ONTARIO
QUEBEC

LAC TEMISCAMINGUE

CLAY - SAND - GRAVEL

CLAY - SAND - GRAVEL

RIVIERE FONTLEROY

RIVIERE LARDER

LAC REMIGNY

LAC CAIRE

LAC DES QUINZE

LAC DES QUINZE

RIVIERE DES QUINZE

RIVIERE OSKELANEO

LEGEND

CENOZOIC — PLEISTOCENE — RECENT

SAND - GRAVEL - CLAY

PALEOZOIC

LIMESTONE, MUDSTONE, SANDSTONE, CONGLOMERATE

PRECAMBRIAN

GRANITE - GNEISS

MARBLE - QUARTZITE

SYENITE

GRANODIORITE

PEGMATITE

PORPHYRITIC ROCKS

VOLCANIC ROCKS, MAINLY ANDESITE, + FERRUGINOUS SEDIMENTARY ROCKS, MAINLY GREYWACKE

QUARTZ - DIORITE

BASIC INTRUSIVE ROCKS

GRANITE, GRANODIORITE, MONZONITIC GNEISS

PORPHYRITIC ROCKS

PLAGIOCLASE - HORNBLENDE GNEISS

HORNBLENDE - PYROXENE GNEISS

ULTRAMAFIC INTRUSIVE ROCKS - PERIDOTITE, SERPENTINITE, PYROXENITE

SYMBOLS

GEOLOGIC CONTACT - KNOWN, APPROX.

INDICATION OF DIRECTION OF FOLIATION TRACE OF AXIAL PLANE OF SYNCLINE

STRIKE & DIP OF BEDDING (INCLINED, VERTICAL OR TOPS KNOWN)

STRIKE & DIP OF BEDDING (INCLINED, VERTICAL OR TOPS KNOWN)

STRIKE & DIP OF FOLIATION (INCLINED, VERTICAL OR TOPS KNOWN)

STRIKE & DIP OF FOLIATION (INCLINED, VERTICAL OR TOPS KNOWN)

ANTICLINAL FOLD AXIS

SYNCLINAL FOLD AXIS

ANTICLINE & DIP OF LIMBS (ONE LIMB) - KNOWN, APPROX.

SYNCLINE & DIP OF LIMBS (ONE LIMB) - KNOWN, APPROX.

BEDDING ATTITUDES

BEDDING SMALL SCALE - VERTICAL

FAULT - KNOWN, APPROX.

OVERTURNED

GRAVEL ROAD

MAIN ROAD OR TRAIL

TRACK

BRIDGE OR MILL

RIVER

CONTOURS

BUILDING

MINERALIZATION

① GALENA
② MOLYBDENITE
③ BERYL
④ COPPER - IRON
⑤ COPPER - IRON - GOLD
⑥ COPPER - ZINC - IRON - GOLD
⑦ IRON
⑧ MOLYBDENITE
⑨ MOLYBDENITE
⑩ MOLYBDENITE
⑪ MOLYBDENITE
⑫ MOLY - COPPER - IRON
⑬ IRON
⑭ CHROMITE

SCALE 1 MILE TO THE INCH OR 1:63360

1 0 1 2 3 4 5 6 7 8 9 10 MILES

CONTOUR INTERVAL 100 FEET

DES QUINZE LAKE - BARRIERE LAKE AREA

COUNTIES OF ROUYN-NORANDA AND TEMISCAMINGUE
PROVINCE OF QUEBEC

GEOLOGY BY J. F. THOMSON
1960 TO 1962 1963

REGIONAL COMPILATION MAP

LEGEND

PALEOZOIC

21 — LISKEARD FORMATION : conglomerate, sandstone

20 — LORRAIN FORMATION : quartzite

19 — GOWGANDA FORMATION: conglomerate, greywacke, arkose

COBALT SERIES

PRECAMBRIAN

18 — Gabbro, peridotite, diorite

17 — Oligoclase-microcline granite, granite gneiss, pegmatite, aplite

16 — Hornblende granite

15 — Pink biotite granite, pegmatitic granite

14 — Grey (oligoclase) granite, grey granite gneiss

13 — Hornblende syenite, biotite syenite

12 — Plagioclase-hornblende rock, amphibolite

11 — Garnetiferous gneiss

10 — Quartzite, quartz-feldspar-sericite schist

9 — Mixed gneisses - (injected paragneiss)

8 — Biotite schist & gneiss (correlative equivalent of Pontiac schist)

7 — Biotite schist & gneiss

6 — Amphibolite

PONTIAC GROUP

5 — Acidic flows, intrusives, sediments

4 — Conglomerate with greywacke

3 — Iron formation

2 — Tuff, slate, agglomerate

1 — Basic lavas, altered basic lavas

SYMBOLS

STRIKE & DIP OF BEDDING, SCHISTOSITY & GNEISSOSITY

SYNCLINAL FOLD AXIS

ANTICLINAL FOLD AXIS

DOME

FAULT

COMPILED FROM :

1 H.B. LYALL, McLACHLIN-BOOTH AREA, Q.D.M. P.R. 391 – 1959

2 R.J.E. SABOURIN, POMMEROY-BELLEFEUILLE AREA, Q.D.M. P.R. 423 – 1960

3 J.L. ROBERT, GUAY-BRUCHESI AREA, Q.D.N.R. P.R. 459 – 1961

4 J.L. ROBERT, FABRE-MAZENOD AREA,

5 J.F. HENDERSON, VILLE-MARIE & GUILLET LAKE AREAS, G.S.C. MEMOIR 201 – 1936

6 P.E. AUGER, BELLETERRE AREA, Q.D.M. G.R. 55 – 1952

7 B.T. DENIS, SIMARD (EXPANSE) LAKE AREA, ANN. REPORT, Q.B.M., PART B – 1936

8 J.Y. CHAGNON, BRODEUR-BASSERODE AREA, Q.D.N.R. P.R. 456 – 1961

9 J.Y. CHAGNON, REMIGNY-VILLARS AREA, Q.D.N.R. P.R. 478 – 1962

10 J.Y. CHAGNON, GUIGUES-PONTLEROY AREA, MAPPED IN 1962

11 P.V. FREEMAN, DARLENS-CHABERT AREA, Q.D.M. P.R. 341 – 1957

12 P.V. FREEMAN, BERAUD-MAZERAC AREA, Q.D.M. P.R. 340 – 1957

13 COOKE, JAMES, MAWDSLEY, ROUYN-HARRICANAW AREA, G.S.C. MEMOIR 166 – 1933

14 KINOJEVIS SHEET, MAP 306A, G.S.C. – 1935

COMPILATION BY : J.L. ROBERT
J.Y. CHAGNON

SCALE : 3 MILES = 1 INCH

THE GEOLOGY

of the

DES QUINZE LAKE - BARRIERE LAKE AREA

TEMISCAMINGUE CO., P.Q.

by

Jean-Y Chagnon

A thesis submitted to the Faculty of Graduate studies and Research in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Department of Geological Sciences,
McGill University,
Montreal.

April 1965

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SUMMARY

The Des Quinze lake - Barrière lake area is located in western Quebec and covers approximately 1400 square miles. It is underlain almost entirely by Precambrian rocks but contains a few occurrences of a Paleozoic formation. The oldest rocks are part of a volcanic-sedimentary assemblage which occurs in the southwest along a N.-60°-E.-trending belt. The volcanics, consisting of andesite, dacite, hornblende rock, rhyolite, quartz-feldspar porphyry, tuff and agglomerate, contain interlayered lenses of greywacke, iron formation and siltstone. The hornblende rock represents, in most places, the coarser-grained portions of thick lava flows, but it may in some instances be of magmatic origin. The volcanic-sedimentary rock sequence is isoclinally folded along east-west, or nearly so, axes, and it dips steeply to the south. The volcanics are altered and somewhat recrystallized, and the mineral assemblage is that of the lower amphibolite facies and, in places, that of the upper greenschist facies.

From observations in the area and in adjacent areas, it is established that the volcanics are overlain conformably by the metasedimentary rocks of the Pontiac group and that the transition from volcanic to sedimentary rocks is gradational.

The Pontiac group is part of the Abitibi series or group and belongs to the upper portions of the Keewatin assemblage north of the area. The units assigned to the Pontiac group in the area are the extensions of members of the group in adjacent areas to the north and to the east. There is stratigraphic continuity from north to south throughout the area and the quartz-feldspar-biotite schist and intercalated amphibolite can definitely be considered, if not a part, at

least a correlative equivalent of the Pontiac group.

Four distinct rock types constitute the Pontiac group: greywacke, amphibolites, quartz-feldspar gneiss and quartz-feldspar-biotite schist. The greywacke is the unmetamorphosed equivalent of the quartz-feldspar-biotite schist and occurs near Des Quinze river. The amphibolites are of diverse origin and many represent basic lavas or intrusives such as diabase or gabbro. The quartz-feldspar gneiss is, in all probability, a partly melted or granitized portion of the quartz-feldspar-biotite schist. It is always associated with oligoclase-microcline granite and contains lenses of quartz-feldspar-biotite schist. The quartz-feldspar-biotite schist is the principal component of the Pontiac group and is of widespread occurrence. It is generally associated with granitic rocks and it frequently forms migmatites and gneisses. The schist is the metamorphosed equivalent of greywacke and represents an accumulation of geosynclinal-type sediments.

The schist of the Pontiac group in the area may be correlated with the metasedimentary rocks described by Henderson (1936), Denis (1938), Auger (1952) and Robert (1963) in adjacent areas to the south and southeast. Thus the width of the belt of Pontiac formations is extended from ten miles to approximately sixty miles, from an area of "Keewatin-type" rocks to one of "Grenville-type" rocks. The grade of metamorphism of the members of the group is that of the staurolite-quartz subfacies of the almandine-amphibolite facies.

Intruding the metasedimentary rocks are diverse acidic igneous masses, ranging in composition from hornblende syenite to highly potassic granites. Hornblende-pyroxene syenite of magmatic origin and related to the granitic rocks occurs in the northern part of the

area. Hornblende syenite outcrops in the vicinity of Brodeur Lake and represents a magmatic and partly metasomatic rock of granitic composition modified by the massive assimilation of basic rocks. A hornblende-plagioclase gneiss related in composition and origin to the hornblende syenite occurs in the south central part of the map-area. Hornblende granite, forming irregular masses in the oligoclase-microcline granite, is believed to be an early mafic-rich phase of the oligoclase-microcline granite. The oligoclase-microcline granite is the principal rock type in the area and it constitutes approximately two-thirds of all the various rock formations. It is of varied composition and includes monzonites, granodiorites, sodic and potassic granites. It is generally massive but may be gneissic, especially near lenses of quartz-feldspar-biotite schist. The oligoclase-microcline granite displays features of catazone batholiths, such as concordant relationships and synkinematic characters, and it may be considered as magmatic in behaviour but metamorphic in origin.

The oligoclase-microcline granite, hornblende granite, hornblende syenite and hornblende-pyroxene syenite were subjected to a period of potassic metasomatism which resulted in the development of large microcline porphyroblasts in several irregularly distributed parts of these rocks. Microclinization of the oligoclase-microcline granite, that is, replacement of plagioclase by microcline, is common and is one extreme aspect of the potassic metasomatism. Pegmatites and aplites accompanying the granites may be the main agents through which the potassic metasomatism of the granitic rocks was effected.

Huronian rocks are represented in the area by the conglomerate and argillite of the Cobalt group which outcrop in the northwestern

corner and by the quartzite and arkose of the Lorrain formation which occur in the southwest near Témiscamingue lake.

Several diabase dykes, generally trending N.-15°-E. or east-west cut all the Precambrian rocks.

The depositional and erosional effects of the Pleistocene glaciation and of glacial lake Barlow-Ojibway are widespread and conspicuous.

Five antiforms and synforms with north-south and northwest-trending axes are recognized in the area. The north-south trends of the folds characterize the structural pattern of the area. No direct evidence of major faulting is present, but linear elements trending N.-30°-E. afford indirect confirmation of the existence of a fault system.

The east-west trend of the volcanics in the southwest differs markedly from that of the other formations in the region. Very little evidence of overprinting of structural trends is found, especially in the north, but the north-south trends appear to be superimposed on the east-west trends.

The map-area is part of the Grenville B subprovince (Osborne and Morin, 1962) as is suggested by the structural pattern, metamorphic grade and location. The Grenville front is a gradational metamorphic transition, the grade of metamorphism increasing toward the south. The map-area is located within the transition zone from the Grenville to the Keewatin subprovinces and some formations, such as the members of the Pontiac group, are shared by both subprovinces.

THE GEOLOGY

of the

DES QUINZE LAKE - BARRIERE LAKE AREA

TEMISCAMINGUE CO., P.Q.

Chapter I

INTRODUCTION

General Statement

The Des Quinze lake - Barrière lake area was mapped during the summer seasons of 1960 to 1963, inclusive, at the instigation of the Quebec Department of Natural Resources. This work was part of a general program of mapping in northwestern Quebec and was an extension of the work done earlier by P.V. Freeman (1957) in an adjoining area to the east. The map-area was considered to be of economical and geological interest. It is close to the Rouyn-Noranda mining area and discovery of ore was regarded as probable. The geology of the area was then unknown, except on a broad basis, but it was considered that its investigation would be most useful in elucidating some problems generally related to the nature of the "Grenville front", and to the relationships between "Keewatin" type rocks to the north and "Grenville" type rocks to the south.

Area - Location

The area is located in western Quebec, and covers approximately 1400 square miles. It is bounded partly by latitudes 47°25' and 48°00' and by longitudes 78°45' and 79°00', and partly by latitudes 47°30' and 48°00' and by longitudes 79°00' and 79°31'. The western limit of the area coincides with the Quebec-Ontario provincial boundary.

INDEX MAP — LIEU DE LA CARTE

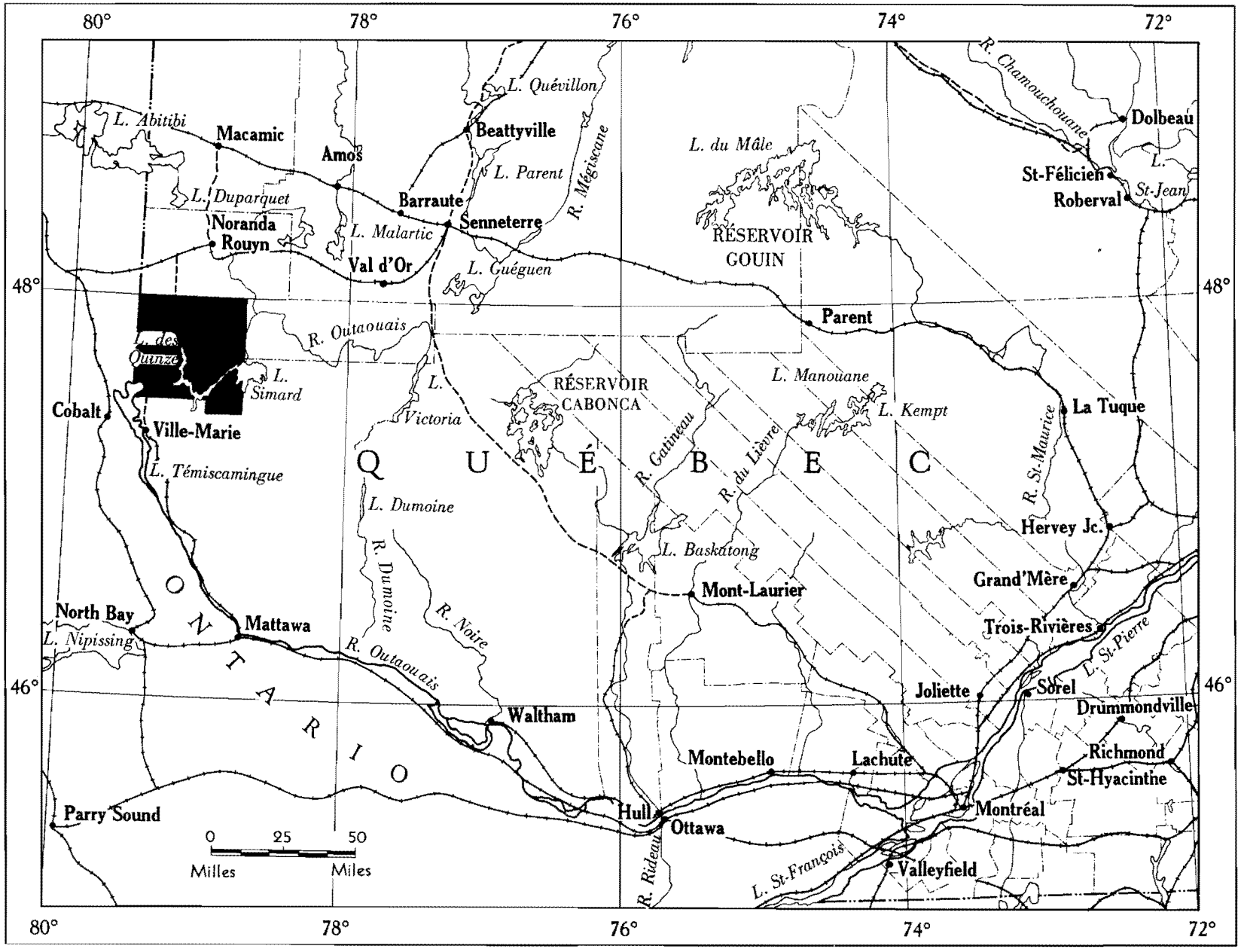


Figure 1 - Location of the map-area.

Most of the map-area is located in Témiscamingue county, but a small part lies within the limits of Rouyn-Noranda county. It includes parts of Basserode, Clérion, Brodeur, Latulipe, Baby and Guigues townships, and all of Caire, Beaumesnil, Bauneville, Villars, Rémigny, Desandrouins, Pontleroy, Montreuil, Guérin and Nédelec townships.

Access

The area, as a whole, is easily accessible by car along an extensive network of roads linked to route 46, the main highway between the towns of Ville-Marie and Rouyn-Noranda, respectively 14 miles to the south and 30 miles to the north of the area.

The northeastern part and the southern central part of the area are not easily reached by road. However a few long, pencil-shaped lakes, which are reached by roads, give access to most, if not all, of these regions. All the major lakes are suitable for the landing and take-off of hydroplanes.

All roads and portages are shown on the geological map.

Field Work

The outcrops shown on the map were located by means of systematic pace-and-compass traverses spaced at regular intervals of half a mile. A few traverses were irregularly spaced, especially in sectors where outcrops are scarce, and extensive use was made of aerial photographs in determining the path of these traverses. All roads, railroads and shores of navigable streams and accessible lakes were examined carefully.

A topographic map at the scale of half a mile to the inch, drawn from aerial photographs, published by the Topographic Division of the Department of Mines and Technical Surveys, Ottawa, and supplied by

the Quebec Department of Natural Resources, was used as a base. The data obtained were plotted on this map which was then reduced to a scale of one mile to the inch by the Quebec Department of Natural Resources.

Sheet 31 M 11 and 14 and the accompanying mosaic from "Operation Overthrust", published by Hunting Technical and Exploration Services Limited, were used as a source of information.

803 rock samples were collected in the field and 293 thin sections were obtained from them.

Acknowledgements

The author acknowledges his indebtedness to the Quebec Department of Natural Resources for granting him the opportunity to map the Des Quinze lake - Barrière lake area and for allowing him to use the data obtained for the purposes of this thesis. The writer is also grateful to Dr. J.S. Stevenson of McGill University, under whose direction this thesis was written, and whose constructive criticism and able advice were invaluable. Thanks are due to Dr. H.W. McGerrigle and Dr. M. Morin, officers of the Quebec Department of Natural Resources, and to Dr. F.F. Osborne of Laval University for their helpful suggestions.

The author was ably assisted in the field by R.N. Diffenbach, V. Kelly and D. Scafe, senior-assistants, and by D. Rota, R.Meloche, P. Corbeil, E. Rieger, J. Boissonnault, Y. Labonté, J. Nadeau, A. Carrier, J.Simard and R. Maranda, junior-assistants. All these men performed their respective duties in a highly satisfactory manner.

Previous work

The earliest recorded geological work within this area was an investigation of the Ottawa river, as far as the " third Rapid " on

Des Quinze river, by Sir William Logan in 1842. In 1872, Mr. Walter McOuat made a geological examination of a"portion of the country on the Ottawa to the northward and eastward of lake Timiskaming". This work included an examination of Des Quinze river and lake . In 1897, A.E. Barlow, in a report on the geology and natural resources of an area included in the Nipissing and Timiskaming map sheets, described in some details the geology along the shores of Des Quinze river and the southwestern part of Des Quinze lake. M.E. Wilson reported on "an area adjoining the east side of lake Timiskaming" in 1910. Included in his report is the southwestern portion of the present map-sheet. Wilson also reported in 1913 on the results of a broad reconnaissance survey of the Kewagama lake area, which includes parts of the northern extremity of the area now under study. In 1935, Henderson and his assistants traversed parts of Brodeur township in obtaining information for the Ville-Marie and Guillet lake map-areas.

In later years, more detailed geological maps and reports were published on areas adjacent to the Des Quinze lake-Barrière lake area, by B.T. Denis (1936,1938), P.E. Auger (1952), P.V. Freeman (1957) and M.E. Wilson (1962).

Nature of the Investigation

The mapping of an area of a large size yields more information than the mapping of a smaller area where the scope is not as extensive. However, there are limitations to the precision, accuracy and usefulness of the results obtained, which have to be recognized and kept in mind. The limitations are due to numerous factors, of which size and time are the most important. Four summer seasons in the field is indeed a brief span of time in which to cover 1400 square miles.

Furthermore, the relative scarcity of outcrops in some parts added to the restrictions inherent in mapping at a scale of half a mile to the inch imposes more limitations. One should also consider that most of the area is underlain by large expanses of granitic rocks; that wherever we observed foliated rocks, we had no key beds or special characteristics to help us in the interpretation of structural data. Sometimes, factors deemed useful for precision are negated by other factors. Such is the case with the volcanic rocks in the southwest corner of the area, where we have much rock exposure and relatively abundant and detailed structural data. The little areal extent of these volcanics and the scale of mapping, however, seriously hinder our interpretation of the data.

Therefore in considering the nature of the work accomplished, one must remember that it is necessarily less precise than detailed mapping and that one has to confine himself to broad generalizations in interpreting the data collected and studied.

Contribution to Knowledge

The author claims that this thesis constitutes an original contribution to knowledge. It contains an interpretation of the geology of an area heretofore unmapped, based on detailed petrographic, petrological, mineralogical and structural studies. Specific contributions are: Optical properties and chemical composition of selected minerals, a comparative study of the mineralogical and chemical composition of the granitic rocks of the area, and specific conceptions of the general geology of northwestern Quebec in the light of the information obtained in the present study.

Chapter II

PHYSIOGRAPHY

Introduction

The Des Quinze lake - Barrière lake area, underlain by Precambrian rocks, with one exception along the shore of Témiscamingue lake, exhibits the topography characteristic of the Laurentian plateau of the Canadian shield. The area is within the limits of the so-called "clay belt" of northwestern Quebec and northeastern Ontario, formerly occupied by glacial lake Barlow-Ojibway. The present-day physiography therefore reflects the double nature of the surficial formations, namely the crystalline rocks and the unconsolidated glacial, fluvio-glacial and lacustrine deposits. The hummocky, gently undulating and irregular features are thus the result of this double control.

The historical development of the physiography of this part of the shield has been elaborated by numerous authors, Wilson (1913, 1918), Cooke, James and Mawdsley (1931), Dresser and Denis (1944), to name a few, and needs not be repeated here. The reader is referred to the authors listed above for detailed information on this subject.

Topography

The topography varies from a relatively flat plain to mountainous country of low relief, being influenced by changes in the character of the bedrock. Regions underlain by the biotite schist of the Pontiac group are lightly undulating flatlands with a maximum relief of fifty feet, whereas regions underlain by granitic rocks have a more rugged topography, the relief being of the order of one hundred feet with a maximum of three hundred feet. However, the granite does not

form large hills; indeed, within a mile they usually come down to the general level of the land, excluding a plateau-like area west of Opasatica lake which rises 250 feet above the level of the lake and slopes gently to the west. The southwest corner of the area,underlain by volcanic rocks, presents a relief of approximately two hundred feet and is highly dissected into a series of small knobs and hills that are in sharp contrast to the flatlands north of the volcanic-schist contact. The Lorrain quartzite occurring near the shore of Témiscamingue lake forms a high,north-south trending ridge with steep slopes.

There is an intimate relation between the proportion of exposed rock and its nature. Volcanic rocks, granites and gneisses are resistant to weathering and stand out abundantly, whereas biotite schist is easily eroded and of rare occurrence.

The foliation of the rock usually exerts a strong influence upon the general trend of the hills and ridges. Similarly, in massive rocks, joints are important factors of physiographic development.

A large part of the region is covered by the glacial lake deposits of the clay belt which have modified the topography. Clays and varved clays form plain-like,gently rolling areas, dissected by streams and rivers deeply entrenched in valleys with steep banks.The clays are always observed in the vicinity of the lakes, at an elevation of approximately 865 to 900 feet and never in areas of higher elevation. The absolute thickness of the clay cover is unknown but is believed to be about fifty feet except in deep clay-filled valleys. Ridges of glacial deposits,gravel mounds with aprons of sand,protrude through this blanket.

The maximum elevation of the area is about 1300 feet above sea level, in the northeast corner of the area, the minimum is 575 feet at Témiscamingue lake and the average elevation is 1000 feet. The slope of the ground is to the southwest, towards Témiscamingue lake, but is locally west as in the vicinity of Opasatica lake. A remarkable feature is the uniform elevation of the hills, especially in the north, suggesting the former presence of a plateau, now dissected.

Drainage

The rivers and lakes of the area belong to the hydrographic system of the Outaouais river, flowing south and southwest to Témiscamingue lake.

The drainage pattern is of the dendritic type, although locally rectangular, as in the southeast sector of the area where the structural pattern exerts a strong influence upon the rivers and lakes. The drainage is consequent and superimposed, the water flowing over lacustrine clay and glacial drift and in places reaching the rock formations of the basement. The glacial features have a marked influence on the actual drainage pattern although, in parts, the control of the rock structure is dominant. Features such as rapids, cascades, gorges and swift current characterize the streams and rivers of the area and are those of streams at an early stage of development.

Numerous, narrow, elongated lakes occupying gouge-like depressions in the bedrock are distinctive features of the region that form a pattern of linear elements believed to reflect the structural control of the rocky basement. This subject is discussed in chapter V, (Structural Geology). Some lakes of the clay zone, such as Simard

(Expanse) lake, the western part of which is in the area, have a very irregular shoreline, are shallow and have steep clay banks. Numerous islands are found in Simard and Des Quinze lakes that are low ridges composed only of gravel, no bedrock being visible.

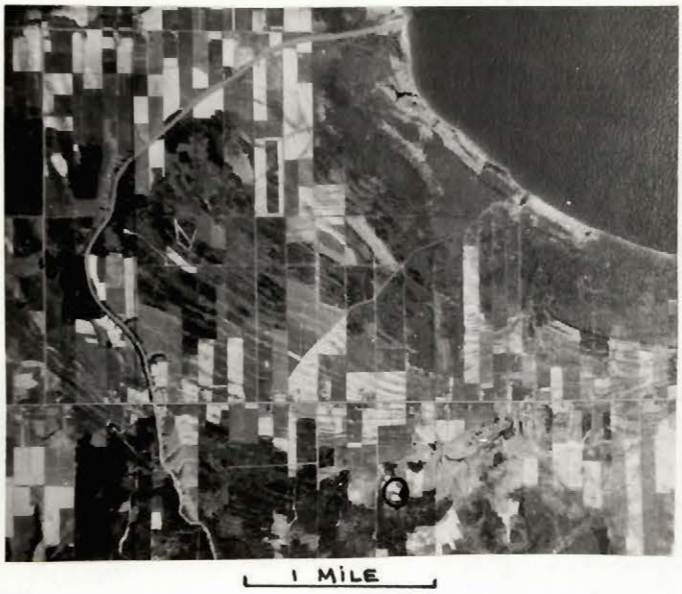
The great abundance of small lakes in the southeastern region is in marked contrast to the few large lakes that cover the rest of the area. Following is a list of the principal lakes and their elevation:

Lake	High water feet	Low water feet
Témiscamingue.....	592	575
Des Quinze.....	865	853
Simard (Expanse).....	865	853
Barrière.....	865	-
Opasatica.....	865	-
Roger.....	900	-

It is to be noted that Des Quinze lake is at a distance of eleven miles from Témiscamingue lake into which it flows through Des Quinze river and that the difference in elevation between the two lakes is 273 feet giving a theoretical slope of 25 feet per mile. This figure, however, is greatly exaggerated because the level of Des Quinze lake is artificially maintained by a dam and because a rapid change in level, of the order of 125 feet, occurs near the shore of Témiscamingue lake, outlining a terrace-like platform. The actual slope of the ground is thus close to ten feet per mile.

Beach ridges, or raised beaches, along the shore of Témiscamingue lake, extend up to two and a half miles inland, slightly past

the 650 feet contour line on a topographic map, recording in this manner a change in level of at least sixty feet. The ridges are faintly apparent in the field and are best seen on aerial photographs (Photograph 1). Adjoining the last ridge is a sharp, 100 feet high, rise to a terrace-like accumulation of glacial deposits (gravel and sand) that extends east for at least eight miles to the first rock exposures.



Photograph 1 : Raised beaches on the northeast shore of Témiscamingue lake. (R.C.A.F. aerial photograph).

Chapter III

GENERAL GEOLOGY

Regional Geology of Northwestern Quebec

To put in perspective the interpretations of the geology of the area now under study it is necessary to present at this stage a brief outline of the geology of northwestern Quebec. (A regional compilation map accompanies this report). A complete and up-to-date historical review of the works of geologists and of their ideas concerning the geology of northwestern Quebec is given by Podolsky (1950) and Freeman (1957). We will present here only the recent concepts regarding the geology, without expanding on their historical development.

The map-area is located at the northern extremity of the Grenville subprovince or province, almost athwart the transition to the Keewatin subprovince or Superior province (Gill, 1949).

The Keewatin subprovince to the north of the area has been mapped in great detail and major rock units have been identified. The Abitibi group (Wilson, 1962), otherwise known as Keewatin series, consists of a volcanic-sedimentary assemblage tightly folded along east-west axes. The Pontiac group which extends from the north into the present map-area is believed by Wilson (1943, 1962, p.6) to be part of the Abitibi group. It consists of mica schists and metamorphosed greywackes, characteristic geosynclinal sediments, with some interstratified lavas and pyroclastic beds. It is folded along east-west axes,parallel to the volcanic-sedimentary belt of the Abitibi group, but to the south "Pontiac strata now form Z-shaped buckles that plunge steeply north." (Podolsky, 1950, p.30). The rocks of the Abitibi and Pontiac

groups are separated from the Timiskaming sedimentary rocks by a great structural unconformity. The existence of this unconformity, recognized by Wilson (1956, 1962), is questioned by Bass (1961) who believes that it records epochal events only and that the volcanic and sedimentary sequences belong to one cycle of accumulation. The Timiskaming series also lies in an east-west trending belt parallel to that of the Abitibi group.

Wilson (1956), supported by Freeman (1957), suggests that the source of the sedimentary rocks of the Pontiac group and of the Timiskaming series is to the south, but Bass (1961) claims that since the sediments are the products of comminution of Keewatin volcanics and intrusives, no single source prevails because the debris was spread radially from volcanic centers. The Abitibi and Pontiac groups and the Timiskaming series are intruded by the granitic rocks of the belt of banded gneisses separating the Grenville from the Keewatin subprovinces. All these rocks are overlain unconformably by the Huronian Cobalt series.

The rocks of the Grenville subprovince are found in the map-area and extend south of it. Osborne and Morin (1962) have divided the Grenville subprovince into two parts, designated by the letters A and B, " a division based on the different tectonic patterns, kind of plutonites and grades of metamorphism in the two parts." (p. 118-119). The Grenville A subprovince to the southeast is characterized by north trending structures, high grade of metamorphism and the presence of "green rocks" or hypersthene augite-bearing series. The Grenville A passes to the northwest into the Grenville B subprovince "near the "green-rock line", which is where the hypersthene augite-bearing series disappears

on the northwest. This line is approximately the demarcation between the granulite and the amphibolite facies". (Osborne and Morin, 1962,p. 119).

The Grenville B subprovince is characterized by irregularly northeast trending structures superimposed over north and east trending older structures. "The newer structures trend generally northeast but are exceedingly irregular, giving the impression of anastamosing zones passing around blocks of somewhat greater resistance than adjacent blocks". (Osborne and Morin, 1962, p. 119). The metamorphism is of the amphibolite facies and no "green rocks" are present. The area now under study is in the northwest part of the Grenville B subprovince.

In the southern part of the area and in adjacent areas to the south and southeast, volcanic rocks are folded along east, or nearly so, trending axes and are overlain by sedimentary rocks, mica schists and gneisses. Henderson (1936, p. 14) mentions that the sedimentary rocks overlie the volcanic rocks conformably. "The metasedimentary rocks close to the greenstone conform to their structure in a general way but going southwest the "waviness" in the pattern resulting from folds with a north trend becomes increasingly apparent and finally the Kipawa syncline with a well-defined north-trend is reached. Between Kipawa and Val d'Or similar but less obvious relationships are found in rocks assigned to the Pontiac group." (Osborne and Morin, 1962, p. 132).The metasedimentary rocks of the Ville-Marie and Guillet lake areas, (Henderson, 1936) have been correlated with the Pontiac group by Freeman (1957).

Between the area described and the Keewatin subprovince is a belt of gneisses and granitic intrusions called "Ottawa mountain" by

Wilson (1956). This belt is marked by a gravity low and is believed (Wilson, 1956) to be the core of a mountain-built chain. The Des Quinze lake - Barrière lake area is in the central part of that belt which is now assigned to the Grenville B subprovince (Osborne and Morin,1962).

The transition from the Grenville to the Keewatin subprovinces should be observed there. This transition, sometimes called "Grenville front",has been the subject of numerous discussions. It appears to be narrow and abrupt in places, whereas it is wide and indefinite elsewhere. Phemister (1960) reports that the boundary between the Grenville and Temiskaming subprovinces in the Sudbury district of Ontario is a metamorphic transition zone, 100 yards wide. Deland (1956) did also suggest a transitional zone corresponding to a change in the grade of metamorphism in the Surprise lake area. On the other hand, the transition is more abrupt in the Temagami lake area,Ontario, where Johnston (1959) reports that a complex zone of thrust faults of major tectonic significance forms the boundary of the Temiskaming and Grenville subprovinces. Osborne and Morin (1962, p. 133) regard the Grenville B subprovince as a zone of transition between the Grenville A and the Keewatin subprovinces, and Robert (1963) writes that the Grenville front corresponds to the staurolite isograd of the amphibolite facies and that the front coincides with the rocks of the Pontiac group.

Age determinations by the K-Ar method on rocks of the Keewatin subprovince indicate that they were formed more than 2,000 million years ago and age determinations on samples from the Grenville subprovince indicate that a period of orogeny accompanied by regional metamorphism occurred about 1,000 million years ago (Snelling, 1962).

Osborne (1962) has proposed the term "Millenary" for this event because he precludes any genetic implication of terms such as "Grenville orogeny" or "Grenville event" and he further proposes that the "Millenary" event was thermal.

To conclude this brief review we will summarize some of the more important points pertaining to the regional geology of northwestern Quebec and the area now under study:

A- The nature of the "Grenville front", although positively recognized as abrupt (of a tectonic nature) or gradual in some areas, is not defined here.

B- The Pontiac group, originally thought to be approximately ten miles wide, now appears to be much more extensive and is even believed to be implicated in the "Grenville front". The extent of the Pontiac group has to be defined, and any consequence that this may have on the views about its origin has to be examined.

C- The nature of the "Ottawa mountain gneisses" or "Ottawa gneisses", presumably present in the Des Quinze lake - Barrière lake area has to be defined.

D- The relation of the volcanic belt in the southern part of the area to the Keewatin volcanics to the north (Rouyn-Val d'Or belt) has to be investigated.

There are numerous other problems related to the regional geology of the map-area, but those enumerated above are believed to be paramount.

Outline of the Geology of the Map-area

A- General Statement

The bedrock of the Des Quinze lake-Barrière lake area,

except for a thin strip of Paleozoic sedimentary rocks along the northeast shore of Témiscamingue lake is of Precambrian age. The oldest rocks belong to the volcanic-sedimentary assemblage underlying the southwest corner, along a N.-60°-E. -trending belt that abuts against a hornblende granite mass and extends deeply into the adjacent areas to the south and southeast. The volcanics consist mainly of fine- to medium-grained andesite and dacite with minor rhyolite, quartz-feldspar porphyry, tuff and agglomerate. Greywackes that pass gradually to mica schists are interbedded in the upper horizons of the volcanic sequence. From relations observed in the vicinity of Des Quinze river by the writer and in adjacent areas by Denis (1938), Henderson (1936) and Auger (1952), it is established that the sedimentary rocks overly the volcanics conformably. The volcanic-sedimentary assemblage is isoclinally folded along nearly east-west-trending axes and the grade of metamorphism is that of the upper greenschist or lower almandine-amphibolite facies of regional metamorphism.

Metamorphosed greywackes represented by quartz-feldspar-biotite schist, and thin layers of amphibolite intercalated within the schist make up an important part of the rock formations. The quartz-feldspar-biotite schist is in contact to the north with the members of the Pontiac group, as defined by Wilson, and it extends south throughout the area, as far as the volcanics with which it is in contact. Thus the width of the Pontiac group is greatly augmented from what it was originally conceived to be. The members of the Pontiac group show evidence of structural continuity and thereby play a major role in outlining the dominant structural trends of the area.

The members of the Pontiac group are intruded and mixed with a variety of syenites,granites and associated gneisses. The syenitic rocks are not abundant and generally occur near the volcanic belt in the southeast, except for a large irregular mass of hornblende-pyroxene syenite in the north. Hornblende granites occupy the center of the region as irregular masses intimately mixed with oligoclase-microcline granite. The oligoclase-microcline granite is the dominant rock type in the region as it occupies well over half of the surface and constitutes more than two-thirds of the rock formations. It is generally massive, but in the vicinity of the quartz-feldspar-biotite schist, it is gneissose and of mixed composition. It is injected into or otherwise associated with the quartz-feldspar-biotite schist and, in places, it forms granitic or quartzofeldspathic gneisses and migmatites.The concordant relations of the granitic masses, the synkinematic features and some metamorphic aspects are characteristic of granites of the catazone. Development of microcline porphyroblasts resulted from a late episode of potash metasomatism that affected not only the oligoclase-microcline granite but also the hornblende granite and the hornblende-pyroxene syenite.

The metamorphic grade of the members of the Pontiac group, gneisses and granitic rocks, as defined by the mineralogical composition, migmatization and granitization, is that of the staurolite-quartz subfacies of the almandine-amphibolite facies of progressive regional metamorphism. Deformation of the schist concomitant with the emplacement and formation of the granitic rocks produced large open synforms and antiforms along north-south- and north-west-trending axes.

Huronian rocks are represented in the southwest by the

quartzite and arkose of the Lorrain formation, and in the northwest by the conglomerate and argillite of the Cobalt group of clastic sediments. Outcrops of these sedimentary rocks are rare and of restricted extent. Diabase dykes are believed to cut all the Precambrian rocks. However, such a relationship between the diabase and the Huronian formations was not observed in the map-area.

Sand and gravel deposited during the Pleistocene epoch cover large sections of the area, especially where the relief is low.

The Grenville front is not recognized as such within the map-area, but when considered on a larger regional basis it appears to be gradational and the map-area would be in the transition zone. The metamorphic grade, the mineralogical characteristics of many rock types and the overall structural pattern relate the area to the Grenville B subprovince as defined by Osborne and Morin (1962).

B- Table of Formations

	Pleistocene and Recent			Sand,Gravel,Clay,Varved clay, Till
	Paleozoic -Ordovician			Conglomerate,sandstone,limestone
PRECAMBRIAN	Proterozoic			Diabase, Gabbro
		Huronian	Lorrain Formation	Arkose, Quartzite
			Cobalt group	Argillite Conglomerate
	Archean			Serpentinite Pyroxenite Lamprophyre Pegmatite,Aplite Oligoclase-microcline granite,Porphyritic oligoclase-microcline granite Biotite granite Grey granite gneiss Hornblende granite,Porphyritic hornblende granite Plagioclase-hornblende gneiss Hornblende syenite Hornblende-Pyroxene Syenite,Porphyritic hornblende-pyroxene syenite Nodular pyroxene syenite Pyroxene-biotite rock
			Pontiac group	Quartz-feldspar-biotite schist,Quartz-feldspar-biotite hornblende gneiss Quartz-feldspar gneiss Amphibolite Greywacke,Arkose
				Paragneiss, Metavolcanics Metamorphosed sedimentary rocks (Quartzite-Greywacke) Iron formation Hornblende schist, Hornblende gneiss Rhyolite, Quartz-feldspar porphyry Agglomerate, Tuff Hornblende rock Andesite, Dacite, Chlorite schist

Chapter IV

DESCRIPTION OF FORMATIONS AND DISCUSSION

A- Volcanic and Associated Sedimentary Rocks

1- Introduction

Volcanic rocks, associated with tuffs, iron-bearing sedimentary rocks and greywackes, occur in the southwest corner of the area, in Baby, Guigues,Guérin and Nédelec townships, north,south and west of Angliers, along a north-east trending zone, approximately nine miles long and seven miles wide. The zone is interrupted to the west and southwest by the clay, sand and gravel cover and to the east by granitic rocks which have intruded and transformed the volcanics into fine-grained hornblende schists and gneisses. It extends south into the Ville-Marie and Guillet (Mud) lake map-areas (Henderson,1936), and is in contact to the north with the biotite schist of the Pontiac group. A few small and isolated outcrops of andesite also occur along and near the southeast shore of Simard lake, in the vicinity of the eastern limit of the area.

The varieties of lavas represented in the area are numerous, from basic to intermediate and to acid, forming a series from dark basalt to pale rhyolite. Intermediate and basic examples are the most widespread and occur in the northern sector of the zone. Rhyolite and porphyritic rhyolite associated with dacite occur mainly in the south, along the border of the area.

The volcanic rocks are usually altered to various degrees, so much in places that thin section examination is worthless, for no accurate determination of the original mineralogical composition can

be effected. Due to the alteration, it is difficult, if not impossible to classify and separate the lavas with precision. Therefore we have recognized and separated only three major groups: a)- Andesite,dacite and chlorite-schist, b)- Agglomerate,tuff, c)- Rhyolite, quartz-feldspar porphyry. Added to these are the sedimentary members of the sequence and one rock type of dubious origin referred to as "hornblende rock".

2- Andesite - Dacite - Chlorite schist

Andesite and dacite are relatively similar, gradational rocks not easily differentiated in the field. Andesite is the most abundant type, dacite occurring as thin lenses in the andesite and, in places, being associated with the rhyolite. Chlorite schist represents zones of intense dynamic metamorphism and occurs as thin lenses in the andesite and dacite. The term andesite is used loosely here and applies to the rocks of basic as well as to those of intermediate composition which constitute the bulk of the volcanic rocks of the area.

The rocks are usually massive and preserve such original textural and structural features as flow textures and ellipsoidal or pillow structures which characterize lavas of this type and are usually best observed on weathered surfaces. The rocks range in colour from light brown to dark green on weathered surfaces and display a great variation in granularity, ranging from extremely fine-grained to medium-grained. Porphyritic varieties are common, especially in the dacites. Amygdaloidal lavas appear to be uncommon and were observed at only one locality.

The andesite and basalt are almost completely altered to a mixture of secondary minerals. Thin section examination of the least

altered phases of the andesite reveals the presence of small prisms and phenocrysts of plagioclase (An_{30}) embedded in a groundmass of plagioclase, blue-green hornblende, actinolite, epidote, chlorite and zoisite. Quartz, when present, occurs only in the matrix as equidimensional granules. Phenocrysts of plagioclase and hornblende are common and average two millimeters in diameter. The plagioclase crystals are in various stages of alteration to sericite, epidote and zoisite, and hornblende is altered to chlorite, biotite and epidote. Chlorite, hornblende and epidote are the dominant minerals of the groundmass with clinozoisite, carbonates, magnetite and pyrite as accessory minerals. The vesicles of the amygdaloidal lavas are filled with carbonates and fine-grained granular quartz. Using staining techniques, no potassic feldspar was observed or detected. Fluidal textures characterize the porphyritic varieties and flow lines around the phenocrysts are common in the groundmass.

The dacite is a pale to medium grey lava, generally porphyritic, confined to the southern extremity of the volcanic zone where it is associated with the andesite and in places with the rhyolite. The weathered surface of the rock is very rough due to the protuberance of quartz and feldspar phenocrysts. The phenocrysts, commonly two millimeters in length, are slightly elongated and have a parallel orientation which gives the rock a trachytic texture. Thin section study shows the phenocrysts to be idiomorphic crystals of plagioclase (An_{30}), constituting up to forty per cent of the rock, and in places crystals of blue-green hornblende, embedded in a fine -grained granulose matrix of plagioclase, quartz, actinolite, clinozoisite, muscovite, sericite and

carbonates. Accessory minerals are magnetite, pyrite and epidote. The dacite associated with the rhyolite is composed of very abundant phenocrysts of plagioclase (An_{15-20}) in a groundmass of plagioclase, quartz, biotite, muscovite and clinozoisite. The dacite is much less altered than the andesite and the components are relatively fresh, only the phenocrysts showing much alteration. No orthoclase was detected in any of the thin sections examined.

Photograph 2 : Porphyritic dacite. Phenocrysts of plagioclase. The large vesicle is filled with carbonates.
(Crossed nicols - X80).

Intense dynamic metamorphism transformed andesite into chlorite schist by recrystallization of chlorite along the foliation planes. The chlorite schist is composed principally of chlorite with traces of tremolite-actinolite. Numerous veins of carbonates and

quartz cut the rock which occurs mainly along shear and fault zones.

Structural features

Ellipsoidal or pillow lava: Pillow structures are not widespread in the volcanic rocks of the area; they are found in the vicinity of Des Quinze river and Baby lake, and have rarely been observed elsewhere. The pillows are from one to four feet long and one to two feet wide, are commonly slightly deformed and are of various shapes, the balloon shaped medium-sized type being the most common. The boundaries of the pillows are marked by chlorite rich layers. Amygdule and

Photograph 3 : Pillow structures in andesite.(Island in Baby lake, at southern border of area.)

variolite zones are absent and therefore top determinations can be obtained only on those pillows that show convex upper sides and a pronounced "tail" end or bottom. Few such determinations have been made, but those along Des Quinze river indicate that the top of the lava flows faces south, while those near Baby lake indicate northward facing flows,

suggesting a synclinal structure. However these determinations have to be evaluated carefully because contradictory results can be obtained if certain conditions are not adhered to in the measurement itself (see Appendix I). We will not discuss the origin of pillow structures here, and the reader is referred to Wilson (1962, p. 17-18) who gives a succinct résumé of this problem.

Amygdules : As mentioned earlier, they are not common features. They have a maximum diameter of a quarter of an inch and are filled with calcite and granular quartz. They are usually elliptical, due to movement in the lava after the formation of the amygdules. No amygdules were observed in pillowed andesites.

Banding: Banding or lamination occurs locally in zones one-twentieth to one fourth of an inch wide. It is usually observed near tuffaceous layers but is uncommon.

Contact: The contact between the andesite and the biotite schist is described and discussed with the rocks of the Pontiac group.

3- Hornblende Rock

Elongated lenticular masses of hornblende rock occur just south of Des Quinze river in the andesite, and large irregular masses occur in the vicinity of Baby lake. The extensive Baby lake occurrences include the most typical examples of this rock type; they appear to be fairly continuous but are interrupted here and there by narrow or wide lenses of fine-grained andesite commonly displaying pillow structure.

