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WACOUNO - WACO AREA, SAGUENAY ELECTORAL DISTRICT

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Québec 

PROVINCE OF QUEBEC, CANADA

DEPARTMENT OF MINES

Honourable PAUL EARL, Minister

GEOLOGICAL SURVEYS BRANCH

GEOLOGICAL REPORT 96

WACOUNO-WACO AREA

SAGUENAY ELECTORAL DISTRICT

by

Roger-A. Blais



QUEBEC

Ministère des Richesses Naturelles du Québec

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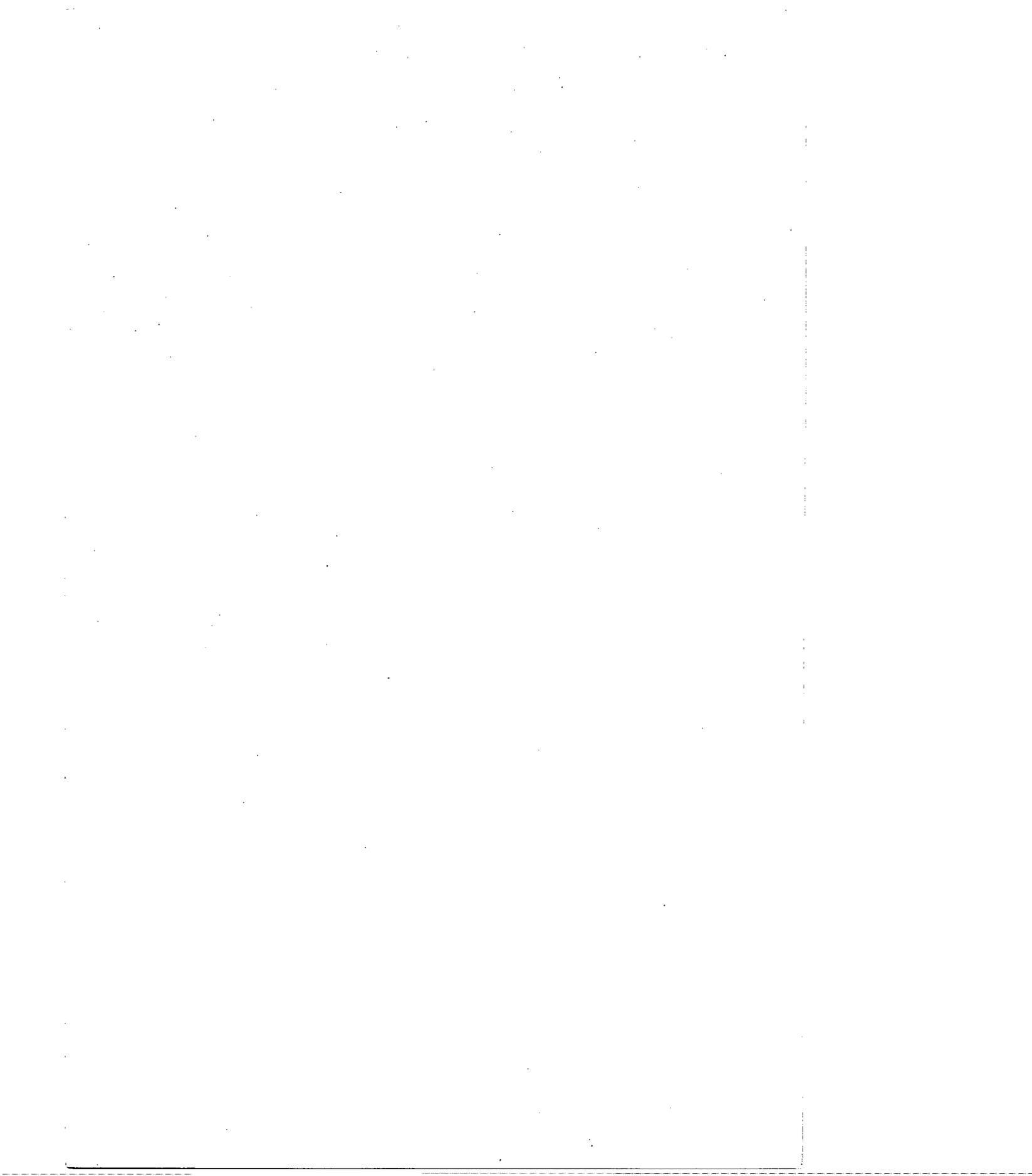


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WACOUNO-WACO AREA

Saguenay Electoral District

by

Roger A. Blais

INTRODUCTION

General Statement

The completion in February 1954, of a 360-mile railroad joining the port of Sept-Iles (Seven Islands), on the gulf of the St. Lawrence, to the mining town of Schefferville, in New Quebec, marked another milestone in mining and engineering developments in the Province of Quebec. Constructed and operated by the Quebec North Shore and Labrador Railway, and officially inaugurated in August 1954, this railroad is used to transport iron ore from the properties of the Iron Ore Company of Canada to Sept-Iles.

The geological survey of the Wacouno area in 1953 and of the Waco area in 1954 was part of the Department's programme of mapping and assessing mineral possibilities of the region bordering the railroad.

The consolidated rocks of the area are Precambrian, mainly granitic gneiss, massive granite, paragneisses and basic intrusives. The paragneiss group is the oldest.

Copper and iron sulphides were found here and there in the area. Molybdenite occurs in a sill of hornblende granite and associated with apatite-bearing pegmatite dykes. Titanium and iron oxides scattered throughout the gabbro bodies of the area point to the possibility of finding commercial concentrations of such metals in the general region.

Location and Means of Access

This report describes the geology of two adjacent areas, each of approximately 250 square miles. The Wacouno, or more southern, area is bounded by longitudes 65°40' and 66°00' and by latitudes 51°00' and 51°15'. The Waco area lies between longitudes 65°30' and 65°50' and latitudes 51°15' and 51°30'. The southern boundary of the area* is approximately 57 miles north-northeast of Sept-Iles.

The Quebec North Shore and Labrador railroad runs north through the area from Mile 67 to Mile 105 (distances from Sept-Iles) along the valley of Wacouno river. Small, semi-permanent camps for maintenance crews have been built along the railroad at intervals of about 20 miles (Plate II-A). The railroad, which became a common carrier in 1955, provides the easiest means of access to and within the region.

The area may also be reached by plane. Temporary landing strips have been constructed along the railroad at Mile 80 and Mile 97. These strips were still in good condition in 1954. Owing to the ruggedness of the country, float planes were used to reach those parts of the area not readily accessible by railroad. Although lakes are numerous only the larger ones are suitable for landing.

Before the advent of the railroad, Indians and trappers from Sept-Iles and Moisie used three main canoe routes to travel to their hunting grounds to the north. All of these routes followed Moisie river and the lower Nipissis to the Nipisso. The longest of the three followed Wacouno river from its junction with the Nipissis and continued northward beyond the area. The Wacouno route is almost un-navigable owing to the numerous falls and rapids, and proximity to the railroad makes it obsolete in any event.

Field Work

Mapping of the area required seven months of field work during the summers of 1953 and 1954. Done on a scale of one inch equals half a mile, the mapping was based on systematic pace and compass traverses at intervals of half a mile or less and oriented as

* In this report the general term "area" applies to both the Wacouno and Waco areas.

much as possible across the trend of the formations. The planning of the traverses was greatly facilitated by interpretation of topographic lineaments and delineation of the main structural trends on aerial photographs (Royal Canadian Air Force) prior to field work.

The field observations were plotted on base-maps at a scale of one inch equals half a mile prepared by Canadian Aero Service Limited from the aerial photographs. The maps accompanying this report are based on the National Topographic Series; the Wacouno map is included in the Canatich Lake topographic sheet and the Waco in the Lac Dufresne topographic sheet.

Approximate elevations above sea-level of the larger lakes and prominent points of the uplands in the area were measured with calibrated aneroid barometers. Elevations recorded were checked against those of bench-marks along the railroad and, in some cases, with aircraft altimeter readings.

Acknowledgments

During the two seasons of field work, the writer was ably assisted by his senior assistant, Wallace B. Emo, graduate student at McGill University. Also, Emo supplied valuable information on the geomorphology of the area and aided in the preparation of this report. In 1953, other members of the party were Robert W. Jubien (McGill University), and Gaston Pouliot (Université de Montréal) junior assistants; Philius Bernatchez and Harry Hamilton, canoeemen; and Paul-Henri Lavoie, cook. In 1954, the other members were Donald McMahon (Acadia University), and Alyre Pineau (Université Laval), junior assistants; Jean Giasson and William Gaudet, canoeemen; and Gilles Caron, cook. All performed their respective duties in a very satisfactory manner.

The assistance given by the Quebec North Shore and Labrador Railway in transporting men and supplies during the two field seasons is gratefully acknowledged. A.E. Moss, chief geologist of the Iron Ore Company of Canada, kindly supplied the writer with reconnaissance geological maps and aeromagnetic maps of the Wacouno-Waco area. Deep appreciation is expressed to that Company for permission to examine their unpublished information.

Previous Work

Detailed geological exploration in the general region started in 1938 when Faessler (1942) mapped the Sept-Iles areas on the north shore of the Saint Lawrence. Larger areas extending north-erly from the north shore and between longitudes 66°00' - 66°25' and 65°35' - 66°00' were examined successively by Faessler (1945) in 1939 and Greig (1945) in 1940. Later, Grenier (1952) and Hogan (1952) surveyed the Nipissis River and Nipisso Lake areas located north of the Moisie area and along the Quebec North Shore and Labrador rail-road. After the survey of the Wacouno-Waco area by the author geo-logical mapping was continued to the north along the railroad by Emo (1956) and McPhee (1956).

The Iron Ore Company of Canada reconnoitred the general district by geological and geophysical surveys.

DESCRIPTION OF THE AREA

Climate, Vegetation, and Animal Life

Because relatively scant data exist on weather condi-tions in this region, various meteorological observations were col-lected during the summers of 1953 and 1954. During a four-month period in 1954, a daily record was kept of the temperature, air pressure, humidity, wind direction, amount of overcast, and amount of precipi-tation (Blais, 1954). During both summers, the amount of rainfall exceeded 15 inches and rainy weather prevailed most of the time. After heavy rainfalls, several rivers became torrential streams, their levels being raised as much as two feet above normal in less than 24 hours. Clear weather prevailed only during the first halves of June and September. In early June, the ground was still frozen and large patches of snow remained on hilltops. Night frosts persist-ed up to the middle of June and reappeared early in September. During the four summer months of 1954, the average maximum day temperature was 65°F. and the average minimum night temperature was 40°F. Such observations indicate that the region has a humid microthermal climate ("Dcf" climatic belt of the Köppen system).

The taiga vegetation in this region grows on acid podsols and is chiefly represented by black spruce, with some bal-sam fir, poplar, tamarack, jack pine, and alders. Tall and thick stands of black spruce on several hillsides would be suitable for

logging, but they are generally not readily accessible. In June, 1954, a forest fire devastated the forest along the railroad for about 30 miles. In the uplands, glacial denudation has left only a thin veneer of soil and the vegetation is dwarfed and sparse.

Animal life is moderately abundant. Caribou, black bear, porcupine, muskrat, rabbit, and partridge were seen on several occasions. Mink and otter are rare. Old beaver works were seen only in the southern half of the area. Speckled trout are abundant in Wacoune river and in Prémio-Réal, Waco and Tremblay lakes.

Physiography

Topography

The area is in the Laurentian uplands and has the rugged topography characteristic of the whole North Shore region. Hill summits are all at about 2,800 feet above sea-level and thus form a singularly level and regular sky line. They are considered to be remnants of a pre-glacial peneplain that slopes gently to the south (Plates III-B, V-A) and that is now deeply dissected by narrow and trench-like valleys (Plate III-B).

The general elevation of the main streams drops from 1,800 feet in the north to 575 feet in the south. The local relief, which varies from 100 to 1,500 feet, is greatest in the southern part of the area and decreases gradually to the north as the central plateau of New Quebec is approached.

The topography reflects to a large extent the nature and structure of the underlying rocks. Granitic rocks underlie areas of high elevation but of low relief. Granitic gneisses, which cover more than three-fifths of the area, form the high tableland of the central part near Mîche, Mîmi and Croissant lakes (Plates I, V-B). This tableland lies at an average elevation of 2,800 feet and has little relief other than a series of small ridges and valleys resulting from differential erosion along joints parallel to the strike of the gneissic layering (Plate I). The more gently dipping the gneisses, the flatter the tableland. The batholith of massive granite in the southwestern part of the area also forms a high tableland which is, however, more deeply dissected than the expanse of granitic gneisses (Plates IV-A, -B).

In the uplands of the central part of the area, mainly near Mische, Waco, and Carmelle lakes, gabbro monadnocks stand from 100 to 400 feet above the general level of the peneplained surface. The gabbro is more massive and less jointed than the surrounding granitic rocks and has resisted better to erosion.

Differential erosion is evidenced in paragneisses and mixed gneisses which occur in linear depressions in the uplands. The deepest of these depressions, at Vatchichitet lake in the southeastern corner of the area, is occupied by Nipisso river and is 1,000 feet below the upland surface. Most are 100 to 500 feet deep and trend across the major river valleys.

All the major rivers in the area flow in deep valleys trending south-southwest, parallel to a pronounced system of joints. As an example, Wacouno river flows in such a valley incised in granitic gneisses that trend southeasterly. Some deep valleys, like those of Dufresne and Vatchichitet lakes, follow not only the direction of jointing but also that of gneissic layering.

Differential weathering and erosion along closely-spaced joints have controlled the formation of several small and narrow valleys which are singularly straight for several miles (Plate I). In these small valleys, a stream commonly links a chain of small elongated lakes, as in the Waco area. Another characteristic feature of the uplands is the presence of low but very continuous ridges parallel to the strike of the gneisses (Plate I).

Drainage

The area lies in the drainage system of Moisie river, which empties into the Gulf of Saint Lawrence, 15 miles east of Sept-Iles. It is very well drained by Nipisso, Nipissis, Wacouno, and Kachipitonkas rivers. All four rivers flow to the south-southwest in valleys incised 700 to 1,500 feet below the surface of the uplands. They form a sub-parallel drainage system, partly blocked in several places by extensive glacial deposits.

Both Wacouno and Kachipitonkas rivers flow across the whole area, heading in Waco and Dufresne lakes, respectively. Rarely more than a hundred feet wide, they fall and cascade to a level of 1,300 feet below their headwater lakes in a distance of about 37 miles. A scenic waterfall in Wacouno river, about 120 feet high, is found near the railroad at Mile 68.7 (Plate IV-B).

Nipisso and Nipissis rivers are two large rivers that flow across the southeastern and northwestern corners, respectively, of Wacouno area. These rivers, having a more gentle gradient and fewer falls and rapids than the Kachipitonkas and the Wacouno, were preferred by the Indians when travelling to and from their hunting grounds to the north.

