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LABRIEVILLE AREA, SAGUENAY

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Énergie et Ressources naturelles
Québec

DEPARTMENT
OF NATURAL
RESOURCES
MINES BRANCH

GEOLOGICAL EXPLORATION SERVICE

LABRIEVILLE AREA

Saguenay County

GEOLOGICAL REPORT - 141

MARCEL MORIN

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INTRODUCTION

The harnessing of the hydraulic resources of a section of Betsiamites river by the Hydro-Québec Electric Commission provided numerous workings that offered an excellent opportunity for a geological study of the area.

Location and Means of Access

The Labrieville area, which is in Saguenay county, is bounded by longitudes 49°15' and 49°30' and latitudes 69°30' and 70°00'. It includes most of the townships of Janssoone and Le Baillif and part of Bedout, but is mainly in unsurveyed land within the timber limits of the Anglo Canadian Pulp and Paper Mills Company.

Labrieville is the new townsite developed by the Hydro-Québec Electric Commission. This centre of operations is located in the southeastern corner. The area is easily accessible from Forestville, about 205 miles from Quebec City, on the north shore of Saint-Laurent river. From Forestville, a good gravel road follows Sault-aux-Cochons river for 48 miles, and it crosses the height of land between Sault-aux-Cochons and Betsiamites* rivers to reach Labrieville on the bank of the latter. Since the survey of the area, a new road branching off the main highway a few miles east of Forestville leads to Labrieville.

Good access roads in the timber limits and around the power project facilitated access to more than half of the area. Betsiamites river is navigable from Labrieville to Waweashton lake. Biscuits (or Brochet) river, which empties into Waweashton lake, is also navigable for two miles from its mouth.

Description of the Area

The area is well within the "Laurentian Plateau" of the Canadian shield (Plate IA). The strongly dissected uplands slope gently south. The topography reflects the structure of the underlying rocks with the long axis of the hills parallel to the strike of the gneissic structure. However, in places, the main rivers flow across the regional strike.

The local relief is diverse in the area; it is 1,100 feet near Betsiamites river and about 200 feet in the southern part. Cassé lake is 1,145 feet above sealevel, whereas Waweashton lake, on Betsiamites river, about six miles east, is 450 feet above sealevel.

The principal rock masses form indented, flat-topped highlands, which are separated by broad valleys partly filled with alluvial deposits. Cuesta-like ridges with talus composed of angular blocks at the bottom of

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* Several variations of this name have been used, the most widely known being Bersimis, originally given to a post office at the mouth of the river.

PLATE I

A — View of a part of the area including the townsite of Labrieville and the strongly glaciated valley of Betsiamites river.

B — Overhanging stream along the valley of Betsiamites river. Section from the "main dam" to Grand Remous lake.

the escarpment slopes are common. A spectacular escarpment about 600 feet high forms the east bank of the upper part of the river. The north shore of many of the smaller lakes is marked in many places by a steep cliff (Plate VIB). These east-west joint cliffs are readily observed on the mosaic of aerial photographs. Moreover, the streams running into Cassé lake follow this direction.

Drainage

Besides Cassé and Sault-aux-Cochons lakes, which are the largest bodies of water, there are several smaller lakes in the area. Few are accessible to float-planes at any time, and others are only accessible with proper wind conditions.

Cassé lake, which is about 10 miles long and one mile wide, is merely an enlargement of Betsiamites river. The northern part of Sault-aux-Cochons lake extends into the area. Although its long axis is nearly at right angles to the underlying rocks, the irregularities of its shoreline and the long east-west bays tend to follow the foliation in the anorthositic rocks and the gneisses.

Betsiamites river is the only important stream in the area. It drains most of the area which it crosses from the centre of the western half to near the southeastern corner. For description purposes the river valley is divided into two sections, i.e., the section from the main dam to Waweashton lake, and the section which extends southward from this lake. The main features along the section from the falls at the main dam to Waweashton lake are the steep gradient accompanied by a few falls, overhanging streams (Plate IB) and potholes (Plate IIA) up to ten feet in diameter. The valley gradually narrows and becomes a gorge downstream. At Waweashton lake and southward, the river has a low gradient interrupted by small falls.

Desroches river joins Betsiamites river below the main dam. Although it drains a rather large area, it is a small stream which meanders in sandy alluvial material. The valley of this river is the site of the tunnel intake for the power project. Terraces are common along its banks.

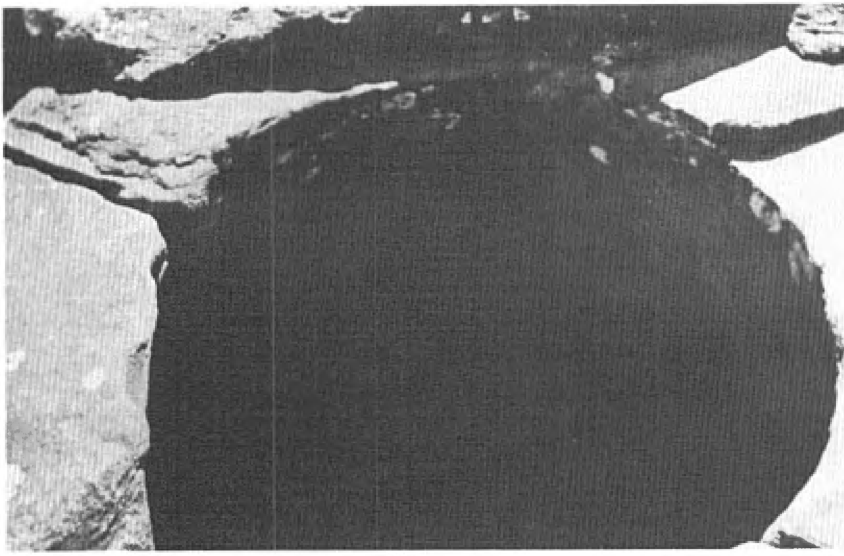
Biscuits river, the outlet of Brochet lake to the north, is the main tributary of Betsiamites river in the area. In the northern part of the area, the river flows through a steep groge which ends at the falls about five and a half miles slightly east of north of Waweashton lake. From the falls to a point about 2 miles upstream from Waweashton lake, its valley becomes wider and is partly filled with sand. The river has a strong current in a boulder-strewn bed. Several meander scars and terraces are seen along the banks. For the last two miles, the river meanders in the sand of the broad valley.

Lionnet river empties into Cassé lake about two miles north of the main dam. The stream north of Lionnet river occupies a rather wide valley partly filled with gravel, sand, and clay, and, in places, bordered by terraces. This valley can be followed from the mouth of the stream to Dubuc lake.

Power Resources

As mentioned above, the surface of the water drops some seven hundred feet along its course from the outlet of Cassé lake to Waweashton lake. The Hydro-Québec Electric Commission built two dams, rockfill-type,

PLATE II



A — Giant pothole along the bank of Betsiamites river. Diameter 10 feet. Section from the "main dam" to Grand Remous lake.

B — Slope wash coarse gravel overlying fluvioglacial sand near the power house entrance at Labrieville.

and a tunnel to develop power. The development of the power project started in 1953. Three years later, the construction was completed and some turbines were in operation.

The dams are at the outlet of Cassé lake above the first falls and on nearby Desroches river. They consist of a repetition of superposed layers of graded material ranging from large quarry blocks to sand and clay, all of which are available in the vicinity of the project. These layers are convex facing the principal current or that of the original river channel. The southern end of the main dam is anchored on solid rock, whereas the northern end rests upon varved clay, boulder clay, and a few sandy layers which presumably fill the abandoned channel of the river at that locality. The dam on Desroches river closes a narrow U-shaped valley.

The concrete-lined tunnel and the power house are entirely underground in solid rock. The tunnel is 31 1/2 feet in diameter and 40,139 feet long.

Forest, Fish and Game

The area is moderately forested with stands of spruce, balsam, hemlock, birch and less common poplar trees. Only a few small tarmaracks were seen in the northern part of the area. Whereas birch is more common on the higher ground, spruce and balsam trees mostly occupy the valleys. Hemlock is confined to flat sandy alluvial plains.

Trout and pickerel abound in Betsiamites river. Trout fishing is excellent in Sault-aux-Cochons lake. Speckled trout are common in many of the smaller lakes.

Moose and caribou are moderately abundant in the area. Beaver huts were seen : one on Brûlé lake and others on the lake of the north central part. Such animals as the black bear, fox, wolf, lynx, fisher and wolverine are rare.

Field Work and Acknowledgements

Three seasons were spent in the field. R. Béland of Laval University acted as chief for the first half of the summer in 1954. During the remainder of the season, after the writer took over, the study was mainly devoted to geology relating to construction projects. Mapping of the areas was completed in 1955 and 1956. Trips were made from time to time during the winter of 1954/55 to follow the progress in the excavation of the tunnel.

The writer was assisted successively by G.G. Grondin and M. Vallée, during the summer of 1954. During the season of 1955, M.L. Melvill acted as senior assistant, B. Pavlu, as junior assistant, and C. Monaghan as laborer. In 1956, C. Ezeani was senior assistant, I. Sankoff and A. Gagné, junior assistants, and X. Vollant and J.B. Picard, two Indians from the Betsiamites reservation, acted as canoemen.

The writer wishes to express his thanks to the management of Hydro-Québec Electric Commission, Anglo Pulp and Paper Mills Company and Laurentian Forest Protective Association. They have been most helpful and cooperative throughout the execution of the work.

The information gathered the first two years served as a basis of a thesis (Morin, 1956) presented at Laval University in partial fulfilment of a D.Sc. degree. Deep gratitude is owed to the professors of the Geology Department of the University, particularly to F.F. Osborne for his generous help and advice.

Previous Work

Geological mapping was done before the development of the hydroelectric project started. Diamond drill-holes were put down to obtain information before commencing the excavation of the tunnel and the power house. This work was accompanied by a map at one inch to 400 feet. Mapping and extensive diamond drilling were conducted at and near the dam sites.

Most of the general mapping in the area has been and is being done by private companies for prospecting purposes.

A.P. Low ascended Betsiamites river as far as Waweashton lake in 1885. He then followed a ten-mile portage between Waweashton and Cassé lakes. His report contains brief descriptions of some of the rocks encountered along the portage and on the shore of Cassé lake.

GENERAL GEOLOGY

All the rocks of the area are Precambrian in age. They belong to three groups, namely, the paragneisses, the mixed gneisses, and a complex of igneous origin.

The paragneisses are tentatively assigned to the Grenville Group principally because they form assemblages somewhat similar to those of the type locality. They consist largely of quartzite interlayered with garnet, sillimanite, hornblende-plagioclase and biotite gneiss, all of which are found in two main bands. The members of the paragneiss group can be followed around folds. Their contact with the pink granite gneiss is commonly gradational. They are also included as long lenses in the green gneisses. Several dikes and sills of pegmatite and aplite occur throughout the paragneisses.

The pink granitic gneiss is particularly abundant in the southeastern part of the area. It is foliated and shows several inclusions of dark hornblende-plagioclase gneiss. West of Desroches river, a thick layer of a salmon-pink syenite gneiss borders the green gneisses. Minor augen gneiss and some injection gneiss are included in this group.

Most of the northern part of the area is underlain by rocks of igneous origin surrounded by green gneisses. These gneisses have a marked foliation as shown by the numerous boudins, and layers of hornblende-pyroxene-plagioclase gneiss. They vary in composition from dioritic to granitic and may have been locally remelted yielding dikes. The association of both types of anorthosite with the gneisses in some zones can be interpreted as reaction or as magmatic consanguinity.

The green porphyritic granite is in several aspects similar to the gneisses. Except near the margins of the masses, it has a diagnostic porphyritic texture. In several exposures, dikes and sills of green porphyritic rocks are found within the gneisses.