This rock is closely associated with the andesite into which it grades in places although it may appear to intersect it

elsewhere. Two main types have been distinguished, on the basis of external appearance and mineralogical composition. However they share similar characteristics such as texture, associations and relations, and are treated here as a unit because they are believed to be of similar origin.

The hornblende rock is medium- to coarse-grained, dark green on a fresh surface, green to black on weathered surfaces which are usually rough and clotted due to the protrusion of hornblende grains. The rock is always massive and may display a porphyroblastic texture in places, with hornblende porphyroblasts up to half an inch across. One type of hornblende rock is lighter in colour than the other and has a deep, soft and bleached weathered zone; it never is porphyroblastic.

The dark variety is composed mainly of hornblende (60 %) and plagioclase (30 %). Both components are highly altered, hornblende to chlorite and epidote, plagioclase to sericite, calcite, epidote and zoisite. The composition of plagioclase is An_{35-40} as determined on the less altered examples. The plagioclase occurs in lath-shaped crystals giving the rock a pseudo-ophitic texture, and also occurs as almost completely altered coarse grains similar in outline to the hornblende grains. Hornblende is generally in large euhedral crystals, lying in a groundmass of quartz, chlorite, calcite, epidote, clinozoisite, magnetite and ilmenite. The hornblende possesses the following optical properties: $2Vx = 75\text{-}80°$, $Z\wedge c = 22°$. Absorption formula: X = pale light-green, Y = yellowish green, Z = bluish green. It is shredded in the more altered examples and, in these, cumulophyric actinolite is common.

The light coloured variety of the hornblende rock is compo-

sed mostly of plagioclase (40 %) and amphibole (40 %) with chlorite, epidote, calcite and quartz as accessory components. As with the dark variety, the rock is much altered and secondary epidote from the alteration of plagioclase and hornblende may constitute up to thirty per cent of the rock. The plagioclase, in all thin sections examined, was too altered to be determined. The main difference between this variety and the other is in the proportion of plagioclase and hornblende.

The hornblende rock occurs only within the belt of volcanic rocks and has not been observed anywhere else in the area. It is closely associated with the andesite into which it has frequently been observed to grade. However,it also appears to trend across the lavas here and there,and to intersect them,but no contacts have been observed.

Retty (1931), Denis (1936, 1938), Henderson (1936) and Auger (1952) have described similar rocks, in the eastern and southeastern extension of the belt, under the designations of : amphibolite, diorite and spotted green rock. Wilson (1962) also dealt with similar formations in the Rouyn-Beauchastel area. The hornblende rock is believed to be the same rock type as the diorite, amphibolite and spotted green rock to the east and may be related to the diorite of Wilson.

Origin:

The dark variety of hornblende rock undoubtedly is part of the volcanic sequence and is believed from field evidence to represent the coarser portions at the center of thick lava flows. The light coloured variety may be a facies of the same rock or an altogether different member, not even related to the volcanic rocks.

Denis (1938) wrote that the relationships of the "diorites"

and greenstones which occur together throughout "Keewatin" areas is a major but, as of now, unsolved problem encountered by many geologists. He describes amphibolites which, he suggests, may be "flows coarser than the typical greenstones" (p. 20), or "diorites which are the equivalent of the Rouyn-Bell river "older gabbros"" (p. 26). Henderson and Retty regarded this rock as intrusive but Denis did not find enough field evidence to support this view and considered the probability of a volcanic source. He referred to the "diorites" as coarse facies of the Keewatin volcanics although he did not preclude the possibility of their being intrusive rocks of "Keewatin age".

Henderson (1936) definitely stated that he considered these rocks to be intrusive into the volcanics and wrote: "It is believed that the majority of the intrusives are diorites, but some are undoubtedly gabbros" (p. 15). Auger (1952) distinguishes "volcanic diorites", "spotted green rocks" and "diorites". The volcanic diorite he believes to be a phase of the volcanic rocks transformed under the influence of the intrusive diorite, or a lava injected under already congealed surface lava. He refers to the spotted green rocks associated with the volcanics as secondary and recrystallized rocks. He proposes an intrusive relationship for the diorites because they exhibit features of intrusive rocks, but he also mentions that they grade into the volcanics in places.

Wilson (1962), in the Rouyn-Beauchastel area, separated from the zone of volcanic rocks now under discussion by a sixty-five miles wide belt underlain by granites and schists, observed members of the volcanic sequence showing features similar to those of the

hornblende rock. He distinguished diorites of intrusive origin and the dioritic interior of the lava flows but noted the lithological similarities between the two rock types.

These authors record many similarities between the features of the hornblende rock and the diorites but shed little light on the problem of their origin. That the dark variety of hornblende rock is the dioritic interior or coarse-grained central part of thick lava flows is undoubted and is amply supported by field evidence. The light variety of hornblende rock may be the equivalent of the diorites of Henderson, Denis and Auger and thus be an intrusive rock, but this is mere speculation because we have no field evidence to support this view.

4- Agglomerate - Tuff

Agglomerate and tuff are uncommon members of the volcanic sequence. They occur in two distinct bands or zones: one, south of Des Quinze river, is narrow and extends east from Baby lake for a mile and a half, and the other occurs west of Angliers, is four miles long, up to one mile wide and trends approximately N.-60°-E. The width given here as one mile is a maximum width; the average is closer to half a mile and includes beds of sedimentary rocks, tuffs, iron formation and andesite. The true width is probably no more than five hundred feet.

The agglomerate and tuff, which usually occur together, agglomerate being the dominant member, are associated with the andesite flows and in places with the iron formation and intercalated sedimentary rocks.

The typical agglomerate consists of rounded and sub-rounded fragments, half an inch to five inches in diameter, embedded in a dark

grey matrix. The fragments are fine-grained, pale grey and of uniform composition. Thin section examination shows the fragments to be composed of sixty per cent oligoclase phenocrysts, in a groundmass of plagioclase, chlorite, epidote, clinozoisite, blue-green hornblende, granular quartz and biotite. The parallel orientation of the hornblende phenocrysts defines a fluidal or trachytic texture further enhanced by the analogous trend of the mafic components. The matrix of the agglomerate is finer-grained than the fragments and is of similar composition, but is richer in chlorite and clinozoisite and holds no phenocrysts. The overall mineralogical composition of the rock is that of a quartz latite or dacite. The fragments are slightly elongated and are aligned in a direction parallel to the trend of the foliation of adjacent rocks.

The Baby lake agglomerate is composed of irregularly shaped and distributed pebbles of andesite in a tuffaceous matrix. It occurs in the pillow andesite (photograph 4) as thin horizons interlayered with banded tuff.

The tuff is of variable composition, texture and appearance. Typically it is very fine-grained, massive, soft weathering, medium to dark grey and banded. The alternating layers are of variable grain size, some very fine-grained layers adjoining medium-grained fragmental layers. The mineralogical composition of the fine-grained portions is difficult to recognize in thin sections. The coarser parts consist of a fragmental mixture of plagioclase, biotite, muscovite, fine granular quartz, pyrite, epidote and calcite. The rock is much altered and it is impossible to determine the exact proportions of the minerals, which, anyhow, vary from one layer to another. The alteration of the plagiocla-

se is in places so complete that even the outline of the original feldspar disappears and the mixture of epidote, sericite and calcite is the sole remaining evidence of its former existence in the rock. Flow structures are present in some layers which exhibit a preferred orientation of their components.

Photograph 4 : Tuff and agglomerate layers over pillowed andesite. Island on Baby lake.

The Baby lake occurrence is characterized by well-bedded, very fine-grained, light grey to white weathering tuffs of acidic composition. The beds are very thin, one quarter to half an inch, and show little variation in composition. The tuff occurs as fifty feet wide bands associated with pillowed andesite and agglomerate, and readily indicates the true attitude of the lava flows. The pillows indicate that the flows face north and the tuff dips steeply south, suggesting overturned beds and flows.

5-Rhyolite - Quartz-feldspar porphyry

Rhyolite and quartz-feldspar porphyry outcrop west of Grand Lac Long, near the southern limit of the area, as lenses and irregular masses interstratified with the andesite and hornblende rock, and constitute a minor part of the volcanic assemblage. They extend into the Ville-Marie and Guillet (Mud) lake map-areas (Henderson, 1936), where they are more abundant than in the presently discussed area.

The rhyolite is usually porphyritic, fine-grained to very fine-grained and grey or brown on fresh fractures. It weathers a light grey with a rough hackly surface on which the quartz phenocrysts protrude in places. Dark varieties also occur but they are infrequent. The phenocrysts are rounded or elliptical,one-eighth to one-quarter of an inch in diameter, and consist of quartz, feldspar and in some places ferromagnesian minerals. Some quartz phenocrysts are not simple but are made up of aggregates of hyaline quartz with sutured borders.Feldspar phenocrysts are irregular in outline or idiomorphic and the plagioclase, oligoclase, is usually altered to sericite and in extreme phases to sericite, calcite, epidote and quartz. A phenocryst of potassic feldspar, untwinned, was observed in one thin section, and it is the only such example, potassic feldspar appearing to be lacking. The mafic phenocrysts consist of biotite, chlorite and epidote, probably alteration products of hornblende, and are of rare occurrence. The phenocrysts may make up to fifty per cent of the rock but generally constitute about twenty-five per cent of it. The matrix material is fine granular quartz, muscovite, sericite, plagioclase, chlorite, epidote and, here and there, calcite. Flow lines around the phenocrysts are defined by

alignment of the mafics. Cobaltinitrite staining revealed the presence of little potassic feldspar in the groundmass.

The quartz-feldspar porphyry is similar to the rhyolite, except for the greater amount of feldspar phenocrysts. The two rock types are intermixed and cannot be separated. The rhyolite has the characteristic features of extrusive rocks but the quartz-feldspar porphyry, in some places, appears to be intrusive into the andesite. Small dyke-like bodies of quartz-feldspar porphyry which have been observed to intersect the andesite and the hornblende schist may be related to the rhyolite.

6- Hornblende schist - Hornblende gneiss

Hornblende schist and hornblende gneiss occur at the eastern extremity of the belt of volcanic rocks in the contact zone with the hornblende granite, north and south of Angliers.

The rock is fine-grained to very fine-grained, with grains from 0.05 to 0.5 millimeter; it is dark green and possesses a foliation defined by the parallelism of the hornblende grains, and,in some instances, a strong compositional banding outlines the gneissic structure. A lineation, apparent on the foliation plane, is formed by the orientation of some hornblende grains along their length. The rock is fresh, relatively unaltered and appears to be entirely recrystallized. The hornblende is a fresh, highly pleochroic variety that occurs in idiomorphic rod-like fragments. It exhibits the following properties: $2V = 60°$, $Z \wedge c = 23°$, X = light greenish-brown, Y = brownish-green, Z = smoky blue-green. It is the prevalent mineral of most thin sections, constituting up to seventy per cent of the rock. In one thin section

from a sample near the contact zone with the granite, the hornblende crystals are bordered by bleached rims enclosing dark zones, and the hornblende alters to biotite which it encloses poikilitically. This peculiar alteration may result from the action of granitic solutions. Feldspar is commonly altered except in some thin sections from samples near the granitic rocks. It is usually untwinned, and appears to be oligoclase-andesine because it has indices slightly higher than that of Canada balsam. Quartz occurs as very fine granular and equidimensional grains intimately mixed with the feldspar. Other components are chlorite, epidote, biotite, apatite, magnetite, pyrite and, in one thin section, microcline.

Hornblende schist and hornblende gneiss undoubtedly represent the intermediate volcanic rocks to the west and are metamorphic equivalents. They are in contact with the hornblende granite, along a north-south direction and this contact is not abrupt but gradational. Wilson (1910, p. 16) described the rock which he termed "metamorphosed greenstones" and concluded his description by writing that "the transition which can be observed both microscopically and in the field between the more massive greenstones and the schist, leaves little doubt but that originally the two rocks were identical... While.., the close association of the schists with the borders of the intruded acidic rocks would indicate that the contact action was an important transforming agency. Not only do the schistose rocks adjoin the intrusives, but the direction of their foliation is parallel to their margin".

7- Iron formation

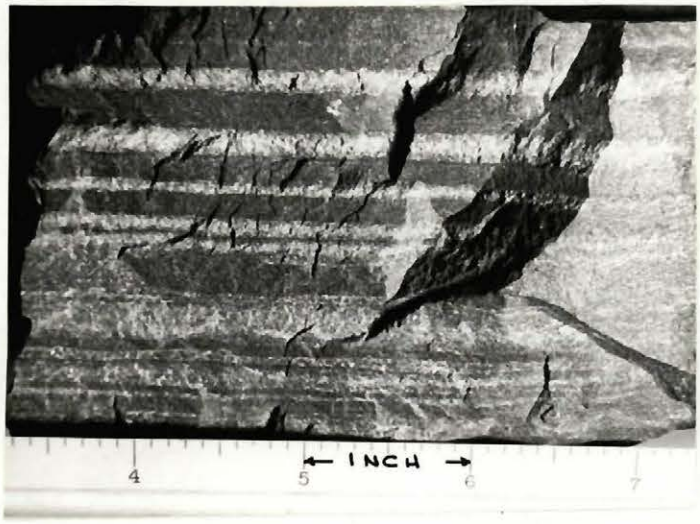
Thin bands of iron formation interbedded with intermediate

lava flows and metamorphosed sediments outcrop in the southwest corner of the area in the vicinity of Des Quinze river. The bands are of two types characterized by their width, composition and associations.

The first type occurs one quarter of a mile south of Des Quinze river, which it intersects near the power station. Outcrops were also observed south of Renard lake and near Des Quinze lake, east of Guérin. This iron formation is commonly associated with pillow-lava and with hornblende rock. It is close to the contact between the volcanics and the Pontiac schist, one outcrop being only five hundred feet south of this contact. The bands of this type of iron formation are frequently forty feet wide, but may be as much as 150 feet wide. They are very contorted and, in places, brecciated.

The rock consists of dark, thin magnetite-rich layers alternating with quartz-rich layers. The width of the laminations varies from one quarter of an inch to half an inch. The magnetite-rich layers are dark grey, dense and are composed of magnetite, quartz and actinolite. The actinolite is usually on the edges of the magnetite layers but some crystals actually are in the magnetite-rich bands. The actinolite is oriented in a direction parallel to that of the layering. The magnetite makes up approximately thirty per cent of the rock and this value is relatively constant along the trend of the bands. The quartz-rich layers are light grey to bluish grey. Some layers consist of fine-grained quartz displaying a granular mosaic and other layers consist of coarse-grained quartz with sutured texture. Shreds and acicular crystals of actinolite are present in small amounts and have no preferred orientation. Small grains of magnetite are finely disseminated in

these layers. Epidote and calcium carbonate are common secondary minerals.



Photograph 5 : Iron formation, first type.The magnetite makes up approximately thirty per cent of the rock.

Photograph 6 : Iron formation, second type.The magnetite makes up almost fifteen per cent of the rock.

Photograph 7 : Iron formation, first type. Good example of contorted, faulted and slightly brecciated iron formation.

Photograph 8: Iron formation first type. Magnetite layers are relatively wide and abundant.

The outcrops of this type of iron formation occur along a N.-60°-E. trending zone, seven miles in length, suggesting that the formation is continuous over this distance. The zone is interrupted at its eastern extremity by hornblende granite and at the western end is covered by overburden. The outcrops probably belong to more than one band of iron formation, unless their distribution along the zone results from faulting or shearing. Two outcrops are immediately south of the volcanics-Pontiac schist contact and the majority of outcrops is more than two thousand feet south of it.

The second type of iron formation occurs along a zone parallel and south of that of the first type. The bands are generally less than ten feet wide, although they may be as much as thirty feet wide. They are relatively undisturbed, lying conformably within the sedimentary and tuffaceous layers with which they are interbedded. Folding and brecciation were observed at only one place.

The rock consists of thin magnetite-rich layers, rarely exceeding one quarter of an inch, interbedded with wide, up to six inches, layers of sedimentary and tuffaceous rocks. The magnetite-rich layers consist of fine-grained magnetite, granular quartz, and small crystals of actinolite. The magnetite makes up almost 15 per cent of the rock. Layers of bluish-green hornblende crystals, with their long axes at an angle of thirty-five degrees to the foliation direction are often in contact with the magnetite-rich layers. Magnetite is sparsely scattered in these layers.

The outcrops of this iron formation are not numerous but they are always found approximately 2500 feet south of the first type.

Both types of iron formation are of sedimentary origin, but they are so recrystallized that it is difficult to determine accurately what type of sedimentary iron formation they represent.

8- Metamorphosed Sedimentary Rocks (Quartzite-Greywacke)

Metamorphosed impure quartzite, siltstone and greywacke occur near both shores of Des Quinze river. The principal occurrences are northeast of the village of St-Eugène where the rocks are found as intercalated layers in the volcanics. They are associated with andesite, tuffs, agglomerate and iron formation and are of limited extent.

Most of the rocks consist of impure quartzite and siltstone. Layers of greywacke are infrequent. The rocks are dense, very fine-grained to fine-grained, light grey on a weathered surface and dark grey on fresh surfaces. Sedimentary characteristics such as bedding and graded-bedding are commonly displayed. The beds are finely laminated, varying from one-eighth to one thirty-second of an inch in thickness. The rocks have been recrystallized to various degrees and in many instances are schistose. The quartzite consists of thin layers made up of quartz (70 %) and mafics (30 %). Magnetite is a prominent mineral in some layers, especially in the vicinity of the iron formation with which the quartzite is sometimes associated. The siltstone consists of well-indurated, silt-sized particles of ferromagnesian minerals, quartz, feldspars and carbonates. Thin, dark, mafic-rich layers alternate with quartz-plagioclase layers. This rock is generally associated with tuffs and agglomerates, and tuffaceous layers are undoubtedly interbedded with it.

These sedimentary rocks may be related to the Pontiac group,

but the relationship is obscure and they are accordingly described separately. The position of these rocks in the volcanic sequence is unknown; if they are near the upper limit of the sequence they may represent the initial stage in the change to dominantly sedimentary conditions. However, they may be isolated occurrences in the volcanic sequence, without any specific relation to the Pontiac group.

9- Paragneiss - Metavolcanics

Metamorphosed basic volcanic rocks interlayered with metasedimentary bands occur along an east-west trending zone in the southeast corner of the area, just south of Kloch bay, in the vicinity of the road to Laforce. The zone is one and a half mile long and one thousand feet wide and extends east into an area mapped by Denis (1936), where it was found to be part of a volcanic complex. The zone is intersected to the west by hornblende syenite and does not reappear but is nevertheless believed to be the continuation of the volcanic formations observed in the southwest corner of the area.

The metavolcanics form a low ridge, twenty to fifty feet high, trending east-west. The rock is fine-grained, dark grey, fresh, and in places finely laminated. The laminations, varying in width from one-eighth to half an inch, are apparent on weathered surfaces but are very faint on a fresh fracture. The rock is contorted and the fine laminations give it the external appearance of a complexly folded paragneiss. The volcanic layers are more massive, not laminated, but definitely gneissose. The rock fractures along the gneissosity.

Examination of a thin section shows that green hornblende constitutes more than fifty per cent of the rock. The hornblende

crystals are aligned in the direction of the gneissic structure. Epidote is the next most important component and it does not display a preferred orientation, being arranged in a decussate pattern. Plagioclase and quartz are present in minor amounts except in the thin laminations where they are most abundant.

In the area to the east, these rocks are considered to be part of a "Keewatin-type" volcanic assemblage of great areal extent. The rock therefore represents basic to intermediate lavas with intercalated sedimentary formations.

10- Structure of the volcanic assemblage

Shear zones and faults: Numerous shear zones of little extent have been observed in the volcanics. They usually are narrow and lenticular, and are filled with talc-chlorite schist. Minor faults have been observed but they are not abundant. Major faults are discussed in chapter V.

Folds: No minor or parasitic folds were observed except in the much contorted and disrupted iron formation. Major folds are inferred from the following evidence: the contact of the volcanic rocks with the overlying biotite schist of the Pontiac group, the ellipsoidal structures, the bedding of sedimentary formations and the iron formation trend N.-60°-E. in the north part of the belt, and ellipsoi - dal structures and tuff bands trend east-west in the south. In all cases the dip is very steep and almost invariably to the south. Tuff layers intercalated in the volcanics at Baby lake have an east-west trend and dip steeply to the south, whereas the top of the associated lava flows faces north, indicating that the rocks are overturned.

Henderson (1936, p. 14) found that the structure of the volcanics is a monocline, "it represents the southern limb of a major fold that has been cut off on the north by the granite..", "the major structure of the greenstone belt may be considered as a broad anticline plunging at an extremely steep angle to the southeast.." Auger (1952) wrote that the volcanic rocks of the Belleterre area were on the southern flank of an anticline trending east-west and plunging east.

The observations in the map-area do not indicate that the volcanic rocks belong to the prolongation of the south limb of the anticline described by Henderson. Instead, the constant dip of the structural trends to the south and the overturning of members indicate one or more isoclinal folds trending N.-60°-E., with axial planes dipping steeply to the south. This structural pattern would be similar to that of the Rouyn-Val d'Or belt.

Metamorphism: The volcanic rocks are in general very altered and rarely contain their original components. A few sections are recrystallized, especially in the vicinity of the hornblende granite but otherwise the rock is made up of the alteration products of the original components. The mineral assemblage is that of the staurolite-quartz subfacies of the almandine-amphibolite facies (Fyfe, Turner and Verhoogen, 1958). The presence of oligoclase, associated with epidote is characteristic of this facies. However the presence of albite, quartz, actinolite, biotite and chlorite in some places may indicate that the rocks straddle the boundary between the upper greenschist facies and lower almandine-amphibolite facies. Retrogressive metamorphism related to the numerous masses of granitic rocks which intrude the volcanics

may account for the more extreme alterations.

11- Correlation of the volcanic sequence with the "Keewatin" rocks of adjacent areas

Henderson (1936) and Denis (1936,1938) used the term "Keewatin" and Auger (1952) the more restricted term "Keewatin-type" for the volcanic rocks of adjacent areas. This term was used because the lavas share many characteristics with the Keewatin volcanics of the Rouyn-Cadillac belt, and also because the lavas were, in cases, correlated with those of the belt. Although the author prefers to disregard the use of "Keewatin", inasmuch as it has special connotations, the use of that term for the volcanic rocks of the area and of adjoining areas may be justified. The external and internal features, mode of occurrence and associations of the volcanics of the area and those of the volcanics of the Rouyn-Cadillac belt are in many ways similar.The relations of the volcanics to the Pontiac group are identical and may indicate that the volcanics in the two areas are correlative equivalents.

B- Pontiac Group

1- Introduction

The term "Pontiac group" has been used by Wilson (1912, 1913) and Freeman (1957) to designate a relatively continuous assemblage of sediments and metamorphosed sediments in which lenses or bands of volcanic rocks and amphibolite are intercalated. Freeman (1957) wrote an exhaustive description of this group. In the present map-area the Pontiac group includes rock types very similar to those described by Wilson and Freeman and which are, in part, the western prolongation of the rocks described by Freeman. The rocks in the south of the area are considered to be part of the Pontiac group, although they are a

long distance south of the main zone in which the group occurs. There is stratigraphic continuity between the northern and southern parts of the group and the lithology is similar. The rocks can definitely be considered, if not part of the Pontiac group, as originally defined, at least correlative equivalents of the group. Local variations in lithology, hitherto undescribed, have been recognized and will be mentioned here as part of the Pontiac group.

A four-fold division of the assemblage can be made on the basis of lithology and origin:

1- Greywacke - Arkose
2- Amphibolites
3- Quartz-feldspar gneiss
4- Quartz-feldspar-biotite schist and quartz-feldspar-biotite-hornblende gneiss

The Pontiac group makes up an important part of the basement of the map-area and is the only source of information as to the structural pattern and history. Its importance extends further because it is the only link between two major divisions of the Canadian Shield. The volcanic and sedimentary rocks of the "Keewatin" to the north are directly separated from the metamorphic terranes of the Grenville subprovince to the south by the rocks of this group. (See figure I, which shows the structural trends and the distribution of the Pontiac group).

2- Greywacke - Arkose

Greywacke and arkose with interlayered beds of quartzite occur along both shores of Des Quinze river, north of the Pontiac group-volcanic rocks contact and are associated with quartz-feldspar-biotite schist into which they grade.

The rock consists primarily of dense, well-bedded, fine-grained greywacke. It is greenish grey on a weathered surface and dark to medium-grey on fresh surfaces. The fresh surface is homogeneous and does not always exhibit the bedding which is more conspicuous on a weathered surface. Features such as bedding, graded-bedding, scour-and-fill structures, small-scale cross-bedding and intraformational deformation, which afford means of distinguishing top from bottom, have been observed frequently.

Photograph 9 : Outcrops of greywacke on both shores of Des Quinze river. The steeply dipping foliation is faintly apparent.

The greywacke in the vicinity of the quartz-feldspar-biotite schist commonly displays a schistose structure, the development of which can be observed from the initial to the final stages. In the initial stages, the foliation is faintly apparent and does not affect all of the beds; moreover the rock is not recrystallized. In the terminal

stages the schistosity is all-pervasive, the rock is completely recrystallized and all traces of bedding or of any other sedimentary features have vanished. The final result is a biotite schist differing very much in appearance and mineralogical composition from the original greywacke. The greywacke is commonly folded tightly, and in many instances overturned beds have been observed. At one place only, was the greywacke found to be undisturbed, the rock being massive, homogeneous and thickly bedded.

Photograph 10 : Greywacke cut by veins of granitic material. Scour-and-fill, graded-bedding and intraformational deformation are visible.

No exact determination of the thickness of the greywacke could be obtained because of the possible duplication of strata due to faulting or folding and also because of the non-continuity of the outcrops.

Petrography: The greywacke consists mainly of poorly rounded, sometimes angular, fragments of plagioclase, quartz and mafic

minerals. Plagioclase (An_{15-25}) is the most important component, making up to fifty-five per cent of the rock. It occurs generally as poorly rounded grains of variable size, oftentimes displaying a gradation from coarse down to the size of the matrix. The grains, in some cases, have corroded borders and a sutured texture. Microcline has been observed in one thin section and it possesses characteristics similar to those of the plagioclase. Quartz is usually disposed around the plagioclase grains as fine angular fragments. Actinolite needles were seen in one thin section from a sample of undeformed greywacke. Accessory minerals are biotite, apatite, sphene and zircon. The greywacke is relatively

Photograph 11 : Greywacke. A few actinolite needles are present. (Crossed nicols - X80)

unaltered and secondary minerals are chlorite and epidote.The mineralogical composition is not constant and varies slightly from place to place. In the more recrystallized phases of the rock, the mineralogical

composition is uniform and the components are equigranular. The greywacke has been observed to grade into the Pontiac schist of which it is therefore the unmetamorphosed equivalent. The origin of this rock will be discussed with that of the Pontiac group.

3- Amphibolites

Various types of rocks are grouped herein as amphibolites. The term amphibolite is used in the broad sense and pertain to rocks "consisting mainly of amphibole and plagioclase." (Howell, AGI, Glossary of Geology, 1960, p. 9). It bears no genetic connotations and includes rocks of diverse origin, diverse modes of occurrences and diverse associations. Most amphibolites belong to the Pontiac group and some are of doubtful affinity but are nevertheless included here for reasons of convenience. All cases of dubious origin and relations will be mentioned separately.

Amphibolites are widespread in the map-area; they are evenly distributed except in the dominantly granitic parts where they are scarce. Noteworthy occurrences are northeast of Rollet, southwest and southeast of Guérin, and in the vicinity of Chevreuil lake.

The amphibolite generally occurs as elongated masses in the intrusive rocks or as intercalated lenses in the biotite-schist of the Pontiac group. In some instances, the amphibolite seems to have discordant relationships with the enclosing rocks and in others, the relationships are not clearly defined. The lenses or masses range from a few inches to 1500 feet in width and the observed length may be as much as one mile.

The rock may be massive, gneissose or even schistose, the

massive variety being prevalent. Thin bands of finaly laminated hornblende schist are intercalated with the biotite schist northeast of Rollet. The texture is generally equigranular, but may be panidiomorphic-granular, or porphyritic or porphyroblastic. Grain size is usually coarse, but fine and medium-grained varieties are common. The amphibolite is dark green or black, consisting mostly of hornblende.

Petrography: Thin section study shows that hornblende may make up as much as 95 % of the rock. The hornblende commonly occurs as stout, euhedral crystals or prisms. Crystals five inches long have been observed near the contacts of amphibolite and granites. The hornblende is almost invariably a blue-green variety displaying strong pleochroism. The absorption formula is:

X = pale brown
Y = pale blue-green Z>Y>X
Z = deep greenish-blue

Other properties are: $2Vx = 80°$ $Z \wedge c = 20°$

$Nx = 1.633 \pm 0.002$
$Nz = 1.653 \pm 0.002$

A chemical analysis of hornblende from an amphibolite from the southwest corner of the area is presented in Table 1. The optical properties of this hornblende are the following:

$2Vx = 71°$ $Z \wedge c = 12°$

$Nx = 1.658 \pm 0.002$
$Nz = 1.670 \pm 0.002$

The chemical composition and the optical properties are characteristic of hastingsite, a sodi-calcic hornblende, and are similar to those given by Deer, & all. (1963, vol. II, p. 288, no. 12).

In two thin sections of amphibolite from the northern part

of the area, colourless tremolite and pale green actinolite are the principal rock-forming minerals. Tremolite is also present as an accessory mineral in numerous thin sections. Pale green, slightly pleochroic diopside occurs in a hornblende gneiss as concentrations characterizing certain layers which alternate with hornblende bands. Augite is also

Table 1 : Chemical Analysis of Hornblende

SiO_2	43.10	H_2O^-	0.00
TiO_2	1.26	CO_2	0.05
Al_2O_3	11.21	S	0.019
Fe_2O_3	4.79	Cr_2O_3	0.12
FeO	8.56	V_2O_3	0.053
MnO	0.17	NiO	0.05
MgO	13.67	BaO	0.017
CaO	11.86	SrO	0.004
Na_2O	1.91	CuO	0.01
K_2O	1.02	Li_2O	0.009
P_2O_5	0.02	ZnO	0.04
H_2O^+	2.28	Total	100.22

Analyzed at the Department of Natural Resources Laboratories by Z. Katzendorfer and H. Boileau.

present in some thin sections but is a minor component of the rock which is usually replaced by hornblende. It is biaxial positive with a 2V of 55°, and $Z\wedge c = 42°$. Plagioclase is an important component of most amphibolites and ranges in composition from An_{13} to An_{25}, the average being An_{15}. One section contains plagioclase of a more calcic composition, An_{42}. Plagioclase occurs in xenoblastic grains showing

alteration to sericite and epidote to varying extents. It is usually twinned, but in some gneissic parts the twinning is less conspicuous and sometimes is entirely lacking. Biotite is a secondary mineral commonly enclosed poikilitically in the hornblende but is rarely abundant. Microcline is present in large quantities in some parts as a secondarily introduced component. Secondary minerals are quartz, epidote, clinozoisite, chlorite, magnetite and calcite. Accessory minerals are sphene, apatite and pyrite.

Table 2 : Modal Analyses of Amphibolites

	I	II	III	IV	V	VI	VII	VIII	IX
Hornblende	77.42	53.10	92.37	55.24	54.83	68.66	33.49	55.3	78.0
Plagioclase	1.99	37.25	-	25.46	19.47	29.96	45.99	22.6	10.0
Pyroxene	15.93	-	-	-	-	-	2.10	-	-
Biotite	0.99	4.87	6.50	-	1.68	-	6.2	4.1	11.0
Chlorite	-	-	-	2.28	0.73	tr.		-	-
Microcline	-	1.91	-	15.27	20.57	-	5.73	-	-
Epidote	tr.	1.34	-	1.06	1.62	tr.	5.16	7.0	2.0
Sphene	-	tr.	-	tr.	tr.	-	tr.	-	-
Apatite	1.69	tr.	tr.	-	tr.	tr.	tr.	-	-
Quartz	-	tr.	-	-	tr.	-	tr.	5.1	-

Sample I - from northeast of Rollet, Plagioclase = An_{20}. Layers of pyroxene.

Sample II - halfway between north end of Caire and Barrière lakes, Plagioclase = An_{16}.

Sample III- west shore of Des Quinze lake, northeast of Angliers.

Sample IV - west shore of Lebret lake, plagioclase = An_{16}.

Sample V - southwest of Nédelec, Plagioclase = An_{13}.

Sample VI - south of Angliers, plagioclase = An_{42}.

Sample VII- west of Rond lake, Plagioclase = An_{16}.

Sample VIII-from J.L.Robert, p.90, 1963- Average of 6 analyses-Plag.=An_{22}.

Sample IX - from P.V. Freeman, p. 40, 1957, Plagioclase is albite.

Modal analyses of seven thin sections (Table 2) illustrate the above-mentioned diversity of mineralogical composition. Classifying the rocks according to the system proposed by Jung and Brousse (1959), which uses the data of modal analyses to calculate color, saturation, potassic and other indices, we obtain contradictory results. Most amphibolites are rightly termed, but three are classed respectively with diorites, syenodiorites and hornblende monzonites. This lack of agreement is due to the fact that the classification applies to eruptive rocks. Sample VIII and IX are taken from Robert (1963) and Freeman (1957) and are included here to illustrate the similarity between the amphibolites of this area with those of adjacent areas.

Table 3 presents the chemical analyses of three samples from the area and of four different rock types from adjacent areas. To obtain an approximate chemical analysis of a rock from a modal analysis we used the chemical analysis of hornblende in the modal analyses of those amphibolites which are located in the vicinity of the analyzed hornblende and which also have hornblende with similar optical properties. Adjustments were made for the biotite and other minerals when necessary. The results are not to be taken as absolute but rather as relative figures. They indicate the relatively constant chemical composition of the amphibolites; the major variations are in the Na_2O and K_2O content and are caused by the selective appearance of microcline.

Stratigraphic relationships: The amphibolites are always associated with the biotite schist of the Pontiac group or with rocks of younger age. They are present in granitic rocks of all types but are always older than these granites as is indicated by cross-cutting

Table 3 : Chemical Analyses of Amphibolites

	I	II	III	A	B	C	D
SiO_2	42.44	49.94	49.98	50.20	50.62	49.88	54.02
Al_2O_3	11.40	14.93	14.52	15.90	14.95	13.88	15.67
Fe_2O_3	5.25	3.05	3.09	0.60	2.63	2.55	2.38
FeO	9.71	5.59	5.71	5.09	6.10	11.84	8.46
MgO	12.82	8.69	8.39	5.60	9.02	6.17	4.12
CaO	10.99	8.15	7.89	6.77	7.98	10.19	7.14
Na_2O	1.77	3.38	2.94	2.40	2.92	2.36	4.84
K_2O	1.48	2.81	3.71	0.34	2.78	0.41	0.64
H_2O	2.19	1.66	1.51	3.47	2.18	1.46	0.04

Samples I - II - III- correspond respectively to samples III-IV-V of Table 2.

Column A : Analysis of andesitic basalt from Duverny township, Faessler, 1962 - p. 48, no. 265.

——— B : Analysis of diorite from Lévy township, Opemisca intrusion- Faessler, 1962 - p. 60, no. 323.

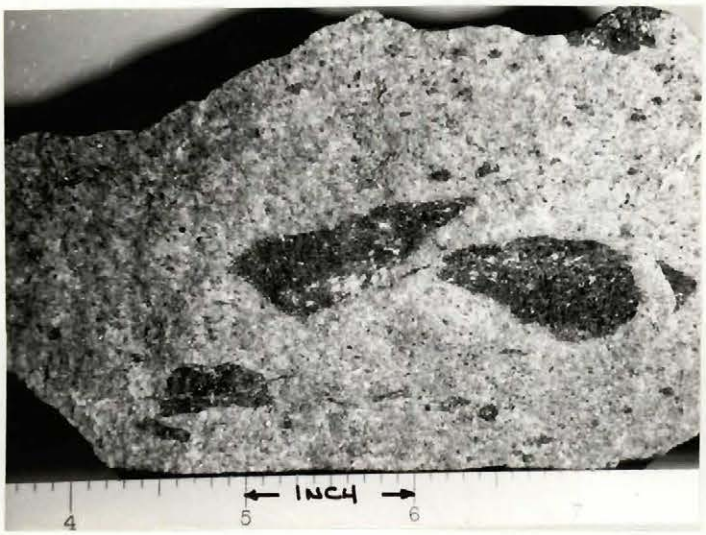
——— C : Analysis of diabase from Desmeloizes township - Normetal Mine - Faessler, 1962 - p. 76, no. 375.

——— D : Analysis of andesite from Dufresnoy township, Faessler, p. 45, no. 245, 1962.

and intrusive relationships. In the northwest part of the area amphibolite is invaded by hornblende-pyroxene syenite. North of Roulier, it is intruded by hornblende granite and oligoclase-microcline granite, being brecciated extensively. In the vicinity of Chevreuil lake it is intruded by hornblende syenite, and small elongated lenses of fragmented amphibolite remain as xenoliths in the syenite. (Photographs 12 and 13).

Origin: The origin of the amphibolites is problematical and certainly not unique; amphibolites of diverse origins are believed to be present in the area. To clarify the situation we have divided the amphibolites into six groups on the basis of location, composition, association and mode of occurrence. Each group will be discussed separately.

Photograph 12 : Fractured and partly assimilated inclusions of amphibolite in hornblende syenite, northeast of Chevreuil lake.



Photograph 13 : Small inclusions of amphibolite in hornblende syenite from northeast of Chevreuil lake. A light-coloured ring surrounds the inclusions.

A- Amphibolite associated with the biotite schist:

Most of the amphibolite belongs to this group and is as described above. The amphibolite could originate from the transformation of dolomitic greywacke, tuffaceous sediments, andesites, basalts, diorites and diabases or could be of igneous origin. Dolomitic greywacke can be excluded as a probable source because it is non-existent within the Pontiac group. Samples I to V in Table 2 belong to the presently discussed category of amphibolites and are of diverse mineralogical composition. Table 3 shows the chemical composition of three of these amphibolites and of samples of diabase,diorite, andesite and andesitic basalt from adjacent areas. It appears from this table that A, B, C and D are nearly equivalent to I, II and III, there being only minor variations, and they could be transformed without difficulty to amphibolites. Therefore, basalts, andesites, diorites and diabases could be represented in the area by the amphibolites. Undoubtedly we can add tuffaceous sediments to this list. Denis (1938) did describe some amphibolites occurring in sediments and expressed the belief that they represented a sedimentary facies. Northeast of Rollet there is a great mass of amphibolite containing some laminated and very schistose layers which could represent tuffaceous sediments. Pillow-like structures are also present in another part of that mass that are defined by a thin light-coloured layer. They could indicate the former presence of andesitic lavas.

Because of their concordant relationships, Robert (1963) supports the view that the amphibolites in the Kipawa lake area are derived from basic lavas or sills of basic intrusives. Wilson (1962)

writes: "Within the mica schist are five known occurrences of recrystallized volcanic rock originally probably andesite or in a few places, where banded phases occur, andesite tuff. The original andesite is now amphibolite, amphibolite-schist or a diorite-like rock type.." (p. 19).

Diffenbach (1961) holds the view that the amphibolite associated with the biotite schist west of Nédelec is of magmatic origin. The amphibolite at this location is very coarse-grained, porphyroblastic and massive. He writes: "The texture and composition of this rock are believed to be largely due to magmatic processes, modified somewhat by metamorphism and possibly by hydrothermal alteration. The size and the stout, euhedral shapes of the large hornblende crystals favor a magmatic origin. The presence of pyroxene helps to confirm this, because the highest grade of metamorphism to which the region has been subjected, indicated by the surrounding schists, is the amphibolite grade, which excludes the formation of pyroxenes." (p. 5). It should be explained to clarify the mention of hydrothermal alteration that molybdenite is associated with quartz veins cutting the amphibolite. The main outcrop of this occurrence displays confusing relations: The amphibolite is observed as sills and also as dyke-like bodies in the biotite schist. However, the rock was much deformed and irregular "boudins" of amphibolite are surrounded by schist which they seem to intersect. The size and shape of the hornblende grains are not believed to be criteria of magmatic origin and the presence of pyroxene may well indicate that the original rock was basic and was subsequently affected by retrogressive metamorphism. The pyroxene is strongly altered to hornblende and only ill-defined remnants are apparent at the core of some hornblende grains.

A magmatic source therefore seems improbable. The origin of this rock held to be most likely is from the metamorphism of intermediate to basic lavas or intrusives.

B - Amphibolites associated with granitic rocks:

The amphibolites associated with granitic rocks and other acidic intrusives are in every way similar to those mentioned above. They are not in contact with rocks of the Pontiac group but are older than the intrusive rocks. They are believed to be portions of the Pontiac group that were not assimilated by the granites. Their origin is then the same as that of the first category.

C - Amphibolite occurring south of Angliers:

This amphibolite occurs as a large elongated body near the southern limit of the area. Sample VI of Table 2 is representative of this rock. The plagioclase, andesine, is more calcic than that of any other amphibolite. In one thin section from this rock, remnants of pyroxene occur in the core of hornblende grains. A pseudo- or semi-ophitic texture is preserved, lending support to the assumption that the rock represents a diabase or a gabbroic rock.

D - Amphibolite occurring in the vicinity of Rond lake :

This amphibolite occurs south of Moffet as small and large separated masses and is characterized by the ubiquitous presence of pyroxene and by a porphyritic texture. Pyroxene, although not abundant, was observed in most of the thin sections of this rock. The amphibolite is altered and little pyroxene now remains. Small phenocrysts of hornblende, ranging in size from one-sixteenth to one quarter of an inch, held in a groundmass of hornblende, plagioclase and microcline

are common. The rock is intruded by hornblende syenite and oligoclase-microcline granite and is intensely brecciated in parts. Numerous elongated inclusions of amphibolite are found in the syenite adjacent to the amphibolite. The rock is believed to represent basic intrusives partly assimilated by granitic rocks.

E - Amphibolites in the vicinity of Bull Rock and Opasatica lakes:

Small dyke- or sill-like masses of amphibolite occur in the northwest corner of the area. The rock is composed of a felted mass of colourless tremolite and pale green actinolite, chlorite and magnetite. The magnetite is abundant and occurs as scattered dust. The rock is highly altered and the components are sometimes recognized with difficulty. The weathered surfaces display structures resembling pillows or polygons. This rock is in the vicinity of pyroxene dykes and of a small mass of serpentinite and may represent such ultrabasic rocks. It is not a member of the Pontiac group.

F - Amphibolite occurring south of Guérin:

This amphibolite is not really different in origin from category B. It consists of three occurrences of amphibolite along the east-west portion of the road just south of Guérin. It is characterized by strong brecciation in places and by a conglomerate-like appearance elsewhere. Rounded pebbles of amphibolite up to two inches across and of uniform size are enclosed in a matrix of hornblende and biotite and angular blocks of amphibolite, one to three inches in length, are enclosed in a matrix of hornblende and plagioclase. The brecciation is caused by the intrusion of hornblende granite but the origin of the

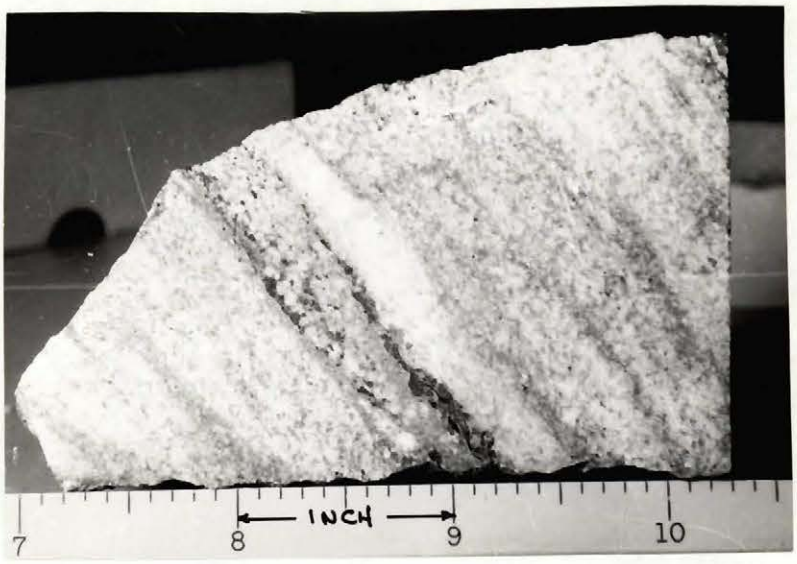
conglomerate-like part of the rock is unknown. It may be due to deformation prior to or contemporaneous with the intrusion, but there is no compelling evidence to support this opinion.

Metamorphism: The typical mineralogical association of the amphibolites is that of the staurolite-quartz subfacies of the almandine-amphibolite facies. Turner writes: "Here derivatives of basic igneous rocks consist essentially of hornblende and calcium-bearing plagioclase with or without epidote." (Fyfe, Turner and Verhoogen, 1958, p. 228). This classification corresponds to the lower part of Eskola's amphibolite facies. Eskola (1952) mentions that green hornblende is a reliable criterion of the amphibolite facies.

4- Quartz-feldspar Gneiss

Rocks belonging to this group occur in two widely separated parts of the area. The major zone of occurrence is along a curved belt between the two diverging branches of Des Quinze lake, northeast of Angliers and west of Moffet. The other zone, north of Rollet in the northwest corner of the area is much smaller than the first. The two zones contain rock types that may not be exactly similar and might more accurately be classified separately, but their mode of occurrence and association points to a common origin. The rock is usually in contact with the biotite schist into which it passes gradually. It forms lenticular masses of limited size intercalated in the biotite schist in the northwest part of the area. The quartz-feldspar gneiss in the south occurs as a wide belt which has a gradational contact with the biotite schist to the north and is injected and mixed with granitic material in the south.

The gneiss is fine-grained to medium-grained, whitish on weathered surfaces and grey to pink on fresh surfaces. Fine laminations, from one-sixteenth to one thirty-second of an inch in thickness, defined by concentrations of biotite, alternate more or less regularly with quartz-plagioclase layers, one quarter to half an inch in thickness.



Photograph 14 : Sample of quartz-feldspar gneiss.

The rock consists of essentially anhedral grains forming a granular mosaic with directional structure. Allotriomorphic and slightly elongated grains of quartz are intimately mixed with plagioclase grains in the dominantly acidic layers. The plagioclase is oligoclase (An_{15} to An_{18}), is usually untwinned and shows alteration to sericite. Biotite is present in small amounts as aligned euhedral crystals. Microcline occurs as interstitial grains and is never abundant. Bluish-green hornblende was found to occur in small quantities at a few localities. Clinozoisite is also a rarely occurring mineral. The rock is

relatively fresh and alteration products are not abundant. Epidote is the most frequently encountered secondary mineral. Accessory minerals are sphene, apatite, zircon, pyrite and magnetite.

In table 4 are shown the results of five modal analyses of quartz-feldspar gneiss from both zones of occurrences. The mineralogical composition of both types is very similar.

Table 4 : Modal Analyses of Quartz-feldspar Gneiss

	I	II	III	IV	V
Quartz	27.77	23.67	23.59	29.77	25.34
Plagioclase	64.54	60.49	67.88	55.39	63.88
Microcline	2.92	7.07	1.81	11.72	1.79
Biotite + chlorite	3.60	3.62	tr.	2.37	1.08
Epidote	tr.	tr.	1.18	-	tr.
Hornblende	-	4.56	4.99	-	6.92
Apatite	tr.	tr.	tr.	tr.	tr.
Sphene	tr.	tr.	tr.	tr.	tr.

Sample I- From the north end of Gaboury lake. Plagioclase = An_{16}.

Sample II- On small island in Des Quinze lake, just south of Fish Creek, Plagioclase = An_{15}.

Sample III- Halfway between Gaboury and Des Quinze lake. Plag. = An_{16}.

Sample IV- From the northwest corner of the area, along the highway, half a mile south of northern limit. Plagioclase = An_{18}.