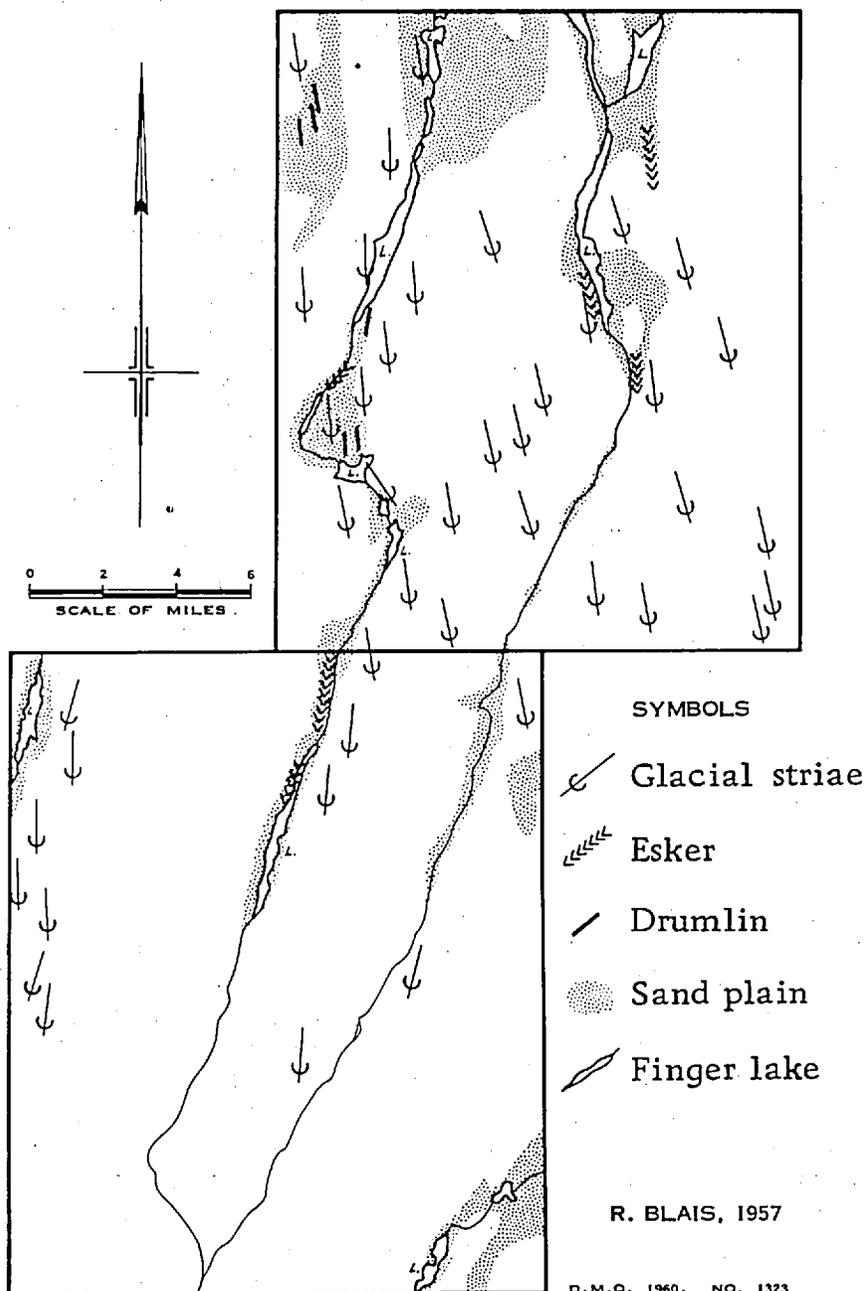
Lakes are numerous. The smaller and shallower ones occupy irregular rock-walled depressions on the uplands (Plate I). The larger lakes are long and narrow and lie in the major river valleys. They are Vatchichitet, Kachipitonkas and Favre lakes in the Wacouno area, and Carmelle, Croissant, Dufresne, Waco, and Wacouno lakes in the Waco area. Several of these lakes are more than 5 miles long, and yet rarely more than half a mile wide. They lie in morainic material which partly fills the major river valleys. They are 500 to 1,000 feet below the level of the near-by highlands and are often only a few hundred feet away from the base of high cliffs (Plate III-B). These lakes have all the characteristics of "finger lakes", formed by glacial obstructions in deep pre-glacial valleys partly filled with drift. Most may be considered as mere widenings of major rivers.

Some lakes on the uplands are comparable in size to the finger lakes, but they lie about 500 feet above the main water-plane. They include Prémio-Réal and Mamikam lakes in the Wacouno area, Miche and Doiron lakes in the Waco area. They rest in glacially scoured and rock-walled basins, and are much deeper than the finger lakes.

Glaciation

Effects of continental glaciation are abundant and varied in the area (Figure I). Erosional features include striations, polished rock surfaces, friction cracks, chatter marks, grooves, glacial potholes, plucked or quarried slopes, roches moutonnées, U-shaped valleys and hanging valleys. There is also quite a variety of depositional glaciation features: till and stratified drift mantling the lower parts of the area, erratic stones and boulders, boulder trains, valley trains, drumlins, ground moraines, eskers, kames, kettles, and outwash sand plains. As mentioned above, the northern half of the area has a much lower relief than the southern half. Depositional features of glaciation are therefore prominent in the northern half, and erosional features in the southern half. In fact, extensive morainic deposits cover most of the northern third of the Waco area and

FIGURE I
GLACIAL MAP OF THE WACOUNO-WACO AREA



outcrops are restricted to isolated, low hills. A map of the main glacial features of the area is given in Figure I.

Most glacial striations are found on granitic rocks, and very few in areas of soft rocks like paragneisses. They appear on rock slopes facing north, and also on outcrops on some lakeshores. Locally, striae grade into grooves. The orientations of the striae vary from south to 20 degrees east of south in the northern half of the area, and from south to 20 degrees west of south in the southern half. Only one set of striae was recognized. The striae observed do not indicate the direction of movement of the ice; however, other glacial features, such as plucking, friction cracks, chatter marks, and erratics indicate that the movement was southward. The south-southwesterly deflection in the southern part of the area probably was the result of topographic control over the ice-sheet advancing from the north-northwest.

Small potholes 10 to 12 inches deep and 12 to 18 inches in diameter were found on flat hill summits at an elevation of 2,500 feet. They are circular and partly filled with sand. The bare surrounding rock is glacially grooved and striated. As there are no surface irregularities where the potholes are found, they must be attributed to the work of glacial moulines caused by the eddying motion of sub-glacial streams.

Plucking or quarrying by glacier ice has roughened the southern or lee slopes of many gabbro knobs and of east-west granitic ridges to irregular or even to step-like profiles. Plucking has even imparted to several valleys a step-like profile in places where bed-rock protrudes through drift-covered valley floors. This is well displayed along Wacouno river, near the railroad between Mile 74 and Mile 68, where the river falls and cascades over a series of steps due to glacial quarrying of big joint blocks. The biggest step of all is the 120-foot Wacouno falls at Mile 68.7 (Plate IV-B). Here, a set of closely spaced and steeply dipping joints, and a predominant set of flat-lying joints, have permitted the removal of angular blocks much too big to have been displaced by the river alone even with its present volume increased several times.

A distinct glacial feature of the area as a whole is the U-shape of the major river valleys (Plate III-B). Also, the headward part of the major valleys, near the source-lakes, has a relatively steep, step-like, long profile. Downstream, this profile flattens out into rock basins partly filled with unconsolidated deposits. Since

the retreat of the glaciers, the valleys have further been modified by frost wedging of blocks, forming overhanging cliffs, and by normal erosion of slopes.

In the southern half of the area, the glaciated major valleys show a striking asymmetry. The valleys of Nipisso, Nipissis, Wacouno and Kachipitonkas rivers, and the shallower valley of Mamikam lake, all trending to the south-southwest have steep cliffs on the west and comparatively gentle, drift covered slopes on the east (Plate III-B). The processes that produced such asymmetry are not well understood. It is believed to be a glacial phenomenon resulting from the modification of the former V-shaped valleys. The continental ice-sheet moving south-southeasterly encountered, in the Wacouno area, deep valleys trending south-southwesterly. Glacial quarrying of big joint blocks may have roughened and steepened the west sides of the valleys, and glacial abrasion together with drift deposition may have smoothed the east sides.

Several small hanging valleys contain small streams which, upon entering the main valleys, cascade for several hundred feet over cliffs to reach the floor of the main valleys. Hanging valleys are most common along the Wacouno and Kachipitonkas valleys, and along the Mamikam Lake and Vatchichitet Lake valleys.

Erratic boulders and stones are very abundant on the uplands. Most cannot be traced to their origin. However, a few have a characteristic lithology. Such indicators include well rounded boulders, a few feet in diameter, of white, coarse-grained and thick-bedded quartzite. This particular rock is very similar to the Wapus-sakattoo quartzite mapped by the writer in 1949 while working for the Labrador Mining and Exploration Company, and also studied by Gill et al. (1937), in the Wabush Lake area some 125 miles north-northwest of this region. Also included among the indicators are foot-sized, well-rounded blocks of ironstone which presumably come from the Labrador Trough as no such formation is known to outcrop between the Trough and the territory studied. Such indicator stones include jasperoid chert, cherty metallic ironstone and green chert. The line joining the area to the presumed points of origin of these indicator stones and boulders varies in direction from north to north-northwest. It is thus parallel to the direction of glacial striae in the northern half of the area. A distance of transport of more than 125 miles is suggested for these indicators.

Long and narrow boulder trains of big, semi-angular and assorted boulders derived from the local bedrock are found on the lee side of several hills. Valley trains are generally found at the mouths of tributary valleys emerging into flat outwash sand plains.

A series of drumlins stands out over the morainic plain in the northwest corner of Waco area. These are sub-parallel, cigar-shaped, sandy till ridges trending parallel to glacial striae. They are about 40 feet high and 500 to 2,000 feet long. Other drumlin-shaped ridges are found in the Kachipitonkas valley, between Dufresne lake and Kachipitonkas lake.

An extensive ground moraine mantles most of the northern third of Waco area. Farther south it is restricted mainly to low-land parts of the Waco and Wacouno areas. In the north, the moraine forms undulating plains, with a local relief of 30 to 40 feet. A striking feature in these plains is a series of parallel morainic ridges, which are 40 to 100 feet high, 100 feet to 1,000 feet wide, 2,000 feet to one mile long. These ridges of unsorted drift are separated by low, swampy valleys 100 to 2,000 feet wide. This particular land form gives the impression that a huge rake has been drawn over the ground moraine. These "longitudinal" or "ridged" ground moraines trend parallel to glacial striae. They are believed to have originated much in the same fashion as drumlins and drumlinoid ridges.

Several long and narrow eskers winding through morainic and outwash sand plains follow the floors of the main river valleys (Plate III-A). They parallel the direction of glacial striae. The eskers are one to 5 miles long, 20 to 50 feet high, and 50 to 300 feet wide. The material forming the eskers appears to be very similar to that of the local till.

Valley flats are commonly dotted with small kames and kettles. A good example of this type of topography is the sand plain at the north end of Carmelle lake which lies in a deep basin protected by surrounding highlands.

A characteristic depositional feature of glaciation throughout the area is the blanket of outwash material covering the floors of all the main valleys and forming singularly flat and poorly forested plains (Plate III-A). Most finger lakes of the area lie in these very long and narrow bodies of glacial outwash (Plate III-B). Sand predominates over gravel in the outwash material, and it is

generally well sorted and roughly stratified. Cross bedding in the sand indicates deposition from the north. The Quebec North Shore and Labrador railroad has conveniently been located in the drift-floored Wacouno River valley. The outwash plain followed by the railroad has provided not only a smooth gradient but also gravel for railroad ballast. The large-scale ballast operations at Mile 84, with a crushing plant and several side tracks running from gravel pits, provided most of the ballast required for the railroad from Mile 50 to Mile 200 (Plate II-B).

Most outwash sand plains in the area are terraced at three distinct levels. The elevations of the terraces vary from plain to plain, but they are always found in the following relationships. The lowest terrace is generally 5 to 10 feet above the water-plane and is closest to lake shores. Some 500 to 1,000 feet back, another terrace rises steeply from 10 to 20 feet. Moreover, at distances of 1,000 to 2,000 feet from lake shores, a third terrace is 35 to 40 feet above the main water-plane. The lowest and the middle terraces are more commonly visible whereas the highest is eroded away in several places.

GENERAL GEOLOGY

General Statement

All the consolidated rocks in the area are of Precambrian age. They consist of paragneisses intruded by granitic gneisses and basic rocks, which, in turn, are cut by a younger granite and various minor dykes. Paragneisses and basic intrusive rocks, roughly in equal amounts, underlie about one-quarter of the area. The remainder is occupied by granitic rocks, either gneissic and conformable to the sedimentary rocks, or massive and generally intrusive into surrounding formations.

The paragneisses rocks are well layered and include a few lenticular beds of quartzite and of silicated crystalline limestone. They are widespread and form long and narrow belts within gneissic granite. The paragneiss belts, as mapped, include large amounts of mixed and banded gneisses (migmatites) made up of varying amounts of granitic material of intrusive origin.

The basic rocks, nearly all restricted to the Waco area, generally are in thick, tabular, intrusive bodies that are more or less conformable with the structure of surrounding orthogneisses.

and paragneisses. A large mass of anorthosite, with gabbroic, monzonitic and syenitic border facies, extends from just within the east boundary of Waco area more than 20 miles eastward.

Granitic rocks of variable composition predominate over all other rocks in the area. They are either gneissic or massive. Most of the distinctly gneissic granites contain isolated remnants of sedimentary rocks and, together with these, form a complex into which gabbros and other granites have been intruded. Augen gneiss, gneissic granite, and granite gneiss are the main varieties of these early, intrusive or metasomatic granitic rocks. They outcrop in wide and long belts over more than half of the area. The late granites are generally massive and crop out as large bodies, the main one covering more than half of the Wacouno area, and as small stocks and bosses piercing through the complex of gneisses. The early granitic gneisses differ from the later, massive granites in structure, texture, composition, and mode of occurrence.

Dykes of pegmatite, aplite and lamprophyre, as well as veins of quartz, cut the late granites and are therefore presumed to be the youngest intrusive rocks in the area. Both pegmatite and aplite are closely associated with the late granites.

Table of Formations

CENOZOIC	Recent and Pleistocene	Sand, gravel, stratified drift, till, erratic stones and boulders
Great Unconformity		
P R E C A M B R I A N	Late granite	Lamprophyre dykes (not shown on the map) Quartz veins Pegmatite and aplite dykes
		Leucogranite Porphyritic granite and syenite
		Granodiorite
	Waco igneous complex	Syenite, granite, and rare pegmatite Hornblende monzonite Diorite and quartz diorite
		Meta-gabbro, flaser gabbro and ortho-amphibolite gabbro, olivine gabbro, norite and hornblende gabbro
Anorthosite and gabbroic anorthosite		
Early intrusive and metasomatic rocks	Gneissic granite and granulated granite Augen gneiss Granite gneiss Mixed gneiss (migmatite) Ortho-amphibolite	
	Metamorphosed sedimentary rocks (Paragneisses)	Crystalline limestone and silicated facies Quartzites Garnetiferous gneiss (Graphitic gneiss) Amphibole-pyroxene gneisses Hornblende-biotite schists Hornblende-biotite gneisses

Paragneisses

General Statement

The paragneisses are similar to those of various localities of the North Shore region. Although several authors (Engel and Engel, 1953) have assigned these rocks to the Grenville series, it seems preferable to group them into a local complex of paragneisses and orthogneisses of Archean age, because of the distance from here to the type locality, near Grenville village, Argenteuil electoral district, Quebec, and the lack of data on the geology between these two regions.

The paragneisses crop out mainly in the southeastern corner and the northern third of Wacouno area, and in the southwestern corner of Waco area. They form sinuous and arcuate bands from 200 to 1,000 feet wide and one to ten miles long. These bands are flanked by mixed gneisses or migmatites that represent all stages of transition from a typical paragneiss through hybrid granitic gneisses to a gneissic granite relatively free of elongated inclusions of paragneisses. Rocks mapped in the field as paragneisses contain less than 25 per cent granitic material, whereas mixed gneisses comprise between 25 and 75 per cent granitic material. Rare, associated amphibolites, perhaps originally volcanic rocks or basic sills, form lenses up to 100 feet thick.

Hornblende-biotite Gneisses

A large proportion of the metasedimentary rocks are gneisses composed essentially of hornblende, biotite, quartz, and feldspars. For petrographic description and discussion, these gneisses are divided into biotite gneiss containing more than 25 per cent biotite, hornblende gneiss with more than 25 per cent hornblende, and quartzo-feldspathic hornblende-biotite gneiss with less than 50 per cent hornblende and biotite combined.

Quartzo-feldspathic Hornblende-biotite Gneiss

This paragneiss predominates over all other types of metasedimentary rocks in the area and is a member of all belts of paragneiss. It is mainly exposed in the southeastern corner and in the northern third of the Wacouno area. Near Croissant lake, in the southwestern corner of the Waco area, the gneiss is interlayered with garnet gneiss and micaceous quartzite.

The rock is light to dark grey, fine- to medium-grained, and has a distinct gneissic layering. Layers of quartz and feldspars alternating with biotite and hornblende layers render the rock fissile. Under the microscope, the gneiss shows a granoblastic texture, with biotite flakes and stubby hornblende crystals roughly parallel to the gneissosity. The average grain size is 0.5 mm. In the eight thin sections examined, this gneiss has the following average mineralogical composition: plagioclase (35 per cent), potassic feldspar (14 per cent), quartz (20 per cent), hornblende (10 per cent), and biotite (16 per cent). Titaniferous magnetite, pyrite, apatite, sphene, and zircon are present in minor amounts. Some specimens also contain some anthophyllite or some garnet and sillimanite. The plagioclase ranges in composition from An_{23} to An_{38} and averages An_{30} ; it is slightly sericitized or saussuritized and it shows narrow polysynthetic twins. Clear grains of microcline, which is the predominant potassic feldspar, fill interstices between plagioclase and quartz grains. Chlorite (clinochlore) occurs as an alteration of the reddish brown biotite.