Labradorite anorthosite crops out as a narrow band along the east shore of the northern part of Cassé lake. In the massif of the middle part of Cassé lake, it occurs as layers and boudins in a gabbroic rock which seemingly grades into green gneisses. Farther south, it is found in lenticular bodies of considerable extent near the contact of the andesine anorthosite with the green gneisses. A small plug-like mass also occurs near Biscuits river, 3 miles north of Waweashton lake. Small pockets of magnetite-ilmenite were observed in one locality along the shore of Cassé lake.

PLATE III

A — Excavation in boulder clay along access road to Cassé lake.

B — Fluvioglacial deposit of outwash plain at the aggregate plant.

TABLE OF FORMATIONS

PLEISTOCENE AND HOLOCENE		Sand, gravel, boulder clay and varved clay
PRECAMBRIAN	INTRUSIVE ROCKS	Pink porphyritic granite; plagioclase-quartz hornblende dike; pegmatites Green porphyritic granite Hornblende-pyroxene-plagioclase gneiss layers Apatite diorite Andesine anorthosite Gabbros, labradorite anorthosite, magnetite-ilmenite
	MIXED GNEISSES	Hornblende-pyroxene-plagioclase gneiss layers Green oligoclase gneisses Hornblende-plagioclase gneiss layers Minor injection and augen gneisses Pink syenite gneiss Pink granitic gneiss
	GRENVILLE (?) PARAGNEISSES	Quartzite, sillimanite gneiss, garnet gneiss, hornblende-plagioclase gneiss, and biotite gneiss

The andesine anorthosite is surrounded by the green granite, syenite, and monzonite gneisses. It appears in a batholitic mass slightly tilted to the southeast. Lenses of ilmenite-hematite are found near the centre of the anorthosite body where dips are shallower.

The pink porphyritic granite is closely associated with coarse green granite in the vicinity of Labrieville. It is in a concordant body located at the southern end of the small mass of green rocks near the southeastern corner.

GRENVILLE (?) PARAGNEISSES

Paragneisses of Grenville type are restricted to two narrow bands, which pinch out along the strike. They consist mainly of massive quartzite with minor garnetiferous varieties and are interlayered with sillimanite and garnet-bearing gneisses, hornblende-plagioclase gneiss bands, and a few lenses of biotite gneiss.

At a locality about three-quarters of a mile northwest of the tunnel intake, a band of paragneisses forms the side of the hill on the northeast bank of Desroches river. A syncline and an anticline can be traced in it. The band crosses the access road to Cassé lake and is exposed on the south bank of Betsiamites river, approximately three miles northeast of the main dam.

On the hills west of Labrieville, similar paragneisses are also followed in a syncline and an anticline. The band follows the main Forestville-Labrieville highway and pinches out about a mile west of the access road to tunnel section No 2. A thick series of paragneisses was intersected by the tunnel, but the sequence may be repeated through faulting. In adit No 2, the dominant quartzite appears in three thin layers, which suggest that the paragneisses terminate in a tongue-like fashion.

In the southeast corner of the area near the southern boundary, exposures of quartzite and garnet gneisses are interpreted as relics included in the granite gneiss. Similar rocks also occur as lenses on both sides of Biscuits river.

Quartzite

Quartzite is found in layers of diverse thicknesses, but most of them do not exceed one hundred feet. Thick layers of pure quartzite are exposed on a vertical section along the transmission line about 2 miles west of Labrieville. In tunnel section No. 2, massive quartzite also forms the bulk of the rocks mapped as paragneisses. In the center of the area, the paragneisses are associated with green gneisses and some pink granite gneiss. The layers are more lenticular than those of the band to the west of Labrieville.

The quartzite is a coarse-grained rock, locally foliated, composed largely of quartz with some feldspar, biotite, chlorite, garnet, magnetite, apatite, and zircon. The more massive type is usually white, but it is commonly spotted with pink feldspars, which, if abundant, makes it difficult to distinguish the quartzite from the adjacent granitic gneiss. It is intruded by many sills and dikes of pegmatite and aplite. These sills and dikes are particularly abundant near the contact of the quartzite with the pink porphyritic granite (Plate VA).

Under the microscope, large anhedra of quartz with sutured boundaries show a marked undulatory extinction. Perthitic microcline fills the interstices between the grains and is also enclosed within quartz grains. Plagioclase, some grains of which are myrmekitic, has a composition from An_{15} to An_7 and occurs with microcline although in smaller proportion. A sericitic alteration is commonly observed.

Biotite is seen as thin lath-shaped flakes. Apatite, sphene, and zircon are the common accessory minerals. Magnetite is most abundant in the rock. However, a small vein in a quartzite layer has s high content of secondary magnetite. Pyrite was found coating the thin-layered quartzite in the tunnel section.

Garnet is scarce in the highly quartzose rock, but some impure varieties contain pink, rounded porphyroblasts of almandine. In tunnel section No 2, a granitic rock between two layers of quartzite has as much as 10% almandine.

Sillimanite and Garnet Gneisses

Sillimanite gneisses are generally found among garnetiferous members of both bands of paragneisses, near the contact with the granite gneiss. Their color ranges from gray to white or pinkish white depending on mineralogical associations. The proportion of sillimanite is reflected by the characters of the rocks: it is abundant in thin layers (1/2 inch or less) and becomes disseminated in the massive rocks of the thicker layers. The grains of some thin layers have a conspicuous orientation imparted by the prisms of sillimanite. In some cases, sillimanite appears in pegmatitic stringers of feldspars and quartz in a medium-grained biotite gneiss.

PLATE IV

A — Ice contact feature showing gravel pocket in mixed sand and gravel in outwash plain at the aggregate plant.

B — Sheet joints in green porphyritic granite along shore of lake near northern boundary of the area.

Quartz is the dominant mineral in the rocks. Microcline and plagioclase occur in variable amounts. Sillimanite is in prisms oriented parallel to the direction of layering in the rock. Garnet porphyroblasts (2-5 mm.) were observed in most specimens except in a gneiss from the exposure near the intersection of the main Forestville-Labrieville highway with the access road to tunnel section No. 2; there, sillimanite is in the light-colored layers between those with a high percentage of biotite. Muscovite is present in the band near Desroches river.

Hornblende-plagioclase Gneiss

Layers of hornblende-plagioclase gneiss are commonly intercalated with the paragneisses, but, along the road, near Labrieville, in the valley between the hills west of that locality, and in tunnel section No. 2, they occur near the contact of the paragneisses with the porphyritic granite. In the tunnel section, they also form layers in the quartzite of a maximum thickness of 3 feet.

Along the northeast band of Desroches river, the margins of some lenses of the gneiss are rich in garnet, whereas the centers of the lenses are devoid of this mineral.

A specimen from tunnel section No. 2 shows a difference in mineralogical composition in layers less than 1/4 inch thick. Alternate layers have chlorite-plagioclase and hornblende-plagioclase. The plagioclase, which forms not less than 50%of the rock, is oligoclase (An_9-An_{21}). There does not seem to be a difference of composition of the plagioclase in the layers, but that in the chloritic layers is partly altered to zoisite. The granularity is not uniform from layer to layer, and hornblende-rich layers tend to be more even-grained than the others. The accessory mineral are magnetite, sphene, apatite, and zircon.

A layer of similar rock from the right of way for the transmission line about 2 miles west of Labrieville has hypersthene porphyroblasts. The rock is fine grained and the plagioclase is altered to zoisite with chlorite in some layers.

The layering observed in these rocks may be the trace of the original bedding as suggested by the difference in mineralogical composition and the close association with paragneisses.

Biotite Gneiss

Biotite gneiss is not common in the paragneisses. It is a medium- to fine-grained rock in which the plagioclase is porphyroblastic and gives the rock a mottled appearance.

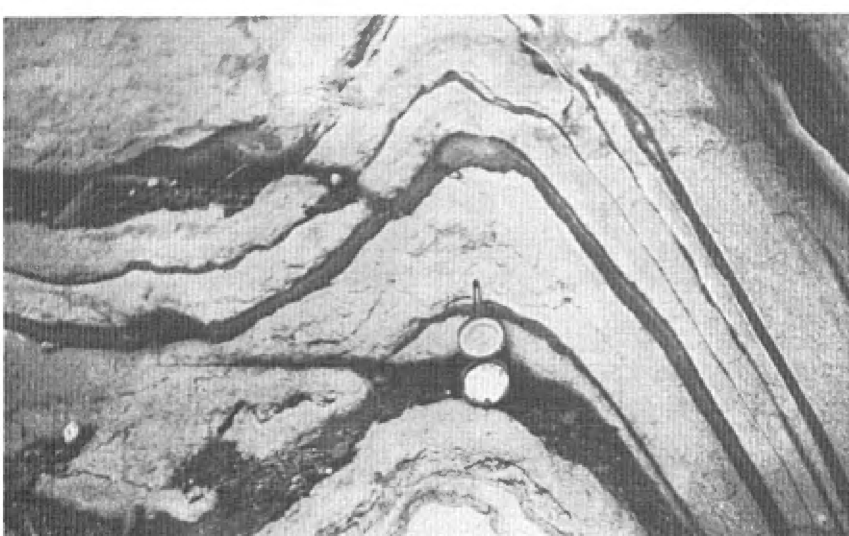
The biotite gneiss from a lens in the quartzite northwest of the tunnel intake is composed of andesine porphyroblasts, quartz, biotite, chlorite, sphene, zircon, apatite, and hematite. A specimen from the same band of paragneisses but from a locality farther northwest contains the same minerals with potassic feldspar and garnet.

Breccia

In tunnel section No. 2, in the paragneiss series, a fault zone was intersected. Extensive crushing is evident along the hanging wall. Large rotated fragments are cemented in a quartz matrix in which vugs up to two feet in diameter are filled with hexagonal quartz crystals. Some quartz

PLATE V

A — Quartzite injected with pegmatite showing tight folding.



B — Hornblende-pyroxene-plagioclase gneiss layers in granulose green oligoclase granite.

crystals are as much as six inches in diameter and have grown toward the centre of the vugs.

Many of the smaller and the larger vugs were filled or partly filled with tar. This tar also occurs along slip planes in the quartzite and plasters the interior of the cavities.

This tar still contains considerable volatiles and is younger than the rocks in which it is contained. It is soft and has been observed to seep out on one vug to form a light brown streak of oily substance on the wall.

The occurrence of the tar suggests that it is a natural product but it cannot be distinguished from an industrial product. The only hypothesis to explain its occurrence in rocks that have been submitted to intense metamorphism is that Paleozoic rocks once covered the area and were removed by later erosional processes. This sedimentary cover may have been the source of the tarry substance that has penetrated the underlying older rocks through the pores and cavities formed along the fault zone. This occurrence of tar is believed to be different from the occurrence of gas found in certain Adirondack Grenville gneisses (Engel and Engel, 1953).

MIXED GNEISSES

Pink Granite Gneiss

Pink granite gneiss underlies most of the southeastern part of the area besides occurring as lenses in the green gneisses and in the green porphyritic granite. The distribution of the lenses is erratic, and they are more numerous near the contact with the green gneisses.

The pink granite has a foliation shown by the thin dark layers and inclusions of hornblende-plagioclase gneiss and by the orientation of its constituent minerals. Locally, the rock is apparently closely folded, and, also, it is commonly injected ***"lit-par-lit"*** by other rocks. Some varieties have a well-developed augen structure. It is cut by many dikes of green porphyritic granite and green gneisses. In places, alternating pink and green granitic rocks or those intermediate in color make it difficult to assign an exposure to one group or to the other.

The rock is pink in most exposures, but, in places, it is white or almost red. In the tunnel, the presence of red potassic feldspar everywhere indicates a shear zone nearby. Local spots of darker color, commonly red, are visible to the naked eye.

Thin-sections show microcline-perthite, quartz, plagioclase, hornblende, and biotite with magnetite, apatite, sphene, and zircon. The mineral which forms the cores of the red spots has a brownish yellow color and is probably metamictic allanite. Calcite and chlorite are secondary minerals. The grains have sutured boundaries and microcline-perthite has a greater tendency toward idiomorphism than the plagioclase.

