

TH 0027

GEOLOGY OF DUCHARME-MIGNAULT MAP-AREA, ROBERVAL COUNTY, QUEBEC

Documents complémentaires

Additional Files



Licence



License

Cette première page a été ajoutée
au document et ne fait pas partie du
rapport tel que soumis par les auteurs.

Énergie et Ressources
naturelles

Québec 

ANDRE F. LAURIN
(DOCT. ES. GEOL.)

GEOLOGY
OF

DUCHARME - MIGNAULT
MAP - AREA
ROBERVAL COUNTY
QUEBEC

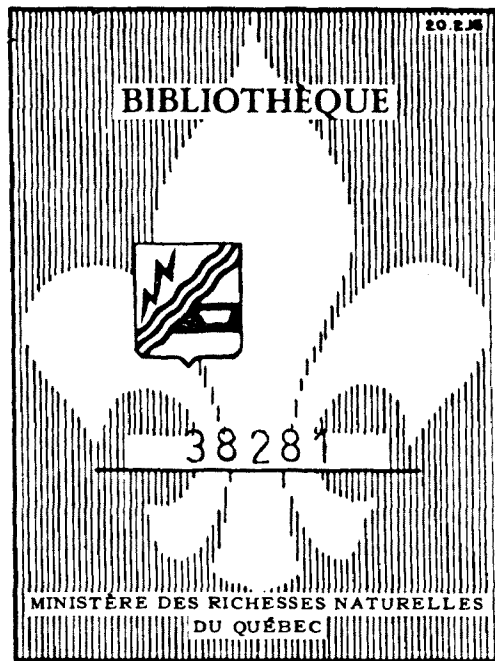
1957

1
0
4

Thèse
QE
193
L385g

B
DE
193

L355g



TH 0027

FACULTE DES SCIENCES

THESE

PRESENTEE

A L'ECOLE DES GRADUES
DE L'UNIVERSITE LAVAL

POUR OBTENIR

LE GRADE DE DOCTEUR ES SCIENCES

PAR

ANDRE F. LAURIN

BACHELIER ES SCIENCES
DE L'UNIVERSITE DE MONTREAL

ET

MAITRE ES SCIENCES
DE L'UNIVERSITE McGill - 2 -

GEOLOGY OF DUCHARME-MIGNAULT MAP-AREA

ROBERVAL COUNTY

Q U E B E C

MAI 1957

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION -----	1
Location and access -----	1
Travel within the areas -----	3
Previous work and history of development -----	5
Present work -----	7
Acknowledgements -----	9
DESCRIPTION OF THE AREA -----	10
Topography -----	10
Drainage -----	12
Natural resources -----	12
Flora -----	12
Fauna -----	13
Effects of pleistocene glaciation -----	14
Climate, soil, and possibilities of farming -----	15
GENERAL GEOLOGY -----	16
Regional geology -----	18
Table of formations -----	19
GNEISSES -----	24
Paragneisses -----	24
Hornblende paragneiss -----	25
Petrography -----	25
Amphibolite variety -----	29
Hornblende paragneiss inclusion -----	30
Mineral assemblage and metamorphic facies ---	32
Origin of the hornblende gneisses and amphibolites -----	35
Biotite paragneiss -----	42
Petrography -----	44
Mineral assemblage and metamorphic facies ---	47
Origin -----	50
METAGABBRO -----	52
Petrography -----	52
Mineral assemblage and metamorphic facies -----	56
Origin of the metagabbro -----	60
BIOTITE INJECTION GNEISS -----	61
ORTHOGNEISSES -----	64
Mineral assemblage -----	66
Origin -----	69
PEGMATITE -----	73
BASIC DYKES -----	77

GLACIAL GEOLOGY -----	79
STRUCTURAL GEOLOGY -----	82
Shear zones and faults -----	83
Relationship between folding of the Keewatin-type rocks and the structure of the Grenville-type gneisses -----	84
AGE RELATIONSHIPS AND CORRELATION -----	86
History and nomenclature -----	87
Correlation with nearby Areas -----	88
Correlation of the granitic gneisses -----	93
ECONOMIC GEOLOGY -----	99
APPENDIX -----	101
The "Grenville front" -----	101
BIBLIOGRAPHY -----	110

MAPS AND ILLUSTRATIONSMAPS

		<u>Page</u>
Map 1	- Location of areas -----	2
Map 2	- Location of areas in relation to height- of-land and shore of former lake Barlow- Ojibway -----	81
Map A	- Geological map (1 mile:1") Ducharme-Mignault ----- (in pocket)	
Map B	- Geological map (1 mile:1") Lorne-Avaugour ----- (in pocket)	
Map C	- Compilation map (12 miles:1") Abitibi-Mistassini Area ----- (in pocket)	

TABLES

Table I	- Table of formations -----	19
Table II	- Hornblende paragneiss (Volume) -----	27
Table III	- Hornblende garnetiferous paragneiss (Chemical analyses, norms, and modes)-----	33
Table IV	- Rosiwal analyses of hornblende garnet- iferous paragneiss (Volume) -----	35
Table V	- Biotite garnetiferous paragneiss (Chemical analyses, norms, and modes) -----	48
Table VI	- Rosiwal analyses of biotite garnetiferous paragneiss (Volume) -----	50
Table VII	- Metagabbro (Chemical analyses, norms, and modes) -----	57
Table VIII	- Rosiwal analyses of metagabbro (Volume) -----	59
Table IX	- Biotite-hornblende orthogneiss (Chemical analyses, norms, and modes) -----	67
Table X	- Rosiwal analyses of biotite-hornblende orthogneiss (Volume) -----	69

PLATES

	<u>Page</u>
Plate I - A. Hornblende garnetiferous paragneiss. White area is mainly plagioclase with minor quartz. Natural light, X11.5.	
B. Hornblende garnetiferous paragneiss showing relic of coronitic structure. Note magnetite and pyroxene in the center of amphibole patches in the center of the photograph. Natural light, X11.5. -----	43
Plate II - A. Biotite garnetiferous paragneiss showing parallel alignment of biotite crystals. White is mainly plagioclase and minor quartz. Natural light, X36.	
B. Biotite garnetiferous paragneiss. Natural light, X36. -----	51
Plate III - A. Metagabbro showing coronitic structure made of magnetite surrounded by amphibole and garnet. Note the olivine in upper part of the photograph and the clouded feldspars. Natural light, X36.	
B. Same as above (crossed nicols), X36. -----	62
Plate IV - A. Biotite-plagioclase orthogneiss. Natural light, X36.	
B. Biotite-plagioclase orthogneiss. Crossed nicols, X36. -----	74
Plate V - A. Glacial deposit on the east side of the Consolidated Paper Company road to base camp on lake Nicabau.	
B. Typical esker, western part of Boute-roue lake. -----	107
Plate VI - A. Lenses of hornblende paragneiss in biotite orthogneiss, Chaudière river.	
B. Typical peneplane topography of the area, looking eastward from a small hill on the west side of Tonnerre river.--	108
Plate VII - A. Typical garnetiferous biotite paragneiss, on a small lake 1.5 miles N.W. of Aigremont lake. -----	109

FIGURES

	<u>Page</u>
Figure 1 - Ratio of normative Ab, An, and Or. Abitibi analyses. -----	75
Figure 2 - Ratio of normative Ab, An, and Or. Grenville analyses. -----	76
Figure 3 - Diagram of analyses of Abitibi intrusive rocks. -----	95
Figure 4 - Analyses of rocks from Abitibi region: Ratio of albite, potassic feldspar, and quartz of norm. -----	96
Figure 5 - Ratio of normative feldspars in "para- gneisses". -----	97

Histogram of the rocks of the area. -----	78

GEOLOGY OF DUCHARME-MIGNAULT AREAAbstract

This thesis is based on fieldwork done in the seasons of 1954, 1955, and 1956 on three 15-minute map-areas along Chibougamau road at localities about 80 miles from St. Felicien. All the bedrock is Precambrian and the region is considered to belong to the Grenville sub-province because typical meta-volcanic of the Keewatin-type and associated meta-sediments are not present but instead hornblende-plagioclase gneisses, which in part are derived from volcanic rocks, and biotite-plagioclase gneisses occur. The chemical characteristics of the paragneisses were confirmed by chemical analyses in addition to numerous Rosiwal analyses. Some hornblende-plagioclase gneisses were once gabbros and it is believed that they are metamorphic equivalents of gabbros occurring in the Keewatin-Timiskaming region.

The structure of the areas is unlike that of the Keewatin-Timiskaming sub-province in which the formations strike east and are relatively continuous. In the areas described here the paragneisses form lenses or sigmoid outcrops and, although the strikes are irregular, they trend to be mostly northeast. Because the rocks of the Keewatin-Timiskaming sub-province can be traced into the gneisses on the southeast it is inferred that the structure of the Keewatin-Timiskaming rocks is older than the northeast structure.

Intrusives rocks are characteristic of the areas described in the thesis. Rosiwal analyses show a high ratio of albite to potassic feldspar. This is a characteristic of the intrusive rocks particularly stocks of the Keewatin-Timiskaming sub-province, and the analyses fall in the field of the Keewatin-Timiskaming rocks. Furthermore they fall on the Chibougamau curves. This may be taken as evidence that the igneous rocks of the areas described here are similar to the Keewatin-Timiskaming region.

The evidence of the areas shows that some revision of the view of the Keewatin-Timiskaming and Grenville sub-provinces is necessary. Rocks of Grenville aspect are metamorphic equivalent of some in the Keewatin-Timiskaming region. Furthermore orthogneisses have some Keewatin-Timiskaming characteristics. The biotite-plagioclase gneisses and hornblende-plagioclase gneisses are common throughout much of the Grenville region in Quebec. However, quartzites, crystalline limestones, and sillimanite garnetiferous gneisses are considered characteristic of the Grenville. Such rocks do not extend to within 100 miles of the Keewatin-Timiskaming sub-province. It is therefore reasonable to suggest that the Grenville sub-province should be separated into at least two units.

INTRODUCTION

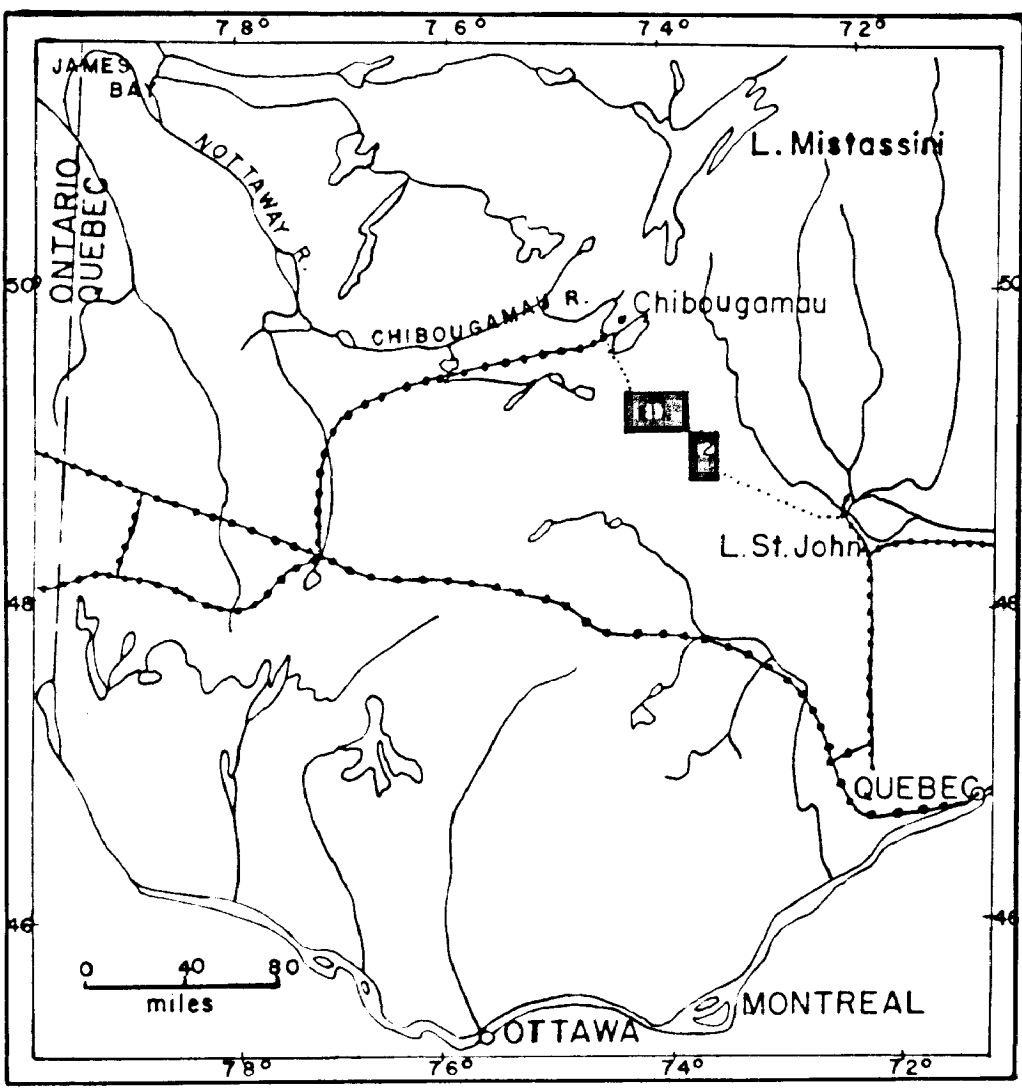
The Ducharme-Mignault and the Lorne-Avaugour areas were studied geologically as part of a program of systematic mapping, started by the Quebec Department of Mines after completion of the St-Felicien-Chibougamau highway. The present areas are outside the Chibougamau mining district and, their study was undertaken to determine some of the characteristics of the metamorphism in the Grenville-type rocks. The relationship between the Timiskaming and the Grenville sub-provinces of the Canadian Shield is one of the problems of Precambrian geology, and it was hoped that further work near the boundary of these two sub-provinces would give data on the relative ages of the different rock types.

The work was done in the summers of 1954, 1955, and 1956, under the direction of the Quebec Department of Mines.

Location and Access

The Ducharme-Mignault and the Lorne-Avaugour areas are in Roberval county, Quebec (Fig. 1), and are bounded by latitudes $49^{\circ}15'$ and $49^{\circ}30'$ North and by longitudes $73^{\circ}45'$ and $74^{\circ}15'$ West, and by latitudes $49^{\circ}00'$ and $49^{\circ}15'$ North and by longitudes $73^{\circ}30'$ and $73^{\circ}45'$ West, and comprise about 575 square miles. The centre of the areas is about 95 miles northwest of Lake St. John and 40 miles southeast of Chibougamau lake. The map-areas include the townships of Ducharme and Mignault, large parts of Lorne, Bouteroue, Aigremont, Denault and Avaugour, and smaller parts of D'Esclis, Bochart, Argenson and Cazeneuve townships.

Map. I - Location of Areas



1- Ducharme-Mignault, 1954-55.

2- Lorne - Avaugour, 1956.

The adjoining area to the west was mapped by Gilbert (1952) in the summer of 1951, and part of the area to the north was mapped in 1953 (Neale, 1954).

The St. Felicien-Chibougamau all-weather highway crosses the eastern limit at mile 66 and the northern boundary at mile 112, both distances being from St. Felicien. This highway gives access to these areas, by truck, car, or autobus from all points in the Lake St. John region.

Travel within the Areas

Travel through the western part of Ducharme-Mignault area is facilitated by Boisvert river, which discharges into Normandin river by a string of lakes. From Nicabau lake (1), one can reach any western part of this area by canoe, with but few short portages. In the southwest corner of this map-area, Bouteroue lake gives access to the whole southwestern and western parts of the area through Nemenjish river and two small portages on the river. Scatsi river, also called Askitichi river (Barlow, Gwillim and Faribault, 1911), forms part of a canoe-route to the headwater of St. Maurice river. In the northwest corner of the area, Boisvert river and a string of lakes are easily passable by canoe. In the northeast corner of Nicabau lake, Coquille river (1) flows through Liasse lake and a few

(1) According to Barlow, Gwillim and Faribault, 1911, the name Nicabau is pronounced Ni-ko-pau, and means "Willow Point lake", and the Coquille river, was originally named Witouche river.

small enlargements of the river. Not far from the outlet of Nicabau lake on the Normandin river, Tonnerre river and a string of small lakes lead in the northern middle part of the area. Going eastward, there is Chaudiere river, which is part of a canoe-route from its outlet on Normandin river near the big bend in the river, up to the very northern part of the map-area. At the very eastern edge of this map-area, there is La Loche river which gives access to the whole surrounding area through some small lakes. This river is shallow and provides a good access only during high water, the same is applicable to Chaudiere river.

Travel through the main parts of Lorne-Avaugour area is made easy by the many lumber roads. Audet's road at mile 70 and Martel-Séguin's road at mile 72.5 give access to the north-east corner of the map-area, and Gagnon's road at mile 74.5 gives access to most the southern part of the area. A string of long lakes (Argenson, Chamouchouane, and D'Esclis) also facilitates access to some parts that cannot be reached by lumber roads. These lakes are part of an old canoe-route that was followed by Barlow, Gwillim, and Faribault, in 1911, on their way to Chibougamau. Argenson or Chigoubiche (which should be spelled "Ochikopiche") meaning "Little Sawbill water having a narrows" is divided into two parts, separated by a long narrows. The lower and larger portion has a general north-west direction, whereas the upper part (D'Esclis lake) trends nearly north and south. The lower part is that passed through on the canoe-route, the distance to be travelled being about 12 miles. In this distance the lake varies from a mile to

nearly two miles in width, and this large stretch of open water is only broken by three comparatively small islands. The portage out of d'Argenson lake (Chigoubiche) starts from a small bay forming the elbow made by the change in the direction between the lower and upper parts of the lake, and is about one and a quarter miles long. It reaches a bend in a small sluggish stream known locally as "Rivière Croche" which flows in a very tortuous course through a wide swamp into a small and a crooked lake of the same name.

Rivière Croche flows into Chamouchouane lake at its very southeast corner. Chamouchouane lake, which is about 9 miles, trends in a general northwest-southeast direction and is from half a mile to a mile wide. Chamouchouane lake gives access to most of the southwest corner of the map-area through Nicole's creek and Nicole's lake and a string of portages and small lakes south of this lake.

Lakes that afford good landing places for aircraft are numerous and well located to provide access to all parts of these areas. Short flights can be made from bases on Caché lake (Boreal Airways, and Fecteau Air Service), and from St. Félicien.

Previous Work and History of Development

Argenson (Chigoubiche) lake, Chamouchouane, Ducharme, Nicabau, Jourdain, Branch, and Poisson Blanc (Narrow Ridge lake) lakes formed part of the canoe-route from Lake St. John to Chibougamau and Mistassini lakes (Richardson, 1872).

Richardson surveyed this route in 1870 when travelling north to Lake Mistassini. He noted the presence of red and grey gneiss, both fine- and coarse-grained, with black hornblende-rock, and layers of black mica-schists. In 1884, the Bignell-Low Mistassini expedition passed through the region. In 1892 and 1905, A.P. Low explored the vicinity of Chibougamau lake. All these expeditions followed the waterways and no areal mapping was attempted. The development of the Chibougamau district started in 1903 when discoveries of copper and asbestos were made on the shores of Chibougamau lake. Subsequent discovery of gold and iron minerals led more prospectors into the district. In 1909, people interested in the development of this region asked the Quebec government to construct a railroad to the Chibougamau area. In response to this request, the Quebec government formed the Chibougamau Mining Commission. This commission had to appraise the discoveries already made and determine whether future mining possibilities warranted the construction of the railroad. The report of the Mining Commission (Barlow, Gwillim and Faribault, 1911) did not favor the immediate construction of the railroad, however they concentrated their work on the known mineral occurrences and did little geological mapping.

H.C. Cooke in 1919, while studying the Nemenjish series, crossed the present area, but he did not describe them. The results of his investigation are included on the Chibougamau Sheet, East-Half (Mawdsley and Norman, 1938) of the Geological Survey of Canada. This map, published on a scale of four miles

to the inch, has marginal notes, but no final report has yet been issued.

In 1949, the Quebec Department of Mines completed the all-weather St. Felicien-Chibougamau highway. With easier access to the area, exploration, prospecting, and geological mapping were carried out at a much accelerated pace. Prior and during the writer's investigation, prospecting was active especially in the vicinities of Aigremont lake. Geophysical survey was also made near the same lake.

Present Work

Field work was carried on by the writer in the summers of 1954, 1955, and 1956. During each field season, a fifteen-minute sheet was covered. Preliminary reports (Laurin, 1955; Laurin, 1956) covering the Ducharme-Mignault area have been published by the Quebec Department of Mines. The report covering the Lorne-Avaugour area will be available in 1957.

More than 300 days were spent in the field. Whenever weather conditions were favorable, two and occasionally three traversing parties were used for the mapping. The area was covered by pace and compass traverses and the shorelines were examined. The traverses were 2000 feet to 2200 feet apart, and whenever possible were run across the trends of the formations. This was found more profitable than trying to walk out the contacts which are transitional and are covered with glacial drift in most places. Much information was derived from work along the shorelines where bedrock is better exposed than in the areas between the lakes.

The traverses and shoreline geology were plotted on a base map with a scale of half a mile to the inch. The base map was compiled in the offices of the Quebec Department of Mines from preliminary surveyed maps and a set of vertical aerial photographs taken by the Royal Canadian Air Force. The position of mile posts along the surveyed lines and of bench marks on the shorelines gives good control in plotting the outcrops on the base maps.