Biotite gneiss

Biotite paragneiss is closely associated with and grades into the quartzo-feldspathic hornblende-biotite gneiss, but it is richer in biotite and has a less conspicuous, gneissic layering.

The biotite gneiss is generally fine-grained and medium to dark grey, with shades of pink or green. It has a lepidoblastic texture. The grain size is about 0.5 mm. The essential constituents are plagioclase (37 per cent), biotite (28 per cent), quartz (13 per cent), and hornblende (10 per cent). Accessory minerals include titaniferous magnetite, sphene, apatite, and zircon. In the two slides examined, potassic feldspars are absent and the plagioclase ranges from An_{25} to An_{29} . This feldspar is slightly altered to saussurite or to carbonate and sericite. The biotite is greenish brown. Sphene commonly rims the titaniferous magnetite.

Hornblende gneiss

The only bands of metasedimentary rocks with abundant hornblende gneiss are those of the northern third of the Wacouno area. Elsewhere, the hornblende gneiss is subordinate to, and interlayered with, quartzo-feldspathic hornblende-biotite gneiss.

The hornblende gneiss is very schistose and has a weak layering accentuated in places by thin sills of leucogranite and pegmatite, as well as by thin sheets of hornblende-biotite schist. Near granitic sills, the gneiss has been recrystallized locally to a very coarse aggregate of hornblende and feldspars. The hornblende gneiss varies in colour from dark greenish grey to black and is fine- to medium-grained. Average grain size is 0.6 mm. In the seven thin sections examined this rock is essentially a granoblastic aggregate of hornblende (47 per cent) and plagioclase (36 per cent) with reddish brown biotite, chlorite (penninite or clinochlore), quartz, microcline, magnetite, and rare diopside. Accessory minerals include apatite, sphene, and zircon. The plagioclase ranges from An_{32} to An_{49} and averages An_{42} . It is less altered and more calcic than the plagioclase of the two preceding types of paragneiss. The hornblende has a poikilitic habit. Clinzoisite and chlorite are alteration minerals. Some plagioclase grains show metamorphic zoning.

Hornblende-biotite Schists

Schists consisting essentially of biotite or hornblende, or both, occur sparingly as thin and discontinuous layers within paragneiss and micaceous quartzite bands. The schist layers have sharp contacts with the adjoining rocks and commonly appear at regular intervals in a well layered sedimentary sequence (Plate VI-A). In many cases, the schist layers probably represent sedimentary beds of different chemical composition, whereas those included in mixed gneisses are probably the result of metamorphic differentiation (Plate IX-A).

The hornblende-biotite schists are medium- to coarse-grained, dark and highly fissile. They contain more than 60 per cent hornblende and biotite, with varying amounts of plagioclase (sodic andesine or calcic oligoclase) and quartz. Sphene, apatite, and magnetite are the accessory minerals.

Amphibole-pyroxene Gneisses

The well layered sequences of paragneisses in the southwest corner of the Waco area generally contain some relic beds of amphibole-pyroxene gneisses. Similar gneisses were also found interlayered with hornblende-biotite gneisses and impure quartzite on the shores of Froidevaux and A l'Aigle lakes, a few miles east of the northeast corner of the Wacouno area.

Amphibole-pyroxene gneisses are generally found in zones made up of layers one to twelve inches thick. The rock is generally dark green and has a characteristic pitted and brownish green weathered surface. Individual layers are commonly massive. The amphibole-pyroxene gneiss has a grain size varying between 0.5 and 2 mm., with a typical granoblastic texture. It consists essentially of plagioclase (46 per cent), pyroxene (18 per cent), and amphibole (17 per cent). Quartz, reddish brown biotite, chlorite (penninite and clinocllore), microcline, and magnetite are in small amounts. Plagioclase ranges in composition from An_{11} to An_{80} and averages andesine An_{40} ; it is slightly altered to sericite or saussurite. Diopside predominates over hypersthene. The amphibole is either common hornblende or tremolite, the latter being closely associated with diopside. Chlorite occurs as an alteration product of biotite. Magnetite is more abundant and in larger grains than in the hornblende-biotite gneisses.

Graphite Gneiss

Graphite gneiss in small amount was found in layers between 2 and 15 inches thick in the small area of banded paragneisses and quartzites, 3.5 miles west of the railroad at Mile 91. It is characterized by a rusty and very friable weathered surface. Numerous graphite flakes, from a quarter of an inch to one inch long, lie in the planes of relic bedding. The rock is light grey, medium-grained, and nearly massive.

Under the microscope, the graphite gneiss appears as a granoblastic aggregate of more or less equidimensional grains of andesine An_{30} and quartz; these two minerals are roughly in equal amounts and form about 85 per cent of the rock. Sub-parallel flakes of reddish brown biotite and of graphite are present, together with very small amounts of pyrite, apatite, sphene, and zircon as accessory minerals. Rare myrmekitic plagioclase is also observed in some specimens.

Garnet Gneiss

Micaceous quartzite and several other types of paragneisses contain garnet, but this mineral is particularly abundant in the bands of paragneisses near Croissant, Dufresne, and Canatiche lakes.

In well layered sequences, layers from one inch to one foot thick contain abundant wine-red garnets up to one inch in diameter. The rock is medium grained, dense and fairly massive garnet-cummingtonite gneiss, and presumably had a composition slightly different from that of the adjacent layers. It weathers dark grey or dark green.

Microscopic examination of this rock shows the following essential constituents: calcic plagioclase (35 per cent), garnet (20 per cent), quartz (20 per cent), cummingtonite (10 per cent), magnetite (5 per cent), and reddish-brown biotite (5 per cent). Minerals forming the rest include wollastonite, tremolite, apatite, zircon and sericite. In the two slides examined, the plagioclase has the composition of bytownite, even though the plagioclase in adjacent paragneiss layers is sodic andesine. It is fresh and well twinned. Garnet and cummingtonite form large sieve-like porphyroblasts. Plagioclase grains within garnet commonly have vermicules of quartz.

Quartzite

Thin but continuous beds of grey micaceous quartzite are commonly interlayered with paragneisses near Croissant and Canatiche lakes. A few lenses of white vitreous quartzite, 10 to 50 feet thick, are found in the migmatic paragneisses near Kachipitonkas lake. Quartzite in the whole area probably represents less than 10 per cent of the typical paragneisses.

The grey, impure quartzite weathers greyish white and is in beds between 1 inch and 10 inches thick. The beds are parallel to the gneissosity of the interlayered garnet gneisses. The white, vitreous quartzite, on the other hand, shows no layering but only vague relic bedding along with potassic feldspar has been introduced. Average grain size ranges from 0.7 mm. in the impure quartzite, to 2 mm. in the pure variety.

The average mineralogical composition of the quartzite determined from 11 thin sections is: quartz (62 per cent), plagioclase (17 per cent), potassic feldspar (10 per cent), and biotite (7 per cent). The remainder consists of hornblende-actinolite, diopside-hypersthene, garnet, graphite, sillimanite, magnetite-hematite-pyrite. Accessory minerals include sphene, apatite, and zircon. The plagioclase has the average composition of calcic oligoclase (An_{28}); however, in the metasomatized white quartzite, it is albite-

oligoclase and it may be more calcic in some cases. Perthitic microcline, commonly in large porphyroblasts, is the predominant potassic feldspar. The granoblastic texture of the rock is inherited largely from the mosaic of sutured and irregular quartz grains more or less elongated parallel to the foliation. Quartz vermicules are common in the plagioclase.

Crystalline Limestone and Silicated Facies

Crystalline limestone and associated silicated facies were found on the west shore of A l'Aigle lake, 6 miles east of the railroad at Mile 80. Calcareous meta-concretions were also noted in hornblende paragneiss on the northeast shore of the same lake, as well as on the north and west shores of Froidevaux lake about 4 miles east of Mile 80. These rocks are generally rare in similar metasedimentary sequences of the North Shore region. Their association with hornblende paragneiss is indicative of the origin of at least part of the hornblende-biotite gneisses in the area.

The crystalline limestone exposed on, and near the west shore of A l'Aigle lake is a coarsely crystalline, brownish-white, friable rock. It occurs as lenses from 10 to 75 feet thick within hornblende paragneiss and para-amphibolite, and as massive beds from 6 inches to 4 feet thick. The typical crystalline limestone contains less than 10 per cent impurities, mainly scattered phlogopite flakes which account for the speckled appearance of the rock. Green layers rich in diopside and tremolite, with a thickness and a grain size comparable to those of the limestone, are found at several horizons.

The calcareous meta-concretions in the hornblende paragneiss a few miles east of the northeastern corner of the Wacouno area stand out in relief over the weathered surface (see Plate VII-A). Their average diameter is about one foot. Some concretions have a concentric structure caused by a compositional layering around an epidote-rich or diopside-rich core. Others are massive and have very fine-grained borders. Most concretions have the composition and texture of the hornblende paragneiss country rock, and are somewhat elongated parallel to the schistosity of the hornblende paragneiss (Plate VII-A). Under the microscope, the matrix of the massive concretions or nodules is a medium-grained and granoblastic schistose aggregate of calcic andesine (An_{48}) and common hornblende, with about 10 per cent brown biotite and quartz, and traces of magnetite and apatite. The andesine is in clear, irregular, rarely twinned

grains that suggest a secondary origin. Hornblende is in large, sieve-like porphyroblasts. On the other hand, the concretions with a concentric structure have a different composition. The core consists of a fine-grained and massive mat of sieve-like grains of epidote and pale green diopside, with small amounts of interstitial, altered andesine. The successive layers around the epidote-diopside core have essentially the same mineralogical composition as the country rock, but they differ in the proportions of epidote, plagioclase, and hornblende.

Origin of the Paragneisses

Among the rocks of the area mapped as paragneisses, the micaceous and pure quartzites, garnet-cumingtonite gneiss, graphite gneiss, and crystalline limestone have a mineralogical composition that strongly suggests a sedimentary origin. The hornblende-biotite gneisses are commonly closely associated with these units and contain calcareous meta-concretions. Thus, they presumably are also of sedimentary origin. However, they may also be metamorphosed equivalents of extrusive or basic intrusive rocks (Turner, 1948).

The paragneisses belong to the amphibolite facies and, more precisely, to the sillimanite-almandine sub-facies as defined by Turner (1948). Through metamorphism, metasomatism and, to some extent, granite injection, the original sedimentary rocks have acquired a new mineralogy, a granoblastic texture, and a gneissic structure. In several instances, gneissic layering has been superimposed on the original sedimentary banding. The best example of this is just northwest of Canatiche lake. Here, thin relic beds of micaceous quartzite are intercalated between more massive layers of hornblende-biotite gneisses. The plagioclase in the quartzite is calcic, whereas that in the adjacent mafic layers is oligoclase-andesine, which is the average composition for all paragneisses in the area. The presence of a calcic plagioclase in the quartzite is most probably due to calcareous impurities in the original sandstone.

Another excellent example of original compositional layering is given by the thin layers of mafic, garnet-cumingtonite gneiss within micaceous quartzite and hornblende-biotite gneiss.

Metasomatism has affected even the best preserved meta-sedimentary rocks, as shown by the large porphyroblasts of microcline in paragneisses hundreds of feet away from the nearest

granitic body. Addition of potash to these rocks is also shown by the introduction of microcline into pure quartzite (Plate VI-A). At the other extreme, paragneisses grade into migmatites or hybrid gneisses showing numerous signs of intimate pervasion of granitic fluids.

Early Intrusive and Metasomatic Rocks

In common with several parts of the Grenville sub-province, the area has a complex assemblage of early intrusive and metasomatic rocks (ortho-amphibolite, mixed gneisses, granite gneiss, augen gneiss, gneissic granite, and granulated granite) which in more or less close association with paragneisses form a complex of gneisses. Some of these rocks definitely intrude the paragneisses but others grade into, and appear to be metamorphic differentiates of, paragneisses.

Ortho-amphibolite

Several small bodies of highly altered basic igneous rocks occur within the gneisses of the Wacoua area. Most are sills of ortho-amphibolite and meta-diorite in paragneisses and mixed gneisses. The sills are 3 to 100 feet thick and 50 feet or more long. There are also some small bosses of massive meta-gabbro which appear to be large inclusions in the surrounding granite gneiss. The age of these rocks relative to the granitic gneisses is not clear but, as they apparently are older than the massive and relatively fresh gabbros of the large tabular bodies in the Waco area, they are grouped with the early granitic gneisses.

The ortho-amphibolites are dark coloured and medium to coarse in grain. Some are massive, but others have a schistosity parallel to the structure of the surrounding rocks. Average grain size is about 2 mm. Under the microscope the ortho-amphibolite shows a granoblastic texture superimposed on a relic, gabbroic or granitoid fabric. In the six thin sections examined, the rock has the following average composition: plagioclase (40 per cent), pyroxene (8 per cent), hornblende (30 per cent), and biotite (6 per cent). The rock also includes small amounts of opaque minerals (mainly magnetite), quartz, chlorite (penninite or clinocllore), epidote, and sericite-saussurite (after feldspar). The plagioclase is andesine ranging in composition from An_{33} to An_{49} , with an average of An_{41} ; it occurs as large subhedral grains clouded with felty sericite. The pyroxenes (augite or hypersthene, or both) are extensively altered

to either the normal or the basaltic variety of hornblende. The chlorite has developed from reddish brown biotite, with corresponding development of epidote and zoisite.

Mixed Gneisses

Under the generic term "mixed gneisses" (injection gneisses; migmatites) are grouped various hybrid gneisses composed of varying amounts of paragneisses with intercalated granitic layers. They are transitional between typical paragneisses and granite gneisses containing a few relic lenses of paragneiss. Their distribution in the area clearly indicates the presence of former belts of paragneiss which have been extensively injected by early granites and have been metasomatized.

Two main types of mixed gneisses are distinguished: the veined migmatites in the southeastern corner of the Wacouno area, and the injection gneisses forming long and narrow zones in the northern third of the Wacouno area and in the southern third of the Waco area. The veined migmatites are irregularly layered rocks cut by a complex assemblage of aplitic and pegmatitic dykes. The injection gneisses consist of thin but continuous bands of paragneisses and gneissic granite with very few granitic dykes. Both types are associated with hornblende-biotite paragneisses.

The mixed gneisses have a pronounced layered structure (Plates VII-B, IX-A), caused by numerous layers or lenses of granitic material along the gneissosity of the paragneisses. The thin, sinuous, hornblende-biotite septa within the granitic layers appear to be remnants of thicker layers of paragneisses (Plate VIII-A). In many places, the granitic component appears to have been segregated in place from the paragneiss, with alkalis being added to allow the formation of large amounts of potassic feldspars.

The mixed gneisses have a variable composition as a result, presumably, of variations in degree of granite injection and metasomatism in the paragneisses. The average grain size is about 0.6 mm., and the texture is distinctly granoblastic and equigranular. The essential minerals are: plagioclase, microcline, quartz, biotite, and hornblende. The accessory minerals include magnetite, sphene, allanite, apatite, and zircon. The plagioclase varies in composition from An₁₁ to An₃₅, and averages An₂₂ (oligoclase). The grains of plagioclase are anhedral and have characteristic clear reaction rims of

a more sodic plagioclase where in contact with microcline. These rims, about 0.02 mm. wide, contrast with the moderately saussuritized and sericitized core of the plagioclase grains. Vermicules of quartz are common in the larger plagioclase grains. The reaction rims of sphene around (titaniferous?) magnetite are also characteristic of this rock. The biotite, which is greenish or reddish brown, shows slight alteration to chlorite (clinocllore). The accessory minerals are generally associated with biotite and hornblende.

Granite Gneiss

The belts of typical paragneisses in the area grade into mixed gneisses (migmatites) laterally as well as along strike. Similar changes are observed where the mixed gneisses are in contact with large masses of gneissic granite or augen gneiss. The transitional contact is marked by an ill-defined zone of granite gneiss about 200 feet wide.

The granite gneiss is fine to medium grained and pinkish, and it weathers to a whitish grey. It is characterized by a thin gneissic layering with laminae of biotite and hornblende alternating regularly with laminae of quartzo-feldspathic material. The grain size averages 1 mm. In the three thin sections examined, the rock has the following essential constituents: plagioclase (31 per cent), microcline and perthite (36 per cent), quartz (22 per cent), hornblende and biotite (8 per cent). The rest comprises the accessory minerals (magnetite, apatite, sphene, and zircon), and the alteration products (saussurite) of the plagioclase. Where perthite is absent, the potassic feldspar is microcline but the two may appear together. The plagioclase here, about An_{16} , has the same reaction rims and myrmekitic quartz intergrowths as that of the mixed gneiss. The accessory minerals are usually confined to the laminae of biotite and hornblende.