The pink granite gneiss may contain as much as 60% microcline-perthite in which grid-twinning is as a rule well developed, and, in many instances, used as a criterion to distinguish the pink granite gneiss from the green gneisses in which the perthitic grains show only faint twinning. Quartz is relatively abundant, commonly more so than plagioclase in the pink granite gneiss. Plagioclase crystals between An_{28} and An_{15} make up to

25% of the rock. The grains show albite and Carlsbad twin lamellae, and some of them have a myrmekitic structure. Microcline-perthite often surrounds myrmekitic grains. Common hornblende, pleochroic in tints of deep green to yellow, and biotite flakes are aligned parallel to the foliation of the rock. They form about 2% of the rock. Apatite shows the characteristic moderate relief, although very low near that of the fluor-bearing variety. Zircon prisms are never abundant. Magnetite is a minor constituent. Chlorite is derived from hornblende, and calcite is secondary.

Pink Syenite Gneiss

Syenite crops out west of the road parallel to the west branch of Desroches river as a band about a mile wide. The rock has a marked foliation and shows numerous inclusions similar to those in the pink granite gneiss.

Under the microscope, the rocks show microcline-perthite, plagioclase in places myrmekitic, quartz, hornblende, biotite, apatite, zircon, and magnetite. A metamict mineral, probably allanite, also occurs. The rock consists of anhedra of microcline-perthite more than 2 mm. in diameter surrounded by oligoclase grains less than 1 mm. in diameter. The composition of the plagioclase is about An_{20}. Quartz forms only a minor portion of the rock and is interstitial.

A Rosiwal analysis of one specimen gives: microcline-perthite, 54.6%; oligoclase, 39.9%; quartz, 2.2%; hornblende, 1.2%; biotite, 0.4%, and accessories, 1.7%.

Augen Gneiss

Along the access road to Cassé lake, about one mile from the intersection with the main Forestville-Labrieville highway, a pink granite gneiss has a well-developed augen structure. Minor augen gneiss facies, some of which may be injection gneiss, were also observed along the Forestville-Labrieville highway and in tunnel section No. 1. Although these rocks are easily identified in the field, it was not found possible to map them as a separate unit because of their restricted occurrence and because of the few exposures in the area that they underlie.

Differences in composition believed to be related to the origin of the augen gneisses are noticeable particularly in the content of the mafic minerals. A leucocratic rock is considered to be a local variation of the pink granite gneiss, and a more mafic gneiss is possibly a variety of an injection gneiss. The mafic gneiss also occurs near highly injected hornblende-plagioclase gneiss.

In thin-sections, the rock is composed of microcline-perthite, oligoclase, with a few grains having a myrmekitic structure. Accessory minerals are magnetite, apatite, sphene, and zircon. A red metamict mineral is also observed.

The augen are formed of an aggregate of microcline-perthite and oligoclase grains. The oligoclase of composition An_{17} to An_{25} in the specimens studied is more idiomorphic than quartz and microcline, and, in places, it makes the cores of the augen, many of which are as much as 2 cm. in diameter. In several occurrences, oligoclase crystals alone form the augen.

Hornblende is present in most of the specimens examined and it belongs to the common variety with its pleochroism from dark green to yellow. It is associated with thin platy crystals of biotite, and the greater dimensions of both minerals are parallel to the gneissic structure of the rock. The growth of augen has apparently disturbed the layering as shown by the more mafic layers which curve around them.

Along the Forestville-Labrieville highway about 2 miles from the intersection mentioned above, a lens of augen gneiss is included in the pink granite gneiss. The lens, where it is observed, shows a lineation which is cut by the foliation of the pink granite gneiss. The feldspar augen do not parallel the edge of the inclusion.

Injection Gneiss

The name injection gneiss is given to the rocks which show pink pegmatitic layers alternated with layers of hornblende-plagioclase gneiss or pink granite gneiss. Thus defined, they overlap certain types of the pink granite gneiss, particularly those in which the augen structure is not developed and those which border shear zones.

However, along the access road to Cassé lake, about 4 1/2 miles from the intersection, a band of injection gneiss is exposed next to the augen gneiss. It consists of layers about 2 inches thick of pegmatitic material which have penetrated hornblende-plagioclase gneiss mostly along fracture planes.

Hornblende-plagioclase Gneiss Layers

Hornblende-gneiss layers and inclusion-like blocks are numerous in the pink granite gneiss. Many inclusions can be seen from the outline of their broken edge to be separated parts of one layer. The rock, generally dark and foliated, is composed largely of hornblende with white feldspar peppering the surface. The layers are of variable thickness; they do not exceed 20 feet, and locally occur at nearly regular intervals.

Thin-sections of the rock examined under the microscope show an allotriomorphic assemblage of plagioclase, hornblende, biotite, apatite, and magnetite. In some specimens, microcline-perthite is present in small amounts accompanied with quartz, chlorite, and epidote. These minerals are believed to be of secondary origin. Skeleton crystals of hornblende as much as 1.5 mm. de diameter were seen, but most of the grains in the rocks are 0.5 mm. in diameter.

Plagioclase between An_{36} and An_{20} is surrounded by porphyroblastic hornblende. The skeleton crystals of hornblende are pleochroic to olive-green and yellow colors. Flakes of biotite are oriented parallel to the foliation.

Rosiwal analyses gave the following composition for the rock: andesine, 41.2%; hornblende, 42.3%; biotite, 15.2%; apatite, 0.5%; and magnetite, 0.5%. Microcline and quartz account for about 20% of the rock when they are present.

An unusually coarse-grained inclusion of hornblende-plagioclase gneiss was observed in the pink syenitic gneiss. It is mainly composed of plagioclase, with minor hornblende. Magnetite and apatite are present as accessory minerals. The grains are of variable size and may be as much as 1.5 mm. for plagioclase and hornblende. The magnetite is less than 1.0 mm.

The anhedral grains of a clear plagioclase are An_{61}. A Rosiwal analysis gave the following composition: labradorite, 68.0%; hornblende, 31.7%; biotite, 0.3%; and the accessory minerals account for only traces in the rock.

Green Oligoclase Gneiss

East and west of Cassé lake, green gneissic rocks are exposed between the bodies of green porphyritic granite and andesine anorthosite. They extend to the south and to the east where they are in contact with the pink granite gneiss, many lenses of which are elongated parallel to the foliation of the green gneisses. They surround the pink syenitic gneiss outcropping near the centre of the area.

In the southwest corner of the area, a small plug of green porphyritic granite is surrounded by the green gneisses.

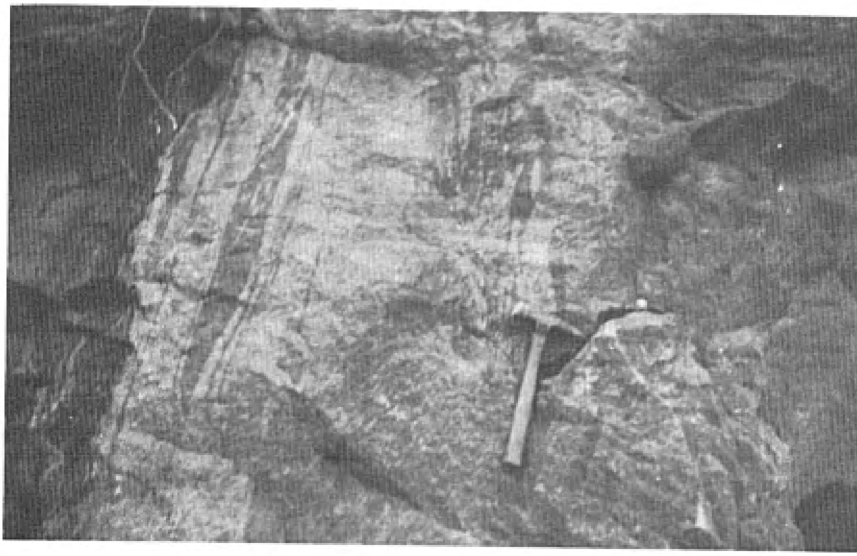
In tunnel sections No. 1 and No. 2, thick layers of gneissic rocks consist of alternating pink and green granitic rocks. The green layers are much more quartzose and coarser than the gneissic green rock and are considered to be pegmatitic infiltrations into the pink granitic rock.

The rock is well foliated with numerous platy inclusions of hornblende-pyroxene-plagioclase gneiss in them (Plate VIA). It also has thin layers of the dark rock which have been folded with the associated gneisses. Stringers of quartz about a foot long are found in many of the exposures. In the quarry near the dam sites, these quartz stringers are particularly abundant, as are also thin red pegmatitic layers along or parallel to a set of vertical joints. The gneisses below a white surface weather to a brownish yellow color, and, according to Low (1885), they have on weathering somewhat the aspect of a "friable sandstone". The surface of the fresh rock is green, and the intensity of the color decreases with the increasing granularity.

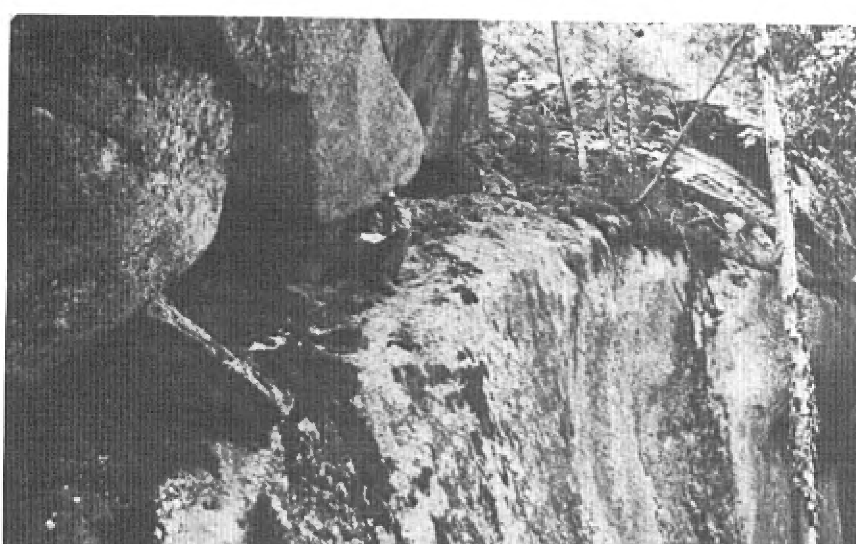
For the purpose of description, the gneisses are divided arbitrarily into granitic, syenitic and monzonitic on the basis of their mineralogical composition. The subdivisions have no implication on the igneous origin of the rocks.

The rocks are fine to medium grained, and they are characteristically granulose. In thin-sections, the rocks show a great diversity in composition, although they appear to belong to only one mappable unit. Microcline-perthite (Plate X) was observed in all specimens except one in which the dominant feldspar plagioclase is similar to that of the andesine anorthosite. These rocks have either hypersthene and/or augite. Among the other minerals forming the rocks, hornblende and biotite are present with minor accessory minerals such as apatite, magnetite, and zircon. Calcite and chlorite are secondary. The grains, commonly less than 1 mm. in diameter, have sutured boundaries. Many microcline-perthite grains show the perthitic bleds concentrated at the cores with margin edges without intergrowth. Larger exsolution bleds are commonly surrounded by a thin rim of clear feldspar. Many perthitic grains are bordered with a rim of plagioclase about 0.03 mm. thick, and this relationship holds even when the adjacent grains are quartz. The size of the bleds ranges within wide limits, such as 0.2 mm. to 0.006 mm. in length, and 0.03 mm. to 0.003 mm. in width.

PLATE VI



A — Inclusions of hornblende-pyroxene-plagioclase gneiss in granulose green oligoclase granite.



