace faces the lake, and the other borders a depression in which small, stagnant ponds occur.

It is doubtful, for many reasons, that this deposit originated in direct contact with the ice. It would be difficult, however, if not impossible, to be certain of its origin. In the first place, it circles the lake almost continuously and at one level; further, it is made up essentially of sand and clay, the latter being observed mainly in the lower part of the deposit. A 5-foot-deep trench cut across the deposit revealed only poorly cross-bedded sand and a very few boulders. At one place beside Merchère lake, a slide has exposed a thick bed of clay under 6 to 8 feet of fine, clean sand.

All of this evidence, even if it does not run counter to the ice-contact theory, leads to the belief that this deposit represents the remainder of a fluviatile terrace or of an outwash plain. However, the possibility of it being a kame terrace cannot be rejected, because, in places, rock spurs cut the terrace and also because some stream sections, or cuts, expose boulders and pebbles. Perhaps, then, the deposit could be a kame terrace that was remodeled by wave action when the lake was at a higher level.

RECENT

Erosion and Transportation

Water was the principal post-depositional agent affecting the glacial deposits. Torrential streams flowing down gorges and valleys carried everything with them to be redistributed at lower levels. East of Merchère lake, at an altitude of a little more than 650 feet above sea-level, hundreds of little lakes are oriented N.20°W. The lakes are shallow, fill depressions in fine gravel, and are separated from one another by gravel ridges or by bedrock. It would seem that a mantle of river gravel had been distributed thinly over an undulating surface underlain by slates.

In the center of the extreme south end of the area is a mesa-like deposit made up of mixed glacial material. Its summit, about 1/2 mile across, is more than 550 feet above sea-level. In view of the size of the deposit and the presence of terraces at identical altitudes on either side of the valley, it is likely that, formerly, the valley was completely filled with debris and that the waters readily overflowed beyond the present valley limits to rework the deposits of the plain east of Merchère lake.

Many terraces cut in alluvial deposits were noted along the valley of Merchère, Garigue and Bérard lakes. The terraces are at different altitudes, both longitudinally and transversely. This indicates that the river that formerly flowed through the valley had a considerable slope.

Along the banks of Feuilles river, two terraces, one 550 feet and the other 250 feet above sea-level, are perched on top of granite cliffs.

A few miles southwest of Dentelle lake, no less than six terraces lie between 200 and 600 feet above the sea. Some of these continue for many miles and may be compared with equivalent terraces on the west side of the north arm of Bérard lake.

The action of frost, although less important than that of water, offers problems of equal interest. The area is in the zone of discontinuous permafrost (Potzger and Courtemanche, 1955); in other words, the soil is not frozen everywhere. On the contrary, the soil thaws out during the brief summer season where exposed to the sun and where snow has not piled up. This applies particularly to south-facing slopes, although some are not affected. Permafrost is found at variable depths between 15 and 30 inches. The total thickness of the actual permafrost zone is not known to the writer.

Permafrost commonly accompanies such features as solifluction, polygonal soils, boulder rings, rock glaciers and landslides, all of which occur in the area. Solifluction produces giant ripples, recognizable only on aerial photographs. Polygonal soils of all types abound; some are of giant size, being as much as 75 feet, or even more, in diameter. They are recognizable only by lines or bands of moss or shrubs that grow on the looser soil at their borders. Their centers are rich in clay. Smaller polygons are arranged ladder-like on the slopes of hills, and some are present in shallow lakes. In many places, enormous boulders have been lifted by frost action (Plate XVI-A).

Deposition

Many peat bogs occur in the southern part of the area, some being about 10 feet thick. At one place, near Côuteau lake, a mass of peat has been completely changed to a red mass of limonite in which the original plant structure may still be seen.

TECTONICS

Nature of the Contact between the Archean Basement and the Proterozoic Cover

The western contact of the Labrador Geosyncline is an angular unconformity. In many places in the area, basal conglomerates or breccias composed of granitic material lie directly and discordantly on the source rocks. Elsewhere, conglomerates made up of chert, quartz and jasper lie on the basement. Also, quartzites and dolomites occur in old joints in the Archean surface. Deep gorges cut across the contact and, where the Archean consolidated regolith is well preserved by a thin cover of sedimentary rock, the old erosion surface of the Archean basement rocks may be seen.