Laboratory work included a petrographic study of about 250 thin sections. The geology was plotted on a half a mile to the inch base map, and the map was then sent to the Quebec office for reduction of scale. The final map is on a scale of one mile to the inch.

Seven samples from mineralized zones were analysed in the laboratories of the Quebec Department of Mines to determine the presence and amounts of gold, silver, copper, lead, zinc, or nickel.

Eight samples were submitted for geochemical analyses. Part of these samples was subjected to the usual gravimetric and magnetic separations combined with X-ray determinations to obtain a better knowledge of their composition. Calculations, based on the chemical composition and their Rosiwal analysis, were also made to ascertain the proportions of the various constituent minerals.

Acknowledgements

The writer acknowledges his indebtedness to Dr. F.F. Osborne for his supervision of this thesis. The other professors of the Department of Geology, Université Laval, have also been very helpful.

This thesis was made possible through a bursary of the Quebec Department of Mines. The writer wishes to express his gratitude to the Quebec Department of Mines for permission to use in the preparation of this thesis the material collected during the three seasons spent in the field.

The writer also wishes to express his thanks to the managements of the Consolidated Paper Company (Nikauba division), and to the Laurentian Forestry Protective Association for the many courtesies shown to the party during the field seasons.

The willing aid and perseverance of field assistants Jean Bérard, Peter Clarke, William Halletsey, Gill Cyr, John Auston, Stanislas Michalski, Jean Lajoie, and George Pajari greatly expedited the work.

DESCRIPTION OF THE AREA

Topography

The areas under study are a short distance east of the height-of-land separating the St. Lawrence and James Bay drainage basins. The height-of-land is only six miles west of Poisson Blanc lake, near the northwestern border of Ducharme-Mignault map-area. The areas slope very gently to the southeast, that is towards Lake St. John. The general elevation near the western border is about 1200 feet above sea-level and is slightly over 1100 feet near the eastern border.

The elevations of the lakes show the general south-eastward slope of the region: (1).

Height-of-land east of Chibougamau lake....	1500 feet
Poisson Blanc lake	1286 feet
Branch lake	1266 feet
Nicabau lake	1258 feet
Chamouchouane lake	1160 feet
Argenson (Chigoubiche) lake	1130 feet

The difference in elevation between the westernmost lake and the easternmost one is 156 feet, and the distance between these two lakes is about 30 miles. The Normandin-Chamouchouane river, which connects all these lakes, thus has a general gradient of about 5 feet a mile.

(1) Elevations of lakes are taken from Chibougamau-Roberval Sheet, National Topographic Series - 32SE, 1951.

The topography is typical of this part of the Canadian Shield. The local relief is not marked, and the land surface, in general, is remarkably flat. Closer examination, either in the field or from aerial photos, shows that in most places this flat surface is slightly irregular with many low hills. Most hills have gentle slopes, and few summits are more than 100 feet above the general level of the lakes. Part of the low ground in the map-area not covered by bodies of water has swamps and muskeg. There are, however, a few hills that are exceptions: Patrick mountain (Faribault, Gwillim, and Barlow, 1911), immediately west of Poisson Blanc lake, has an altitude of about 1650 feet and is 400 feet above that of the nearby lake. Some other moderate size hills occur north and east of Argenson lake, where the country rises into rough and rocky ground to a height of 350 feet above the lake. "Chigoubiche mountain" is about 400 feet above the lake and seems to be a spur or extension of the Partridge range of mountains farther south. Two other fairly high hills were used for the erection of observation towers, one, fire tower No. 73 of the Laurentian Forestry Protective Association, is near the southeast corner of Nicabau lake and has an altitude of about 1550 feet, and the second one, fire tower No. 714 of the Quebec Department of Lands and Forests Protective Association, is north of Argenson lake and has an altitude about that of No. 73.

Most of the local relief bears little or no relation to structure or composition of the underlying bedrock.

Drainage

The main lakes listed previously are all connected by the Chamouchouane river. The western part (Ducharme-Mignault) is drained by Normandin river, a tributary of Chamouchouane river. From Chamouchouane lake, Chamouchouane river flows south-eastward into St. Lawrence river through Lake St. John and Saguenay river.

The lakes and rivers constitute a complex drainage system that cannot be classified as one of the standard drainage patterns. Some of the larger lakes, like Bouteroue and Aigremont, are characterized by very intricate shorelines. There is apparently no structural nor lithologic control over the sizes and shapes of these lakes.

After deglaciation, Normandin river has deepened its channel across unconsolidated glacial material. The channel is twenty to thirty feet deep in most places, but where the river cuts through coarser glacial material, or has encountered bedrock, the channel is shallow with many rapids.

The lakes and streams of the area are shallow, and their shapes and courses are controlled by unconsolidated glacial deposits that cover much of the bedrock of the area.

Natural Resources

Flora

Most of the areas are wooded, except for a few muskegs west of Nicabau lake, near Brassard lake, and on both

sides of Croche river, and two patches of burned ground east of Tonnerre river and Aigremont lake.

Black spruce, rarely more than 12 inches through the butt, is by far the most abundant forest tree. White spruce, red spruce, jackpine, and balsam are common. Jackpine is also common in areas of considerable glacial drift. Birch, tamarack, and aspen are scarce, but they are found on any hilltop of the area and also on a few promontories in the lakes. Cedar was seen on the shores of some swampy lakes.

Fauna

All of these areas are within the limits of the Chibougamau hunting and fishing reserve. The Quebec Department of Game and Fisheries has camps in the reserve, one is on the north side of Argenson (Chigoubiche) lake, another is on the south side of Aigremont lake. At both places there is accommodation for tourists.

Wild life is abundant throughout the area. Moose and bear are very numerous. Muskrats are the most abundant fur-bearing animal, although otter, fox, and hare were seen, and signs of the presence of beaver and wolves were noted. Ruffed grouse are abundant. Common ducks are rather scarce, although the brown mergansers are numerous.

Pike, weighing as much as 25 pounds, can be caught in most of the lakes of the area. Pickerel up to five pounds are caught in many of the streams, especially near rapids. "Witouche", a fish of the carp family, more or less edible, occurs in a few streams. Species of the trout family were seen

only in the small lakes west and north of Pie XII lake.

Effects of Pleistocene Glaciation

Striations, chatter-marks, friction cracks, and stoss and lee topography show that the direction of flow of the glacier ice was from S10⁰W to due south. Boulders of cryptozoon-bearing limestones of the Mistassini series are found in the till deposits of the area and are an indication of the southward movement of the Pleistocene ice-sheet.

A few eskers occur in the area. All of them have a rather sinuous course from south to southeastward, and in places even southwestward. Two of these eskers are about 10 miles long. Short stretches of private roads have been located on others; one on the east side of the Tonnerre river has been used by the Consolidated Paper Company at mile 102, and another on the south side of Croche lake has been used by the Gagnon Lumber Company at mile 74.5.

Numerous gravel pits have been and are still used for road construction material, the most extensive of these being at mile 76.25 and at mile 102.25 along the Chibougamau highway. Sand and varved clay are seen on the shores of Croche and Chamouchouane lakes, and on the banks of Normandin river. Good examples of cross-bedding are to be seen in the unconsolidated sandy beds on the side of Croche lake, and on the banks of Normandin river.

Climate, Soil, and Possibilities of Farming

No severe night frost occurred in the area during the months of June, July, and August, of 1954, 1955, and 1956, and the minimum temperature recorded during that time was 38°F. Daytime maxima of 80°F. were frequently recorded. The precipitation was more abundant than usual during the summers of 1954 and 1956, and in the morning relative humidity commonly was in the eighties.

A blanket of variable thickness of clayey soil covers most of the low parts of the area. This soil usually supports a thick vegetation and would probably be suitable for selective farming.

GENERAL GEOLOGY

The areas mapped by the writer are indicated on Fig. 1. Exposures of bedrock are relatively scarce throughout the regions, except west and northeast of Argenson lake, west of the Chibougamau highway near mile post 80, and at a few places in the Ducharme-Mignault map-area.

All the consolidated rocks of the area are Precambrian, and their textures and structures suggest that they belong in the Grenville sub-province, but they are called here the Grenville-type. The term Grenville was originally applied by Sir Wm. Logan near the town of Grenville in Argenteuil county, Quebec, on the Ottawa river, to some Precambrian meta-sedimentary rocks. The general field usage now in eastern Ontario is to refer to paragneisses, amphibolites, quartzites, and schists of higher metamorphic grade to the Grenville series, or to call them metasedimentary rocks of the "Grenville-type".

The consolidated rocks of the areas are divided into two major groups: a) metamorphosed volcanic and sedimentary rocks, b) intrusive rocks, including both mixed gneisses, and orthogneisses.

Hornblende garnetiferous gneisses are found mainly close to the contact zone between the two different sub-provinces, but eastward from the contact small remnants of these rocks, or small lenticular inclusions occur in orthogneisses. They are the representative of metamorphosed volcanics, or metamorphosed gabbros.

Garnetiferous biotite gneisses are found not only close to, but also farther away from the contact. They usually crop out as narrow bands or small lenses, but occurrences of larger bodies have been found on the west side of Argenson lake. These gneisses have characteristics suggesting an ultimate sedimentary origin.

A coarse-grained, rusty-weathering gabbro was seen at many places throughout the region, though it is most common close to the contact zone between the two sub-provinces; farther from the contact it forms small isolated patches and in the area mapped in 1956 only three small outcrops were found. The distribution of this rock through the area suggests that it is an older intrusive rock.

Orthogneisses characterized by biotite or hornblende or both underly much of the areas. They intrude the paragneisses and are considered the youngest rocks in the area. The gneissic granite, as it is commonly named, has an irregular gneissic structure with a northeast strike. In many places, the orthogneisses are cut by numerous irregular bodies, mainly dykes, of pegmatite with large flakes of biotite.

A few, generally small basic dykes, probably late-Precambrian, are present in the area.

Very little prospecting was done in the areas prior to the summer of 1954 when some copper minerals were found in a small shear zone in the hornblende paragneisses on the south side of Aigremont lake.

The crystalline gneisses and granite of the areas are within six miles of the northwestern boundary of the Grenville sub-province. No part of these areas mentioned in this dissertation crosses the boundary between the two sub-provinces, but because the author has worked with Neale in the area immediately north of Ducharme-Bouteroue, he has seen lithologic and structural evidence that the metamorphic hornblende and biotite gneisses are the respective metamorphosed equivalents of the Keewatin-type lavas and sedimentary rocks into which they pass gradationally. Faulting is only a minor structural feature.

Except for scattered outcrops, all the Precambrian rocks are covered by unconsolidated glacial material of Pleistocene age.

A tentative sequence of the formations of the area is presented in Table 1.

Regional Geology

An understanding of the geology of these areas requires some knowledge of the geology of the whole surrounding district.

Gill's (1948) nomenclature of the different sub-provinces of the Canadian Shield is used. The area under study lies in the westernmost portion of the Grenville province. M.E. Wilson (1913) introduced the concept of sub-provinces in Canada (1) and applied the geosynclinal theory to rocks of the

(1) The name sub-province was used for the first time by Van Hise and Leith in Monograph 52 of the United States Geological Survey when they divided the Lake Superior Region into north and south sub-provinces.

TABLE ITable of Formations

CENOZOIC	Peat, sand, gravel, glacial till
Unconformity	
PRECAMBRIAN	Diabase: dykes
	Orthogneisses: Biotite gneiss, biotite-hornblende gneiss, hornblende gneiss, pegmatite
	Biotite injection gneiss
	Metagabbro
	Paragneisses: Garnetiferous biotite gneiss, biotite gneiss. Garnetiferous hornblende gneiss, hornblende gneiss

Canadian Shield: he interpreted the central belt of Laurentian banded gneisses, which extends from the north shore of Lake Huron to Lake Mistassini, as the core of a Precambrian mountain chain which stood as a geanticlinal belt between geosynclines formed by the Abitibi group and the Grenville series.

The division by the writer into sub-provinces was done to help in the correlations of similar rocks found over such wide areas that outcrop correlation was impossible. Local names are used for each sub-province. However, the size of the

sub-province makes correlation an impossible task in many instances. This led to a terminology which expressed lithologic similarity without equivalence in time. The terms used: Keewatin-type, Timiskaming-type, and Grenville-type, have a time-stratigraphic significance in the type localities but have been used in a general way by most geologists as purely lithological terms carrying no time connotation. This is the usage followed in this thesis. The terms Keewatin-type or Timiskaming-type could be applied to such rocks found in any geological province in Canada, or elsewhere for that matter, without signifying anything about equivalence in time.

The nature of the boundary between the Grenville and the Superior provinces has not yet been settled. A conclusion adopted by many is that the boundary is a fault zone. The names "Huron-Mistassini fault zone" (J.T. Wilson, 1949) or "Huron-Mistassini thrust" (J.T. Wilson, 1949a) or "Grenville front" (Derry et al., 1950) have been used.

Norman (1936) believed that the boundary between the Grenville and Timiskaming provinces is a structural feature resulting from "mountain building" of the Grenville orthogneisses and paragneisses in late-Precambrian time. Folding of the Archean rocks of the Timiskaming sub-province along east-trending axes antedated, and was truncated by, this boundary.

Cooke (1947) in discussing this structural feature between the two sub-provinces showed a big fault extending from Lake Huron to Labrador, on the assumption of Quirke's work northeast of Georgian Bay, and Norman's work in the Mistassini lake area. One must not forget that these two faults linked

together by Cooke are 350 miles apart. Since then, many areas have been mapped on the supposed contact between the two sub-provinces between the two points previously mentioned, and at many places no trace of faulting has been recorded.

Gill and Wilson have expanded on Norman's suggestion: they divided the Canadian Shield into provinces characterized by distinct structural trends. They refer to the Grenville sub-province as the "Grenville Province". The limits of the Timiskaming sub-province have been expanded, and it too is considered a province.

Gill (1948) considers that the Grenville province marks the site of a late-Precambrian mountain belt, which had a trend parallel to that of the Appalachian mountains farther southeast. His reasons include:

- a) truncation of the eastern-trending structures of the Superior province by the northeast-trending structures of the Grenville sub-province.
- b) radioactive dating of the Grenville rocks.

He subscribes to Norman's hypothesis that the rocks of the Grenville sub-province have been raised relative to those of the Superior Province by thrusting.

Regarding the Grenville front, Johnston (1954) says:

"the two sub-provinces are in fault contact along a zone of northeast-striking, east-dipping faults, with displacement of the Grenville, or southeast side, upward. The amount of displacement at these faults ranks them with the major tectonic features of the earth's crust."

McLaughlin (1954) regarding the Grenville front proposed the extension of this front from Lake Huron to the Mississippi embayment. This suggestion is based upon earthquake epicenters lying on a line which he mentions to be in strike with the Grenville front in the Canadian Shield.

Recently, Garland (personal communication from F.F. Osborne) suggested that the so-called Grenville front in Quebec is the northwest edge of a zone of injection which corresponds to a gravity low.

Since Lowther mapped the Villebon-Denain area, in 1936, geologists from the Quebec Department of Mines have consistently supported another hypothesis which has been supported by mapping that has been done during the last seven years along that contact between the two sub-provinces in the Mistassini-Chibougamau-Surprise Lake regions.

In the Mistassini Lake region, Gilbert (1952) reported:

"the mapping done along the northeastern and eastern edges of the Mistassini Lake sedimentary basin confirms the existence along the eastern and southeastern margins of the Mistassini Lake sedimentary basin and farther northeastward of a high angle reverse fault trending between $N15^{\circ}E$ and $N45^{\circ}E$ and dipping 45° to 55° towards the southeast. The magnitude of the movement along the fault plane is difficult to evaluate but its vertical component does not seem to be as considerable as had been suggested before."

In the Bignell area, Gilbert (1952a) found the same characteristics, except in the southern part where he states:

"the granite gneiss of the hanging wall of the fault also pinches out and the zone of generally garnetiferous paragneiss, which to the north lies at a variable distance east of the break, becomes in immediate contact with the Keewatin-type greenstones considered as belonging to the Timiskaming sub-province. From there southwestward and westward, to at least as far as beyond Surprise lake, the contact between the greenstones and the gneisses is of a gradational or intrusive type with no indication of a major dislocation zone in the immediate vicinity of that contact."

Deland (1955) in the Surprise lake area lists 12 pieces of evidence that indicate that in this area the boundary between the two sub-provinces is not a sharply defined line and he concludes by saying:

"that it is rather a zone of transition through which mappable rock units pass from a lower to a higher grade of metamorphism."

The present author concurs in this conclusion as a result of his observations in the area mapped by Neale (1953) and in the areas described here. Schistose basaltic and andesitic Keewatin-type volcanics on the west side of the zone become more recrystallized towards the southeast and the schistosity is replaced by a gneissic structure with a lineation, faint at first, but becoming more and more marked southeastward. Furthermore orthogneisses have some Keewatin-Timiskaming characteristics. The biotite-plagioclase gneisses and hornblende-plagioclase gneisses are common throughout much of the Grenville region in Quebec. However, quartzites, crystalline limestones, and sillimanite garnetiferous gneisses are considered characteristic of the Grenville. Such rocks do not extend to within 100 miles of the Keewatin-Timiskaming sub-province. It is therefore reasonable to suggest that the Grenville sub-province should be separated into at least two units: a) true Grenville and, b) Ottawa gneiss zone (transition zone).

GNEISSES

The predominant rocks of the area are fine- to medium-grained gneisses. Only about five per cent of the area is underlain by metagabbro and diabase. The gneisses are of two principal categories: orthogneisses having the composition of plutonic rocks but with a distinct gneissic structure that has been impressed on them during or after their consolidation; paragneisses that are also gneissic but have been derived from pre-existing sedimentary and volcanic rocks, most of them in this area being rich in biotite or hornblende or both, with some varieties having garnet. This usage is not strictly according to the original definition because volcanic rocks, being of igneous origin, should form orthogneisses, but in practice a usage such as given here is necessary. Mixed gneisses or less properly composite gneisses are the result of the injection of igneous material into and reaction with paragneisses. Layered gneisses and injection gneisses are common gneisses of this category.

Paragneisses

About 35 per cent of the area is underlain by gneisses having compositions and structures of metamorphosed volcanic, sedimentary, or basic intrusive rocks. These paragneisses are divided into two groups, one characterized by hornblende and the other by biotite.

Hornblende Paragneiss

Gneissic garnetiferous, hornblende-feldspar rock underlies about 20 per cent of the area mapped. In the Ducharme-Mignault area, the hornblende paragneisses crop out in the western part as an east-west band which crosses Nicabau lake, and as a northwest trending band west of the same lake. In the eastern part of the area, the hornblende gneisses crop out as a number of irregular bands and zones, the most extensive of which are south of Aigremont lake, in the southwest quarter of Mignault township, and northwest of Mignault lake. Exposures of this rock are also found in the southwest corner of the area and near the middle reaches of Normandin river. Another large lens of similar rock occurs north of Jourdain lake.

In the Lorne-Avaugour area, hornblende paragneisses crop out mainly in the northwest corner where, on the east side of the Chibougamau highway, a single band can be traced for five miles. Elsewhere in the area, they crop out as lenses, most of which can be considered as inclusions in the surrounding rocks.

Petrography

The rocks included in this group show a wide range of compositions and a diversity of textures. Some consist almost entirely of amphibole, others of amphibole and plagioclase, and still others of amphibole, plagioclase and quartz. Varieties are fine-, medium-, or coarse-grained; massive, schistose, or gneissic; equigranular or porphyroblastic. Some have suggestions of primary stratiform structures, although,

the origin of most of the rocks cannot be ascertained definitely.

Most specimens of the hornblende gneisses are slightly to markedly layered with schistosity somewhat variably developed. Gneissic structure is visible to the naked eye, and is caused by diversity of tenor of dark green hornblende, white feldspars, and red garnets in different layers. In most varieties, hornblende needles make up about 55 per cent of the rock. Light colored plagioclase feldspar is commonly concentrated in parallel stringers and lenses. Some varieties have 10 to 20 per cent of red garnets. A few specimens from the inclusions in the granite show no definite fabric orientation and the anhedral (1) grains form a granulitic texture. In the northwest corner of the Ducharme-Mignault map-area, the foliation is insignificantly developed, and the rocks have the appearance of garnetiferous amphibolites, although most of these rocks have a definite alignment of the hornblende needles. Layering is not conspicuous in these gneisses except where they have injections of igneous materials, but such rocks are more appropriately called composite gneisses rather than hornblende paragneisses.

The mineral grains of the hornblende paragneisses and of the so-called amphibolites in the northwestern corner of Ducharme-Mignault area, have very sharp boundaries and are in smooth contacts with their neighbors. In most sections the

(1) Euhedral, subhedral and anhedral are used in this thesis for both igneous and metamorphic rocks.

grains vary between 0.2 mm. and 2 mm., but in places porphyroblasts of garnet and hornblende are as much as 2 centimeters in diameter. Most of these porphyroblasts show no tendency to be elongated parallel to the schistosity. In places, however, the large crystals of hornblende are aligned parallel to the gneissic structure.

The essential minerals occur in highly variable proportions as shown in the ensuing table which is based on many Rosiwal analyses.