Sample V - From the vicinity of Fish Creek. Plagioclase = An_{22}.

The gneissic structure is defined by the elongation of the quartz and feldspar grains, by the parallel alignment of the platy minerals and by the compositional layering. The rock may become schistose near the biotite schist, or the gneissic structure may slowly disappear in the vicinity of granitic intrusives and the texture then becomes hypidiomorphic granular as in normal granitic rocks.

The origin of this member of the Pontiac group is in all probability related to the granitic intrusions which transformed portions of the schist to the quartz-feldspar gneiss. The gneiss in the northwest part of the area has a gradual contact with the biotite schist and may be a clean facies of the schist representing arkosic layers. However, the quartz-feldspar gneiss also grades into the grey granitic gneiss which is abundant to the west of the major occurrences and may represent a partly melted and "remade" portion of the schist. The quartz-feldspar gneiss in the south occurs in a wide belt and has relations to the schist and granite similar to those of the northern gneiss.

Photograph 15 : Outcrop of quartz-feldspar gneiss at northern end of Gaboury lake. The dark layers are lenses of biotite schist.

Bands of oligoclase-microcline granite have been found in the central portion of the belt of gneiss, strongly indicating that the gneiss is partly of granitic derivation. The distinction between the two rock types is sometimes so subtle that it is difficult to tell them apart.

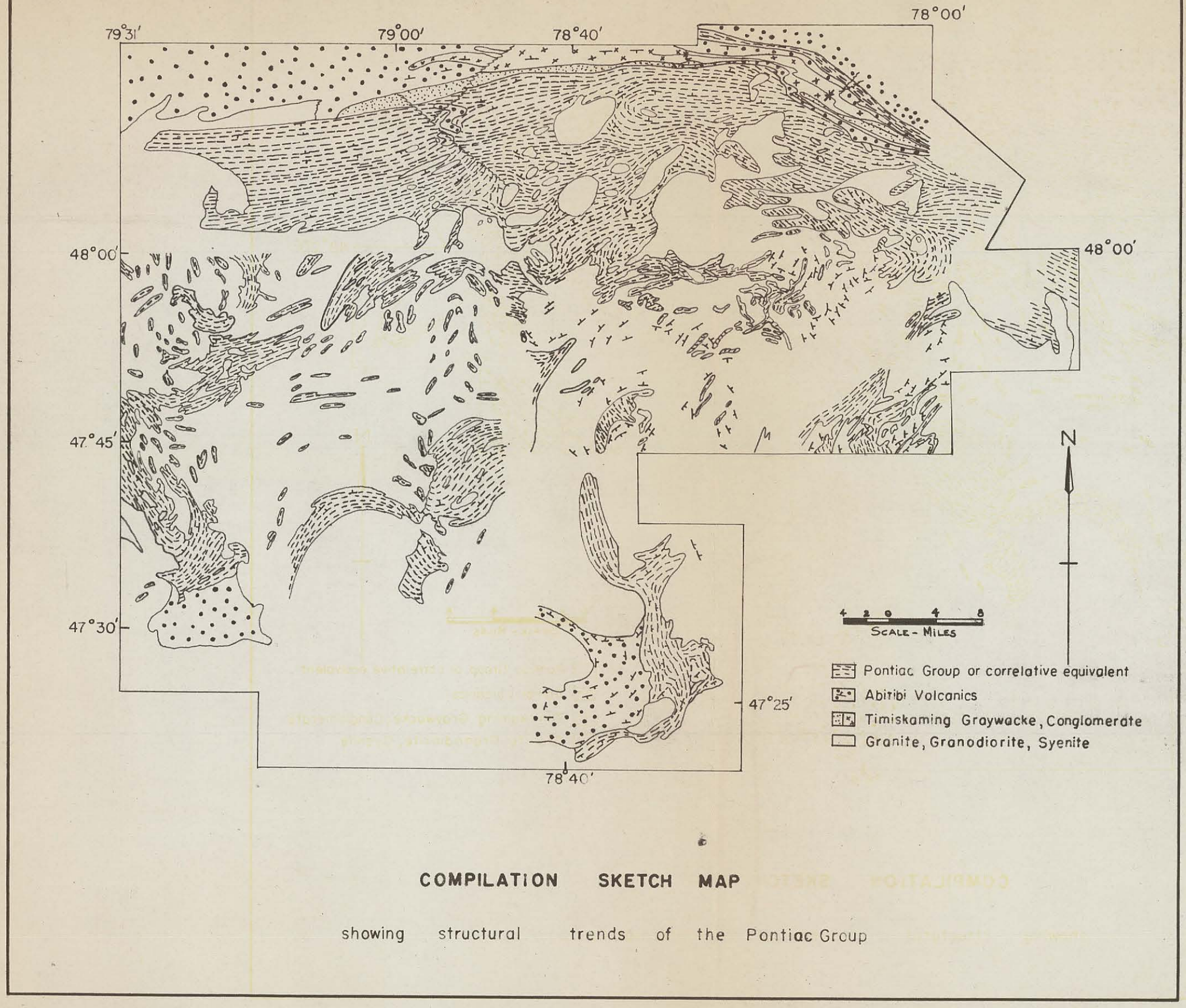
Thus this division could be classified with the granite, but it is discussed here because of its strong affinities to the biotite schist.

5 - Quartz-feldspar-biotite Schist and Quartz-feldspar-biotite-hornblende Gneiss

This division of the Pontiac group is the most important because of its widespread occurrence and structural significance.

The biotite schist outcrops mainly in the southeast, southwest and northwest parts of the area along wide belts but minor occurrences are present elsewhere as irregular lenses in the intrusive rocks. Three principal belts are defined by the schists and are separated by masses of granitic rocks (see figure II, showing the distribution of the Pontiac group). These belts appear on topographic maps as low curvilinear ridges trending in a direction paralleling that of the foliation. They consist mostly of quartz-feldspar-biotite schist with minor intercalations of amphibolite. Biotite schist occurs also as isolated lenses of various dimensions in granitic rocks. The lenses are numerous near the belts where they appear to be structurally continuous. Away from the belts, they are increasingly tenuous but seem to preserve their structural continuity and to be relatively undisturbed. The quartz-feldspar-biotite-hornblende gneiss occurs within the biotite schist at a few localities and is never abundant.

Lithology: The biotite schist consists of biotite rich layers, from half an inch to eight feet in thickness, alternating with quartz and plagioclase rich layers from half an inch to two feet wide.(Photograph 16). The layers are not uniform and homogeneous but show concentrations of mafics along the foliation, giving the rock a laminated appearance. Some layers appear to be massive and are homogeneous,

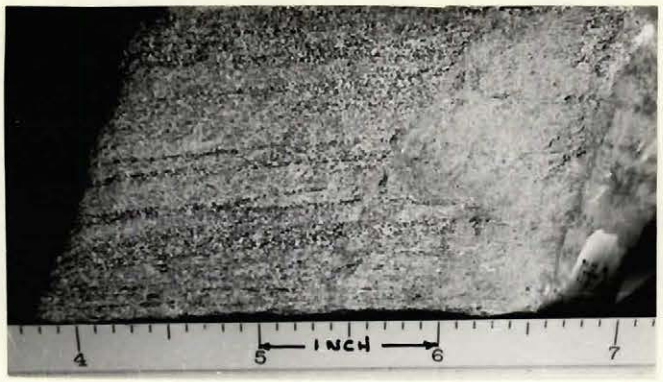


COMPILATION SKETCH MAP

showing structural trends of the Pontiac Group

figure 2.

whereas others appear to be massive on fresh surfaces but are actually laminated, the laminations appearing only on weathered surfaces.



Photograph 16 : Sample of Pontiac schist . The biotite-rich layers are apparent.

Photograph 17 : Ridged appearance on weathered surface of biotite schist

Veins, lenses and pods of quartz, commonly elongated along the schistosity, give the rock a ridged appearance on weathered surfaces because of differential weathering. Similar ridges also protrude

that are composed not only of quartz but also of feldspar and biotite as in the surrounding rock. Wilson (1912, p. 28) writes: "The greater resistance to weathering shown by the schist at these points arises apparently from a slightly finer texture since the ridges differ in no respect from the rest of the rock. The origin of the textural variation was not apparent but might possibly arise by recrystallization along rectangular joint planes." Most of the ridges examined are more siliceous than the adjacent schist and thus could also result from differential weathering.

Petrography: The biotite schist is a dense, light grey to dark grey, fine-grained to medium-grained rock. In some places it has a rusty appearance due to oxidation of pyrite which it sometimes contains.

Examination under the microscope shows that the rock consists of a lepidoblastic aggregate of fine grains of biotite, quartz and feldspars. Muscovite and microcline are present here and there but always in small amounts. Accessory minerals are apatite, sphene, zircon, pyrite and magnetite. Secondary minerals are sericite, chlorite and epidote. Epidote, generally formed at the expense of biotite appears to be rich in iron. Alteration products are not abundant, because as a rule, the biotite schist is fresh. Biotite commonly displays bleached borders and incipient alteration to chlorite and/or epidote. Quartz occurs as small undulose and elongated individuals, frequently coming to extinction simultaneously. In samples from the southern part of the area, quartz was found to be of varied size and angular, coarse- to medium-sized grains lying in a fine-grained matrix of quartz, plagioclase and biotite. Plagioclase is usually granular, untwinned and often shows

incipient alteration to sericite. The composition of the plagioclase is not constant but varies from An_{15} to An_{25}, from north to south. Layers of granitic material introduced into the biotite schist contain grains of twinned plagioclase of An_{20} composition.

Biotite occurs as medium-sized grains and has the following properties: Ny = Nz = 1.632 ± 0.002.

Absorption formula : X = pale-yellow
Y = reddish-brown
Z = dark brown

Biotite usually has a strong preferred orientation, although in the more massive examples it displays no such structural feature. Some of the grains are slightly bent to conform with the curvature of grains of feldspar and quartz and in samples from the southern part of the area, blastopsammitic grains are enveloped by biotite. In one sample from a locality where nodular pyroxene syenite intrudes the schist, garnets are abundant in the schist and displace the foliation outlined by the parallel alignment of biotite. Coarse, porphyroblastic grains of biotite are sometimes present in the rock, especially where it is strongly deformed. Common green hornblende occurs in some parts as medium-sized grains concentrated along layers. The biotite is then rare and the foliation is not strongly developed.

The foliation is always apparent in thin sections, excluding some extreme cases. Usually, layering is suggested by a concentration of ferromagnesian minerals and foliation is outlined by the parallel alignment of the platy minerals and is further enhanced by the simultaneous extinction of the quartz grains. The samples from the southern part of the area are not distinctly foliated, the texture is

not equigranular and the rock is not entirely recrystallized.

Table 5 contains the results of seven modal analyses of biotite schist, five of which are from adjacent areas. All the samples are believed to come from the Pontiac group or correlative equivalents. Table 5 illustrates the fact that the mineralogical composition varies within a narrow range.

Table 5 : Modal analyses of Biotite Schist

	I	II	III	IV	V	VI	VII
Quartz	33.01	26.32	26.0	35.0	30.0	60.0	50.0
Plagioclase	44.18	53.07	51.0	48.0	44.0		
Microcline	tr.	-	-	-	-	-	-
Hornblende	-	18.60	-	-	-	-	-
Biotite	21.06	0.61	15.0	8.0	15.0	35.0	16.0
Muscovite	1.28	-	tr.	5.0	5.0	-	34.0
Chlorite	-	-	-	-	-	2.0	tr.
Epidote	-	-	5.0	-	2.0	-	-
Apatite	tr.	tr.	-	-	-	-	-
Magnetite + pyrite	tr.	1.14	-	-	-	3.0	1.0

Sample I - from the south end of Roger lake. Plagioclase = An_{20-22}.

Sample II- Two and a half miles west of Opasatica L., opposite Solitaire bay. Plagioclase = An_{25}

Sample III- IV- V - Lake Kipawa area, Robert, 1963, p. 46. Biotite-muscovite paragneiss. Plagioclase = An_{21} for all samples.

Sample VI - VII - Malartic district, Kewagama group (Pontiac series), VI is from unaltered greywacke, VII is from greywacke. Eakins, 1962.

Granitization - Migmatization : In the west central part and in the northeast corner of the area, the biotite schist is invaded by oligoclase-microcline granite and this intrusion is accompanied by large-scale granitization and migmatization.

Granitization is indicated by the presence of "ghosts" or streaks of schist in the granite and by an increase in the size of the

biotite in the schist; muscovite, as a replacement of biotite, is also present. Gradational contacts between the layers or streaks of biotite schist and the granite are very common and numerous lenses of partly digested schist are left which show structural continuity although they may be widely separated.

Complex interlayering of the schist with granitic matter is a characteristic feature of areas that are in the neighbourhood of the granitic masses. Granitic and pegmatitic material occur as lit-par-lit injections, concordant lenses or discordant bodies. In these areas, the schist preserves its characteristic features but is highly disturbed.

Structure : Bedding - The original sedimentary bedding, graded-bedding and small-scale cross-bedding are well preserved in the less deformed portions of the schist adjacent to the greywacke near Des Quinze river. In the more typical parts of the schist no bedding is visible as such but is assumed to be represented by varied compositional layering alternating more or less regularly and always parallel to the schistosity. These layers sometimes give the rock a varve-like appearance. It has been suggested that the bedding is always parallel to the schistosity (Wilson, 1913 and Freeman, 1957), but this relation cannot be expected to apply everywhere. Indeed, in the less deformed portions of the schist, the foliation can be seen to intersect the bedding in some places and to be parallel to it in other places.Whenever a fold closes, the relation suggested by Wilson anf Freeman cannot be used.

Foliation - The foliation defined by the pre - ferred orientation of the tabular mica along s-planes is a dominant

character of the rock, except in the southern half of the area where the schistosity is not strongly developed and some parts of the rock are almost undisturbed. Quartz grains commonly show simultaneous extinction, denoting a preferred lattice orientation of the grains. The foliation is not always apparent on fresh surfaces but is best observed on weathered surfaces. The schistosity is an axial plane foliation which has probably developed from slaty cleavage with progressive metamorphism.

Lineation - Three different types of lineation were recognized:

A- A lineation faintly defined by the preferred orientation of boundaries of tabular crystals within the schistosity plane.

B- A lineation outlined by the parallelism of the axes of microcrenulations on the s-surfaces. On a slightly bigger scale, this lineation is also formed by the parallelism of the axes of parasitic folds.

C- A lineation defined by the intersection of bedding and schistosity, where bedding is preserved.

Jointing - A joint set is developed perpendicular to the schistosity and where the dip is low gives rise to cuesta-like ridges. Veins of quartz, granitic material and pegmatite commonly occupy joint planes. The general joint pattern is discussed more extensively in chapter V.

Shearing and Faulting - A small number of shear zones of limited extent have been observed in the schist. Numerous small faults with negligible displacements also occur in the biotite schist. These features are not important but they are useful. Many of these faults are the result of deformation contemporaneous with the intrusion of the granitic rocks as is indicated by the

relationships displayed by granitic dykes and the faults. Some granite dykes are displaced while other dykes having similar attitude and composition are not displaced by the same fault. Acidic dykes often occupy fault planes. Strike-faulting is undoubtedly common but never obvious and, in a few instances, acid dykes are displaced along the schistosity indicating the presence of these faults. Only one major fault has been observed in the biotite schist, at the northeastern extremity of Barrière lake. It is discussed in chapter V.

Folding - The biotite schist of the Pontiac group has been folded intensively. The various types of folds can be divided on the basis of their order or magnitude into two principal classes:

A- Minor Folds:

1)- Parasitic folds: large folds are inferred by the presence of mesoscopic folds,"drag-folds", of different forms and amplitudes. The smallest folds occur within biotite-rich layers less than half an inch thick and define a crenulation not unlike small-scale ripple-marks.The larger folds involve more than one layer and may be as much as fifteen feet wide.

2)- Intrafolial folds: Turner and Weiss (1963, p. 116-117) define them in the following terms: "They are tightly oppressed plane folds occurring sporadically as relatively slight distortions of dominantly planar foliation....Closely related are rootless intrafolial folds which consist generally of an isolated closure or of a pair of opposing closures in a disrupted portion of a layer now "floating" as a tectonic inclusion in relatively unfolded foliation." Such folds have been

Photograph 18 : Parasitic folds in biotite schist. The dark layer is rich in amphibole. Faulting is apparent.

Photograph 19 : Parasitic fold in biotite schist. The dark layer is rich in amphibole. Crenulations are visible at the center of the photograph.

recognized in the map-area and can be used as "one of the criteria of transposition of s-surfaces." (Turner and Weiss, 1963, p. 117). However it is also possible that these folds are not of tectonic origin.

3)- Disharmonic folds: folds of diverse forms within a larger fold have been observed and although different from the larger fold they share some geometric elements and preserve its identity. These folds may be special cases of 1)- and 2)-.

4)- Ptygmatic folds: this type of fold is common in areas of granite intrusion and injection. It will be described in chapter V.

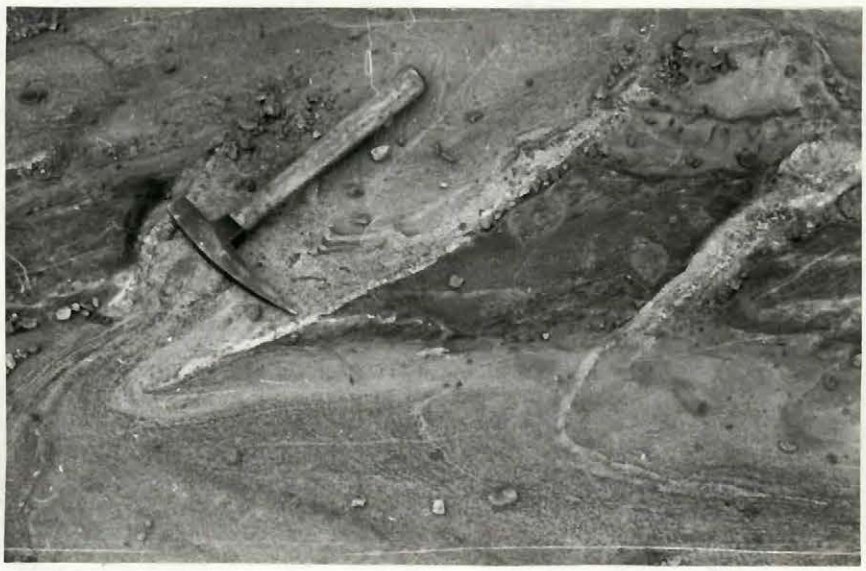
B- Major Folds:

These folds are the most important elements in the regional structural pattern and, because they implicate elements other than the Pontiac members, will be described and analyzed in chapter V. Suffice it to mention here that they are defined by the foliation of the schist which outlines the curvature at the closure of the fold and that no marker horizons are available to outline the precise forms of these structures.

Boudinage - Sausage-like shapes are common in the amphibolite layers intercalated in the biotite schist. The amphibolite, being more competent than the schist, is stretched in a plane parallel to the plane of the foliation and parts in the direction of the dip of the layers. The stretching of the brittle amphibolite is accompanied by squeezing of the more mobile biotite schist on either side into the spaces formed. The "boudins" are often fractured by shear planes oblique to the foliation. In places, the amphibolite breaks into angular blocks along shear planes crossing the layering at a large

angle and forms structures which could be named "cleavage mullions".

Photograph 20 : Boudinage. Amphibolite layer in biotite schist.



Photograph 21 : Boudinage. Angular blocks of amphibolite fractured by shear planes.

Metamorphism : The mineral assemblage of the biotite schist is relatively constant throughout the area. The composition of the plagioclase ranges from An_{15} in the north to An_{25} in the south.

Exceptions and variations occur where granitic intrusions have transformed the biotite schist and albite has been observed in one thin section from the northern part of the area.

The biotite schist belongs to the staurolite-quartz subfacies of the almandine-amphibolite facies as defined by Turner (Fyfe, Turner and Verhoogen, 1958, p. 228) and is characteristic of relatively high-grade zones of progressive regional metamorphism. "Prevalence of hydrous silicates (micas and amphiboles) points to high water pressure. Since rocks of this facies commonly grade into migmatites veined with granitic materials, the upper limit of temperature cannot be much less than 700° C." (Fyfe, Turner and Verhoogen, 1958, p. 228). Evidence indicative of retrogressive metamorphism was observed in a few thin sections, biotite being sometimes altered to chlorite or displaying a "diseased" appearance.

Stratigraphic Relations : The stratigraphic relations of the biotite schist, and of the Pontiac group in general, cannot always be established from direct evidence obtained in the field and it becomes necessary to supplement the field evidence with the available data published in the literature. The biotite schist is a poor source of information due to the lack of distinct stratigraphic units and only the intrusive relationships are of use. The amphibolite bands intercalated in the schist are of no significant value because of their limited extent and lack of distinctive characteristics. Only the less deformed parts of the biotite schist, where sedimentary features are preserved, yield useful information.

1- Relation of the Pontiac group to the volcanic-sedimentary assemblages.

A- Northern extent of the group : The rocks of the Pontiac group occur from the southern part of the map-area to the northern boundary and, although not actually continuous over the whole distance, they appear to have stratigraphic continuity which is evident from the proximity of the various zones, the monotonously similar lithology and the structural pattern of the area. They extend north of the boundary into adjacent areas, where they have been observed and described by Wilson (1912, 1913,...1962) and Podolsky (1950).

B- Relations to the "Keewatin-Timiskaming" volcanic-sedimentary assemblage north of the area : The relations of the Pontiac group to the volcanic-sedimentary rocks north of the area cannot be established from evidence obtained in the present map-area because no units from these assemblages occur here. We will therefore present the conclusions of those authors who expressed their views on the subject.

Podolsky (1950) writes that the Pontiac group is separated from the overlying Timiskaming rocks by a structural and erosional unconformity but that the relationships of the Pontiac to the Keewatin are unknown. Wilson (1962, p. 6) suggests "that the Pontiac group may belong to the Abitibi group" and he supports the hypothesis of Gunning and Ambrose (1939) "that the rocks of the Pontiac (Kewagama) group are part of the south limb of a major syncline.", he further writes (p. 18) that "originally the belt must have been considerably more extensive, for it is cut off on the north by the pre-Timiskaming unconformity..." The only observed contact between the Pontiac group and the Keewatin volcanic rocks is a faulted contact.

In concluding we will summarize the prevalent views on this subject: The Pontiac group is overlain unconformably by the Timiskaming. It is part of the Abitibi series or group, is equivalent to the Kewagama group and belongs to the upper portion of the Keewatin assemblage.

C- Relations of the Pontiac group to the volcanic-sedimentary assemblage in the southern sector of the area : The Pontiac group is in contact with a volcanic-sedimentary assemblage that extends south of the area into the Ville-Marie and Guillet map-areas described by Henderson in 1936.

The contact between the volcanic rocks and the biotite schist was observed over a distance of fifty feet at one locality, 1400 feet north of Des Quinze river, almost due south of Guérin. Elsewhere in the region, the contact can only be inferred by extrapolation between outcrops of the two rock types and by interpretation of physiographic details. The lavas usually have more relief than the schist and an abrupt change in topography corresponds to the contact zone. The observed contact is abrupt, suggesting a rapid change in conditions from volcanic to sedimentary. South of the contact, the volcanic rocks exhibit deformed pillow structures, but in the contact zone itself they are schistose. The zone is not more than four inches wide, excluding the deformed portions of the Pontiac group. The lavas are massive up to two inches from the contact and from there are transformed into a chloritic schist. The contact itself is a regular line which separates the two types along a direction parallel to the foliation of the biotite schist. It displays no spectacular features and is so inconspicuous that it can easily be overlooked because of the similar external aspect of

the two different rock types. The schist of the Pontiac group is similar to the biotite schist found anywhere else in the area, except that it is finer-grained. No sedimentary features are preserved at the contact,but 2000 feet north of it they are apparent and the rock as a whole is not deformed.

On the south shore of Des Quinze river, one mile east of the extremity of the north-south road from St-Eugène, along or close to a fault zone, lenses of sedimentary rocks intercalated in the volcanics were observed. This occurrence is at a locality just south of the contact, of which it may actually be part, implying that the contact is not abrupt but a gradual transition. North of the river, northeast of the observed contact, small lenses of volcanic rocks were observed in the schist, also indicating a gradual passage from dominantly volcanic to dominantly sedimentary conditions. The presence of chlorite schist and deformed parts of the Pontiac group at the contact may indicate that it is faulted and therefore that the true nature of the contact cannot be known. However, even if faulting did occur, there are still some valid indications as to the nature of the contact. The presence of volcanic lenses in the schist not far away from the contact zone and the observed occurrence of sediments in the volcanics near the contact zone clearly indicate a gradual transition rather than an abrupt change.

The attitude of the sedimentary rocks just northwest of the contact, where sedimentary features are preserved, indicates that the sedimentary rocks overly the volcanic rocks. However, we have no determination on the attitude of the lavas near the contact, but

further south pillow structures indicate that the top of the lava flows is to the south. We cannot therefore determine if the sedimentary rocks overly the volcanic rocks conformably.

Denis (1938, p. 33) mentions that "light to dark grey schists occur as intercalations near the top of the greenstones", and adds further that the schists are more abundant upwards. He also states that "Temiscamian-type metasediments" overly the greenstone belt, the trend of the sedimentary belt being similar to that of the greenstone belt (p. 69-70). He did not see any evidence of unconformity between the schist and the volcanics; instead he suggested a gradational contact because of the frequency of the metasediments near the top of the greenstones. "Conformity of attitude of the formations favor conformable relationships." (Denis, 1938, p. 71).

Auger (1952, p. 20) reports similar observations and conclusions. Henderson (1936) shows that the sedimentary rocks overlie the greenstone and states (p. 13) "The contact between the Keewatin volcanic rocks and the overlying sediments appears to be gradational.." and "The conformable relations between the Keewatin volcanics and the pre-Huronian sediments appear, therefore, to be well established.."

The "Temiscamian-type metasediments" of Denis, the sediments of Auger and the "Keewatin (?) sediments" of Henderson are in every way similar to those of the area under study and are also in close spatial relationship. Consequently the observations and conclusions of these authors are considered as additional supporting evidence for the view that the Pontiac group overlies the volcanic rocks conformably.

2- Relation of the Pontiac group to the granitic rocks.

The Pontiac group is intruded by hornblende granite and oligoclase-microcline granite and in the case of the latter the intrusive relationships are obscured somewhat by granitization.

Age and Correlation : The rocks of the Pontiac group have always been assumed to be of Archean age because of their relationships with the Timiskaming sediments and their association with the Keewatin formations. This is supported by the relationships observed in the area and also by absolute age determinations. From a sample of biotite schist collected by K.R. Dawson and P.V.Freeman in the region adjacent to the northeast part of the map-area, absolute age determination by the K-Ar method yielded a figure of 2,460 million years (Lowdon, 1960, p. 33). The age obtained for this sample is valid for the rocks of the Pontiac group in the northern part of the area and corresponds closely with the ages obtained for rocks of the Keewatin assemblage. Snelling (1962, p. 13) states "that regional metamorphism of the Pontiac schist (GSC 59-77) occurred 2,460 million years ago and intrusion by granitic rocks (GSC 59-78) about 2,285 million years ago." However, no age determinations were obtained on samples from the southern part of the area and the result of the above-mentioned analysis cannot be used as representative of the whole area. Lower ages would probably be obtained in the south, inasmuch as the effects of the metamorphism of the Grenville orogeny are progressively stronger to the south.

The sedimentary rocks of the Pontiac group are believed to be correlative equivalents of the "Temiscamian-type metasediments" described by Denis (1938) and Auger (1952) and the "Keewatin (?)

sediments" described by Henderson (1936). J.L. Robert (1963) mentions that the schists in the northern part of the Kipawa lake area are correlative equivalents of the Pontiac group. This view, also held by the author, is supported by lithological and structural evidence. The width of the belt of Pontiac rocks is thus extended from "10 or more miles" (Wilson, 1962, p. 18) to approximately sixty miles, including numerous interruptions.

Origin : The origin of the Pontiac group has been extensively discussed by P.V. Freeman (1957) and M. E. Wilson (1962). Their views will be condensed and discussed in the light of observations made in the area now under study.

The following features of Pontiac rocks pertain to their origin:

1- Graded-bedding is abundant in the well preserved parts of the rock.

2- Cross-bedding is rare.

3- Ripple-marks are absent.

4- Scour and fill features are common.

5- The predominance of greywacke is in marked contrast to the absence of pure quartzite and limestone.

6- The bedding in the greywacke is similar to the varves of the clay of post-glacial lakes.

7- The abundance of plagioclase in the rock is characteristic.

The first six features are those of Archean sediments and are those enumerated by Pettijohn (1943) who concluded that the greywackes of the Canadian shield are the result of rapid, probably marine, accumulation in a geosyncline adjacent to mountains. This opinion is

supported by Podolsky (1950) who writes that the Pontiac strata were deposited in a rapidly sinking geosynclinal trough. He also mentions that the sediments are typical "poured-in flysch-type" (p. 89). Wilson (1962, p. 27) presents four alternative modes of origin and concludes that "The mica schist, presumably metamorphosed greywacke, of the Pontiac group illustrates a remarkably uniform and extensive belt of sediments of the unsorted type, and if it is the structural equivalent of the relatively thin Clériсy or Kewagama zone of similar rocks in the north limb of the synclinorium, as Gunning and Ambrose believed, then it thins northward away from its southern mountain source, and therefore, has all the characteristics of piedmont deposits laid down either in a large lake or in the sea."

Freeman (1957) also adds that the relative abundance of plagioclase in the southern greywacke suggests that the southern source was already a mountain built land, in which granites had been emplaced, as the plagioclase is of the acidic type, commonly associated with rocks of the granite family.

The mica schist definitely is the metamorphosed equivalent of the greywacke into which it was observed to grade. This would imply that, excluding local variations, the greywacke was deposited over an extensive belt. This implication presents an objection to a southern mountain source for the sediments (Wilson, 1962). The belt, it is now evident, is wider than was originally thought and the source would be much farther south than originally assumed, unless it is in the central part of the area, now occupied by granitic rocks. If the source were south of the belt, it would be in the Kipawa lake area or south of it.

That the source was in the central part of the area, where granitic rocks now occur, cannot be proven because the intrusions have obliterated any evidence that might remain. Bass (1961) suggests that there is no single source of sediments but many volcanic centers from which the debris spread radially. This idea is plausible because volcanic rocks appear south of the main belt (Rouyn-Malartic) and are interlayered with the sediments, presenting a picture of conditions alternating from volcanic to sedimentary.

The nature of the source is intimated by Freeman (1957) to be a mountain built land in which granite had been emplaced. There is little evidence, other than the abundance of plagioclase in the rock to support this view, all traces of the mountain built land being obliterated. There is also no evidence for a source of any other nature except the proximity of intermediate and basic volcanic rocks.

To summarize : the biotite schist of the Pontiac group is the equivalent of greywacke, the greywacke has characteristics of geosynclinal sediments derived from acid igneous rocks and the location of the source of sediments is unknown, but it may not be too localized and may possibly be of diverse nature.

C - Intrusive Rocks

1- Pyroxene-Biotite Rock

Two outcrops of a pyroxene and biotite bearing rock were examined in the vicinity of Barrière lake. The most accessible and the best exposure is along the west shore of Barrière lake, four and a half miles north of the village of Rémigny. The second outcrop is one and a half mile away from the east shore of Barrière lake, just south of Chabot lake.

The rock is medium-grained, dark brown on a weathered surface and dark-green on fresh surfaces. The weathered surface is pitted, the easily soluble carbonates having been removed by weathering. The texture of the rock can best be described as allotriomorphic-granular, although the biotite is sometimes coarsely developed, giving the rock a pseudo-porphyritic texture.

The principal component of the rock is diopside, occurring as subhedral grains. Biotite, present in subordinate amounts, is also a major constituent of the rock. Accessory minerals are apatite, sphene, quartz, hornblende, plagioclase and microcline. Secondary minerals are chlorite, epidote and carbonate (calcite or dolomite). Biotite, when it occurs as phenocrysts, usually has bleached borders.

The pyroxene-biotite rock is cut by dykes of granite and pegmatite, from two to five inches wide. Oligoclase-microcline granite is also present near the pyroxene-biotite rock but no sharp contact is apparent. The transition zone in which a gradual passage from one rock type to the other is effected, is approximately two feet wide. Elongated fragments of a rock, intermediate in composition between the two types, are sometimes present in the transition zone. They probably represent broken up parts of the transition zone itself.

The origin of this rock is problematical. The pyroxene-biotite rock may be a lamprophyre, although it does not display conspicuously the characteristics usually associated with lamprophyres. The rock does not appear to occur as a dyke and the porphyritic texture is not a dominant and ubiquitous feature. The rock may be a relatively melanocratic facies of the hornblende granite with a basic character

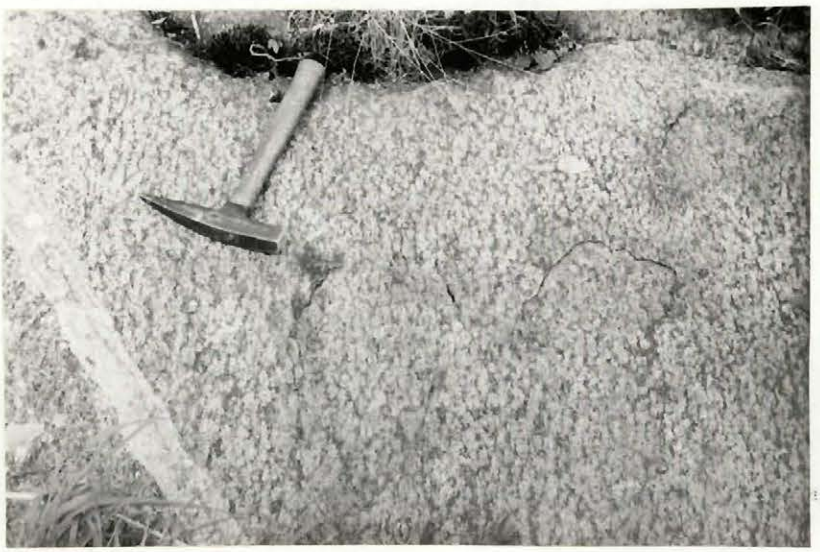
due to assimilation of extraneous material. The hornblende granite although not in direct contact with the pyroxene-biotite rock is abundant in the vicinity of the two outcrops observed. Another hypothesis is that the rock is related to the nodular pyroxene syenite which resembles it in composition and mode of occurrence. Nodular syenite was recognized in the vicinity of the outcrop of pyroxene-biotite rock located south of Chabot lake. The texture of the two rock types is different but the presence of the nodules is not a pervasive character of the syenite. The composition of the two types is not exactly alike, the syenite being rich in plagioclase and potassic feldspar. But the central portion of the syenite masses is often similar in composition to the pyroxene-biotite rock.

2- Nodular Pyroxene Syenite

Small masses of nodular syenite were observed at many places in the map-area. The most conspicuous and spectacular examples are located just south of Solitaire river, two miles southeast of Rollet,and along the west shore of Barrière lake. Small outcrops occur at many points along both shores of Barrière lake, on the northeast tip of Bryson island in Simard lake, three miles north of Moffet, west of and along route 46a, southeast of Chabot lake and near the village of Rémigny. Outcrops of this rock were also found elsewhere but they were of such limited extent that they could not be represented on the map.

The rock occurs as irregular masses, sills and dykes, varying from a few feet to one thousand feet in width. It is generally medium-grained, brownish on a weathered surface and green on a fresh surface. The nodular texture is a distinctive characteristic of the

rock which is best observed on weathered surfaces where discrete light-coloured patches of feldspathic material stand out prominently from a dark brown groundmass. The diameter of the patches or nodules varies from one quarter of an inch to one inch in the more striking examples, the average size being half an inch. The nodules are not perfectly spheroidal, but are elongated in two of their dimensions, namely the length and the height, so that they resemble ovoid cylinders. However, the nodules are an integral part of the rock; they do not weather out as separate bodies, like the pebbles of a conglomerate. They merely are the result of a textural effect and they are difficult to distinguish on fresh surfaces and are not recognizable in a thin section.



Photograph 22 : Nodular pyroxene syenite. The density of the nodular texture is very high here. (West shore of Barrière lake).

The composition of the rock is not constant and varies widely within a single showing and also from one outcrop to another. The

rock consists of plagioclase, pyroxene and microcline. Hornblende, biotite and quartz are sometimes important constituents of the rock but are relatively uncommon. The plagioclase varies in composition from An_{15} to An_{25} and is commonly altered to sericite to various degrees. It constitutes from five percent to forty-one percent of the rock and occurs in grains slightly larger than those of the other minerals. Plagioclase often contains inclusions of amphibole and pyroxene. The pyroxene is usually augite and occurs as equant grains generally smaller than those of adjacent minerals. The augite alters to hornblende which commonly rims it and it is twinned. It makes up to fifty-five per cent of the rock, twenty-five per cent being common. Microcline occurs as interstitial grains, often showing replacing relationships to plagioclase, such as patches in plagioclase crystals or veinlets of microcline cutting through a plagioclase crystal and apparently penetrating along cleavage lines. Microcline constitutes up to thirty-five per cent of the rock, the mean average being ten per cent. Hornblende is a common mineral of the syenite, either as a primary or as a secondary component. The optical properties of the hornblende from a representative sample are as follows: $Nx = 1.669 \pm 0.002$, $Nz = 1.688 \pm 0.002$,

$2V = 62°$, $Z\Lambda c = 22°$,

Absorption formula: X = light green, Y = yellowish green, Z = bluish green. These properties are similar to those of hastingsite. Hornblende usually occurs as large automorphic grains, sometimes four times as large as the pyroxene crystals. It frequently displays twinning and alters to chlorite and epidote. The syenite contains up to forty-four per cent hornblende, twenty-five per cent being the average. Biotite constitutes

up to seventy per cent of the rock and is usually a primary mineral. It alters readily to chlorite. Quartz is a rare component, but in one case it makes up to seven per cent of the rock, occurring as small interstitial grains. Common accessory minerals are apatite, sphene and magnetite.

Table 6 shows the results of the modal analyses of four thin sections.These results show the extreme variations in mineralogical

Table 6 : Modal Analyses of Nodular Pyroxene Syenite

	I	II	III	IV
Plagioclase	36.21	41.31	30.86	31.62
Microcline	10.06	6.56	8.72	16.92
Pyroxene	0.67	2.05	22.22	-
Hornblende	44.68	33.94	18.02	42.65
Quartz	-	-	0.16	-
Chlorite	4.19	13.44	17.69	2.57
Epidote	tr.	tr.	tr.	4.70
Apatite	tr.	tr.	tr.	tr.
Sphene	1.00	1.39	0.80	tr.
Biotite	2.18	---with chlorite---		

I - Sample from an isolated outcrop along the east shore of the southern extremity of the east branch of Barrière lake. Irregular mass of syenite. Plagioclase = An_{17-18}.

II- Sample from the outside part of a sill - along the southwest shore of Barrière lake, two miles south of Solitaire river. Plagioclase = An_{23}.

III-Sample from the central part of a sill (Same as II).

IV- Sample from an isolated outcrop along the road, one mile north of Rémigny. Plagioclase = An_{17}.

composition. The center of a sill is generally enriched in pyroxene and the border zones contain much hornblende. This is especially true for the major occurrences.

The nodular pyroxene syenite usually outcrops in the

vicinity of hornblende granite into which it grades. It is also of common occurrence near the volcanic rocks west of Des Quinze lake, north of Angliers. In the northern parts of the area, in the neighborhood of Rollet, the syenite is frequently intersected by dykes of oligoclase-microcline granite and of pegmatite. Few sharp contacts with the adjacent rocks were seen.

Origin: The syenite is similar in mode of occurrence to porphyritic syenites and syenite porphyries described by Wilson (1962) and Cooke, James and Mawdsley (1931) in areas to the north of the map-area under study. The syenitic masses described by these authors are different however in their age relationships. The syenite here antedates the granites whereas it is the youngest intrusive, excluding the basic dykes, in the areas studied by Wilson.

The syenite occurring southeast of Rollet appears to be a composite intrusive mass, forming a sill in parts and a dyke in other parts. This is indicated by the various compositional bands and by the thermal metamorphism exhibited by the host rocks. Narrow bands, from one foot to six feet in width, of diverse mineralogical composition, alternate irregularly in a zone approximately thirty feet wide. There are three or four similar zones within a thousand feet. The composition varies from intermediate to basic, some layers containing as much as fifty-five per cent pyroxene. The syenite intrudes lenses of quartz-feldspar-biotite schist and five feet away from the contact a garnetiferous belt, thirty feet wide, has developed in the schist parallel to the contact. The outcrop of syenite along the west shore of Barrière lake, south of Solitaire river is a continuation of the one just

mentioned. There we did observe a reversal in the nodular texture near the border of the mass. Dark patches or nodules are enclosed in a light-coloured groundmass. The mineralogical composition is unchanged, except for the proportions, and only the texture seems to be different.

The intrusive relationships displayed in these two places suggest the probability of a magmatic origin for the syenite.

In the majority of cases the origin of the syenite is different. No intrusive relationships are shown but the rock appears to grade into the hornblende granite with which it is associated. No contacts are present, but instead a gradual transition is observed in which the textural characteristics become less and less pronounced to the point where a normal granular texture is the only one present. The syenite here may be the product of metasomatic processes or may represent partially digested xenoliths in the hornblende granite.

3- Hornblende-Pyroxene Syenite - Porphyritic Syenite

Hornblende-pyroxene syenite occurs in three places; north-east of Caire lake, west of the northern extremity of Barrière lake where it is most abundant, and south of the village of Guérin close to Renard lake. These occurrences, although widely separated, display a remarkable similarity of association, external appearance, mineralogical composition and mode of occurrence. The syenite forms large irregularly shaped masses, up to five miles across, south and southeast of Fréchette lake, and small irregular or lenticular masses elsewhere. Two types of syenite are distinguished on the basis of texture: a) massive and homogeneous - b) porphyritic. Both types are commonly intermixed and also occur separately but the porphyritic variety is predominant.

The syenite generally exhibits a gneissic structure or a lineation defined by the parallel alignment of the feldspar megacrysts, but in places it is massive and of a hypidiomorphic-granular texture. It is medium- to coarse-grained, dark grey to pink and has a deep and rough weathered surface.

The syenite is composed essentially of plagioclase, microcline, perthite, augite, amphibole and biotite. Secondary minerals are chlorite and epidote and accessory minerals are apatite, sphene, magnetite and zircon. Anhedral twinned grains of albite (An_5 to An_8) are common in the groundmass of the porphyritic type, but plagioclase of An_{18-22} composition is more typical of the massive variety. Plagioclase is always slightly altered to sericite and shows albitic outer zones where in contact with microcline. Microcline occurs as clear allotriomorphic and unaltered grains and also as patches and irregular blebs in the plagioclase. It also constitutes most of the augen-like megacrysts characteristic of the porphyritic variety. The megacrysts vary from one-quarter to one inch in length and from one-sixteenth to half an inch in width, are commonly subangular and have irregular outlines. In places, they are surrounded by a finely granulated matrix of plagioclase, fresh microcline and augite, giving the rock a mortar structure. Idiomorphic and allotriomorphic grains of colourless, frequently twinned augite, partly altered to hornblende and biotite are minor components of the syenite. A chemical analysis of pyroxene is given in Table 7. The optical properties of this augite are the following:

$Nx = 1.698 \pm 0.002$ $\quad 2V = 61°$
$Ny = 1.706 \pm 0.002$
$Nz = 1.728 \pm 0.002$ $\quad Z \wedge c = 40°$

The chemical composition and the optical properties are those of a sodian augite. Blue-green hornblende is common as a secondary mineral resulting from the alteration of pyroxene. The optical properties of this hornblende are :

Nx = 1.653 ± 0.002 2V = 62°
Ny = 1.658 ± 0.002
Nz = 1.663 ± 0.002 Z∧c = 15°

The chemical composition given in Table 7 and the optical properties are those of common hornblende.

Table 7 : Chemical Analyses of Pyroxene and Amphibole

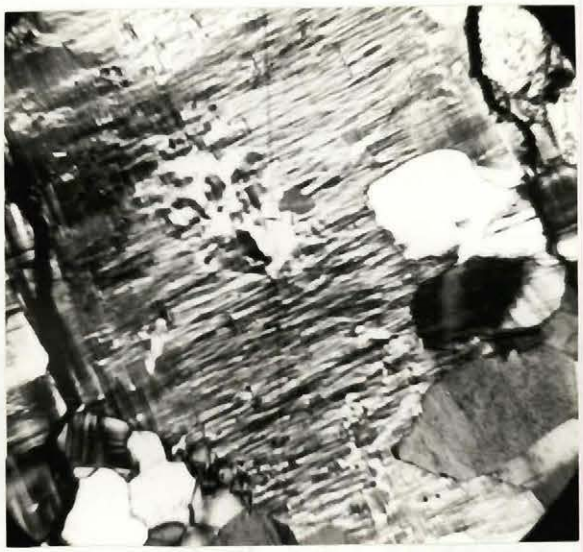
	Pyroxene	Amphibole		Pyroxene	Amphibole
SiO_2	51.50	48.86	H_2O^-	0.11	0.01
TiO_2	0.27	0.47	CO_2	0.07	0.03
Al_2O_3	1.50	4.71	S	0.01	0.046
Fe_2O_3	4.96	5.03	Cr_2O_3	0.10	0.13
FeO	8.40	12.35	V_2O_3	0.048	0.041
MnO	0.30	0.32	NiO	0.05	0.06
MgO	11.21	13.01	BaO	0.004	0.004
CaO	18.93	10.86	SrO	0.080	0.020
Na_2O	1.70	1.39	CuO	0.01	0.01
K_2O	0.15	0.72	Li_2O	0.028	0.005
P_2O_5	0.02	0.01	ZnO	0.05	0.05
H_2O^+	0.62	2.00	Total:	100.120	100.136

The pyroxene and amphibole come from the same sample which is from a locality north of Rollet, east of the highway. Analyzed by Z. Katzendorfer and Boileau H., Quebec Dept. of Natural Resources Laboratories.

Olive-green biotite occurs as euhedral grains generally in contact with or close to the augite or is enclosed poikilitically in augite. Perthite is present in the megacrysts of the porphyritic type as film, braid, stringlet, bead and patch perthite (photographs 23 and 24). Microcline and plagioclase are present and usually are in optical continuity. In most cases, microcline is the prevalent component of the perthite, especially the film, braid, stringlet and bead varieties, but in patch perthites plagioclase may be dominant, only infrequent islands of microcline being apparent. The cross-hatching of microcline is always conspicuous but the albite twinning of plagioclase is generally faintly perceptible and indistinct. Several megacrysts are composed of two or more units of perthite; in other words, there is no optical continuity throughout the grains and sharp boundaries separate the units which, nevertheless, form a single euhedral megacryst. In two samples, microcline appears only along concentric zones separated by plagioclase, much like ordinary compositional zoning in plagioclase.(Photograph 24). The groundmass material is usually free of perthite but replacement relationships are commonplace in all the thin sections.

Table 8 contains the results of six modal analyses of syenite. The last column shows a modal analysis of a rock believed to be identical to the syenite. Gussow (1937) named it "augite-syenodiorite orthogneiss". Four chemical analyses are given in Table 9, they correspond to the modal analyses of Table 8 and illustrate the relative constancy of the chemical composition of the syenites. The amounts of K_2O and Na_2O may be slightly in error because of the perthite present in some samples and the impossibility to measure them accurately in modal

analyses. However, the alkali content of the rock is remarkably high, but not abnormally so for a syenite.



Photograph 23 : Patch and film perthite in a microcline megacryst in hornblende-pyroxene syenite. (Crossed nicols -X80).

Photograph 24 : Perthite. Microcline occurs in concentric zones in a megacryst composed of more than one unit. (Crossed nicols-X20).