The contact extends for 95 miles through the present area, and may be divided into four types, as follows:

a) true unconformity, 6 miles;
b) fault contact, 6.5 miles;
c) regolith, 0.5 miles;
d) assumed, 82 miles.

The last is based on structural relations, aerial photographs, the proximity of exposures of the two ages of rocks, and on angular rock debris.

The fault-contact classification applies only where faults are marked in the field by escarpments, by friction breccias, or by vertical or tangential displacement. At least eight fault scarps were examined. The most spectacular occur north of Bérard lake and north of the northern arm of the lake.

The regolith is made up of a thin bed of autochthonous sediments lying on the fresh granitic surface. In places, the fresh granodiorite gives place to a red rock less than 3 inches thick. The latter is slightly broken and covered with shaly siltstone. The siltstone may cement the rock splinters by virtue of intercalations up to 2 mm. or more in thickness. Such layers are cross-bedded and are made up of rhythmic alternations of very thin black layers and thicker lighter-coloured layers.

Stratigraphy and Structure

The relations existing between stratigraphy and structure are discussed below. Facies changes and variations in formation thicknesses are features that have a tectonic cause. When sediments accumulate in a trough, they are distributed by transporting agents that govern the sedimentation processes. Where a fault cuts sedimentary rocks, the raised side furnishes sediment to the adjacent depression. An illustration of this occurs west of Merchère lake, where the south side of a fault was completely stripped of its sedimentary cover and a thick conglomerate was formed from this material to the north of the fault.

The lavas and the Larch River formation disappear east of Dusay lake. They do not appear farther on. These formations apparently fade out either by mechanical discordance or through a stratigraphic break.

The Chioak and Abner formations are regular and continuous south of Feuilles lake. However, they disappear to the north of the lake, and perhaps suffered the same fate as the lavas and the Larch River formation. They may be represented to the north by a different facies and, if so, the structural history of the Geosyncline would be greatly simplified, and a broad-scale correlation could be based on the dolomitic rocks. On the other hand, it is possible that these formations are masked by several transverse and longitudinal faults.

Faults

In the following discussion, only the most important faults, clearly indicated by topographic or structural features, are considered. Geometric and kinematic analyses, etc., are made for each example given; in some cases, an explanation of the deformation in terms of dynamics is attempted.

In the Archean basement, four vertical faults of some importance have been mapped, each being well marked topographically. However, because of homogeneous rocks and the lack of reference horizons, it is not possible to evaluate the amount of movement. A general idea of the crushing intensity can be obtained from the degree of mylonitization and mechanical brecciation that accompany the faults.

Important faults were observed to the west of Merchère and Chaperon lakes. The one at Chaperon lake is nearly 4 miles long.

Three important strike faults extend along the contact between the sedimentary and basement rocks. In each case, the basement and the sedimentary rocks were dislocated at one and the same time. In places, the sedimentary rocks were bent upward against the basement, indicating that they had dropped relative to the latter. The tilting, at any one place, extended scarcely more than 50 feet. The best example of a contact fault is north of Bérard lake. Here, the fault faces south and the scarp is very clean and straight. Along the scarp, which rises above 250 feet, the granodiorite is crushed over a width of more than 200 feet. The fragments are in a matrix of chlorite, quartz, and dolomite. Slickensides are omnipresent; talc and minerals of the serpentine clan occur in shear fractures. It is quite evident that, toward the end of the Proterozoic, the basement took part in the movement along this fault. The vertical throw on the north side of the fault is at least 300 feet (a very conservative estimate). On the south side, the Alison quartzite, the iron-bearing rocks and the Chioak formation are cut by the fault and tilted upward near it.

At the north arm of Bérard lake and west of Quatre Ours lake, identical faults separate the sedimentary rocks from the basement. In each case, the sedimentary rocks are tilted upward at the fault, and the shear zone is accompanied by breccias composed of fragments of granite, ferriferous rocks and quartzite.

These three contact faults originated during the late stages of deformation of the Labrador Geosyncline. They are witness to the intensity of the horizontal thrust as well as to the importance of the resultant vertical component. The presence of gouges, or slickensides, oriented in three directions on the same surface should also be noted. The maximum divergence among them is 90°.