Although the granite gneiss has typically the composition of a granite, structural and textural features indicate that this rock is a migmatite. The complete transition from paragneiss to granite gneiss suggests that the latter is a granitized paragneiss.

Augen Gneiss

The early intrusive and metasomatic rocks of the area include a large amount of augen gneiss. This is a distinctive rock

of granitic composition with numerous elongated phenocrysts or porphyroblasts of feldspar (Plate IX-B). The augen gneiss occurs mainly in the Waco area, where it constitutes the bulk of the granitic rocks. It is found mainly in a belt, about 2 1/2 miles wide, trending northwesterly from the southeastern corner of the area to Waco lake where it branches out to the east and northeast. This northeastern branch flanks the western margin of a large, basic intrusive complex. Along the belt, irregular areas of gneissic granite grade into augen gneiss. Another body of augen gneiss, about 4 miles long and half a mile wide, trends north, along the southwestern shore of Dufresne lake.

The only body of augen gneiss in the Wacouno area is an elliptical mass that flanks the southeastern edge of a granite batholith about 2 1/2 miles east of the railroad between Mile 67 and Mile 74. It is elongated towards the northeast and is about 2 miles wide and 6 miles long, with a thin tabular body at the south end projecting westward for 3 miles into the granite batholith.

Field relationships indicate all degrees of transition between augen gneiss and granite gneiss or gneissic granite, and the transition zones are generally about 1,000 feet wide. The boundaries between these rock types are therefore somewhat arbitrary, as shown, and the age relations, not clear in every case. However, it is clear that the pink biotite granite forming the batholith of the Wacouno area cuts the augen gneiss and is therefore younger. Also, the augen gneiss is probably older than the gabbroic and anorthositic intrusive rocks in the Waco area.

The augen gneiss probably marks one of several stages in the formation of the early granitic rocks which, in some places, appear to be highly deformed and recrystallized intrusive granites, and, in others, granitized sedimentary rocks. It appears to be closely associated in time, space, and mode of formation, to the gneissic granite.

The rock is pink with shades of grey, and medium- to coarse-grained. It has a pronounced sugary texture and a generally well developed gneissic layering. The augen consist of single crystals of pink potassic feldspar or aggregates of feldspars and quartz, elongated parallel to the gneissic layering and 1/4 inch to 1 1/2 inches across. Twin planes in feldspar crystals commonly lie in the plane of the gneissic layering. In much of the augen gneiss, particularly where gneissic layering is poorly developed, the long axes of feldspar

crystals are parallel and the augen constitute a large part of the rock. Where single crystals of pink feldspar constitute the augen, the rock is well layered and the augen appear as porphyroblasts which developed during or after recrystallization. The porphyroblastic type of augen gneiss was probably formed by injection of granitic fluids into schists of sedimentary origin. The poorly layered augen gneiss and the strongly lineated variety are intensely granulated and appear to have been formed by crushing and recrystallization of an early biotite-hornblende granite of metasomatic or intrusive origin.

Under the microscope, the augen gneiss has a distinct granoblastic texture. The phenocrysts or porphyroblasts of feldspars and lenticles of quartz are embedded in a sugary matrix with a grain size of about 1 mm. In the five thin sections examined, the rock has the following constituents: plagioclase (25 per cent), potassic feldspar (42 per cent), quartz (20 per cent), hornblende (4 per cent) and biotite (4 per cent). Magnetite, pyrite, sphene, allanite, apatite, and zircon, and alteration products after plagioclase are also present. The plagioclase ranges in composition from An_{16} to An_{27} , and averages An_{22} (oligoclase). The plagioclase grains have the same type of reaction rims and vermicular intergrowths of quartz observed in the migmatized paragneisses. Clear microcline perthite is the only potassic feldspar present. Textural features indicate that the microcline has replaced part of the plagioclase. Quartz occurs as lenticles parallel to the gneissic layering and as small grains between feldspar crystals. Hornblende occurs as anhedral grains commonly associated with the greenish or reddish brown plates of biotite.

Gneissic Granite and Granulated Granite

Gneissic granite underlies more than one third of the area. It is distributed between the main bodies of massive intrusive rocks, that is, between the granite batholith occupying most of the Wacouno area and the basic intrusive complex of the Waco area. The gradation of the gneissic granite into augen gneiss and migmatitic gneisses suggests that all these rocks are closely related even though the processes of their formation may be different.

The gneissic granite generally has only a vague gneissic structure, mainly defined by elongated feldspar grains or quartz lenticles. However, upon approaching migmatitic zones, the rock becomes well foliated, grades into a granite gneiss, and the percentage



Aerial photograph of uplands near Miche lake, in southeast corner of Waco map-area. The SSE. - trending, arcuate topographic lineaments follow the strike of foliation of the gneisses. The joint-controlled gulleys are singularly linear and trend N., E., and NE.



A - Waco station on the Quebec North Shore and Labrador railroad at Mile 101.2. This semi-permanent camp is used by railroad maintenance crews.



B - Ballast operations at Mile 84. Gravel of good quality is dug out of the outwash plain in the Wacouno River valley.

Plate III



A - Outwash sand plain at north end of Kachipitonkas lake. Looking north. Braided eskers in right foreground disappear under the lake.



B - Asymmetric valley of Kachipitonkas lake. Looking south. The slope of the cliffs on the west side of the valley is lessened by the accumulation of huge talus blocks. The flat upland on the west stands 1,000 feet higher than the lake.

Plate IV



A - Mountains formed by the Mamikam granite batholith. Photograph taken one mile south of south end of Kachipitonkas lake. Looking west.

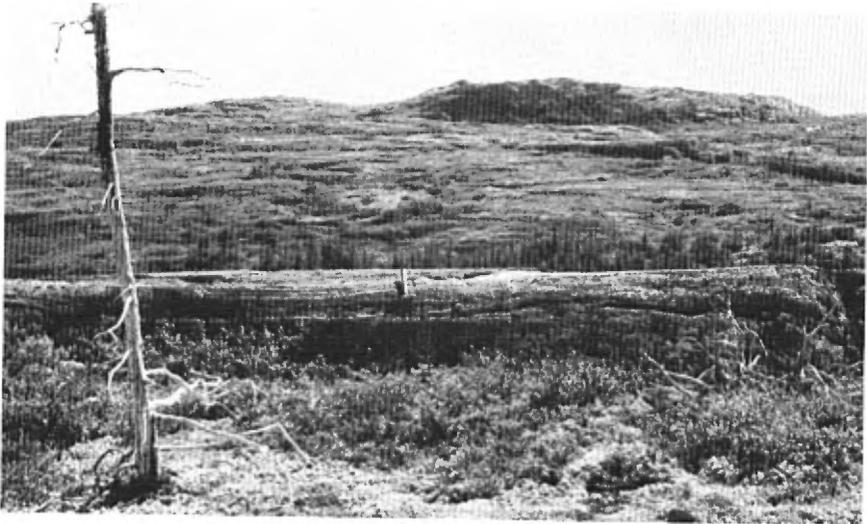


B - Wacouno waterfall (120 feet) at Mile 68.7. The granite cliffs in background are 1,200 feet high.

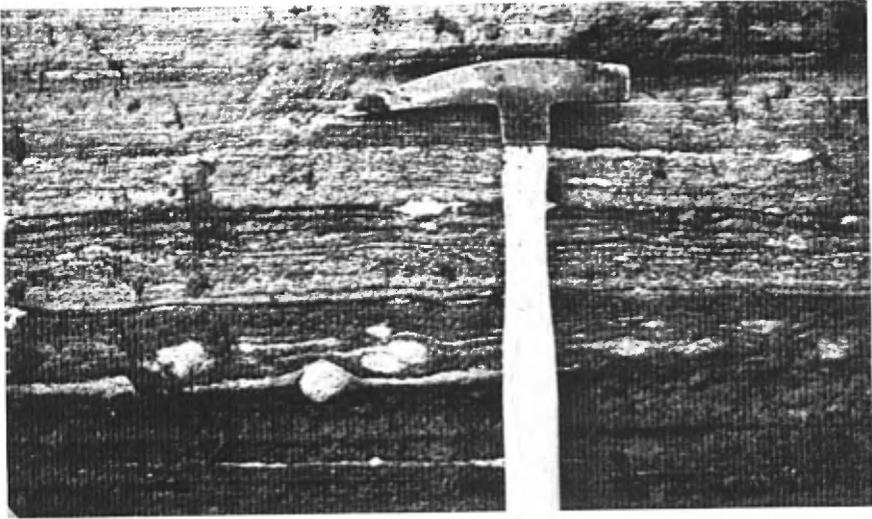
Plate V



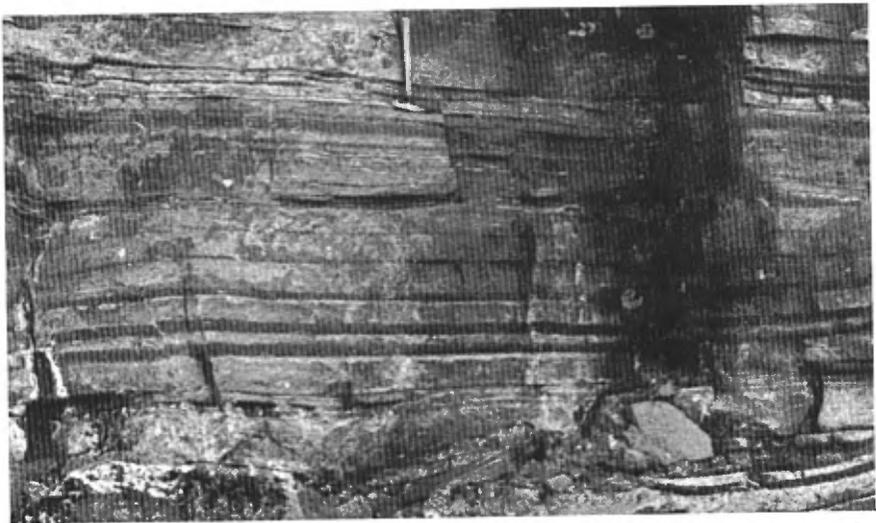
A - Uplands in southwestern corner of Waco area . Looking north . The uplands stand at an elevation of 2,800 feet and bear only dwarf vegetation .



B - Uplands in southeast corner of Waco area . Looking east . In background is the highest summit of the area — 3,000 feet above sea-level .



A - Garnetiferous paragneiss. The hammer point is touching a porphyroblast of garnet. The dark layer in the bottom third of the photograph is hornblende-biotite schist. The white blobs immediately above this layer are porphyroblasts of microcline.



B - Layer-cake migmatite. The white layers are thin sills of leucogranite.

Plate VII

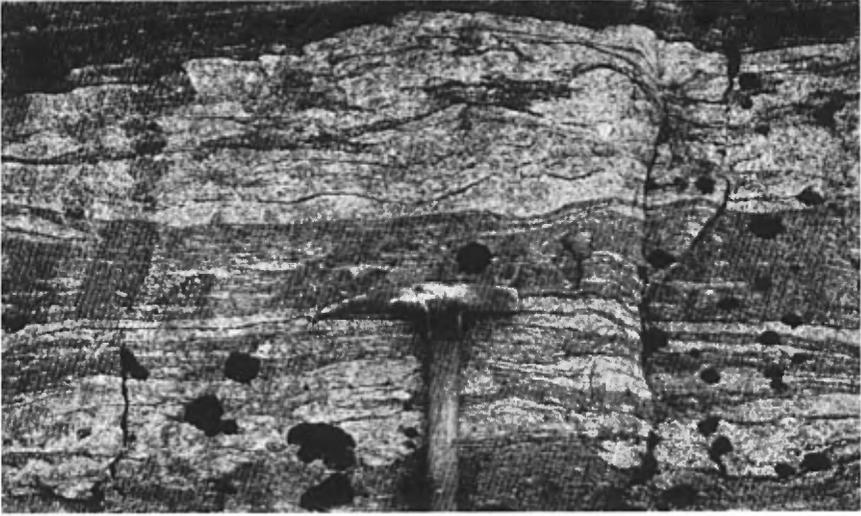


A - Calcareous meta-concretions in amphibolite. Northeast shore of à l'Aigle lake.

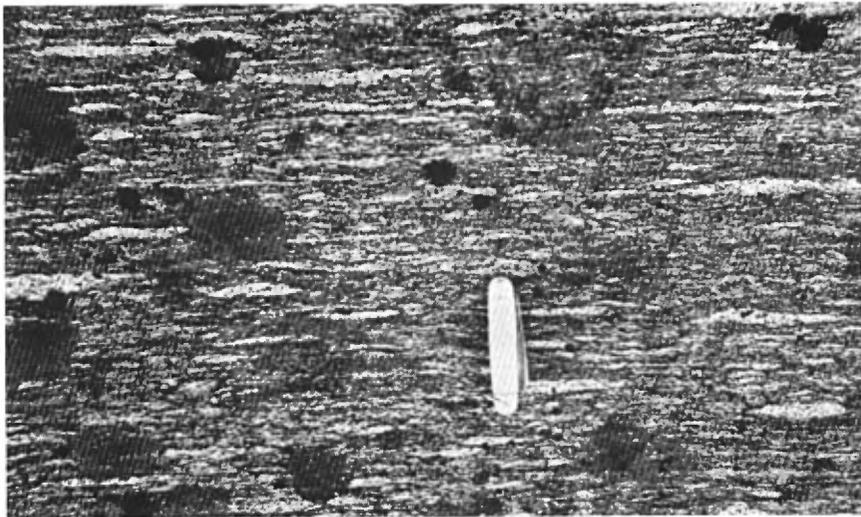


B - Hybrid gneiss (arteritic migmatites). Northern third of Wacouno area.

Plate VIII



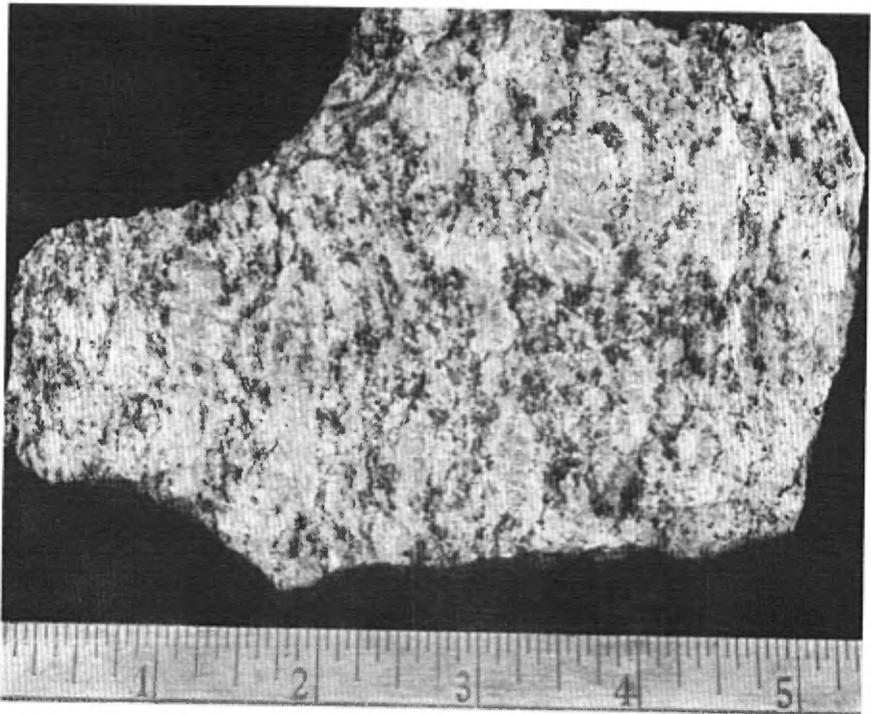
A - Mixed gneiss. Complex structures resulting from anatexis or lit-par-lit injections.



B - Mixed gneiss. Original paragneiss is intimately pervaded by granitic material.



A - Complexly folded mixed gneiss.