Table 8 : Modal Analyses of Pyroxene Syenite

	I	II	III	IV	V	A
Quartz	-	-	-	tr.	4.90	-
Microcline	15.44	23.58	6.46	28.00	24.58	27.00
Plagioclase	59.61	53.18	84.26	58.99	38.96	45.00
Hornblende	tr.	-	1.23	6.66	24.09	15.00
Pyroxene	14.03	7.16	7.28	3.41	-	10.00
Biotite	9.24	14.58	-	-	6.03	1.00
Epidote	tr.	tr.	tr.	tr.	tr.	-
Chlorite	tr.	-	-	-	-	-
Apatite	tr.	tr.	tr.	tr.	tr.	1.00
Magnetite	tr.	tr.	tr.	1.05	tr.	1.00
Sphene	-	tr.	tr.	tr.	tr.	-

I- Sample from Fréchette lake area - Massive - Plagioclase = Ang.

II- Sample from Fréchette lake area - Massive - Plagioclase = An_6.

III-Sample from north of Rollet, along route 46, massive. Plag.=An_6.

IV- Sample from the west shore, north end of Barrière lake, massive. Plagioclase = An_6.

V- Sample from the west shore, one mile south of Solitaire river, Barrière lake, massive. Plagioclase = An_{22}.

A- From Bellecombe township, west of Caron lake. Augite-syenodiorite orthogneiss (Gussow, 1937). Oligoclase.

No modal analyses of porphyritic syenite were obtained because the megacrysts would unbalance the results and also because of the presence of perthite in these samples.

Origin of the perthites : Three processes are known to produce perthites or perthitic structures: 1- Unmixing of alkali feldspar with the consequent appearance of Na-rich and K-rich components. Exsolution of this type generally produces film perthites. 2- Simultaneous crystallization of the two components of the perthite. 3- Replacement of orthoclase or microcline by plagioclase or vice-versa.

The second process can be ruled out here because of the

Table 9 : Chemical Analyses of Syenite

	I	II	III	A
SiO_2	59.93	64.51	62.10	57.12
Al_2O_3	16.45	18.21	17.22	15.16
Fe_2O_3	1.61	1.11	2.03	2.49
FeO	4.17	1.21	1.36	4.81
MgO	2.15	1.20	1.57	3.82
CaO	4.08	2.83	2.46	5.05
Na_2O	6.44	9.29	6.59	4.90
K_2O	3.35	1.06	4.52	4.62
H_2O^+	0.14	0.03	0.18	0.85
H_2O^-				0.30
TiO_2				0.48
MnO				0.09
P_2O_5				0.44
F				0.04
S				tr.
Total	98.32	99.45	98.03	100.17

I - II - III - correspond to I - III - IV - of Table 8 and are derived from the modal analyses.

A - Analysis of syenodiorite orthogneiss (Gussow, 1937). Analyst : W.H. Herdsman.

large diversity in the proportion of the two components. However, it may have been active at the earliest stages of rock formation.

Process no. 1- may explain the presence of some film perthites but cannot adequately account for patch perthites, especially the examples where only small islands of microcline are found in the plagioclase.

The third process, replacement of microcline by plagioclase appears to be plausible and may explain, with restrictions, the observed perthitic structures. However, we cannot preclude the reverse process, that is, replacement of plagioclase by microcline. The following facts have to be kept in mind when discussing the relative merits of the two

modes of occurrence:

a)- Perthite is present almost exclusively in the megacrysts.

b)- Film, braid, stringlet, bead and patch perthites are common.

c)- Microcline and plagioclase are in optical continuity and in varying proportions.

d)- Cross-hatching of microcline is always strong and albite twinning of plagioclase is weak.

e)- Megacrysts are, in a few instances, composed of two or more units.

f)- Microcline may be disposed in concentric zones and along the cleavages of plagioclase.

g)- Some fractures in the perthite are filled with microcline.

h)- Fresh, unaltered plagioclase is present as small crystals in some megacrysts.

i)- The more granulated the rock is, the more perthite there is.

Gates (1953) offered evidence of replacement of potassic feldspar and wrote : (p. 63) "The potash feldspars in the zones into which the sodic material migrates will contain a wide variety of perthitic textures and will show evidence of replacement. In some places unquestionable porphyroblasts of potassic feldspar have been almost completely replaced by plagioclase." Gates also said that potash feldpar will generally crystallize before sodic feldspar in the formation of the rock and will be replaced selectively in zones of intense fracturing. He concluded that much of the plagioclase of ordinary granite represents replaced potassic feldspar. Items c)- and d)- mentioned above, support the view of replacement of microcline by plagioclase, but are not conclusive.

Schermerhorn (1956) and Robertson (1959) described the development of perthitic structures from plagioclase by late potash metasomatism. Items f)-, g)- and h)- indicate that this mode of origin is possible here, although g)- may be explained otherwise. The microcline in the fractures may have been derived from the adjacent walls and does not necessarily imply a mobile or diffuse solution. But the presence of microcline along concentric zones in some megacrysts is hard to explain in any way other than by replacement of zoned plagioclase crystals by microcline, some zones being chemically more amenable to replacement than other zones. The same process would also apply where there are no zones. However, if we accept the replacement of plagioclase by microcline as a working hypothesis, we still have to account for the presence of fresh, unaltered albitic crystals in the center of some megacrysts. They could, unlikely, represent original albite which was unreplaced, and more likely be products of complete unmixing consecutive to replacement. These crystals are infrequent and may be located only in areas where conditions are propitious to their development.

Thus we would suppose the following sequence of events: 1)- formation of crystals of plagioclase, zoned in places, in a semi-solid and mobile medium, 2)- followed by partial replacement by microcline and by 3)- incipient unmixing of the partially replaced megacrysts.

The source of potash is problematical. It is undoubtedly associated with small dykes, rich in microcline, that intersect the syenite, yet the time of the metasomatic replacement is unknown but can probably be correlated with that of the metasomatism of the oligoclase-microcline granite.

External Relationships of the Syenite : Both types of syenite have the same relations to adjoining rocks and are treated as a single unit. The syenite has been observed to intersect and cut the biotite schist and the amphibolite of the Pontiac group. It contains numerous inclusions of schist and amphibolite in the contact zone and the inclusions appear to trend in a direction parallel to that of the foliation of the rock. The inclusions have reacted with the syenite as is indicated by the development of hornblende crystals disposed radially along the edges of the included fragments. The contact with the amphibolite is not always well defined, being gradational here and there. The syenite is usually gneissic near the contacts with the schist and the amphibolite.

The syenite is intruded by the adjacent oligoclase-microcline granite and by pegmatite dykes, and inclusions of syenite are common in the granite. In the vicinity of Renard lake the rock is in contact with hornblende granite into which it seems to grade. Therefore the syenite is younger than the rocks of the Pontiac group but older or equivalent to the hornblende granite and older than the oligoclase-microcline granite.

Numerous masses of syenitic rocks have been described in areas to the north and northeast of the present region. The Hub lake syenite (Cooke, James and Mawdsley, 1931) and Aldermac syenite (Gunning, 1927) are similar in composition, mode of occurrence and appearance to the hornblende-pyroxene syenite and appear to be related to it. James (1924) mentions the presence of a large mass of syenite porphyry and augite syenite in a zone immediately north of the map-area,

and this syenite is probably part of the mass present here. Wilson (1962) also describes a syenitic rock occurring as dykes or sills of little extent.

The syenite to the north is believed by many to be the youngest intrusive rock, excluding the diabase, but this opinion is questionable. Wilson (1962, p. 31) states: "The exact place of the syenite porphyry in the succession of Early Precambrian intrusive rocks is uncertain. It intrudes the Timiskaming conglomerate and greywacke and is intersected by dykes of quartz and olivine diabase of Late Precambrian age." Gussow (1937, p. 160) claims that he observed a dyke of the porphyry intruding the albite granite in Beauchastel township. This observation is in contradiction with the observations of the author in the map-area now under study and may signify either that the albite granite to the north is older than the hornblende granite near Renard lake or that the syenite to the north is unrelated to the syenite of the area.

Origin of the syenite : Gussow (1937, p. 157-159) concluded that the augite syenite west and east of Caron lake in Bellecombe township was not a truly magmatic rock but was an orthogneiss. The fluidal structures near the contacts of the syenite with the schist and the amphibolite and the gneissic portions of the rock may be representative of this orthogneiss, although the gneissic structure may result from intrusion before complete crystallization.

James (1924) suggested that the syenite is a phase of the granite. It is, in places, similar to the cumulates, from orthocumulate to adcumulate, described by Wager et all. (1960), and we believe that

it is a member of the granitic group of rocks to the south. The syenite, of magmatic origin, provided a host for the development of the microcline megacrysts that resulted from potash metasomatism after the rock was emplaced.

4- Hornblende Syenite

Hornblende syenite occurs in the vicinity of Rondelet, Brodeur and Simard lakes, as elongated masses, the topographic expression of which is characterized by lofty lenticular ridges. Bryson island in Simard lake, with a northeast trending ridge, is a typical illustration of the way in which this rock occurs. The syenite is associated with hornblende granite and amphibolite into which it grades in places. It contains numerous basic inclusions and dark schlieren (Photographs 12 and 13) which appear to be related to the andesite and biotite schist. In the vicinity of Blanchard bay, in Simard lake, inclusions of relatively fresh andesite are frequent and some attain a diameter of approximately twenty feet.(Photograph 25). The thin band of paragneiss and metavolcanics, just south of Blanchard bay, trends longitudinally along the syenite into which it vanishes to the west. No pegmatite dykes and scarcely any granitic material intersect the syenite.

Petrography : The hornblende syenite is commonly massive, although gneissic here and there, fine- to medium-grained, light grey to white on weathered surfaces and pink on fresh surfaces. The gneissic structure is defined by the parallelism of platy minerals and by a faint compositional layering. The parallel arrangement of the needle-like hornblende grains outlines a strongly apparent and ubiquitous

lineation. The texture of the syenite varies from allotriomorphic-granular to hypidiomorphic-granular and is porphyritic in places.

Photograph 25 : Large angular inclusions of volcanic rocks in hornblende syenite. (Blanchard bay).

The rock is composed principally of amphibole, plagioclase and microcline, with minor amounts of quartz and, in some instances, pyroxene. Secondary minerals are albite, quartz, biotite, chlorite and epidote, and accessory minerals are sphene, apatite, pyrite, iron oxide, zircon and allanite. Hornblende occurs as euhedral, lath-like grains, slightly bigger than most of the other components, and displaying a strong preferred orientation. A chemical analysis of a hornblende characteristic of this rock is given in Table 10. The optical properties of this hornblende are the following: $Z \wedge c = 14°$, $2V = 57°$,

$Nx = 1.642 \pm 0.002$ Absorption formula: X = pale yellow-green
Y = dark green
$Nz = 1.654 \pm 0.002$ Z = light blue-green

Hornblende with different optical properties has also been

observed in a few thin sections. This other type has : 2V = 64°, Z∧c = 28°, X = pale green, Y = dark green, Z = medium brownish-green.

Table 10 : Chemical Analysis of Hornblende

SiO_2	51.29	CO_2	0.05
TiO_2	0.55	S	0.043
Al_2O_3	3.28	Cr_2O_3	0.07
Fe_2O_3	4.52	V_2O_3	0.025
FeO	9.68	NiO	0.05
MnO	0.29	BaO	0.01
MgO	15.10	SrO	0.005
CaO	11.19	CuO	0.01
Na_2O	1.51	Li_2O	0.003
K_2O	0.49	ZnO	0.05
P_2O_5	0.04		
H_2O^+	2.03		
H_2O^-	0.00	Total :	100.286

Analyzed at the Quebec Department of Natural Resources Laboratories by Z. Katzendorfer and H. Boileau. Sample from the Brodeur lake area.

Fibrous, colourless tremolite is an uncommon amphibole typical of the more altered examples of the rock. Lamellar twinning was observed in a few samples but is infrequent. Hornblende alters to epidote, epidote and chlorite or to biotite which it encloses poikilitically. Plagioclase is the most abundant component of the rock, making up to sixty per cent of it. It varies in composition from An_{13} to An_{22}, and secondary albite is common. Plagioclase occurs as coarse, rounded or euhedral grains displaying a finely spaced albite twinning and in rare instances chessboard structure. In places, where there is evidence of deformation of the rock, the extinction of the plagioclase is undulatory and poorly defined. In some thin sections, light-coloured albitic rims fringe the plagioclase where it is in contact with microcline, and, rarely, myrmekitic intergrowths of quartz and plagioclase have been observed

at such contacts. The plagioclase is commonly altered to sericite or paragonite and epidote along poorly defined zones or at the core of the grains, and islands or blebs of microcline are present in many grains, especially along the cleavages. Microcline is the only potassic feldspar of this rock, and occurs as interstitial anhedral grains or as large euhedral crystals. In the porphyritic portions, microcline occurs also as "phenocrysts" or megacrysts. The quantity of microcline is highly variable; in some thin sections, it makes up to forty per cent of the rock, whereas in others it constitutes less than five per cent of the rock, twenty-five per cent being the average content of most thin sections. Microcline is usually fresh and relatively unaltered in comparison with the plagioclase. Perthitic intergrowths form a small part of the microcline of some samples. Microcline was the latest mineral to form in the syenite, as it is interstitial, replaces plagioclase and contains inclusions of plagioclase, biotite, hornblende and epidote. The porphyritic syenite contains rectangular megacrysts of microcline and perthitic microcline. The perthite, of the string and patch type, occurs in rare instances and is believed to be due to replacement of the plagioclase by microcline.

Quartz is a minor component of most thin sections and is usually primary, especially in the more granitic facies of the rock, but may be secondary elsewhere. Pyroxene, augite, is a rare component occurring as large anhedral grains replaced almost entirely by hornblende. Epidote occurs as a secondary mineral after hornblende and also as a constituent of numerous small veins and brecciated zones.

Table 11 gives the results of nine modal analyses of

hornblende syenite, and Table 12 contains six chemical analyses obtained from the modal analyses. The classification of the rocks from the results

Table 11 : Modal Analyses of Hornblende Syenite

	1	2	3	4	5	6	7	8	9
Plagioclase	52.84	42.34	56.96	48.81	56.72	52.69	29.51	59.08	26.26
Microcline	25.43	32.59	14.90	2.91	17.82	26.94	36.49	15.60	25.36
Hornblende	11.82	22.73	25.96	44.21	15.13	10.61	28.66	22.71	29.09
Quartz	8.35	-	tr.	tr.	9.49	1.20	tr.	1.71	5.23
Epidote	tr.	tr.	1.08	1.66	tr.	3.19	3.84	tr.	12.68
Chlorite	-	-	tr.	tr.	-	4.67	tr.	-	tr.
Sphene + Apatite	tr.	tr.	tr.	1.60	tr.	tr.	1.00	tr.	1.10
Magnetite	tr.	tr.	-	-	-	tr.	-	-	tr.
Biotite	-	-	-	tr.	tr.	-	-	-	tr.

Samples 1-2-3-4- are from the Brodeur lake area. Plagioclase is : 1- An_{20} , 2- An_{22} and An_2 , 3- An_{16} , 4- An_{13} .

Samples 5-7-8- are from the Simard lake area. Plagioclase is : 5- An_{15} , 7- An_{17} , 8- An_{10} .

Sample 6- is from the Blue lake area. Plagioclase = An_{17}.

Sample 9- is from the Rond lake area. Plagioclase = An_5.

of the modal analyses, according to the method described by Jung & Brousse (1959) yields classes such as monzonites, granodiorites, diorites, syenodiorites and mainly subalkaline syenites. This is because An_{20} is used in this system as a demarcation line between alkaline and calcic plagioclase. The chemical analyses point out the remarkable variability of K_2O, but otherwise the composition of the rock is that of an ordinary syenite.

Replacement of plagioclase by microcline : In most thin sections examined microcline was observed to replace plagioclase. The evidence for this relationship is not always conclusive and in some

Table 12 : Chemical Analyses* of Hornblende Syenite

	1	2	3	4	5	6
SiO_2	64.14	60.70	59.58	56.46	64.94	61.76
Al_2O_3	15.46	14.53	15.72	12.02	15.79	15.41
Fe_2O_3	0.98	1.98	1.49	2.40	0.83	1.22
FeO	1.51	2.87	2.95	4.79	1.77	2.60
MgO	2.17	3.90	4.59	7.46	2.76	4.06
CaO	3.90	3.06	5.41	6.99	3.70	4.14
Na_2O	5.08	5.28	5.76	5.29	5.79	6.36
K_2O	4.12	4.99	2.43	0.67	2.91	2.55
H_2O	0.32	0.53	0.65	1.04	0.37	0.54
Total	97.68	97.84	98.58	97.12	98.86	98.64

* Analyses obtained from the modal analyses of Table 11. Chemical analyses 1-2-3-4-5-6- correspond respectively to modal analyses 1-2-3-4-5-8- of Table 11.

cases it may be surmised that the opposite situation occurs. Indeed, it is often difficult to decide which mineral is replacing which, because the evidence observed is ambiguous and can be used equally well to support one or the other relation. The sum of all the evidence, however, points to a replacement of plagioclase by microcline. We will present this evidence and discuss it. (The features mentioned were observed in numerous thin sections but rarely occur together and, thus, may in some cases be unrelated.) :

1- Microcline occurs as islands at the center and along the cleavages of plagioclase grains.

2- No plagioclase was ever observed at the intersections of the cross-hatching of microcline.

3- Microcline is optically continuous when it occurs as blebs in a grain

of plagioclase. It is also continuous, in places, when it occurs in two adjoining, optically differing, grains of plagioclase.

4- Plagioclase is not always in optical continuity when it occurs as blebs in microcline.

5- Microcline has a tendency to occur in clusters. Large parts of some thin sections, containing twenty per cent microcline are devoid of this mineral.

Photograph 26 : Square patches of microcline in a grain of plagioclase. Microcline surrounds the plagioclase. (Crossed nicols-X80).

6- Alteration products of plagioclase, such as epidote and sericite or paragonite are found in grains of fresh microcline alongside remnants of plagioclase.

7- Microcline is always fresh, even in the most altered rock examples, where plagioclase and hornblende are strongly altered.

8- Microcline contains inclusions of biotite, hornblende and epidote.

9- There are albitic rims on the plagioclase when in contact with microcline and chessboard structures may be present. Both features are infrequent.

10-Myrmekitic intergrowths of quartz and plagioclase are present at crystal boundaries of plagioclase and microcline.

11-Patch and string perthites generally contain inclusions of hornblende, epidote, plagioclase and biotite.

12-The variations in the respective amounts of plagioclase and microcline are broad.

1-,2- and 6- are self-explanatory and indicate late replacement of plagioclase by microcline. Item 3- suggests that the orientation of the plagioclase controls the orientation of the microcline, and item 4- indicates that microcline may replace more than one grain of plagioclase and preserve its optical continuity irrespective of the orientation of the plagioclase. These two items are contradictory and inconclusive. Item 5- may be considered to signify that clusters of plagioclase are replaced because they are along the pathways of the replacing solutions. Item 7- points to the late appearance of microcline, although this condition may result from equilibrium states where plagioclase is unstable and microcline is stable. 8- added to 7-, or alone, clearly hints at a late appearance of microcline in the rock. 9-, rimming by sodic plagioclase indicates decalcification and alteration and is a common feature accompanying potash metasomatism. Chessboard structures are believed to accompany albitization (Anderson, 1937), but may be related to deformation and result from readjustment to stresses. 10-, cauliflower-like or rounded intergrowths of quartz and

plagioclase at a contact with potassic feldspar are deemed to attest to the action of soda metasomatism. "This fits in well with the hypothesis that the quartz is released as a result of the replacement of potassic feldspar....by plagioclase.. " (Hatch, Wells,Wells, 1961, p. 174). Wahlstrom (1950, p. 283) also mentions the association of myrmekite with albitization. However, Drescher-Kaden (1948) and Osterwald (1955) demonstrated the association of myrmekite with potash metasomatism, this association requiring the introduction of silica. Thus, this evidence is inconclusive. It should be mentioned that myrmekites are rare and that they occur only in samples that show evidence of deformation. As with myrmekites, the presence of perthites, item 11-, is inconclusive. The origin of perthites was discussed under Hornblende-pyroxene syenite and was seen to be related to albitization or microclinization. Item 12-, the large variations in the amounts of plagioclase and microcline are due to the fact that one replaces the other. The sum of the two components is relatively constant. If plagioclase replaces microcline, the rock was originally dominantly potassic, an unlikely event in view of the preceding considerations.

The most important conclusions of the previous discussions are that potassic feldspar replaces plagioclase and that potassic feldspar is later than most of the other components. The potash metasomatism is probably related to the same period of metasomatism that affected the oligoclase-microcline granite, and both will be discussed together under oligoclase-microcline granite.

Structural features of the hornblende syenite : The lineation due to the linear parallelism of the hornblende trends almost

constantly to the northwest and in places to the north. It plunges at shallow angles varying from 20° to 40°, very much like the lineation observed on the bedding planes of the paragneiss and metavolcanic rocks south of Blanchard bay. The gneissic structure trends east-west to the south and northeast to the north, excluding local variations. These structural trends may represent the trends of the rocks intruded by the syenite but are more likely the results of regional stresses concomitant with the emplacement of the rock. Thus, they could represent circumferential stretching of the walls of the intrusive mass.

Numerous faults and microfaults of insignificant displacement were observed in the rock, megascopically and microscopically. Brecciated zones filled with granular plagioclase, microcline, quartz and epidote are numerous but inconspicuous. Evidence of strain is commonly observed in thin sections. Undulatory extinction of the plagioclase and chessboard structures in plagioclase are accompanied by much secondary quartz and albite.

Origin of the hornblende syenite : The hornblende syenite is believed to represent a magmatic or partly metasomatic rock, such as the oligoclase-microcline granite, modified by the massive assimilation of basic rocks. The frequent occurrences of dark, basic schlieren in the syenite, and the spatial relationships of the rock to the volcanics to the east are strongly indicative of the origin. To the north, where the rock is more granitic, the origin is not manifest, but the assimilated material may be related to the amphibolite and biotite schist of the Pontiac group, as is apparent from the nature of the inclusions.

Freeman (1957) described a similarly occurring hornblende syenite, to the northeast of the area, and added that a study on the frequency of twin types suggested a magmatic origin. However, Deer, Howie and Zussman (1963, vol. 4, p. 106) write : "Many of the results of other studies on the frequencies of twin laws are not in accord with the above statements nor with each other, and it is probably fair to say that general rules of correlation are not yet fully established." Therefore, we consider that the purely magmatic origin of the rock is unproved.

Henderson (1936, p. 19) described granitic rocks in the Ville-Marie and Guillet (Mud) lake map-areas, just south and possibly into the southern part of the southeast enclave of the area now under study. He wrote: "Hybrid granites of a different character are developed locally along the contacts of the greenstone and granite in the northern part of the area. Here little or no pegmatitic material is present and there is no tendency for gneisses to develop. Near the contact the granite becomes low in quartz, high in hornblende, and approaches the composition of a hornblende syenite or diorite. The presence of inclusions of greenstones in these basic border phases of the granite leaves little doubt that assimilation of the greenstone by the stoping action of the granite magma is responsible for the development of this rock." This statement strongly reinforces the views expressed above.

The potassic metasomatism of the syenite is believed to have transformed the rock at a late stage of its formation.

5- Plagioclase-Hornblende Gneiss

The plagioclase-hornblende gneiss includes various rocks

of similar composition, texture and structure, but of different association and mode of occurrence, hence possibly of different origin. Terms, such as diorite, amphibolite, granodiorite and hornblende granite could be used to designate individual examples, but it is considered more appropriate to describe them here under a common designation.

The rock is found in the southern sector of the area, in the vicinity of the western shore of Des Quinze lake, opposite the village of Moffet, along Four Miles Bay, and east of Gaboury and Roger lakes. An important portion of the gneiss occurs as short and thin lenses intercalated in the biotite schist and is associated with amphibole-rich fractions of that rock, but the greater part occurs as isolated, narrow and elongated bodies in the hornblende syenite, quartz-feldspar gneiss or oligoclase-microcline granite. The isolation of the masses

Photograph 27 : Lenses of Pontiac schist in plagioclase-hornblende gneiss. (East of Gaboury lake).

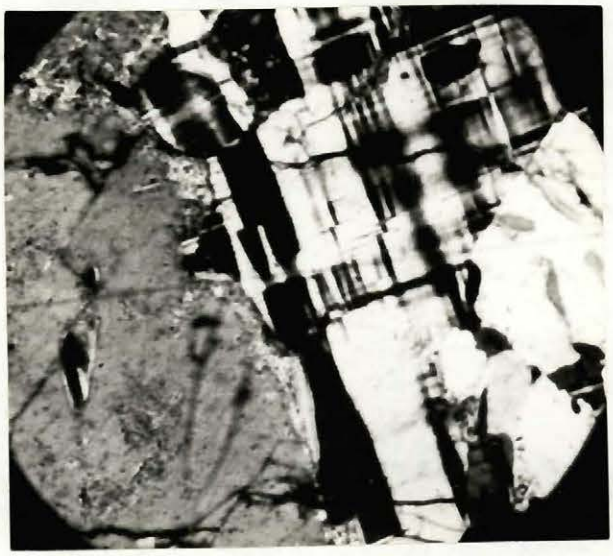
may be apparent only and may be due to the scarcity of outcrops in this corner of the area. Everywhere the rock displays a gneissosity which appears to be concordant with the structural trends of the adjoining formations. Diversely dimensioned lenticular inclusions of dark, dominantly ferromagnesian, basic rocks are omnipresent and characterize the plagioclase-hornblende gneiss.

The plagioclase-hornblende gneiss is medium- to coarse-grained, light pink to grey and exhibits a granoblastic texture. The gneissic structure of the rock is invariably well developed and is outlined by the parallel alignment and segregation into layers of the mafic components. However, the gneissic structure is not always apparent in thin sections, where the texture is often hypidiomorphic-granular, because of the coarse size of the minerals.

The gneiss is composed primarily of hornblende and plagioclase, with subordinate amounts of microcline, quartz, biotite, epidote and chlorite. Accessory apatite, sphene and zircon occur here and there. Pleochroic, deep green to light blue-green or pale yellow-green hornblende occurs as euhedral crystals showing a preferred orientation and constitutes from ten per cent to forty per cent of the rock. The optical properties of the hornblende are not constant but vary from thin section to thin section, reflecting the variety of origin of the diverse occurrences. The extinction angle $Z\wedge c$ varies from 21° to 30° and the optic angle 2V is usually large, most measurements being from 70° to 80°. Lamellar and contact twins are common. Hornblende generally alters to biotite which it may enclose poikilitically, and in highly altered phases to chlorite and pale-yellow epidote. Plagioclase occurs

as large subhedral to euhedral crystals and makes up to seventy per cent of the rock, the average being forty-five per cent. The composition varies from An_{17} to An_{22}, depending on the rock it is associated with, and in one case sodic plagioclase of An_8 composition was observed. The plagioclase is always altered, occasionally slightly but commonly to a high degree, so much in places, that only residual fractions are left. Sericite or paragonite and epidote are the usual alteration products, but quartz and albite may occur from the breakdown of some plagioclase. Sericitization occurs at the core or along the grain boundaries and tends to selectively attack certain twin lamellae. In numerous thin sections, the twin lamellae were observed to be bent slightly and to show undulatory extinction. Sodic plagioclase occurs as thin and clear rims on plagioclase grains, this feature being best observed where plagioclase is in contact with potassic feldspar. Myrmekitic intergrowths of quartz and plagioclase occur but are unusual. Microcline is a rare component of the gneiss, but whenever it occurs it generally is abundant, making up to thirty per cent of the rock. It was observed in samples obtained from occurrences associated with oligoclase-microcline granite and hornblende syenite. Microcline displays replacing relationships to plagioclase which it penetrates. (Photograph 28). String perthite with inclusions of hornblende, plagioclase, biotite and apatite was observed in one thin section. Quartz occurs as anhedral interstitial grains or as a secondary product, but is of rare incidence.

A few thin sections disclosed evidence of deformation in the form of microfaults or brecciated zones filled with chlorite and epidote or granular fragments of quartz, albite, microcline and sphene.



Photograph 28 : Plagioclase penetrated by microcline. Myrmekite in plagioclase to the right. (Crossed nicols - X80).

The plagioclase-hornblende gneiss is believed to be derived from the assimilation of basic rocks by granitic material, and thus represents a basic facies of the rocks it is associated with. The ultimate origin of the gneiss is therefore related to the origin of the primary material. This relation is indicated by the mode of occurrence and by the ubiquitous mafic-rich inclusions. In most instances, granitic material occurs in the vicinity of the gneiss; in the biotite schist of the Pontiac group, lit-par-lit injections of oligoclase-microcline granite are common, and there the gneiss may represent intruded and transformed amphibolitic horizons. Locally, metasomatism may have been an efficient agent in the transformation of the gneiss.

Metamorphism of argillaceous, calcareous or dolomitic

rocks may also produce plagioclase-hornblende gneisses, but in the map-area, there is hardly any indication that the gneiss is a derivative of such rocks. The proximity of the occurrences to the volcanics to the south reinforces the plausibility of the above-mentioned mode of origin.

6- Hornblende Granite - Porphyritic Hornblende Granite

General Statement

Hornblende granites, massive and porphyritic, are important members of the rock sequence, that include rocks occurring in widely separated regions, not always in contact with each other and rarely displaying evidence of continuity, hence of presumably diverse origin.

The hornblende granite outcrops in six different areas: 1- As small isolated irregular bodies in the hornblende syenite near Brodeur lake, north and east of it. 2- As a small rounded mass associated with oligoclase-microcline granite, east of the north end of Roger lake, along the eastern boundary of the area. 3- Along the southern limit, southeast of Angliers, as lenses of varying dimensions in quartz-feldspar gneiss and plagioclase-hornblende gneiss. 4- As isolated, rounded or elongated, masses in the volcanics and biotite schist, north and east of Témiscamingue lake. 5- As extensive zones where it is mixed intimately with oligoclase-microcline granite in the central part of the area. 6- As isolated lenses in the northern part of the area, along Opasatica lake, Barrière lake and Caire lake. There, the rock is usually associated with oligoclase-microcline granite. To this list we may add numerous isolated lenses occurring in various parts of the area, but too small to be shown separately on the map.

The hornblende granites from these different sectors share many common characteristics but differ markedly in some features. A separate description of each rock type and association would be appropriate but would also entail needless and tedious repetitions. To obviate the disadvantages of individual descriptions we will group together the various occurrences and report on their common features but will point out the peculiarities of each, if necessary under a separate heading. We will refer to each of the various occurrences by the geographic associations mentioned above.

Petrography

The hornblende granite is generally medium-to coarse-grained, dark grey on weathered surfaces and whitish to pink on fresh surfaces. The porphyritic variety is most abundant, occurring everywhere except in the granite southeast of Angliers, and constitutes approximately sixty per cent of all the hornblende granite exposed. Granite with a normal hypidiomorphic-granular texture may adjoin the porphyritic type or may be excluded entirely, as in the Opasatica lake examples. The rock is usually massive, but gneissic segments may be locally abundant, the gneissic structure being defined by the parallelism of the mafic components and frequently by the segregation of the ferromagnesian minerals into layers or bands. The gneissic granite is dominant in the region southeast of Angliers.

The hornblende granite is composed principally of hornblende, plagioclase, microcline and quartz with secondary chlorite, epidote and biotite which may be locally abundant. Accessory apatite, sphene, zircon, magnetite and monazite are present here and there. Hornblende

is present in varying amounts in all the thin sections, as euhedral grains with prismatic edges and often as crystals having an elongated habit. It may be corroded and altered to greenish-brown biotite and pale yellow to colourless epidote, and contains numerous poikilitic inclusions of biotite, sphene and apatite. The absorption formula of the hornblende most commonly observed is: X = light bluish-green, Y = dark yellowish-green, Z = dark green. Twinning parallel to 100 was observed in several thin sections. Southeast of Angliers and south of Solitaire bay, the hornblende has the following absorption formula : X = deep blue-green, Y = pale yellowish-green, Z = dark green. The optic angle 2V is approximately 70°, and the extinction angle $Z\Lambda c$ equals 20°. This hornblende appears to be an alteration product of pyroxene, remnants of which are visible amongst the hornblende. A chemical analysis of hornblende from the porphyritic granite in the central part of the area is given in Table 13. The optical properties of this hornblende are : $Nx = 1.652 \pm 0.002$, $2V = 59°$

$Nz = 1.668 \pm 0.002$, $Z\Lambda c = 18°$

The composition and the optical properties are those of common hornblende.

Plagioclase feldspar is the most abundant mineral in the hornblende granite, except in the highly porphyritic portions where microcline may be dominant. The composition of the plagioclase is commonly about An_{20}, but varies locally from An_{15} to An_{26}, with minor exceptions such as in the Rémigny area where An_{5-7} was found to occur. The plagioclase often appears to be more calcic at the center than at the margin and a clear sodic rim is often observed at the contact of

Table 13 : Chemical Analysis of Hornblende

SiO_2	47.39	P_2O_5	0.19	CuO	0.01
TiO_2	0.60	H_2O^+	2.71	Li_2O	0.004
Al_2O_3	6.56	H_2O^-	0.09	ZnO	0.05
Fe_2O_3	5.09	CO_2	0.02		
FeO	10.94	S	0.037	Total	100.045
MnO	0.38	Cr_2O_3	0.07		
MgO	13.21	V_2O_3	0.04		
CaO	11.08	NiO	0.04		
Na_2O	0.95	BaO	0.002		
K_2O	0.58	SrO	0.002		

Analyzed at the Quebec Department of Natural Resources Laboratories by Z. Katzendorfer and H. Boileau. The sample is from the central part of the area.

plagioclase and microcline. The average size of the grains is 2mm., but some may measure as much as 10 mm. In many thin sections, the plagioclase tends to form large rectangular crystals, much bigger than the other components, and usually disposed in a sub-parallel arrangement. The plagioclase is altered to a mixture of sericite or paragonite and epidote in varying degrees and fashions. Generally the alteration products are concentrated at the core of the grains or along the borders, but in many instances they are evenly distributed throughout the plagioclase. Here and there, sericite occurs along definite concentric zones, imitating oscillatory zoning, or it occurs along specific twin lamellae. Oscillatory zoning was not observed but is presumed to be represented by the zoned alteration. Chessboard structures were observed in one thin section of gneissic hornblende granite from an area southeast of Angliers.

Microcline, the only potassic feldspar of the granite, is

an important component of the rock, but has an erratic distribution that does not appear to follow a traceable pattern. In places, microcline makes up to thirty-five per cent of the rock, whereas it may constitute only two per cent elsewhere, but it is most abundant in the porphyritic members. In Table 14, samples 8 and 11 are from porphyritic granites and yet do not contain much microcline; this is due to the fact that megacrysts were avoided in the preparation of the thin sections in order to obtain representative samples of the groundmass. Large thin sections would have to be cut to obtain representative samples of the whole rock. The microcline occurs as interstitial grains or as replacement patches in plagioclase but never as idiomorphic crystals, with the exception of the megacrysts. It always shows the typical twinning, cross-hatching or tartan pattern, and in places is perthitic, with string-, bead- and patch-shaped fractions of plagioclase. The origin of the perthites was discussed earlier (hornblende-pyroxene syenite) and they were found to result partly from replacement and partly from exsolution. Here, most of the perthites result from replacement of plagioclase by microcline, because exsolution could not account for the large amount of plagioclase of most grains and also because of the large variations in the amounts of "unmixed" plagioclase. Exsolution perthites could be expected to contain a relatively constant quantity of plagioclase, but this is not so here and some examples, which should actually be called antiperthites, co-exist with perthites, clearly denoting a replacement origin. Actually, perthites are scarce and when they occur, they form only a small proportion of the rock. Microcline is essentially unaltered in comparison with the plagioclase and this, coupled with other features,

Table 14 : Modal Analyses of Hornblende Granite

	1	2	3	4	5	6	7	8	9	10	11	12	13
Quartz	20.26	11.72	5.82	8.00	14.66	3.31	9.54	14.77	17.41	10.72	tr.	21.88	7.39
Plagioclase	41.50	44.96	46.26	57.46	51.73	50.36	47.69	57.69	47.71	49.36	41.01	55.83	43.70
Microcline	18.14	17.66	33.42	2.92	17.35	15.61	3.95	1.31	17.92	16.78	17.65	11.74	18.47
Hornblende	14.07	10.26	12.00	17.39	10.53	17.99	15.86	12.59	12.12	10.96	28.99	6.96	24.56
Pyroxene	-	-	1.10	-	-	-	-	-	-	-	-	-	-
Biotite	-	-	-	8.23	4.55	12.44	18.29	13.21	3.48	11.01	-	-	5.35
Magnetite	-	-	tr.	tr.	-	-	tr.	-	-	tr.	tr.	tr.	-
Epidote	2.80	6.33	tr.	3.85	tr.	tr.	3.82	tr.	tr.	tr.	1.00	tr.	tr.
Chlorite	2.76	8.80	tr.	tr.	tr.	tr.	tr.	-	tr.	tr.	9.80	2.84	-
Apatite + sphene	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	1.30	tr.	tr.
Plagioclase	An_{7}	An_{5}	An_{7}	An_{26}	An_{17}	An_{23}	An_{22}	An_{18}	An_{17}	An_{10}	An_{15}	An_{22}	An_{15}

Samples 8 and 11 are porphyritic. — Samples 1 to 8 are from the central part of the area. Sample 9 is from an area north of Témiscamingue lake. Sample 10 is from an area north of Des Quinze river. Sample 11 is from an area around Brodeur lake. Sample 12 is from the southeast of Angliers. Sample 13 is from an area south of Fraser lake.

causes it to appear to be the latest mineral to have formed in the rock. The refractive indices of microcline from the vicinity of Brodeur lake are : Nx = 1.518 ± 0.002, Nz = 1.525 ± 0.002.

Quartz is always present as interstitial grains or as veinlets, blebs and vermicular intergrowths in the plagioclase, and it frequently contains inclusions of plagioclase and apatite, especially when it is in coarse grains. It is generally abundant, as is illustrated in Table 14, but may be lacking in the mafic-rich facies of the rock, which then grades into a syenite. Pale green to dark brownish-green biotite, resulting from the transformation of hornblende, is common in small amounts, but in rare instances, primary olive-green biotite may constitute as much as twenty per cent of the rock. Shredded remnants of pyroxene were observed in a few thin sections of granite from areas south of Solitaire bay and northeast of Angliers.

The modal analyses presented in Table 14 demonstrate the variability of the mineralogical composition of the granites, even within a restricted area. The five chemical analyses of hornblende granite of Table 15 were computed from five modal analyses and illustrate the variations in K_2O and Na_2O and the relative constancy of the sum of these two components.

Replacement of Plagioclase by Microcline

This subject was discussed earlier with the hornblende syenite and, on the basis of observations, it was concluded that microcline definitely replaced plagioclase. The same problem was again encountered with the hornblende granite and observations such as were noted for the hornblende syenite were again made. We will not repeat them but

Table 15 : Chemical Analyses of Hornblende Granite

	1*	3*	5*	9*	12*
SiO_2	67.19	64.20	65.36	65.78	68.13
Al_2O_3	14.00	16.41	15.96	15.99	16.02
Fe_2O_3	1.22	0.91	0.76	0.85	0.49
FeO	2.41	1.71	2.61	2.07	1.50
MgO	2.80	2.07	1.82	2.10	1.74
CaO	3.19	2.74	3.14	3.50	3.36
Na_2O	4.53	5.11	5.05	4.82	5.13
K_2O	2.95	5.41	3.27	3.32	1.93
H_2O	0.88	0.44	0.43	0.40	0.60
total	99.17	99.00	98.40	98.83	98.90

* Corresponds to the number of the modal analysis (Table 14) from which it is derived.

will present here any additional evidence of a conclusive nature.

Tongue-like apophyses extending from microcline to plagioclase grains are numerous and are unequivocal signs of replacement of plagioclase by microcline. The interstitial nature of the microcline, the euhedral megacrysts and, in places, the exclusive occurrence of microcline as patches in the plagioclase are also conclusive corroborations of replacement. Furthermore, the association of the replacement features with the feldspar megacrysts is more than coincidental and both phenomena are probably related in time and are manifestations of a unique episode of potassic metasomatism.

Myrmekites

Vermicular blebs of quartz in the plagioclase at its contact with the K-feldspar are common features observed in most, if not all, thin sections. In places, rounded quartz inclusions are disposed along

the borders of the plagioclase grains or anywhere in them and the plagioclase is not in contact with microcline, and in places there is no potassic feldspar in the rock except as replacement patches in some grains. According to Raguin (1957) these characteristics are typical of intense myrmekitization, under the influence of very mobile solutions. Drescher-Kaden (1948) discussed such features and wrote that they indicated that microcline is later than plagioclase, because it attacks the plagioclase and forms the quartz blebs and vermicules before crystallizing, and, furthermore, microcline does not necessarily crystallize along the plagioclase. This phenomenon involves a silica and a potash metasomatism. It is remarkable that plagioclase so attacked presents little evidence of replacement, that it contains no microcline, as if the replacement was prevented by the development of myrmekite.

Zoning of the Plagioclase

Zoning of the plagioclase was mentioned above as being outlined by concentrations of secondary sericite or paragonite along definite zones, but no true zoning, in which calcic and sodic zones alternate, was observed. However, the presence of concentric zones of alteration is significant inasmuch as it reflects variations in stability of the primary components and hence variations in composition. This zoning is not widespread but occurs in those parts of the granite that contain large elongated plagioclase crystals, and it is different from the zoning defined by the rimming of plagioclase by clear sodic fringes, which is considered to be secondary.

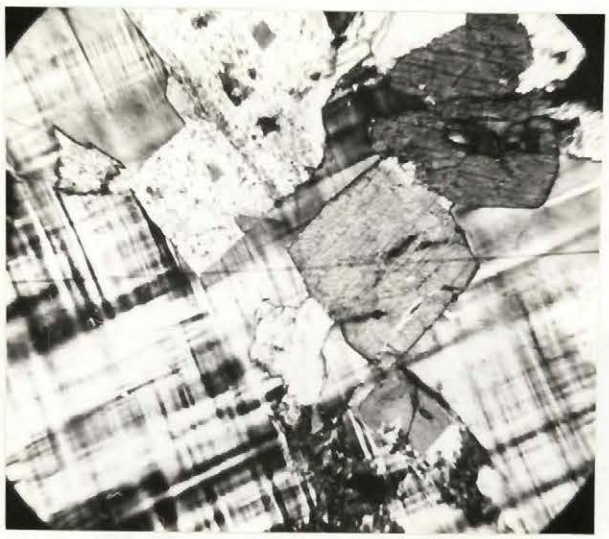
The zoning of plagioclase is irregularly distributed not only from area to area but even in a thin section, where it may be

displayed by several isolated grains, whereas in other grains, sericitization is general throughout the plagioclase or occurs only along the borders. Therefore the significance of this zoning is difficult to evaluate.

The alteration zones may result from the earlier unmixing of potash on cooling and thus indicate a magmatic source. However, the absence of zoning in co-existing plagioclase contradicts this view, because the zoning of plagioclase in magmatic rocks is uniform throughout the rocks. The absence of zoning, or progressive zoning, is considered to be characteristic of rocks which have crystallized in areas of regional metamorphism. Emmons (1953, p. 112) considers that "uniform sericitization in contrast with zones of sericite in plagioclase suggests zoning of a progressive character.... We use it as indirect evidence of a metasomatic environment." Thus, we have in the same sample, characteristics typical of two different modes of formation. It may be that the features are not as typical as they are deemed to be or that both modes of formation are involved, one being superposed on the other without obliterating it completely.

Microcline Megacrysts (Porphyroblasts)

Idioblastic microcline, one quarter to one inch long, occurs as euhedral rectangular grains and, exceptionally, as roughly hexagonal grains such as the megacrysts of the granite south of Solitaire bay. The porphyroblasts contain inclusions of quartz, plagioclase, hornblende, biotite, apatite and, in places, epidote (Photographs 29 and 30). The included plagioclase is generally smaller than that of the groundmass and invariably has sodic borders. The inclusions

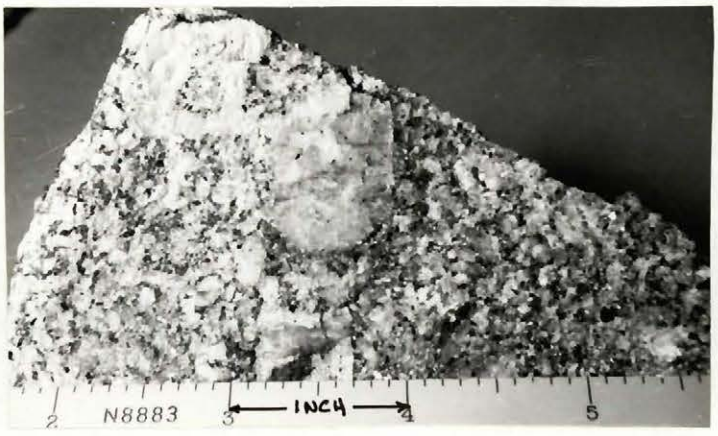


Photograph 29 : Hornblende and plagioclase inclusions in microcline megacryst. Note the microcline patches and the light rim on the plagioclase. (Crossed nicols - X80).

Photograph 30 : Inclusion of hornblende in microcline. (Crossed nicols - X80).

usually have no special arrangement in the megacryst but appear to preserve the texture of the groundmass, as if the replacing microcline had enveloped them. The microcline may, in parts, be perthitic, with strings and patches of plagioclase. The porphyritic granite is cut by dykes of oligoclase-microcline granite and pegmatite and it was noticed that the megacrysts infringe here and there on the dykes and, in some cases, are almost completely enclosed in them.

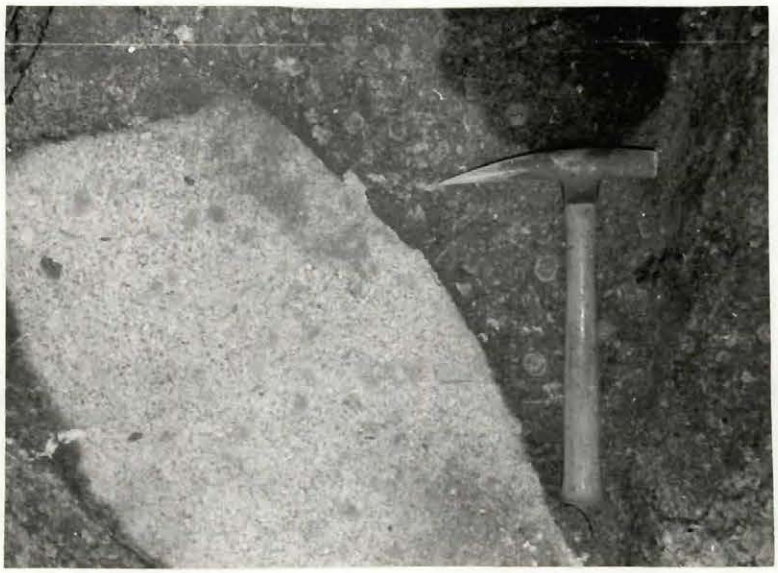
The hexagonal megacrysts found in the granite south of Solitaire bay are unusual in some respects and will be described here along with the rock. The granite contains quartz and hornblende in equal amounts (15 %) and roughly thirty per cent each of microcline and plagioclase (An_{15}), both displaying replacing relationships, with



Photograph 31 : Microcline megacrysts in hornblende granite. South of Solitaire bay.

remnants of pyroxene and hornblende. Epidote and biotite are secondary minerals, and sphene, apatite and zircon are accessory minerals. The

microcline megacrysts enclose small euhedral grains of hornblende, sphene, apatite, plagioclase, epidote and anhedral quartz, disposed in zones parallel to the borders of the microcline. The unusual features of the porphyroblasts are : The hexagonal shape, the large number of megacrysts and the concentric distribution of the inclusions.