In addition to longitudinal faults, the contact zone between the basement and cover rocks includes numerous transverse faults, most of which are quite small. One of these, west of Merchère lake, merits attention because it prepared the way for important lithologic changes in the Chioak formation. Erosion must have continuously accompanied the uplifts of rock along the fault and cut down the projecting or uplifted part. As a result, the sedimentary rocks underlying the Chioak would appear in the conglomerates and arkosic sandstones in a more or less reversed position. This fault also gave rise to a ferriferous conglomerate, and brought a sliver of the lower dolomite to the surface.

About a mile west of Chioak lake, two transverse faults cut the Fenimore, Dragon and Chioak formations. Here, the beds are almost flat and undeformed. The throw is slight, and the displacement is made apparent only because the throw is vertical. The two faults lie at right angles, and the bisectrix strikes S.80°E. One is right-handed and the other left-handed. It would seem that these faults were the result of a thrust in a direction parallel to their bisectrix, and this hypothesis is supported by the joint pattern that accompanies the faults.

Some of the reverse strike faults cut the iron formation, quartzites and shales northwest of Dusay lake. The friability of most of the rocks made it impossible to trace the faults with any certainty, but they could be inferred from the following evidence: shearing, polished surfaces on the debris littering the crushed zones, the recrystallization of some rocks, and stratigraphic repetitions.

Many thrust faults are present in the eastern part of the area, a good number being observed in the sedimentary rocks underlying thick gabbro sills and lava flows. Most of them have very distinct characteristics. In particular, they are marked by westward-facing escarpments at the bases of which the sedimentaries that are almost invariably present include mechanical breccias and zones of sulphide mineralization.

The faults are well shown by topographic features, but the study of their movement is rendered difficult to impossible by a lack of reference points. Nevertheless, the importance of the horizontal movement may be appreciated by first studying the nature of the tectonic breccia and then evaluating the stretching out of the underlying formations. Thus, east of Dusay lake, the lavas and the Larch River beds are probably concealed beneath the gabbro sills. Here, a very thick tectonic breccia and some quite friable deposits of graphitic schist occur. The porous breccia is made up of angular fragments, 1 mm. to 5 dm. in diameter, of sedimentary rocks. Some of the fragments are composed entirely of graphite; others are shales or dolomitic schists that have been altered on the outside only. The cement is made up of limonite and clay minerals.

Near Lachance lake, a breccia localized in the sedimentary rocks under a gabbro sill consists of angular fragments of hornfels enveloped in a thin layer of pink microcline and cemented by calcite and sphalerite.

It is quite possible that a thrust fault separates the thick gabbro sills from the sedimentary rocks northeast of Refuges bay. In many places, the sedimentaries are sheared and the dolomitic rocks are altered to talc and to folded sericite schists. Such a thrust would explain the proximity of the gabbros to the basement rocks at this locality.

Folds

The valley of Garigue and Merchère lakes is localized on the flexure of a monocline. The horizontal part of the monocline represents a very distinct structural unit; the steeply inclined part to the east belongs to another unit.

Near Chioak lake, the sandy sedimentary rocks are in open, parallel, symmetrical folds, with a radius of curvature varying from 100 to 200 feet. The pelitic facies of the same formation are more strongly folded, and overturns to the west are common. The Abner dolomite west of the valley is practically undeformed, although, at some places, it is in chevron folds or in parallel folds cut by radial faults.

The structural unit of the eastern part of the area is more strongly folded, and closed folds, overturned to the west, are quite characteristic. South of Sèche bay, a dozen closed folds which were traced by the author had axial planes trending N.30°W. and axes plunging gently south. Most of these folds are right-handed, indicating a horizontal thrust from the northeast.

Near Feuilles bay, thick gabbro sills form large basins. One, east of Arpenteurs bay, is 2 miles in diameter. The underlying sedimentary rocks dip concentrically inward at angles rarely exceeding 20° - 25°.

Near Chaperon lake, the iron-bearing rocks and the quartzite appear to have formed in an embayment in the basement rocks and were later wedged into the base as an elongated basin. Symmetrically, an anticline formed above the spur of granitic gneiss near Monique lake.