TABLE II

Hornblende Paragneiss (Volume)

	%
hornblende	40-75
plagioclase	10-30
biotite	0- 5
clinopyroxene	0- 5
garnet	0-15
quartz	0-10
minor constituents :	clinochlore, calcite, clinozoisite, pyrite, magnetite, sphene, apatite

Specimens from the southwestern part of the Ducharme-Mignault map-area are fine- to medium-grained, and even, in places, coarse-grained garnetiferous hornblende feldspar rocks, with a slight lineation (1). Hornblende needles, which make up more than half the rock, are aligned, and thin streaks of white

(1) Lineation is used here to describe parallel linear arrangement of the minerals.

feldspars parallel this alignment. The amphibole weathers dark green or dark brownish black, and porphyroblasts of red garnets, as much as $\frac{1}{4}$ of an inch in diameter, stand out on the altered surface. A similar material occurs on the Chibougamau highway at the road-cut near mile post 101. The hornblende, which in most specimens is green and very strongly pleochroic, is colorless in some and is peppered with minute magnetite grains. In a few places it is slightly chloritized. In some cases the hornblende occurs as large anhedral to euhedral porphyroblasts which are crowded with included grains of quartz. The optical properties of this hornblende are:

Pleochroic formula: X=light yellowish green
 Y=deep bluish green
 Z=deep grass green

$Z \wedge C = 18-30$ degrees
 (-) $2V=75-80$ degrees
 absorption: $Z > Y > X$

In thin section, the rock is seen to consist of hornblende (60 per cent) plagioclase An₂₆ to An₃₄ (30 per cent), pink garnet (15 per cent), greenish clinopyroxene (5 per cent), with biotite, sphene, magnetite, and apatite as accessory minerals. The texture of the rock is granoblastic, and the fabric of one thin section suggests a relic ophitic texture. The hornblende is strongly pleochroic from light yellowish green to dark bluish green to dark grassy green. This amphibole has a moderate birefringence and an extinction angle, $Z \wedge C$, of 18 to 30 degrees. Andesine (An₃₀₋₃₄) is in anhedral clear grains in the hornblende groundmass and is optically positive. Albite twinning is seen in a few sections, although, in general, it is

rare. A faint zoning structure is occasionally observed. The composition of the plagioclase varies unsystematically between calcic oligoclase (An₂₆) and sodic andesine (An₃₄).

A greenish clinopyroxene (ferriferous augite) makes up about 10 per cent of the thin section. It shows a 2V of about 65°, is biaxially positive, and occasionally two cleavages may be detected, although usually only one is seen. The pyroxene has an extinction angle, $Z \wedge C$, of 41°.

Clinozoisite occurs mostly in the true hornblende paragneiss, and it was not observed in the hornblende gneisses found as inclusions in the granite.

Quartz is found as clear anhedral grains. According to Gilbert (Ms.) those facies of hornblende paragneisses that have granitic injections and, according to Deland (1955), those apparently of sedimentary origin contain a higher than normal tenor of quartz, as much as 45-50 per cent, but the author has not seen any section containing more than 20 per cent quartz.

Garnet is in anhedral porphyroblasts as much as 6 mm. in diameter. It is characterized by large numbers of inclusions of quartz, plagioclase, hornblende and magnetite. The garnet is a red variety and it has a slight pinkish colour as seen under the microscope. The index of refraction (1.795) and the color indicate that the garnet is an almandite.

Amphibolite variety

A specimen of a variety considered to be amphibolite from the northwest corner of the Ducharme-Bouteroue map-area, is very massive, and is made up principally of fine,

well-orientated, needles of hornblende with thin white layers of feldspar parallel to the schistosity. The rock weathers dark green. Very minute specks of red garnet may be detected on the altered surface as well as on the fresh surface.

The thin section cut across the gneissic structure and normal to the hornblende needles shows a very fine-grained granoblastic texture with a fine gneissic structure. The specimen is made up of granular hornblende (50 per cent), plagioclase (An₄₇) (30 per cent), quartz (10 per cent), garnets (10 per cent), and sphene, clinozoisite, biotite, and magnetite as accessories. The hornblende shows the same strong bluish green pleochroism as in the previously described section, one good cleavage, and an extinction angle, $Z \wedge C$, from 10° to 12° in most sections but in certain fragments as much as 30°. Plagioclase (An₄₇) makes up about 30 per cent of the rock and shows albite and Carlsbad twinnings. In this thin section no trace of clinopyroxene was seen, but this does not exclude the possibility that it was present and changed to amphibole. In places, the hornblende has been more than 50 per cent replaced by rusty-weathering iron carbonate. This process, with pyritization, is probably related to hydrothermal activity.

Hornblende Paragneiss Inclusion

Another specimen collected from the south band, along Normandin river at the head of the long rapid, in Mignault area, was also studied and compared with a specimen taken from the border of the same mass. The specimen is a very massive,

medium- to coarse-grained, garnetiferous ferro-magnesian feldspar rock, with a slight lineation. The rock weathers to a dark black and is filled with granular red garnets, which in places stand out on the altered surface. Pyrite was also seen, disseminated through the rock. The same is true for the specimen from the border zone.

In thin section, the rock is seen to consist of plagioclase An₃₄ (43 per cent), greenish clinopyroxene (25 per cent), pink garnet (10 per cent), with scapolite, sphene, clinozoisite, magnetite, and carbonate as accessory minerals. Hornblende is present in very small amount. The section shows an inequigranular granoblastic texture, and the fabric suggests a relic sub-ophitic texture. Andesine (An₃₄), which is optically positive, shows marked albite twinning in places. A greenish clinopyroxene (ferriferous augite) shows a 2V of about 65°. It is biaxially positive, and has an extinction angle, $Z \wedge C$, of 41°. The pyroxene is slightly greenish and shows a very faint pleochroism from pale green to colorless. In places it is altered to a light bluish green amphibole.

For comparison with the specimen described above, a specimen was taken on the rim of the same inclusion. It shows the same features as those of the previously described rock, but there is a difference in the tenor of ferro-magnesian minerals, mainly in that most of the pyroxene has been replaced by amphibole, and also a reduction of the tenor of felsic minerals, although quartz is present in the second thin section. This, of course, is a result of uralitisation, which according to

Tyrrell (1949), occurs when hornblende is produced directly from pyroxene, and epidote and quartz may develop as by-products of the change. The difference in the felsic composition, even though there is addition of quartz of as much as 10 per cent, can be a result of addition from the younger gneisses.

Mineral Assemblage and Metamorphic Facies

Three representative samples of hornblende paragneiss taken in the Ducharme-Mignault area were selected for a Rosiwal analysis, and a complete geochemical analysis (Table III). Analysis of metadiabase from O'Sullivan lake area is also given for comparison. In Table IV, 5 different Rosiwal analysis are plotted, the four first samples being from Ducharme-Mignault area, and the last sample being from Lorne-Avaugour.

TABLE IIIHornblende Garnetiferous Paragneiss

	L13-33	L42-67	C31-49b	I
SiO ₂	51.00	48.01	46.97	49.39
TiO ₂	1.17	1.14	1.52	1.04
Al ₂ O ₃	14.18	14.54	16.59	13.59
Fe ₂ O ₃	2.26	3.31	3.12	3.78
FeO	8.87	11.18	9.13	8.97
MnO	0.17	0.24	0.19	0.21
MgO	5.29	6.40	7.44	7.03
CaO	11.10	10.78	10.05	10.12
Na ₂ O	3.03	2.25	2.53	1.78
K ₂ O	0.64	0.31	0.40	0.28
Li ₂ O	-	-	-	-
P ₂ O ₅	0.07	0.09	0.13	0.26
H ₂ O (+)	0.99	1.31	1.46	
H ₂ O (-)	0.03	0.02	0.05	3.91
CO ₂	1.14	0.38	0.23	
S	0.008	0.03	0.06	-
Sr ₂ O	0.01	0.02	0.04	-
BaO	0.01	0.01	0.01	-
V ₂ O ₃	0.06	0.07	0.03	-
Cr ₂ O ₃	-	0.01	0.01	-
CuO	-	0.01	-	-
NiO	-	-	-	-
PbO	-	-	-	-
ZnO	-	-	-	-
CoO	-	-	-	-
ZrO ₂	-	-	-	-

TABLE III (cont'd)

<u>Norms</u>	L13-33	L42-67	C31-49b	I
Quartz	1.9	-	-	5.0
Orthoclase	3.9	1.9	2.4	0.7
Albite	26.0	19.4	21.6	14.7
Anorthite	23.1	28.9	33.0	32.4
Diopside	20.6	20.7	13.7	15.4
Hypersthene	16.2	19.2	11.7	23.5
Olivine	-	2.6	8.8	-
Magnetite	3.3	4.9	4.6	5.7
Ilmenite	2.2	2.2	2.9	2.0
Apatite	0.2	0.2	0.3	0.6
Calcite	2.6	-	-	-

Modes (Volume)

Andesine	28.21	28.27	27.88
Hornblende	48.19	53.00	53.20
Ferri-Augite	9.35	4.18	-
Biotite	2.35	-	0.39
Quartz	tr.	5.63	5.96
Garnet	10.36	-	12.15
Sphene	1.49	-	-
Calcite	tr.	tr.	-
Magnetite	-	tr.	0.39

L13-33 - Hornblende garnetiferous gneiss, 500 feet away from mile post 101 on Chibougamau highway in Ducharme township, Quebec. F. Claisse and F. East, analysts.

L42-67 - Hornblende garnetiferous gneiss, on the south side of Normandin river, in Aigremont township, Quebec. H. Boileau and F. East, analysts.

C31-49b - Hornblende garnetiferous gneiss, two miles west of the south-west corner of Bachois lake, in Mignault township, Quebec. H. Boileau and F. East, analysts.

I - Coarse-grained metadiabase, from O'Sullivan lake area, Ontario, D.A. Moddle, analyst (Pfeffer, 1955).

TABLE IVRosiwal Analyses of Hornblende Paragneiss (Volume)

Specimen No.	L 10-19	L 41-63	C 21-29B	C 58-84	L 4-11
Plagioclase	29.57	26.06	24.88	27.28	40.51
Quartz	1.95	4.61	5.27	3.88	1.11
Hornblende	64.62	57.10	54.44	63.18	40.20
Biotite	1.61	1.68	3.06	-	8.30
Clinopyroxene	-	-	-	4.11	-
Garnet	-	8.23	-	1.38	5.10
Clinochlore	2.23	-	12.31	-	-
Carbonate	tr.	{ 4.61	-	{ 0.18	-
Opaque	-		-		4.75
Clinozoisite	-	-	tr.	-	-
Sphene	-	-	tr.	-	-
Apatite	tr.	-	-	-	tr.
Plagioclase Composition, An%..32		30	31	34	30

As shown in the modes Table, these gneisses contain hornblende, sodic andesine, the diagnostic minerals of the amphibolite metamorphic facies. Their mineralogy suggests that they belong to the staurolite-kyanite subfacies of the amphibolite facies (Turner and Verhoogen, 1951). This assemblage is typical of the alteration of basic igneous rocks under conditions of medium- or high-grade regional metamorphism.

Origin of the Hornblende Gneisses and Amphibolites

The origin of the hornblende gneisses and amphibolites is a problem that has attracted the attention of petrologists for many years.

The definition of an amphibolite as given by Brongniart, in Holmes' "Nomenclature of Petrology" is the following:

"A granulose or glomeroblastic metamorphic rock, consisting essentially of amphibole and plagioclase, and often containing quartz, epidote, or garnet."

Amphibolite has been used with a variety of meanings, although it was originally applied by Brongniart (1813) to any rock whose groundmass is hornblende and in which other minerals are disseminated. Brongniart distinguished four varieties "amphibolite-granitoid^e, - actinotique, - micacée, and - schistoid^e," thus including rocks that are now regarded in part as igneous and in part as metamorphic. Naumann (1849) followed Brongniart's definition closely, but considered the rock a variety of diorite, whereas Senft (1857) made it one of his larger divisions and included diorite and diorite-porphry. Neither made any distinction between igneous rock and metamorphic rock.

Rosenbusch (1908) considered amphibolite a metamorphic rock commonly derived from diabase, gabbro, etc. ... To call both igneous and metamorphic rocks amphibolites is confusing; and Dana's (1875) term "hornblendite" for igneous rocks seems preferable, although even some of these are metamorphic.

It has long been recognized that many different types of rocks can give rise to amphibolites. Adams (1909) lists three possible modes of origin for the amphibolites of the Grenville sub-province:

- (1) by metamorphism and recrystallization of impure calcareous sediments,
- (2) by the alteration of basic dykes and similar igneous intrusions,

- (3) by the alteration of limestone through the action of the intruding bathyliths of granite.

Adams and Barlow (1910) in their memoir on the Haliburton-Bancroft areas mentioned that the hornblende-bearing inclusions in the grey gneisses may be basic differentiates of a granitic magma. Eskola (1914) believes that the amphibolites of the Orijärvi region in Finland are definitely of two different origins: some originated by metamorphism of calcareous shales, probably mingled with volcanic materials; others formed from igneous rocks. The composition of amphibolites is similar to that of some igneous rocks, and if the amphibolites were melted and resolidified under volcanic conditions the minerals formed would be those that are now found in these igneous correlatives. Osborne (1936) believes that the amphibolites of the Shawinigan Falls district are the metamorphosed equivalents of lava flows, basic tuffs and graywacke, as well as basic dykes and impure calcareous sediments. Buddington (1939) believes that the amphibolites, in the Adirondack region, are derived from tuffs and lava flows. Uytendogaardt (1954) states that regional metamorphism of some sedimentary rocks or of some basic igneous rocks may give rise to metamorphic rocks of about the same composition. Thus hornblende gneisses and amphibolites may be derived from at least five different kinds of rocks, including:

- (1) calcareous sediments

- (2) basic dykes

- (3) volcanic rocks
- (4) graywacke
- (5) basic differentiate of a granitic magma

In the present areas, the amphibolites and hornblende gneisses are believed to be derived from three different types of rocks listed below:

- (1) andesite and basalt flows or tuffs
- (2) gabbro-diorite sills
- (3) ultrabasic intrusives

(1) Andesites and basalts are common Keewatin-type rocks, and they are believed to account for most of the amphibolites of the area. By metamorphism, lavas give rise to chlorite schist, to hornblende schist, and finally to hornblende gneiss and amphibolite. The transition from one end member to the other can be seen more easily where it takes place within a short distance, for example a half a mile. Thus, near the contacts of the granite on the shore of La Dauversière lake in Imbault's Queylus area, and southeastward in Ducharme-Mignault area, the progressive change of the lavas into hornblende gneiss and amphibolite can be followed without difficulty. The same gradation between chlorite schist, hornblende-chlorite schist and hornblende gneiss can also be observed around Au Couteau lake in Dollier-Charron area in which the author worked as senior assistant.

(2) Practically all the sills of gabbro-diorite associated with the volcanics have been metamorphosed to amphibolite. The field relations and the preservation of the original ophitic texture leave little doubt as to the origin of these amphibolites.

(3) Some very coarse-grained amphibolite found in the area is believed to be derived from an ultrabasic intrusive. The great abundance of amphiboles, together with the very low content of plagioclase and quartz, are very suggestive of an original ultrabasic intrusive. According to Williams, Turner, and Gilbert (1954), the abundance of light-colored, magnesium-rich amphiboles is also an indication of a derivation from ultrabasic rocks.

No evidence was found in the area by the author to justify a conclusion that some of the hornblende gneisses and amphibolites are derived from sedimentary rocks. However, Deland (1955) mentions such a possibility for some of the rocks in his area, although he is quite skeptical of the conclusion. This mode of origin in the present areas is uncertain for two reasons: impure calcareous sediments, from which hornblende gneisses and the amphibolites are likely to be derived, have not been found in the belt of Keewatin-type rocks; and most sediments of the area have yielded biotite paragneiss on metamorphism. Quartz-rich hornblende paragneisses are rare or absent.

The problem of determining the origin of an amphibolite or hornblende-plagioclase gneiss becomes increasingly difficult as the grade of metamorphism increases and as the original features of the rocks are obliterated. As stated by Adams and Barlow (1910):

"When the origin of a body of amphibolite is not discoverable from its field relations, it is impossible to determine whether it is an altered igneous (rock) or a body of altered sediment."

The original nature of the hornblende gneisses and amphibolites found as inclusions cannot be ascertained. Many geologists have considered them to be basic differentiation products from the acid magma while others like Smyth and Frosterus (1902) have looked upon them as fragments of foreign rocks caught up by the granite.

Adams and Barlow (1910) postulate three different modes of origin:

- (1) as basic differentiation products from the granite magma,
- (2) as portions of the rock forming the walls or roof of the batholith, which had fallen into the granite magma and had partaken of its subsequent movements,
- (3) as fragments of intrusive masses, dykes, stocks, etc. ... which, if the granite be supposed to represent the original sub-crust in a softened or remelted condition, cut through this crust and were connected with basic effusives at the surface. These masses having been torn to pieces by the subsequent movements of the softened granite now appear as scattered fragments.

From these statements some criteria may be derived that can be used to determine whether an amphibolite is of ultimate sedimentary, volcanic, or basic intrusive origin. A high quartz tenor, for example, could suggest a sedimentary origin, whereas the presence of sphene and epidote would rather suggest a medium- or high-grade metamorphism of basic rocks, because minerals are common in the metamorphosed basic igneous rocks of the amphibolite facies (Turner and Verhoogen, 1951).

Garnet in low-grade hornblende paragneisses and amphibolites might suggest that the rocks have been derived from aluminous sediments probably near the composition of a shale. However, the presence of garnet in an amphibolite is not in itself a criterion of sedimentary origin. As proof of this, the presence of small garnets in obviously meta-lavas of the transition zone may be cited. Garnets suggest a sedimentary origin if they are concentrated in regular layers and if hornblende gneiss is interbanded with biotite paragneiss.

At one time, any layered, or even gneissic, rock was considered to be of sedimentary origin. Obscure structures in anorthosite led pioneer geologists to consider them meta-sedimentary. Some of the old interpretation remains, and many geologists are still prone to invoke a sedimentary origin for any layered rock. However, even a massive rock can become layered. This is the case especially in granites when they are intersected by sheared zones and are converted to a layered gneiss. Not only does movement produce gneissic structure and layering, but also the "S" planes formed during movement may

allow access of solutions promoting re-crystallization. The rather insignificant layering of the hornblende-plagioclase gneisses is not evidence of a sedimentary origin.

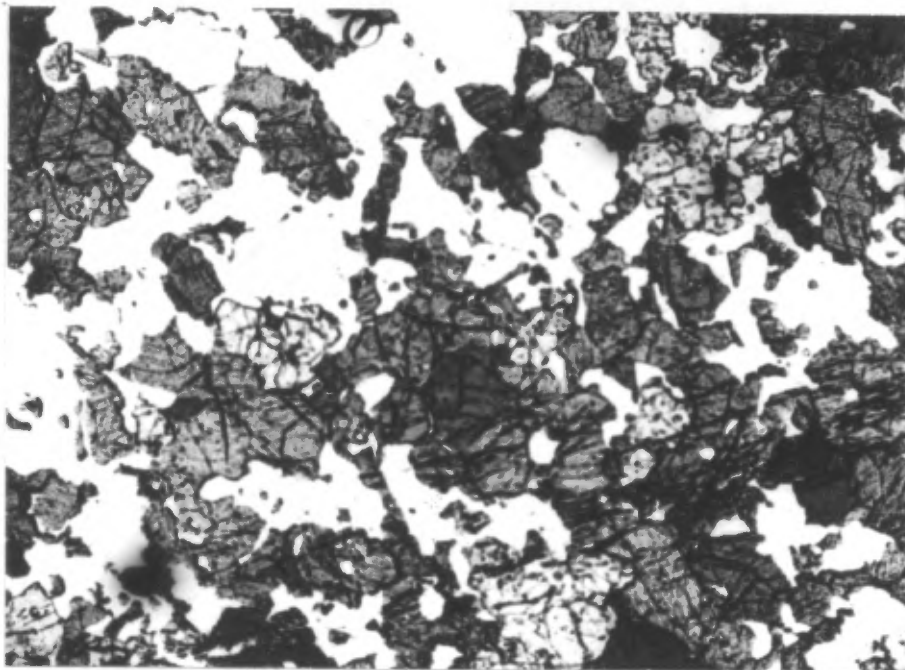
The possibility of tracing the origin of the amphibolites through their trace elements was not neglected, as clues to the derivation of these amphibolites seem to exist in their differential inheritance of accessory elements. Amphibolites derived from mafic igneous rocks for example, are, like their parents, commonly higher in Co, Ni, Cr, and Cu, and lower in Pb, Au, and Ba, than amphibolites derived from carbonate sediments. Apparently dynamothermal metamorphism of the gabbros does not remove the initial concentrations of Sc, Cr, Ni, and Cu as rapidly as it obliterates other diagnostic properties. Conversely, amphibolites derived by replacement of marbles tend to maintain higher concentrations of Ba, Pb, and Au than many known ortho-amphibolites.

The accessory-element values in some amphibolites described by Béland (1953) and in some of their component minerals were compared with the amphibolites found in the areas under discussion and it was found that the accessory-element values in the rocks concerned could not be used to determine the origin of the amphibolites..