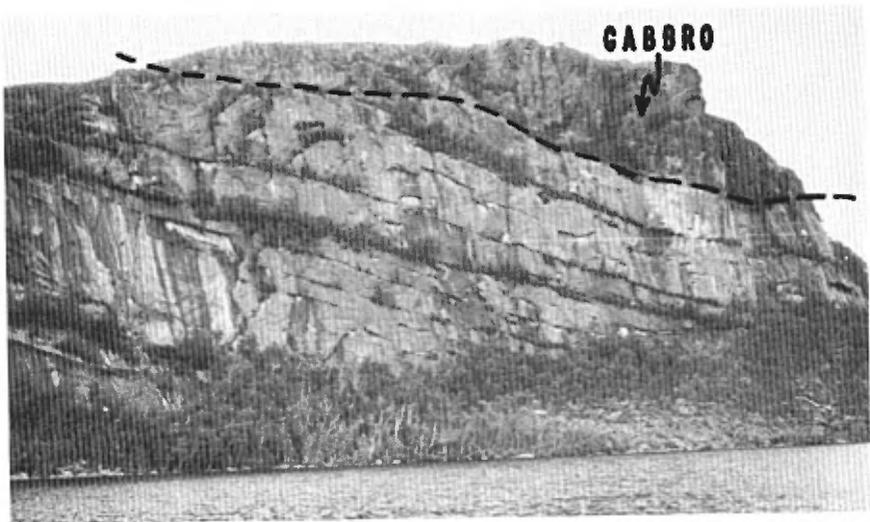


B - Augen gneiss. The phenocrysts consist of perthitic microcline.

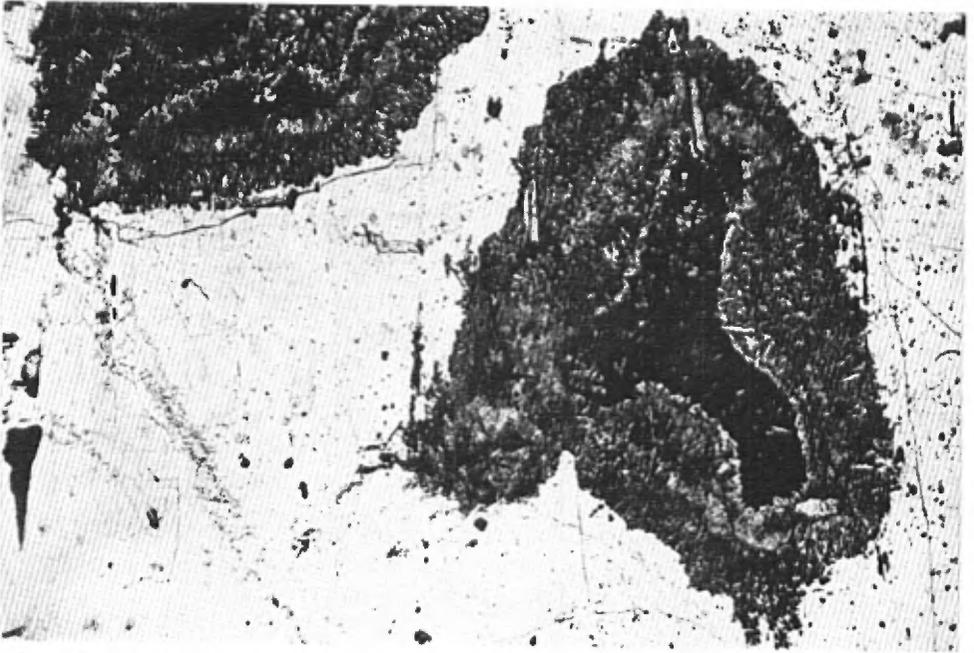
Plate X



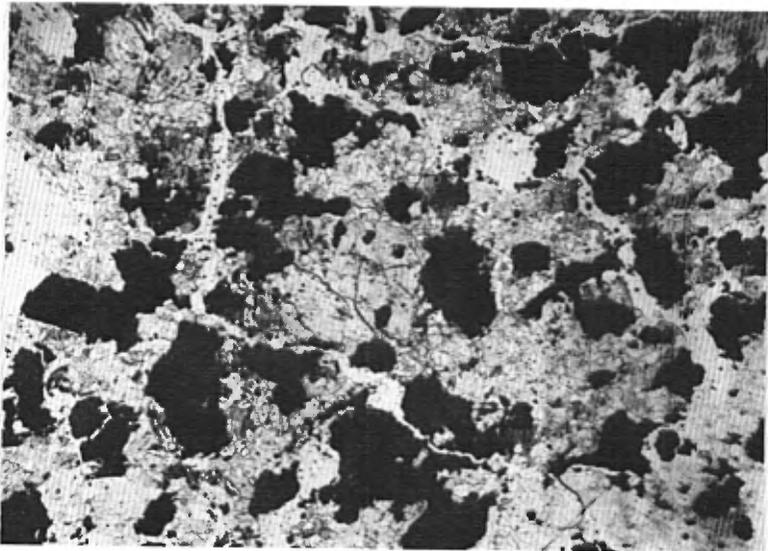
A - Layered norite with primary segregation lenses of anorthosite. The lenses occur along definite planes and constitute an original flow structure .



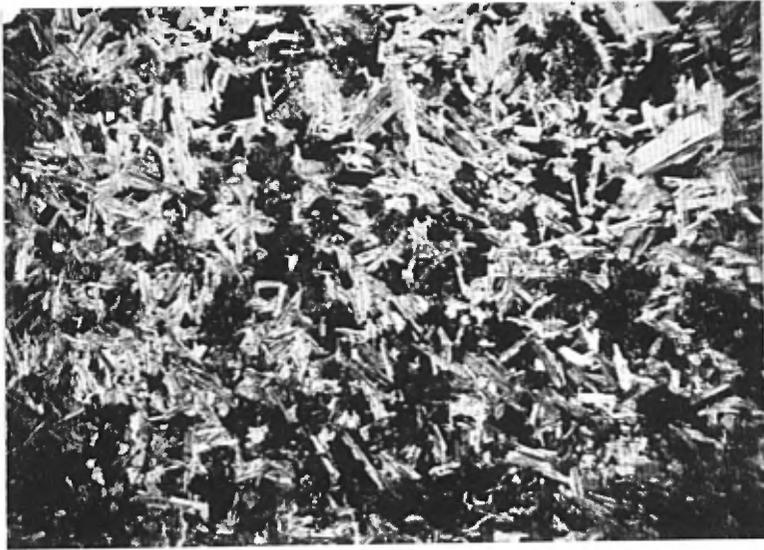
B - Gabbro sill overlying granitic gneiss. This 600-foot scarp is at the east end of Miche lake . The lines of trees on the scarp are parallel to the foliation of the gneiss .



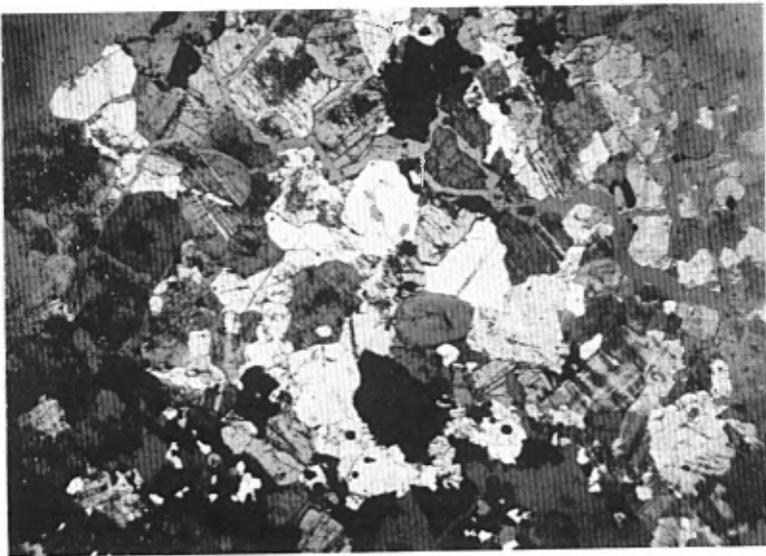
A - Photomicrograph of mafic coronas in anorthosite. Natural light. (x20)



B - Photomicrograph of pyroxenite. The crystals of pigeonite are almost opaque owing to innumerable inclusions of magnetite. Natural light. (x11)



A - Photomicrograph of olivine gabbro. Rock has a typical sub-ophitic texture. Crossed nicols. (x11)



B - Photomicrograph of monzonite. Black crystals are hastingsite. Rock contains an equal amount of oligoclase and orthoclase with microcline. Crossed nicols. (x11)

of paragneiss inclusions increases. Away from migmatitic zones, the gneissic granite is remarkably uniform in composition and structure, as in the south central part of the Waco area. It is pink to greyish pink on fresh surface, and pinkish grey on the weathered surface.

Under the microscope, the gneissic granite has a granitoid but somewhat sugary texture. In several instances granulation and recrystallization have reduced the rock to an equigranular aggregate, with an average grain size of about 1.5 mm. Gneissic structure is generally inconspicuous under the microscope. The average mineralogical composition determined from 14 thin sections of specimens from widely separated localities is: plagioclase (26 per cent), microcline (32 per cent), quartz (25 per cent), and biotite (6 per cent). The rest consists of hornblende, magnetite, chlorite, and muscovite with sphene, allanite, apatite, zircon, and saussurite-carbonate (alteration after the feldspars). The plagioclase has about the composition of oligoclase An_{13} . Albitic reaction rims and vermicular quartz intergrowths also occur in this rock. The microcline is slightly perthitic. The hornblende is anhedral and is, in some places, replaced by biotite. Chlorite, probably clinocllore, occurs as an alteration of biotite. Muscovite is clearly secondary after the feldspars. Sphene is commonly associated with magnetite; in one specimen it is keilhauite, a variety with very high birefringence and which contains 4.6 per cent of rare earth elements (mainly cerium). Allanite, probably primary, generally is scattered throughout the rock. Round grains of wine-red garnet were seen in a few exposures.

The granulated granite crops out in a semi-circular area of about 10 square miles between the Wacouno airstrip at Mile 79 and the east boundary of the Wacouno area. It is almost surrounded by late biotite granite. The granulated granite is pink, medium- to coarse-grained, and practically free from ferromagnesian minerals. Its essential and accessory constituents are the same as those of the gneissic granite, with muscovite slightly more abundant. In contrast with the gneissic granite, this rock has been highly granulated. Quartz is segregated as sub-parallel lenticles that produce a distinct lineation. These rod-shaped lenticles are from one-quarter inch to 3 inches long.

Local facies of granulated granite are also found within the gneissic granite. The transition between these two rocks, as well as similarities in texture and mineralogical composition, suggests that they are closely related in time and mode of formation.

Waco Igneous Complex

General Relations

Basic intrusions, some with acidic border facies, are found mainly in the Waco area. As these bodies appear to be genetically, chronologically, and structurally related, they are referred to in this report as the "Waco Igneous Complex".

Vital-Labrador Anorthosite Mass

The eastern edge of an anorthosite mass that probably covers more than 500 square miles crops out in the east-central part of the Waco area. This mass extends eastward beyond the area for at least 20 miles. Reconnaissance to the east (see Figure 2) in the fall of 1954, showed that the mass largely consists of a coarse-grained, dark grey, autoclastic anorthosite. Westward, towards the contact in the Waco area, the rocks first become gabbroic, then grade into monzonitic and syenitic border facies. That part of the mass within the area is composed mainly of syenitic and monzonitic border facies, with local and irregular patches of gabbro and gabbroic anorthosite.

The western boundary of the mass, representing the lower contact, has an arcuate outline trending parallel to the structure of the adjacent granitic gneisses; the southern part seems to cut the bands of gneisses. The syenitic and monzonitic border facies are commonly gneissic, strike parallel to the contact and dip steeply to the east. Farther to the east and closer to the centre of the mass, the anorthosite is generally massive, although, in several places, it has a distinct lineation plunging in an easterly or southeasterly direction, at angles between 15° and 30° . This lineation is produced by parallel tabular crystals of labradorite. This structure suggests that the anorthosite mass is a giant lopolith or, at least in some parts, a semi-horizontal tabular body.

Tabular Bodies of Gabbro

Several tabular and stock-like bodies of gabbro and related rocks, probably satellitic to the Vital-Labrador anorthosite mass, occur in the Waco area (see Figure 2). The largest, 6 miles long and 500 to 1,500 feet wide, is a tabular body trending 20° east of north, near the east shore of Dufresne lake.

Most of these bodies of gabbro appear conformable to the gneissic layering of the surrounding granitic rocks but this relationship is only apparent. Several cut the structure of the country rock and others are nearly flat-lying in minor synclines, in the crest of minor anticlines or elongated basins formed by secondary folds in the granitic gneisses. The best example of a nearly flat-lying body of gabbro may be seen at the east end of Miche lake. Here, gabbro with anorthositic facies forms a capping over augen gneiss in an escarpment about 500 feet high (Plate X-B). The sill-like body of gabbro near Dufresne lake is concordant only in its southern half along which several dykes cut the surrounding granitic gneisses.

In general, the gabbro bodies have a distinct topographic expression. They form residual knobs about 150 feet higher than the surrounding granitic upland, with a surface highly smoothed and rounded by glacial abrasion.

None of these gabbro bodies show evidence of gravity differentiation, although irregular mineralogical variations are common. The rocks of these bodies include norite, troctolite, olivine gabbro, normal gabbro, hornblende gabbro, meta-gabbro, diorite, and monzodiorite. As all these rocks have the same habit and similar structural relationships, and as many of them closely resemble facies of the Vital-Labrador anorthosite mass, they are considered to be more or less of the same age and co-magmatic with the anorthosite mass (Emo, 1955).

Age Relationships

The age relationship between rocks of the anorthosite-gabbro suite and granitic gneisses is not clearly established. The main problem is whether the anorthosite post-dates or predates these gneisses. Recently, Engel and Engel (1953) presented a review on the ideas expressed on this subject, including rocks of the North Shore region. Like many of his co-workers in the Adirondack region, he has concluded that the anorthosite is the oldest rock intrusive into the "Grenville series". The evidence from the Waco area leads to a different interpretation and indicates that the formation of the anorthosite was preceded by a period of granitic injection, or, at least, by granitization of the pre-existing sedimentary rocks which may or may not be equivalent to the Grenville series.

The gabbro bodies satellitic to the anorthosite all appear to be roughly contemporaneous in age and to post-date the formation of the surrounding granitic gneisses. Some bodies definitely cut across the structure of the gneisses, whereas others are found as cap-pings on the gneisses (Plate X-B). Dykes of gabbro very similar in composition to some facies of the main bodies cut the granitic gneisses.

In one exposure of gabbro, 1 1/2 miles southwest of Croissant lake, thin segregation layers of anorthosite may be seen (Plate X-A), thus indicating a genetic relationship of the anorthosite with the gabbro. Some of the tabular bodies of gabbro show an a-lineation plunging at an angle of about 50° towards the mass, the direction of plunge being the same for tabular bodies trending north-south or slightly south of east. This lineation may be a primary structure resulting from flow movement during the crystallization of the gabbro.

The anorthosite of the Waco igneous complex is, at least in part, older than the satellitic bodies of gabbro. It is cut in a few places by dykes of meta-gabbro which have essentially the same composition as the amphibolitic border facies of the satellitic bodies. In spite of this apparent difference in age, both the anorthosite and the gabbros are probably co-magmatic and younger than the granitic gneisses.

The syenitic and monzonitic border facies of the anorthosite mass are probably younger than the anorthosite, as indicated by dykes of similar rocks in it. The relationships between the syenite, the monzonite and the various types of gabbros are unknown.

Anorthosite and Gabbroic Anorthosite

The reconnaissance mapping done in the fall of 1954 to the east of the area, in the region between Fournier and A l'Aigle lakes (see Figure 2), has shown that the typical anorthosite outcrops east of Mariauchau lake, 4 miles east of the eastern boundary of the Waco area. At Vital lake, 9 miles east of this boundary, the anorthosite is typically black and coarse-grained.

Westward and away from the core of the Vital-Labrador mass, the anorthosite grades into gabbroic anorthosite, with an increase of as such as 22 per cent mafic minerals. The rock varies in colour from light grey, mauve to black, but is generally medium grey. The weathered surface, rusty brown or just slightly darker than the

fresh surface, has characteristic cup-shaped holes up to 2 inches in depth and width caused by the weathering-out of mafic clusters. The rock is coarse-grained to very coarse-grained, with tabular crystals of calcic plagioclase up to one foot long. In many places, these crystals are sub-parallel and the rock is distinctly lineated.