B — East-west joint forming a cliff near the north shore of lakes. Note coarse granularity of the green porphyritic granite.

The content of plagioclase can only be approximated because of the abundance of the perthitic grains. The grains of plagioclase are commonly smaller than those of microcline and none are larger than 2.0 mm. Most occur in the finer portion of the rock. In a southwesterly trending belt passing in the vicinity of the clay pit, there are several pockets of rocks composed mainly of the andesine anorthosite. In tunnel section No. 2, the phenocrysts of plagioclase of a porphyritic facies have the same composition as the grains of the groundmass (An_{17}) and microcline-perthite replaces the phenocrysts as irregular patches.

The plagioclase is between An_{34} and An_{17}, and most of it is about An_{24}. Antiperthitic plagioclase is virtually non-existent in these rocks except in the plagioclase-rich rock. Myrmekite grains are distributed sporadically in the rocks. Plagioclase also occurs as rounded inclusions and in diffuse irregular patches in some grains of microcline perthite.

In what is here called the granitic suite, quartz in grains less than 2 mm. in diameter rarely forms as much as 30% of the rock.

In these rocks augite or hypersthene or both have a more pronounced greenish color in many places. Grains of these rocks are too thin to be identified positively. Augite exsolution lamellae can be observed in hypersthene but the reverse is less common. Pyroxenes occur mainly as smaller interstitial grains. A red alternation to a fibrous mineral is common along the cleavage.

The hornblende is pleochroic in olive-green, greenish brown, and yellow tints. One thin-section of a specimen of a sill-like body shows hornblende replacing augite along the margins of the grains and the prismatic cleavage. Biotite, generally in small amounts, occurs as a small lath-shaped mineral. Apatite and zircon occur as rounded prisms. Sphene occurs as an aggregate of grains surrounding magnetite or ilmenite grains, but it is also present as individual grains.

The green gneisses have many similarities to rocks of the charnockite series. Besides being associated with anorthosite, they are commonly streaked by inclusions of hornblende-pyroxene-plagioclase gneiss. Their mineralogical composition, texture, and green color is also characteristic of the series. However, garnet does not appear in any of the green gneisses in the area.

The chemical compositions of four specimens are given in the following tables, and they are compared with analyses of rocks of the charnockite series from several localities.

The rocks vary in composition from quartz monzonite to granite, syenitic and granitic facies being more common than the more basic rocks. Notable contents of minor elements are shown in the analyses, in particular barium and strontium.

GRANITE

TABLE I

	D-52	L-43	I	Norms	D-52	L-43	I
SiO_2	72.50	71.06	71.80	Quartz	28.31	25.01	26.16
TiO_2	0.36	0.38	0.26	Orthoclase	31.43	31.26	24.46
Al_2O_3	13.41	13.88	14.90	Albite	30.61	32.09	35.63
Fe_2O_3	1.80	1.15	1.10	Anorthite	4.66	5.24	9.45
FeO	1.04	1.57	1.08	Diopside	0.61	0.77	1.12
MnO	0.03	0.07	—	Hypersthene	0.61*	2.00	1.10
MgO	0.36	0.38	0.39	Magnetite	2.25	1.67	1.62
CaO	1.08	1.62	2.20	Ilmenite	0.68	0.71	0.46
Na_2O	3.61	3.78	4.17	Apatite	0.10	0.17	—
K_2O	5.30	5.28	4.11	Calcite	0.07	0.61	—
P_2O_5	0.04	0.07		Zircon	0.13	0.07	—
$H_2O(+)$	0.25	0.44					
$H_2O(-)$	0.04	0.03					
CO_2	0.03	0.27					
S (total)	—	0.01					
Cr_2O_3	tr.	tr					
ZrO_2	0.09	0.05					
Ga_2O_3	tr.	tr.					
BaO	0.19	0.14					
SrO	0.01	0.01					
RB_2O	0.01	0.02					

D-52 Green granite gneiss on a road cut along access road to Cassé lake, at the clay pit. H. Boileau and J. Gagnon, analysts. Normative plagioclase: $An_{12.55}$.

L-43 Green granite gneiss, on a road cut along the main Forestville-Labrieville highway, at lake three miles east of the tunnel water intake. H. Boileau and J. Gagnon, analysts. Normative feldspar: $Or_{44.90}$ $Ab_{48.26}$ $An_{7.44}$.

I Hypersthene granite, Mount Gbon, Ivory Coast (Lacroix 1910, p. 21) Pisani, analyst.

* Enstatite.

SYENITE

TABLE II

	D-48	II	III	Norms	D-48	II	III
SiO_2	53.48	53.45	57.21	Quartz	1.12	8.28	1.26
TiO_2	2.36	1.38	0.69	Orthoclase	23.05	15.01	20.57
Al_2O_3	15.43	14.97	16.03	Albite	34.61	16.77	34.58
Fe_2O_3	2.13	3.31	1.65	Anorthite	12.24	10.84	15.01
FeO	8.61	10.61	7.38	Diopside	0.40	13.71	8.36
MnO	0.17	—	0.18	Hypersthene	15.90	14.34	15.71
MgO	2.25	1.72	3.36	Magnetite	3.08	10.56	2.32
CaO	4.60	6.43	5.18	Ilmenite	4.48	6.60	1.37
Na_2O	4.08	3.50	4.12	Apatite	3.46	3.22	0.34
K_2O	3.89	3.74	3.50	Calcite	0.36	0.30	—
P_2O_5	1.47	0.71	0.20	Zircon	0.18		
$H_2O(+)$	0.78	0.14	0.56				
$H_2O(-)$	0.18	0.10	0.30				
CO_2	0.16						
S (total)	0.07		0.10				
Cr_2O_3	tr.						
V_2O_3	—						
ZrO_2	0.12						
Ga_2O_3	tr.						
BeO	—						
NiO	—						
BaO	0.14						
SrO	0.17						
Cu	—						
Pb	—						
Zn	0.03						
Co	tr.						
Sn	—						
Bi	—						
Rb_2O	0.01						

D-48 Augite syenite, road cut along access road to Cassé lake. H. Boileau and J. Gagnon, analysts.
Normative feldspar: $Or_{32.00}Ab_{50.99}An_{17.01}$
Normative plagioclase: $An_{25.01}$

II Mafic syenite, quarry northeast of Moody Pond, Saranac Quadrangle (Balk, 1931, p. 425)

III Monzonite, Svartsbervik N. Ulfön, Nordingra, Sweden. Washington Tables, p. 454, No. 60.

QUARTZ MONZONITE

TABLE III

	D-58	IV	V
SiO_2	48.13	50.19	50.56
TiO_2	3.01	2.72	1.71
Al_2O_3	13.83	11.57	14.71
Fe_2O_3	5.48	4.39	3.54
FeO	9.67	8.96	8.90
MnO	0.24	0.32	0.13
MgO	3.15	2.79	4.07
CaO	6.70	7.60	7.58
Na_2O	3.67	4.24	2.94
K_2O	2.39	1.53	2.10
P_2O_5	2.18	1.12	
$H_2O(+)$	0.53	1.54	1.12
$H_2O(-)$	0.03	0.32	1.06
CO_2	0.65	0.02	
S (total)	0.16		
Cr_2O_3	tr.		
V_2O_3	—		
ZrO_2	0.17		
Ga_2O_3	tr.		
BeO	—		
NiO	—		
BaO	0.22	0.03	0.25
SrO	0.09		tr.
Cu	—		
Pb	—		
Zn	0.03		
Co	tr.		
Sn	—		
Bi	—		
Cl		0.05	

Norms	D-58	IV	V
Quartz	2.28	1.62	3.78
Orthoclase	14.18	8.90	12.23
Albite	31.14	35.63	24.63
Anorthite	14.14	16.40	20.85
Diopside	1.23	11.60	7.61
Hypersthene	15.98	10.80	17.11
Magnetite	7.93	6.50	5.10
Ilmenite	5.71	5.17	3.19
Apatite	5.14	2.69	2.69
Calcite	1.48		
Zircon	0.26		

D-58 Dark green fine-grained monzonite gneiss at the contact with paragneiss near the dam sites. H. Boileau and J. Gagnon, analysts.
Normative feldspar: $Or_{18.77}Ab_{43.75}An_{18.73}$
Normative plagioclase: $An_{35.90}$

IV Mugearite, Skomer Island, Pembrokeshire, Wales. Washington Tables, p. 496, No. 130.

V Basalt, near Mount Ingalls, Plumas County, California. Washington Tables, p. 492, No. 96.

The chemical composition of specimen D-58 is compared with that of a basalt. The rock is fine grained and interpreted as a chilled facies of the gneisses against the paragneiss series.

Rosiwal analyses of prominent members of the green gneisses show the following percentages of minerals:

TABLE IV

ROSIWAL ANALYSES OF GREEN GNEISSES

	I	II	III	IV
Microcline-perthite	21.0	34.0	47.5	57.5
Oligoclase	41.1	44.9	24.4	27.1
Quartz	17.9	2.4	23.1	1.7
Hypersthene	5.5	5.9	—	1.0
Augite	5.9	1.8	—	2.4
Hornblende	4.2	3.8	2.8	7.0
Biotite	1.5	3.5	1.3	0.1
Accessories	2.8	3.7	0.8	3.0

I — An_{25}, obtained from 4 specimens
II — An_{25}, obtained from 3 specimens
III — An_{20}, obtained from 7 specimens
IV — An_{21}, obtained from 3 specimens

The alkali feldspars of the gneisses show faint zoning and very rare microcline grating. They are all perthitic and failed to homogenize at a temperature exceeding 1050°C. and below 1100°C. In one case, the axial angle markedly decreased but, in other cases, a strong moiré structure developed.

Hornblende-pyroxene-plagioclase Gneiss Layers

In the green gneisses, several tabular inclusions and layers of a dark mafic rock are oriented parallel to the foliation (Plates VB, VIA). In tunnel section No. 1, a samll mass of similar rock cuts the pink granite and roughly follows planes formed by jointing. On the west edge, the contact is jagged and vertical. Irregular tongues of the mafic rock project into the granite gneiss at right angles to the direction of the contact. Small stringers of pink pegmatitic material were also observed in the rock but they may be relict inclusions as well as thin injections of the granitic magma. Two dikes, 1 foot thick, were followed through the tunnel excavation for 500 feet.

In tunnel section No. 2, a similar dike intersects the foliation of the granite gneiss at an angle of 30°. The rock is very similar to that of the other dikes and it, moreover, contains porphyroblasts of a black feldspar.

The rock is usually medium grained and granular and its platy minerals are arranged in a parallel orientation. Veinlets of greenish feldspar and coarse pyroxene grains are commonly observed crossing the inclusions and layers in all directions.

Under the microscope, these rocks have two pyroxenes. They also contain plagioclase, hornblende, biotite, and minor accessory minerals such as magnetite and apatite. Calcite is also present filling the interstices between the grains and chlorite, as a secondary alteration product. The granularity of the rock is about 1 mm.

The modal analysis is: plagioclase (An_{32}), 31.1%; hornblende, 53.1%; hypersthene, 4.5%; augite, 4.5%; biotite, 5.3%; and accessory minerals, 3.8%.

The dark inclusions in the green gneiss are similar in chemical composition (see Table V) to the hornblende norite of the charnockite series of India and to the mafic layers in the quartz syenite rocks of the Adirondacks. The specimen analysed is, however, more mafic than the average, and olivine and nepheline appear in the norm, the silica content being too low to form hypersthene. The similarity of the hornblende-pyroxene-plagioclase gneiss to the rocks of dikes cutting the pink granite gneiss suggests an igneous origin. These rocks were later incorporated as layers in the green gneisses in places as much as 50 feet thick.

It is significant that these mafic layers do not contain more than traces of barium, whereas strontium accounts for only 0.02%. They may represent remnants of gabbroic rocks in the green gneisses.