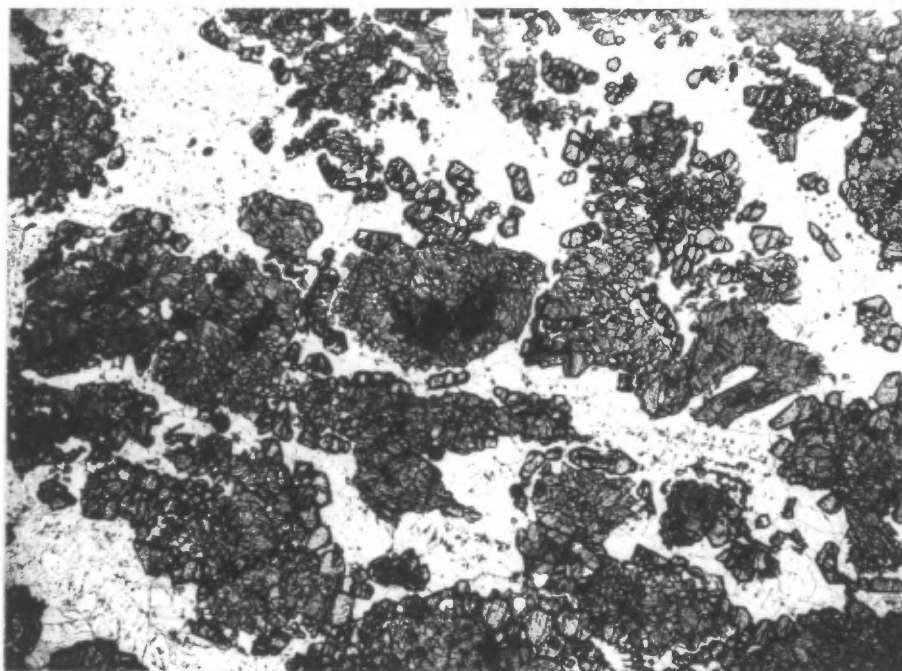
Biotite Paragneiss

Garnetiferous biotite paragneiss underlies about 15 per cent of the areas. In the Ducharme-Mignault map-area, it occurs in an east-west trending band in the southern part of the

PLATE I



A. Hornblende garnetiferous paragneiss. White area is mainly plagioclase with minor quartz. Natural light, X11.5.



B. Hornblende garnetiferous paragneiss showing relic of coronitic structure. Note magnetite and pyroxene in the center of amphibole patches in the center of the photograph. Natural light, X11.5

area, and along the western boundary where its outcrops extend northeast towards Nicabau lake. In the eastern part of the map-area, biotite gneisses crop out as lenticular patches northwest and east of Aigremont lake, and south of Mignault lake. A few isolated small exposures occur here and there in the area. In the Lorne-Avaugour area, biotite paragneisses crop out most extensively in two irregular zones, one northeast and the other west of d'Argenson lake, and small lens-shaped masses are found elsewhere in the area.

Petrography

The biotite paragneiss is a granoblastic rock in which, despite the metamorphism and the injections of granitic and pegmatitic material, the original bedding of sedimentary or tuffaceous rocks has generally been preserved in the form of a conspicuous consistent layering. It is generally a medium- to fine-grained, biotite-feldspar-quartz-garnetiferous paragneiss. The relic bedding is indicated by the regular alternation of bands rich in biotite with others rich in lighter colored minerals. A faint lineation is generally visible within individual layers. Some layers are made up of quartz, white feldspar, and minute red garnets, whereas others are very rich in biotite. In a few places, the rock contains reddish garnets (as much as 10 per cent), and the garnet grains are mainly concentrated along certain layers, whereas elsewhere in the rock garnet may be inconspicuous.

The biotite paragneiss varies in composition, texture, and color within short distances. Generally the rock is dark grey, to dark green, to almost white in the quartzose layers, and has a characteristic rusty-weathering surface typical of many biotite-bearing schists and gneisses. The rock is somewhat friable and the garnet grains stand out on the weathered surface. Greenish veinlets of epidote, either parallel or inclined to the gneissic structure, are common in the paragneiss near the granite contact. In places, much elongated lenses of darker gneisses rich in hornblende are enclosed by the biotite-rich rock.

The best examples of the rusty-brown weathered rock were found on Scatsi river, near the southern limit of the Ducharme-Bouteroue map-area, and some sand-brown specimens of the same rock occur on Chaudière river. A typical medium dark grey band consists of a granoblastic aggregate of 40 per cent anhedral quartz, 35 per cent subhedral plagioclase (An₂₈), 20 per cent aligned flakes of biotite, and epidote, muscovite, garnet as accessory minerals.

Studies of a few thin sections of these gneisses show that the rock has a schistose structure and a granoblastic texture not particularly marked.

Quartz and plagioclase (An₂₈ to An₃₀), which make up about 75 per cent, occur as anhedral equigranular grains that have diameters from 0.1 mm. to 0.5 mm. Plagioclase is very seldom twinned, though fine albite twins can be seen in some sections, and the plagioclase is slightly sericitized in

places. The biotite flakes, of which most are 0.5 mm. long, are aligned parallel to the structure. The biotite is strongly pleochroic from light straw yellow to dark greenish brown. It is partly altered to chlorite, and pleochroic halos were noted in many places around allanite grains. These three minerals tend to occur in biotite-rich layers with feldspar and quartz. Epidote overgrows allanite and tends to be in layers with garnet. Minor minerals are muscovite, magnetite, sphene, sericite, and pyrite.

In the more massive as well as in the schistose rocks, garnet is in porphyroblasts that may be as much as 3 mm. in diameter. These porphyroblasts, although highly irregular tend to be rounded, and characteristically have inclusions of quartz and feldspar.

Close to the western side of the Ducharme-Mignault map-area, the biotite paragneisses have a more pronounced gneissic structure than those on the eastern side. The schistosity is well-marked, and the layers are much thinner. Furthermore, garnet is rare; this is perhaps the result of pegmatitic injections. Interbands of hornblende or hornblendic inclusions are also fairly numerous. The rock is fine- to medium-grained with well-aligned biotite blades. The main constituents of the rock are quartz and feldspar.

A study of a thin section of this group shows that small anhedral quartz grains make up from 15 to 20 per cent of the rock, and plagioclase (An_{30} to An_{32}) makes up another 50 to 65 per cent of the rock. A strongly pleochroic biotite,

from light tan to dark brown, is always present, ranging in amount from 15 to 20 per cent. Fractured garnets, with many inclusions of quartz and feldspar, are commonly present, and make up from 5 to 10 per cent of the rock. Apatite, allanite and magnetite are common. Products of alteration include chlorite, clinozoisite, and sericite.

In general, the plagioclase of the biotite paragneiss is clear, untwinned, and has indices of refraction close to that of balsam. In certain cases it cannot be readily distinguished from the quartz with which it is closely associated in the fine-grained groundmass. The feldspar varies, in general, between very calcic oligoclase (An_{28}) and sodic andesine (An_{32}), and is therefore nearly the same in composition as the plagioclase observed in the hornblende gneisses.

Mineral Assemblage and Metamorphic Facies

Two representative samples of biotite paragneiss were selected for complete geochemical analysis, as well as a Rosiwal analysis. Two analysis of graywacke were added for comparison. The results are shown on Table V. Table VI gives the results of five additional Rosiwal analysis.

TABLE VBiotite Garnetiferous Paragneiss

	L13-20	C58-88	I	II
SiO ₂	75.52	68.38	69.69	65.05
TiO ₂	0.44	0.47	0.40	0.46
Al ₂ O ₃	11.40	15.64	13.53	13.89
Fe ₂ O ₃	0.68	0.87	0.74	0.74
FeO	2.70	2.86	3.10	2.60
MnO	0.08	0.10	0.01	0.11
MgO	1.00	1.59	2.00	1.22
CaO	3.29	5.18	1.95	5.62
Na ₂ O	2.70	2.93	4.21	3.13
K ₂ O	0.86	0.95	1.71	1.41
Li ₂ O	-	-	-	-
P ₂ O ₅	0.07	0.10	0.10	0.08
H ₂ O (+)	0.57	0.61	2.08	2.30
H ₂ O (-)	0.03	0.03	0.26	0.28
CO ₂	0.36	0.03	0.23	2.83
S	0.017	0.02	-	-
SrO	0.04	0.07	-	-
BaO	0.02	0.02	-	-
V ₂ O ₃	0.02	0.03	-	-
Cr ₂ O ₃	-	-	-	-
CuO	-	-	-	-
NiO	-	-	-	-
PbO	-	-	-	-
ZnO	-	-	-	-
CoO	-	-	-	-
ZrO ₂	0.03	0.03	-	-

TABLE V (cont'd)

<u>Norms</u>	L13-20	C58-88	I	II
Quartz	47.41	43.54	35.26	37.24
Orthoclase	5.10	5.70	10.10	8.37
Albite	23.10	25.00	35.71	26.56
Anorthite	13.80	14.30	7.67	9.51
Diopside	-	-	-	-
Hypersthene	6.30	8.00	-	-
Olivine	-	-	-	-
Magnetite	1.00	1.30	1.10	1.10
Ilmenite	0.80	0.90	0.80	0.90
Apatite	0.20	0.20	0.22	0.19
Calcite	0.80	0.10	0.52	6.43
Corundum	1.00	0.60	1.93	3.71

Modes (Volume)

Andesine	47.60	51.40
Biotite	5.56	7.80
Quartz	38.20	37.30
Garnet	5.56	2.00
Muscovite	2.91	-
Clinozoisite	-	1.33
Allanite	tr.	-
Apatite	tr.	tr.
Magnetite	tr.	tr.
Calcite	tr.	-

L13-20 - Garnetiferous biotite paragneiss, from 1.5 miles west of Aigremont lake, Aigremont township, Quebec. F. Claisse and F. East, analysts.

C58-88 - Garnetiferous biotite paragneiss, from the south-west corner of Clarke lake in Aigremont township, Quebec. F. East and H. Boileau, analysts.

I - Franciscan graywacke Jurassic, average of 3, Taliefero, American Association of Petroleum Geologists, 1943.

II - Graywacke, Eocene, Washington, Brun.

TABLE VIRosiwal Analyses of Biotite Paragneiss (Volume)

Specimen No.	C 27-45	C 57-79	A 36-45	H-9-6	J14-5
Plagioclase	40.00	56.8	44.1	56.3	54.2
Quartz	29.70	33.5	30.4	31.6	37.3
Biotite	18.00	4.5	17.5	10.1	5.4
Muscovite	-	1.3	4.3	-	-
Garnet	2.70	2.2	2.2	2.0	3.1
Hornblende	9.70	-	-	tr.	-
Sericite	-	1.7	-	-	-
Clinochlore	-	-	tr.	-	-
Allanite	-	-	tr.	-	-
Apatite	tr.	tr.	-	tr.	tr.
Opaque	tr.	tr.	1.5	tr.	tr.
Carbonate	-	-	-	-	-
Clinzoisite	-	tr.	-	-	tr.
Plagioclase Composition An%	33	31	31	30	30

These rocks differ in composition from orthogneisses in their greater content of biotite, in the absence of potash feldspar, and also in their content of red garnet, which is absent in the orthogneisses or at least has not been detected. It is believed that such rocks are of ultimate sedimentary origin, and that they may be derived from sediments such as are found with volcanic rocks in the Chibougamau series.

The mineralogy of the garnetiferous biotite paragneisses suggests that they belong to the amphibolite metamorphic facies equivalent to the staurolite-kyanite subfacies derived from feldspathic sandstone deficient in potash (Turner and Verhoogen, 1951).

Origin

In the areas studied by the writer, no gradation from slightly metamorphosed sedimentary rocks through fine-grained

PLATE II



A. Biotite garnetiferous paragneiss showing parallel alignment of biotite crystals. White is mainly plagioclase and minor quartz. Natural light, X36.



B. Biotite garnetiferous paragneiss. Natural light, X36.

schists to garnetiferous paragneisses was observed. However, Deland (1955) saw the transition rocks in the Surprise lake area, and comparison of both specimens and thin sections shows so much similarity that it is certain that the biotite paragneisses are metamorphosed equivalents of sedimentary rocks found within the belt of Keewatin-type rocks.

METAGABBRO

Six lenticular masses of coarse-grained ophitic metagabbro occur in the Ducharme-Mignault map-area. One large mass is in the southern part of the area between Scatsi and Nemenjish rivers. Another mass crops out on one of the long bays of Bouteroue lake, a third and probably the largest one crosses Nicabau lake in an east-northeast direction. The three other masses crop out in the northeast part of the map-area. Several isolated outcrops were also seen in the area, and they were mapped as small lenses. In the Lorne-Avaugour map-area one small lenticular mass was observed in the northwestern corner, and two small exposures occur elsewhere.

Petrography

The rocks belonging to this series are dark bluish grey on fresh surface and grey-brown on the weathered surface. They are a very massive and medium- to coarse-grained rock. The texture is ophitic with a coronitic structure. The weathered zone, in some cases, may extend from two to five inches deep, and in places even deeper. As a result of the rapid decay, the

metagabbro has a pitted surface, on which the ophitic texture is quite apparent in the medium-grained varieties, but very poorly shown in the coarse-grained types. The composition is from a dioritic to a basic gabbro. The metagabbro is in large massive outcrops and is thus unlike rocks of the same composition in Gilbert's Rohault area (Ms.). The rock is made up of much saussuritized plagioclase; secondary, probably uralitic, hornblende; with titanite, leucoxene, magnetite, apatite, biotite, saussurite, carbonate, and quartz.

Remnants of rocks belonging to this series were also seen at a few places in the zone of garnetiferous hornblende paragneiss. On the Chibougamau highway near mile post 89, and north of the same road between it and Aigremont lake, there are exposures of rock the core of which is a massive, medium-grained, altered dioritic gabbro grading into a garnetiferous hornblende gneiss. Similar relationships are to be seen in the Lorne-Avaugour area in the northwestern corner of the map-area, on the west side of the Chibougamau highway, and also along the township line between Lorne and Denault townships between mile posts IX and X. In places the rock is mainly a garnet-hornblende-feldspar gneiss or a garnetiferous amphibolite, but there are also remnants of a gabbro of an anorthositic aspect that shows its typical pitted weathered surface and has retained its massive, equigranular texture despite a later growth of scattered to abundant porphyroblasts of garnet.

An examination of a thin section of the rock shows an ophitic to sub-ophitic texture with a pronounced coronitic

structure. The section consists of equal amounts of plagioclase and pyroxene, with small amounts of magnetite and red garnets. The plagioclase laths are up to 1 cm. long and are surrounded by pyroxene. The plagioclase is diverse from one section to another and is from labradorite (An₅₉) to andesine (An₃₄); it is quite probable that the original plagioclase was more calcic than An₅₉ and also more abundant than it is now (about 20-30 per cent of the rock), for much of it has been replaced by garnet and saussurite. The plagioclase is clouded with minute dust-like inclusions and is light brownish grey in plane polarized light. The feldspar shows albite and Carlsbad twinnings. Clinopyroxene, hornblende, and biotite were also noted in all the thin sections. No olivine was seen in these sections, although it may have been once present. Garnet, in some cases up to 25 per cent, usually makes up the outer rim of the coronas. Serpentine and magnetite are present as accessory minerals. Coronitic structure can be noted throughout the sections. Clinopyroxene usually occurs in the cores of the coronas, followed by a dark brown pleochroic biotite, followed generally but not always by a discontinuous rim of pale green aggregate (now a pleochroic serpentine or more probably chlorite) and amphibole, and finally by a thicker zone of fractured red garnets. Uralitisation of the clinopyroxene to an amphibole is quite common. No feldspar was seen inside the coronas. Small amounts of quartz fill triangular areas between divergent laths of plagioclase.

During the summer of 1956, in the Lorne-Avaugour area, a few small outcrops of metagabbro were found.

Megascopically, the rock looks exactly like the metagabbro found farther west, that is, it has an ophitic to sub-ophitic texture and a pitted weathered surface. Under the microscope olivine was detected. Some of it is fresh but some is slightly altered to a red-orange mineral, probably iddingsite. Both the plagioclase laths and the clinopyroxene are clouded by minute, dust-like inclusions. Clinopyroxene has a "moth-eaten" appearance, probably caused by uralitisation. Clinopyroxene, magnetite, and fresh and altered olivine are surrounded by two- and three-tiered coronas that separate them from the plagioclase. Biotite, garnet, and hornblende are the corona minerals. The order through a typical, three-tiered corona is: magnetite - biotite - garnet - hornblende - plagioclase. Garnet is the most important of the corona minerals in terms of volume, and makes up more than 15 per cent of one specimen. Very minute amounts of quartz were observed between the laths of plagioclase. The plagioclase is from An₅₂ to An₆₂, and as in the rocks from the Ducharme-Mignault area; it is quite probable that originally the plagioclase was more calcic than now. Sections where olivine is still present have from 30 to 40 per cent feldspar, compared to 20 to 30 per cent in the more metamorphosed type. Clinopyroxene is in moth-eaten porphyroblasts. It has a $2V=65^\circ$, and is biaxially positive. The birefringence is moderate to high. The crystals are fractured up, and they have a greyish color, as if they had been sprinkled by dust. The extinction angle $Z \wedge c = 39$. The amphiboles, which make up 10 to 20 per cent of the rock, resemble an ordinary biotite on

account of its pleochroism. The birefringence is low to medium, and its extinction angle $Z \wedge c$ varies from 12° to 18° . The amphibole is an ordinary hornblende. The mica (biotite) has a pleochroism from light drab to medium reddish brown and this makes it easy to distinguish it from the ordinary hornblende. The olivine grains, as mentioned before, are quite fractured. The 2V measured on the Federoff stage has an optic axial angle of 74° , and is biaxial negative. The extinction is parallel to the cleavage traces. The olivine is about 40 per cent forsterite, and 60 per cent fayalite. Some reddish orange streaks fill the fractures in these crystals. Some of the olivine crystals have all been largely replaced by iddingsite.

Mineral Assemblage and Metamorphic Facies

One complete geochemical analysis was made of this rock. Analyses of a hornblende garnetiferous gneiss, two analyses of gabbro, and two analyses of diabase are given for comparison in Table VII.

Table VIII has seven Rosiwal analyses of this kind of rock taken from the areas under study. The last three analyses show, first, a higher calcicity of the feldspar (ranging from An₅₂-An₆₂), secondly, the presence of olivine, in part fresh, in part altered to iddingsite and, thirdly, a higher ratio of pyroxenes to amphiboles.

TABLE VIIMetagabbro

	B5-10	C31-49B	I	II	III	IV
SiO ₂	46.92	46.97	50.14	49.01	49.54	49.88
TiO ₂	1.04	1.52	2.13	0.52	0.89	1.02
Al ₂ O ₃	16.28	16.59	22.19	16.01	18.35	13.88
Fe ₂ O ₃	1.78	3.12	1.74	6.92	2.32	2.55
FeO	10.86	9.13	6.49	7.31	7.87	11.84
MnO	0.20	0.19	0.10	0.12	0.15	0.29
MgO	9.55	7.44	2.25	4.99	7.06	6.17
CaO	10.27	10.05	8.94	11.64	10.15	10.19
Na ₂ O	1.92	2.53	3.52	2.70	2.68	2.36
K ₂ O	0.32	0.40	1.39	0.30	0.28	0.41
Li ₂ O	-	-	-	-	-	-
P ₂ O ₅	0.06	0.13	0.39	0.10	0.26	0.13
H ₂ O (+)	0.55	1.46	0.32	0.33	0.31	1.46
H ₂ O (-)	0.02	0.05	-	0.10	0.09	0.02
CO ₂	0.14	0.23	0.02	0.03	0.02	0.13
S	0.05	0.06	0.17	-	-	0.15
SrO	0.05	0.04	-	-	-	-
BaO	0.01	0.01	-	-	-	-
V ₂ O ₃	0.03	0.03	-	-	-	-
Cr ₂ O ₃	0.01	0.01	-	-	-	-
CuO	-	-	-	-	-	-
NiO	-	-	-	-	-	-
PbO	-	-	-	-	-	-
ZnO	-	-	-	-	-	-
CoO	-	-	-	-	-	-
ZrO ₂	-	-	-	-	-	-

TABLE VII (cont'd)

<u>Norms</u>	B5-10	C31-49B	I	II	III	IV
Quartz	-	-	0.20	2.38	-	0.66
Orthoclase	1.91	2.40	8.30	1.78	1.67	2.40
Albite	16.39	21.60	29.70	22.89	22.74	20.06
Anorthite	35.00	33.00	39.40	30.65	37.17	26.05
Diopside	13.30	13.70	2.50	27.92	13.72	20.44
Hypersthene	12.30	11.70	12.60	8.64	16.81	22.94
Olivine	16.50	8.80	-	-	5.01	-
Magnetite	2.60	4.60	2.50	10.00	3.35	3.71
Ilmenite	2.00	2.90	4.00	0.98	1.68	1.93
Apatite	0.13	0.30	0.90	-	-	-
Calcite	-	-	-	-	-	-
Pyrite	-	-	-	-	-	0.25

Modes (Volume)

Plagioclase	31.97	27.88
Hornblende	16.85	53.20
Ferriferous augite	13.06	-
Biotite	tr.	0.39
Garnet	17.14	12.15
Hypersthene	18.82	-
Quartz	-	5.96
Magnetite	2.16	0.39

- B5-10 - Metagabbro from the southwest side of Léda lake, Ducharme township, Quebec. H. Boileau and F. East, analysts.
- C31-49B - Hornblende garnetiferous gneiss, two miles west of the south-west corner of Bachois lake, Mignault township, Quebec. H. Boileau and F. East, analysts.
- I - Diabase, one mile east of McDiarmid lake, Flett township, Ontario. Analysts: Provincial Assay Office, Ont., Ref. M.E. Hurst.
- II - Gabbro, from Pascalis lake, Pascalis township, Abitibi-East Co., Quebec. M. Archambault, analyst. Ref. Que. Bur. Mines, Ann. Rep. 1933, Part B, p. 51, L.V. Bell.
- III - Gabbro, from Tiblemont island, Tiblemont lake, Tiblemont township, Abitibi-East Co., Quebec. M. Archambault, analyst. Ref. Que. Bur. Mines, Ann. Rep. 1933, Part B, p. 51, L.V. Bell.
- IV - Diabase, from Normetal Mine, Desmeloizes township, Abitibi-East Co., Quebec. H. Boileau, analyst. Ref. Que. Bur. Mines, Unpub. G.R. 34 (Normetal Mine area, 55 typescript pages), p. 24, (1941), C. Tolman.