The two systems of fold axes north of Feuilles lake, one trending north and the other east, probably belong to the same period of folding and simply reflect the irregular nature of the basement.

PLATE XVI

A.— Blocks of granite displaced by frost.

B.— Trellis joints in Chioak sandstone. The hammer lies in the bedding plane.

PLATE XVII

A.— En echelon joints in the Chioak sandstone west of Chioak lake.

B.— Kame in Merchère lake. Abner dolomite in the background.

Joints

The Archean basement is cut in all directions by several series of joints. Generally, they do not follow any particular pattern, although many appear to follow the gneissic structure of the rocks. Their random distribution and orientation are quite in keeping with the deformations of various types that these rocks experienced through many geological periods.

The multiple system of fractures in the Chioak sedimentaries west of Chioak lake is without doubt the best developed and the easiest to study. This system is composed of three sets of vertical joints (extension, compression and shear) in beds that are almost flat-lying. The extension and compression joints lie at right angles to each other, forming enormous square blocks. In places, the development of a trellis structure (Plate XVI-B) has resulted in blocks 6 to 12 inches wide. The joint surfaces are smooth, even in conglomerates; the boulders of the latter rock show very fresh breaks. Some joint faces form very straight walls, without any irregularities.

The shear joints are the en echelon type (Plate XVII-A) in many cases, and their faces are characterized by a feathery structure. They are distributed at angles of 30° to 50° to the other two sets, and lie parallel to the paired faults described above.

The compression joints strike north, and the extension joints, in many cases filled by quartz veins, strike east.

The gabbro sills north of Feuilles lake have very well developed rectangular joints. One series strikes N.45°W. and forms straight, vertical walls; another series is perpendicular to the first and forms almost vertical walls that curve toward the south. Two types of joints occur in gabbro sills and lava flows near Laric lake; one is rectangular, and the other forms prisms with five, six, or even more sides. The former possibly had a mechanical origin. The latter type of joint is probably the result of cooling, and the main axes of the prisms lie perpendicular to the walls of the lavas.

Stratification, Schistosity and Cleavage

As already mentioned, the sedimentary formations along the contact south of Bérard lake are horizontal or nearly so, their dips rarely exceeding 20°. Eastward, the dips increase to 40° - 85°E. In many places, such as south of Sèche bay, the beds are overturned. Some facies of the

Chioak formation contain cross-bedded layers and granoclastic beds. At one place, north of Bérard lake, a cross-bedded zone in the Alison quartzite, 20 feet or more thick, carried normal cross-beds 2 to 5 feet long.

Many breaks and discordances separate formations and mark arrests in, or sharp changes of, sedimentation. In places, facies of the same formation are separated by minor discordances (diastems).

Almost all of the sedimentary rocks of the eastern half of the area are characterized by a well developed schistosity which, almost throughout, is parallel to the bedding.

North of Feuilles lake, fracture cleavage occurs in addition to schistosity or schistose cleavage. The fracture cleavage occurs along the axial planes of minor folds in the original schistosity, and forms an angle of about 80° with the schistosity. The two types of cleavage are common in the talcose schists underlying thick gabbro sills.

East of the middle arm of Bérard lake, the fracture cleavage generally cuts the beds at an angle of between 30° and 60°, and there is a refraction of the cleavage between sandy beds and shaly beds.

Along the east shore of Merchère lake, good quality slates form homogeneous, smooth plates, 3 feet or more across, that can be split into plates a few millimeters thick. The homogeneity results from the parallelism of cleavage and bedding.

False Ripples, Boudinage, Ptygmatic Folds

Near Quatre Ours lake, marks strongly resembling ripple-marks, observed in shaly layers, were actually caused by a layer of sandstone sliding over a shaly, plastic layer.

The hornfels in contact with gabbro sills display beautiful examples of boudinage structure. Massive chert beds have been stretched and flattened within a very plastic rock, with the result that plates of chert were isolated and, in places, nodules of chert remained jointed to the source rock by a fine cord of chert.

In certain places the Abner dolomite contains true ptygmatic folds originating by means of the multiple faults that cut the quartz veins. It is believed that some of this dolomite acted as a plastic substance, as shown by the fan-shaped and ptygmatic folds.