Photograph 32 : Hexagonal megacrysts in hornblende granite south of Solitaire bay. The concentric distribution of the inclusions in the megacrysts is apparent.

Megascopically, the megacrysts exhibit alternating dark and light-coloured layers and the zonal arrangement of the inclusions is evident. A thin section through a megacryst (Photograph 33) discloses the following sequence: 1- The contact zone between the megacryst and the groundmass of the rock consists of a fine-grained granular mixture of quartz, plagioclase, microcline and hornblende. There are myrmekitic intergrowths and sodic rims on the plagioclase. This segment is thin and is in sharp contrast with the coarser groundmass, where large elongated crystals of oligoclase and coarse interstitial quartz and fine

Photograph 33: Thin section through a megacryst. Shows only the border zone. (Crossed nicols - X20).

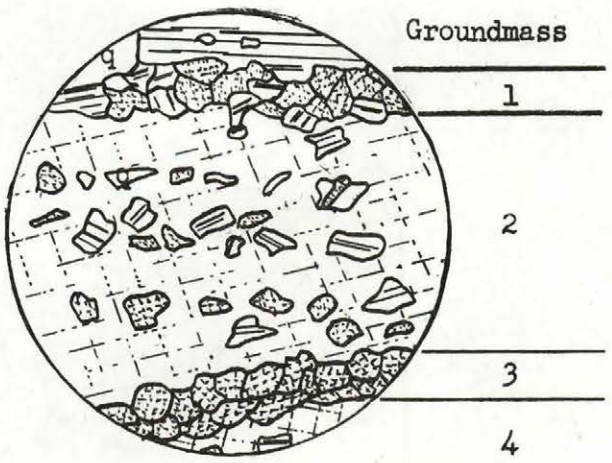


Figure 3 : Section through a megacryst of microcline. (X16). The sketch shows only a small portion of the porphyroblast. The zones are outlined.

anhedral interstitial microcline occur. 2- The marginal area of the microcline contains small elongated inclusions of quartz and hornblende disposed along a line parallel to the edge of the megacryst but away from it. There are also numerous small islands of plagioclase inside this line of quartz and hornblende, towards the core, that give the microcline the appearance of a patch perthite and that increase in size and number in the direction of the center. These inclusions are not optically continuous. Surprisingly, there are rounded inclusions of microcline in the microcline megacryst, that are discernible because of their different optical orientation. 3- There is a thin zone similar to 1- but consisting mostly of granular microcline with minor amounts of quartz, plagioclase and hornblende. 4- Adjoining the granular microcline is a single grain of microcline with islands of plagioclase as in 2-, without quartz however. Here the microcline is not in optical continuity with the microcline of 2- and 3-, thus giving the impression that 2- is a growth ring around 4-. (re: figure 3). This description is that of one megacryst and may not be representative of all the others.

From these observations of the microcline porphyroblasts the following can be concluded: The inclusions, although zonally arranged, show no disposition to optical arrangement relative to the megacryst and therefore predate the microcline. The size of the inclusions, especially those of plagioclase, hornblende and epidote, is smaller than that of those minerals in the groundmass and may indicate either corrosion or the inhibiting influence of microcline on the growth of these minerals once they were included. The microcline is later than the other components of the rock and is at least contemporaneous with,

if not younger than the oligoclase-microcline granite and the pegmatitic material which intrudes the hornblende granite. The optically different core of the porphyroblasts may record changes in the rate of growth and even periods of inactivity of the metasomatic processes. The hexagonal shape of the porphyroblasts is a peculiarity of this granite that is difficult to explain. Such porphyroblasts have been described elsewhere and may be common, but here they are unusual. They may represent a more active phase of metasomatism in which an increase in the surface area of the porphyroblasts corresponds to a greater efficiency of metasomatic processes such as diffusion.

Origin of the Porphyroblasts

Porphyroblasts such as those described above are of common incidence in granitic rocks and have frequently been described in the geological literature. As early as 1894, Michel-Lévy, describing such feldspars called them "dents de cheval" and recognized that they were a contact phenomenon. The consensus of opinion as regards their formation favors metasomatic or solid diffusion processes. Perrin and Roubault (1949) elaborated a theory of solid diffusion which explains readily the various puzzling features of the megacrysts, such as inclusions, lack of deformation about and around them and their large size. In the present case, however, it would not account for the interstitial nature and the replacing relationships of the microcline. Schermerhorn (1956), discussing the microclinization of the granites of Trancoso, described porphyroblastic developments of microcline and ascribed their origin to the metasomatic action of solutions acting in a fluid environment. A similar mode of origin is favored here because it best

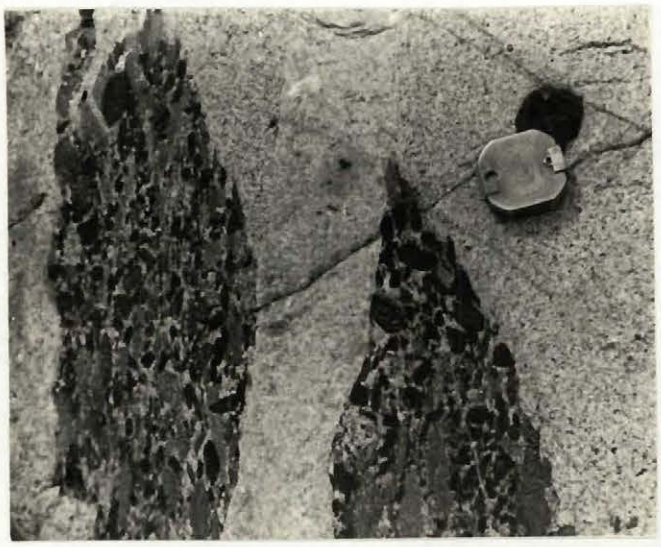
explains the interstitial nature of the microcline and the corrosion features of the plagioclase such as myrmekites and isolated quartz blebs. Drescher-Kaden (1948) suggests that such corrosion features are proof of intergranular diffusion and we believe that they may also be proof of the action of solutions. We cannot, however, discard the possibility of the non-coeval formation of the interstitial microcline and of the megacrysts. It is probable that primary microcline existed in the rock and this is suggested by the "inclusions" of microcline in the megacrysts. The erratic orientation and random distribution of the inclusions create the impression that they have been enveloped in the growing porphyroblast. The hexagonal porphyroblasts of the Solitaire bay occurrence and their zonally distributed inclusions are a special case which may be explained either by a slow rate of growth or by rapid growth in very mobile solutions. The border zone is composed of granular quartz, microcline, plagioclase and hornblende, which indicate that there is a breakdown of the groundmass before it is enveloped. This breakdown may concentrate along the borders some components which are disposed zonally once they are engulfed in the growing porphyroblast. A slow rate of growth will allow the components to attain equilibrium with the diffusing elements and the concentration of those portions that are not in equilibrium. A rapid rate of growth would not tend to dispose the inclusions zonally unless it was in a very mobile environment. The primary nature of the inclusions and the shape of the megacrysts are in agreement with this last hypothesis and support it.

Therefore, we conclude that the porphyroblasts are the result of metasomatism or metamorphic differentiation from the

differential movement of ions in a fluid solution under the influence of gradients in chemical potential. The origin of the potash is unknown but it may come from still crystallizing magmatic material.

Age Relations and Correlation of the Hornblende Granite

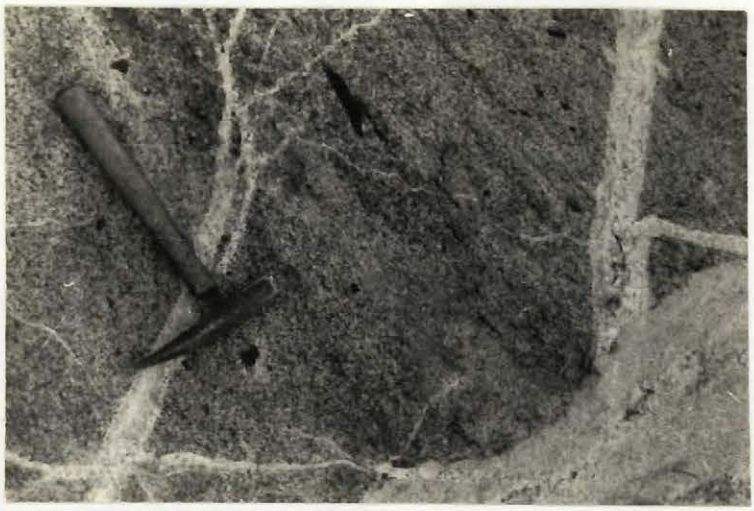
The hornblende granite contains numerous elongated inclusions and, in places, large lenses of amphibolite and biotite schist of the Pontiac group (Photograph 34). Near Brodeur lake the hornblende granite is mixed and associated with the hornblende syenite into which it appears to pass gradually. Southeast of Des Quinze lake, the rock contains numerous inclusions of volcanics and shows a wide contact zone with the andesite to the west. These observations indicate that the hornblende granite is younger than the volcanics to the south, the Pontiac group to the north, but is contemporaneous with the hornblende syenite in the Brodeur lake area.



Photograph 34 : Elongated inclusions of amphibolite in the hornblende granite. A light-coloured dyke of aplitic material separates the cluster. Barrière lake area.

Photograph 35 : Hornblende granite intersected by oligoclase-microcline granite. Dark angular fragments of hornblende gneiss. Barrière lake area.

In the central part of the map-area, abundant dykes and veins of oligoclase-microcline granite and pegmatite cut and dissect the hornblende granite, whereas in parts, the rock seems to pass gradually to oligoclase-microcline granite. Thus the hornblende granite is older than or is an early manifestation of the oligoclase-microcline granite. The hornblende granite, in the vicinity of Témiscamingue lake, is younger than the volcanics which it intrudes but is not in contact with any other rocks. However, pre-Huronian granites similar to the hornblende granite have been described by Henderson (1936) along the east shore of Témiscamingue lake, just south of the area now under study.



Photograph 36 : Hornblende granite cut and dissected by dykes of pegmatite and oligoclase-microcline granite . (Brodeur lake area).

Origin of the hornblende granite

The fact that the hornblende granite is closely associated with oligoclase-microcline granite, into which it grades, in most parts of the area indicates that it is a mafic-rich facies of it. Furthermore, the numerous dykes of oligoclase-microcline granite indicate that it is an early manifestation of that rock. In the Brodeur lake sector, a similar relation is also evident as the granite is intimately mixed and associated with hornblende syenite.

The growth of porphyroblasts in rocks is considered by several authors as typical of contact zones surrounding margins of granitic masses and the literature abounds with such examples. Thus if this view is accepted as a general rule, we can consider the hornblende granite as a marginal facies of the oligoclase-microcline granite, which formed by assimilation of country rock and was transformed later by the action of the more advanced phases of the granite. This view is

not improbable but cannot unfortunately be supported by confirmatory evidence and must remain in the realm of the conjectural.

Various features of the granite create ambiguities as regards the mode of formation of the rock. For example, the apparent zoning here and the lack of it there, the altered cores and the sodic rims of the plagioclase are contradictory peculiarities, some indicating magmatic processes, some indicating metasomatic processes. In all probability the magmatic features are original and the zoning and rimming of the plagioclase and the myrmekites are associated with a late episode of potassic metasomatism.

However, the feldspars may not record the whole history of the rock as they may have been unmixed and recrystallized more than is now apparent. The evolution of the hornblende granite may be more complex than is indicated here.

7- Grey Granite Gneiss

Grey granite gneiss intimately mixed and associated with oligoclase-microcline granite and the quartz-feldspar-biotite schist of the Pontiac group outcrops in the northwest corner of the map-area, in the vicinity of Opasatica lake, three miles north of Rollet. A large elongated mass, trending approximately north with shallow dips to the east, occurs north of Solitaire bay. Thin, short lenses trending northwest, with gentle dips to the southwest and northeast, occur near the western shore of Opasatica lake and outline an antiform structure with a northwest trending axis. The topographic expression of the gneiss consists of low, narrow ridges elongated in a direction parallel to that of the foliation of the rock.

Lenticular inclusions of biotite schist and quartz-feldspar-hornblende schist are numerous and frequently display gradational contacts with the gneiss. Oligoclase-microcline granite intersects the rock as dykes and veins in places, but gradually passes into it elsewhere. Lit-par-lit veins of granitic material are characteristic features of the grey granite gneiss.

The granite gneiss is medium-grained, pale grey to dark grey on fresh and weathered surfaces, with pinkish lenticular zones here and there. Dark-coloured, mafic-rich layers, one-thirty second to one sixteenth of an inch thick, are interspersed with dominantly quartzose or feldspathic bands, one-fourth to half an inch thick. There are no sharp contacts between the layers and they usually appear to fade into each other. The gneissic structure is defined on a megascopic scale by the compositional layering and, on a microscopic scale, by the sub-parallel alignment of the mafics and the elongation of the quartz grains.

The gneiss is composed principally of plagioclase and quartz, and the accessory minerals are microcline, biotite, muscovite, epidote, chlorite, sphene, apatite, garnet and iron oxide. Oligoclase of An_{22} composition, occurring as coarse sub-angular grains, makes up to seventy-five per cent of the rock. It is relatively fresh and sericitization is observed mostly along the grain boundaries. Twinning is infrequent, and when present, it is indistinct, the twinned grains being cloudy and the lamellae weakly discernible. Flattened lenses of quartz occur along definite layers, in thin but long grains that show undulatory or strain extinction. Small blebs of quartz are also common in the plagioclase and in the microcline as secondary features.

Table 16 : Modal Analyses of Grey Granite Gneiss

	1	2	3	4
Quartz	22.40	24.29	27.77	30.00
Plagioclase	72.58	70.48	64.54	65.00
Microcline	tr.	3.19	2.92	-
Biotite	2.69	1.00	3.60	4.00
Chlorite	tr.	tr.		-
Muscovite	1.43	tr.	-	tr.
Epidote	tr.	tr.	tr.	tr.
Sphene + Apatite	tr.	tr.	tr.	tr.
Iron Oxide	tr.	tr.	-	-
Plagioclase	An_{22}	An_{16}	An_{16}	An_{21}

1 and 2 are from an area north of Solitaire bay.
3- quartz-feldspar gneiss from the north end of Gaboury lake.
4- Grey granite gneiss, from the Kipawa lake area, Robert, 1963, p. 102.

Microcline is of rare incidence and is usually fine and interstitial. It displays replacement relationships with the plagioclase, accompanied by sodic rimming of plagioclase and myrmekitic structures. The relations are not definite and do not indicate which of the feldspars is replacing which, but from analogous features previously described and discussed, we believe that microcline replaces plagioclase.

Olive-green to brownish-green biotite is a minor but typical constituent of the rock. It commonly has a "diseased" appearance and is transformed to colourless or pale-yellow epidote and chlorite. Tattered crystals of muscovite usually occur along the biotite and epidote. Small pale reddish garnets have been observed at various places in the rock but they are uncommon.

Table 16 contains two modal analyses of the granite gneiss.

A modal analysis of quartz-feldspar gneiss is also presented to illustrate the similarity in the mineralogical composition of the two rock types.

Table 17 : Chemical Analyses of Grey Granite Gneiss*

	1	2
SiO_2	72.31	70.00
Al_2O_3	16.27	17.97
Fe_2O_3	0.02	0.07
FeO	0.28	0.76
MgO	0.03	0.08
CaO	2.12	3.19
Na_2O	7.05	6.64
K_2O	0.62	0.51
H_2O	0.02	0.11
Total	98.72	99.33

* Obtained from the modal analyses of Table 16. Chemical analyses 1 and 2 correspond respectively to modal analyses 2 and 1.

The grey granite gneiss is related in mineralogical composition to the oligoclase-microcline granite and to the biotite schist, and it probably represents a mixture of the two rocks. It is very similar in composition and appearance to the quartz-feldspar gneiss of the Pontiac group (sample 3, Table 16) and it may equally represent a granitized portion of the biotite schist. Robert (1963) described a similar rock (Table 16, modal analysis no. 4) and concluded that it was an anatexite. The chemical analyses of grey granite gneiss (Table 17) have many similarities with those of the oligoclase-microcline granite, excluding the K_2O content, and afford additional evidence regarding the origin of the rock.

The mineralogical composition of the granite gneiss is

typical of the staurolite-quartz subfacies of the almandine-amphibolite facies of regional metamorphism (Fyfe, Turner & Verhoogen, 1958), which includes rocks that " commonly grade into migmatites veined with granitic materials,.." (Fyfe et all., 1958, p. 228).

To summarize, we believe that the grey granite gneiss, because of its mineralogical composition, chemical composition and field associations, represents members of the Pontiac group partly assimilated by, and intermixed with the oligoclase-microcline granite. This rock has not been subjected to the intense potassic metasomatism that affected most of the granitic rocks of the area.

8- Biotite Granite

An arcuate band of biotite granite, seven miles long and up to two miles in breadth, occurs in the southeastern corner of the map-area, in the vicinity of Brodeur lake. The zone extends from the southeast shore of Des Quinze lake to a region southeast of Brodeur lake, with a general northeast to east-west trend. Similar rocks are present on the west shore of Des Quinze lake and in places south and southeast of the main zone, but the occurrences are too small to be mapped separately. The biotite granite is associated to the north and southwest with hornblende syenite, and to the south with gneissic oligoclase-microcline granite into which it grades. Lenticular masses of biotite granite, of restricted dimensions, are common in the southern oligoclase-microcline granite, but no definite contacts can be observed and both rock types appear to pass gradually into one another. Conversely, small elongated masses of oligoclase-microcline granite occur in the biotite granite. The rock is intersected by relatively few

pegmatite and diabase dykes.

The biotite granite is coarse-grained, almost invariably gneissic, dark grey on weathered surfaces and light- to medium-grey on fresh surfaces. The grain size is not constant but varies from medium to coarse, and the grains are not equidimensional, plagioclase occurring as stout euhedral or subangular grains much bigger than the other components. In places, the size of the plagioclase is so unrelated to that of the other constituents that the rock has a porphyritic appearance. Quartz forms grains smaller than those of plagioclase but they are generally larger than those of the mafic minerals. In the gneissic portions of the rock, quartz tends to be concentrated along layers.

The gneissic structure is outlined by the parallelism of the ferromagnesian minerals, by their tendency to be segregated into layers or to envelop the plagioclase, and also by the sub-parallel arrangement of the elongated plagioclase grains. The gneissic structure is never a dominant feature of the rock inasmuch as it is not everywhere well-defined and apparent. In thin sections, it is not always evident and the rock appears to possess the hypidiomorphic-granular texture typical of many granites.

The biotite granite is composed essentially of plagioclase and quartz, with minor biotite, chlorite and epidote. Accessory minerals are hornblende, apatite, sphene, microcline, iron oxide, allanite and zircon. Plagioclase, of average An_{22} composition, constitutes approximately sixty per cent of the rock, as is illustrated in Table 18. It is always altered to sericite or paragonite and epidote, usually from the core or along the grain boundaries, but sometimes

the alteration is distributed evenly throughout the grains. Epidote tends to occur in clusters or agglomerations in the plagioclase. The plagioclase commonly displays zoning, this feature being observed in most thin sections, but not all grains are so characterized. The zoning is defined by alternating concentric dark and light layers and by the zonal distribution of the alteration products in some crystals. (Photograph 37). The boundaries between the zones are not sharp but diffusely pass into each other. Twinning, when it is present, is usually superimposed on the zoning. One-third to one-half of the plagioclase grains

Photograph 37 : Diffuse zoning in plagioclase with superimposed twinning.(Crossed nicols- X80).

are twinned, and frequently the grains are cloudy and the twinning is faint and hardly discernible, as if it was obliterated. Chessboard structures are present but they are of rare incidence. Small crystals of plagioclase also occur as inclusions in the coarse grains of plagioclase.

Table 18 : Modal analyses of Biotite Granite

	1	2	3	4	5
Quartz	28.42	26.87	26.70	32.79	25.80
Plagioclase	60.24	58.51	63.54	59.48	60.53
Microcline	tr.	tr.	tr.	1.00	7.14
Biotite + Chlorite*	5.63	6.35	8.39	2.57	5.60
Hornblende	1.36	tr.	tr.	tr.	-
Epidote	2.81	6.76	tr.	3.69	1.00
Iron Oxide	tr.	tr.	tr.	tr.	-
Apatite + Sphene	tr.	tr.	tr.	tr.	tr.
Plagioclase	An_{22}	An_{20}	An_{22}	An_{17}	An_{25}

Samples 1 and 2 are from the vicinity of Brodeur lake.

Sample 3 comes from an outcrop two miles northeast of Moffet along the east-west road.

Sample 4 comes from the southeast shore of Des Quinze lake.

Sample 5 comes from the southeast corner of the area, outside of the main belt of biotite granite.

* Chlorite makes up very little of the biotite + chlorite association, except in sample 2 where it is dominant.

Microcline is a minor constituent of the rock that forms small interstitial grains or replacement patches in plagioclase. It is accompanied by myrmekitic structures and sodic rimming of the plagioclase where the two minerals adjoin each other. The evidence as regards the nature of the microcline is poor and inconclusive, and it is impossible to learn from it whether the microcline is replaced by plagioclase or whether it represents incipient microclinization of the rock. In sample 5 of Table 18, it is seen that microcline is relatively abundant. This sample comes from a lens of biotite granite in the oligoclase-

microcline granite, southeast of the main occurrence and is not representative of the biotite granite as a whole. However, it demonstrates the increase in the amount of microcline associated with the increase in the amount of oligoclase-microcline granite in the rock.

The biotite granite contains about twenty-seven per cent quartz as interstitial grains, the size of which varies from fine to medium. Where quartz is concentrated along layers, as thin long lenses consisting of optically continuous material, it may form grains three times as long as the plagioclase grains. Blebs and vermicules of quartz also occur in plagioclase, but they constitute a very minute proportion of the rock. The quartz almost constantly shows moderate to high undulance but is not granulated.

Hornblende is present in most thin sections in very small quantities. It is usually pale to dark green, has a large optic angle, and an extinction angle, $Z \wedge c$, of 22°. It contains poikilitic inclusions of quartz and biotite, and alters to yellow epidote and green biotite. The biotite,always present in small amounts, characterizes the granite. It is pale yellowish-green to dark brownish-green, often has a "diseased" appearance and alters to chlorite and epidote. The epidote is colourless to deep yellow, may be twinned, and often shows small vermicular intergrowths of quartz or feldspar. Clinozoisite infrequently occurs in some samples. Epidote, hornblende, apatite, sphene, biotite and iron oxide display a proclivity to occur in clusters.

The origin of the rock is obscured by much conflicting evidence and is therefore problematical. The zoning of the plagioclase, the mineralogical composition, the frequent porphyritic nature and the

association of the rock with the oligoclase-microcline granite are compatible with a magmatic source. The gneissic structure, the undulatory extinction of quartz, the faint twinning and the chessboard pattern of some plagioclase are indicative of deformation. Thus we may have a granite deformed in the late stages of its emplacement. The relative abundance of epidote as a replacement of hornblende and biotite, as well as of the feldspar, may denote an episode of calcium metasomatism.

On the basis of composition, the biotite granite may also represent a quartz-feldspar gneiss or schist invaded and partly absorbed by oligoclase-microcline granite, with consequent development of plagioclase porphyroblasts as is typical of the marginal facies of granitic intrusives. The mineralogical composition of the rock is characteristic of that of quartzo-feldspathic assemblages of the staurolite-quartz subfacies of the almandine-amphibolite facies of regional metamorphism (Fyfe, Turner and Verhoogen, 1958). This mode of origin is further suggested by the presence of quartz-feldspar gneiss west of the main occurrence of biotite granite, and by the position of the granite as an extension of the quartz-feldspar gneiss. Thus the granite would represent quartz-feldspar gneiss partly modified and assimilated by the oligoclase-microcline granite.

9- Oligoclase-Microcline Granite

General Statement

The designation oligoclase-microcline granite includes diverse rocks of generally acidic composition that show so much variation in mineralogical composition and texture that appellations such as : monzonite, quartz monzonite, granodiorite, alkali granite,

etc.. would be used if it was attempted to describe and classify each type separately. Consequently the term granite is used in a general way rather than in the restricted meaning of the word. Granite, as used here, denotes the acidic composition, with an excess of silica, and the texture of the rock but does not convey the usual concept of a dominantly potassic or sodi-potassic rock. Actually the rock is in parts a granite in the restricted sense of the word, but it is more commonly of granodioritic composition. The potassic feldspar content varies widely and is almost invariably subordinate to the plagioclase content. However, the plagioclase is usually of such a composition, in the alkali range, as to enable us to classify the rock as a granite. We therefore deem it preferable to use the term granite, with the prefix "oligoclase-microcline" to connote more precisely the affiliations of the rock. Some extreme cases, where the rock passes gradually to a syenite or a diorite, were encountered but they are exceptional. The compositional variations are wide but are always within the range encompassed by the designation "oligoclase-microcline granite".

The granitic rocks can be broadly subdivided into two groups: a microcline-rich portion and an oligoclase-rich variety. However, the passage from one group to another is so imperceptible in the field that it is impossible to map them separately. The oligoclase-rich type appears to be most abundant, at least on the basis of the thin sections examined, but seems to pass within short distances to the other type and to be so mingled with it that no traceable pattern can be recognized in the distribution of oligoclase and microcline.

Introduction

The oligoclase-microcline granite underlies more than half the area but constitutes more than two-thirds of the rock, because granitic material invades, is injected into or is otherwise mixed with other rock types in amounts too small to appear separately at the present scale of mapping. The granite outcrops mostly in the northwest, northeast and southeast corners and in the central part of the area. Elsewhere it is merged with lenses of biotite schist, amphibolite, quartz-feldspar gneiss, grey granite gneiss, hornblende granite and plagioclase-hornblende gneiss. These hybrid portions of the rock may appear to be negligible when viewed separately but are important when considered as a whole. Porphyroblastic varieties of the granite are present here and there, being distributed erratically, and constitute a minor part of the rock. The oligoclase-microcline granite is always accompanied by numerous dykes and irregular masses of pegmatite and aplite.

The granite does not appear to have a strong influence on the topography, except locally by control of the drainage pattern. The relief of areas underlain by granite averages one hundred feet, and hills or ridges are scarce and not very conspicuous.

Petrography

The oligoclase-microcline granite is white or pale grey to pink, usually medium-grained, but may be fine-grained or coarse-grained, the grain size being extremely variable even within a thin section. Almost everywhere the rock is massive, uniform and homogeneous, with a notable exception in the southeast corner where the rock is gneissose.

Gneissose sections also occur elsewhere, in the vicinity of contacts with quartz-feldspar-biotite schist for instance, but they are not very abundant and constitute no more than ten per cent of the rock. The gneissic structure is outlined by the sub-parallel alignment of the mafic components, the elongation of the plagioclase grains and the compositional layering. In places, it is evident only on a mesoscopic scale, no gneissic structure being apparent in thin sections. The texture varies from allotriomorphic-granular to hypidiomorphic-granular and is sugary in the aplitic portions. The rock is rarely equigranular, the plagioclase grains being usually larger than the other components, and there are porphyroblastic varieties with coarse megacrysts of microcline, up to one-fourth of an inch in length. The rock is fresh to moderately altered and most components show little alteration except in rare instances where corrosion is strong.

The rock is composed mainly of the following minerals in variable quantities as is illustrated in Table 19: quartz, microcline, plagioclase, biotite, muscovite, chlorite and epidote. Accessory hornblende, pyroxene, apatite, sphene, zircon, pyrite, magnetite, ilmenite, allanite and monazite are present in some thin sections.

Quartz: Quartz constitutes from two to thirty-five per cent of the rock and occurs as interstitial grains and as a secondary mineral in corrosion structures. It often forms large elongated grains concentrated into layers, especially in the gneissic parts. Several large grains of quartz contain rounded inclusions of plagioclase and biotite and partially envelop some coarse grains of plagioclase. Undulatory extinction due to strain is a common feature of the quartz

in numerous thin sections, especially those from gneissic granite. Some highly deformed grains show lines or rows of tiny inclusions, sometimes called Boehm lamellae. Secondary quartz is formed as a result of corrosion in myrmekitic intergrowths in plagioclase at the contact of potassic feldspar and also as isolated blebs disposed along the borders of plagioclase and microcline grains. (Photograph 38).

Photograph 38 : Isolated blebs of quartz in plagioclase. (Crossed nicols - X80).

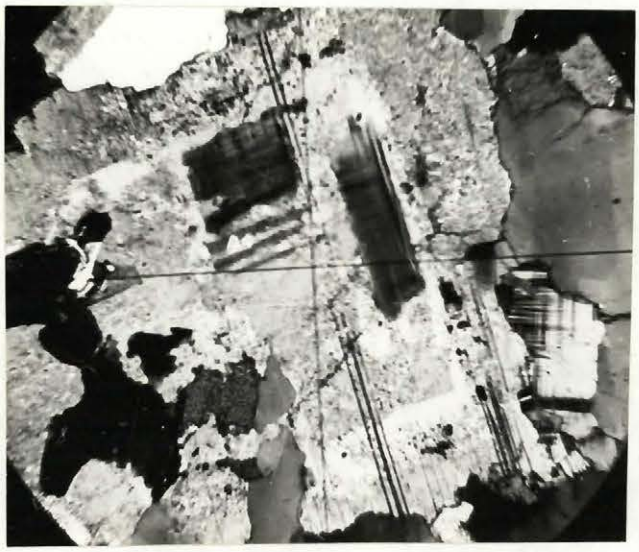
Microcline: Microcline generally constitutes about twenty per cent of the rock, with variations from one to forty per cent, and is always subordinate in amount to the plagioclase. It is so erratically distributed that it may be misleading to mention an average such as twenty per cent and it is by far preferable to consider each incidence separately such as in Table 19 in order to obtain a more accurate idea of the distribution of microcline. The microcline content varies not

only from area to area but also within a single outcrop where it can sometimes be observed as concentrations in layers.

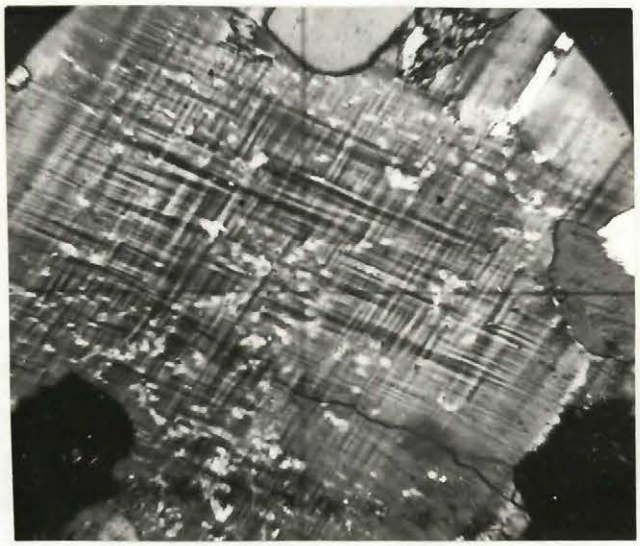
The microcline occurs as fine interstitial grains, as large porphyroblasts enclosing smaller grains of plagioclase, quartz, microcline, biotite and muscovite, or as rectangular or irregular patches within the plagioclase. In the gneissic parts, microcline occurs in the groundmass with the quartz and displays little granulation. Exceptionally, microcline forms large anhedral grains, smaller than the porphyroblasts and about the same size as quartz and plagioclase. When it occurs as fine interstitial grains it may, in places, surround or envelop numerous large grains of quartz and plagioclase and still preserve optical continuity, this representing the initial stages in the development of a porphyroblast or simply the permeation of a relatively solid rock. The cross-hatching or "tartan" pattern typical of microcline is always well developed and the microcline is always fresh and undeformed.

The porphyroblasts of microcline are of rectangular outline, from one-eighth to one-fourth of an inch in length, and contain inclusions of the other components as indications of their late formation. In several instances, rows of round quartz blebs were observed in the microcline along the borders. They suggest corrosion and may be products of the replacement of plagioclase by microcline.

Perthitic microcline occurs in numerous thin sections as string, bead and patch perthites. String perthites are rare, whereas patch perthites are abundant. The variations in the plagioclase content are so wide that some grains are actually antiperthitic. The development of the perthite is the result of the replacement of plagioclase by



Photograph 39 : Optically continuous rectangular patches of microcline in plagioclase. (Crossed nicols - X80).



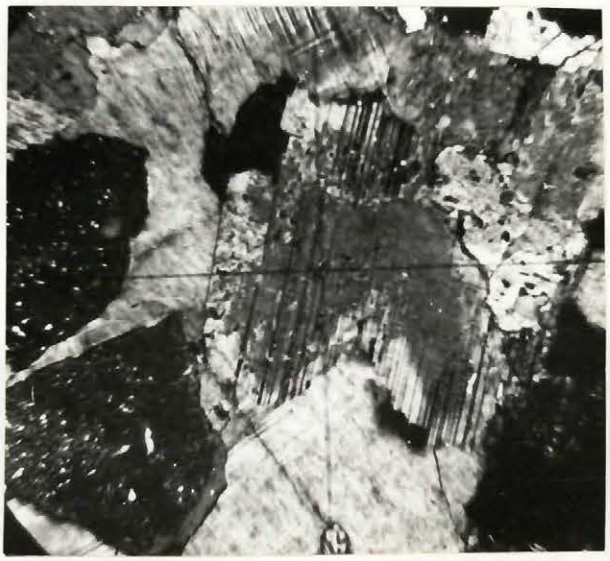
Photograph 40 : Microcline with development of perthitic structures. (Crossed nicols - X80).

microcline and this is suggested by the variations in the plagioclase content and by the shapes of the patches. This subject was discussed earlier with the hornblende-pyroxene syenite, and it was concluded that the formation of perthite as a result of replacement was not incompatible with the observed facts. All stages of the replacement can be viewed, from incipient with few patches of microcline in plagioclase to complete with string perthite.

Plagioclase :Plagioclase is the principal constituent of the granite, making from thirty to ninety per cent of the rock, with an approximate average of forty-five per cent. It occurs as large anhedral to subhedral grains in the massive granite and as large subrounded or elongated grains with serrated edges in the gneissic portions. The plagioclase is generally coarser than the other components with the exception of the microcline porphyroblasts, and in the gneissic granite it lies in a granulated groundmass of quartz, plagioclase and microcline. Some of the large grains of plagioclase are composite, that is, they are made up of two or more segments of different optical orientation. The composition of the plagioclase is generally An_{16-17}, but there are some examples where it is as low as An_4 and others where it is as high as An_{26}. These variations do not appear to represent trends and may be due to the diverse rocks associated with and assimilated by the granite.

The plagioclase is commonly altered, usually slightly but, in places, moderately to intensely. The commonest alteration products are sericite, paragonite and, in the highly altered phases, epidote, zoisite and calcite. In most examples the alteration products are

distributed at the core or along the grain boundaries and in rare isolated cases they are disposed along concentric zones. In places, the alteration is uniform and the products form a homogeneous mat throughout the grains whereas, elsewhere, they are observed only along certain twin lamellae or are disposed with their long side parallel to the direction of the twin planes. Evidence of corrosion is found at the contacts of plagioclase and potassic feldspar as quartz blebs, vermicular intergrowth of quartz and clear sodic rims along the plagioclase grains. (Photograph 41). In highly corroded specimens these



Photograph 41 : Clear sodic rim along plagioclase grain. (Crossed nicols - X80).

features are present even if there is no interstitial microcline or if the plagioclase is not in contact with potassic feldspar. No relations could be established between the degree and type of alteration (core, rim, zone) and the deformation of the rock.

Zoning of the plagioclase is of rare occurrence in the oligoclase-microcline granite and is outlined by the concentric

distribution of sericite and paragonite. In places, it is defined by the alternation of light and dark layers with diffuse boundaries, this zoning being best observed at or near the extinction position. Twinning is usually superimposed on the zoning.

Twinning of the plagioclase according to the albite and albite-carlsbad law is common but twinning is not a pervasive characteristic of the rock. In the gneissic portions it is either absent or very faint and indistinct, and in the massive rocks not all grains display clear and well-defined twins. In some sections only the finer plagioclase grains are twinned, whereas in others only the larger grains are twinned. Chessboard patterns due to readjustment of the lamellae to strain have been observed in deformed granites. They are usually accompanied by undulance and bending of the crystals. No attempt has been made at classifying the twin laws in order to correlate them with external factors along the lines proposed by Turner (1951) and Gorai (1951) because such a study would not be conclusive. "Many of the results of other studies on the frequencies of twin laws are not in accord with the above statements nor with each other, and it is probably fair to say that general rules of correlation are not yet fully established." (Deer, Howie and Zussman, 1963, vol. 4, p. 106).

Biotite: Pale yellowish-brown to dark brownish-green or dark brown biotite constitutes four per cent of the rock, with exceptions where it makes up to twenty-two per cent or is completely absent. It occurs mostly in the central part and the southeast corner of the area and is rarely observed in the northernmost occurrences. Rounded quartz inclusions in the biotite were detected here and there. Biotite

alters to chlorite with ancillary development of rutile. The refractive indices of biotite from a sample from an area northeast of Rémigny are: Ny = Nz = 1.634 ± 0.002. Secondary green biotite from the alteration of hornblende is present in small amounts here and there. In the southeast corner of the area, biotite, epidote, magnetite and apatite have a tendency to occur in small clusters in the rock.

Muscovite : Colourless muscovite constitutes up to ten per cent of the rock but is generally not abundant. It occurs mostly in the northern granites where it is often the sole mica. In many instances, small flakes are dispersed within the plagioclase crystals and appear to be secondary products.

Epidote: Epidote occurs in most thin sections in very small quantities as colourless to pale yellow and deep yellow anhedral grains, often displaying twinning. Small hair-like or rounded intergrowths of quartz or clear feldspar were observed in a few grains at the contact of epidote and quartz.

Accessory minerals :Light-green to dark-green to dark bluish-green hornblende occurs in several places, usually in the vicinity of amphibolite and hornblende granite. It is shredded and readily alters to epidote and biotite which it encloses poikilitically. Pyroxene, usually a sodic augite, was observed in thin sections of samples from granite adjoining the hornblende-pyroxene syenite and also from other occurrences unrelated to pyroxene-bearing rocks. It is present in small amounts and is frequently so altered that only remnants are seen. Zircon is a widely occurring mineral in the granite which is observed in most thin sections as small crystals enclosed in biotite and surrounded by

Table 19 :

	1	2	3	4	5	6	7	8	9
Quartz	15.79	30.47	24.48	29.63	25.07	30.01	16.69	32.29	34.45
Microcline	21.40	31.58	19.30	3.45	tr.	11.82	27.08	11.49	21.16
Plagioclase	58.61	34.18	53.53	59.56	70.24	53.29	47.74	45.77	42.32
Hornblende	-	-	-	1.40	-	-	-	-	-
Biotite	3.48	1.85	1.99	-	1.24	1.59	7.45	-	tr.
Pyroxene	-	-	-	-	-	-	-	-	-
Epidote	tr.	tr.	tr.	4.15	2.39	-	tr.	-	tr.
Muscovite	tr.	-	-	-	-	tr.	-	10.45	1.18
Chlorite	-	tr.	-	tr.	-	3.29	bio.	-	tr.
Sphene + Apatite	tr.	tr.	tr.	tr.	tr.	-	tr.	-	-
Iron ores	tr.	tr.	tr.	tr.	tr.	-	tr.	-	-
Allanite	tr.	tr.	-	-	-	-	-	-	-
Plagioclase	An_{15}	An_{17}	An_{17}	An_{4}	An_{15}	An_{7}	An_{26}	An_{10}	An_{21}

Samples no. 1-2-3-4 are from the vicinity of Moffet (Gaboury and Des Quinze

Sample 5 is from the southeast corner of the area.

Samples 6-7-8 are from the northeast corner, Basserode and Caron lakes.

Samples 9 to 17 (incl.) are from the north central half of the area.

Samples 18 to 24 are from the west central part. (Nédelec, Guérin).

Samples 25 to 29 are from the northwestern angle (Opasatica lake, Rollet)

Sample 30 is from an area in the vicinity of Des Quinze river.

Modal Analyses of Oligoclase-Microcline Granite

10	11	12	13	14	15	16	17	18	19	20	21	22	23
28.00	2.35	24.19	18.85	5.06	28.45	23.92	26.10	26.94	25.58	22.85	20.39	23.16	19.95
27.20	-	18.95	20.24	23.88	29.21	tr.	15.06	18.92	33.47	31.21	23.75	29.78	31.09
42.20	88.07	48.57	56.01	69.66	41.53	51.57	52.86	44.54	39.30	43.74	51.59	43.65	45.88
-	3.92	-	-	tr.	-	tr.	-	-	-	-	-	-	-
2.00	-	tr.	3.05	-	-	22.16	tr.	-	-	-	-	-	tr.
-	tr.	-	-	tr.	-	-	-	-	-	-	-	-	-
tr.	1.37	1.94	tr.	tr.	tr.	1.57	tr.	2.74	-	tr.	1.35	1.00	tr.
tr.	-	tr.	-	-	tr.	-	3.36	-	1.60	tr.	2.65	2.37	tr.
tr.	-	4.79	1.57	-	tr.	tr.	1.56	6.60	-	1.33	tr.	tr.	tr.
-	tr.	tr.	tr.	tr.	-	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.
-	tr.	tr.	-	tr.	tr.	-	tr.	tr.	-	tr.	-	tr.	tr.
-	-	-	-	-	-	tr.	tr.	-	-	tr.	-	-	-
An_{16}	An_{15}	An_{17}	An_{16}	An_{5}	An_{14}	An_{25}	An_{16}	An_{19}	An_{17}	An_{17}	An_{6}	An_{6}	An_{11}

lakes).

24	25	26	27	28	29	30	
30.10	27.67	12.41	28.59	29.27	21.15	24.46	Quartz
24.45	15.63	39.78	29.02	25.05	17.90	17.55	Microcline
41.91	50.37	39.30	38.86	41.01	57.26	50.79	Plagioclase
-	-	-	-	-	-	-	Hornblende
3.09	4.95	-	tr.	-	-	4.68	Biotite
-	-	-	-	-	-	-	Pyroxene
tr.	tr.	tr.	-	-	tr.	1.29	Epidote
tr.	tr.	8.23	3.39	3.07	1.48	-	Muscovite
-	tr.	musc.	tr.	1.60	1.94	tr.	Chlorite
tr.	tr.	tr.	-	-	tr.	tr.	Sphene + Apatite
-	tr.	-	-	-	-	-	Iron ores
-	-	-	-	-	-	tr.	Allanite
An_{16}	An_{18}	An_{15}	An_{10}	An_{14}	An_{17}	An_{5}	Plagioclase

pleochroic haloes. Reddish-brown to greenish-brown allanite (orthite) occurs as a metamict core in epidote minerals and as small isolated grains. Light-yellow monazite is a rarely occurring mineral.

Modal Analyses

The thirty modal analyses of oligoclase-microcline granite, presented in Table 19, illustrate the large variations in the mineralogical composition of the rock. All components vary in amount, and not only a few as was common in the other granitic rocks of the area. Some samples represent transitional rock types and are not granites in the proper sense (i.e. :nos. 11 & 14). We have not included modal analyses obtained from the literature because it is useless to compare the modal analyses of this area with those of adjacent areas in view of the compositional variability of the rock. It is relatively easy to find similarities between the various granitic rocks of this and adjacent areas but no useful purpose is served because extreme divergence are also found. In Table 19, the samples are grouped on a geographical basis in order to illustrate the compositional variations not only from region to region but also within a region. This grouping of the modal analyses discloses that the distribution of the minerals does not follow a definite pattern, but is erratic, except maybe for muscovite which is observed mostly in samples from the north. Consequently the distribution of the minerals can be said to depend on the invaded, assimilated or re-melted rocks rather than on a singular dominant process (i.e: metasomatism, metamorphic differentiation, magmatic crystallization..).

A classification of the granitic rocks on the basis of the modal analyses, according to the system proposed by Jung and Brousse

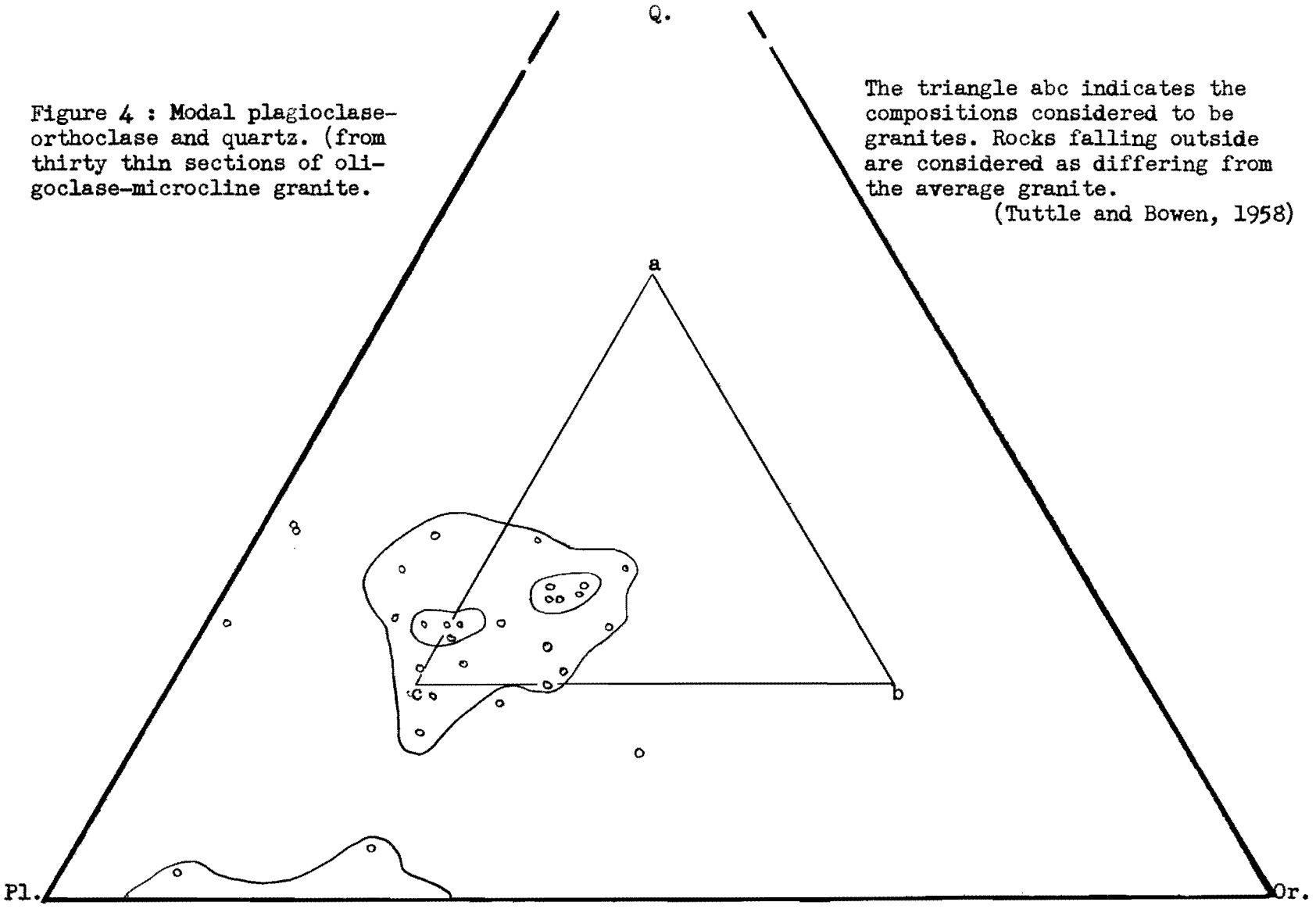


Figure 4 : Modal plagioclase-orthoclase and quartz. (from thirty thin sections of oligoclase-microcline granite.