TABLE VIIIRosiwal Analyses of Metagabbro (Volume)

Specimen No.	L 2-7	C 14-20	C 54-73	A 20-34	L 15-18	L 22-22	H 2-1
Plagioclase	35.12	37.47	35.05	28.96	36.98	28.81	37.88
Hornblende	31.34	12.66	11.60	10.07	18.97	19.93	7.38
Ferriferous augite	20.24	15.33	2.07	25.13	24.84	5.74	23.28
Hypersthene	-	13.88	19.16	15.23	-	14.35	13.80
Olivine	-	-	-	-	4.73	-	16.33
Biotite	1.36	1.00	7.60	2.00	1.00	5.00	0.31
Garnet	10.83	17.56	24.50	17.37	11.83	18.71	tr.
Clinozoisite	tr.	-	-	-	-	-	-
Iddingsite	-	-	-	-	tr.	tr.	tr.
Calcite	-	-	tr.	-	-	-	-
Magnetite	1.09	2.07	tr.	1.22	1.63	7.44	1.00
Plagioclase Composition An%	38	38	38	48	53	62	52

As shown in the Table of modes, this rock contains hypersthene and augite, and thus the rocks may have formed under temperature and pressure conditions corresponding to those of the granulite facies. However, according to Yoder (1952), if the rocks had an excess of water, it is quite possible that the rocks under the same temperature and pressure conditions may have formed minerals typical of the amphibolite metamorphic facies. Derivatives of basic igneous rocks are well represented among the garnetiferous amphibolites (plagioclase-hornblende-almandine-biotite-quartz), and in these, from the very nature of the parent rocks, biotite and quartz are inconspicuous, and the CaO/Na₂O ratio may be sufficiently high to cause the appearance of epidote and zoisite as an additional phase. This assemblage is typical of the alteration of basic igneous rocks by medium- or high-grade regional metamorphism.

Origin of the Metagabbro

The disposition of the metagabbro in the field shows that most of the outcrops are relics of what formerly were larger masses which have been cut up into separated masses by orthogneisses. As noted above, the rocks are diverse from locality to locality. In some places the diversities are original, whereas elsewhere the differences are the result of metamorphism and are probably determined by the position of the original rocks on folds, the thickness of the original body of gabbro, or some other physical conditions.

Enough original differences in texture and proportion of minerals is discernible to allow the inference that the primary differences are a result of differentiation of a basalt magma. Many such differentiated bodies are stratiform and were emplaced as horizontal sills and it is reasonable to assume that at least much of the metagabbro is of this origin. The conclusion is supported by the presence of the nearby Chibougamau stratiform mass.

Allard (1956), in discussing the gabbro sills in the Chibougamau district, points out that the magma which formed the sills may have been very similar in composition to the magma which formed the volcanic rocks. Allard suggests that the sills are absent from the lower part of the volcanic sequence, because of excessive load, whereas higher in the layered sequence the force of intrusion may have been sufficient to pry apart some volcanic layers making room for the emplacement of the sills. He also shows that the original pyroxene has been

uralitized and that the original plagioclase has been saussuritized during the regional metamorphism of the gabbro of the Chibougamau complex.

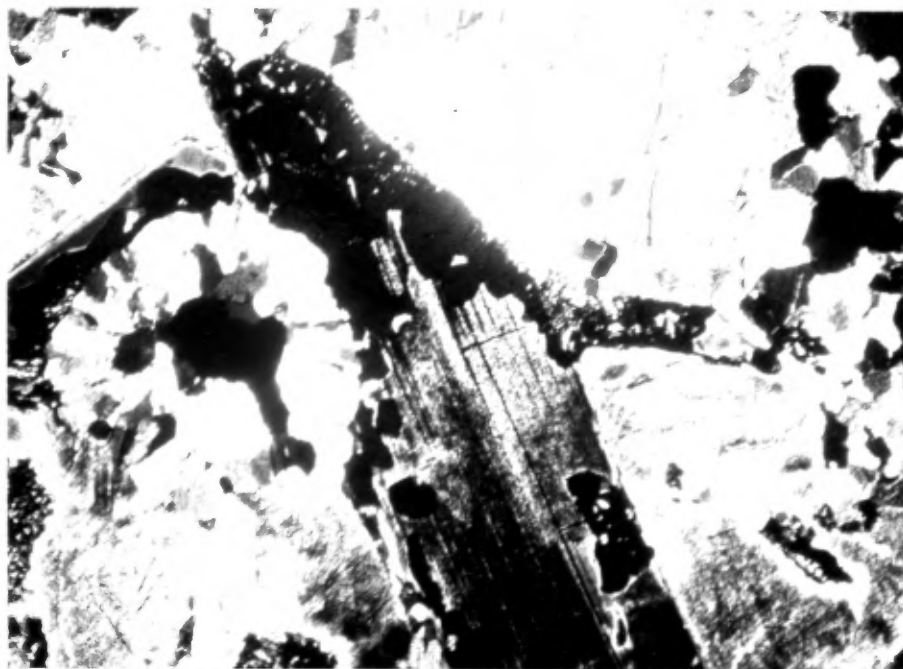
These changes, as mentioned previously, require an addition of water, but only minor rearrangement of the other constituents. Controls on the introduction of water are complex and depend on availability, water pressure, grain size, porosity of the rock, pressure and temperature of the rock mass, and the presence of hydrous minerals in the original rock, Yoder (1952).

The origin of coronas is quite problematical. Recent writers, like Buddington (1939), believe coronas to be a result of regional (dynamothermal) metamorphism, but Shand (1945) and Osborne (1949) suggest contact (thermal) metamorphism. Gilbert (Ms.) favors the hypothesis of regional metamorphism, whereas Neale (Ms.), in this general region, suggests a late magmatic or autometamorphic process. The author believes that they are the result of heating caused by granitic intrusion. Furthermore, the presence of clouded feldspars, which according to Poldervaart (1954) is a result of an adequately high temperature for a sufficient length of time, supports the hypothesis of thermal metamorphism.

Biotite Injection Gneiss

Some layered gneisses found in the middle of the northern part of the Ducharme-Mignault map-area and near the southwestern end of Nicabau lake were mapped as injection gneiss. These rocks probably are the result of an injection of the magma,

PLATE III



A. Metagabbro showing coronitic structure made of magnetite surrounded by amphibole and garnet. Note the olivine in upper part of the photograph and the clouded feldspars. Natural light, X36.



B. Same as above (crossed nicols), X36.

with accompanying metasomatism, into rocks of ultimate sedimentary and volcanic origin. The author found it illogical to map them with true orthogneisses, and they were mapped as a separate unit.

The grey, biotitic, composite gneisses are uniformly medium-grained, but they vary considerably in appearance. Layers of the light grey orthogneiss alternate with medium grey to medium dark grey biotitic bands which were derived from the intruded country rock. Individual layers are from 2 mm. to 10 cm. thick. Locally, lenses, streaks, and elongated angular fragments of dark grey biotite schist are present. A typical medium dark grey band consists of a granoblastic and gneissic aggregate of 25 per cent anhedral quartz, 50 per cent subhedral plagioclase (An_{28}), 20 per cent aligned flakes of biotite, with small amounts of epidote, muscovite, zircon, and almandine garnet. Such a layer differs from the orthogneiss in its greater content of biotite, traces of garnet, and absence of potash feldspar. It is conceivable that such biotitic bands could be derived from feldspathic sedimentary rocks of "Timiskaming-type".

Hornblendic varieties of the composite gneisses have resulted chiefly from the lit-par-lit injection of grey biotite orthogneiss into the hornblende gneiss. These specimens are characterized by small amounts of biotite that has formed at the expense of hornblende, and also by their higher tenor of clinozoisite. The medium dark grey hornblendic layers in this rock consist of about 55 per cent plagioclase (An_{32}), 40 per cent hornblende, and small amounts of quartz, biotite, and epidote.

Orthogneisses

More than 70 per cent of the areas mapped are underlain by biotite-hornblende orthogneiss which has been intruded into the paragneisses previously described. It covers about 50 per cent of the Ducharme-Mignault area, but farther east the amount of biotite-hornblende gneiss increases until it is about 80 per cent of the area.

The orthogneiss is a well-foliated, quartzose, fine- to medium-grained rock. It is grey to pink, depending on the amount of potash feldspars present in the rock. In places, it contains abundant inclusions of more or less digested lenses or discontinuous masses of amphibolite and paragneiss, and numerous injections of pegmatite. The fine-grained facies is generally richer in biotite than the medium-grained variety in which hornblende may be the dominant or even the only mafic mineral.

The orthogneisses are faintly to distinctly gneissic. Their color varies from very light grey to medium grey and often pink. They are composed of clear to smoky quartz and white to light grey plagioclase in equal amounts. Biotite is usually present in quantities varying from 5 to 10 per cent, and hornblende is usually present in the outer zones of the intrusive mass.

In most of these rocks the section shows a gneissic structure determined by a common orientation of the biotite crystals. The rock is seen to be made up of lineated or foliated, granitoid aggregates of strained quartz, 25 to 30 per cent, but ordinarily about 35 per cent, and twinned, commonly sericitized plagioclase (An₂₈-An₃₁), 5 to 15 per cent

microcline, 5 to 15 per cent of either biotite or hornblende, or both. Apatite, iron oxide, sphene, muscovite, epidote, occasionally allanite, and carbonate are present as accessory and secondary minerals. The potassic feldspar corrodes and includes all the other minerals and is present in many of the sections studied. It is also interstitial to both quartz and plagioclase and penetrates the latter along fractures. Furthermore, microcline is replaced by myrmekite (Sederholm, 1899). The fabric of the rock suggests crystallization with deformation. In a few specimen no foliation is visible.

Pink orthogneisses, like those found on the shores of Branch lake, were also studied with care, because the author thought that their composition would be different from the grey gneisses, but such is not the case, as they have a somewhat greater tenor of potassic feldspar. These gneisses are strongly foliated, and, in places, have an augen structure. They are fine-grained, except for the coarse potassic feldspars found through the rock. Under the microscope one may see from 25 to 30 per cent granitoid aggregates of quartz, 40 to 55 per cent twinned phenocrysts up to three inches in length of plagioclase (An_{30}), 10 to 15 per cent microcline, and about 10 per cent biotite, which one is generally in flakes or laths, strongly pleochroic from light green to dark greenish brown. Some sections, especially those with potassic feldspar, have large flakes of white mica, probably muscovite. Epidote, muscovite, sphene, and allanite are present as accessory and secondary minerals. The section shows a granoblastic texture with a

fairly marked gneissic structure. Allanite has been converted to, or overgrown by, epidote, for in places a core of the former mineral is found in the epidote.

Mineral Assemblage

Geochemical analyses of two of these rocks were made and the norms were calculated. Analyses of three other granites are given, for comparison with the results obtained.

TABLE IX

Biotite-Hornblende Orthogneiss

	L16-27	L48-95	I	II	III
SiO ₂	71.16	65.95	73.79	73.13	71.37
TiO ₂	0.23	0.31	0.39	0.42	0.30
Al ₂ O ₃	16.01	15.51	11.83	16.07	14.47
Fe ₂ O ₃	0.56	1.19	0.72	0.04	tr.
FeO	1.03	1.87	4.18	0.96	2.31
MnO	0.14	0.06	0.07	-	tr.
MgO	0.60	2.24	0.62	0.43	0.93
CaO	2.64	5.24	2.21	2.11	2.26
Na ₂ O	5.52	4.48	3.94	4.57	4.77
K ₂ O	1.34	1.46	0.85	1.80	2.38
Li ₂ O	-	-	-	-	-
P ₂ O ₅	0.06	0.12	0.09	-	0.16
H ₂ O (+)	0.66	0.85	0.90	0.70	0.50
H ₂ O (-)	0.03	0.03	0.40	0.19	0.60
CO ₂	0.08	0.38	-	-	-
S	0.01	0.02	tr.	-	0.08
SrO	0.08	0.08	-	-	-
BaO	0.07	0.08	-	-	-
V ₂ O ₃	0.01	0.04	-	-	-
Cr ₂ O ₃	-	-	-	-	-
CuO	-	-	-	-	-
NiO	-	-	-	-	-
PbO	-	-	-	-	-
ZnO	-	-	-	-	-
CoO	-	-	-	-	-
ZrO ₂	0.04	0.01	-	-	-

TABLE IX (cont'd)

<u>Norms</u>	L16-27	L48-95	I	II	III
Quartz	27.40	21.27	38.93	33.89	29.01
Orthoclase	7.93	8.70	5.02	10.66	25.40
Albite	47.10	38.30	33.43	38.80	36.01
Anorthite	12.40	17.90	10.97	10.49	4.07
Diopside	-	4.30	-	-	-
Hypersthene	2.80	5.70	8.01	21.34	3.24
Olivine	-	-	-	-	-
Magnetite	0.80	1.80	1.04	0.04	-
Ilmenite	0.40	0.60	0.75	0.79	-
Apatite	0.10	0.30	-	-	-
Calcite	0.20	0.90	-	-	-
Corundum	0.90	-	0.29	2.74	1.35

Modes (Volume)

Oligoclase	81.40	80.26			50.00
Microcline	1.40	-			13.00
Quartz	8.80	9.31			29.00
Biotite	8.20	6.33			7.00
Muscovite	0.20	-			0.10
Epidote	-	1.40			
Calcite	-	1.40			
Apatite	tr.	tr.			0.40
Hornblende	-	1.30			
Magnetite	-	tr.			tr.

L16-27 - Biotite granite gneiss from Cazeneuve township, Quebec. F. Claisse and F. East, analysts.

L48-95 - Biotite granite gneiss from Ducharme township, Quebec. F. East and H. Boileau, analysts.

I - Granite (albite granite) from Duprat township, Rouyn-Noranda Co., Quebec. W.H. Herdsman, Glasgow, Scotland, analyst. Ref. G.S.C., Memoir 229, p. 35, 1941, M.E. Wilson.

II - Granite from Lake LaMotte, LaMotte township, Abitibi-East Co., Quebec. G.W. Bain, Columbia University, New York, analyst. Ref. Journal of Geology, Vol. 33, p. 738, 1925, G.W. Bain.

III - Granodiorite from Indian Point, Kewagama lake, LaPause township, Rouyn-Noranda Co., Quebec. W.H. Herdsman, Glasgow, Scotland, analyst. Ref. R.S.C. Trans. 31 (4), p. 156, (1937), W.C. Gussow.

TABLE XRosiwal Analyses of
Biotite-Hornblende Orthogneiss (Volume)

Specimen No.	L 1-2	L 18-19	L 41-62	L 46-75	C 50-70	C 58-87
Plagioclase	68.73	59.28	69.2	65.5	66.46	73.30
Microcline	17.18	10.16	2.4	-	4.95	8.58
Quartz	4.45	22.35	17.4	18.7	19.02	13.30
Hornblende	tr.	-	-	4.5	4.49	2.30
Biotite	7.84	8.19	8.5	8.0	5.05	1.25
Muscovite	0.40	-	2.4	0.5	-	-
Clinozoisite	-	tr.	-	2.3	tr.	0.45
Scapolite	-	-	-	-	-	0.80
Allanite	-	-	-	0.5	tr.	-
Apatite	tr.	tr.	tr.	tr.	tr.	-
Opaque	0.30	-	-	-	-	-
Sphene	-	-	-	-	tr.	-
Calcite	1.06	-	-	-	-	-
Plagioclase Composition An%	27	27	32	31	29	31

Origin

The rocks described in this section include the following varieties: quartz diorite, syenite, albite granite and pegmatite. These rocks except for the pegmatite and most of the albite granite are either massive or have a marked gneissic structure. They can be divided into two groups: an intermediate group including quartz-diorite and syenite, and an acidic group represented by albite granite and pegmatite. The relationship between these two groups is not a simple one. In places the albite granite and pegmatite cut into the rocks of the more basic group, elsewhere they grade into them. No essential difference in composition, appearance, structure, and

texture was found between the acidic group and the intermediate group. Consequently, all the intrusive rocks of the area were mapped as one unit. The more acidic varieties of granite, however, appear to be facies of an earlier granite here grouped in the intermediate division. They are the product of the same magma that produced their counterpart, and are a later differentiation product.

In the field these quartz diorite-syenite rocks were referred to as grey granite gneiss because of their characteristic grey color and generally marked gneissic structure. These gneisses are composed essentially of feldspar, quartz, biotite and hornblende, with clinozoisite and chlorite. In most of the rock biotite is the dominant mafic mineral, although in places biotite and hornblende are equally abundant, and locally the latter exceeds biotite. Gneissic structure is generally well developed. Rarely is the rock massive, though in the finer-grained specimens the gneissic structure is not everywhere obvious.

In some exposures the quartzose rock grades into syenite. This was observed only locally, but it could not be mapped as a separate entity, as most of the time one end of the outcrop will contain much quartz whereas the other end will be quartz-free. The syenite is a medium- to coarse-grained rock, with many crystals as much as 5 or in some places even 8 mm. in diameter. Pink feldspar and hornblende are the only essential constituents, and quartz and clinozoisite are the accessories. It is mainly an hornblende syenite.

The albite granite underlies much of the areas studied. This granite is massive, medium-grained, pink to red on the fresh surface and light pink to grey on the weathered surface. The content of mafic minerals is lower than in the quartz diorite. The structure is gneissic with bands of quartz alternating with feldspar rich bands. Clinozoisite also forms layers parallel to the structure. The grain size is about 1 mm., but some grains are as much as 3 mm. in diameter. The rock is well jointed and some of the joints are filled with quartz.

The fine-grained biotitic facies of the rock strongly resembles some non-garnetiferous massive facies of the biotite paragneiss, and it is possible that some exposures of one type have been attributed to the other variety, especially where the gneiss is more or less composite. However, the more calcic and fresher plagioclase, the iron-rich biotite, the absence of potassic feldspar, and the greater evenness of granularity of the paragneiss are criteria for distinguishing between the two varieties of rocks.

The gneissic structure and the shear zones around the masses of granite are parallel to the contacts with the intrusive. Apophyses of granite and veinlets of quartz and epidote projecting into the country rocks are very common. The country rock around the granite has been altered by contact metamorphism, and the place of hornblende garnetiferous gneisses has been taken by amphibolites. All these relationships suggest that the lava flows and the sedimentary rocks near the

western end of the Ducharme-Mignault map-area have been intruded by but not extensively replaced by the granite. The granite therefore is of magmatic origin. It must be pointed out, however, that the contact metamorphic effects on the greenschists and on the sedimentary rocks are neither widespread nor intense.

In the main granite mass, many exposures have remnants of the volcanic and sedimentary rocks. However, in some outcrops the nature of these mixed gneisses so formed is not easily determined. The mineralogy and chemical compositions of certain of these rocks suggest either a magmatic or a metamorphic origin. The high percentage of mafic minerals, especially hornblende, the absence of quartz, and the high content of potash feldspar and of garnet are features that, where found together, are suggestive of rocks of composite origin.

The gneissic structure in some parts of the main granite mass is very irregular. In nearby areas, Gilbert, Deland, and Neale have inferred that this complex gneissosity was caused by deformation rather than by post-consolidation movement or by movement in a magma.

The two new analyses of orthogneiss allow a comparison of the composition of the rocks with those of the Keewatin and Grenville districts. The comparison between the two districts based on the published and unpublished analyses in Quebec has been made by Osborne (1957). He has shown that the rocks of the Keewatin province, when plotted on a triangular

diagram with the vertices showing molal albite, anorthite, orthoclase, fall in the third of the triangle near the albite vertex, although some scattering of the rocks into the part of the triangle away from the vertex is apparent. Many of the analyses are of rocks from small stocks associated with gold mineralization. Extensive areas of granite are poorly represented. (See Plate I and II).

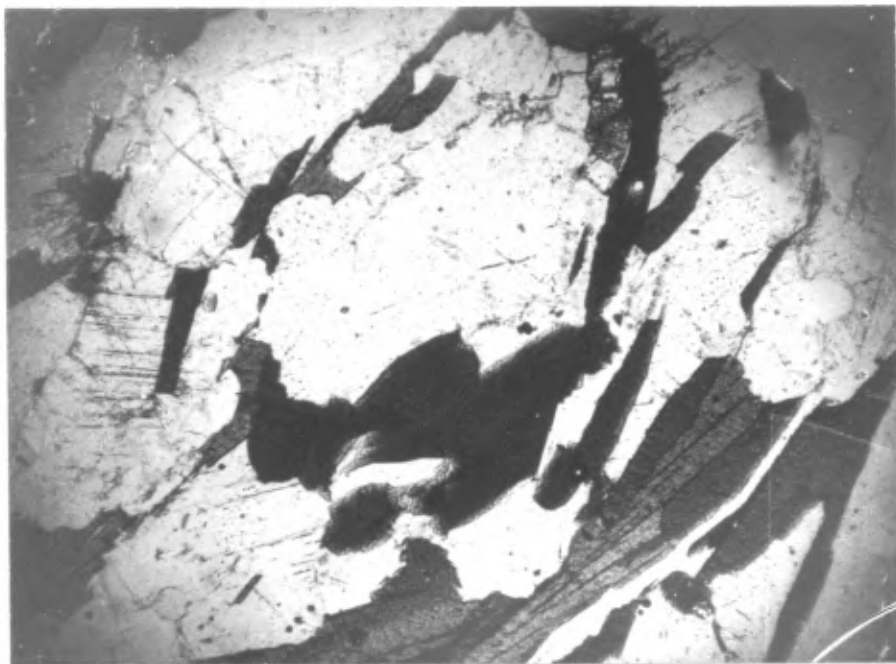
Pegmatite

The granite complex is invaded by numerous irregular bodies and dykes of pegmatite. The irregular bodies are thin, but the dykes are as thick as 10 feet. The contacts of the pegmatite with the other bodies is very sharp.