As determined under the microscope, the typical anorthosite has the following average composition: labradorite feldspar (87 per cent), olivine (3 per cent) and pyroxene (3 per cent). The rest consists of brown biotite, muscovite, penninitic chlorite, ilmenite and titaniferous hematite, green spinel (pleonaste) and apatite. Antigorite and iddingsite occur after the olivine, either as veinlets or as irregular alteration patches. The labradorite is slightly altered to carbonate (calcite) and forms subhedral, finely twinned crystals. It averages An_{53} in composition. Hypersthene and augite, both of which may appear in the same thin-section, and olivine, are generally interstitial between labradorite crystals. Most ferromagnesian minerals occur in clusters commonly in a coronitic structure (Plate XI-A). The coronas are made up of a kernel of olivine, surrounded by successive rims of hypersthene, hornblende, and, in the third or outer rim, of actinolite and colourless amphibole. The coronas and the slight alteration of the plagioclase are late-stage crystallization phenomena, probably the effects of deuteric solutions in partly crystallized anorthosite.

Normal Gabbro, Olivine Gabbro, Hypersthene Gabbro, and Hornblende Gabbro

In view of the great diversity in texture and mineralogical composition of the gabbro bodies in the Waco area, and because of the transitions between the many varieties of gabbro, even within a single body, a detailed description of the occurrence, the structure and the petrography of each type of gabbro is not warranted in this report. Furthermore, as many gabbro bodies show the same structural, textural, and compositional variations, their similarities are indicative of consanguinity even though some varieties may differ slightly in age. As the distribution and the structure of the gabbro bodies have been discussed above, the following chapters are devoted to a description of only the main types and to a discussion of their respective mineralogical composition.

On a mineralogical basis, the gabbros forming the so-called satellitic bodies fall into four categories: normal gabbro, olivine gabbro, hypersthene gabbro and hornblende gabbro. As stated

previously, one or several of these types may be found within a single body. There seems to be no particular arrangement of these gabbros with respect to the anorthosite mass.

On the other hand, the gabbros forming border facies of the anorthosite mass tend to be anorthositic. They grade eastward into gabbroic anorthosite and westward into olivine gabbro, suggesting a gradual transition between anorthosite and gabbro.

The normal gabbro occurs locally within the tabular gabbroic bodies which are intrusive into granitic gneisses and mixed gneisses, and represents only a small proportion of these bodies. It grades into the three other varieties of gabbro, both through variations in the amount of its original constituents and through mineralogical changes induced by late magmatic alteration. It is characteristically massive, dark brown, brownish black weathering and coarse-grained. Its exposures are well-rounded.

In the four thin sections examined, the normal gabbro is sub-ophitic to intergranular in texture or, more rarely, porphyritic. The average grain diameter usually exceeds 2 mm. The normal gabbro has the following average mineralogical composition: plagioclase (47 per cent), clino-pyroxene (19 per cent), hornblende (13 per cent), magnetite and titaniferous hematite (8 per cent), hypersthene (5 per cent), and small amounts of olivine, garnet, spinel and apatite. The slight alteration of the plagioclase has produced a little sericite and carbonate, and that of olivine, a little iddingsite.

The plagioclase is generally calcic andesine in subhedral lath-shaped crystals with abundant albite and pericline twins; it ranges in composition from An_{40} to An_{53} and has the average composition of andesine An_{45} . The clino-pyroxene, which is either pigeonite or augite, is often so dusted with tiny dark inclusions as to be almost opaque. The roughly simultaneous crystallization of the andesine and the clino-pyroxene has resulted in a sub-ophitic arrangement of their crystals, with the pyroxene occupying angular spaces between the plagioclase laths. Hypersthene forms kelyphitic rims around the few grains of olivine present, but also occurs in clusters of tiny round grains mantled by hornblende. Another common type of corona is shown by thin mantles of amphibole around large stumpy crystals of clino-pyroxene. Magnetite and titaniferous hematite form the cores of mafic clusters between plagioclase crystals; they are surrounded by small plates of reddish brown biotite which, in

turn, are enveloped by hornblende. Green spinel (pleonaste) is rare and is associated with magnetite. Garnet occurs as small anhedral grains at the outer boundary of olivine-hypersthene-hornblende coronas and generally appears within the calcic plagioclase.

Olivine gabbro, with its altered derivatives, is the most abundant variety of gabbro in the tabular and concordant gabbroic bodies of the Waco area. In this respect it is similar to the gabbro found in the Charpenay-Coopman area some 80 miles to the south-southeast and which Klugman (1955) believes to be associated with the Romaine River anorthosite mass. Similar bodies of olivine gabbro are also found some 30 miles to the south, in the Nipisso area (Hogan, 1952). Field observations in the present area indicate a gradual transition between the olivine gabbro and the hypersthene gabbros grading into norites. Petrographic study of representative specimens suggests that the main cause of this transformation is the change in crystallization from olivine to hypersthene.

The olivine gabbro is medium-grained, massive, equigranular and very dense. The fresh rock varies from dark grey to greenish black and weathers to a rusty brown surface having a salt-and-pepper appearance. The exposures are typically well rounded and smooth.

The texture is sub-ophitic or intergranular (Plate XII-A) and markedly coronitic, with an average grain diameter of about 3 mm. In the 11 thin sections studied, the olivine gabbro contains the following essential constituents: calcic plagioclase (38 per cent), olivine (19 per cent), clino-pyroxene (13 per cent), hornblende (10 per cent), and hypersthene (7 per cent). There are also small amounts of reddish brown biotite, magnetite, ilmenite, titaniferous hematite, garnet, colourless and green spinels, apatite, and very rare crystals of zircon. The plagioclase is slightly altered to clinozoisite and sericite, and the olivine to iddingsite and serpentine.

The plagioclase, which varies between An_{44} and An_{52} and has the average composition of calcic andesine An_{49} , is more basic than that in any other variety of gabbro. It forms stubby laths more or less intergrown in ophitic fashion, with large clino-pyroxene subhedral crystals. In common with the sodic labradorite of the anorthosite, this plagioclase contains a dust of microscopic inclusions and is finely twinned after the albite law (it is rarely twinned after

the pericline law, however). Some small patches of plagioclase are interwoven with vermicules of colourless pyroxene in typical symplectitic fashion. The large euhedral crystals of olivine, often corroded on their periphery and along fractures by iddingsite and serpentine minerals, show typical successive rims of hypersthene, green hornblende, and small garnets, with the hypersthene and hornblende often plaited. Hypersthene also occurs as clusters of tiny granules surrounded by hornblende. The clino-pyroxene varies in composition from pigeonite to diopsidic augite, but in all cases it contains a fine dust of almost opaque inclusions. It occurs as large subhedral crystals, commonly rimmed by hornblende. In six of the slides examined, the amphibole is brown basaltic hornblende (lamprobolite). The opaque minerals, locally with spinel, are nested in clusters of biotite enveloped by hornblende, but they are also found within the olivine. Apart from the coronas, which probably represent deuteric alteration phenomena in the crystallizing magma, the olivine gabbro is remarkably fresh.

The hypersthene gabbro, grading locally into norite, is less widespread than the olivine gabbro and the normal gabbro, but it grades into these rocks with decreasing amounts of hypersthene. Most gabbros in the Waco area contain some hypersthene and this suggests that they all belong to the same parent magma. In one exposure, three-quarters of a mile southwest of Croissant lake, the hypersthene gabbro is a norite which contains parallel segregation lenses of anorthosite about one foot long and half an inch thick (Plate X-A). These primary structures indicate a genetic relationship between the hypersthene gabbro and the anorthosite.

In the field, the hypersthene gabbro is distinguished from the other varieties of gabbro by its finer grain size and its reddish brown weathered surface having a typical "salt-and-pepper" appearance. The rock is dense, massive, brittle and generally fine-grained, with a somewhat shiny, greenish or brownish black fresh surface. It is markedly equigranular.

The texture varies from xenomorphic to sub-ophitic, regardless of mineralogical composition. The average grain diameter is about 0.8 mm. In the four thin-sections examined, the hypersthene gabbro has the following average composition: andesine feldspar (43 per cent), hypersthene (27 per cent), hornblende (14 per cent), clino-pyroxene (6 per cent), with small amounts of magnetite, ilmenite, reddish brown biotite, and garnet or spinel. The feldspar is only slightly altered to clinozoisite and sericite.

The plagioclase, which varies in composition from An₄₁ to An₄₇, has about the same composition as the feldspar in the normal gabbro and is slightly less calcic than that of the olivine gabbro. Where the rock is xenomorphic, the plagioclase constitutes a ground-mass of small, equidimensional grains showing no evidence of granulation. Elsewhere, it occurs as stubby laths finely twinned after the albite law. The study of a suite of representative specimens taken across a tabular gabbroic body indicates clearly that the hypersthene is, in part at least, derived from the olivine. However, there is no corresponding transformation of the accompanying plagioclase. The clino-pyroxene has the properties of either augite or pigeonite; it forms large subhedral crystals mantled by hornblende and containing irregular alteration patches of this mineral. In the hypersthene-rich gabbro, the gedrite variety of amphibole occurs as an alteration of bronzite, even though the common amphibole in this rock is olive green hornblende. This latter mineral is pseudomorphous after the clino-pyroxene, but also occurs in clusters of small anhedral grains around biotite and magnetite. The apatite is generally associated with the plagioclase crystals, whereas garnet or spinel forms reaction products between hypersthene and plagioclase. As olivine is absent, coronitic textures are much less prominent in this hypersthene gabbro than in the olivine-bearing and normal varieties of gabbro.

The hornblende gabbro is distinguished from the other varieties of gabbro by its high content of amphibole and its coarse grain. It occurs in almost every exposure of gabbro. The contacts between this facies and others are possibly transitional but they have not been recognized in the field.

The rock has a more blotchy and darker brown weathered surface than the surrounding gabbros. It decomposes readily and many of its exposures are covered by as much as one foot of the loosened debris. On fresh surface, it is mottled dark green or dark grey, with relic phenocrysts of purplish plagioclase.

Under the microscope, the hornblende gabbro shows a variety of textures, from sub-ophitic, intergranular to xenomorphic. The average grain diameter generally exceeds 5 mm. In the four thin sections examined, the rock has the following average mineralogical composition: andesine feldspar (45 per cent), amphibole (33 per cent), biotite (7 per cent), opaque minerals (7 per cent), and small amounts of orthoclase, pyroxene, chlorite (penninite) and apatite. The plagioclase is slightly altered to saussurite and minor sericite.

The plagioclase is less calcic than that of the other three varieties of gabbro and has the average composition of sodic andesine (An_{37}). It is in slightly altered, equidimensional or stubby lath-shaped crystals, having numerous albite twins but none of pericline. The crystals are penetrated and replaced by a fine-grained mosaic of round completely fresh grains of untwinned sodic plagioclase and orthoclase. The amphibole is common hornblende, but hastingsite and cummingtonite are present locally. These minerals, with associated flakes of reddish brown biotite and anhedral aggregates of magnetite-ilmenite, occur as clusters of small anhedral grains in partly granulated and recrystallized portions of the feldspar mosaic. Many crystals of hornblende poikilitically enclose grains of plagioclase and magnetite, while others contain numerous hematite blades along their cleavage planes. These features clearly indicate that at least some of the hornblende is secondary and not representative of the original, dominant mafic mineral of the rock. Moreover, in the pyroxene-bearing varieties, the hornblende in the gabbro has replaced the diopsidic pyroxene, but not the rare hypersthene also present.

The hornblende gabbro is believed to have originated from pyroxene-rich varieties of gabbro by processes of late-magmatic alteration. It is unlikely that the scattered and ill-defined masses of hornblende gabbro represent a distinct intrusion. More likely, as suggested by Emo (1955), they are due to a patchy distribution of fluxes in the basaltic magma; a greater concentration of these fluxes would result in a crystallization delay of certain constituents, as well as in increased fluidity, and an ultimate development of a coarser texture and the growth of low temperature silicates (Wells, 1954).

Meta-gabbro and Ortho-amphibolite

Several well defined dykes and sills of meta-gabbro and ortho-amphibolite occur in the Waco area. They clearly intrude the granitic gneisses and are generally satellitic to nearby larger gabbro masses. This constitutes further evidence that most gabbro bodies in the area post-date the granitic gneisses.

The distinction made in the field between the meta-gabbro and the ortho-amphibolite is somewhat arbitrary, as both consist predominantly of intermediate plagioclase and amphibole and represent altered facies of olivine-, hypersthene- and hornblende-bearing varieties of relatively fresh gabbro. As a rule, however,

the meta-gabbro is massive and grades into fresh gabbro within a single body and over a distance of a few hundred feet; on the weathered surface, it resembles closely the hornblende gabbro, as well as the normal gabbro. In places, the original gabbro is highly sheared and the resulting meta-gabbro has a flaser structure, with sub-angular clots of ferromagnesian minerals scattered in a groundmass of granulated crystals of plagioclase, extensively invaded by potassic feldspar. The meta-gabbro, as such, shows a wide diversity of texture and mineralogical composition, inherited mainly from variations in degree of alteration of the original gabbro. On the other hand, the ortho-amphibolite is generally a foliated, granular, marginal facies of the tabular bodies of gabbro accordant with the structure of the adjacent granitic gneisses. It has a remarkably uniform texture and composition. Both in the field and under the microscope, it resembles closely the quartzo-feldspathic, hornblende-biotite paragneisses. It forms dykes cutting granitic gneisses and anorthosite, as well as thin sills in the granitic gneisses. It is also found at the margins of, but within, the big gabbro bodies and never cuts these bodies. All these features clearly indicate that both the meta-gabbro and the ortho-amphibolite are genetically related to the tabular or stock-like masses of relatively unaltered pyroxene gabbro and olivine gabbro.

The meta-gabbro is massive or slightly foliated and is, in places, highly sheared with a flaser or augen structure. The grain size varies from fine to coarse and the colour from various shades of grey to dark green or dark brown. In the massive varieties, the texture is either xenomorphic-granular or granitoid and rarely porphyritic, whereas the foliated varieties commonly have a granular or lepidoblastic texture. All varieties weather dark.

In the eight thin sections examined, the meta-gabbro has the following average composition: plagioclase (34 per cent), amphibole (27 per cent), biotite (10 per cent), and potassic feldspar (8 per cent). They also contain small amounts of quartz, clinopyroxene, hypersthene, magnetite, ilmenite, apatite, sphene, phlogopite, muscovite, chlorite, zircon, garnet, green spinel (pleonaste), and, in quartz-free varieties, olivine. The slight alteration of the feldspars has produced small amounts of carbonate and epidote, with rare sericite and clinozoisite, whereas the olivine is altered to iddingsite and serpentine.

The plagioclase generally has the composition of andesine An_{90} , although in one thin section containing abundant

potassic feldspar it is oligoclase An_{18} , whereas in others it is as calcic as andesine An_{47} . The plagioclase crystals are generally subhedral; in the schistose meta-gabbro, their (010) plane trends to parallel the foliation. Both albite and pericline twins are present, with the former more abundant. The plagioclase crystals are replaced by irregular patches of potassic feldspar, represented either by orthoclase, microcline, or by hairline antiperthitic material. In one thin-section, the large phenocrysts of oligoclase are zoned and rimmed by perthite replacing the oligoclase. The amphibole is generally common hornblende, although in some slides it is hastingsite or cummingtonite. In one thin section of meta-norite, anthophyllite is very abundant. The amphibole crystals are generally euhedral and poikilitic. Flakes of reddish-brown biotite and anhedral crystals of iron ores generally occur in association with the amphibole, without reaction rims such as are found in relatively unaltered gabbros. The original clino-pyroxene in the meta-gabbros has been converted into amphiboles, but some large, anhedral relic grains of augite remain. Hypersthene and muscovite are rare. Quartz is secondary and interstitial. Phlogopite is present as an alteration of anthophyllite only in the meta-norite. The reddish-brown biotite is probably titaniferous because, in some thin sections, it is extensively altered to sphene and chlorite (clinocllore). The meta-gabbros are characterized by the variety of their constituents, as well as by the presence of potassic feldspar and sphene, both being found only in this type of gabbro.

The ortho-amphibolite is equigranular, greyish black, and black weathering. The rock is commonly foliated, and has an average grain diameter of less than 1 mm. In the four thin sections examined, it has the following estimated mineralogical composition; sodic andesine (43 per cent), hornblende (38 per cent), brown biotite (12 per cent), and magnetite (4 per cent). Accessory minerals include quartz, apatite, sphene and zircon. The rock also contains a little saussurite and sericite, as alteration products of the plagioclase feldspar.