The triangle abc indicates the compositions considered to be granites. Rocks falling outside are considered as differing from the average granite.
(Tuttle and Bowen, 1958)

Table 20 :

	1	2	3	4	5	6	7	8	9	10
SiO_2	68.83	74.06	72.24	73.47	72.33	74.95	74.54	75.75	74.34	64.00
Al_2O_3	17.42	14.17	15.76	13.97	16.88	14.44	16.00	14.23	14.27	20.65
Fe_2O_3	0.09	0.15	0.05	0.54	0.27	0.07	-	0.02	0.05	0.40
FeO	1.00	0.72	0.57	0.33	0.03	0.65	-	0.19	0.55	0.55
MgO	0.10	0.26	0.06	0.41	0.01	0.69	-	0.02	0.06	0.65
CaO	1.77	1.38	1.72	1.81	2.77	0.64	0.92	1.80	0.85	3.53
Na_2O	5.88	3.36	5.32	6.63	6.99	5.91	4.84	3.96	4.51	8.76
K_2O	3.84	5.37	3.36	0.56	0.30	2.14	3.19	3.69	4.67	0.66
H_2O	0.06	0.17	0.03	0.24	0.13	0.49	0.50	0.07	0.03	0.18
Total	98.99	99.64	99.11	97.96	99.71	99.98	99.99	99.73	99.33	99.38
M. A. *	1	2	3	4	5	6	8	9	10	11

M.A. * - The numbers correspond to the numbers of the modal analyses of Table 19, from which the chemical analyses were obtained.

28 ** - Analysis of Muscovite leucogranodiorite, from the south shore of Solitaire river, near the road. Analyzed by W.H. Herdsman. Faessler, C., (1962), p. 58, no. 302.

29 *** - Analysis of muscovite leucogranodiorite, from the outlet of Mourier lake (east of the map-area). Analyzed by W.H. Herdsman. Faessler, C., (1962), p. 58, no. 303.

30 **** Analysis of muscovite granodiorite, from the La Motte-Lacorne batholith. Analyzed by W.H. Herdsman, Faessler, C., (1962), p. 60, no. 317.

Chemical Analyses of Oligoclase-Microcline Granite

11	12	13	14	15	16	17	18	19	20	21	22	23	24
69.00	69.56	67.75	74.32	71.50	73.31	71.96	71.93	73.09	71.07	74.32	71.58	67.23	74.62
15.86	17.13	18.54	14.39	16.11	15.58	16.01	16.40	15.65	16.11	14.25	15.22	19.25	14.91
0.90	0.11	0.05	-	0.56	-	0.13	0.15	0.11	0.13	0.08	0.12	-	-
1.22	1.18	0.08	-	0.55	-	0.28	0.02	0.01	0.01	0.88	1.35	-	-
1.01	0.42	0.11	-	0.33	-	0.28	0.01	-	-	0.09	0.15	-	-
2.20	1.92	0.88	1.18	1.69	1.36	1.67	1.00	0.81	1.25	1.27	2.02	1.19	0.79
4.72	5.49	7.87	4.25	5.22	3.89	4.37	5.73	4.87	4.90	4.22	4.74	3.97	4.16
3.07	3.62	3.93	4.79	2.87	5.72	5.13	4.21	5.18	5.21	4.32	3.04	7.58	5.20
0.64	0.25	-	-	0.35	0.08	0.19	0.17	0.14	0.07	0.05	0.08	0.40	0.16
98.62	99.68	99.21	98.93	99.18	99.94	100.02	99.62	99.86	98.75	99.48	98.30	99.62	99.84
12	13	14	15	17	19	20	21	22	23	24	25	26	27

25	26	27	28**	29***	30****
73.97	70.69	72.15	73.54	73.60	73.64
15.13	17.11	14.75	14.48	14.57	14.48
0.03	0.04	0.27	0.06	0.14	0.03
0.32	0.39	1.34	1.42	1.16	1.52
0.34	0.41	0.15	0.25	0.53	0.08
1.16	1.96	0.87	0.82	0.92	0.96
4.18	5.63	5.66	4.24	3.37	4.59
4.50	3.12	3.32	4.29	4.88	4.52
0.35	0.31	0.11	0.70	0.60	0.32
99.98	99.66	98.62	99.80	99.77	100.12

28 29 30

(1959), yields diverse rock groups. Alkaline and sub-alkaline granites are dominant and monzonitic granites and granodiorites occur in large numbers. Thus the modal classification is in agreement with the appellation of the rock as discussed previously in the general statement.

Figure 4 is a triangular plot of modal plagioclase, orthoclase (microcline) and quartz which shows that most of the granites fall within the range of the average granite. Isolated points are from transitional rock types.

Chemical Analyses

The chemical analyses of Table 20 were calculated from the modal analyses of Table 19, except for the last three which are chemical analyses obtained from the literature. In contrast to the modal analyses, the chemical analyses do not display great variations. The SiO_2 content is seen to vary but little with two main groups of figures around 69.00 % and 73.00 %. Persistent variations predictably occur in the Na_2O and K_2O content, but the sum of these two oxides is nearly constant. The K_2O and Na_2O variations can be directly related to the potassic metasomatism. Analysis no. 28 is from a granite located near Rollet and analysis no. 29 from a granite near Mourier lake in the adjacent map-area to the east. Both analyses are similar and indicate a relation between the rocks of the two areas. It is also to be noted that these analyses are identical to some of the calculated analyses. Analysis no. 30 is from the LaMotte-LaCorne batholith and illustrates the similarities in the composition of this granite and of the granites of this area.

The chemical analyses present a unifying picture in

comparison with the modal analyses in this that whereas the rocks have diverse mineralogical composition, they nevertheless have a constant chemical composition. This is an important point which will be mentioned again in the discussion on the origin of the rock.

Porphyroblastic Granite

Porphyroblastic oligoclase-microcline granite is not as plentiful as the porphyroblastic hornblende granite, but many examples have been observed. The rock does not contain inclusions, does not appear to be related to the hornblende granite and is not a border phase. In other words, the distribution of the microcline porphyroblasts cannot be related to any particular feature.

The porphyroblasts are generally of rectangular outline and are not much bigger than some of the larger plagioclase grains. They contain numerous small inclusions of plagioclase, quartz, biotite, muscovite and epidote disposed randomly or along the edges. Some of the plagioclase islands are optically continuous and may be isolated parts of a previously larger grain. The porphyroblasts have no influence on the texture and structure of the host rock, that is, they do not disrupt the arrangement of the minerals about them.

The development of the porphyroblasts is probably one aspect of the wholesale microclinization of large segments of the oligoclase-microcline granite. The origin of the porphyroblasts has been discussed in the section dealing with the hornblende granite, and the conclusions were that they are the result of metasomatism or metamorphic differentiation from the differential movement of ions in a fluid solution under the influence of gradients in chemical potential. Thus

the formation may be due to the local concentration of potash brought about by migrating solutions. The work of Orville (1963) and Wyart and Sabatier (1956) shows that alkali metasomatism may take place in the presence of an alkali-bearing vapor phase as a natural consequence of temperature, pressure and compositional gradients in the earth's crust. Furthermore, Harme (1958) writes that microcline porphyroblasts are independent of the host rock and this explains why we find them in the hornblende-pyroxene syenite and the hornblende granite as well as in the oligoclase-microcline granite.

Porphyroblastic granites are commonly referred to as synkinematic in the literature, and it is generally considered that the development of porphyroblasts is favoured by mechanical deformations which facilitate the influx and diffusion of the elements. Marmo (1958) mentions that the formation of microcline in the microcline granites has been correlated with their formation in a paratectonic environment. However we do not believe that they can be related to strong tectonic deformation such as is outlined by Arribas (1961) for granite porphyries, because the deformation of the granites in the map-area, although general, is weak.

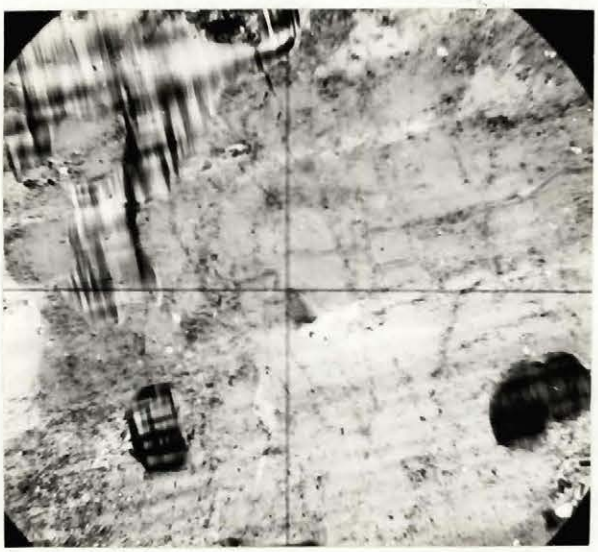
Myrmekites

Myrmekitic intergrowths of quartz in plagioclase at the contact of potassic feldspars are of common occurrence in the oligoclase-microcline granite, although they are not as widespread as in previously described rock types. In rare instances, round blebs of quartz are disposed along the boundaries of some plagioclase grains that are not in contact with potassic feldspar.

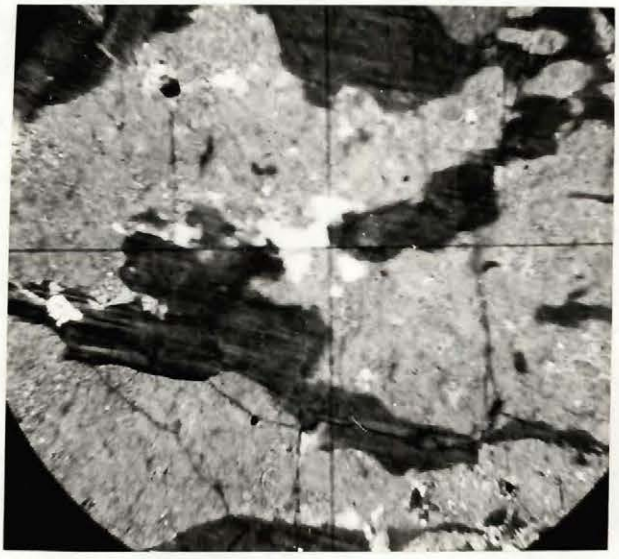
Myrmekites were discussed with the hornblende syenite and the hornblende granite, and it was concluded that they could result from replacement or corrosion of plagioclase by microcline. The isolated quartz blebs may result from silicification because Sederholm (1916) has suggested that the juxtaposition of plagioclase and microcline or orthoclase is essential for the formation of myrmekite. However, Drescher-Kaden (1948) wrote that such corrosion phenomena could result from intense myrmekitization under the influence of very mobile solutions. It is believed that the blebs observed here represent intense myrmekitization rather than silicification.

Microclinization

In almost every thin section of oligoclase-microcline granite, microcline is seen to replace the plagioclase. The evidence pertaining to this relationship is not always clear, not everywhere present, but as a whole it is conclusive. In rare instances, wedges or tongues of microcline intersect or penetrate into the plagioclase along and across the twin lamellae. Patches of microcline in plagioclase are sometimes linked with interstitial microcline by short tenuous strings of microcline. Isolated patches and blebs of microcline are common in plagioclase, sometimes in small quantities and sometimes almost completely obliterating the plagioclase. Thus, all stages of replacement are present from incipient (Photograph 42) to late where only fragments of plagioclase remain as in a perthite. Other, less convincing, features such as those described earlier for the hornblende-pyroxene syenite and the hornblende granite were also noted here. In places, no definitive indications are observed, but the fretting of plagioclase by



Photograph 42 : Incipient replacement of plagioclase by microcline. Note microcline embayments in plagioclase. (Crossed nicols - X80).



Photograph 43 : Intermediate stage of replacement. Microcline permeates the plagioclase. (Crossed nicols - X80).

microcline is reflected by the development of sodic rims and by the myrmekitization of plagioclase. Albitic rims on plagioclase usually accompany microclinization, although they are regarded by some geologists as a product of direct crystallization during the later stages of magmatic solidification (Rogers, 1961).

Photograph 44 : Replacement of plagioclase by microcline and rimming of plagioclase. (Crossed nicols - X80).

Not all of the microcline, however, is due to replacement and this is intimated by the presence of discrete microcline blebs in microcline porphyroblasts. It is difficult to establish the proportion of primary to secondary microcline now present in the granite but it appears to be very low. Thus, the observed facts point to the replacement of plagioclase by microcline and this is further supported by the interstitial nature, the late appearance of the microcline, the development of porphyroblasts and also by the occurrences of similar

features in other rock types. This subject has already been discussed in the section on the hornblende syenite and hornblende granite and it was concluded that microcline did replace the plagioclase and that the replacement of plagioclase in those rocks occurred during the episode of potassic metasomatism that affected the granite. Freeman (1957) expounded on the formation of granite from granodiorite by the replacement of plagioclase by microcline and considered granulation as very important in bringing about microclinization of the rock. No granulation to speak of was observed in the northern part of the area, whereas it is a dominant feature of the southeastern granites, and in both places the microclinization is widespread, although it is more so in the north. However,almost all of the granite show evidence of deformation, albeit usually very faintly.

It is notable that the large amount of microcline in some granites in the north is accompanied by large quantities of muscovite which may thus also be related to the potassic metasomatism. Another side-effect of the microclinization may be the formation of epidote as demonstrated by Ch'Ih (1950).

Migmatization

Migmatization occurs in the west central, northwest and northeast corners of the area where the biotite schist and the grey granite gneiss are invaded and injected by the oligoclase-microcline granite. In the neighbourhood of the contact of the granitic masses with the schist and gneiss there is complex interlayering of the rock types. Lit-par-lit injection of granite, granitic dykes and sills, and ptygmatic veins accompanied by myrmekitization and microclinization

are typical features of the migmatized rocks.

Migmatites are usually observed in the vicinity of the large lenses of quartz-feldspar-biotite schist and granite gneiss and rarely with the small isolated lenses which are so common in the central part of the area. Thus it seems that the migmatites are the forerunners of the granitic masses or that they represent the early phases of differential anatexis and injection associated with the emplacement of the granite. This last view is held by several geologists. Harme (1959) writes that migmatites represent an intermediate stage in the granitization process and that they are products of the injection of the granitic melt. Therefore the migmatites are of metamorphic origin but are concomitant with the emplacement of the granite of which they are a manifestation.

Structural Features

Gneissic structure - Layering - Banding : The granitic rocks of the southeastern part of the area display a well-defined gneissic structure trending north to northeast. Elsewhere, gneissic structures are present, especially near the contacts with other rock types, but they are not persistent and are only minor features of the rock. Here and there, weakly defined layering and banding, outlined by the segregation of minerals into layers, are present. Flow layering parallel to the contacts of the granite with other rock types is common.

Lineation : A lineation defined by the parallel orientation of the platy and elongated minerals is of common occurrence in the northern granites near the biotite schist lenses but is rare in the central part of the area. The lineation is generally parallel to the

structural trends of the surrounding rocks. Where the porphyroblasts are abundant, they may define a lineation by exhibiting parallelism. Inclusions of foreign material are usually stretched and elongated, and define a lineation.

Pinch and swell : Structures in which sills of granitic material in biotite schist pinch and swell at regular intervals are frequent. These features are as much part of the schist as of the granite and may represent incipient boudinage. Their origin is very likely related to that of boudinage.

Joints : Cross-, longitudinal and flat-lying joints are part of a major joint system which is discussed in chapter V along with the joint pattern of the area. Flat-lying joints are abundant and are frequently occupied by aplitic and pegmatitic material.

Faults: No major faults or evidence of major faults were noticed in the oligoclase-microcline granite. However their presence can be inferred and this is discussed at length in chapter V. Minor faults of insignificant displacement are common, especially in the southeastern granites. Microfaults surrounded by granulated matter, undulance of the minerals and deformed crystals are frequently observed in thin sections.

Cataclastic Structures : Small-scale cataclastic structures can be observed in several thin sections of granite. Crushing, granulation and microfaults are associated with wavy extinction, chessboard patterns in the plagioclase, Boehm lamellae in quartz, myrmekites and bent or otherwise deformed crystals. Such structures are not abundant and do not characterize the granite.

Folding : Folding of the granite is not generally conspicuous and is restricted to the lenses and sills associated with the quartz-feldspar-biotite schist.

Ptygmatic folds : Granitic veins in the migmatized zones of the quartz-feldspar-biotite schist are frequently highly contorted. Some are very thin, from one-fourth to half an inch, and others are as much as six inches in width. They are folded very tightly but are not fractured. They can be observed to originate from larger granitic dykes or sills and to extend across migmatitic layers and even oligoclase-microcline granite. (Photograph 45). They usually preserve their width

Photograph 45 : Ptygmatic folds. Granitic dykes and sills in Pontiac schist. (Roger L.)

through the fold closures, although they may be thinner or wider in places, this change in width being independent of the folding. They frequently branch and some branches are straight and sill-like, whereas others are folded. The style and nature of this folding is unlike that of any other deformation in the area. Various modes of origin have been

proposed by geologists to account for ptygmatic folding. Wilson (1952) argues that in several cases the folding occurred before the crystallization of the vein, by the forceful push of the vein matter against an obstacle. Dietrich (1960) reviewed the origin of ptygmatic features and concluded that they develop in a passive host or are due to magmatic flowage but are not the result of other processes. That they develop in a passive host during the differential anatexis phase of granitization is considered a likely mode of origin for many of the folds encountered. But some folds which more or less correspond in pattern with the deformation of the host rock indicate that the host was not entirely passive.

Photograph 46 : Ptygmatic folds in granitic material, amphibolite and Pontiac schist. (Vicinity of Roger Creek).

Stratigraphic Relations

The oligoclase-microcline granite intrudes or is injected into all the rock types previously described, excepting the volcanic

rocks which definitely antedate it. The granite is most frequently in contact with the quartz-feldspar-biotite schist of the Pontiac group, this contact being here sharp and there gradational. It merges slowly into the grey granite gneiss and the quartz-feldspar gneiss which appear to be transitional phases of the oligoclase-microcline granite. It grades into and has abrupt contacts with the hornblende granite into which it sends numerous dykes. (Photograph 47). Inclusions of all

Photograph 47 : Oligoclase-microcline granite invading hornblende granite. (Vicinity of Roulier).

sizes of any of these rocks are encountered in the granite, the most abundant being those of biotite schist and amphibolite which form streaks or elongated schlieren. Many inclusions appear to be unrelated to any rock type now exposed and this is probably due to assimilation or partial digestion with consequent compositional changes of the inclusions. The porphyroblastic granites cannot be said to be border phases because no such relationship was observed. Their distribution is seemingly erratic and seems to be independent of the intruded rocks.

The granite is intersected by pegmatitic material, a few lamprophyre dykes and by several diabase dykes. It is overlain by the Cobalt conglomerate in the northwest corner of the area.

Age and Correlation

No absolute age determinations are available for the oligoclase-microcline granite within the map-area. However, two determinations from granitic rocks in the adjacent area to the east have been published (Lowdon, 1960, p. 32-33). Potassium-argon age determinations of a quartz-monzonite from Béraud township gave 2,600 million years (G.S.C. 59-76) and of a biotite granodiorite from Béraud township gave 2,285 million years (G.S.C. 59-78). These determinations indicate that the emplacement of the granite occurred about 2,285 million years ago (G.S.C. 59-76 is highly chloritized and the dating probably incorrect). Snelling (1962, p. 14) writes: "The results do suggest, though only faintly, that metamorphism of the Pontiac schists and granitization in the Ottawa Mountain granite belt occurred a little later than the deformation and metamorphism that affected the rocks of the Abitibi Group.. ..The batholith (Preissac-LaCorne) was intruded after deformation and metamorphism of the Abitibi Group in contrast to the granites in the Pontiac Group which were probably intruded contemporaneously with metamorphism.....More important is the definite indication provided by these two determinations that the metamorphism of the Pontiac Group and the formation of the Ottawa Mountain granite belt occurred or perhaps one should say was initiated, more than 2000 million years ago.."

The oligoclase-microcline granite of the area is the western prolongation of the acidic rocks described by Freeman (1957) in

the adjacent area to the east and these granites can undoubtedly be considered as a single unit of considerable extent. Some phases of the Preissac-LaCorne batholith to the northeast show many similarities to the oligoclase-microcline granite. However, because of slight differences in age, different mode of emplacement and association, the two granites cannot be correlated, although Gussow (1937) did establish a relation on the basis of similar compositions. There are numerous small masses of granitic rocks in areas to the north that are much like the oligoclase-microcline granite and may be correlative equivalents, although this cannot be established because no basis other than that of similarity of composition is available now. Robert (1963), Auger (1952), Denis (1938) and Henderson (1936) mapped and described granitic rocks which they sometimes referred to as "Pre-Huronian granites". They are of varied composition but often show similar features and may be correlative. Some are the south and southeast prolongation of the oligoclase-microcline granite of this area and, consequently, all may have mutual relations. Osborne (1956) wrote that the granitic intrusives of the Keewatin-Grenville transition zone may be related on the basis of chemical composition to the Timiskaming intrusives.

Emplacement

The subject of the emplacement of the granite is complex and somewhat obscure because of much contrasting evidence. The bulk of the oligoclase-microcline granite, in the central part of the area, is massive and fairly homogeneous. There, the granite contains few large inclusions and is rarely in contact with large masses of other rock types. In the southeast corner the granite also holds few inclusions

but is dominantly gneissic. Elsewhere in the area the granite grades into or is in contact with other rocks.

The large mass in the center is juxtaposed on the north and on the south to wide belts of biotite schists and quartz-feldspar gneiss into which it has gradational or digitated contacts. The belts are comparably folded into wide, open, northeast trending antiforms and synforms and the granite has a conformable attitude. The shape of the granite mass is that of a wide stratoid lens and its relation to the schist and gneiss is that of a phacolithic intrusion. However, this may be too exaggerated an interpretation because of the extensive width of the granite mass and the locally discordant relations. Extrapolations of observations over such a long distance necessarily imply a lack of precision. Elsewhere the granite has concordant relationships with the quartz-feldspar-biotite schist. The structural features of the granite are usually similar to those of the invaded rocks and the granite must have been emplaced while the rock was being deformed. The development of porphyroblasts and other signs of potassic metasomatism added to the concordant structural features imply a synkinematic emplacement. The relations with the hornblende granite do not give much information on the nature of emplacement and in this respect the hornblende granite should be regarded as a phase of the oligoclase-microcline granite.

The features described above are those of mesozone to catazone batholiths such as classified by Buddington (1959). Mesozone batholiths are in part discordant and in part concordant whereas catazone batholiths are predominantly concordant. The relationships of the

oligoclase-microcline granite to the surrounding rocks are of a predominantly concordant nature and this enables us to classify the rock as a catazone granite. A discussion on the mechanism of emplacement is too related to the question of origin to be considered separately, and therefore this topic will be discussed later.

Origin

The extensive mass of granite in the area displays several features that can be interpreted in different, and even opposite, fashions, according to the point of view of the analyst. We will present the evidence first and discuss it later in order to preserve as much objectivity as possible. Perfect objectivity cannot however be attained because, over the years, the field observations and the petrographic work on the granites of the area have led to a sometimes unconscious appraisal of the origin and the impression created cannot be easily uprooted.

Field Relations:

(1) The area underlain by the granite is very large, covering approximately 1000 square miles.

(2) There is widespread evidence of deformation (shape of the granitic masses, slight granulation in the southeast, foliation,..)

(3) A large quantity of pegmatite is associated with the granite.

(4) Few lamprophyre dykes were noted in the granite.

(5) The contacts between the granite and the country rocks are generally gradational. This is not meant to indicate that there is a complete transition marked by gradual changes in composition from one rock to the other but that the contact zone is wide and

includes a mixture of the two rock types. Gradual changes in composition do occur but are not characteristic features.

(6) Dykes and sills of granitic material are common in country rocks bordering the granite. The dykes have sharp contacts but no chilled borders.

(7) Migmatization is common in the contact zone and it is associated with ptygmatic folding.

(8) Inclusions of country rocks are common. They are brecciated and dislocated in parts, and appear to preserve their original composition and attitude elsewhere. They are not abundant in the center of the area.

(9) The structural features of the country rocks extend into the granite in places, apparently preserving their trends and general attitude (gneissic structure, parallelism of elongated inclusions.)

(10) Segregations of minerals such as quartz, biotite and muscovite along parallel layers are suggestive of layering or of ghost stratification. Such features are common in the border zones but are also observed in the central part of the area.

(11) The granite occurs in an area subjected to regional metamorphism and the mineralogical composition of the granite is compatible with that of the metamorphic grade of the surrounding schists and gneisses. Regional metamorphism extends throughout the granite.

(12) There are no aureoles of thermal metamorphism.

(13) The granite is not of uniform texture and mineralogical composition. Variations are large, not only over long distances but also within a few feet. The massive variety of granite is more prominent

than the gneissic type.

Mineralogical Data:

(1) The composition of the plagioclase is not constant through the area. The variations in composition do not appear to follow a traceable pattern and no compositional zones are apparent.

(2) A few plagioclase grains show evidence of zoning and these grains are irregularly distributed.

(3) Core and rim distribution of alteration products in plagioclase is abundant whereas uniform sericitization is rare.

(4) Twinning of plagioclase often is faint and indistinct.

(5) The proportions of the feldspars are not constant but vary over a wide range.

(6) Porphyroblasts are developed in the granite.

(7) Perthitic structures are common with abundant bead and patch types and few string perthites.

(8) Myrmekites and corrosion structures are of frequent incidence.

Chemical Data:

(1) The chemical composition of the rock is relatively constant in comparison with the mineralogical composition.

(2) The compositions of the granite and of the biotite schist are similar and there is no great disparity between the two.

(3) The presence of two feldspars in the granite may be regarded as characteristic of sub-solvus granites.

These facts and observations are presented here as typical of the granitic rocks. Undoubtedly, there are other observations that may be significant but any omission is involuntary.

Discussion : Many of the aforementioned observations can be used to demonstrate that the granite is the result of widespread granitization, but there are minor contradictions and some observations are typical of magmatic granites.

The large area covered by granitic rocks (1) is a proof neither of magmatic origin nor of metamorphic origin. However this fact can be linked to the fundamental subject of the "room" problem and it presents a major obstacle to any "magmatic" explanation of the disappearance of the quartz-feldspar-biotite schist from the center of the area. The evidence of deformation (2) and the outline of the granitic masses indicates a synkinematic granite. The deformation alone could be regarded as post-emplacement but this view is invalidated by the concordance in structure from the schist to the granite. The concordant stratoid mass of granite does not possess the irregular shape of batholiths. However, this evidence is not conclusive because magma may be concordantly injected into a complex during deformation as well as it can be formed "in situ". (3) The presence of pegmatites, especially potash-rich pegmatites, in large amounts is inconclusive but useful evidence. Pegmatite is usually associated with magmatic granites but large amounts are often regarded as typical of granitized areas. Crowder (1959) considers such pegmatites as the end-products of anatectic magmas. (4) That there are few lamprophyre dykes may be taken to indicate a metamorphic or metasomatic origin although this is far from confirmed. The origin of such dykes is problematical, but if they are considered as diaschistic, their absence is a significant proof of the metamorphic origin of the granite. (5) Gradational contacts such

as mentioned above are typical features of granitization and are in sharp contrast to the abrupt and chilled borders of purely magmatic masses. The border phases of mesozone to catazone intrusions are diffuse and present gradational contacts and the concept of granitization applies only to these phases, the core of the intrusions being considered as magmatic. (6) Dykes and sills of granite in the country rock and also in the granite itself are regarded as evidence of a magmatic origin, although they can also be explained in terms of granitization. They may represent remnants of the last stages of a mobile phase or be part of a younger stage in the evolution of the rock. The absence of chilled borders indicates that they were injected in rocks that were not much cooler than they themselves were, or that they are of metasomatic origin. (7) Migmatization with its associated features such as ptygmatic folding is almost invariably regarded as convincing evidence of granitization. (8) Inclusions of country rocks are indecisive indications of the origin. They may be roof pendants or xenoliths and thus be characteristic of forcefully intruded granites. They may also be remnants of partly digested or assimilated country rock. The brecciated inclusions clearly point to forceful intrusion whereas the undisturbed portions seem to represent partly assimilated country rocks. Their absence from the center of the area may signify that this is a deeper part of the granitic mass and,or, the core of the intrusion. (9) Parallelism and preservation of structural features from host to invader is often quoted as characteristic of granitized rocks or syntectonic granites. Lest there should be any misconceptions, it should be pointed out again that this occurs mostly in border phases and in the

southeastern corner but rarely in the center of the area. (10) Segregation of minerals, when observed in the field, is strongly reminiscent of stratification. Again this is not abundant but it is clear evidence of granitization. (11) That the granite should preserve the grade of metamorphism of the country rock is useful evidence of granitization that shows the granite, as it now is, to be a result of regional metamorphism. It is possible to have an already emplaced granitic mass subjected to regional metamorphism and be remobilized. But the synkinematic features of the granite militate against this view and, anyhow, the former history of the mass is irrelevant because after subjection to metamorphism it can be considered as a new granite. (12) The absence of thermal aureoles is not surprising after the preceding considerations. But rather than implying a non-magmatic origin, it refers to the level of intrusion. (13) The extreme variability in texture and composition is incompatible with a magmatic origin. The changes in composition may be partly explained as the result of microclinization of a magmatic granite, but the lack of homogeneity in the texture is not so easily interpreted. The erratic changes in grain size are not typical of magmatic rocks.

The mineralogical data are more conclusive than the field observations. (1) The variability of the composition of the plagioclase is significant because a magmatic rock will usually show a relative constancy in this domain and the variations will be distributed along well-defined zones. In the present situation the variations in composition appear to result from assimilation and are local gradational phenomena that indicate the action of granitization. This variability,

however, contradicts the view that the granite has preserved the grade of metamorphism. But local variations in mineralogical composition may be due to local changes in chemical composition, especially in transition zones. (2) The zoning of plagioclase, though rare, reflects the role of liquid in the formation of the rock. But because of the small percentage and irregular distribution of zoned plagioclase we may preclude a magmatic origin. Emmons (1953) writes: "...thin sections, especially large ones, may show the percentage of oscillatory zoned plagioclase to be low enough to suggest that liquid has played a locally prominent but generally minor role. This irregular distribution of significant zoning.....is interpreted as a dilatant effect characteristic of metasomatic granites." The general absence of zoning or progressive zoning according to Emmons (1953) "....is characteristic of rocks which have recrystallized in areas of "regional metamorphism", that is, remote from igneous contacts." (p. 112). (3) The distribution of the alteration products is not conclusive evidence; Emmons (1953) considers that uniform sericitization suggests progressive zoning and uses it as indirect evidence of a metasomatic environment. It was just seen that lack of zoning is related to metamorphism so that, whether we have zoning or not, we still have metasomatic or metamorphic rocks. However, in the area,uniform sericitization is rare and core or rim sericitization is much more common. But, no relations are established between rim and core alteration and magmatism, so that the evidence afforded by this feature is negative. (4) The type of twinning observed cannot be related to a magmatic or metamorphic origin as was explained earlier. But, that many plagioclase grains show indistinct twins, and

even lack twinning, may be a result of metamorphism. This is logical, considering that the granite shared in the regional metamorphism. Thus this evidence is ambiguous because it may pertain to a metamorphosed magmatic granite or a purely metamorphic rock. In view of already established facts, the latter seems probable, but the truth is probably somewhere between these two extremes. (5) and (6) The variation in the proportion of feldspars and the development of porphyroblasts is symptomatic of microclinization and not of origin. But these features can be linked to the question of the origin in this that they are typical of synkinematic granites. Wyckoff (1952) considers that the appearance of microcline marks the final rather than the initial stages of granitization of aluminous schists and this can be related to the microclinization of the rocks of the area. (7) Again, the perthites are related to microclinization and are not features to be associated with magmatic granites. String perthites are generally considered as indicative of magmatism but they are infrequent here. (8) Myrmekites and corrosion structures indicate and accompany replacement of plagioclase by microcline. Bellière (1960) believes that in migmatitic rocks, in the absence of introduction of foreign material, such structures indicate the presence of a mobile phase rich in water within the solid rock. Tuttle and Bowen (1958) suggest that these structures are results of post-crystallization reactions. This could be interpreted as signifying that microcline is a solid state phenomenon. However, most of the evidence is against this and indicates the presence of a liquid fraction. Wyckoff (1952) regarded myrmekites and corrosion structures as features of granitization.

The chemical data are significant and indicate a metamorphic origin of the granite. (1) The relative constancy of the chemical composition as contrasted with the variability of the mineralogical composition is typical of granitized rocks which usually display a unifying tendency whereas magmatic rocks by their very nature exhibit a patterned change of composition, especially over large areas. (2) The similarity in composition between the granite and the biotite schist of the Pontiac group, although not established between samples from this area, is suggestive of granitization. (3) The presence of the two feldspars could be taken as characteristic of sub-solvus granites. However, most of the microcline is secondary, and it was mentioned earlier that the amount of primary microcline was believed to be very low. The feldspars may have crystallized as sub-solvus phases in a magma, but under conditions of very high water-vapour pressure the granite liquidus can be depressed so as to intersect the solvus, and the two feldspars can crystallize simultaneously. The presence of the two feldspars is therefore inconclusive evidence.

From these considerations we can gather that the oligoclase-microcline granite is of metamorphic origin. Indeed, the evidence, even if often inconclusive, strongly hints at this mode of origin. But we cannot entirely reject a magmatic source because the evidence cited comes mostly from the border zones of the granitic mass where one would expect granitization to occur. Therefore we may have a magmatic granite with metamorphic aspects. It is important at this stage to define our concept of magmatic granites; They are regarded here as granites that have crystallized from a mobile magma, whatever the origin

of the material may have been. We are not concerned with the more fundamental problem of the ultimate origin of the rock, i.e. as a primary rock produced by differentiation from basaltic magma. Magmatic granites, in the sense adopted here, involve a large mass of liquid or semi-liquid material and do not apply to local re-melting of rock, which we prefer to classify as of anatectic origin.

The oligoclase-microcline granite mass of the area shows evidence of origin from a melt, but this is localized in the central part and we believe that a large portion of the rock is formed by other processes, especially if we include the grey granite gneiss and the quartz-feldspar gneiss amongst the granites. It remains now to point out the processes involved and their share in the development of the rock.

So far, we have refrained from defining granitization and have indifferently used terms such as metamorphism, metasomatism and granitization. Generally the terms are synonymous and granitization refers to the production of granitic rocks from sedimentary rocks by unspecified processes, i.e. metasomatism, solid diffusion, zone melting, anatexis, etc.

The concept of granitization as given by Sederholm, and many European geologists, called on granitic magmas with their component juices and emanations to convert the country rock to a new anatectic magma. Wegmann and Kranck (1931) re-examined some of Sederholm's area and concluded that granite can be derived from granitic solutions soaking into the country rock and making parts of the transformed rock mobile enough to behave as intrusions. Chemical readjustments controlled

by concentration, permeability, temperature gradients and deposition may result in a mantle around the central core showing different kinds of enrichment. Read (1948) interpreted transitions from country rocks to granitic rocks through a zone of feldspathization and migmatites as migmatization of country rock or as the production of granite from country rock.

Perrin and Roubault (1939, 1949) and Perrin (1954) advocate granitization by diffusion and reaction in the solid state and reject a polygenetic origin of the granites. Anatectic melting of rock and palingenesis, implying rebirth of a new rock from the melting of a previously existing one are processes supported and promoted by several geologists (Eskola, 1933, 1948, 1961, Glangeaud, (1947, Moore, 1931,...). Winkler (1960) demonstrated that anatectic liquids play an important role in granitization and in the formation of migmatites. The association of granitization and regional metamorphism is commonly observed in most granitized areas.

The monogenetic formation of granite appears unlikely and we favour the subsequent or concomitant involvement of diverse processes. During the evolution of the rock, physical and chemical conditions will change and it is therefore natural that the processes will vary in accordance with the prevailing conditions.

The association in the map-area of regional metamorphism and large granitic tracts is compatible with the formation of granite by anatexis and concordant emplacement of the anatectic melt. That granite was localized as a melt (magma) in the deeper zones is probable. Whether it all originated from melting of the rock "in situ" or came

from outside sources is impossible to demonstrate but it is clear that a large part of the granitic material behaved as a magma. In the border zones, granitic material was injected into the host rock, which may have been simultaneously undergoing differential melting. Therefore it appears that different processes may have been active contemporaneously but in different zones. Solid diffusion is believed to be unimportant in the formation of the oligoclase-microcline granite. The evidence indicates mobility of the material and the presence of active fluid solutions, and therefore solid diffusion is precluded. However, it may have been active in the last stages of the evolution, particularly during the late phases of the episode of potash metasomatism. The potash metasomatism that affected the granite is unequivocally indicated and it represents a late stage phenomenon concomitant with deformation, as is typical of regions of convergence of granitic intrusions and metamorphism. Potassic granites in which the microcline is due to metasomatism are common in granitized areas and have been frequently described (Marmo, 1956, 1958, Schermerhorn, 1956, Eskola, 1956, 1961). Marmo (1958) wrote that microcline granites are mainly synkinematic and late-kinematic and that the formation of microcline occurs when the emplacement is protracted. Eskola (1961) designates microcline granites as serokinematic because he believes that they follow synkinematic granites in the same orogenic cycle. The source of potash is problematical; potassium is too abundant in the rock to originate from the biotite-chlorite transformation resulting from the alteration of the granite (Chayes,1953). It may however result from a concentration of the potassium coming from diverse sources (i.e. from the biotite of the Pontiac schist).

Conclusions

The oligoclase-microcline granite may be considered as a magmatic rock in its behaviour and as a metamorphic rock in its origin and may be said to result from "assimilative granitization" a term used by Lacy (1960).

The major cause of confusion in explaining the origin is related to the limited picture that we can obtain from a bidimensional examination, " since those granites which we see represent in our view only the uppermost extensions of igneous effects as they have blended with roof materials, we may appropriately view them for the most part as highly metamorphosed roof rocks.." (Emmons, 1953, p. 116). This brings us back to Buddington's concepts of granite emplacement and this problem was ably summarized by Clark and Stearn (1960, p. 262): "Although in the upper part of the crust granite appears to have been intruded as a liquid, if we could dissect a mountain chain at various levels we would probably see all stages in the transition from sedimentary rock, through sedimentary and igneous phases intimately mixed (migmatites), to gneisses, and finally to granite." Read's opinion that the granite problem is non-existent because each granite should be regarded as a unit to be discussed by itself is demonstrated here (Read, 1957). There remain fundamental subjects such as those related to the primary nature of the granitic magma which cannot be examined here.

10 - Pegmatite - Aplite

Introduction

The oligoclase-microcline granite is intersected by or grades

into large amounts of pegmatite and aplite. In places, the pegmatite makes up more than sixty per cent of the granitic material and could actually be shown separately on the map, but usually it constitutes no more than five per cent. The pegmatite is closely associated with aplitic material and both are mixed intimately here and there, giving the rock a banded structure. The pegmatite and aplite outcrop mostly in the northern granitic rocks and in the central part of the area, east of Beaumesnil lake and west of Gérin-Lajoie lake, where they form large homogeneous masses up to two square miles in extent. South of Brodeur lake, very little pegmatite and aplite is associated with the gneissic oligoclase-microcline granite, and this is in sharp contrast with the northern granite. The pegmatite and aplite usually occur as dykes or sills, but they also form irregular masses, clots and lenses. They are associated mainly with the oligoclase-microcline granite, frequently with the quartz-feldspar-biotite schist and rarely with the hornblende granite. The pegmatite cuts the oligoclase-microcline granite as dykes, forms small isolated blebs in the granite or may be intimately mixed with it, constituting a coarse-grained pegmatitic granite. Aplite occurs almost exclusively as dykes in the granite and is not as abundant as the pegmatite. Few inclusions of amphibolite and quartz-feldspar-biotite schist have been observed in the pegmatite and aplite.

Petrography

The pegmatite is generally massive, with minor exceptions where it is slightly foliated, such as at the contacts with the biotite schist, or where it shows a banding defined by the segregation of

minerals (micas, garnets) into layers. The grain size is not uniform and varies from medium to coarse to very coarse with components up to eight inches long. The rock is rarely equidimensional and consists of fine interstitial quartz and large crystals of feldspar and mica. The aplite is a fine-grained equidimensional rock with a sugary texture.

The pegmatites can be classified as simple or complex on the basis of mineralogical composition. The simple type is composed essentially of microcline, quartz and muscovite whereas the complex type is composed of plagioclase, quartz, microcline, muscovite, biotite with accessory garnet, magnetite, apatite, beryl, molybdenite and chlorite. All these components are not present together everywhere but occur in varying amounts in diverse occurrences.

Microcline constitutes, in places, up to fifty per cent of the rock, and is the dominant feldspar of the simple pegmatite. However, it is entirely lacking in some dykes or it may be roughly equal in amount to the plagioclase. The microcline is usually perthitic, and string, film and vein perthites are common. It is usually white to pink, but a green variety was observed. The refractive indices of the microcline are : $Nx = 1.520 \pm 0.002$, $Ny = 1.524 \pm 0.002$, $Nz = 1.527 \pm 0.002$. Microcline forms large subhedral crystals up to eight inches in length, and it may also occur as fine grains or as patches in the plagioclase.

Plagioclase of An_{4-6} composition occurs mostly in the complex pegmatites where it may constitute sixty per cent of the rock. It is generally absent from the large pegmatite masses of the central part of the area. Albite forms large crystals, never as big as those of microcline however, on which the twinning is readily apparent, even

in hand specimens. In many instances albite occurs as fine material interstitial to the coarse plagioclase and the quartz.

Colourless or milky quartz makes up to thirty per cent of the pegmatite and occurs as small grains interstitial to albite or microcline, as blebs or elongated intergrowths in the large crystals of feldspar and as large blocks in the center of many dykes. It also forms euhedral crystals extending radially from the walls of vugs. It is the sole component of many dykes and small irregular blebs associated with the pegmatite.

Muscovite occurs in small quantities in the simple microcline-rich pegmatites, generally in amounts smaller than five per cent, although it may locally constitute up to twenty per cent. It forms small platelets irregularly distributed in the rock or large "books" up to six inches across and two inches thick. The basal prismatic and the pinacoidal faces are the most common forms encountered. The muscovite is generally fresh, but here and there it may be stained with a purplish oxidation product. North of Roger creek and along the northeast shore of Roger lake, dendritic intergrowths of quartz and muscovite were observed. They form fan-shaped feathery aggregates with muscovite seemingly growing out from a stem at acute angles. When several such intergrowths are disposed side by side they create a chevron pattern. Freeman (1957) describes similar intergrowths as "plumose" and believes that they represent "remade" inclusions of country-rock.

Biotite is of widespread occurrence in the pegmatite but it is never abundant, though in places, it may make up to ten per cent of the rock. It often accompanies the muscovite to which it is subordinate

and, like the muscovite, it forms small plates or large "books".

The accessory minerals are not usual components of the pegmatite and occur in few places. Deep red garnet is locally abundant in the northeast corner of the map-area, as euhedral or deformed crystals, from one-sixteenth to half an inch in diameter. It occurs with quartz, plagioclase and magnetite and is frequently altered to chlorite. Magnetite is widely distributed and occurs as octahedrons or anhedral grains associated with biotite and muscovite. Apatite is found in most pegmatites as tiny prismatic crystals. Beryl is of rare incidence and was actually observed at only one locality as small (one fourth of an inch), pale green, prismatic crystals. Molybdenite is frequently associated with pegmatitic material and its occurrence will be mentioned in greater detail in the chapter on economic geology.

The aplite contains the same minerals as the pegmatite but they have a regular distribution and because of its texture the rock is more similar to the oligoclase-microcline granite than to the pegmatite.

Zoning

Zoning defined by textural and mineralogical variations is characteristic of several pegmatite dykes, especially the narrow ones. Textural zoning with variations from fine-grained to coarse-grained, from the wall toward the center is relatively rare, and , in this respect, most pegmatites are homogeneous. Core zoning, or zoning defined by changes in mineralogical composition across the width of the dykes is common. Usually a quartz-rich central core is juxtaposed to microcline-rich bands on each side up to the walls.

Graphic Pegmatite

Graphic pegmatite or granite occurs in several places as irregular masses representing textural variations of the pegmatite. Two types of quartz-microcline intergrowths are observed : one is a fine-grained, cuneiform, homogeneous intergrowth with a regular distribution of the components giving it a runic texture, whereas the other is composed of rods of quartz irregularly dispersed in the microcline. The quartz generally forms sub-parallel, elongated prisms which pass through the microcline, and the quartz to feldspar proportion is about one to four. The origin of the graphic pegmatite may be due to crystallization of a eutectic or cotectic mixture of the two components. Origin by replacement of the feldspar by quartz is not precluded however, and it is advocated by several geologists. The former mode of origin is favoured by the writer for the graphic pegmatites observed in the area.

Emplacement of the Pegmatite and Aplite

The emplacement of the pegmatite and aplite is frequently controlled by the structure of the host rock. In the quartz-feldspar-biotite schist, the pegmatite is usually emplaced concordantly as sills along the foliation planes, sills which often show pinch and swell structures, and as dykes along joints. In the oligoclase-microcline granite, the pegmatite is emplaced along joints, especially flat-lying joints. In many instances, however, there is no apparent control over the emplacement, and this is especially true of the irregular masses and the numerous blebs in the oligoclase-microcline granite.

The pegmatite dykes occupying joints are usually narrow, have sharp contacts, display zoning with respect to the wall-rock and

Photograph 48 : Pegmatite in biotite schist. Partly sill-like, partly dyke-like. South of Roger creek.

Photograph 49 : Pegmatite dyke in biotite-schist with sill-like extensions,probably emplaced before the dyke. Dilation dyke.

commonly the dykes offset one another. Several dykes show evidence of forceful emplacement, or dilation, the country rock being moved aside by the pegmatite.(Photograph 49). They have abrupt contacts, they offset the wall-rock units and they have uniform mineralogical composition and width. Other dykes are not accompanied by evidence of movement of the country rocks, and the pegmatites may have been introduced quietly into the site of emplacement or derived locally by residual segregation or host-rock breakdown (Chadwick, 1958).

Photograph 50 : Pegmatite nearly parallel to the foliation of the biotite schist. Quartz pod in the lower part of the photograph.

Age Relations

From the field evidence, most of the pegmatite and aplite appear to be contemporaneous. The pegmatite is slightly younger than the oligoclase-microcline granite to which it is genetically related and it is believed to be a late member of the granitic rocks.

Origin

The pegmatites and aplites are related in space and time to the oligoclase-microcline granite and represent a late stage in the evolution of the granitic rocks. Their origin is therefore related to that of the granite and, like it, they present conflicting evidence, some pegmatites appearing to result by crystallization from a melt, others appearing to be formed through metasomatic processes.

The magmatic pegmatites are those which are forcefully emplaced, which have graphic textures, which show constancy of mineralogical composition, and possibly those which contain perthitic microcline. Metamorphic pegmatites are those which show textural variations, have no chilled borders, no sharp contacts, and those which exhibit zoning and layering.

Actually it is not realistic to separate such closely related rocks into two groups of diverse origin. The pegmatite occurs in a regionally metamorphosed terrane where granitization is widespread and, like the oligoclase-microcline granite, we can expect it to behave differently under locally different conditions. Thus, although the pegmatites are all related, they may be formed by different processes at different places or stages in the evolution of the rock. The microcline-rich dykes may be related to the episode of potassic metasomatism that affected the granite and the microcline microperthite of the pegmatite may itself result from metasomatic processes as described by Higazy (1949). Indeed, the microcline pegmatites may be the main agents through which the potassic metasomatism of the granite was effected, as is suggested by Freeman (1957).

11- Lamprophyres - Pyroxenite - Serpentinite

Numerous dykes of lamprophyre have been observed throughout the area. They are most abundant in the southwestern corner where they are associated with the volcanic rocks. Elsewhere, they appear to be less abundant. Different types of lamprophyre are grouped here under the same heading although their composition and association are varied, for the reason that it is not convenient and it is hardly feasible, from the insufficiency of relevant data, to describe each type separately with the rock to which it is related.