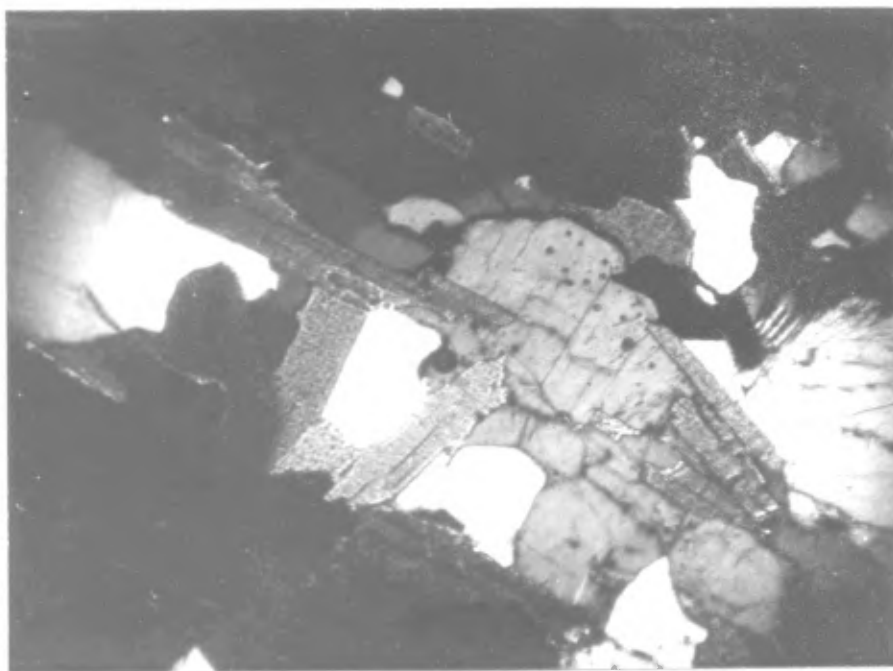
The pegmatite cuts the orthogneisses as well as the paragneisses. Much of the rock is pink and coarse-grained, with feldspar crystals as much as two inches long. It consists mainly of feldspar and quartz with minor amounts of dark minerals such as biotite and magnetite. Good examples of the dykes may be seen on Nicabau lake about a mile and a half north of the Laurentian Forestry Protective Association camp on the eastern side of the lake and also on the Chibougamau highway near mile post 101. A good example of the sheet-like form may be seen on the southwest side of Chamouchouane lake, where crystals of magnetite as much as one inch across may be found.

Examination under the microscope shows the rock to be composed of 60 per cent plagioclase, 30 per cent quartz, and 10 per cent microcline. Muscovite, biotite and magnetite

PLATE IV



A. Biotite-plagioclase orthogneiss. Natural light, X36



B. Biotite-plagioclase orthogneiss. Crossed nicols, X36.

1H 0027
pool

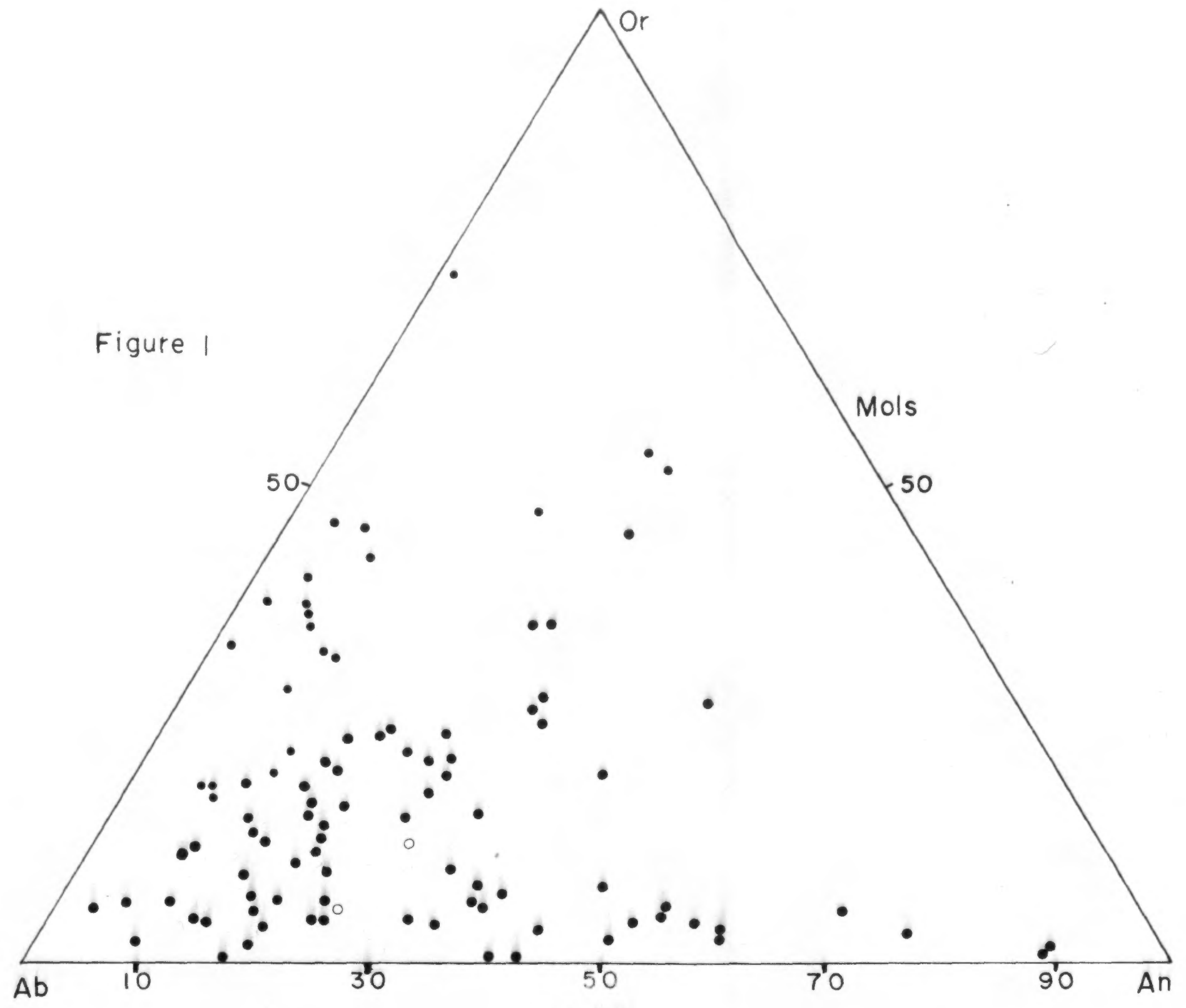
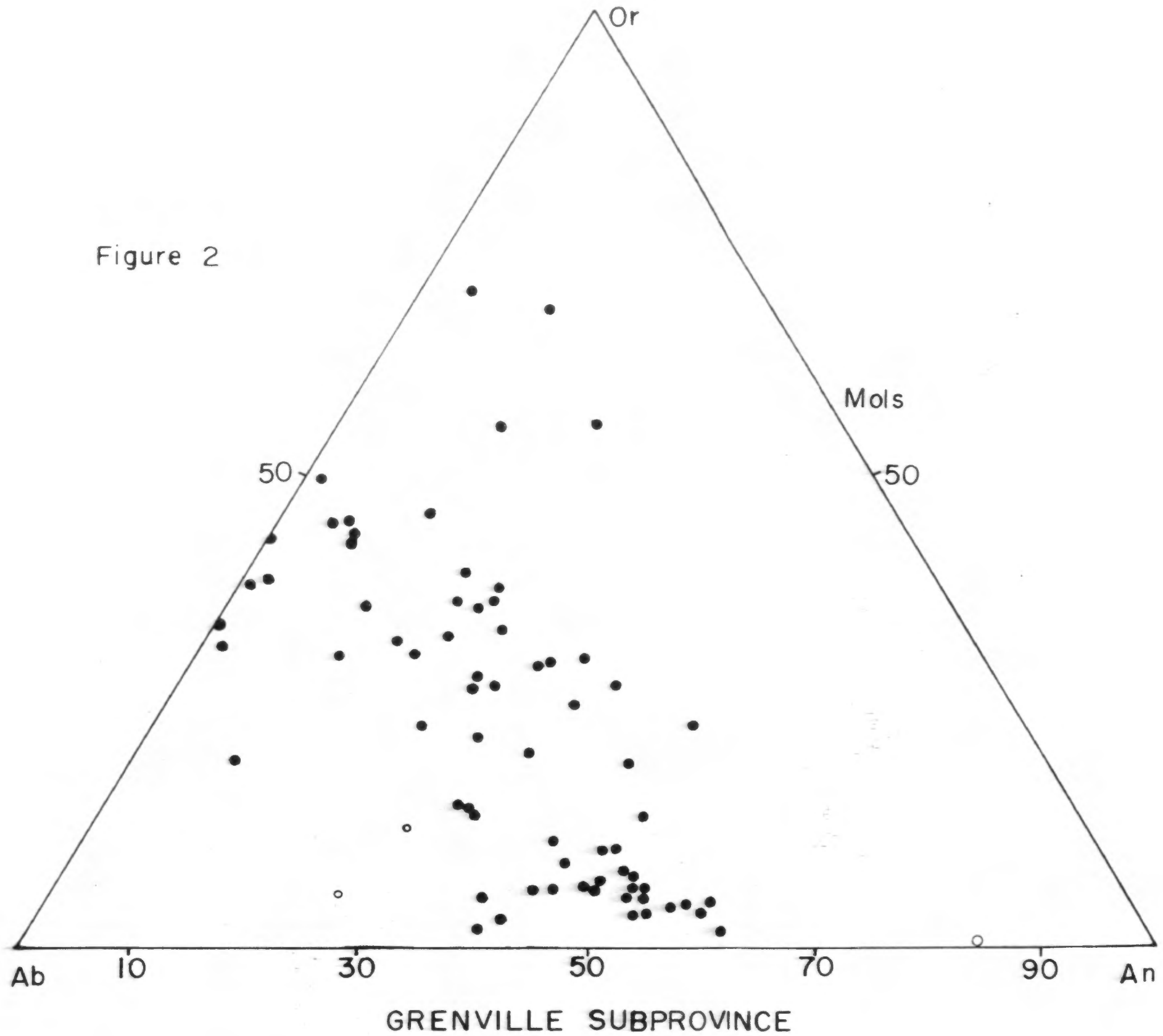


Figure 1

○ - Ducharme-Mignault

Figure 2



o - Ducharme - Mignault

were found as accessory minerals. The texture is somewhat cataclastic with granulations common near the grain boundaries and with strained grains of quartz. Plagioclase and quartz commonly form intergrowths giving rise to micrographic texture.

The pegmatites associated with the granitic rocks are massive and cut across the gneissosity of the granite. Whenever found in the granite as well as in the country rocks, they have sharp contacts and cross-cutting relations. Because of their occurrence and composition, the pegmatites of the area are believed to be of magmatic derivation.

Basic Dykes

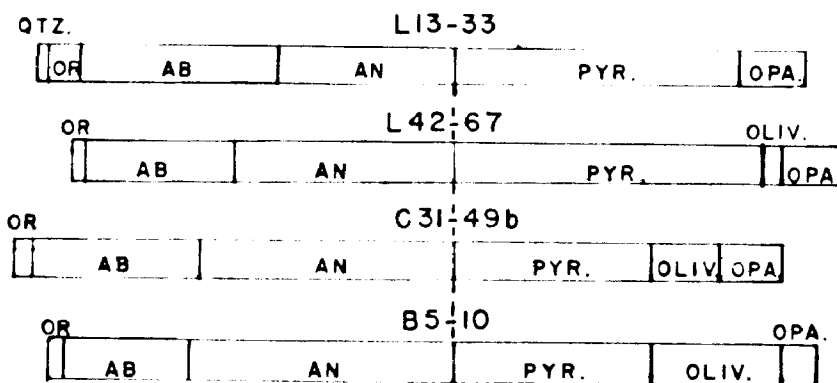
A few thin dykes of lamprophyre occur in the area. Most of them are in areas of extensive outcrop of injection gneiss. They do not exceed a thickness of one foot and cut both orthogneisses and paragneisses. The best examples of these were seen on the south shore of Marcel lake and on the bank of Normandin river on the west side of the big bend. They are associated with the coarse-grained, diabasic variety of basic dykes discussed by Gilbert (Ms.) in the Rohault area, and it is quite possible that all the basic dykes are magmatically related. The lamprophyre dykes are black, very fine-grained, porphyritic rocks in which the phenocrysts are pyroxenes, amphiboles, or biotite. They are quite fresh compared to the metagabbros.

HISTOGRAM

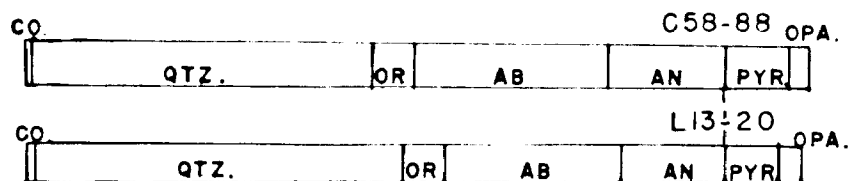
SALIC %

FEMIC %

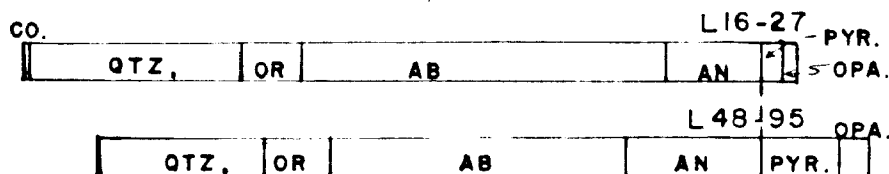
HORNBLENDE GARNETIFEROUS GNEISS and METAGABBRO



BIOTITE PARAGNEISS



GRANITE ORTHOGNEISS



Based on Normative Mineral Composition

Glacial Geology

The area was completely covered by the Pleistocene ice sheet the passage of which left, however, few striking destructive or constructive features.

Glacial striae and a few chatter-marks were seen along the shores and on the islands of the many lakes of the areas. They indicate that the last movement of the ice sheet was S.10°W. to due south.

In general, the mantle of overburden is rather thin near the hill tops. In the low areas, glacial till is abundant enough to support a thick stand of various evergreens. It is reported by Riverside Chibougamau Mines Limited that the overburden is 100 feet thick on their property; however, it is quite probable that this is near the maximum thickness of the Pleistocene, but there is no evidence to prove that it cannot be thicker locally.

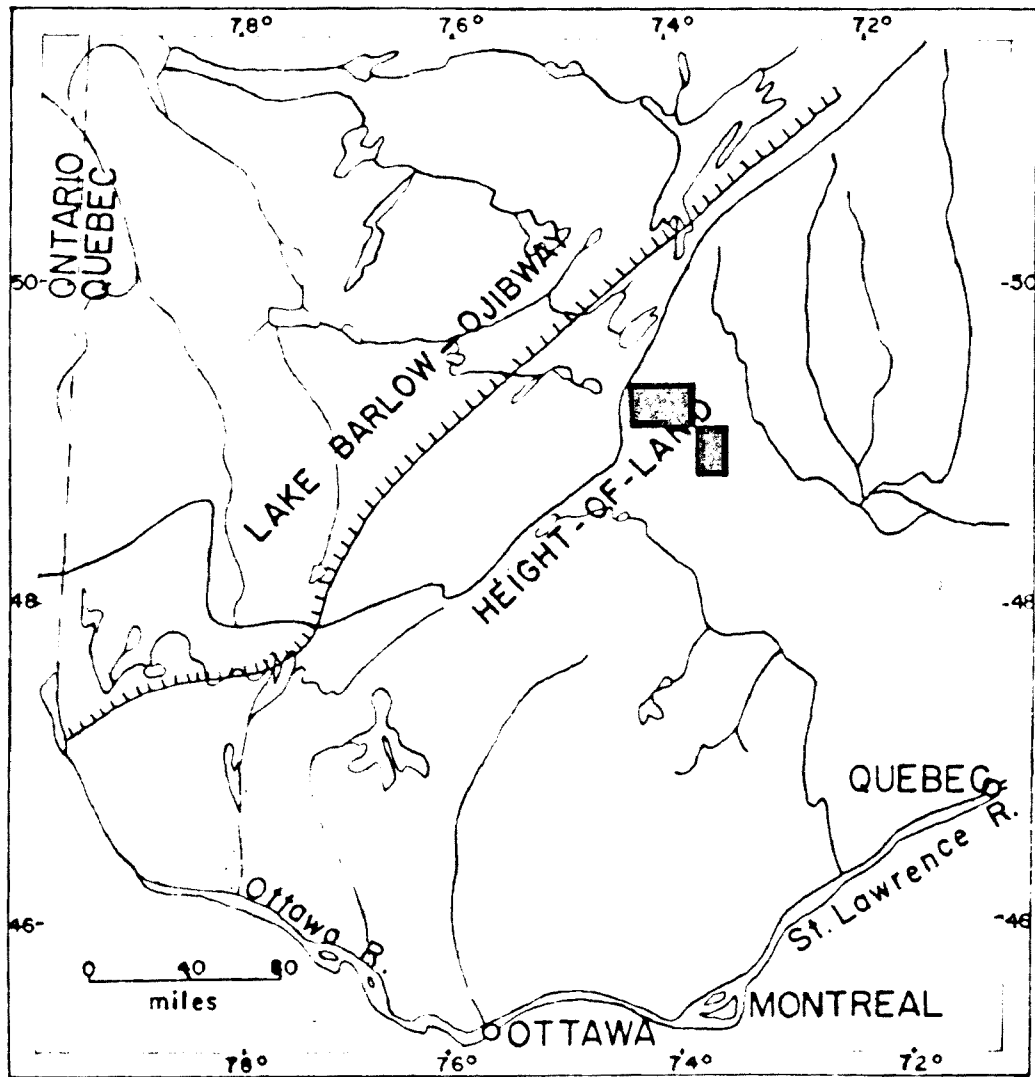
Most of the large boulders of the till are of local origin, and it is believed safe to assume that over 80 per cent of the large erratics are derived from bedrock less than half a mile away. However, locally erratic boulders of cryptozoan limestone of the Mistassini series, and hematite blocks of the Albanel iron formation were found in the area. Their direction from source conforms with the direction indicated by glacial striae.

The glacial material consists mostly of till with material ranging from boulders to fine silt. In places, sorted

material such as boulders, gravel, sand and clay forms accumulations, but these are rare and of small extent in comparison with the unsorted drift.

Fluvio-glacial deposits include unstratified and varved clays, and eskers. Unstratified clays are scattered throughout the area, but they are rare. These are not covered by younger drift. Varved clays were seen in the area mainly on Normandin river. In most places they are topped by cross-bedded fine-grained sand.

Eskers are common in the area. They are composed of silt, sand, and gravel, and do not show a good sorting. The sinuous ridges trend southwards to southwestwards. Most of them are more than 60 feet high and 100 feet wide at the base. The slopes of these ridges are fairly steep, being about 40 to 45 degrees. Two of these eskers have an over-all length of about 10 miles. The eskers like most other glacial features are best studied from aerial photographs.



Map.2- Location of area in relation to height-of-land (Antevs, 1925, fig.27) and shore of former lake Barlow-Ojibway (Dresser and Denis, 1946, fig.2).

STRUCTURAL GEOLOGY

The examination of the geological maps of regions near these shows the difficulty of interpreting the structure. There is little agreement between adjacent maps even as to the trends of formations. In many areas, the trends of the formations are not obviously related to the strike of the structures. Furthermore, the absence of exposures at many critical localities is a handicap in mapping. In the area west of the present ones Gilbert (Ms.) has chosen to extrapolate the formations along the strike of the gneissic structures and as a result has inferred several folds to explain the structure. The mapping of the present area has shown a pattern that is somewhat less complex than that mapped by Gilbert, but at the same time there is little evidence for folds, even those shown on the map.

The granite orthogneisses and some of the injection gneisses have an igneous habit and, therefore, may be to some extent independent of the structure of the enclosing rock.

Because of the way in which the biotite-plagioclase gneisses and the hornblende-plagioclase gneisses originate, the distribution of the two rocks, although they are mapped as formations, does not give a true picture of the structural relationships.

The axes of minor folds trend northeast and, with one exception, plunge from 60° to 90° southwest. This may be a small scale model of the structure of the area but this is only an inference.

The examination of the map of the area however suggests an explanation. Outcrops are irregular in habit; in many places, they are sigmoid, and furthermore formations do not extend far. The inconsistencies of the structure suggest that this region has been deformed by stresses operating in different directions at different times. Furthermore, the considerable amount of granitic material in the region suggests that at least the last deformation took place when rocks were plastic.

Shear Zones and Faults

Several shear zones were seen in the area, a prominent one west of Aigremont Inn on the south side of Aigremont lake has a strike of N.25°E. and dips 75° southeast. In the northern part of Ducharme-Mignault map-area, near Brassard lake, shear joints striking about north and dipping from 85° east to vertical were noted, although they are not abundant. In Lorne-Avaugour map-area, a few shear zones were noted along the Chibougamau highway, but all of them are insignificant.

A few small faults were seen in the orthogneisses, one on the west side of d'Argenson lake has a strike of N.10°W. and dips vertically. Most of the other faults have an apparent displacement of only a few inches and strike northeast.