Age Relationships

The relationship of the pink granite gneiss to the pink syenitic gneiss is unknown because the rocks have not been seen in contact.

The pink granite gneiss is cut by many dikes of the green granitic rocks. In tunnel section No. 2, where a small cupola of green granite cuts the foliation of the pink granite gneiss, many dikes leave the main body at diverse angles. Similar dikes were also observed along the main highway about 3 miles from Labrieville where they cut the foliation of the pink granite gneiss as well as the hornblende-plagioclase gneiss layers.

In tunnel section No. 2, near the intersection of the adit with the tunnel, a zone of foliated hornblende-plagioclase gneiss shows detached blocks surrounded by narrow stringers of green gneisses.

No direct evidence was obtained of the age relationship of the pink granite gneiss to the anorthosite. Evidence suggests that the anorthosites are older than the green granite and therefore younger than .the pink granite gneiss.

TABLE V

HORNBLENDE-PYROXENE-PLAGIOCLASE GNEISS

	D-46	VI	VII	VIII	IX
SiO_2	45.17	48.32	49.78	50.04	45.19
TiO_2	3.59	3.44	2.96	1.93	4.04
Al_2O_3	11.84	14.97	13.44	11.65	13.40
Fe_2O_3	2.96	3.31	4.94	2.63	2.97
FeO	14.78	10.61	12.99	15.76	13.19
MnO	0.28	—	0.24	—	0.19
MgO	5.43	2.54	3.85	5.58	4.23
CaO	9.91	7.22	7.27	7.89	9.79
Ma_2O	3.17	1.97	2.16	3.08	2.47
K_2O	1.20	2.48	1.30	0.89	0.49
P_2O_5	0.50	1.36	0.27	0.20	0.12
$H_2O(+)$	0.85	0.32	0.56		2.41
$H_2O(-)$	0.05	0.07	0.10	0.19	0.39
CO_2	—	0.14			
S (total)	0.23	0.14	0.02		
Cr_2O_3	0.03				
V_2O_3	—				
ZrO_2	0.04				
Ga_2O_3	tr.				
BeO	—				
NiO	—				
BaO	tr.				
SrO	0.02				
Cu	tr.				
Pb	—				
Zn	0.02				
Co	tr.				
Sn	—				
Bi	—				

Norms	D-46	VI	VII	VIII	IX
Quartz	—	8.28	9.40	—	0.90
Orthoclase	7.09	15.01	7.70	5.00	2.78
Albite	20.78	16.77	18.30	26.20	20.96
Anorthite	14.50	10.84	20.33	15.29	23.91
Diopside	26.43	13.71	11.78	19.43	19.76
Hypersthene	—	14.34	19.06	20.27	14.35
Magnetite	4.28	10.56	7.15	3.71	4.41
Ilmenite	6.81	6.60	5.60	3.65	9.58
Apatite	1.18	3.22	0.64	0.34	0.34
Calcite	—	0.30			
Pyrite				5.63	
Olivine	14.58				
Nepheline	3.30				
Zircon	0.05				
Modes					
Oligoclase	34.6			40.8	
Hornblende	52.0			19.6	
Augite	4.4				
Hypersthene	5.1			31.0	
Biotite	tr.				
Magnetite	4.0				
Apatite				8.6	

D-46 Hornblende-pyroxene-plagioclase gneiss layer in green gneiss. Road cut along access road to Cassé lake. H. Boileau and J. Gagnon, analysts.

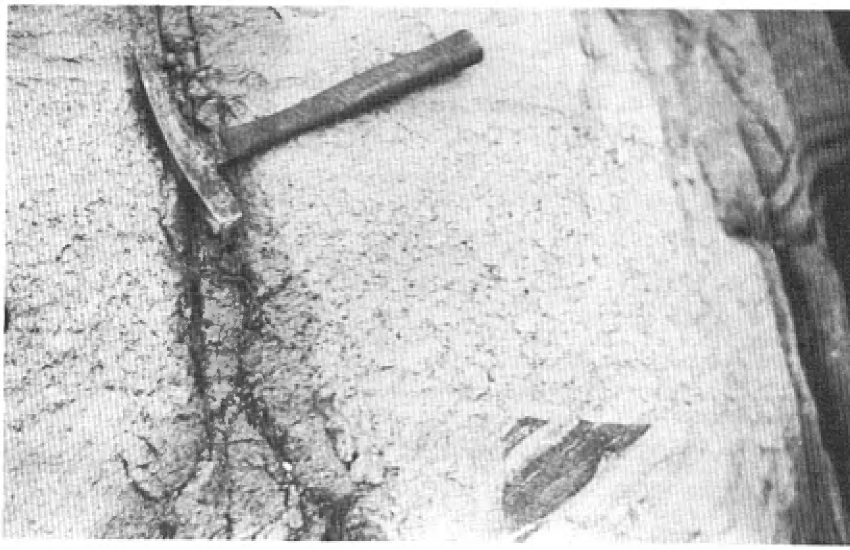
VI Mafic syenite (shonkinite). Quarry northeast of Moody Pond, Saranac Quadrangle (Balk, 1931, p. 425). R.B. Ellestad, analyst.

VII Paragneiss inclusion in gabbro west of Canimiti river, latitude 47°21'25"N. and longitude 77°08'45"W. H. Boileau, analyst.

VIII Hornblende norite, St. Thomas's Mount, Madras. H.S. Washington, analyst (1916, p. 328).

IX Quartz gabbro, Brazo, New South Wales. A. Bain, analyst. Washington Tables, p. 662, No. 173.

PLATE VII



A — Dike of green porphyritic granite cutting pink granite gneiss and hornblende-plagioclase gneiss layer.

B — Portal of adit No. 3.

POST-GRENVILLE (?) INTRUSIVE ROCKS

Gabbros

Although gabbros do not cover large parts of the area, many layers and lenses of them occur at or near the contact of the labradorite anorthosite with the green gneisses and also within the andesine anorthosite body.

Two lenticular masses of gabbro crop out east of the road intersection in the southwestern corner of the area. A lens of similar rock is also found near the west shore of Cassé lake in the andesine anorthosite. A gabbroic rock with a different mineralogical composition is in contact with labradorite anorthosite in the massif of the central part of Cassé lake, along the east shore of the northern part, and along Lionnet river to the north of Dubuc lake.

Both types of gabbro occur in the southwestern corner of the map-area. A dark dense hornblende-rich rock with disseminated garnet porphyroblasts is the most abundant. It is weakly foliated and contains plagioclase, hornblende, hypersthene, garnet, apatite,and iron oxide. A similar rock forms an inclusion or a layer in the adjacent green gneisses.

Labradorite is well twinned in clear anhedra with hornblende grains between them. The hypersthene is strongly pleochroic to pronounced pink and greenish tints. Garnet occurs as isolated porphyroblasts or associated with magnetite, hypersthene, and hornblende.

Along the west shore of Cassé lake, a rock composed almost entirely of ferromagnesian minerals froms lenses in the anorthosite near the contact with the green gneisses. The plagioclase, An_{65}, forms aggregates of small grains entirely enclosed within the mafic minerals. Enstatite and augite show many inclusions of opaque minerals oriented parallel to the cleavage forming a grid (Plate IXA). The inclusions are only slightly magnetic and are most abundant near the centres of the grains. The amphibole has an extinction angle of 15° and a higher birefringence than the normal hornblende. It is pleochroic with $Z =$ yellow. It replaces the pyroxenes and forms patches and polygonal grains in them. Red biotite also occurs as a minor constituent. The opaque grains are slightly magnetic and have colorless isotropic grains, probably spinel, in their cores.

The labradorite anorthosite in the massif of the middle part of Cassé lake seems to grade into an even-grained greenish gabbroic rock which, near the contact, has conspicuous clots of pyroxenes enclosed in a plagioclase groundmass.

Under the microscope, the rock shows plagioclase, augite, biotite, and hornblende with minor apatite and magnetite as accessory minerals. Chlorite and sericite are the usual secondary minerals resulting from alteration.

The plagioclase, An_{44}, which forms the bulk of the rock, consists of large anhedral grains with smaller equant anhedra completely surrounding the clots of augite, hornblende, and biotite. Many opaque inclusions occur at random in the plagioclase.

The augite is nearly colorless and is in large rounded grains. The hornblende which forms rims around and small polygonal grains replacing augite is pleochroic in brownish green and yellow colors. Biotite as thin flakes is transverse to the plagioclase grains. Apatite and magnetite make up less than 1% of the rock. Along Lionnet river, north of Dubuc lake, the rock has a composition similar to that of the gabbro of the massif of the middle part of Cassé lake, and it is also associated with the labradorite anorthosite body nearby.

Labradorite Anorthosite

This facies of the anorthosite is so named to distinguish it from the sodic andesine of the anorthosite massif to the west of Cassé lake. The labradorite anorthosite can ordinarily be distinguished from the andesine anorthosite by its characteristic gray to black color. Where the rock has been granulated, large grains of the black feldspar are enclosed by smaller grains of the gray feldspathic groundmass. Locally, the labradorite anorthosite is pink, and it is, therefore, very difficult to separate it from the andesine anorthosite.

Along the east shore of the northern part of Cassé lake, a thin layer of the gray anorthosite abuts against the pink andesine anorthosite to the south. A small knob standing above the sand plain south of the massif in the middle part of Cassé lake is composed of grayish white anorthosite. West of Danielle lake, a series of gabbroic and dioritic rocks apparently grades into layers of dark gray to black anorthosite. Several layers, at the most 10 feet thick, are parallel to the strike of the associated rocks.

Labradorite anorthosite is also found in other localities north and south of Lionnet river and west of Biscuits river. North of Lionnet river, it forms a small rounded hill and the anorthosite is pink with black crystals of plagioclase. The rock occurs in an elongated body which underlies a small area north of the dams. The small mass south of the sand plain to the west of the main dam may be its extension to the south. West of Biscuits river, the anorthosite underlies a small rounded hill protruding through the sand of the valley.

Another lenticular mass of the labradorite anorthosite is parallel to the edge of the andesine anorthosite north of Dubuc lake.

Under the microscope, thin-sections of the rock show almost exclusively plagioclase with less than 2% potassic feldspar, augite, biotite, and hornblende. The accessory minerals recognized are apatite, magnetite, and sphene. Sericite and calcite are secondary minerals.

Small anhedra of feldspar fill the interstices between the large polygonal grains of labradorite. In the granulated specimen, the larger crystals are rounded, and the interstitial grains make up much of the rock. Many of the grains show twinning lamellae. The grains contain numerous rounded inclusions about 0.020 mm. long and 0.003 mm. wide, which have their long axes in three directions. Under parallel light some of these inclusions are red and under crossed nicols show a high birefringence. Hematite and rutile have these properties. The plagioclase is from An_{61} to An_{47}. The more calcic varieties are dark gray to white.

The less calcic feldspars show considerable crushing and a wavy extinction. The larger grains are about 2 mm. in diameter and the smaller 0.3 mm. Small interstitial grains with lower refractive indices than those of labradorite show a faint grid twinning. They have a large negative axial angle and are probably microcline. They occur particularly in the granulated facies of the anorthosite.

Hornblende as short prisms, pleochroic in green and yellow, is associated with the smaller grains. Thin biotite flakes are seen in many places transverse to grain boundaries. Sericite may be abundant in the pink variety. Apatite, sphene, zircon, and magnetite prisms are not larger than 0.1 mm. and form a very minor part of the rock.

At the northern end of the anorthosite ridge to the north of Lionnet river an inclusion of anorthosite was observed in what is interpreted as a tongue of the green gneisses. The inclusion, which is about a foot in diameter, shows dark red crystals of labradorites nearly an inch long. The plagioclase is An_{51} and is slightly less calcic than that of the ridge, which is An_{57}.