The plagioclase crystals are generally anhedral, equidimensional and fresh. Their polysynthetic twinning is much less prominent than that in the other gabbroic rocks. Their composition varies from An_{86} to An_{48} and averages that of andesine An_{43} . Common hornblende occurs generally as anhedral crystals intergrown with the feldspar or forming clusters elongated parallel to the rock foliation. Many hornblende crystals are poikilitic and contain irregular grains

of plagioclase and granules of secondary, clear quartz. Biotite flakes and granules of magnetite occur in association with hornblende, both as inclusions within, and interstitial to, the amphibole crystals. Sphene and zircon are rare accessory minerals, whereas apatite is common.

Diorite

In addition to all the basic intrusive rocks described above, the Waco Igneous Complex also includes some diorite. In contrast with the gabbros, diorite has a restricted distribution and outcrops only near Waco lake, where it forms four small bodies, and in the railroad cut at Mile 95.4 at the east end of a large stock of normal gabbro. The diorite is near the pear-shaped mass of late granite one mile west of the southern part of Waco lake and is cut by numerous thin dykes of late granite. These features may indicate that the diorite is not a primary product of crystallization. It may have been a gabbro which has become modified by thermal solutions derived from the late granite.

The diorite is massive, medium-grained and grey on the fresh surface. It is mesocratic and weathers light to dark grey. The texture is typically intergranular and the grain size varies from 1 mm. to 3 mm. In the four thin sections examined, the average composition of the rock is as follows: calcic andesine (57 per cent), hornblende (15 per cent), dark brown biotite (8 per cent), orthoclase (7 per cent), and quartz (4 per cent) with small amounts of augite, magnetite, garnet, apatite and zircon. The plagioclase is slightly altered to saussurite, sericite, and rare carbonate. The diorite differs from most gabbros in the area in its lighter colour and in the presence of orthoclase and quartz.

The plagioclase varies in composition from An_{40} to An_{49} , with a mean of An_{45} ; this is the average composition of the plagioclase in most fresh gabbros in the area. The crystals are up to 7 mm. long, lath-shaped and randomly oriented. They show prominent albite and pericline twinning and many contain micrographic intergrowths of quartz. Orthoclase, which is abundant in some places and absent in others, forms small, clear and untwinned grains intergrown with the plagioclase crystals and replacing them in part. Common green hornblende is the dominant mafic mineral and occurs as anhedral and highly poikilitic crystals, enclosing numerous granules of clear quartz, as well as blades and granules of magnetite. This amphibole commonly

occurs as aggregates between the plagioclase laths, with associated biotite flakes, irregular grains of magnetite and interstitial secondary quartz. The few anhedral crystals of pale green augite present are extensively altered to hornblende. Garnet is locally abundant and forms large, anhedral and highly poikilitic crystals enclosing small and irregular grains of plagioclase and hornblende. Apatite appears as subhedral prismatic crystals, within the plagioclase, and zircon, as tiny crystals within the biotite flakes.

Hastingsite Monzonite and Augite Syenite

Monzonite and syenite are marginal facies of the Vital-Labrador anorthosite mass and, as such, are part of the Waco Igneous Complex. The anorthositic mass extends westward into the east-central part of the Waco area for a distance of about two miles. The arcuate contact of this mass is well delineated by aeromagnetic contours and marked by pronounced negative magnetic anomalies.* That part of the mass within the Waco area consists of complexly inter-related monzonite and syenite. Monzonite predominates near the western boundary of the mass and the syenite becomes gradually more abundant eastward, toward the anorthosite. About 5 miles east of the eastern boundary of the Waco area, that is, about one mile east of Mariauchau lake (see Figure 2), the inner part of the syenite band grades into anorthositic gabbro which, in turn, grades into gabbroic anorthosite. Finally, about 6 miles east of the eastern boundary of the Waco area, the Vital-Labrador mass consists of coarse-grained, dark grey anorthosite.

Tabular bodies of monzonite and syenite, similar in structure and occurrence to the gabbro bodies satellitic to the Vital-Labrador anorthosite mass, occur in the granitic gneisses of the south-central part of the Waco area. Within these bodies, monzonite grades to syenite and both grade to hornblende gabbro.

Although contact or cutting relationships between syenite and monzonite were not seen, it seems probable that these rocks are associated genetically and structurally with the anorthosite-gabbro suite of rocks. Rare dykes of monzonite and syenite cut the hornblende gabbro cropping out at the south end of Waco lake,

* A.E. Moss, personal communication.

and rare dykes of pink, sugary syenite cut the anorthosite on the shore of Vital lake, about 9 miles east of the eastern boundary of the Waco area. For these reasons, both the monzonite and the syenite are considered to be slightly younger than the gabbroic rocks. The age relationships between the monzonite and the syenite are unknown but, on the basis of petrology, the monzonite is believed to be the older.

The hastingsite monzonite in the area occupies an intermediate position between syenite and diorite and is characterized by approximately equal amounts of potash feldspar and plagioclase, with the hastingsite variety of amphibole as the main mafic constituent. The rock is medium-grained and leucocratic, with a generally pinkish grey, fresh surface and a characteristically friable, yellowish brown weathered surface. The average grain size varies between 2 and 3 mm. It has a granitoid-hypidiomorphic texture and is generally massive, although in some places it is slightly gneissic, with tabular streaks of amphibole and biotite.

Eight representative thin sections provided the following average mineralogical composition: plagioclase (35 per cent), potassic feldspar (31 per cent), hastingsite and rare hornblende (11 per cent), quartz (6 per cent), augite (4 per cent), biotite (3 per cent), opaque minerals (3 per cent), and very small amounts of hypersthene, olivine, chlorite, apatite, sphene, zircon, and allanite. The plagioclase crystals are slightly altered to dusty saussurite and flaky sericite, whereas olivine is extensively altered to iddingsite and serpentine.

The plagioclase varies in composition from An_{11} to An_{46} . This spread in composition is apparently a function of the varying acidity of the rock, for the most calcic plagioclase occurs in a monzonite variety rich in ferromagnesian minerals and the more sodic in varieties rich in potassic feldspar, particularly perthite. The plagioclase forms equidimensional and subhedral crystals, with numerous polysynthetic twins. The potassic feldspar present may be either orthoclase or microcline, but both grade into perthite. Hastingsite is the dominant ferromagnesian mineral. It forms large poikilitic anhedral crystals, enclosing granules of secondary quartz, and also occurs as a thin reaction rim around the pyroxene crystals or as irregular alteration patches within them. Hypersthene appears in the more basic varieties of monzonite as small rounded grains free of alteration products. Augite is the dominant pyroxene and

is in large subhedral, generally unaltered crystals between the plagioclase. The biotite flakes, which contain numerous inclusions of quartz and magnetite, are of secondary origin. The ilmenite-magnetite crystals commonly show a thin reaction rim of sphene, which is locally enveloped by highly chloritized biotite. The above observations indicate a definite sodic trend away from the gabbros. The monzonites differ mainly from these gabbros in the presence of hastingsite and potassic feldspar. This trend is moreover followed in the syenites.

The augite syenite looks somewhat similar to some medium-grained facies of gabbroic anorthosite, but it has a typical olive-green fresh surface and weathers yellowish brown. Its general appearance is much like that of the hastingsite monzonite. The syenite has a granular, xenomorphic to hypidiomorphic texture, with an average grain size ranging between 1.5 and 4 mm. It is generally massive, although slightly gneissic and distinctly lineated facies occur locally.

In the eight thin sections of syenite examined, the average mineralogical composition was estimated as follows: potassic feldspar (55 per cent), sodic plagioclase (16 per cent), aegirinaugite or augite (11 per cent), hastingsite (7 per cent), and olivine (4 per cent), with small amounts of magnetite, dark brown biotite, quartz, apatite, and zircon. The plagioclase is, in places, slightly altered to carbonate and saussurite. Syenites of this composition are classified as alkali-lime syenites or orthosyenites.

The plagioclase varies in composition from An_{18} to An_{33} and, on the average, is slightly more sodic than that of the monzonite. It is complexly intergrown with, and replaced by, the potassic feldspars. These feldspars constitute an inequigranular groundmass of subhedral or anhedral grains and represent an intricate sequence of growth, recrystallization and replacement. Large, subhedral grains of oligoclase are replaced by elongated blebs and irregular patches of orthoclase, forming a coarse anti-perthite. Orthoclase and microcline are also found as individual grains. The whole assemblage of feldspar is then replaced by large subhedral crystals of exsolution-type microperthite. Some large crystals of microperthite in contact with smaller grains of perthitic microcline show thin reaction rims. These features indicate fluctuations in conditions of crystallization of the end products of the syenitic magma, as well as in the amount of potash. This contrasts with the relatively uniform composition of the feldspars in the associated gabbro facies of the Waco Igneous Complex.

The dominant ferromagnesian mineral in the syenites is a clinopyroxene which has generally the optical properties of aegirinaugite or, less commonly, of augite. The presence of this mineral and of the associated hastingsite indicates that the ferromagnesian minerals, as well as the feldspars, became richer in soda as the residual parent magma reached the composition of syenite. Most pyroxene crystals are euhedral and unaltered and occur at random in the feldspar groundmass. On the other hand, olivine forms anhedral crystals partly altered to iddingsite and serpentine. In common with all the olivine found within the various anorthositic, gabbroic, and monzonitic facies of the same magmatic stem, it is ferriferous and optically negative. Hastingsite occurs as a replacement of some augite crystals, as well as clusters of large anhedral grains containing inclusions of unstrained secondary quartz, biotite, and magnetite. It is associated, in one thin section, with rare cummingtonite secondary after pale green augite. Quartz is present both as granules within hastingsite and as myrmekite in the plagioclase. Apatite, in large euhedral crystals, is more abundant in the syenite than in any of the rocks previously described. Zircon has a similar habit, but is less common.

Andesinite, Syenite and Pegmatite Dykes

The rocks of the Waco Igneous Complex are cut, in some places, by thin dykes of andesinite, pink syenite, and hornblende pegmatite. These, in turn, are cut by dykes of massive biotite granite similar to that of the large masses in the area.

Andesinite dykes cut augite-hornblende gabbro at the south end of Doiron lake and in the railroad cut at Mile 95.3; they are one to 6 inches thick and have sharp unaltered contacts. The andesinite is massive, fine- to medium-grained, whitish grey, and greyish white weathering. It is equigranular, with an hypidiomorphic texture. The rock is highly feldspathic, with about 90 per cent of andesine An_{40} forming a mosaic of subhedral, relatively fresh and well-twinned crystals. Minor amounts of quartz, hornblende, biotite, chlorite, muscovite, serpentine and carbonate are also found.

On the west shore of Vital lake, about 8 miles east of the northeastern corner of the Waco area, there are several thin dykes of pink, sugary syenite cutting typical coarse-grained anorthosite. The syenite is massive, fine-grained and weathers light grey. It is composed of a mosaic of equidimensional, subhedral

crystals of albite and slightly perthitic microcline, in approximately equal amounts. The feldspars are slightly altered to scaly sericite and dusty saussurite.

The tabular bodies of gabbro in the Waco area are cut by rare dykes of hornblende pegmatite, from a few inches to 2 feet thick. The pegmatite is white and contains hornblende as the mafic mineral. In contrast, the late pegmatites associated with the late granites are pink and contain biotite instead of hornblende.

Origin of the Waco Igneous Complex

The rocks of the Waco Igneous Complex are all believed to be of magmatic origin and to have been derived from the same parent magma. They apparently post-date the granitic gneisses of the area and are believed to have been intruded after a major period of orogeny.

The monzonite-syenite marginal facies of the anorthosite mass probably originated when the parent magma became enriched in sodium and potassium due to the crystallization differentiation of its anorthositic and gabbroic components.

Late Granites

Granodiorite

Several small and irregular bodies of granodiorite occur between Wacouno river and the western boundary of the Wacouno area. They are all within the batholith of porphyritic biotite granite and, inasmuch as they are cut by several well-defined dykes of this granite, they are remnants of an earlier intrusion.

The granodiorite is generally massive. In several places it is sheared and its secondary foliation is marked by a parallel arrangement of ferromagnesian minerals. The rock is pinkish grey and medium-grained. The texture is typically hypidiomorphic-granitoid, with a few large subhedral phenocrysts of saussuritized and well-twinned sodic oligoclase. Many plagioclase crystals contain blebs of clear quartz.

In the 5 thin sections examined the granodiorite has the following average mineralogical composition: sodic oligoclase (36 per cent), potassic feldspar (21 per cent), quartz (13 per cent), biotite (8 per cent), chlorite (4 per cent), hornblende (2 per cent),

sphene (3 per cent), and opaque minerals (3 per cent), with apatite, allanite, zircon, and saussurite-carbonate alteration of the plagioclase. The plagioclase varies from An_8 to An_{22} , and has the average composition of sodic oligoclase An_{16} . The potassic feldspar consists largely of untwinned microcline, which forms clear and irregular grains interstitial to the plagioclase crystals. Hornblende is generally idiomorphic. The biotite, commonly reddish brown, is partly secondary after hornblende. The opaque minerals include magnetite, ilmenite, rare pyrite, and leucoxene secondary after the ilmenite. Chlorite is secondary after biotite.

Porphyritic Granite and Syenite

Porphyritic granite grading into porphyritic syenite forms masses of batholithic dimensions and of uniform composition. The largest occupies more than half of the Wacouno area and covers more than 120 square miles. It is bounded on the north and on the east by belts of gneisses, and it extends many miles southwest of the area. Another large mass covers the northeastern corner of the Waco area and extends several miles to the northeast. Both these batholiths have a few included belts of granitized sediments. The batholiths are uniformly porphyritic in the centre and grade outwards into a more siliceous, equigranular, pink biotite granite. Smaller masses, such as those in the northwestern corner of the Wacouno area and in the centre of the Waco area, have more irregular outline and consist largely of equigranular biotite granite.

Both the porphyritic granite and the porphyritic syenite cut the granitic gneisses. The following indirect evidence, as given below, indicates that they are younger than the gabbroic intrusives of the area. The gabbros are cut by dykes of granite similar to that associated with the porphyritic granite; the gabbroic bodies are generally tabular and they follow more or less the structure of the granitic gneisses, whereas the masses of porphyritic granite have disrupted the structure of the gneisses; at the south end of Doiron lake in the centre of Waco area, a tabular body of gabbro is brecciated and granite has been introduced between the gabbro blocks.

The porphyritic granite and the porphyritic syenite appear to be closely related in age and origin. Both rocks are cut in a few places by dykes of equigranular and leucocratic granite, similar to that found near the margins of the batholiths. The

characteristic porphyritic texture of the rocks of the central part of the granite batholiths is an indication that the inner portion of the batholiths cooled at a slower rate than the outer, more siliceous portion.

The porphyritic granite is characteristically pink, massive, and coarse grained. The feldspar phenocrysts, from 4 to 10 mm. in diameter, consist of plagioclase and slightly perthitic microcline. Some oligoclase phenocrysts show reaction rims of albite where in contact with microcline.

In the 7 thin sections examined, the porphyritic granite has the following average mineralogical composition: sodic oligoclase (26 per cent), potassic feldspar (35 per cent), and quartz (24 per cent), with biotite, rare hornblende, sphene, magnetite, muscovite, apatite, allanite, and zircon. The oligoclase is altered to carbonate, sericite and saussurite. It ranges in composition from An_{11} to An_{19} , and has the same average composition (An_{16}) as the oligoclase of the granodiorite. The porphyritic granite contains nearly twice as much potassic feldspar as the granodiorite. Myrmekitic inclusions of quartz are common in the plagioclase. Many biotite crystals are extensively altered to clinocllore mixed with some clinozoisite. Zircon generally occurs within biotite. Apatite and sphene in euhedral crystals are generally associated with biotite. Allanite also occurs as euhedral crystals, but it is uncommon. Muscovite is secondary after the feldspars.

The porphyritic syenite is pink, massive, and coarse grained. The phenocrysts of microperthite and slightly perthitic microcline are more irregular than those in the granite and they corrode the interstitial crystals of oligoclase.

Four thin-sections of the porphyritic syenite have the following average composition: sodic oligoclase (17 per cent), potassic feldspar (70 per cent), quartz (4 per cent), and biotite (3 per cent). The remainder consists of muscovite, rare hornblende, chlorite, magnetite, rare scapolite, apatite, sphene, rare allanite, zircon, and alteration products of the plagioclase. Muscovite and chlorite (penninite) are pseudomorphous after biotite. Apatite, sphene, and zircon occur as idiomorphic crystals. Quartz is invariably interstitial and generally occurs between the feldspar grains.

Leucogranite

The east margin of the Mamikam batholith of porphyritic granite and syenite consists largely of leucogranite, an equigranular and quartz-rich rock containing very little ferromagnesian minerals. Dykes, sills, and small irregular masses of a leucogranite are also found within the large masses of porphyritic granite and within the belts of granitic gneisses.