Relationship between Folding of the Keewatin-type Rocks and the Structure of the Grenville-type Gneisses

In this section on structural geology it is suggested that the area has been folded twice or more. The suggestion of two episodes of folding is consistent with the history of the area. Examination of the general map shows that rocks of the Keewatin-Timiskaming sub-province strike east. The east trend terminates along a rudely defined zone with a northeast trend. Southeast of the termination of the east striking rocks, granitic rocks are abundant and the strikes within these are northeast.

The meta-sedimentary and meta-volcanic rocks of Keewatin-Timiskaming sub-province are traceable along strike into more metamorphosed rocks that gradually lose their identity in the granites. There is little doubt that the northeast-striking structural zone is younger than an east-west folding. The actual transition zone is not completely shown in these areas, but the data from nearby areas supplement those available in the area.

Deland (1955) in Lake Surprise area found that the belt of Keewatin-type rocks strikes easterly; Gilbert (Ms.) in Rohault area shows a more complex structural trend but in many places the general strike is eastward. Neale (Ms.) shows an east-west structure for the Keewatin-Timiskaming-type rocks with a gradual change towards a northeast strike as the transition zone is approached. In the present areas although the general trend of the formations is still eastward, most of

the strikes are erratic, many of them being northwest to north or northeast. In the transition zone the rocks, namely granitic gneisses, strike from 15° to 20° north of east or northeast, except near dome-shaped structures.

This change from the easterly trend of the Keewatin-type rocks to the northeasterly trend of the transition zone of the Ottawa gneisses has been interpreted as a superimposition of northeasterly mountain structure on the already east-west trending folds of the Superior province.

AGE RELATIONSHIPS AND CORRELATION

Because of the location of the areas the problem of correlation is difficult. Rocks belonging to one division of the Canadian Shield pass into another division, and in view of the fact that the nomenclature of the units in the different divisions is not only different but also in either sub-province is inconsistent, it is necessary to give a brief statement of the meaning to be attached to the names of formations. However in a measure, the names used must be determined by the inference adopted by a worker concerning the nature of the boundary between the divisions.

The correlation as used in this report has no time implication but merely represents the equivalence of rock units on the basis of lithology. The distinction between the terms Keewatin and Keewatin-type and between the terms Grenville and Grenville-type has been discussed previously in this report. The term Keewatin-type is applied to those rocks of the Ducharme-Mignault map-area possessing characteristic features of the Keewatin-type assemblage of the Timiskaming sub-province, and the gneisses, which underlie much of the rest of the map-area, are similar to some of the rocks that have been described as typical of the Grenville sub-province.

The criteria used in correlation are lithologic similarities, degree of metamorphism, and physical continuity. These criteria are not held in high esteem by stratigraphers, but such criteria are nevertheless the only means available to

geologists working in unfossiliferous and metamorphosed terrains of Precambrian. Because of such uncertainties, the correlation is tentative.

History and Nomenclature

The term Keewatin was first used by A.C. Lawson in 1885 in the Lake of the Woods district for volcanic rocks of which even today the structure is not known. The term has since been used to describe any old appearing assemblage of mainly volcanic rocks in much of the Canadian Shield. As an example of the use of the name, Cooke, James and Mawdsley in 1931 correlated some lava flows and sedimentary rocks of the Rouyn-Harricana region in Quebec with those found by Lawson. In the present areas Keewatin is applied to hornblende-plagioclase-garnetiferous gneisses.

The term Timiskaming was first used by W.G. Miller in 1911 as a result of his work near Lake Timiskaming. He applied it to a series of Archean sediments unconformably overlying lava flows. This term never gained the widespread usage that Keewatin did, and stratigraphic relationship of Timiskaming to Keewatin is still not perfectly known. The term Timiskaming-type has been used for sedimentary rocks intimately associated and seemingly in conformable contact with a Keewatin-type volcanic series. Because of these facts, the use of the term Timiskaming in the present areas is not warranted.

The term Grenville was first used by W.E. Logan in 1863 to describe a thick series of metamorphosed sedimentary rocks associated with igneous rocks that he found in Grenville township of southern Quebec. Most mapping done before 1939 was

of isolated areas. M.E. Wilson (1939), with the then available information, in his paper on the Canadian Shield, tried to locate the western boundary of the Grenville sub-province more accurately than heretofore. Among the rocks typical of the Grenville series are coarsely crystalline limestone, quartzite, garnetiferous and sillimanite paragneisses, hornblende gneisses and amphibolites. Anorthosite and gneissic granite form conspicuous masses within the Grenville rocks. Dresser and Denis (1946) have divided the Grenville sub-province into four different regions, one of which is a border zone bounded on the northwest by the Timiskaming sub-province. The northwestern part of the Ducharme-Mignault area is within this border zone.

Most of the terms previously discussed have not been applied as such in this report, because they imply a specific correlation with the type localities for the various formations or series, but the terms Keewatin-type, Timiskaming-type and Grenville-type have been used as they rather indicate lithologic similarities.

Correlation with Nearby Areas

In the Table of formations the author has not used any of these terms, but if he had to do so, he would use the terms Keewatin-type for both the hornblende-plagioclase-garnetiferous gneisses and the amphibolites, and the biotite-plagioclase gneisses, and Grenville-type for the higher grade gneisses.

The author has not used the term Timiskaming for the biotite-plagioclase paragneisses as previous mapping of these meta-sediments by Mawdsley and Norman (1938) indicates

that these rocks are in part probably younger than Keewatin, but in part possibly Keewatin.

The areas with which this report is concerned do not lie across the contact zone between the two sub-provinces, but the northwestern corner of Ducharme-Mignault area is within a mile or so of the contact with the Timiskaming sub-province. The author has not seen in this area a true gradation from one side of the zone to the other side. However, while mapping with Neale in 1953, he was able to observe that gradation, and the same observations were made by Gilbert in the Rohault area (Ms.) where volcanic rocks of Keewatin aspect grade into amphibolites that continue into the present areas where they grade into garnetiferous feldspar rock. No faulting or definite break has been noted where this gradation in passing from one sub-province to the other has been observed.

Cooke (1919), for the area to the west, set up the Nemenjish series to include certain schistose rocks that were later regarded by Mawdsley and Norman (1938) as equivalent of Keewatin and Timiskaming meta-sedimentary rocks such as crop out to the northwest. Cooke believed these rocks to be the northern equivalent of the Grenville series. He bases his tentative determination on petrography, the main point being that most beds are highly garnetiferous, and he concludes:

"Garnetiferous types, usually garnetiferous hornblende schists, occur locally in the altered basic lavas, often termed "Keewatin", and also in the Mattagami series..... The writer therefore considers this criterion as a reliable one for correlation purposes, until it shall have been shown that another formation with similar bulk characteristics exists in the Pre-cambrian shield."

In the areas here described, the hornblende garnetiferous gneisses and the biotite paragneisses could be the extension of the Nemenjish series. The mafic-rich hornblende gneisses of the area, including garnetiferous varieties, are more than possibly derived from rocks that were basaltic or andesitic, in other words, some of the rocks were Keewatin-type volcanics. In addition, some rocks referred to as paragneiss may be the result of alteration of gabbro. However, it is a matter of doubt whether all the meta-sedimentary rocks are of the same age. These biotite paragneisses could be the metamorphic equivalent of Timiskaming-type sediments. On the compiled map accompanying this report, one is able to follow the gradation from biotite paragneisses into feldspathic sediments in the Lake Surprise area (Deland, 1955).

Cooke (1919) in his report on the Nemenjish series mentioned that the series rests conformably on the lavas, but the author while mapping with Neale in 1953 found a garnetiferous basal conglomerate that compares with the ones found by Cooke in the Brock area and in the Lucky area. This conglomerate was found in Dollier township about 3 miles from the contact zone of the two sub-provinces. The matrix of the conglomerate exposed on Conglomerate lake is similar to that of some of the garnetiferous biotite-muscovite schists and gneisses that crop out on Au Couteau lake. This suggests that the schists and gneisses may belong to the same sedimentary sequence as the conglomerate, and unless overturned the southeast dipping conglomerate beds underlie the schists and gneisses. Neale, in his description

of the conglomerate, says:

"The matrix and the sandy lenses within the conglomerate on the Dollier-Lemoine line are petrographically similar to the "Timiskaming-type" sedimentary rocks that crop out around Stella lake and Wynne creek. This fact, together with the proximity of these rock units, suggests that they may be approximately equivalent in time. The objection to this correlation is that, in adjacent areas, the "Timiskaming-type" sedimentary rocks are interpreted as older than the Chibougamau intrusive complex (e.g. Mawdsley and Norman, 1935). However, the term "Timiskaming-type" refers to a great variety of clastic sedimentary rocks whose only common feature is their low, greenschist grade of metamorphism".

Neale (Ms.) found petrographic evidence showing that the garnetiferous conglomerate passed through such a greenschist stage. Therefore it was once a Timiskaming-type rock. It is quite reasonable to infer that the Nemenjish series as stated by Cooke (1919) is not resting conformably on top of the lavas, but unconformably.

As stated previously in this report, it is difficult to separate the two sub-provinces, one of the main reasons being the absence of the three most characteristic types of rocks found in the type locality of Grenville, namely: crystalline limestone, quartzite, and sillimanite gneiss. However, the hornblende garnetiferous gneisses, the amphibolites, and the biotite paragneisses of the areas under discussion are quite common in the Grenville sub-province and they are considered to be of Grenville aspect. Many workers, e.g. Deland (1955), Gilbert (1952), Imbault (1951), and Neale (1954), in the surrounding areas have considered similar rocks to be Grenville-type. The term Grenville, in this report, is not applied to

these gneisses mainly because of the strong evidence that these gneisses represent at least in part metamorphosed Keewatin (?) or Timiskaming (?) rocks.

The author would correlate the hornblende-plagioclase gneisses and the biotite-plagioclase gneisses with Cooke's Nemenjish series, because of the basal conglomerate found by Neale in 1953, and some lithologic similarities between the two units. It is then concluded that the hornblende-plagioclase gneisses and the biotite-plagioclase gneisses are Timiskaming-type although they are of Grenville aspect.

The correlation of the metagabbro with rocks of nearby areas is somewhat uncertain. Nevertheless it is quite possible that the masses of metagabbro shown on the map are simply relics of much larger masses. In view of the fact that intrusives such as the Bell River, Opawica, and Chibougamau are of the stratiform complex type, it is very reasonable to infer that some of the gabbro, and the anorthosite are co-magmatic, meaning that they were formed as a differentiate of gabbroid magma under suitable conditions. As suggested by Allard (1956) they antedate the major deformation of the Keewatin-type rocks.

In this area metagabbro is not in contact with any sedimentary formation for their age to be closely determined. However, first of all the fact that some of it has been altered into hornblende garnetiferous gneisses, plus the presence of coronas in the gabbro along with the clouding of the feldspars (Poldervaart, 1954) may be considered as evidence that the metagabbro antedates the granitic orthogneisses of Grenville aspect.

Correlation of the Granitic Gneisses

It is difficult to date the granitic rocks of the zone of Ottawa gneisses. In so far as the present areas are concerned, it is reasonable to infer that there was one principal time of intrusion although the magmatic cycle may have persisted for a long time. Inclusions of Keewatin- and Timiskaming-type rocks as well as metagabbro are found in the granite gneisses. Furthermore, as stated previously, the gneisses truncate the east-striking structure of the Keewatin-Timiskaming rocks which were therefore folded before the Ottawa gneisses were introduced. Because of the intimate relationships of the secondary structure in the rocks of greenstone grade to the axes of folding the Keewatin-Timiskaming rocks were metamorphosed to greenstone grade before the Ottawa gneisses were emplaced.

An alternative to trying to date the paragneisses and metagabbro is to attempt to date the orthogneisses. At present the direct dating of such rocks must be by physical methods but it is possible to examine whether the gneisses belong to any sequence of intrusives recognized elsewhere. The two analyses of the orthogneisses, as shown on figures 1, 2, and 4, fall in diagrams of normative compositions on a field dominated by the Abitibi intrusive rocks. Most of the latter are in stocks emplaced after the folding of the Keewatin-Timiskaming rocks. The chemical relationships suggest that the stocks in the Keewatin-Timiskaming region are satellites of the granite gneisses to the south. Support to this inference

is given by the position of the analyses on the diagram (Figure 3) where they fall on the curve for the Chibougamau-Opémiska district.

Although the inferred relationships of the gneisses to the rocks of the stocks may be clear, the relationship to charnockitic rocks characteristic of the southeastern part of the Grenville sub-province is not known. Some evidence suggests that the gneisses of the present areas may pass to the southeast by increase of potassic feldspar into gneisses of similar aspect but of charnockitic affinity.

However, it is very difficult to place the time of intrusion in the geologic column. Radioactive dating is probably the only means at our disposition to date these intrusive rocks and even that means is somewhat inaccurate. Mawdsley and Norman (1938), while mapping in the Chibougamau district, placed the granitic rocks of their area as Archean and "possibly not all of one age". However, there is a strong possibility that these granitic rocks are much younger than Archean and should probably be placed in the Proterozoic.

The lamprophyre dykes found in the area are definitely the youngest consolidated rocks, as they cut the gneissic structure of the granite. The few dykes encountered during the mapping were rather fresh and seem to have been introduced after the formation of the gneisses. Imbault (1951), Gilbert (1952), Lyall (1953), and Deland (1955), who have mapped nearby areas, tentatively correlated the diabase dykes with the Keweenawan (?).

14 0027
9003

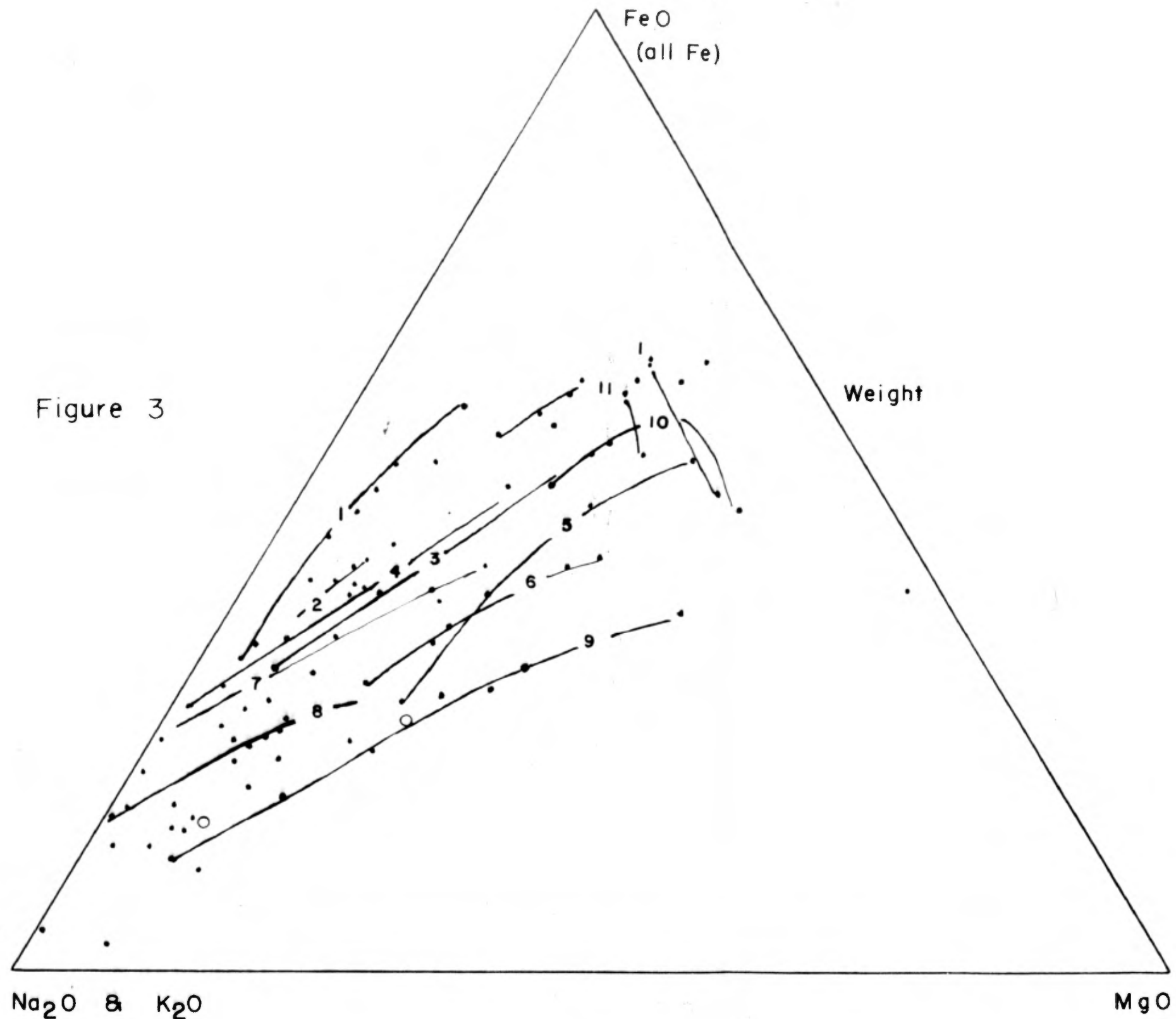
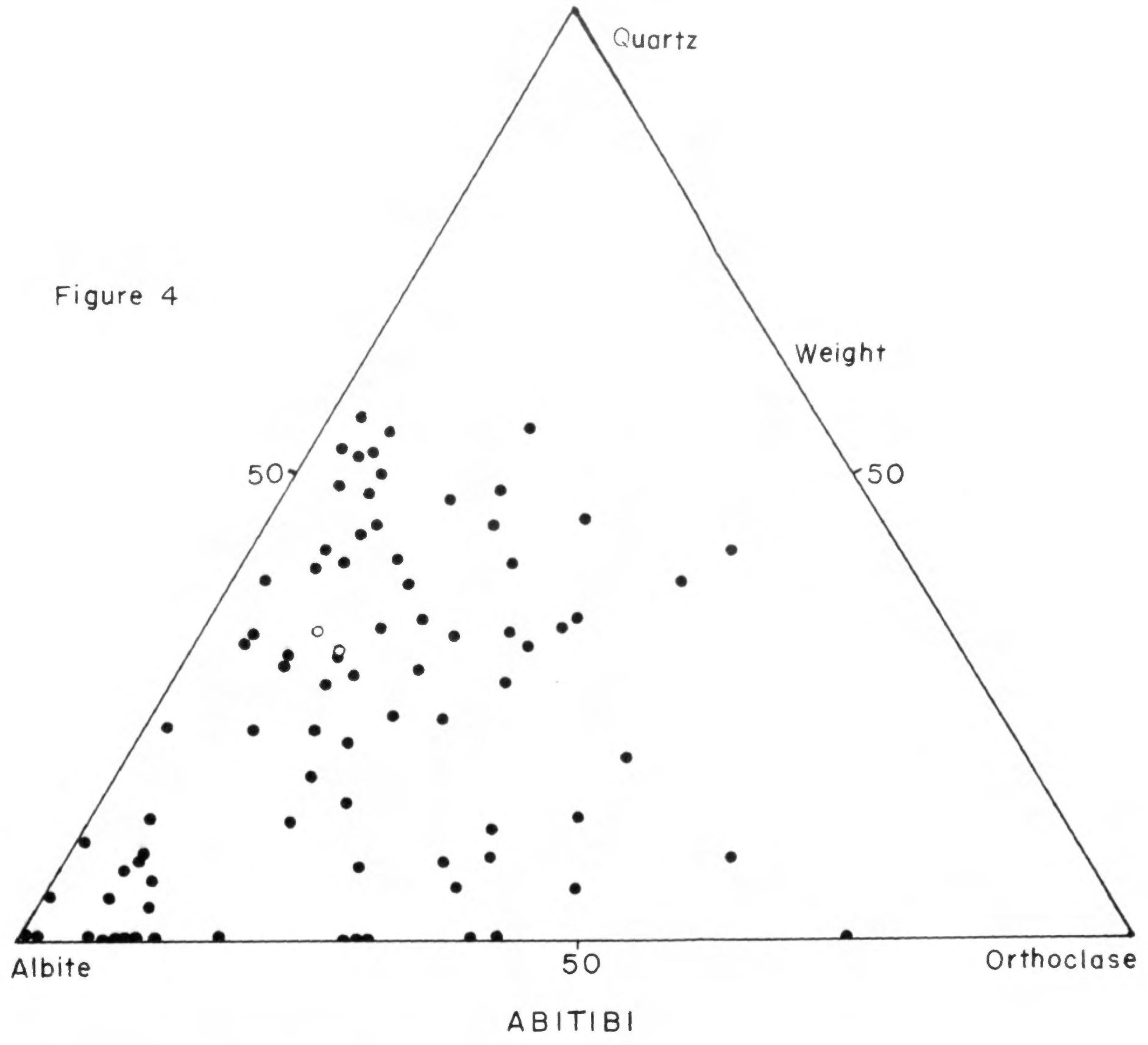


Figure 3

- 1- Pascalis - Tiblemont, 2 - Eldona, 3 - Palmarolle, 4 - **Taschereau**,
5 - MacDonald Mine, 6 - Lamaque Mine, 7 - Duvernay, 8 - Lamotte -
Lacorne, 9 - Chibougamau - Opemiska, 10 - Bourlamaque - Siscoe, 11 - Diorites -
Malartic, - Open circles - Ducharme - Mignault.