Andesine Anorthosite

To the west of Cassé lake, a massif of pink andesine anorthosite is surrounded by the green gneisses and irregular pockets and lenses of diorite and gabbro. The southern end of the labradorite anorthosite on the east shore of the northern part of Cassé lake also terminates against the pink anorthosite.

A weak layering is observed in all the anorthosite, which is porphyritic, particularly near the contact. The tabular phenocrysts have their greater dimensions in the plane of layering. The layered aspect is particularly apparent on weathered surfaces. At several localities, mafic minerals form clots which weather to depressions about 4 inches in diameter.

From the western boundary of the area, the dip of the layers in the anorthosite gradually increases eastward from near horizontal to 60°E. Many shear zones occur within the anorthosite, one of which is near the ilmenite-hematite deposit north of Brûlé lake.

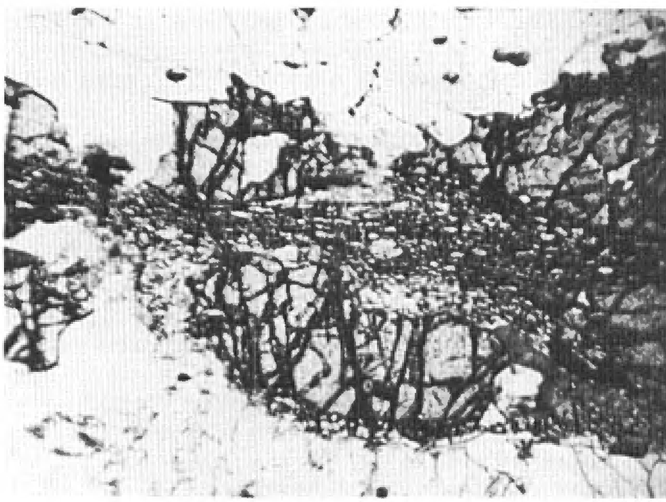
The phenocrysts are light gray to nearly black, and the lighter colored ones are as much as a foot long. Ilmenite and hematite occur commonly as clots evenly distributed throughout the rock.

The rock is purplish pink and usually contains more mafic minerals than the labradorite anorthosite. It is composed of andesine, microcline, biotite, hornblende, with ilmenite-hematite, zircon, and apatite. Quartz may be present. Muscovite, chlorite, sericite, and calcite are secondary.

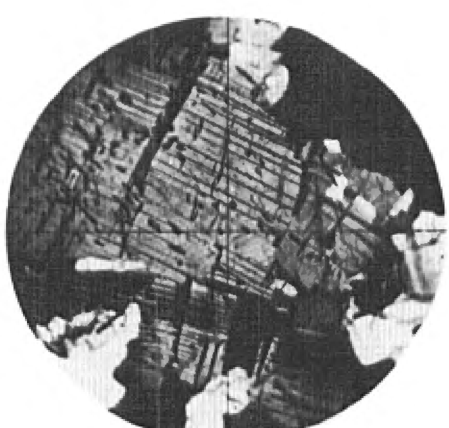
The rock is characterized by antiperthitic andesine (Plate VIIIB). Andesine grains, 2-3 mm. in diameter, are partly surrounded by grains 0.3-0.5 mm. in diameter of the same feldspar. Most of the larger grains and those of intermediate size are antiperthitic, whereas the smaller grains are homogeneous. The grains have sinuous boundaries and are more anhedral than those of the labradorite anorthosite.

The plagioclase is from An_{40} to An_{32}. The most calcic andesine was obtained from a diamond drill core at a depth of about 200 feet. The bleds in the antiperthitic grains form slender rectangular rods about

PLATE' VIII



A — Sillimanite and garnet in paragneiss. Section on northeast bank of Desroches river. X30



B — Antiperthitic andesine in anorthosite. X30

0.02 mm. thick along the twinning lamellae on the (100) face and some were also observed nearly at right angles on (010). Myrmekitic structure is formed in some grains, particularly near the contact of the grain with quartz.

Antiperthitic plagioclase seems to be restricted to a certain composition range in this map-area between An_{40} and An_{30}. In other districts of the Grenville subprovince, a similar structure was observed in plagioclases either more calcic or more sodic than those of the area. Osborne (1928) mentioned antiperthitic plagioclase between An_{60} and An_{50} in the rocks of the vicinity of Ivry, Quebec. In some of the rocks of the Varberg district, Sweden (Quensel, 1941), the plagioclase is calcic oligoclase. Several bodies of rocks similar to those of the area were also described, particularly those of the Saint-Urbain area, Quebec (Mawdsley, 1927) and those of Nelson and Amherst counties of Virginia, U.S.A. (Ross, 1951). The fact that the appearance of this structure is independent of the composition of the host suggests that it may be related to the behavior of crystal structures under different physico-chemical conditions.

Microcline forms a considerable proportion of the rock if the intergrown feldspar of the antiperthitic grains be included with the interstitial grains. The moiré structure characteristic of microcline is observable in many of the grains and in some of the blebs. The interstitial grains are about 0.2 mm. in diameter, and they also form narrow rims around the plagioclase grains of intermediate size. Quartz with undulatory extinction occurs both as large and small grains.

A pyroxene with high birefringence and inclined extinction was identified as augite. Hornblende, most of which is ploechroic in tints of green and yellow, occurs. However in one specimen an amphibole with a greenish blue color was found with the green variety. Biotite forms lath-shaped crystals, is pleochroic in brown and yellow colors, and is mainly interstitial to feldspar. Rounded prisms of apatite are about the size of the finer grained plagioclase grains with which they are associated. Ilmenite-hematite, with the latter mineral showing in reflected light as a coarse intergrowth in ilmenite, is common in the rock.

Sericite and calcite are present in most of the specimens studied. Chlorite was observed to surround grains of augite and, in some cases, to replace the latter completely. Epidote grains are few in number.

Apatite Diorite

Several facies of dioritic rocks are found in the andesine anorthosite batholith and near the contact with the green gneisses. They are all characterized by the presence of two pyroxenes and a fairly high content of magnetite, ilmenite-hematite, and apatite. Whereas the leucocratic and intermediate varieties mark the border zone, the dark rock is likely different and intrusive into the anorthosite suite. A granulose variety observed in the layers of anorthosite weathers to a light brownish color.

A mafic variety is found in the southwest corner of the area, where it forms a tongue in the anorthosite. It is well exposed on the shore of Sault-aux-Cochons lake and along the road in the southwest corner of the map-area. It also crops out as dike-like bodies along the contact of the anorthosite with the gneisses, particularly near the west shore of Cassé lake. Leucocratic facies are restricted to the contact zone.

The diorite consists of a mosaic of granular antiperthitic plagioclase and some microcline. In the leucocratic facies, the feldspar phenocrysts, partly granulated, are accompanied by interstitial rounded grains of augite, hypersthene, apatite, magnetite, and ilmenite-hematite. Quartz, biotite and pyrrhotite are commonly present. The phenocrysts of plagioclase may be up to 6 inches long. In the mafic rock, the plagioclase is in rounded phenocrysts set in a dark matrix of the same ferromagnesian minerals. Their respective plagioclase compositions are An_{36} and An_{31}. Both types show an antiperthitic intergrowth of microcline which may form as much as 6% of the rock as isolated grains.

The granulose variety on fresh surface shows rounded white feldspar grains enclosed within a fine granular groundmass of mafic minerals with much magnetite and ilmenite-hematite. The feldspar grains are elongated in the direction of the layering in the anorthosite. In thin-section, this rock differs from the other varieties in that its antiperthitic plagioclase has a very high content of intergrown K-feldspar accompanied by a greater amount of perthitic potassic feldspar. It would appear as a transition rock between anorthosite and granite or syenite.

Apatite as rounded prisms about 1.0 mm. in diameter is associated with the pyroxenes and constitutes as much as 8.8% of the mafic rock and 1.0% of the leucocratic facies. In the latter, apatite is also concentrated in the mafic part. Magnetite and ilmenite-hematite skeleton crystals surround all the other minerals. Although, the intergrown ilmenite-hematite has all the optical properties of this assemblage, it reacts easily with hydrochloric acid. The presence of intergrown lamellae of magnetite could not be positively confirmed under high magnification.

On the south shore of Brûlé lake, quartz is a minor constituent of the rock and, when present, it is found between the pyroxenes and the ilmenite-hematite grains. It cannot be ascertained that it is a reaction mineral. Pyrrhotite is disseminated throughout the rock.

The composition of both the dark and the leucocratic facies obtained from Rosiwal analyses gave the following percentages.

TABLE VI

ROSIWAL ANALYSES OF APATITE DIORITE

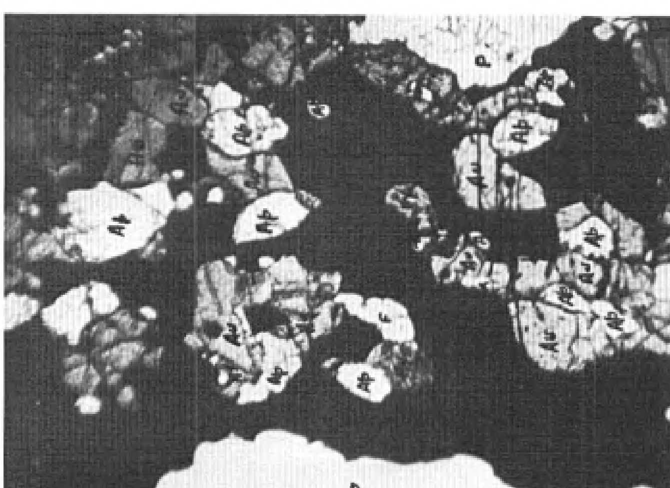
	Mafic	Intermediate	Leucocratic
Andesine	39.2	55.6	71.4
Augite	18.7	15.3	12.0
Hypersthene	16.6	8.1	9.6
Apatite	8.8	8.5	2.1
Ilmenite-hematite	16.1	12.4	5.6
Quartz	0.3	—	—
Biotite	0.3	—	—

Hornblende-pyroxene-plagioclase Gneiss Layers

A tabular inclusion of hornblende-pyroxene-plagioclase gneiss in anorthosite has been broken into fragments along the layering of the anorthosite against which it is bordered by a reaction zone. The space between the fragments is filled with coarse pegmatitic material. North of the northeast end of the same lake wide exposures of the gneissic rock also occur. On the east shore of Cassé lake, a similar rock apparently cuts gabbroic rock.

PLATE IX

A — Schiller inclusions in pyroxene. Pyroxene is also partly replaced by amphibole. E = enstatite, H = amphibole, and B = red biotite. X30



B — Apatite gabbro inclusion in andesine anorthosite. Ap = apatite, Hy = hypersthene, Au = augite, and P = andesine. Dark area is ilmenite-hematite. X30

Near the anorthosite mass in the green gneisses, many tabular inclusions are found. They are finer grained than those observed in the anorthositic rocks, but their composition suggests that they may be related to them. They resemble the fine-grained hornblende-plagioclase gneiss layers of the pink granite gneiss.

The inclusions in the anorthosite consist of a dark medium-grained rock in which a weak layering is commonly observable. It is composed of plagioclase, hypersthene, augite, hornblende, biotite, apatite, and ilmenite-hematite. The granularity of the rock is about 1 mm.

Under the microscope, thin-sections show a mosaic of equant plagioclase grains with hornblende, augite, and hypersthene forming the bulk of the rock. Hornblende is slightly porphyroblastic and forms variable proportions of the specimens examined.

The plagioclase is from An_{62} to An_{55}. Zoning is common and the maximum difference in mole composition is about 10%. The hornblende content is variable and may form as much as 40% of the rock. Augite and hypersthene form respectively about 10 and 5% of the rock. They are closely associated and surrounded by skeleton crystals of hornblende. Some apatite is in grains as large as those of augite, but it is commonly only a minor constituent. Slender flakes of biotite may be present.