Leucogranite dykes cut all the previously described rocks, including the porphyritic granite and syenite. Local gradations with the latter rocks suggest that the leucogranite is a late differentiate of the batholiths of porphyritic granite and syenite.

The leucogranite is pink, medium to coarse grained and massive, and weathers pinkish white. The texture is typically equigranular and granitoid. Myrmekitic intergrowths of quartz and plagioclase are common.

The leucogranite has the following estimated mineralogical composition, based on 7 thin sections examined: sodic plagioclase (31 per cent), potassic feldspar (36 per cent), quartz (23 per cent), biotite, chlorite and muscovite (5 per cent), with magnetite, apatite, sphene, allanite, and zircon. The plagioclase ranges in composition from An_7 to An_{18} . It forms subhedral, well-twinned crystals that are slightly altered to saussurite, sericite, and carbonate. The potassic feldspars consist of slightly perthitic microcline and replacement-type perthite; they are anhedral and they replace the plagioclase crystals. Chlorite is secondary after biotite, and muscovite replaces the feldspars. Zircon and sphene are generally associated with biotite.

Pegmatite

Numerous thin tabular bodies of granitic pegmatite occur, especially at the margins of the granite batholiths. They are found also in gabbro, granitic gneisses, and paragneisses.

The pegmatites within the paragneisses tend to be aplitic and appear to be of two ages, with the younger being coarse grained and in sharply defined dykes.

The pegmatite consists essentially of perthitic microcline, albite, and quartz, with small amounts of biotite, hornblende, zircon, and magnetite. Scapolite is rare. Hornblende occurs only in dykes cutting hornblendic paragneisses. Magnetite is more common in dykes cutting the granites and forms crystal aggregates as big as 2 inches in diameter, representing about 5 per cent of the rock volume.

A few dykes of fine-grained, sugary aplite cut the granitic gneisses and the batholithic granites. They are slightly younger than the leucogranites but are older than most pegmatite dykes. They consist of microcline, albite, quartz, and rare biotite. Magnetite is the only accessory mineral.

Quartz Veins

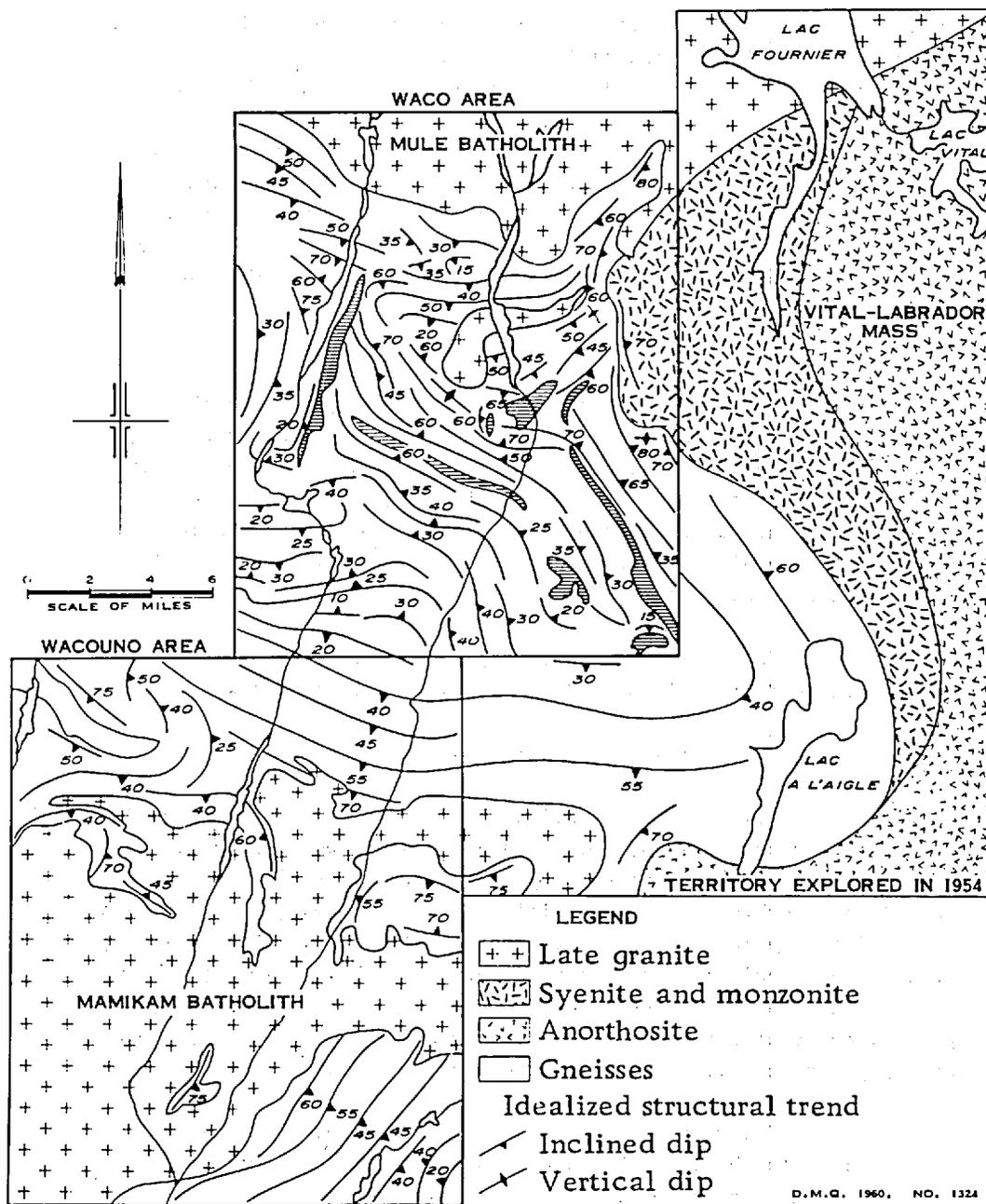
Several quartz veins with pegmatitic affinities cut the granitic gneisses near Mimi lake, in the northern half of Wacouno area. These veins consist of coarse-grained, glassy white quartz, with about 5 per cent scattered microcline crystals. They are about 6 inches wide and less than 200 feet long. Their sharp walls suggest fracture filling and their texture and composition indicate that they are highly siliceous pegmatitic residues.

Lamprophyre

Rare dykes of highly altered lamprophyre cut the granitic gneisses and the tabular bodies of gabbro. They are generally one inch thick and 100 feet long.

The lamprophyre is massive, extremely fine-grained, dark grey on fresh surface and dark brown weathering. The rock has scattered phenocrysts of clino-pyroxenes, now completely serpentized or amphibolitized, and rare stubby phenocrysts of highly saussuritized andesine feldspar. These phenocrysts, ranging from 0.1 to 0.3 mm. in diameter, are embedded in a very fine groundmass of interlocking needles of plagioclase about 0.02 mm. long. The interstices between these needles are filled by a dust of zoisite, uralite, magnetite and leucoxene.

FIGURE 2
SIMPLIFIED STRUCTURAL MAP OF THE WACOUNO-WACO AREA



STRUCTURAL GEOLOGY

The structure of the area is very complex, as shown by the idealized structural map (Figure 2) accompanying this report. However, the following generalities can be made. The paragneisses are associated with and grade into granitic gneisses. The granitic gneisses, presumably of igneous origin, may be synkinematic or they may have been involved with the paragneisses in an early orogeny. Both gneisses are in belts that curve around the Mamikam batholith of late granite in the southwestern corner of the Wacouno area. A deviation from this trend may be seen near the contact of the anorthosite mass and the granite bodies of the Waco area. Here and there, tongues and off-shoots of the late granite cut across the trend of the gneisses.

The basic intrusive rocks, including the anorthosite, were intruded after the early orogeny. Adjustments in the country rocks took place as far as half a mile away from the contact during the intrusion of some of the basic bodies. The tabular bodies of gabbro are either concordant or discordant into the surrounding gneisses. Several are phacolithic. Many are accompanied by thin dykes that cut the country rock.

The relatively late granite batholiths were intruded during a second orogenic period, probably at a late stage.

Gneissic Structure and Lineation

All so-called "gneisses" of the area, of either sedimentary or igneous origin, are foliated to some degree. Original structures in the metasedimentary rocks (paragneisses) have been largely obliterated and now consist only of a compositional layering parallel to the rare but distinct gneissic layering. This layering is remarkably uniform and continuous along strike. In general, the gneissic layers within the paragneisses have sharp contacts but, in places, the contacts are obscured by stringers of pegmatitic material or by common porphyroblasts of introduced microcline.

The granitic gneisses show structures that are not only similar to those of the paragneisses but are also parallel to them, with the exception of a more variable gneissic layering. Some of these gneisses are granitized sediments, others are of intrusive origin. Gneissic layering may be pronounced or very faint. However,

as all these granitic gneisses show a remarkable consistency of structure, mineralogical similarities, and intimate relationships with the paragneisses, it is indicated that all the gneisses in the area may be treated as one structural unit.

Lineation is pronounced only in the granulated leucogranite 2 miles north of Prémio-Réal lake, in the east central part of Wacouno area, and is marked by parallel elongated blebs of white glassy quartz plunging 20 to 40 degrees westwards.

Folds

In the southeastern corner of Wacouno area, the gneisses trend northeast parallel to the southeast margin of the Mamikam batholith. Near the batholith, the gneisses dip to the southeast away from the batholith. They are folded into an open syncline, the axis of which follows a northeasterly trending valley about a mile east of Vatchichitet lake.

The gneisses in the northwestern corner of Wacouno area are in a broad, east-southeasterly-plunging anticline. The formations on the south limb dip about 45° to the south towards the Mamikam batholith. On the north limb, the structure is interrupted by a minor south-plunging anticline, 3 miles northwest of Mimi lake.

The gneisses in the northeastern corner of Wacouno area and the southwestern corner of Waco area are folded into a broad, open anticline plunging at about 25° southeast.

In the Waco area, the gneisses generally strike southeasterly and dip to the northeast. In the northeastern corner, they strike northeasterly and have steep dips. In the northwestern corner, they strike northwesterly and dip southwest. The whole structural pattern of the gneisses in the Waco area reflects the shape of the major intrusive masses.

Faults

The area is dissected by several singularly straight valleys, some of which probably represent major faults, although no other evidence of faults was recognized in the field.

Several small shear zones were found near the gabbro masses and in the layered rocks. None of them could be traced more than 200 feet and they did not appear to be of economic significance.

Joints

All the rocks of the area, particularly the late granites, are markedly jointed, and, as outlined in the section on physiography, joints are responsible for many of the topographic features.

Two main categories of joints are recognized: first, that independent of the structure, and, second, that clearly related to the attitude of gneissic structure.

Joints of the first category are included in several systems. They generally strike a few degrees west of south, south, or east of south, and dip steeply either east or west. Also included are two systems, oriented southeast and southwest respectively, and steeply dipping. Another system includes the common horizontal or gently-dipping joints in the massive granites.

Joints of the second category generally follow the strike of foliation of the gneisses, but they dip at right angles to the planes of foliation. Less abundant are the joints that strike at right angle to the strike of foliation and dip nearly vertically.

The gabbros are crossed by blocky joints, with one set parallel to the attitude of the sheet-like bodies and another set at right angles and dipping vertically. They are also broken by two systems of steeply-dipping joints oriented at 45 degrees to the strikes of the sheet-like bodies.

ECONOMIC GEOLOGY

Small concentrations of metallic minerals found in the area are indicated on the accompanying maps.

Sulphides

A sulphide-bearing zone, with a maximum width of 14 inches and an exposed length of 8 feet, was found about 500 feet west of the outlet of Dimph lake, in the southeastern corner of Wacouno area. Small amounts of pyrite, chalcopyrite and molybdenite are disseminated

in a 3-foot sill of sheared hornblende granite cutting paragneisses. A grab sample assayed: copper, 0.34 per cent; nickel, 0.01 per cent; molybdenum, 0.04 per cent; and silver, 0.046 ounce per ton.

Erratic veinlets of pyrite and chalcopyrite occur in a railroad cut 150 feet long in gabbro, at Mile 79.2 east of the airstrip. A grab sample of the mineralized gabbro assayed: copper, 0.24 per cent; nickel, 0.20 per cent; and silver, 0.010 ounce per ton.

In a railroad cut at Mile 95.6, pyrite, pyrrhotite and chalcopyrite form short stringers in diorite. At the same locality, small quantities of coarse molybdenite occur in, or near, apatite-bearing pegmatite dykes cutting the diorite.

Finely disseminated pyrite is relatively common in the granites, especially on the margins of the batholiths. A grab sample of granite showing a local concentration of disseminated pyrite, at Mile 76.4, had 0.19 per cent copper.

Magnetite and Ilmenite

A zone 10 feet wide of magnetite in granite is present in the railroad cut at Mile 82.1 (locality 5). The extension along strike is unknown because of overburden. A grab sample assayed: iron, 36.47 per cent; titanium oxide, 1.22 per cent; and chromium, 0.01 per cent.

An angular piece of massive titaniferous magnetite, eight inches in diameter, was found on a sandy beach about 2 1/2 miles from the south end of Kachipitonkas lake. Attempts to find the source of this float in the region were unsuccessful.

Magnetite is a very common accessory mineral in the pegmatite dykes. Many dykes less than one foot thick contain more than 10 per cent of this iron oxide. Titaniferous magnetite is commonly disseminated throughout the gabbro bodies of the area, but no concentration of this mineral has yet been found in these bodies.

Small concentrations of ilmenite have been found in the anorthosite mass east of the Waco area, on the shore of Vital lake. Detailed prospecting of this mass is warranted.

B I B L I O G R A P H Y

- BARTH, T.F.W. (1952) - Theoretical Petrology;
John Wiley and Sons, New York.
- BLAIS, R.-A. (1954) - Meteorological Observations Taken in the
Waco Lake Area in Summer of 1954; MSS. in
files of Que. Dept. Mines.
- EMO, W.B. (1955) - Basic Intrusives of the Waco Lake Area;
Unpubl. M.Sc. Thesis, McGill University.
- EMO, W.B. (1956) - Mule Lake Area, Saguenay County;
Que. Dept. Mines, P.R. No. 324.
- ENGEL, A.E. and ENGEL, C. (1953 -
Grenville Series in the Northwest Adirondack
Mountains, New York; Geol. Soc. Am. Bull.,
Vol. 64, pp. 1013-1097.
- FAESSLER, C. (1945) - Moisie Area, Saguenay County, P.Q.;
Que. Dept. Mines, G.R. 21.
- FLINT, R.F. (1957) - Glacial and Pleistocene Geology;
John Wiley and Sons, New York.
- GILL, J.E., BANNERMAN, H.M., and TOLMAN, C. (1937) -
Wapussakatoo Mountains, Labrador; Geol. Soc.
Am. Bull., Vol. 48, pp. 567-586.
- GREIG, E.W. (1945) - Matamec Lake Map-area, Saguenay County;
Que. Dept. Mines, G.R. 22.
- GRENIER, P.-E. (1952) - Nipissis River Area, Saguenay County;
Que. Dept. Mines, P.R. No. 272.
- HOGAN, H. and GRENIER, P.-E. -
Nipissis River - Nipisso Lake Area, Saguenay
Electoral District; MSS. in files, Que. Dept.
Mines.
- HOGAN, H.R. (1952) - Nipisso Lake Area, Saguenay County;
Que. Dept. Mines, P.R. No. 280.

- KLUGMAN, M.A. (1955) - Geology of the Charpenay-Coopman-Bailloquet Area; Unpub. Ph.D. Thesis, McGill University.
- McPHEE, Duncan S. (1958) - Preliminary Report on Eric Lake Area, Saguenay Electoral District; Que. Dept. Mines, P.R. No. 369.
- TURNER, F.J. (1948) - Mineralogical and Structural Evolution of the Metamorphic Rocks; Geol. Soc. Am. Mem. 30.
- WILLIAMS, H., TURNER, F.J., and GILBERT, C.M. (1955) - Petrology; Freeman Publishing Co.
- WELLS, M.K. (1954) - The Structure and Petrology of the Hypersthene Gabbro Intrusion, Ardnamurchan, Argyllshire; Quart. Jour. Geol. Soc., London, No. 456.

A P P E N D I X

Mining Development, 1954 to 1960

by
J.-E. Gilbert

Slight exploration work has been done in the area covered by this report since 1954, except a little prospecting.

A few claims were staked but were not generally kept in good standing for more than a year.

Quebec, April 21 1960.

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