ECONOMIC GEOLOGY

Iron

In 1950, Fenimore Iron Mines Ltd. (now Consolidated Fenimore Iron Mines Ltd.) undertook a vast claim-staking program along the west contact of the Labrador Geosyncline. The company thus acquired mining rights over a zone extending from Larch river to the north side of Feuilles bay. Geological work was carried out for seven years. The particularly interesting zones received the most attention, and these were systematically sampled either by drilling or by trenching. Company geologists also noted many sulphide-bearing zones in the gabbro sills.

The iron-bearing Fenimore formation follows the contact with the basement rocks almost continuously. Under existing conditions, however, only a few zones along the 70-mile length involved could be exploited.

Two deposits hold special attention, and are the only ones described in this report. One is west of Chioak lake (the "Irony Lake" and "Dragon Lake" deposits of Consolidated Fenimore Iron Mines Ltd.); the other is north of Bérard lake. There are many other deposits of lesser importance, particularly southwest of Rouge bay and along Bérard river.

The iron-bearing rocks extend 8 miles to the west of Chioak lake, with an outcrop width of from 300 to 1,800 feet and a dip of 5° to 10° to the east. The west edge of the exposure forms a steep cliff. Reserves of ore assaying 28 to 30% iron are evaluated at about 100,000,000 tons.

The deposit north of Bérard lake comprises two bands. The east band is about 7,000 feet long, and is made up mainly of magnetite- and hematite-bearing quartzite. It is 45 to 65 feet thick and dips 30° to 60° east. The reserves are estimated at more than 26,000,000 tons assaying about 30% iron.

The west band of the Bérard lake occurrence is the most interesting deposit in the area. It extends along strike for more than 3 miles and dips 5° to 10° east. The top of the iron-bearing beds outcrops almost throughout over a width of 200 to 2,300 feet. The average thickness of the iron-bearing beds is 60 feet, the upper 10 feet of which, at least, is made up of spotted silica. These beds would have to be removed to get at the exploitable ore. The reserves are estimated at about 100,000,000 tons assaying approximately 33% iron.

Base and Precious Metals

Two types of base and precious metal deposits occur here. One is in veins cutting sedimentary rocks; the second is in shear zones in gabbros and lavas close to their contacts with sedimentary rocks.

Massive pyrite veins were seen at three places in shear zones in the Abner dolomite, but all were barren of both base and precious metals.

Quartz and calcite veins containing sulphides cut Chioak slates east of Bérard lake. Several selected samples, assayed in the laboratories of the Quebec Department of Mines, gave the following results:

Lead	5.92%	Zinc	2.04%	Copper	0.03%
Gold	$0.29 per ton	Silver	$1.19 per ton		

(Gold and silver were calculated at $35,00 and at $0.90 per ounce, respectively).

These veins are lenticular, and range from 1 inch to 10 inches in thickness. They are parallel, although the distances between veins vary greatly. The veins appear barren on the surface, because the metallic minerals of lead, copper, silver and zinc are easily dissolved out by surface waters. The principal ore minerals are sphalerite, galena, argentite and chalcopyrite. The gangue is made up of quartz, calcite, chlorite and microcline. A systematic study of the veins cutting the slates could prove of interest, particularly in view of the possibility of finding silver-bearing concentrations.

Grab samples from the second type of metallic deposit, those in shear zones in gabbros and lavas, indicated the presence of copper, zinc, nickel and gold. A particularly interesting rock, made up of very angular little splinters surrounded by secondary microcline and cemented by calcite and sphalerite, resembles "terrazzo" on polished surfaces. An assay gave 0.5% copper, 0.05% lead, and 12.83% zinc. This breccia occurs east of Lachance lake. It is quite irregular in thickness, has a variable cement, and metallic minerals are not omnipresent. Microcline is the only cement in many places.

Almost all of the gabbro sills have shear and breccia zones at their bases, and, in many places, these zones are mineralized with pyrite, pyrrhotite, and a little chalcopyrite.

In conclusion, all of the base and precious metal occurrences are of hydrothermal origin. Some resulted from the replacement of the finely ground material on the walls of faults; others, from the filling of cavities in fault breccias. Quartz, calcite, and a pink potassic feldspar are present in almost all cases studied.

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