Green Porphyritic Granite

The green porphyritic granite underlies an area of about 30 square miles east of Cassé lake. It is in contact with the green gneisses. In the southeast corner, a small body is entirely surrounded by the green gneisses.

PLATE X

Microcline-perthite in green oligoclase granite. Note the plagioclase rim against quartz. X20

A dike of the green porphyritic granite cuts the pink granite gneiss on the south side of the main dam, and several dikes of the rock cut the green gneisses at the southwest end of the dam on Desroches river. At the spillway, thin dikes of the green porphyritic granite follow joints in the green gneiss.

The porphyritic granite is nearly free of inclusion except near its margin on the north and south. Phenocrysts of feldspar showing wide Carlsbad twin lamellae are oriented in the direction of the foliation of the rock. They are set in a medium-grained groundmass with mafic minerals. The quartz may also be as phenocrysts which are smaller than those of feldspar. The rock is white on the surface, but beneath this it weathers to a typical brownish yellow color. The rock is green on the fresh surface.

Under the microscope, thin-sections of the green porphyritic granite show large phenocrysts of microcline-perthite and of quartz surrounded by a groundmass of plagioclase, microcline, quartz, hypersthene, augite, and hornblende with magnetite, apatite, and zircon, as accessory minerals. All the grains are anhedral with sutured boundaries.

The microcline-perthite phenocrysts contain inclusions of plagioclase and quartz. Some of the plagioclase inclusions are antiperthitic and myrmekitic. Many of the smaller microcline grains of the groundmass have characteristic grid twinning. The plagioclase grains in the groundmass are An_{24}.

Hornblende, when present, is slightly porphyritic. Hypersthene is found with augite in all the specimens examined. They are very similar to one another but exsolution lamellae is more common in hypersthene than in augite. The accessory minerals are not abundant. Calcite, chlorite, and sericite are the alteration minerals.

Rosiwal analysis of a specimen of the green porphyritic granite gives: microcline-perthite, 46.6%; oligoclase, 31.2%; quartz, 10.9%; hornblende, 4.1%; hypersthene, 3.6%; augite, 1.9%; and accessories, 1.7%.

The inclusions observed in the green porphyritic granite contain a considerable proportion of the potassic feldspar possibly a result of assimilation. They are more mafic than the host rock and have the same mineralogical composition. A Rosiwal analysis is given for comparison: microcline, 38.9%; oligoclase, 14.6%; hornblende, 33.3%; quartz, 3.2%; hypersthene, 5.7%; augite, 1.4%; accessories, 2.8%; and traces of biotite.

The chemical composition of the green porphyritic granite is compared with syenitic rocks of the Adirondacks. Although quartz appears as large grains, in places forming phenocrysts smaller than those of feldspars, the silica content in the granite is intermediate to low and quartz is abundant enough to justify the name.

Pink Porphyritic Granite

The pink porphyritic granite is restricted to the vicinity of Labrieville in the southeast corner of the area. It forms an ill-defined body which borders the green gneisses. It is also found in contact with the pink granite gneiss which it commonly resembles. Tunnel section and adit No. 3 and the east end of tunnel section No. 2 are entirely excavated through the rock.

The rock is coarse grained and shows phenocrysts of feldspar which are oriented in a parallel direction. It has a slight pinkish color, but most of the feldspar grains are white. Many inclusions of biotite-plagioclase and hornblende-plagioclase gneiss are found in the rock. Several tabular bodies of a coarse-grained, green granite rock are believed to be inclusions of the green gneisses.

Under the microscope, coarse anhedral grains of microcline-perthite surrounded by plagioclase, quartz, and interstitial biotite and hornblende are observed with a typical granitic texture. The accessory minerals are apatite, magnetite, zircon, and a metamict mineral.

TABLE VII

GREEN PORPHYRITIC GRANITE

	AR-7A	AR-20	X	XI	Norms	AR-7A	AR-20	X	XI
SiO_2	57.26	63.95	67.06	58.26	Quartz	7.39	12.08	19.98	6.03
TiO_2	1.53	0.83	0.68	1.57	Orthoclase	21.94	33.55	31.14	26.21
Al_2O_3	15.77	15.59	14.39	15.51	Albite	34.77	32.77	28.32	34.06
Fe_2O_3	3.44	1.00	1.03	2.02	Anorthite	13.64	8.39	8.62	10.98
FeO	5.49	3.82	4.49	6.64	Diopside	3.03	0.80	1.09	2.12
MnO	0.14	0.10	—	0.17	Hypersthene	7.98	6.97	6.81	11.67
MgO	1.80	2.80	0.40	1.77	Magnetite	4.98	1.46	1.39	2.86
CaO	4.61	2.80	2.30	4.29	Ilmenite	2.90	1.58	1.29	2.98
Na_2O	4.10	3.86	3.37	4.04	Apatite	1.95	0.84	0.34	2.45
K_2O	3.70	5.66	5.33	4.46	Calcite	0.32	1.00	0.25	0.40
P_2O_5	0.53	0.35	0.29	0.37	Zircon	0.24	0.13		
$H_2O(+)$	0.82	0.35	0.13	1.04					
$H_2O(-)$	0.07	0.06	0.09	0.07	**Modes**				
CO_2	0.14	0.44	0.11	0.16	Oligoclase	62.6	25.8	24.2	74.0
S (total)	0.07	0.04			Microperthite		58.0	46.1	
Cr_2O_3	tr.	tr.			Quartz	13.2	14.3	16.3	4.0
V_2O_3	—	—			Hypersthene	6.0	0.8	5.8	6.5
ZrO_2	0.16	0.09			Augite	3.0	0.8	1.4	6.0
Ga_2O_3	tr.	—			Hornblende	10.2	—	2.8	2.0
BeO	—	—			Garnet	—	—	0.5	—
NiO	—	—			Accessories	5.0	0.2	2.8	2.5
BaO	0.24	0.17							
SrO	0.07	0.08							
Cu	—	—							
Pb	—	—							
Zn	0.02	0.01							
Co	—	—							
Sn	—	—							
Bi	—	—							
Rb_2O	—	0.02							

AR-7A Green porphyritic syenite dike at the "main dam", Cassé lake. H. Boileau and J. Gagnon, analysts.

AR-20 Green porphyritic granite near the main dam at Cassé lake. H. Boileau and J. Gagnon, analysts.
Normative feldspar: $Or_{44.91}$ $Ab_{50.90}$ $A_{18.83}$
Normative plagioclase: $Ab_{73.00}$ $An_{27.00}$

X Augite-hypersthene-quartz syenite, quarry on Racquette Pond at south west end of Tupper Lake village, Long Lake Quadrangle. (Buddington, Table, 32, U.S.G.S. Mem. 7).

XI Augite-hypersthene syenite. Road cut, 0.9 mile southeast of Wisner Scholl, Lowville Quadrangle. Green augen gneiss. T. Kameda, analyst. (Buddington, Table 21, Mem. 7).

Microcline-perthite grains have an irregular extinction and a low content of exsolution feldspar. In some cases, the plagioclase feldspar crosses the grains of the host in a vein-like fashion. Quartz occurs in large grains. The plagioclase of composition An_{24} to An_{18} is, in places, myrmekitic and forms grains of the same size as those of quartz and microcline. The biotite is pleochroic to brown and yellow colors, and some grains are green. Hornblende when present belongs to the common variety with a pleochroism in green and yellow. Magnetite, apatite and zircon are the minor constituents of the rocks.

Rosiwal analysis of five specimens give: microcline-perthite, 41.2%; oligoclase (An_{22}), 30.6%; quartz, 20.9%; biotite, 4.8%; hornblende, 1.2%; and accessories, 1.3%.

Plagioclase-quartz-hornblende Dike

A dense black rock with conspicuous biotite cuts the foliation of the green granitic rock in adit No. 3 and on the road cut along the access road to the surge shaft.

The rock is fine grained and greenish black. Under the microscope, microcline-perthite, plagioclase, quartz, hornblende, and biotite were identified with apatite, magnetite, and zircon as accessories. All the grains are anhedral.

Microcline-perthite forms only a few grains in the rock, and they are slightly porphyritic. Plagioclase determined as An_{27} with quartz form the bulk of the rock. They both contain inclusions of apatite and an opaque mineral. Hornblende is slightly porphyroblastic. The crystals show a weak orientation. Biotite flakes are the largest grains of the rock and are pleochroic to tints of red and yellow. The accessory minerals are abundant.

Pegmatites

Pegmatites occur at several localities in the area. Pink pegmatites are abundant in the pink porphyritic granite and less so in the pink granite gneiss. North of Moose Creek fault, the green gneisses are crisscrossed with dikes of pegmatites. Along the road cut about 3 miles from Labrieville, a dike consisting of coarse microcline, quartz, hornblende, and biotite contains traces of molybdenite. A coarse pegmatite dike cuts the green oligoclase gneiss in tunnel section No. 1 near the intake.

Along Moose Creek fault, several exposures of the pegmatite show a spectacular aggregate of red microcline, green epidote, and quartz.

Green pegmatites occur in the green gneisses. They are also highly quartzose, containing magnetite, and, in one case, molybdenite.

Age Relationship of the Igneous Rocks

In the area, there is no direct evidence of the relative ages of the various rock units. The igneous bodies, including the anorthosites as well as the pink and the green porphyritic granites, are more or less isolated from one another and do not provide any means of establishing their relative ages.

Small dikes of green rocks seen at the contact of the andesine anorthosite with the gneisses may be due to local melting or may represent late differentiates of the anorthosite itself.

The labradorite anorthosite is strongly deformed, compared with the andesine anorthosite. The presence of boudins in the adjacent gneisses may suggest that the deformation occurred during the emplacement of the andesine anorthosite to the west or the green porphyritic granite to the east.

PLEISTOCENE AND HOLOCENE

Much evidence throughout the area suggests widespread glaciation. Glacial striae, crescentic marks, large erratics, and morainic material are found on most of the high hills as well as in the valleys.

The glaciers have left a mantle of morainic material, particularly in the valleys, and, on the higher hills, smooth rounded rock exposures. Glacial striae are well developed on fresh rock and indicate that the ice moved about S. 30°E.

Several types of glacial deposits can be recognized in the area. At the dam site, varved clay forms the north bank of the river, and farther inland, along the access road to Cassé lake, is an extensive boulder clay deposit, which was used as a source of clay material for the construction of the dams. Eskers, kames, kettles, glacial lake deposits and outwash plains cover much of the center of the area a few miles south of Betsiamites river.

The varved clay is found along the north bank of Betsiamites river at the dam site and consists of extremely thin layers of silty clay alternatively pale and dark gray; it underlies a layer of poorly stratified clay. A few pebbles occur in the layers. The extent of this deposit is not known, but it fills part of an abandoned channel of the river.

The boulder clay deposit (Plate III-A) along the road covers the slope of a hill and consists of a bluish gray silty clay with scattered large erratics. Some minor clay occurrences were also observed along the valley of the stream flowing into Cassé lake, about a mile north of Lionnet river.

The boulders found in the till and the drift are of various types of rocks, many of which are not known within the area. There are many boulders of anorthosite, gabbro, granite, and granite gneisses, and some boulders of paragneisses and sedimentary rocks. The boulders of sedimentary rocks seen were mostly of white sandstone, layered red and white sandstone, sandstone conglomerate and breccia, chert, and calcareous siltstone. The source of these sediments has not been ascertained.

Eskers are prominent in the area. The most prominent esker ridge passes into kamic deposits at its southeastern end. This esker forms a steep-sided ridge about 30 feet high which follows a valley partly filled with sand and gravel, even through a constriction, until it reaches the flat area near Rousseau lake. A similar ridge is found at the terminal zone but at right angles to the direction of the esker of which it may be an extension.