Lamprophyre dykes, as a rule, are narrow, their width varying from two to eight inches. The rock usually is green to brown on a weathered surface, which frequently is crumbly, and possesses a porphyritic texture, the ferromagnesian minerals forming phenocrysts in a groundmass of mafic and felsic material. The matrix is usually fine-grained and has an aplitic texture.

The rock-forming minerals of the lamprophyres are varied, but pyroxene, hornblende, biotite and plagioclase are the most common. Quartz and microcline are not always present but have been observed frequently. Common accessory minerals are apatite, sphene and magnetite. The rock is altered to varying degrees, and hornblende, chlorite and epidote are common secondary minerals. The pyroxene is diopside or augite that occurs in the groundmass as disseminated grains or in synneusis aggregates, and it is often altered to hornblende which then occurs along the borders of the pyroxene crystals or as patches in the pyroxene. Hornblende phenocrysts are abundant in some varieties of lamprophyre but hornblende may also be found in the matrix of the rock.

A blue-green hornblende, in coarse bladed crystals, has been observed frequently. The hornblende is normally fresh but may be altered to biotite or chlorite. Biotite occurs as phenocrysts in some rocks and in the groundmass only, in others. Plagioclase is always present in the groundmass as interstitial grains and it is usually altered to sericite. The composition of the plagioclase varies with the rock types and is not always easily established because of strong alteration, but a composition near An_{20} is common. Quartz is not a common rock-forming mineral and is secondary in many instances. In one thin section, apatite was found to be more than an accessory mineral, making up to five per cent of the rock.

The lamprophyres may best be referred to as biotite, pyroxene or hornblende lamprophyres. It is possible to attach more precise names to some examples from which thin sections have been obtained, but few samples have been so investigated.

The dykes appear to be associated with the various granites and with the volcanic rocks in the southwest. Hence they are not all of the same age. It is difficult to say whether they are diaschistic or not; some probably are, but many could be the equivalent of a siliceous rock modified by assimilation of basic material. In some instances, the rock may represent xenoliths of country rock.

Pyroxenite

A few outcrops of a pyroxene-bearing rock were observed northwest and southwest of the village of Rollet. These outcrops represent an indeterminate number of basic dykes, of which the most representative is located near the east-west road to Opasatica lake,

half-a mile south of the northern boundary of the area.

The pyroxenite is a massive, sometimes porphyritic, medium-grained, brownish-weathering rock. Thin section examination of the porphyritic variety shows phenocryst of a light-greenish diopsidic augite, partly altered to hornblende, in a groundmass of fibrous tremolite-actinolite, highly altered plagioclase, chlorite and iron oxide. The mineralogical composition and the texture of this rock are those of camptonite, a lamprophyre, but the rock is classed with the pyroxenite, because it usually is massive. The massive variety is of similar mineralogical composition, only the texture being different.

The pyroxenite dykes are all confined to a small area of oligoclase-microcline granite and biotite schist and appear to be closely related. They may be part of a complex of ultrabasic intrusions.

Serpentinite

A small, irregular mass of serpentinite was examined near the east shore of Opasatica lake, three miles west of the village of Rollet. The serpentinite weathers a light greenish-grey and has a smooth, almost soapy surface. The rock is compact, massive and greenish-black on a fresh surface.

Thin section study reveals that the serpentinite consists of anhedral crystals of antigorite forming an aggregate of fibrolamellar structure, and massive, almost structureless serpophite. Chrysotile occurs as cross-fiber veinlets in the serpentine mass. Muscovite, chlorite and iron oxide are accessory minerals.

The alteration has been so complete that there is no indication of the original mineralogical composition of the rock. No

primary texture is visible, as is commonly the case in many serpentinites.

The relationships between the serpentinite and the adjacent granites and biotite schist are unknown. No contacts were observed, the shape of the outcrop is highly irregular and no indications relative to the mode of emplacement were obtained. Twenty feet south of the serpentinite, a band of very contorted chlorite-schist mixed with lenses of amphibolite was observed. All we can say apropos the origin, is that the serpentinite is the alteration product of an ultrabasic rock. It may be related to the pyroxenite dykes which occur in the neighborhood.

D- Huronian

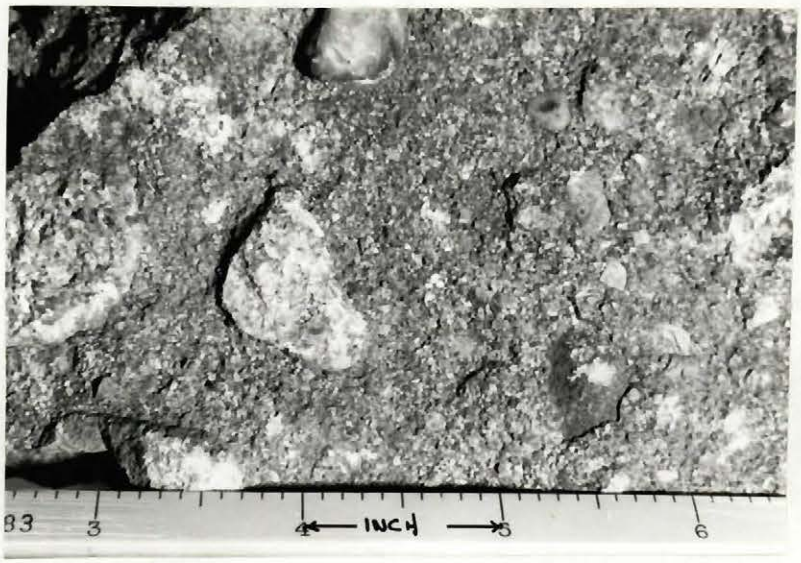
1- Cobalt Group

Conglomerate and argillite of the Cobalt group of clastic sediments overly the oligoclase-microcline granite and the biotite schist of the Pontiac group in the northwest corner of the area.

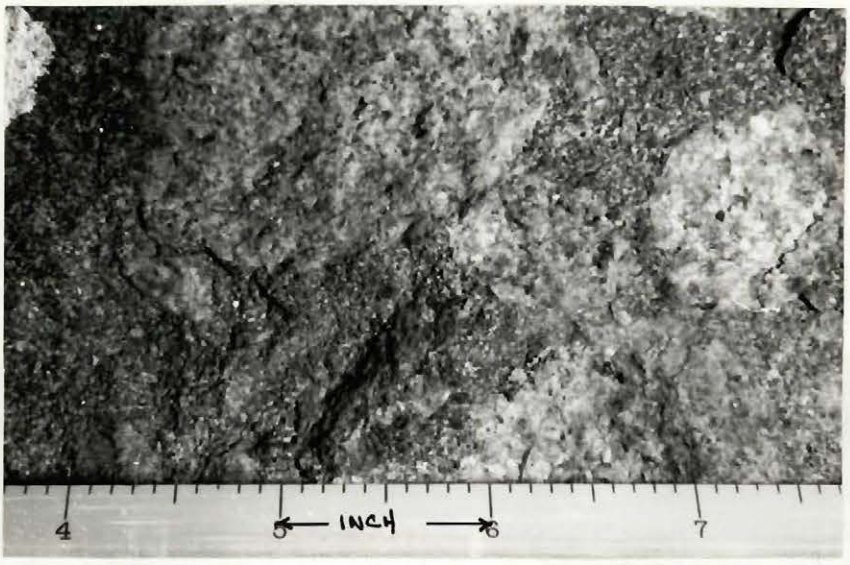
Conglomerate

The conglomerate outcrops a quarter of a mile east of Laberge river. A single outcrop, one mile long, one quarter of a mile wide and approximately thirty-five feet high was observed.

The rock is made up of variegated small and large, angular, subangular and rounded fragments in a greenish matrix of variable grain size. There is no sorting by size or shape of the pebbles, no stratification or bedding being apparent. The weathered surface is very rough, the pebbles standing out prominently. The average diameter of the fragments is three inches, the maximum observed being two feet. The conglomerate carries pebbles and cobbles of granite, andesite,



Photograph 51 : Cobalt conglomerate. Assorted size and shape of pebbles is typical.



Photograph 52 : Large rounded pebbles of oligoclase-microcline granite in Cobalt conglomerate.

rhyolite, basalt and greywacke. The pebbles amount to ninety per cent of the rock near the contact with the basement and to approximately seventy per cent ten feet away from it. Fragments of oligoclase-microcline granite are the most abundant, amounting to forty per cent of the rock. The matrix is generally fine- to medium-grained and consists of small angular fragments of quartz and feldspar embedded in a fine groundmass of chlorite and sericite.

The contact between this rock and the underlying oligoclase-microcline granite was observed at the northeast extremity of the outcrop. At the contact, which appears to be erosional, the rock consists almost entirely of big angular blocks (up to two feet in diameter) of oligoclase-microcline granite embedded in very little matrix. Up and away from the contact, the blocks are smaller, subangular to rounded and less abundant, this change taking place within a few feet of the basement.

This conglomerate extends to the north and the northeast in adjoining areas where it has been observed by Wilson (1913, 1962) who discusses its origin in great detail. Most of the evidence that he observed points to a glacial origin of the conglomerate (Wilson, 1962). The information collected from the single outcrop examined in the area is not significant enough or sufficient to either prove or disprove this view.

Argillite

Argillite crops out a few hundred feet west of the conglomerate, close to the northern boundary of the area. Only one outcrop, ten feet by ten feet, was observed by a senior-assistant.

The rock is very fine-grained, greenish and has a rough weathered surface. It resembles slate but has no definite cleavage. The argillite is composed of quartz, feldspar and chlorite.

No contact was observed between the argillite and the conglomerate. This rock type has been observed and described in adjacent areas (Wilson, 1913) and apparently passes gradually in the conglomerate with the appearance of rock fragments.

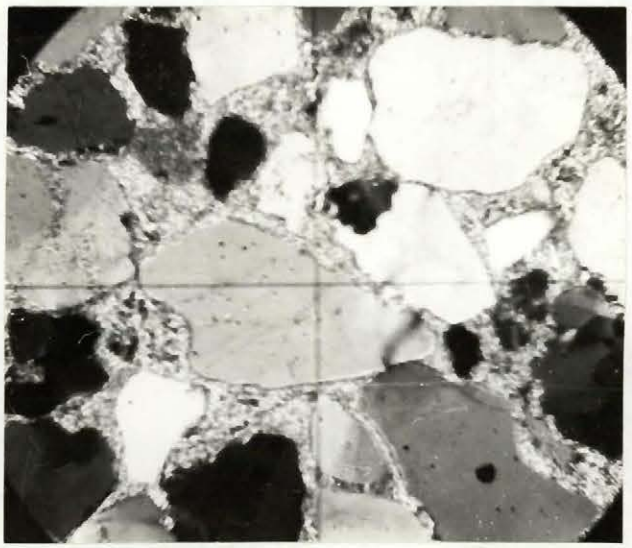
2- Lorrain Formation - Quartzite and Arkose

The quartzite and arkose of the Lorrain formation occur in the southwest corner of the area, near the east shore of Témiscamingue lake. The rock, resistant to weathering, forms a long north-south trending ridge which rises 250 feet above the lake level.

The quartzite is generally yellowish-green, fine-grained to coarse-grained and has a rough weathered surface. It is thickly bedded and lies horizontally. Grain size varies considerably along short vertical distances, coarse and fine fragments alternating frequently within one foot. In places, there are numerous rounded pebbles of quartz of greater size, up to three-quarter of an inch, than any other portion of the rock. Cross-bedding is common in the arkosic parts but was not observed in the quartzite.

Thin section examination shows the quartzite to consist of subangular to subrounded quartz fragments of varying size embedded in a fine-grained matrix of sericite. The fragments, constituting approximately sixty to seventy percent of the rock, are usually not in contact with one another because of the great quantity of sericite in which they are embedded. The bedding direction, not always evident in

Photograph 53 : Lorrain quartzite. Layering is faintly apparent. (Crossed nicols - X20).



Photograph 54 : Lorrain quartzite. Large amount of sericite in the groundmass. (Crossed nicols -X80).

hand specimens, is outlined in thin sections by the subparallel alignment of elongated fragments. There are generally few fragments of altered plagioclase and microcline, but in some thin sections, they constitute an appreciable portion of the rock. These arkosic parts are common and appear as lenses in the quartzite. They cannot here be assigned to any specific part of the Lorrain formation.

Although the contact between the Lorrain formation and the underlying rocks was not observed, it can be suggested that the beds examined are not far above. In all the thin sections studied we noticed the presence of feldspar grains in varying amounts and this is significant because Henderson (1936, p. 21) wrote that "Apart from the basal beds a remarkable feature of the quartzite is the total absence of feldspar grains in all the thin sections examined by the writer. "This relationship was also noticed by Valiquette (1962, p.78). Thus the presence of the feldspar would indicate that the beds observed are near the basement.

E- Diabase - Gabbro

Numerous outcrops of diabase or gabbro, representing at least thirty dykes, have been examined in the map-area. The orientation of the dykes is not constant, varying from northwest to east-west, but the majority trends N.-15°-E., the walls being usually vertical or nearly so. Joints generally perpendicular or parallel to the trend of the dykes are vertical. Diabase frequently forms low ridges, usually exceeding the level of the surrounding rocks by no more than twenty feet.

The width of the dykes varies from one inch to 800 feet, thirty feet being common. The observed length varies from a few feet

to eight miles. However, it is difficult to establish the length with certainty because, in most instances, only a few widely separated outcrops have been observed and there is no evidence as to their continuity. But, although continuity is not always observed in the field, it is often apparent on aerial photographs or on maps.

Petrography

The diabase, as a rule, is fresh, massive and dark green. The grain size is usually medium but becomes fine and microcrystalline in the smaller dykes and along the margins of the larger intrusions. The larger dykes, such as those on the east shore of Basserode lake and southwest of Angliers, are very coarse-grained in their central part. Very fine-grained chill zones, up to one foot wide have been observed at the contact of the diabase and the host rock. They are very dark, microcryptocrystalline and often contain some fragments of the intruded rock.

The texture of the diabase is commonly ophitic and in many instances subophitic, lath-shaped or acicular crystals of plagioclase being embedded in large grains of pyroxene.

Two types of diabase are recognized on the basis of mineralogical composition. In the prevalent type, the rock consists mainly of a calcic plagioclase and a faint brownish pyroxene (augite or titaniferous augite). The other type is an olivine diabase, in which plagioclase, pyroxene and olivine are the main constituents. The olivine diabase, the presence of olivine excepted, is similar in composition, texture and appearance to the olivine-free variety. In both types, biotite, magnetite, ilmenite and apatite are accessory minerals. Secondary

minerals are hornblende, chlorite, epidote and zoisite.

The plagioclase varies in composition from a calcic andesine (An_{46}) to labradorite (An_{62}). It is often slightly altered to sericite and always shows twinning. Pyroxene occurs as large grains enclosing ophitically plagioclase crystals, or as interstitial grains. It is sometimes altered to a green amphibole or to chlorite. Olivine occurs as rounded crystals embedded in the augite and plagioclase. Incipient alteration of the olivine to serpentine, corroded borders, rimming by red-brown iddingsite and breakdown to dark-green chlorophaeite are frequent. Quartz is not commonly present in the rock and

Photograph 55 : Diabase. Plagioclase laths in pyroxene. (Crossed nicols - X80).

when it occurs it usually forms a micrographic intergrowth with feldspar. Magnetite and ilmenite occur as dust or scattered grains on the borders of other minerals or in other minerals. Apatite usually

associated with hornblende and magnetite occurs near grain boundaries. Hornblende is often present in small amounts as a deuteric or secondary mineral.

Some of the diabase differs slightly in composition and texture from that given above. The variant is generally more altered and has a porphyritic texture. The phenocrysts, varying in size from one quarter of an inch to three quarters of an inch, are irregularly shaped and poorly defined. They make up to thirty percent of the rock and are composed of sericite and kaolin, probably representing phenocrysts originally consisting of feldspar. The groundmass is in every way similar to the normal diabase and even exhibits ophitic texture. Not more than four such dykes have been observed

Table 21 : Modal Analyses of Diabase

	1	2	3	4	5	6
Plagioclase	51.36	45.55	56.11	57.68	48.93	50.00
Pyroxene	21.24	49.48	38.34	14.55	43.26	28.00
Olivine	8.63	-	-	17.45	-	-
Hornblende	tr.	-	tr.	-	-	14.00
Biotite	2.66	tr.	-	0.44	0.68	1.00
Epidote	-	tr.	-	-	-	2.00
Chlorite	tr.	tr.	-	-	1.25	
Quartz	-	tr.	tr.	-	-	5.00
Magnetite + Ilmenite	15.61	4.90	5.50	9.61	5.88	tr.
Plagioclase	An_{45}	An_{40}	An_{54}	An_{55}	An_{50}	

Sample no. 6 is taken from Freeman (1957) and is shown here for purposes of comparison. Column 2 is an analysis of the groundmass of a porphyritic diabase.

The results of the modal analyses of five thin sections from five different dykes are presented in Table 21.

These results show that the mineralogical composition of the diabase is not constant, plagioclase being the only mineral to show restricted variations.

Correlation

No cross-cutting relationships were observed between the two types of diabase and they appear to be the youngest Precambrian rocks of the area. However, no diabase was observed to cut rocks of the Huronian and therefore it is impossible to tell if the two types are younger, if only one type is younger or if both types are older than the Huronian. The diabase, as a rule, is similar to the post-Huronian diabase of the Cobalt area and may be of the same age. Cooke, James and Mawdsley (1931) report that porphyritic diabase such as described above has been observed only in pre-Cobalt rocks (pre-Huronian), and on the basis of this observation we may assign some, if not all, of the diabase to the pre-Huronian.

The majority of the dykes trends N.-10°-E. to N.-20°-E. This direction is also that of one dominant joint set and of many linear elements, which may be related to faulting throughout the area. The distribution of the dykes thus appears to be related to the large-scale structural pattern of the area.

Basic rocks related to the diabase

One outcrop of a rock which may be related to the diabase has been observed at the intersection of the railroad and of the road to Ville-Marie at the village of Angliers. This rock is dark, dense, very altered and has a porphyritic texture. The phenocrysts, constituting up to sixty percent of the rock, are composed of saussuritized

plagioclase. They are rounded, vary in size from one quarter of an inch to one inch and give the rock a splotchy aspect. The groundmass consists of coarse blue-green hornblende grains, fine granular quartz and twinned plagioclase (An_{24}). Blastophitic texture is apparent on hand specimens. The rock intrudes the adjacent hornblende schist conformably. However no sharp contacts, or chill zones, have been observed. The porphyry, because of its texture and composition may represent a porphyritic variety of diabase such as was described above.

Wilson (1910, p. 15) did mention the presence of an identical rock: "A peculiar variation in the greenstone was observed on the north shore of Rivière des Quinze, at the foot of the Cypress rapids. Large, augen-like aggregates of feldspars, showing a rough parallelism in their elongation, occur enclosed in a fine-grained, ophitic groundmass." Cypress rapids are or were located between the two dams on Rivière des Quinze and this occurrence is now permanently submerged. This observation of Wilson would increase the extent of the rock to the west for a distance of at least one mile and a half.

Near Des Quinze lake and on two small islands in Des Quinze lake, one and a half mile east of the above mentioned porphyry, three outcrops of a similar rock were examined. The rock there differs appreciably in composition but bears a close external resemblance to the one at Angliers. The slightly gneissic groundmass is almost devoid of plagioclase and quartz, being composed mostly of hornblende. The phenocrysts are similar in shape, composition and degree of alteration. The rock also occurs as a sill in hornblende schist, and on one island it is in contact with the hornblende granite which cuts it. The porphyry is

brecciated where intruded by the hornblende granite.

The rock here seems to be contemporaneous with the schist and may represent a lens of porphyritic amphibolite. This porphyry may or may not be related to the rock observed at Angliers. Both are alike in mode of occurrence but differ in composition. If they are related, both are older than the granite and are unrelated to the diabase.

F- Ordovician - Liskeard Formation

Along the northeast shore of Témiscamingue lake and on Chief island, sedimentary rocks of Ordovician age occur as scattered outcrops. A single outcrop almost continuously fringes the shore of Témiscamingue lake over a distance of one mile, the width of the outcrop being twenty feet. One isolated occurrence was found 600 feet inland along a vertical cliff of Huronian quartzite, and separated outcrops occur along the east and south sides of Chief island.

The sedimentary rocks consist of a conglomerate resting over the Lorrain quartzite, and grading upwards into coarse sandstone followed by finer calcareous sandstone and finally by arenaceous limestone. The conglomerate consists of boulders and fragments of the underlying quartzite cemented together by a matrix of angular to subangular grains of quartz and some limy material. The boulders of quartzite vary in diameter from a few inches to five feet and are very abundant at the base of the contact zone. The sandstone is composed of subangular grains of quartz derived from the Lorrain quartzite, with a little limy material cementing the grains together. The arenaceous limestone is a yellowish-green rock, with a rough weathered surface, composed mostly of limy material with a subordinate amount of quartz. Everywhere the

Photograph 56 : Ordovician-Huronian contact. Large boulder of Lorrain quartzite in Liskeard formation. Shore of Témiscamingue lake.

Photograph 57 : Boulders of Lorrain quartzite at the base of the Liskeard formation. Témiscamingue lake.

sedimentary rocks dip gently to the west, apparently because of the slope of the underlying surface on which the sediments were deposited.

The sandy limestone is a fossiliferous rock, but few fossils were observed. Hume (1925) described the Liskeard formation and supplied a catalogue and complete descriptions of the fossils. Ollerenshaw and MacQueen (1960) studied the fossils of the formation and also presented a list. The reader is referred to these authors for more detailed information on this subject.

Hume (1925), who named the Liskeard formation, correlated it with the Trenton of other districts and wrote (p. 13) : "..a new name, the Liskeard formation, is given by the present writer to that part of the Trenton represented in the rocks of Timiskaming area. .. On the Quebec or eastern shore of the lake, the basal Palæozoic conglomerate and sandstone are certainly of Trenton age.." and further (p. 20) : "On account of a form of Halysites being found here and elsewhere in this formation, these rocks have been confused with Niagaran, but the list of fossils given below is conclusive proof of Trenton age. " Ollerenshaw and MacQueen (1960) more or less supported this view (p. 109) : "In summary, the upper, exposed portions of the Liskeard formation contain species belonging to the Arctic Ordovician faunal assemblage. This assemblage in the opinion of the writer shows strongest affinities with Trentonian faunas, although a transitional age between Trentonian and Richmondian is not impossible." However, Caley and Liberty (in Stockwell, 1957, p. 237) write : "...due..to the recognition of a recurrence of certain Trenton species in the Richmond, the Liskeard is now considered to be Richmond in age and not Trenton."

The preservation of these Paleozoic sediments in an area of Precambrian rocks is explained by Hume as resulting from warping (1925, p. 45-46): "As the elevation of the Liskeard formation at the present time is somewhat below the regional level of the Precambrian surface and the faunal distribution clearly indicates widespread sea connexions at the time of marine invasion, it seems evident that warping must have taken place subsequent to Palæozoic deposition. This warping is believed to have been the controlling cause for the preservation of the Palæozoic sediments, although later faulting has also contributed to the same result." On this subject, Ollerenshaw and MacQueen (1960, p. 105-106) write: "An early idea that the outlier occupies a pre-Ordovician depression has been gradually superceded by the recognition of post-Middle Silurian faulting,....., and the acceptance of a graben structure. Preservation in a depression might imply the existence of similar deposits in the vicinity, whereas preservation by faulting explains the isolation of the occurrence."

G- Pleistocene and Recent

The depositional and erosional effects of Pleistocene glaciation and of glacial lake Barlow-Ojibway are widespread and conspicuous in numerous parts of the map-area. Glacial drift and lacustrine clays cover large tracts in the southeast corner, the central part and the southwest angle of the area. The deposits of glacial origin are partly covered by the lacustrine clays, especially in areas of low elevation. Enormous erratics, up to twenty feet high, have been observed at a few localities.

Noteworthy features are eskers, kames, morainal deposits,

boulder trains, glacial striations, "roche moutonnée" and the deposits of glacial lake Barlow-Ojibway. Many of these features are important and of interest because they record the direction of ice movement.

Four eskers have been recognized in the map-area, two in the east and two in the southwest. All are narrow and tortuous ridges of irregular outline, on top of which kettle holes and small rounded lakes, not integrated in the regional drainage system, are present. They are flanked by swamps and lakes in several places. The two eskers in the east, trend approximately N.-30°-E., the one to the south appearing to swerve east. The eskers in the southwest trend N.-15°-E. and north-south, the latter being the most remarkable of all because it is fourteen miles long and up to four thousand feet wide. Generally the width of the eskers does not exceed two thousand feet and is close to three hundred feet, the height being approximately fifty feet.

A transverse profile of any of the four eskers would show that the cross-section is nearly rounded and that the crest is almost flat, making it difficult to distinguish them in the field. They are best observed on aerial photographs. The eskers are composed mostly of coarse gravel, are flanked by aprons of sand and always show good bedding and cross-bedding. All eskers are copious sources of gravel and sand which are used locally for road construction.

Glacial striations, "roche moutonnée", boulder trains and eskers are suitable indicators of the direction of movement of the ice-sheets. The striations generally trend S.-10°-E. in the south of the area and S.-10°-W. in the north. However, there are several local variations, as can be seen on the geological map, and the general trend

is from north to south. Boulder trains are commonplace in the southern part and support the evidence provided by the striations.

The previous existence of Barlow-Ojibway lake in the map-area is indicated by the widespread occurrence of boulder-clay and varved clays which cover the glacial drift. The clay is common along the shores of the bigger lakes, generally below an elevation of approximately one thousand feet above sea level. Varved clays consist of alternating dark and light layers from one-eighth to half an inch in thickness.

An elongated, east-west trending ridge, approximately seventy-five feet high, half-a-mile to one mile wide, extends from the western limit, through Barrière lake north of Rémigny, to the north end of Roger lake. In the vicinity of Caire lake it widens and becomes almost of circular outline. It is composed mostly of gravel and boulders in the center and is bordered by thickly bedded sand, especially at the western extremity and near Lévesque lake. Coarse pebbles and boulders from six inches to two feet in diameter characterize the central part of the ridge and are the dominant features of the narrow segments, such as at the north end of Rock lake. The ridge intersects the large esker in the west sector and, in the neighbourhood of this intersection, contains numerous kettle holes of large diameter (up to one thousand feet) and depth (one hundred feet). This ridge may be the remainder of morainal deposits reworked by the waters of Barlow-Ojibway lake and may represent interconnected islands with extensive beaches.

Chapter V

STRUCTURAL GEOLOGY

Introduction

The major structural elements will be considered separately prior to an analysis of the structural pattern of the area in relation with the regional pattern. Folds, faults and joints will be discussed, but features such as lineation, foliation, drag folds, etc..., which have already been considered with the various rock types will not be mentioned again.

Folds

Major folds are outlined on the map by the trends of the foliated rocks wherever structural continuity is preserved. The biotite schist, quartz-feldspar gneiss and grey granite gneiss are the principal rock units which establish the conformation of the folds and wherever they are lacking, as in the center of the area, the structural pattern is obscure. The foliation of these rocks, be it gneissic structure or schistosity, is considered to be parallel to the primary structure of the original sedimentary rocks. This relationship is indicated by the parallelism of the biotite schist and the greywacke in the vicinity of Des Quinze river. However, as was shown in a previous discussion, there are exceptions to this general rule. The terms "synform" and "antiform" are used because the stratigraphical succession is unknown, no marker horizons being available. It is evident from this and from the general dearth of information that only the broader outlines of the structural pattern of the area can be obtained.

Five major folds are recognized in the map-area: In the

northeast part, in the vicinity of Roger lake, an antiform with a N.-15°-E. trending axis is defined by the foliation of the schist lenses in the oligoclase-microcline granite. The biotite schist, dipping approximately 60°, defines a large, open asymmetrical fold plunging north to northeast. In the southeast portion, northeast of Moffet, a north-south trending synform axis is shown on the map. The axis is not straight but has a sigmoid trend. The biotite schist dips about 60° on either side of the axis and outlines a large open fold plunging north at a steep angle, as is indicated by drag folds. In the south central sector of the area, a northwest trending antiform, plunging to the northwest, is suggested by the foliation of the quartz-feldspar gneiss. Again the fold axis is not straight as it veers to the northeast at the northern extremity and to the south at the southern extremity. Actually the position of the axis is poorly established because the evidence is incomplete and not very clear. This antiform adjoins and is followed by the above-mentioned synform. Northwest of Rollet, in the vicinity of Opasatica lake, lenses of biotite schist and grey granite gneiss in oligoclase-microcline granite outline two adjacent folds, a synform followed to the northeast by an antiform. The axes have a general northwest trend and both are bent into a sigmoid shape. The plunge of the folds, as indicated by lineations and drag folds, is approximately 60° to the southeast or south. The schist and gneiss usually have gentle dips and the folds are open.

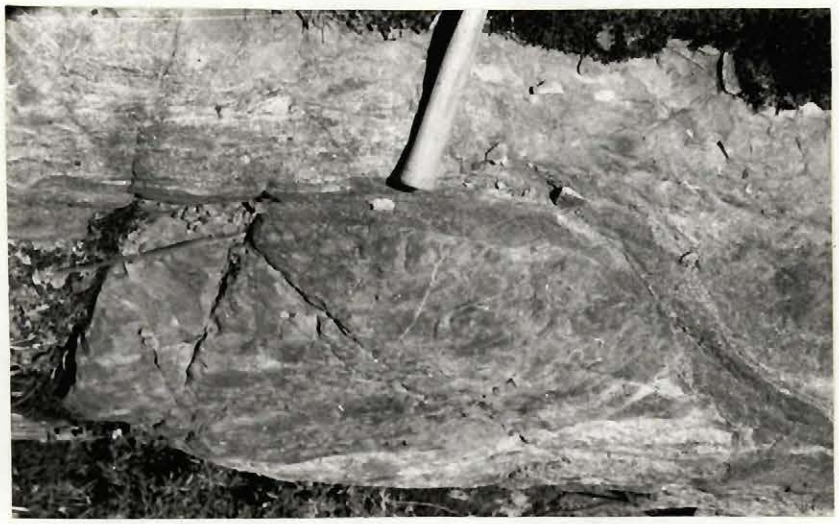
Not indicated on the map is a poorly defined synform suggested by the trends of the biotite schist in the vicinity of Fréchette lake at the northern limit of the area. The axis trends

N.-15°-E. and the plunge is to the north-northeast. It was mentioned before that the volcanic rocks in the southwest angle of the map-area are isoclinally folded along N.-60°-E. trending axes, with southerly dipping planes. There undoubtedly are other folds in the area, in the southwest sector for instance, but the information is so scarce and so poorly distributed that interpretation is nearly impossible and cannot be objective.

No detailed analysis of the structural pattern, as determined by the folds, was attempted because of the lack of information and of the large size of the area. Therefore the number of episodes of deformation represented by the folds is unknown. There is evidence of overprinting of structures but it is not abundant and it is widely scattered. The sigmoid fold axes are considered typical of obliquely intersecting structures (Carey, 1962) and the intrafolial folds observed in the biotite schist are suggestive of transposition of s-surfaces. However, deformation of lineations or bending of mica flakes were rarely observed.

The best and only such example of intersecting structures was observed near the east shore of Prévu lake, southeast of Angliers. There, north to northeast trending quartz-feldspar gneiss intersects east-west trending volcanic rocks. The andesite is broken up into large (up to five feet), elongated blocks which are enveloped and separated from each other by the quartz-feldspar gneiss. (Photograph 58). The larger blocks preserve their original trend (defined by pillows) whereas the smaller fragments are rotated along the foliation direction of the quartz-feldspar gneiss, thereby indicating that the north to northeast

deformation is subsequent to the east-west trend of the volcanics.



Photograph 58 : Blocks of volcanic rocks enveloped by quartz-feldspar gneiss. Orientation of blocks is parallel to gneissic structure, but structural features of volcanic rocks have a different orientation. (Prévu Lake - southeast of Angliers.)

Shear zones and Faults

Shear zones and minor faults, with a horizontal separation of no more than two feet, are common within the rocks that underlie most of the area. The majority of the faults and shears trends approximately northeast-east, and others trend northwest and north. In the granitic rocks few shear zones or faults are recognized.

Two major faults have been observed in the volcanic rocks of the southwestern corner of the area. One trends almost east-west and is characterized by a deep valley extending east from Baby lake to Long lake. The fault zone is approximately fifty feet wide and consists of talc-chlorite schist. No determinations of the attitude of the fault plane could be obtained. Another fault, less evident than the first

but well indicated, trends along the N.-60°-E. part of Des Quinze river. On each shore of the river are chlorite-schist zones trending along the river and dipping approximately 70° to the south, or vertically. However, whenever the river widens, the zones are unseen and the evidence is therefore not continuous. This fault zone extends to the southwest through Profond lake. The contact between the volcanic rocks and the biotite schist is located from 500 feet to 1600 feet north of this zone and may also be occupied by a fault as is indicated by the presence of chlorite schist in the contact zone.

Evidence pointing to the existence of two other faults was also observed along the northeast shore of Barrière lake and the southern extremity of Four-mile bay. On an island, at the northern end of Barrière lake, a brecciated zone was observed. The presence of talc-chlorite schist and the offsetting of rock types from one side of the lake to the other indicate the existence of a north-northeast trending fault, which probably extends north and south along the lake for an unknown distance. The attitude of the fault is unknown. At the northern extremity of a small island just south of Four-mile bay, further evidence of faulting was observed. The rock at this locality is a gneissic hornblende granite mixed with plagioclase-hornblende gneiss and with intercalated lenses of biotite schist. The fault parallels the foliation, trending north-northeast, dipping 50° west and is indicated by a fractured zone filled with carbonates and chlorite schist.

The faults described above are the only ones for which strongly supporting field evidence was obtained. The existence of other major faults can be inferred from indirect evidence. The remarkably

straight course of many rivers and lakes constitutes a pattern of subparallel linear topographic elements which may have been determined by faults (see figure 5, Linear Topographic Elements). However, the origin of these linear elements is unknown.

One is inclined to think that such linears are due to the normal physiographic development of the region with direct or indirect relationships to the structure of the subjacent rock masses. But these elements could also be the result of glaciation alone, as is indicated by the lack of shearing, rupturing, silicification and brecciation which are features that generally characterize faults.

The author's opinion is that these linears are related to the structural pattern of the subjacent rock masses and the following facts support this view:

a)- The lineaments are parallel to the dominant directions of jointing in the area. (See figures 6, 7, 8).

b)- Diabase dykes did occupy parts of some lineaments, as remnants of them are still found along the shores of numerous lakes, trending in a direction parallel to that of the lakes. Erosion of the dykes may have originated the valleys. Furthermore, numerous diabase dykes trend in the general direction of these lineaments, and as diabase dykes have been noted to intrude into fault zones (Billings, 1954, p. 309, De Sitter, 1956, p. 134) occupying tension cracks and shear zones, it is plausible to consider the development of a similar relationship here.

c)- Many rivers and lakes lie in deep valleys (200 feet) with abrupt vertical sides (Photograph 59) and this could hardly be expected

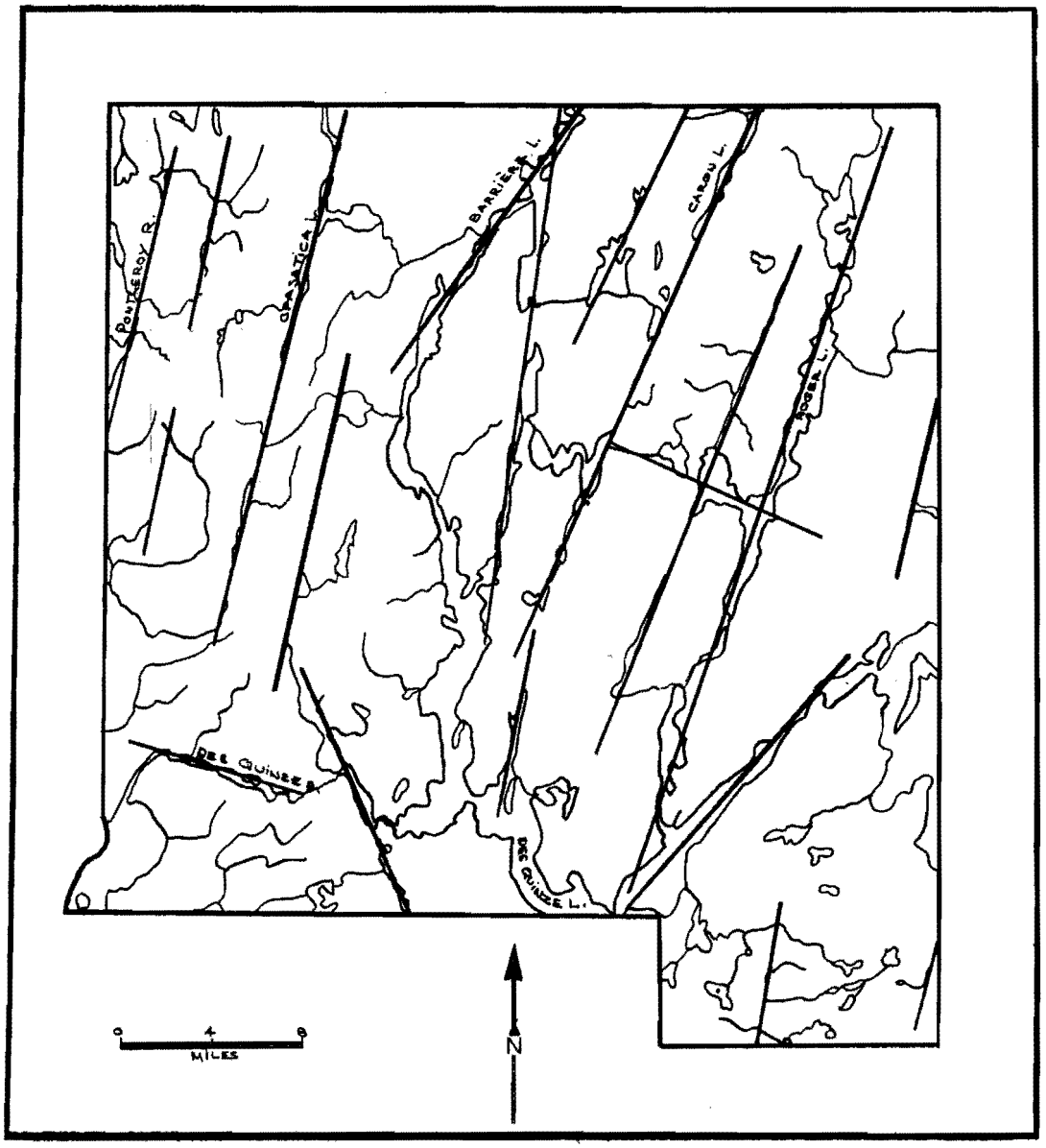


Figure 5 :

Linear Topographic Features.

to be the result of glaciation alone, especially in an area of such low relief.

d)- There appears to be structural discontinuity between formations on opposite sides of linear elements, the trend of foliation sometimes varying from one side to the other as at Roger lake. However, this does not necessarily imply a structural relationship because it can logically be explained by gradual change within the width of the linear (lake, river, valley).

Photograph 59 : Caron lake seen from the southern extremity. The abrupt sides of the valley are visible in the background.

e)- If the linears are regarded as faults, there should be evidence of movement. The rock types generally correspond on opposite sides of linears with minor exceptions. On the east side, at the south end of Roger lake, biotite schist is dominant, whereas on the west side granite is dominant. This would indicate that the west shore moved south relatively to the east shore. Similarly there is a

slight discrepancy between hornblende granite formations across the south end of Opasatica lake, indicating southward movement of the west side. Such indications of movement are rare however and the horizontal movements involved appear to be small and could be explained by other processes. For instance, it is possible that these differences are due to folding or occur in a normal fashion within the widths of the linear elements.

The above-mentioned facts lend support to the idea that the linears are related to the regional structural pattern and it is believed that they are the surface expression of faults or joint sets. Wilson (1918) suggests that the linears are related to faulting of a block-type with very small displacement, and this opinion is regarded favorably by the author. Podolsky (1950) mentions that left-hand cross-faults that strike north to east of north cut the rocks of the Pontiac group in a region north of the area under study. He states:"Displacements along these faults have generally been small, and rarely exceed a few hundred feet. The faults are characterized by straight, parallel lineaments that extend well into the granite to the south but for some reason are not so clearly defined in the northern lavas." These observed faults extend into the present area, along the linears, and their origin is not clearly defined. Johnston (1959) suggests that linear valleys are controlled by fractures and joints "related to deformation at the contact of the Timiskaming and Grenville."

It appears very likely therefore that the linear elements of the area occupy fault zones but the evidence for this is indirect in the area, direct evidence being found to the north of the area only.

We can only say with any degree of assurance that the linears are related to the structural pattern, either to faults or joint sets or to both.

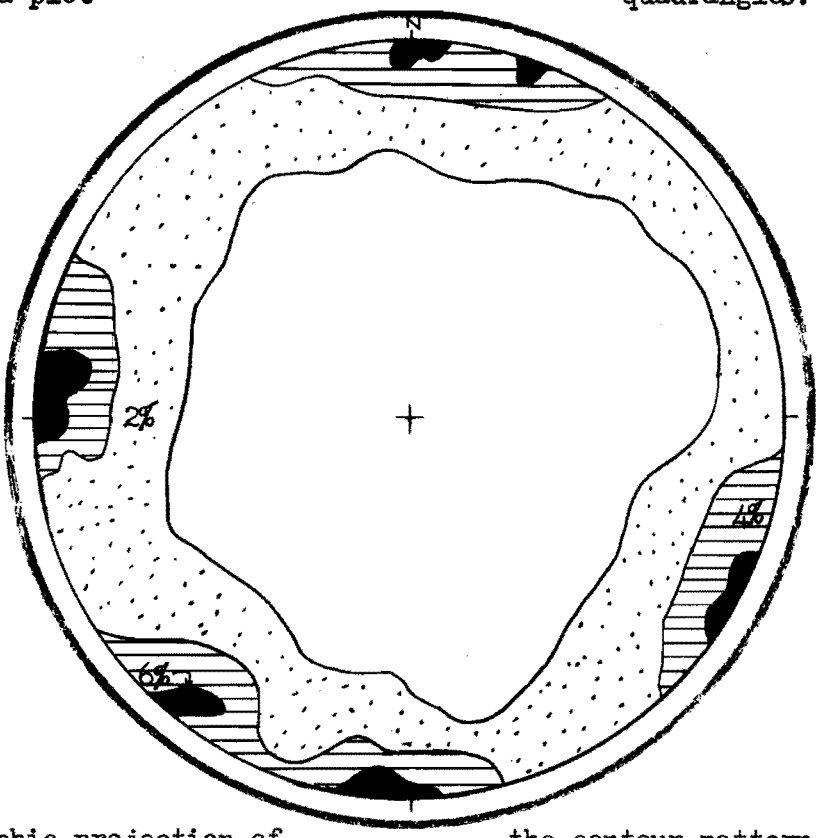
Joints

Joints observed at numerous localities in the map-area, commonly strike either N.-30°-E., N.-90°-E. or N.-112°-S. Other joints strike approximately N.-5°-E., N.-40°-E., N.-125°-S. and N.-159°-S. but are not common. All joints dip steeply, with the exception of horizontal, or nearly so, joints observed frequently in large bodies of pegmatite. Joints often are filled by quartz veins or stringers. In gneisses and schists, one joint set is usually perpendicular to the foliation.

Contour diagrams of the joint poles for the northeast and southeast, northwest, northwest and southwest quadrangles reveal that five joint sets are dominant in each area, four of which are common to the entire map-area. The N.-125°-S. joint set is distinctive in the southwest quadrangle and is related to the volcanics.

The N.-160°-S. and N.-100°-S. joint-sets of the northeast and southeast quadrangles were observed in the field to be shear joints. The N.-30°-E set common to the whole area appears to be a master joint related to the major linears discussed above. The stereographic projection of the contour pattern discloses that it could be a longitudinal joint and that the maximum stress direction would be roughly parallel to the N.-112°-S. joint direction.

Contour diagram of 205 joint poles; northwest and southwest quadrangles.
Equal area plot



Stereographic projection of the contour pattern.

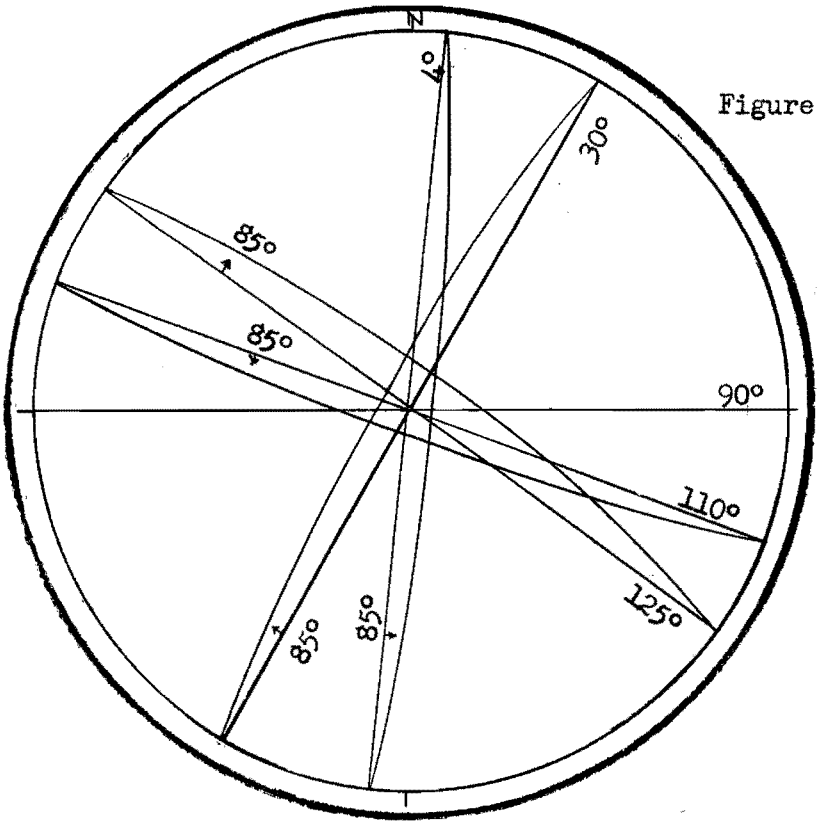
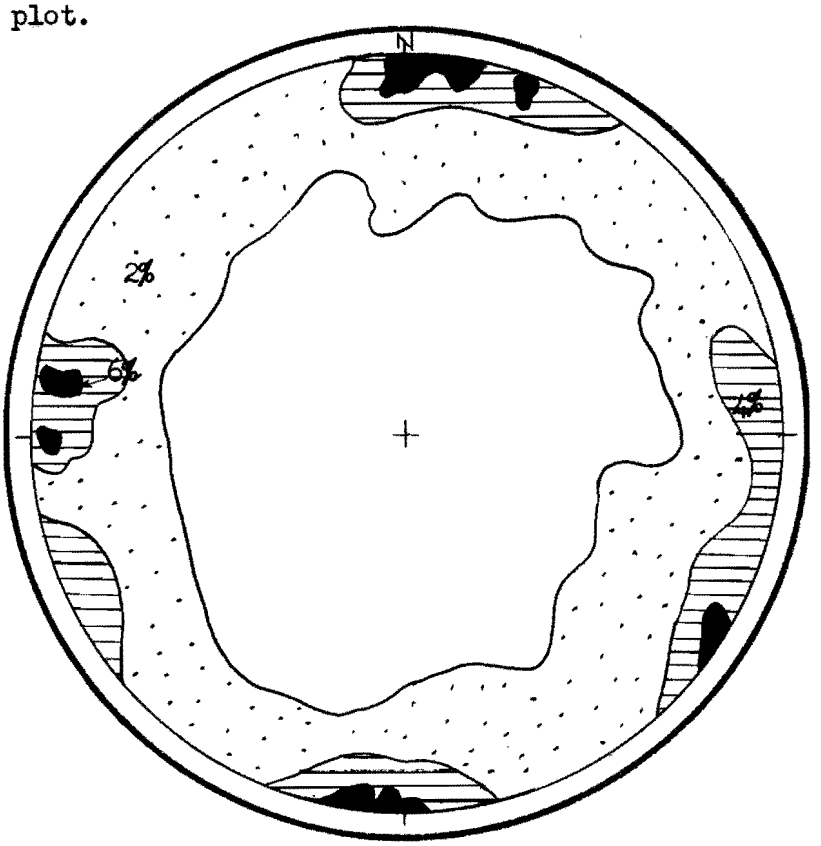


Figure 6

Contour diagram of 105 joint poles; northwest quadrangle.
Equal area plot.