The kame deposits on the flat ground near Rousseau lake form flat-topped, low ridges with intervening kettles partly filled with water. The kettles are believed to have formed through the melting of ice blocks or layers entrapped in the deposited material. This is further supported by the fact that Rousseau lake is entirely surrounded by glacial deposits and probably formed by the melting of a stagnated mass of ice. At the outlet of the lake the finer portion of the glacial material is washed out and a coarse gravel composed of rounded pebbles about 1 inch to 3 inches in diameter remains.

The outwash plains occur immediately south of the main dam and at the intersection of the main Forestville-Labrieville highway with the access road to Cassé lake. Near the main dam, the outwash material, which was used for building material for the dams, is composed of poorly sorted, layered, coarse gravel. The gravel is commonly overlain by a layer of sand. These outwash plains obviously were caused by rapid deposition from a heavily laden stream. Along the sand-filled valley leading to the second outwash plain, sand terraces, at an elevation of 1,340 feet above sealevel, border the bank of Desroches river. To the southeast, in the vicinity of the aggregate plant referred to on the map as "Dufresne", another outwash plain, smaller than the preceding two, was cut by the stream running across it. The bedded gravel lies about 40 feet above the valley and its exploitation exposed cross-sections of poorly sorted gravel interbedded with sand (Plate III-B). Many ice contact features show coarse, rounded cobbles sunk into the layered deposit (Plate IV-A).

Along Betsiamites river and part of Biscuits river, similar bedded deposits form the banks and show the same ice-contact phenomena. The terrace-like deposits are 500 feet above sealevel, compared with 1,340 feet for the others. Stripping revealed coarse gravel with grain gradation and cross-bedding.

An explanation may be found to account for the difference in altitude of these terraces. From the description of the valley of Betsiamites river, it seems probable that the glacier did not considerably modify its gorge from the falls at the main dam to Waweashton lake because the direction of the ice movement was partly transverse to the direction of the river. The ice may have formed an artificial dam which caused the flooding of an area slightly greater than that now being flooded. If the terraces are taken as the maximum height of the water, the elevation is still 50 feet above that of the expected water level in the basin of the hydro-electric project. During the retreat of the ice, the water flooded the valley of its tributaries and deposited its load. A careful investigation did not reveal any abandoned channel, except for a short distance at the dam sites. Therefore, it seems that Betsiamites river is now scouring its preglacial gorge which was temporarily abandoned.

Below Waweashton lake, the valley of Betsiamites river is enclosed between two steep walls. This valley, which is roughly parallel to the direction of the ice movement, was considerably enlarged and deepened by glacial erosion. For some five and a half miles upstream from Waweashton, the valley of Biscuits river is wide with a steep slope on the east side. A valley occupied by lakes and Kabitukimats river near the eastern boundary is also partly filled with sand.

A small delta is forming at the mouth of Betsiamites river where it flows into Cassé lake.

STRUCTURE

All the rocks of the area have a more or less well-defined gneissic structure which is parallel to the contacts of the main bodies.

The labradorite anorthosite and the gabbroic rock into which it grades structurally overlie the gneisses. They form inclusions and lenses in the green gneisses.

Granulation of the labradorite anorthosite increases southward along the trend of its bodies and the eastern edge of the small lenticular masses.

The foliation or primary layering in the pink andesine anorthosite batholith is nearly horizontal near the western boundary of the area and in the southwest corner. The dips increase as the contact is approached. The mass has the appearance of a dome which has remained unaffected by the stresses developed during the intrusion of the younger rocks. Segregation is also commonly observed and it is manifested by the clots of the granular rocks and other layers of chloritic material. They give some evidence of movement during the emplacement of the anorthosite.

Rounded fragments of anorthosite along the contact have rotated about 60°. Rodding in the dioritic inclusions shows a plunge of 10° south. This is in close agreement with the low angle of dip of the anorthosite in the southwest corner of the area.

The phenocrysts are parallel to the foliation in the green porphyritic granite. The angle of plunge is vertical. From these data, it seems that magma has risen vertically during the period of intrusion. Stress caused the orientation of the phenocrysts during crystallization. The orientation is more pronounced near the contact. Later, the whole mass was tilted to the east.

In the southeastern corner of the area, the orientation of the feldspar phenocrysts is not so well defined, and the shape of the mass is very irregular. Plunges measured range between 50° to the south to horizontal.

The pink porphyritic granite contains several inclusions which have moved with the ascent of the magma. Many of these inclusions are impregnated by stringers of intricate shapes and, as mentioned above, in one case were observed to effect the shape of a parabola plunging downward.

Lineations plunge to the south at an angle of about 30°. Tilting may account for all of it, and the pink porphyritic granite probably represents a concordant intrusive of the laccolith type. This is supported by the fact that it nearly surrounds the green gneisses and the green porphyritic granite. The contact with the green granitic rocks is very indefinite, and interlayering of the pink and green rocks was observed in several places. The pyroxene grains in the green granite are partly or completely altered.

The pink granite gneiss crops out as wide bands which follow the structure of the main bodies, and, near the east shore of Cassé lake and the northern boundary, many lenticular bodies were recognized in which some augen gneiss are present. Their primary features have been completely obliterated through metamorphism and folding.

Folding

Folding is evident particularly in the southern part of the area where it is accompanied by faulting. The bands of paragneisses follow the folds which are intersected by a fault in the southeastern part.

The area northwest of Moose Creek fault appears to have a succession of narrow synclines and anticlines indicated by the attitude of the foliation. The paragneiss band strikes southwest, and, after reaching Desroches river, it follows the east side of the hill forming the bank of the river. This structure is seen northward in the green gneisses and the lenses of pink granite gneiss.

The northwest limb of the syncline of the south-central part is bordered by the bands of paragneiss which dip steeply east. In a southwest direction, the axis of the fold is crossed, and a few reversed west dips are found. On the north, the green gneisses are nearly horizontal or dip at low angles, whereas to the southwest the dip increases. The plunge observed along many fold axes changes as it is followed northward. In the paragneisses, it was measured as 50° southwest, and to the north, 25° to the northeast.

Farther southeast, the green gneisses are in contact with a coarse pink granite gneiss, and they describe a sharp fold which is cut by Moose Creek fault.

Near Labrieville, the paragneiss band strikes to the northwest, after it has followed an anticline and a syncline. No dip reversal was observed and the foliation is parallel to the band. The axis of these folds is transverse to those of the folds mentioned above, and a fault also parallels them. This fault is near the intersection of the main Forestville-Labrieville highway with the access road to tunnel section No. 2.

In the exposures of quartzite near the road intersection, the layers are strongly plicated, but the folds may be related to the fault in the vicinity.

The pink granite gneiss near the southern boundary and to the south of Betsiamites river also shows evidence of folding, as indicated by the changes in strike of the foliation.

Faults and Shear Zones

Faults and shear zones are common in the area. Many of them were observed along the tunnel section. They all show a gouge zone with fragments of the rocks in which they occur.

Faults occur parallel and perpendicular to the foliation and to the joints. Several shear zones are found along layers of hornblende-plagioclase gneiss which are planes of weakness in the rocks.

In tunnel section No, 2, a fault zone cuts the paragneiss series along two major planes. These planes are each accompanied by a gouge zone about a foot thick which dips 10° and 20° east respectively. As mentioned previously a brecciated zone in which tar was found accompanies the faults.

In tunnel section No. 3, a brecciated zone about 3 feet thick was also intersected. It has the same direction as the faults of tunnel section No. 2, but the less intense deformation of the surrounding rocks may be explained by their higher resistance.

In tunnel section No. 1, Moose Creek fault shows a gouge zone only about a foot thick. It dips at an angle of 60° east, and on each side the country rocks are permeated with a red pegmatite. The extension of this fault could be traced to near Waweashton lake by the abrupt change in the strike of the foliation and also by the presence of the same type of pegmatite.

Small shear zones were also observed along the bottom of the hills near both dams. They are parallel to the main joints and are found along layers of hornblende-plagioclase gneiss. A gouge zone about 1 foot thick is found in both cases.

Joints

It can be seen that well defined joints occur along the tunnel. The most common are those perpendicular to the foliation and, by order of decreasing abundance, the horizontal joints and those parallel to the foliation.

Chlorite coatings are observed on many joint surfaces in the rocks of the area. They are about 1/8 inch thick and, in many places, show a lineation which most commonly plunges at an angle of 20° south.

The horizontal joints are probably sheet joints and roughly follow the topography. This phenomenon can be observed along the cliffs of the hills at Labrieville.

ECONOMIC GEOLOGY

Ilmenite-hematite

About 1 1/2 miles north of Brûlé lake, near the western boundary of the area, what probably are three lenticular masses of ilmenite-hematite accurs in andesine anorthosite. The central mass is accompanied by a thin lens of apatite-ilmenite rock which commonly contains plagioclase and ferromagnesian minerals. A coarse-grained reddish pink pegmatitic anorthosite separates the ore from the country rock. In places, ilmenite-hematite completely surrounds blocks of anorthosite a foot across. Small veinlets of ilmenite leave the main mass and follow the structure of the host rock. Small pockets of ilmenite-hematite three feet in diameter occur hundreds of feet away from the orebody.

The ore is composed of ilmenite-hematite grains 2.0 to 3.0 mm. in diameter, with scattered grains of spinel. Locally, pyrite and biotite are present in small amount. Under the reflected light, the ilmenite-hematite grains show exsolution lamellae of two generations arranged parallel to the basal plane of the ilmenite crystals. Other wedge-shaped lamellae, probably of titano-hematite, show a reflection intermediate between ilmenite and hematite and are transverse to the wide hematite lamellae. The ore is locally magnetic.

The hematite lamellae are discontinuous and are about 0.03 mm. thick and contain thin discs of ilmenite 0.01 mm. long and 0.002 mm. to 0.003 mm. thick. Between the hematite lamellae, the ilmenite shows discs of hematite of the same size as those of ilmenite in the hematite lamellae.

Chemical analyses of the ore, as given by Bersimis Mining Co., are shown in the following table.

TABLE VIII

CHEMICAL ANALYSES OF ILMENITE-HEMATITE ORE

Fe (total)	44.06	35.06	44.23	44.32	43.97
TiO_2	36.97	27.13	36.60	37.18	36.73
SiO_2	0.58	7.31	0.49	0.29	0.35
Al_2O_3	2.04	1.90	2.35	2.05	1.55
MgO	1.91	1.42	1.62	1.35	1.60
CaO	0.03	6.77	0.05	0.04	0.06
P	0.033	2.13	0.042	0.03	0.01
S	0.013	0.142	0.025	0.01	0.02
Fe (total)	44.57	44.26	44.73	44.98	
TiO_2	36.81	36.41	37.03	36.66	
SiO_2	0.34	0.40	0.28	0.19	
Al_2O_3	1.49	2.02	1.70	1.48	
MgO	1.58	2.06	1.69	1.63	
CaO	0.09	0.03	0.07	0.03	
P	0.004	0.024	0.020	0.022	
S	0.031	0.081	0.009	0.018	

Magnetite-Ilmenite

Small lenses of magnetite-ilmenite were found at the southern end of the labradorite anorthosite layer on the east shore of Cassé lake. Polished sections show that the aggregate is composed of a large amount of magnetite, ilmenite, spinel, and augite grains about 3.0 mm. in diameter.

Other Minerals

Traces of chalcopyrite and pyrrhotite were observed in tunnel section No. 2, near its intersection with the adit. It was also found as disseminated grains in a green layer in tunnel section No. 1. Much of the pyrite was found to coat the foliation planes of quartzite.

Traces of molybdenite were found in three occurrences. About 3 miles west of Labrieville, a coarse pegmatite dike contains a few grains. In the road cut along the access road to the surge shaft, molybdenite traces are found in the pegmatite injecting a hornblende-plagioclase gneiss. The green pegmatite in a diamond drill core from above the intersection of the adit and tunnel section No. 1 also holds a few grains of molybdenite.

Along the road to Cassé lake, near the augen gneiss exposure, the pegmatites injecting the rocks at that locality are slightly radioactive.

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