Stereographic projection of the contour pattern.

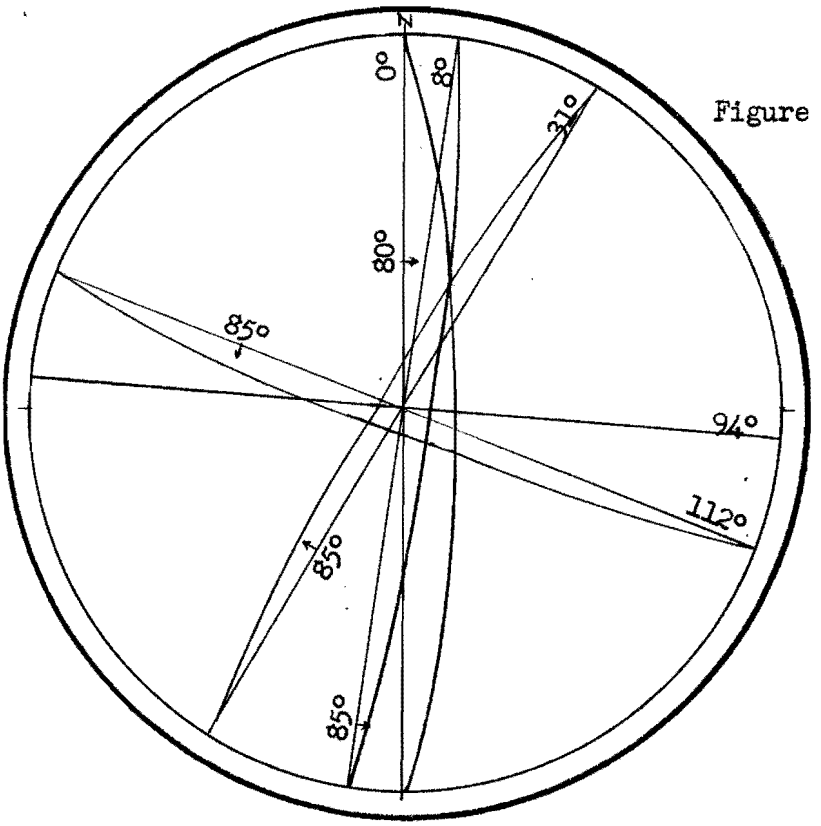
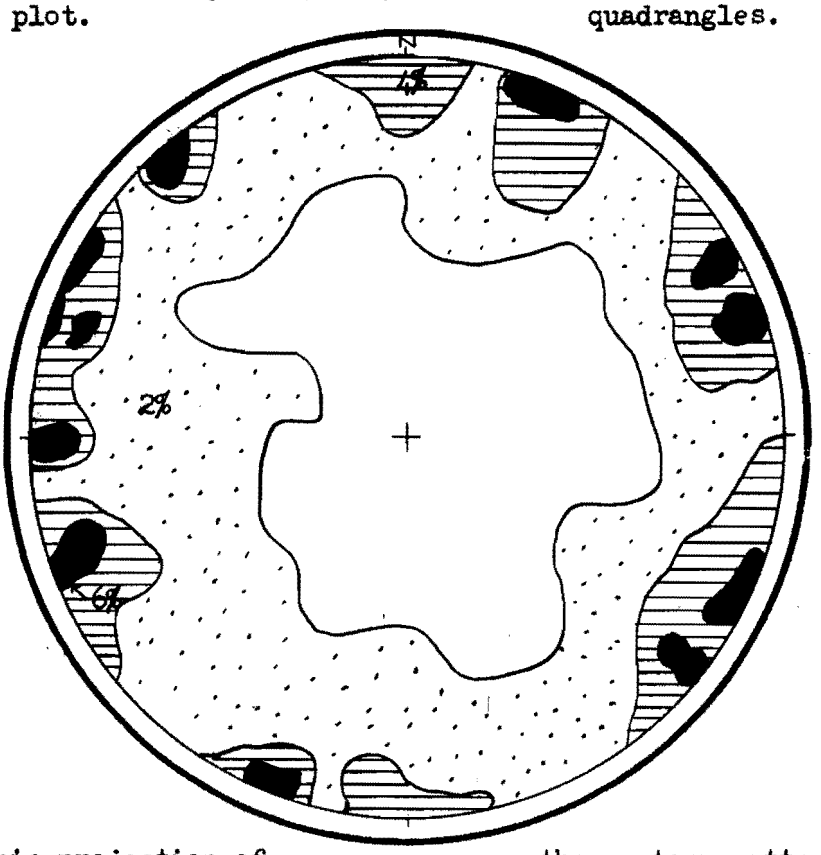


Figure 7

Contour diagram of 256 joint poles; northeast and southeast quadrangles.
Equal area plot.



Stereographic projection of the contour pattern.

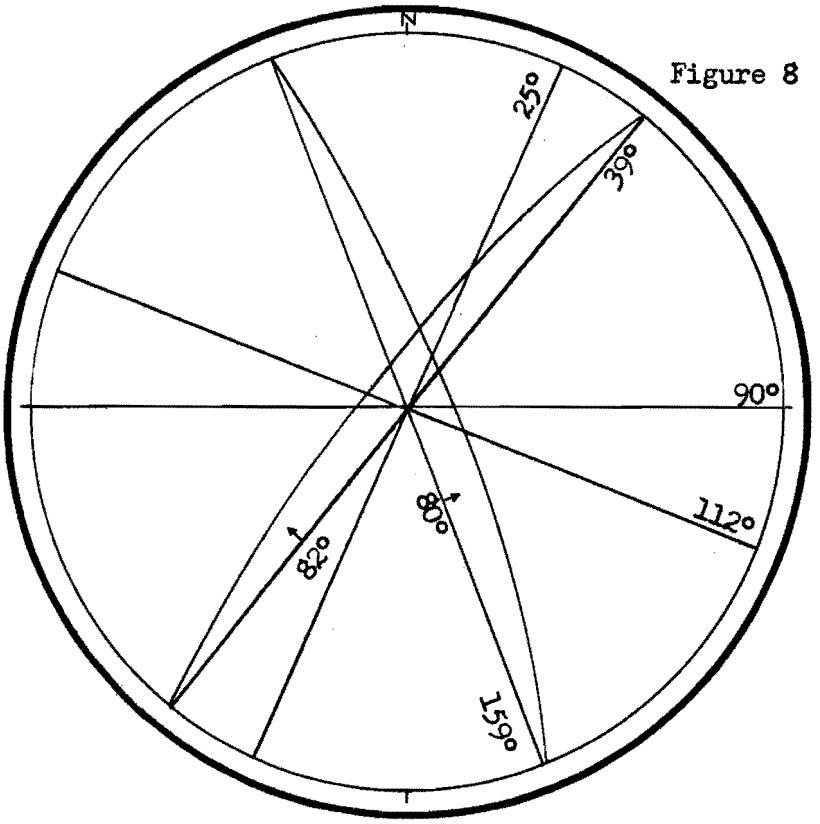


Figure 8

Structural pattern of the area and relations with the regional structure

The volcanic assemblage in the southwest sector trends N.-60°-E. and is isoclinally folded, the deformation being apparently caused by northwest- and southeast-trending compressions. In the adjacent area to the south, Henderson (1936) established that the volcanics were part of a monocline; "it represents the southern limb of a major fold that has been cut off on the north by the granite." (p. 14). Southeast of the area, the volcanic rocks form a broad anticline plunging to the southeast. Henderson distinguished two sets of drag-folds related to this structure: "One set plunges at gentle angles rarely exceeding 30 degrees.... The second set of drag-folds plunges at extremely steep to vertical angles... Evidently the gently plunging drag-folds are the true secondary folds formed by differential movement between beds or flows during the initial longitudinal folding of the rocks along an east-west axis. The steeply plunging drag-folds were formed later by stresses that bore no relation to those responsible for the earlier longitudinal east-west folding". (p. 14). Henderson explains that the steeply plunging drag-folds are associated with the "thrusting action of the invading granite" (p. 15), that is, with the deformation which is dominant north and south of the volcanic zone. This relationship indicates that the north-south and east-west deformations are not contemporaneous.

In the Kipawa lake area, south of the volcanic belt, Robert (1963) describes northeast, north-south and northwest structural trends in paragneisses, trends which he believes to anastomoze with the east-west deformation of the quartz-feldspar-biotite schist and volcanics

to the north of this region. Robert mentions the gradual passage from "Timiskaming-type" metasediments to biotite schist and writes that the north-south trends may be contemporaneous with or younger than the east-west folding. On this topic, Osborne and Morin (1962, p. 128) write: "The northeast-trending structure is obviously younger than both the north- and east-trending folds. The north-trending structures are either the same age or younger than the east-trending folds in the metavolcanic rocks. Of the two hypotheses we prefer the former because we believe that the less altered rocks on top of the greenstones are conformable with more altered sedimentary rocks to the south and these, except close to the greenstone, show no imprint of the old east-trending folding." Robert (1963) established the following sequence for the deformation (p. 187): Initially the east-west folds are created by north-south compression accompanied by granitic intrusions and by transverse folds along north-south trends. Potassic granites are then intruded and this intrusion is followed by northwest movements. Robert therefore accepts the contemporaneity of the east-west and north-south trends. This contemporaneity is difficult to explain, and Osborne and Morin (1962, p. 128) write: "Such disharmonic folding as this has been described and though its mechanics are not well understood it is probably the result of proximity of a section of the crust dominated by thick greenstone units to one composed of bedded rocks including shales."

In the map-area, just north of the volcanic zone along Des Quinze river, the members of the Pontiac group overly the volcanics and show north-south trending structures. The conditions at this locality are very similar to those encountered to the south and discussed by

Osborne and Morin and by Robert. Therefore, similar relationships may exist, but the evidence mentioned earlier indicates the non-contemporaneity of the east-west and north-south foldings. The intersection of east-west structures by the north to northeast trends of the quartz-feldspar gneiss in the vicinity of Prévu lake suggests the superimposition of the north to northeast deformation over the east-west trend of the volcanics. However, this feature may be explained as resulting from the dominance of the north-south deformation at this place, the transverse folds locally interfering with the main east-west folding of the volcanic zone. That little indication of overprinting of structures is observed in the area, especially in the Des Quinze river sector where both trends are contiguous, may be interpreted as negative evidence of the contemporaneity of the east-west and north-south foldings. But, the writer believes that the indications observed in the area and in adjacent areas (Henderson, 1936) strongly point to the superimposition of the north-south trends over the east-west trends.

The younger northeast trends alluded to by Osborne and Morin (1962), as quoted above, are absent from the map-area and it appears that this episode of deformation did not affect the Pontiac group. Robert (1963) also notes that they are infrequent in the Kipawa lake area.

North of the area, in the Rouyn-Beauchastel region, the north-south trends of the Pontiac group give way to the east-west trends of the Keewatin volcanics. There is no sharp break between the east-west and north-south trends, or no large-scale faulting. Wilson (1962) refers to the east-west trends of the Pontiac group in the Rouyn-Beauchastel area and writes: "This supports the hypothesis of Gunning and Ambrose

(1939, p. 37) that the rocks of the Pontiac (Kewagama) group are part of the south limb of a major syncline." (p. 19). However, the presence of north-trending structures has been observed in Rouyn township, north of the map-area, by Podolsky (1950) who writes that the Pontiac strata "form compressed, Z-shaped buckles whose axes appear to plunge steeply north. There is no indication from the fabric diagrams of non-affine movements along cleavage planes to produce such buckles, thus it is concluded that they represent tilted, original pre-Timiskaming folds."(p.89).

In the adjacent area to the east, Freeman (1957) observed northeast trends and wrote that the area was part of a large anticlinal zone trending northeast, within which plunging anticlinal and synclinal structures exist. He also wrote that, in the northern part and to the north of the Béraud-Mazérac area, the rocks are part of the southern limb of a broad synclinal structure trending east-west, with moderate dips to the north. Here again, the juxtaposition of two structures, with different orientations, is observed and no definite break between the two is apparent. Overprinting of structures is not mentioned either by Freeman or by Wilson.

In the map-area, the dominant structural trends are north-south, with local variations to the east and to the west. The northwest orientation of the folds in the northwest corner of the area is interpreted as a local variation of the north-south structural trends and not as a separate structure indicative of a different episode of deformation. Indeed this zone is underlain by the same synkinematic granite that is associated with the north-south trending structures. The granitic rocks were emplaced concordantly during the episode of north-

south deformation. Prior to this emplacement there may have been other deformations, but because of the intensive metamorphism and large-scale granitization, no traces of earlier deformation now remain.

Osborne and Morin (1962) divided the Grenville into two tectonic-metamorphic units. The map-area, according to this division, is part of the Grenville B subprovince, and Osborne and Morin (p. 119) write: "The tectonic pattern of the Grenville B subprovince is distinctive in its irregularity and is a result of the superimposition of new structural trends on older ones. The newer structures trend generally northeast but are exceedingly irregular, giving the impression of anastamozing zones passing around blocks of somewhat greater resistance than adjacent blocks. Both north- and east-trending older structures can be recognized but, in a considerable part of the Grenville B subprovince, though the effects of the two foldings can be recognized, the direction of the older has not been ascertained." These specifications closely conform to the structural pattern of the map-area, except that no truly northeast-trending structures exist. The north- and east-trending structures are present, the northern trends being visible over most of the area and the eastern trends appearing only in the southwest and southeast corners. The older folding appears to be east-west, with the north-south being superimposed over it. The east-west trends are preserved in the volcanic rocks because of their thickness and consequently increased resistance to large-scale deformation.

Chapter VI

METAMORPHISM - NATURE OF THE "GRENVILLE FRONT"

Metamorphism

The degree of metamorphism of all the rocks in the map-area is relatively uniform and most assemblages belong to the staurolite-quartz subfacies of the almandine-amphibolite facies of progressive regional metamorphism, as defined by Fyfe, Turner and Verhoogen (1958). It has already been mentioned that the volcanic sequence in the southwest corner of the map-area may straddle the boundary between the upper greenschist facies and lower almandine-amphibolite facies, but this departure from the normal can be related to retrogressive metamorphism accompanying granitic intrusions or to the greater resistance to metamorphism of a thick volcanic sequence due to a high water content. Therefore, except for the east-west belt of volcanics in the southwest corner, no metamorphic zoning can be recognized throughout the area.

However, if we compare the metamorphic grades of adjacent regions with that of the area under study, a pattern can be outlined. In the Kipawa lake area to the south, Robert (1963) recognizes an increase in grade of metamorphism from north to south and suggests that the paragneisses underlying this region belong to the kyanite-muscovite subfacies of the almandine-amphibolite facies. He writes that the biotite schist, which he believes to be a correlative equivalent of the Pontiac schist, is less metamorphosed than the gneisses to the south but more metamorphosed than the "Keewatin-type" metavolcanics and "Timiskaming-type" metasediments described by Denis (1938), Retty (1931), Auger (1952) and Henderson (1936), in areas to the north. On the basis

of mineralogical composition, he assigns the metavolcanics and metasediments, north of the Kipawa lake area, to the staurolite-quartz subfacies of the almandine-amphibolite facies, which is the metamorphic grade of the rocks in the area now under study. From the descriptions given by Denis (1938), Auger (1952) and Henderson (1936) of the volcanics and sediments, the metamorphic grade appears to be as defined by Robert (1963) with a few exceptions where it is lower, that is, where the rocks belong to the greenschist facies. Robert (1963) explains the lower grade of the volcanics by the moderating effect of the thickness of the volcanic assemblage, approximately three miles, on the speed of metamorphic reactions.

An isograd, the boundary between the staurolite-quartz subfacies and the kyanite-muscovite subfacies, thus passes south of the map-area in a general east-west direction. The trend of the isograd cannot be defined accurately, but it is plausible to visualize it as being parallel to the Grenville A - Grenville B boundary (Osborne and Morin, 1962) which is a tectonic-metamorphic division trending northeast. However, this direction may be modified somewhat by the presence of the east-west trending volcanic sequence. Another isograd, the boundary between the greenschist facies and the almandine-amphibolite facies, may pass in the southwest corner of the area and south of it, along the volcanic sequence.

Freeman (1957) describes the Béraud-Mazérac area to the east of the region now under study and writes that narrow layers of amphibolite belong to the albite-epidote-amphibolite facies and that the biotite schist of the Pontiac group belongs to the biotite-chlorite

subfacies of the greenschist facies "as shown by the mineral assemblage, but it is possible that chlorite is produced as a result of retrogressive metamorphism." (p. 48). This would indicate that there is a north-south trending transition from the greenschist to the almandine-amphibolite facies from one region to the other. Freeman mentions the presence of staurolite, sillimanite and garnet in highly disturbed zones but he explains that this presence is related more to the original chemical composition of the rock than to the grade of metamorphism and he rejects their value as index minerals. From this and from his explanation that chlorite may be a result of retrogressive metamorphism we may conclude that the grade of metamorphism is actually higher than stated and that it corresponds more or less to the lower limit of the almandine-amphibolite facies. Thus there is no transition in grade of metamorphism from one area to the other. This is also indicated by Eakins (1962) who writes that the rocks of the Kewagama group, correlated with the Pontiac group, in the Malartic area belong to the lower and to the higher portions of the epidote-amphibolite facies. The Malartic area is northeast of the Béraud-Mazérac area and the grade of metamorphism is similar to that of the area now under study.

Wilson (1962) writes that the Pontiac schist in the Rouyn-Beauchastel area, north of the Des Quinze lake-Barrière lake area, is composed of quartz, albite-oligoclase and brown mica partly altered to chlorite. This mineral assemblage is that of the staurolite-quartz subfacies of the almandine-amphibolite facies, although the presence of albite in places may indicate a transition to the upper greenschist facies. Eakins (1962) mentions that in the Malartic area, albite gives

way to oligoclase, and thus a transition in grade of metamorphism such as the one just outlined is defined. Snelling (1962, p. 5), referring to the Pontiac group north and northeast of the map-area, notes that the rocks "have suffered regional metamorphism, the metamorphic grade being somewhat higher than that exhibited by the members of the Abitibi Group. The mineral assemblages in members of the Pontiac Group indicate metamorphic conditions of the muscovite-biotite subfacies and the almandine-amphibolite facies." The transition in grade of metamorphism is therefore recognized and defined, and it probably trends east-west, along the volcanic-sedimentary sequence of the Rouyn-Malartic zone.

From these considerations we may conclude that two isograds are recognized in the zone between the Kipawa lake area to the south and the Rouyn-Beauchastel area to the north, and that the degree of regional metamorphism decreases from south to north. The isograds to the south and to the north are respectively the upper and the lower limits of the staurolite-quartz subfacies. The lower isograd occurs north of the area where its position is not well established and also in the southwest corner along the volcanic assemblage. The higher isograd occurs south of the area, in the northern part and north of the Kipawa lake area. (See figure 9, showing the position of the Grenville front.).

Chloritization, saussuritization and epidotization are products of retrogressive metamorphism. The minerals formed are always clearly related to the primary components and generally display relationships indicating their secondary nature. The small amounts of epidote usually present in the granitic rocks may be related to the

wholesale microclinization, as explained by Ch'Ih (1950) who writes that the formation of microcline at the expense of plagioclase during granitization may produce epidote as a by-product.

The Grenville Front

The Grenville front, separating the Superior from the Grenville provinces, is considered to pass in or near the area. It is, however, ill-defined and its location is not established with certainty. The question of the nature and location of the front will now be reviewed in the light of the information obtained from the study of the map-area.

Nature of the Grenville front: "The nature of the "Grenville Front" is a problem that has long puzzled geologists. In some places it is a fault zone and in others a zone of transition whose nature is far from clearly understood." (J.M. Harrison in Snelling, 1962). This opinion succinctly summarizes the problem of the nature of the Grenville front. Grenville formations are usually regarded as being characterized by northeast-trending structures and a relatively high grade of metamorphism, and as being separated abruptly from the east-west trending rocks of the Superior province. The front is commonly shown on geological maps as a fault, probably because it was first recognized as such and also because it often corresponds to faulted zones. However, it has become apparent that the separation between the Superior and Grenville provinces is not everywhere a fault zone but is gradational.

Norman (1940) recognized that thrust faulting was a feature of the Grenville front in the Mistassini lake area, and Wahl (1953), Neilson (1953) and Gilbert (1958) also noted the faulted nature of the

Grenville front in this area. Johnston (1954, 1959) described the Temiskaming-Grenville contact southeast of lake Temagami in northern Ontario as a complex zone of thrust faults of major tectonic significance. However, Norman (1936) suggested that the front was not everywhere characterized by a fault zone, or at least that the faulting was not continuous along the length of the front. Deland (1956) and Deland and Grenier (1959) established that in the Surprise lake area the front corresponds to a two to three miles wide transition zone in which a time-stratigraphic unit passes from a lower to a higher grade of regional metamorphism, the higher grade being in the Grenville province and the lower grade in the Superior province. Phemister (1960) wrote that the contact between the Grenville and Temiskaming subprovinces in the Sudbury district of Ontario was a metamorphic transition, one hundred yards wide. Other geologists, Neale (1959), Freeman (1957), Laurin (1957), to name a few, also noted the transitional nature of the front in diverse areas. In his study of the Kipawa lake area, to the south of the area under study, Robert (1963) established that the front was a metamorphic transition and he assigned it to the staurolite isograd of the almandine-amphibolite facies of regional metamorphism.

Location of the front : The general location of the Grenville front as established by different geologists is illustrated in figure 9. The position of the front in northwestern Quebec is seen to vary according to the ideas of different authors. Derry (1950) locates it just south of the map-area, whereas Robert locates it to the north in the vicinity of the 48^{th} degree of latitude.

Geology of the map-area and its relations to the Grenville front:

The biotite schist of the Pontiac group is generally regarded as part of the Keewatin-Timiskaming sequence of the Superior province. It extends from north to south in the map-area and is in contact in the southwest with the volcanic belt. South of the area, it has been mapped by Robert (1963) and assigned by him to the Grenville. To be more specific, the biotite schist is correlated with the schist of the Pontiac group and is considered as a Grenville-type rock. Thus the biotite schist of the map-area belongs to the two geological provinces according to its geographical location.

No fault zones were observed in the area, north of it and south of it, and therefore the Grenville front is not here a faulted complex as it is elsewhere. The north-south structural trends observed in the map-area are similar to those of the Kipawa lake area, but differ from those of the Keewatin volcanics to the north. On the basis of the tectonic pattern, the area may be considered as belonging to the Grenville since the east-west trends to the north are typical of the Superior province. It was written earlier that northeast trends characterize the Grenville, but no such trends are present in the area and south of it. Robert (1963) notes that such trends are inconspicuous in the Kipawa lake area. Therefore it appears that northeast trends do not characterize all of the Grenville, being locally absent as in northwestern Quebec.

The grade of metamorphism is relatively high in the area, being within the staurolite-quartz subfacies, thus above the staurolite isograd mentioned by Robert as corresponding to the Grenville front.

However, the volcanic zone in the southwest is just below this isograd, and the front, if it corresponds to this degree of metamorphism, must describe a sinuous pattern to circumscribe the volcanics (figure 9).

From these considerations it appears that the rocks of the Keewatin are converted to the gneisses of the Grenville and thus the same rock units are shared by both provinces. The tectonic style differs greatly from one province to the other and, on this basis, the area may be considered as belonging to the Grenville. The metamorphic grade in the area is also that of the Grenville rocks further south. However, it is arbitrary to assign a specific isograd as corresponding to the front, and the writer prefers to use the general trend of the metamorphic transition instead of a particular isograd in order to avoid contortions in the front. (re.: figure 9).

Osborne and Morin (1962) suggested that the east-west and north-south structures of the Grenville B subprovince are contemporaneous. On this basis, the area and parts of the Keewatin subprovince to the north belong to the Grenville B subprovince, and consequently it is implied that the rocks of the Keewatin and the Grenville are both of Archean age, although they may not be contemporaneous.

The age relations of the rock formations on both sides of the front indicate that "an abrupt change in age across the Grenville front corresponds to a sharply defined change in degree of metamorphism." (Snelling, 1962). According to Snelling, the rocks in the vicinity of the front were involved in the 1,000 million year old orogeny of the Grenville province. Osborne (1962) proposed the term "Millenary" for this orogeny and suggested that it was a thermal event.

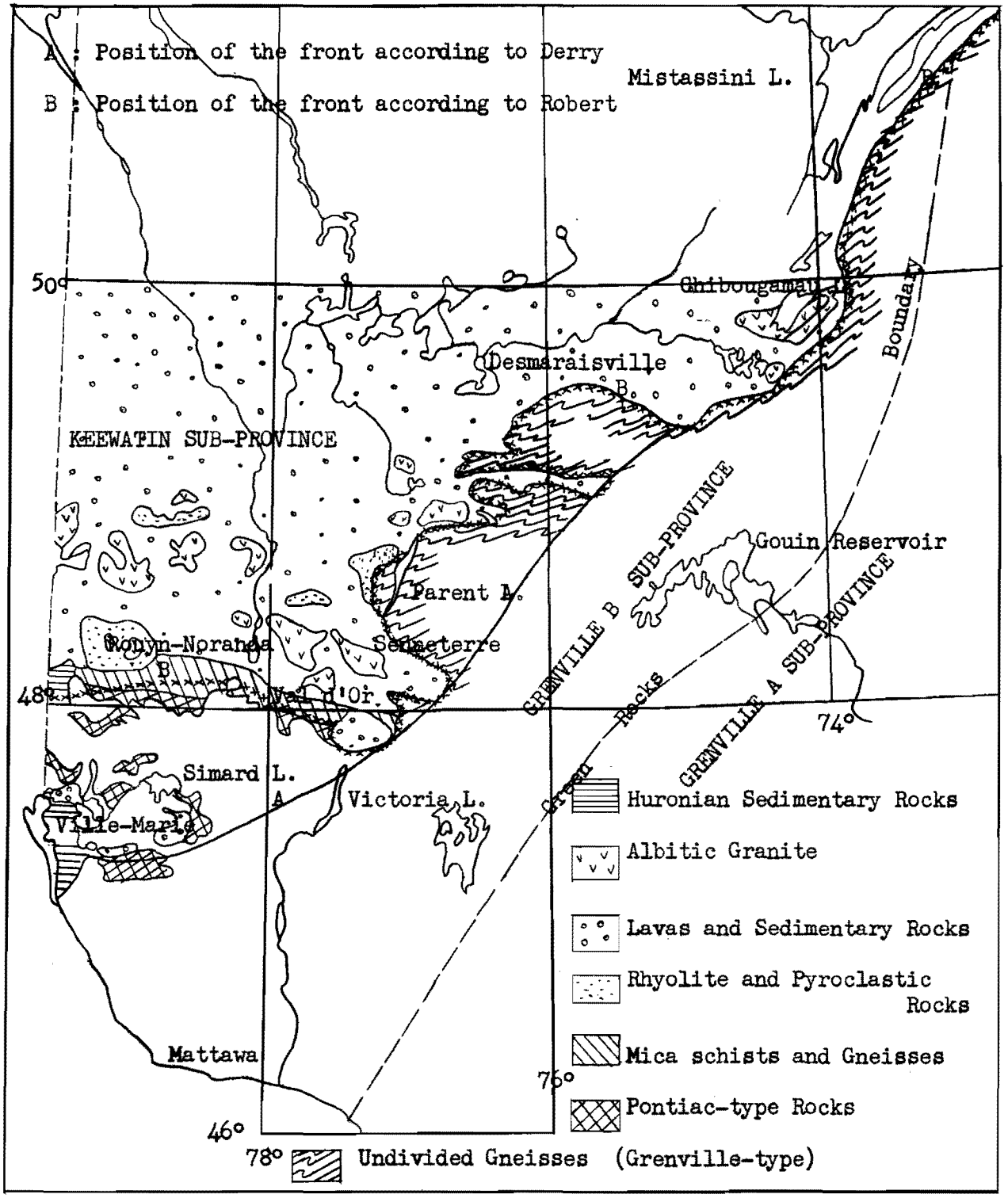


Figure 9 : Location of the Grenville Front

(After Robert, 1963)

To summarize, the Grenville front is considered as corresponding to a metamorphic transition situated somewhere between the limits outlined by the rocks belonging to the kyanite-muscovite-quartz subfacies of the almandine-amphibolite facies and the upper greenschist facies. The front is therefore gradational and does not correspond to a specific line on a map, but is a zone which includes the map-area. Rocks of similar age and lithology on either side of the front are involved in the Grenville orogeny and therefore the front does not correspond to a specific time division.

Chapter VII

ECONOMIC GEOLOGY

Numerous mineralized outcrops were examined and some of them may ultimately be shown to belong to deposits of economic value. However, no economic deposits are now, or have been, exploited within the area. The Rouyn-Noranda deposits to the north, the Belleterre gold mine to the southeast, the Cobalt silver mining camp to the southwest and the recent development of the Lorraine project to the south have spurred prospectors and geologists to search for minerals in the area. The belt of volcanics in the southwest, especially, has been subjected to intensive prospecting and several mineralized showings of interest were discovered. The granitic rocks that underlie most of the area contain few of the economic minerals generally associated with granites. Beryl was observed at one locality but in very small amounts and molybdenite occurs frequently but does not form large deposits. Radioactive minerals associated with biotite occur in pegmatites in the northern part of the area but they are finely disseminated.

The localities where mineralization occurs are indicated on the map by numbers. Following is a brief description of the major features of the most interesting showings:

Molybdenite

Five important showings of molybdenite occur at localities 2, 8, 9, 10 and 11, that is, along the shores of Profond lake, in ranges VII and VIII of Beaumesnil township, along a range road in Guérin township on lots 50 and 51, Range II, and lots 39 and 40, Range I, west of Nédelec in lot 29, Range VII of Nédelec township and

southeast of Rollet on lot 23, Range III of Desandrouins township. Molybdenite was also found at several other places but only as traces in the pegmatite dykes. Molybdenite is always associated with pegmatite dykes and quartz veins cutting oligoclase-microcline granite, quartz-feldspar-biotite schist or porphyroblastic amphibolite (Nédelec). Diffenbach (1961) investigated the nature of the mineralization in Nédelec and Guérin township (localities 8, 9 and 10) and observed the following mineralogical associations: molybdenite, pyrite, chalcopyrite, yellow powdery molybdite, bismuth and bismuthinite. Powellite and bornite are also reported to occur in several diamond drill cores. The order of deposition of the minerals, as established by Diffenbach, is: feldspar, molybdenite, pyrite, chalcopyrite, bismuth, bismuthinite and quartz. Diffenbach (1961) shows the similarities of these mineralized zones with the Preissac-Lacorne deposits and writes about the origin: "The pegmatitic aspect of the deposits and their association with granitic igneous rocks suggest that the mineralization has resulted from the introduction of late stage hydrothermal fluids of magmatic origin."

Exploration work, consisting mostly of geological mapping, trenches, pits and shallow diamond drill holes, was performed on the five major showings but no orebody was outlined and the properties are now inactive.

Iron Formation

The iron formations in the vicinity of Des Quinze river (locality 7) have been the object of much exploratory work by various mining companies. The work generally consists of magnetic surveys,

geological mapping, trenches, pits, diamond drill holes and stripping of overburden. The position of the formations is not accurately established on the map, but they appear to extend intermittently over a distance of seven miles with an average width of 40 feet, with variations from 10 to 150 feet. There are at least two formations, probably three, and of these, the formation just south of Des Quinze river may be of economic value. This iron formation was described earlier as consisting of alternating layers of quartz and magnetite, and analysis has shown that it contains 37 % Fe of which 29% is from the magnetite. Exploration work is still in progress and further developments may eventually lead to exploitation.

Copper-Zinc-Gold

Mineralized outcrops containing copper, zinc and gold were examined at localities 4, along the Rollet-Cloutier road on lot 31, Range VII of Desandrouins township, 5 on the northeast shore of Barrière lake, on lots 3 and 4 of Range X in Caire township, and 6 along the Angliers-Rémigny road on lots 60 and 61, Range VII of Guérin township. The mineralization is never extensive and consists of variable amounts of pyrite, pyrrhotite, chalcopyrite, sphalerite and gold in amphibolite, biotite schist and hornblende gneiss. The results of analyses of grab samples are:

Locality 4:	Cu = 0.07%	Locality 5:	Cu = 0.10%
	Fe = 9.04%		Fe = 35.65%
			Zn = 0.04%
			Au = 0.004 oz./ton
Locality 6:	Cu = 0.35%		
	Fe = 32.06%		
	Zn = 0.10%		
	Au = 0.002 oz./ton		

The mineralized zones are of small dimensions except at locality 6, where the width is twenty feet and the maximum observed length is

1000 feet. Little or no work has been done on these showings.

Lead

At locality 1, on lot 30, Range I of Brodeur township, at the eastern extremity of the east-west road south of Grassy lake, is a small outcrop containing lead and copper. Pyrite, chalcopyrite and galena are disseminated in quartz-feldspar-biotite schist along a narrow zone approximately four feet long. Analysis of a grab sample yielded: Cu = 0.01 %, Pb = 0.49 % and Ag = 0.180 oz./ton. A trench is dug across the mineralized zone but there is no evidence of any other work.

Hematite

Just east of Route 46a, south of Rollet, at locality 13, on lot 15, Range VIII and lots 10 and 11, Range VII of Rémigny township, hematite occurs in small amounts. The hematite is associated with pegmatite dykes, one-quarter to half an inch wide, trending 100°. The hematite forms narrow veinlets within or along the pegmatite dykes and the grains extend perpendicularly from the walls. No work has been done on this showing but it has been examined by prospectors.

Nickel and Copper

At locality 12, on lots 1 to 8 of Range III and IV in Desandrouins township, nickel and copper occur in a thirty-five feet wide mineralized zone in quartz-feldspar-biotite schist. Pyrite, pyrrhotite, chalcopyrite and pentlandite are the principal minerals, and analysis of a grab sample gave: Fe = 39.55%, Cu = 0.11%, Ni = 0.27%. In the vicinity of the showing are several narrow pyroxenite dykes and one small mass of serpentinite. Small, one-sixteenth of an

inch wide, cross-fiber veinlets of chrysotile are found in the serpentinite at locality 14. Work is now in progress on the nickel-copper showing and electromagnetic surveys were made recently, the results of which are not yet available.

Beryl

As mentioned earlier, a few small crystals of beryl were found at locality 3, on lots 56-57, Range X of Caire township. One prospector reports the discovery of crystals up to six inches long in the neighborhood of this locality.

This brief résumé discloses that there is a great variety of mineralization in the area. Industrial minerals are also present in places, but the occurrences examined are not of economic value. Various claims of mica finds have been made by prospectors, notably near Rock, Basserode and Roger lakes, but the showings are generally inextensive and the quality of the micas is unsuitable for industrial purposes.

A granite quarry was opened up in 1946 and 1947 at the east end of lot 31, Range I in Montreuil township, alongside the highway. The granite, the oligoclase-microcline variety, is homogeneous and fine-grained at this place, but quarrying was discontinued when areas of closely-spaced joints were encountered. The granite was used for tombstones and for the exterior facing of the church at Dupuy in Abitibi-west county.

Sand and gravel deposits of good quality are abundant and amply provide for local needs.

APPENDIX I

Note on the use of pillow structures for top determinations

The pillow structures in the andesite of the Des Quinze lake-Barrière lake area are generally balloon-shaped with a "tail" extending downward. Some are slightly elongated or flattened but the "tail" is usually clearly evident. There are no vesicles or variolite zones along the rims of the pillows that could be useful as complementary evidence in top determinations. Therefore the only feature of the pillows that can be relied on is the balloon shape. Similarly shaped pillows are considered reliable for determining the top of a flow by numerous authors. Shrock (1948, p. 365) writes: "The undersurface of the pillow conforms to the V-shaped crevice between the underlying pillows." The convex upward side then indicates the upper surface of the flow and the "tail" indicates the bottom.

Many geologists determine the top of lava flows from such pillows by an evaluation of many attitudes, taking the statistical average as the true direction. This, however, is valuable and reliable only if the measurements are completely performed and recorded.

It can be shown that on a single outcrop it is possible to obtain contradictory results from pillows exposed along differently dipping surfaces. If, as in figure 10 b, the pillow is intersected by a north-south plane passing along line E-F, the top of the pillow will appear on that plane as being to the east. If, on the contrary, as in figure 10 c, the intersecting plane is a north-south plane along line G-H, the top will appear to be toward the west on that plane. In other words, when a pillow structure is intersected by a plane, the top of

the pillow will always appear to be in a direction opposite to that of the dip of the plane if the pillow is not steeply inclined (i.e.: at an angle greater than 45°). This generalization is valid for symmetrical pillows such as rarely occur in nature. The natural occurrences are not well-shaped and symmetrical and therefore can be even more misleading.

These relations are complicated by the fact that pillows can be upright, moderately inclined, steeply inclined or overturned; if this is unknown, only a determination on a horizontal surface will be reliable. From this it appears that it is necessary when making top determinations to record the attitude of the intersecting surface unless horizontal surfaces are used. This simple practice was not always adhered to in the map-area and some determinations are therefore considered to be of dubious value.

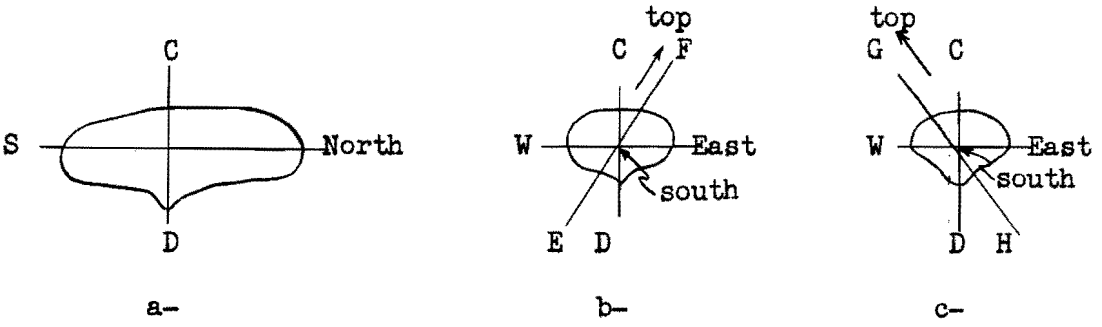


Figure 10 - a: longitudinal section of a pillow,
b-c: cross-section of the pillow
along a plane enclosing line C-D.

APPENDIX II

Modal analyses and Chemical analyses

Introduction : Modal analyses were made on 96 samples of various rock types, eight of which were subsequently rejected. From the results of the modal analyses, the chemical composition of the rocks in terms of oxide percentages were calculated whenever the chemical composition of the minerals were known. The computed chemical compositions were used for purposes of comparison.

Theory and Techniques : Representative thin sections from rocks of suitable grain size were selected for each rock type. Sections containing perthitic intergrowths and myrmekites were avoided unless they were truly representative of the rock as in the case of the pyroxene-hornblende syenite.

The slides were uncovered, etched with HF and stained with sodium cobaltinitrite and Eosin B to facilitate the identification of the potassic feldspar and of the plagioclase. The staining techniques employed were similar to those described by Chayes (1952), Rosenblum (1956), and Broch (1961) but modified somewhat after experimentation. Eosin B staining never yielded perfect results, probably because the short etching period required for the sodium cobaltinitrite staining is insufficient for the Eosin B to react. The slides were then covered.

Each analysis was performed by traversing the slide at specified intervals of one millimeter, and identifying the mineral at the intersection of the crosshairs at every 0.3mm. The minimum number of points in each section was one thousand, in order to keep the standard deviation per section to a minimum. The standard deviation

is expressed by the following formula:

$$\sigma_n = \frac{p\,(100 - p)}{n}$$

where n = number of points
p = percentage of a given mineral.

From this formula it is evident that the greater the number of points is, the smaller the standard deviation will be. For a thousand points, σ_n is smaller or equal to 1.6 %, which is an acceptable value (Jung and Brousse, 1959). The size of the thin section is also important because, on some slides, the surface area may be too small to allow the counting of one thousand points at the specified intervals. As a rule, a minimum surface of 300 square millimeters is required and is readily available because most thin sections have a surface area of 500 square mms. Generally, the number of points counted varied from 1200 to 1800, with the exception of twelve modal analyses performed with a Swift automatic point counter where 2600 points were counted by reducing the traverse interval to 0.5 mm.

To reduce the analytical error, the grain size has to be relatively fine. The coarser the grains, the longer and more numerous the traverses have to be. We used slides with a granulometric index (number of grains per 40 millimeters) of approximately 120 or more for most rock types, but in some cases had to use sections with an index as low as seventy.

In several thin sections there are holes created by the removal of some components of the rock during the grinding process. It is sometimes possible to identify the component from remnants along the edges of the hole, but whenever a hole was encountered whose former occupant could not be identified, the counting was stopped and resumed

at the beginning of the next traverse. The rejected modal analyses usually had so many holes that the surface examined was reduced below the minimum required.

Thin sections of gneissic or otherwise foliated rocks have to be subjected to special procedures in order to yield precise and useful results. It is advised by Jung and Brousse (1959) to make measurements only on sections cut perpendicular to the foliation and to set the trace of this plane at 45 degrees to the traverse line.

Once the results of the modal analyses are obtained, they are calculated on the basis of one hundred to give the modal composition of the rocks as a volumetric percentage. The volume percentage is converted to weight percentage by multiplying the volume of each mineral by its specific gravity and by recalculation in terms of percentage. From this, the chemical composition is computed by multiplying the weight of the minerals by their composition, thus obtaining the chemical composition of the rock as oxide percentages. We did not follow the method advocated by Heier (1961) whereby the chemical composition is calculated directly from the volume percentage by using the equivalent molecular units or cation percentage. It goes without saying that it is necessary to know the chemical composition of the rock-forming minerals in order to compute the chemical composition of the rock. This is relatively simple for many components, but amphiboles, pyroxenes, micas and epidotes are special problems. Chemical analyses of amphiboles and pyroxenes were used here, but we had to assume the compositions of the biotite, muscovite and epidote to be in accord with those of analyzed minerals of similar optical properties and

occurrences as given by Deer, Howie and Zussman (1962-1963).

Reliability and Significance : There is a strong reluctance among many geologists to accept the results of modal analyses and, even more so, of the derived chemical analyses as valuable. Many accept modal analyses as approximate indications of the mineralogical composition, but most refuse to regard the significance of chemical analyses obtained therefrom. This attitude may be an unconscious reaction to the fact that modal analyses can be obtained rapidly and cheaply.

It has been proven that, if performed under certain conditions, modal analyses will yield useful and relatively precise results. Chayes wrote (Fairbairn, 1951) after careful testing of modal analyses: "It is certainly fair to infer from Table 27 that for the purpose of estimating the mineralogical composition of either test rock a single thin section analysis contains about as much and about as reliable information as a single chemical analysis."

The precision and accuracy of the chemical composition calculated from the modal analysis is admittedly lower than that of a chemical analysis but is nevertheless considered valuable. Wahlstrom (1947, p. 237) wrote: "With several variables involved, including the use of specific gravities to convert volume percentages to weight percentages, it cannot be assumed that the computed chemical composition of the rock is very accurate. One of the chief causes of trouble is the fact that most minerals are isomorphous mixtures of two or more mineral "end members". For example, orthoclase almost always contains some soda, but in the calculation of the chemical composition

of a rock containing orthoclase it is generally assumed that the orthoclase is a pure potassium aluminum silicate. Similarly, plagioclase generally contains some potash, but this is not allowed for in the computation." From this it appears that we cannot present the computed chemical compositions with authority, and that it may be exaggerated and even superfluous to give the results with two figures beyond the decimal point. However we believe that the information obtained is useful and reliable for comparison purposes. We had available to us neither the time nor the facilities necessary to conduct an elaborate statistical study on the value and reliability of such results but we are disposed to accept the conclusions of authors who performed such tests. Friedman (1960) concluded that for rocks in which the composition of the individual minerals had been obtained by optical measurements, the major constituents could be determined with the petrographic microscope by modal analysis and the computed chemical analyses could be considered reliable.

Chemical analyses are sometimes tabulated with computed chemical compositions in this work. We do not pretend to assign the same significance to both or to compare them together. The chemical analyses presented are to be taken separately for what they represent and are not to be compared with the computed analyses. It would be futile to compare both types when comparisons are undesirable between chemical analyses themselves; ".. any approach which attempts to establish a difference between two or more rock types by means of comparisons which place much weight on individual analyses by different chemists is immediately suspect." (Chayes, in Fairbairn, 1951).

Conclusions : We have attempted in the last part of this appendix to show that modal analyses and computed chemical compositions are useful and reliable. The modal analyses are evidently desirable, and even considered necessary by Chayes who writes (Fairbairn, 1951): "Provision of numerous reliable quantitative modes of each of the important petrographic units involved in his work ought to be regarded as a major responsibility by anyone working in eucrystalline rocks." The computed chemical compositions are of more restricted value than the modal analyses, but are nevertheless useful and reliable. They cannot be compared authoritatively with chemical analyses but can be compared with one another and the variations detected can be considered as significant.

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LIST OF SAMPLES

Sample no.	Description	Area	Collection number (petrology)
C-9-62	Sheared andesite, very fine-grained,	Angliers	_____
S-14-62	Light-coloured hornblende rock,	Angliers	_____
S-35-62	Dark-coloured hornblende rock,	Angliers	_____
S-36-62	Rhyolite, Banded tuff ,	Long lake	_____
Y-113-62	Hornblende gneiss,(+ thin section),	Angliers	_____
C-53-62	Iron formation, first type, photo.5,	Angliers	_____
C-14-62	Iron formation, second type,photo.6,	Angliers	_____
S-30-62	Metamorphosed sedimentary rock,	Des Quinze R.	_____
S-29-62	Greywacke, biotite schist ,	Des Quinze R.	_____
Z-12-60	Amphibolite,	Rond lake	_____
D-51-60	Inclusions of amphibolite in hornblende syenite, photo. 13,	Chevreuil lake	_____
D-98-60	Quartz-feldspar gneiss, photo. 14,	Des Quinze lake	_____
C-39-62	Quartz-feldspar-biotite schist, photo 16,	Guérin	_____
32 X	Quartz-feldspar-biotite schist, core,	Rollet	_____
Y-79-61	Nodular pyroxene syenite,(+ thin section),	Barrière lake	_____
K-22-61	Hornblende-pyroxene syenite,	Rollet	_____
C-36-60	Hornblende syenite,	Simard lake	_____
C-92-62	Plagioclase-hornblende gneiss,	Gaboury lake	_____
C-110-60	Porphyritic hornblende granite,	Roger lake	_____
S-33-62	Grey granite gneiss,	Rollet	_____
D-18-60	Biotite granite,	Brodeur lake	_____
C-180-60	Oligoclase-microcline granite	Roger lake	_____

C-176-60	Oligoclase-microcline granite,	Roger lake	_____
C-182-60	Pegmatite, graphic intergrowth,	Roger lake	_____
C-105-62	Cobalt conglomerate,	Northwest corner	_____
C-64-62	Arkose, Lorrain formation ,	Témiscamingue lake	_____
C-165-60	Diabase, medium-grained,	Roger lake	_____
C-63-62	Paleozoic, arenaceous limestone,	Témiscamingue lake	_____