1H 0027
p004

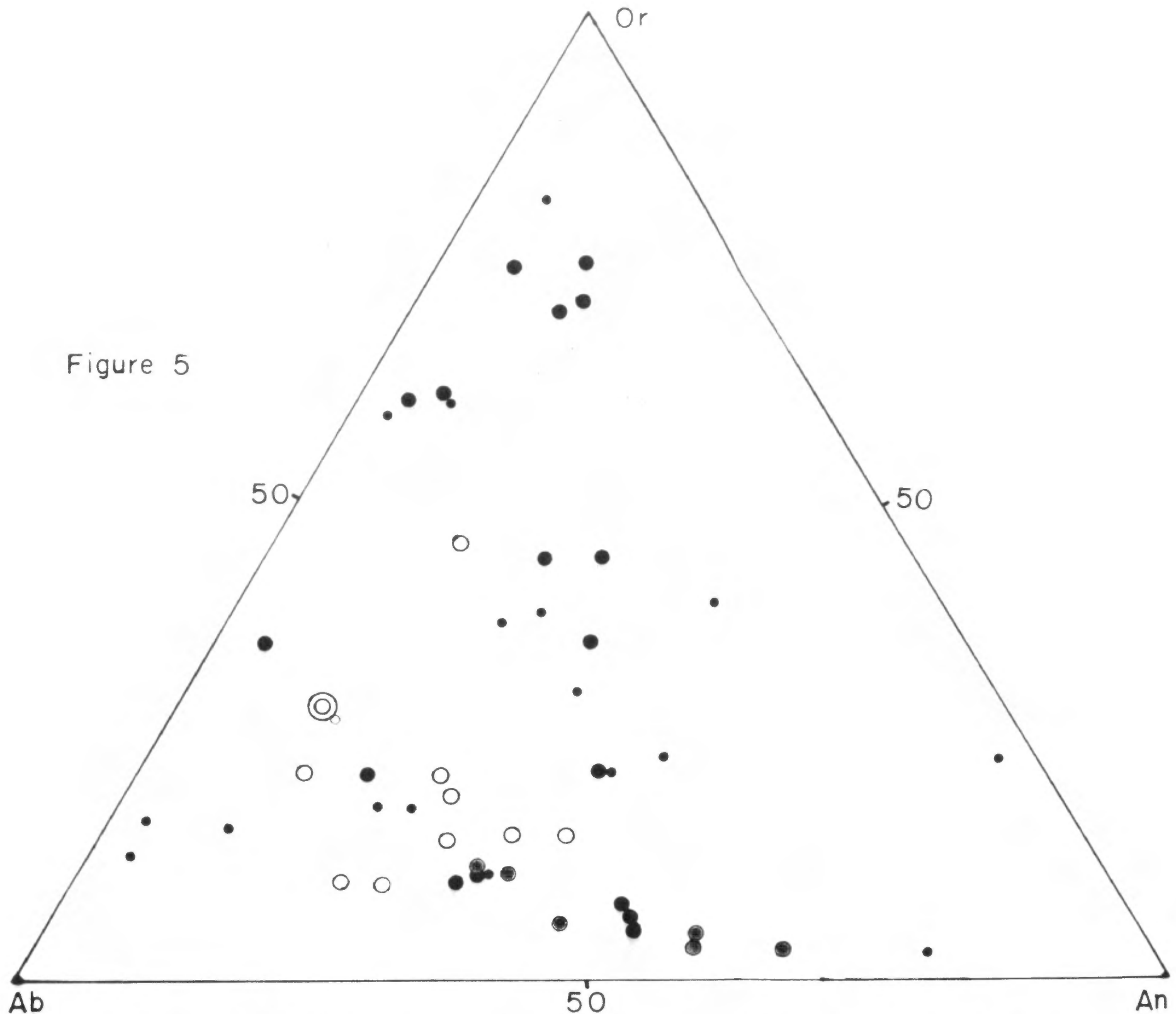
Figure 4



o- Ducharme - Mignault

1H 0027
9005

Figure 5



Small solid circles - "Keewatin volcanics". Large solid circles - Grenville paragneisses. Large open circles - Region between Grenville and Abitibi regions. Concentric circles - Adirondack paragneiss (QbA).

It is very difficult to place the boundary between the Keewatin-type and Grenville-type rocks in the areas under study as they do not straddle the immediate contact zone, but they are on the Grenville side of it. In the author's opinion there is a definite gradation between the Keewatin-type rocks and the rocks of Grenville aspect. This zone is quite wavy due to interfingering and is better exposed on Map C accompanying this report. All rocks seen by the author while mapping are of Grenville aspect as he included the zone of transition with the Grenville-type rocks, but somebody mapping from the other side of the contact zone might place the zone of transition within the belt of Keewatin-type rocks.

A number of Quebec Department of Mines reports, also show that in various places, that same gradation exists between rocks of the Timiskaming sub-province and those of the Grenville. Among them the following may be mentioned:

- 1) Lowther, 1936, Villebon-Denain Map-Area.
- 2) Wahl and Osborne, 1950, Cawatose Map-Area.
- 3) Gillies, 1952, Canimiti River Area.
- 4) Gilbert, 1952, Rohault Map-Area.
- 5) Neale, 1954, Dollier-Charron Map-Area.

ECONOMIC GEOLOGY

No prospecting is known to have been done in the area until four years ago, but by the fall of 1953 more than 55 claims had been staked near Aigremont lake. Since then, all but 15 of these claims have lapsed, 10 on the southwest side of Aigremont lake and 5 on the southeast side. No extensive mineralization was seen on the claims southeast of the lake. On those to the southwest, a quartz vein is found along a quarter-mile-long shear zone. This occurrence is in hornblende gneiss, and the shear and the vein strike northeasterly parallel to the gneissic structure of the rocks. The vein, which is about three feet thick at the highway and about twenty feet thick a quarter of a mile to the northeast, contains pyrite, malachite, and bornite. Of the few samples taken for assay the best analysis was \$0.03 of gold a ton, \$0.12 of silver a ton, 0.56 per cent copper, 0.01 per cent zinc, and 0.02 per cent nickel.

Another slightly mineralized quartz vein occurs in hornblende paragneiss on Normandin river at the head of the long rapid. This vein, which also parallels the gneissic structure has some pyrite and copper stains. This was observed on only one exposure.

Several very thin quartz veins containing a few cubes of pyrite up to one-quarter inch in size occur on Normandin river, at the big bend near the middle part of Ducharme-Mignault map-area.

About one mile and a half from the southern border of the same map-area, and one mile east of Scatsi river, traces of malachite and chalcocite were seen in a much weathered quartz vein.

Near the northwestern corner of this area, in an amphibolite layer next to the volcanics, disseminated pyrite was observed. The host rock is both carbonatized and silicified.

In the Lorne-Avaugour area, numerous pegmatite veins, some with scattered magnetite crystals, were encountered throughout the area. The best examples are on the south side of Chamouchouane lake near the western border of the area. Some loose blocks of hematite were found on the east side of D'Esglis lake. They may have been carried by ice from the region of Mistassini and Albanel lakes.

A local magnetic anomaly was found in the northeastern corner of the map-area, east of D'Esglis lake and half a mile southeast of Valois lake. The compass needle is deflected about 180° . A careful examination showed no rock that could account for the anomaly. At this locality glacial drift is very thick.

All rock specimens collected during the mapping were examined with a Geiger counter. Most of them give the usual very low background reaction but some specimens from exposures along Nicabau river give a reaction slightly above the average.

APPENDIXThe Grenville Front

In earlier sections of this thesis it was shown that the Keewatin-Timiskaming rocks are cut off by a belt of granite gneisses. For a long time after the traverse by Logan (1845) along Ottawa river it was believed that the granitic rocks belong to the Grenville sub-province; however, as suggested elsewhere and also in this thesis, the broad band of gneisses may be considered as a distinctive but separate part of the Grenville sub-province. However, since 1940 other interpretations of the relationship of the rocks of the Grenville and Keewatin-Timiskaming sub-provinces have been offered. Some of them, notably the hypothesis of a Grenville-front fault, have gained such currency that it is desirable to trace the history of the problem.

Logan noted the essential characteristics of the formations along the Ottawa in 1845. Towards the south he found the quartzites and crystalline limestones and paragneisses that he was later to call Grenville series, but northward he found increasing amounts of granitic and syenitic gneisses which finally at Temiscamingue lake terminated against rocks that he later called Huronian and many of which are now called Keewatin. T.S. Hunt (1878) gave the name Ottawa gneisses to the predominantly granitic rocks along Ottawa river. Logan's inferred general relationship of the rocks was considered satisfactory by

most geologists during the time that the main preoccupation of the Geological Survey of Canada was exploratory. By 1907 Adams had evolved the view that the belt of Ottawa gneisses was the roots of an old mountain range. Knopf (1955) comments that this was the first time that a younger Precambrian mountain-built zone was recognized. Morley Wilson gave the name Ottawa mountains to the belt in 1913.

Until about twenty years ago the problem does not seem to have received much attention. Geologists mapping across the zone found, in general, the same relationships as described in this thesis, viz that the granitic rocks intrude the older gneisses.

A conclusion adopted by many workers, particularly those who have not done fieldwork in the district under discussion, is that the boundary is a fault zone. The names "Huron-Mistassin fault zone" (J.T. Wilson, 1949) or "Huron-Mistassini thrust" (J.T. Wilson, 1949a) or "Grenville front" (Derry et al., 1950) have been used.

J.T. Wilson (1949), however, has offered a suggestion as to why the fault has not been recognized. He infers that such a fault has been injected by granites and so obscured. Quirke (1926) was actually the originator of such a suggestion and it was logical for Quirke and Collins (1930) to suggest that much of the granite is granitized Grenville. M.E. Wilson's (1956) own idea in this connection is adequate to show that a major thrust should not have been inferred.

Norman and Tiphane (1947) inferred a fault between the two sub-provinces in the Shamus map-area, but this was based on only one outcrop.

Some faults along the boundary between the Grenville and Superior provinces have been recognized. Faults of the magnitude inferred by some workers have not been recognized by Gilbert (Ms.) in the Bignell area, and Gilbert (Ms.) in the Rohault area states that he has not seen any indication of a major dislocation zone. Deland (1955), in discussing the Lake Surprise area, comes to a similar conclusion. Neale (1953), in the Dollier-Charron area, saw no major fault, but he reported a gradation from the Keewatin-type rocks into the Ottawa gneisses of the transition zone.

Norman (1940) found that the Proterozoic rocks of the Mistassini series are separated from high-grade gneisses by a fault. He inferred that the gneisses had thrust over the Proterozoic and commented that the fault is parallel to Logan's line.

Cooke (1947) extended that fault to Lake Huron, that is, about 350 miles. In recent years many areas have been mapped in Quebec along the inferred contact between the two sub-provinces and few observers have reported any evidence of faulting.

Gill (1948) who supports Norman's theory has expanded on it and writes:

"This (northeasterly) trend cuts directly across the east-west trend of the Keewatin and Timiskaming-type rocks along a line extending from the north shore of lake Huron to lake Mistassini. These relations strongly suggest that the Grenville sub-province marks a Late Precambrian mountain built belt with a trend later followed farther to the southeast by the Paleozoic mountain system."

This statement violates the fact that the Grenville formations in Quebec generally strike north-south and apparently are older than the northeast trending zone as has been shown by Wahl and Osborne (1950).

Innes (1957) in a manuscript copy of his work that he sent to the author, while talking of a gravity low that he found east of Lake Mistassini summarizes his work by the following:

"A belt-like pattern of intensely negative gravity anomalies that parallels the northern border of the Grenville geological province in northern Quebec is believed to reflect batholiths of massive granite that probably intruded during mountain-building activities of the late Precambrian. Considering the great size of the postulated "root" structure and its probable age, it would appear that the rate of uplift and erosion has been much slower than usually thought."

McLaughlin (1954) suggests that the Grenville front extends from Lake Mistassini to the Mississippi embayment. However, there is no valid evidence to support his suggestion.

Johnston (1954) presented a paper on the relationships of the two sub-provinces based on examination of an area near Témiscamingue lake. No direct evidence was obtained but he supported the conclusion that a fault is present. M.E. Wilson

(1956) attacked his conclusion, particularly his interpretation of the field relationships. In this connection it is worthy of note that the gravity results given by Innes (Ms.) do not support the presence of a fault. The region is gravity low rather than gravity high.

All the evidence brought forward for a major fault may be discarded and it is possible to conclude that the "Grenville front" in this area, or as in Dollier-Charron area, is a zone in which rocks of one time-stratigraphic series pass from a lower to a higher grade of metamorphism. In the areas under study, or even in the Bignell area where there is faulting, the relationships would rather suggest that these are secondary tectonic features superimposed on what is essentially a metamorphic facies change.

It is worthy of mention that all along the so-called Grenville front the so-called Grenville-type rocks do not always compare in lithologic variety with rocks identified as Grenville series in central Ontario or even in southern Quebec. Thus the term Grenville series consequently identifies an assemblage of rocks that form a time-stratigraphic unit which is different from other time-stratigraphic units also found in the Grenville sub-province.

From all these data, it is becoming evident that Early Precambrian deformation has been confused in places with Late Precambrian, but even in the Archean the contact is too transitional for the name "Grenville Front" to be appropriate.

The author believes that the Grenville sub-province should be sub-divided and that all the transition zone between the east trending structure of the Keewatin-Timiskaming sub-province and the north-south trending structure of true Grenville rocks of the type locality should be called "Ottawa Gneiss Zone". This zone would include both the hornblende-plagioclase and the biotite plagioclase gneisses, and the whole band of granitic gneisses, that extends from the Keewatin-Timiskaming sub-province, to typical rocks of the Grenville sub-province farther south.

PLATE V



A. Glacial deposit on the east side of the Consolidated Paper Company road to base camp on lake Nicabau.



B. Typical esker, western part of Bouteroue lake.

looking eastward from camp on the
west side of Tonger's river.

PLATE VI



A. Lenses of hornblende paragneiss in biotite orthogneiss. Chaudière river.



B. Typical peneplane topography of the area, looking eastward from a small hill on the west side of Tonnerre river.

PLATE VII



A. Typical garnetiferous biotite paragneiss, on a small lake 1.5 miles N.W. of Aigremont lake.

BIBLIOGRAPHY

- Adams, F.D., et al. (1907) - Report of a Special Committee on the Correlation of the Precambrian Rocks of the Adirondack Mountains, the "original Laurentian area" of Canada and eastern Ontario; Jour. Geol., Vol. 15, pp. 191-217.
- Adams, F.D., and Barlow, A.E., 1910 - Geology of the Haliburton and Bancroft areas, Ont.; Geol. Survey Canada, Mem. 6.
- Allard, G.O., 1956 - The Geology of a Portion of McKenzie Township, Chibougamau district, Quebec; Ph.D. thesis, Johns Hopkins University, Baltimore, Maryland.
- Antevs, Ernst, 1925 - Retreat of the Last Ice-sheet in Eastern Canada; Geol. Survey Canada, Mem. 146.
- Barlow, A.E., Gwillim, J.C., and Faribault, E.R., 1911 - Report on the Geology and Mineral Resources of the Chibougamau Region, Quebec; Que. Dept. Col., Min., Fish., Mines Branch.
- Béland, J., 1953 - Geology of the Shawinigan Map-Area, Ph.D. thesis, Princeton University, pp. 136-143.
- Brongniart, A., 1813 - Essai d'une classification minéralogique des roches mélangées; Journal des mines, XXXIV, p. 40.
- Brooks, T.B., 1876 - On the Youngest Huronian Rocks South of Lake Superior and the Age of the Copper-bearing series; Am. Jour. Science, 3rd series, Vol. 11, art. XXVIII, pp. 206-211.
- Buddington, A.F., 1939 - Adirondack Igneous Rocks and their Metamorphism; Geol. Soc. America, Mem. 7, p. 122.
- , 1957 - Interrelated Precambrian Granitic Rocks, Northwest Adirondacks, New York, Geol. Soc. America, Bull. 68, No. 3, pp. 291-306.
- Collins, W.H., 1925 - North Shore of Lake Huron; Geol. Survey Canada, Mem. 143, pp. 82-85.
- Cooke, H.C., 1919 - Some Stratigraphic and Structural Features of the Precambrian of the Northern Quebec; Jour. Geol., Vol. 27, pp. 180-204, 263-276.
- Cooke, H.C., James, W.F., and Mawdsley, J.B., 1931 - Geology and Ore Deposits of Rouyn-Harricana Region, Quebec; Geol. Survey of Canada, Mem. 166.

- Cooke, H.C., 1947 - The Canadian Shield, Geology & Economic Minerals of Canada, No. 1, p. 20.
- Dana Commemorative Lectures, (1914) - Problems of American Geology, Yale University Press.
- Deland, A.N., 1955 - Geology of the Surprise Lake Area, Quebec; Ph.D. thesis, Yale University, Connecticut. (unpublished).
- Derry, D.R., et al. 1950 - Tectonic Map of Canada; Proc. Geol. Assoc. Canada.
- Dresser, J.A., and Denis, T.C., 1944 - Geology of Quebec, Vol. II, Descriptive Geology; Que. Dept. Mines, G.R. 20.
- Eskola, P., 1914 - On the Petrology of the Orijärvi Region in Southwestern Finland; Comm. Geol. Finlande, Bull. 40.
- Geological Survey of Canada, 1938 - Chibougamau Sheet, east half, Map No. 397A.
- Gilbert, J.E., 1952 - Grenville-Temiscamingue Relations in the Chibougamau and Mistassini Lake Regions; Paper presented to Prospector's and Developers' Association, Toronto.
- , Ms. - Bignell Map-Area; Que. Dept. Mines, G.R. No. (still unpublished).
- , Ms. - Rohault Map-Area; Que. Dept. Mines, G.R. No. (still unpublished).
- Gill, J.E., 1948 - The Canadian Precambrian Shield in Structural Geology of Canadian Ore Deposits, pp. 20-48, Montreal, Mercury Press.
- , 1949 - Natural Divisions of the Canadian Shield; Trans. Royal Soc. Canada, ser. IV, Vol. 43, pp. 61-69.
- Gillies, N.B., 1952 - Canimiti River Area, Quebec; Que. Dept. Mines, G.R. No. 52.
- Harker, A., 1932 - Metamorphism; Methuen.
- Henderson, J.F., 1948 - Extent of Proterozoic Granitic Intrusions in the Western Part of the Canadian Shield; Roy. Society Canada, Trans., sect. 4, Vol. 42, pp. 41-53.
- Holmes, A., 1920 - The Nomenclature of Petrology; London, Thomas Murby & Co., p. 177.

- Hunt, T.S., (1878) - Special Report on the Trap Dykes and Azoic Rocks of Southeastern Pennsylvania; Pt. I, Second Geological Survey of Pennsylvania.
- Hurst, M.E., 1931 - A Deposit of Titaniferous Magnetite in Angus Township, District of Nipissing, Ontario; Fortieth Annual Report of the Ont. Dept. Mines, p. 107.
- Imbault, P.E., Ms. - Queylus Map-Area, Abitibi-East and Roberval counties; Que. Dept. Mines, G.R. No. (still unpublished).
- Innes, M.J.S., 1957 - Gravity and Isostasy in Central Quebec; Paper to be published in "Transactions of the American Geophysical Union", February edition.
- Johnston, W.G., 1954 - Geology of the Timiskaming-Grenville Contact Southeast of Lake Temagami, Ontario; Geol. Soc. America Bull., Vol. 65, pp. 1047-1073.
- Knopf, A., 1955 - Bathyliths in Time, "The Crust of the Earth", Geo. Soc. America, Special Paper No. 62, pp.685-702.
- Laurin, A.F., 1955 - Preliminary Report on Ducharme-Bouteroue Area, Roberval and Abitibi-East counties; Que. Dept. Mines, P.R. No. 310.
- , 1956 - Preliminary Report on Mignault-Aigremont Area, Roberval county; Que. Dept. Mines, P.R. No.317.
- , 1956 - Preliminary Report on Lorne-Avaugour Area, Electoral District of Roberval; Que. Dept. Mines, P.R. No. 329.
- Lawson, A.C., 1885 - Report on the Geology of the Lake of the Woods Region with Special References to the Keewatin (Huronian?) belt of Archean Rocks; Geol. Survey Canada, Ann. Rept., Vol. 1, pt. cc., pp. 1-155.
- Logan, W.E., 1847 - Report of Progress for the year 1845-46; Geol. Surv., Canada.
- , 1863 - Geology of Canada, Montreal; Dawson Brothers.
- Lowther, G.K., 1936 - Villebon-Denain Map-Area, Quebec; Que. Bur. Mines, Ann. Rept. for 1935, pt. c, pp. 39-52.
- Lyall, H.B., Ms. - Brogniart-Lescure Map-Area, Quebec; Que. Dept. Mines, G.R. No. (still unpublished).
- Mawdsley, J.B., and Norman, G.W.H., 1935 - Chibougamau Lake Map-Area, Quebec; Geol. Survey Canada, Mem. 185.
- , -----, 1938 - Chibougamau sheet east half; Geol. Survey Canada, Map 397A.

- McLaughlin, D.B., 1954 - Suggested Extension of the Grenville Orogenic Belt and the Grenville Front; *Science*, August 20, Vol. 120, pp. 287-289.
- Miller, W.G., 1911 - Notes on the Cobalt Area; *Eng. and Min. Jour.*, Vol. 96, pp. 645-649.
- Naumann, C.F., 1849 - *Lehrbuch der Geognosie*; I. Leipzig, pp. 579-580.
- Neale, E.R.W., Ms. - Dollier-Charron Map-Area, Abitibi-East and Roberval counties; Que. Dept. Mines, G.R. No. (still unpublished).
- Norman, G.W.H., 1936 - Northeast Trend of Late Precambrian Tectonic Features in the Chibougamau District; *Trans. Royal Soc. Canada*, ser. IV, Vol. 30, pp. 119-128.
- , 1940 - Thrust Faulting of Grenville Gneisses Northwestward against the Mistassini Series of Mistassini Lake, Quebec; *Jour. Geol.*, Vol. 48, pp. 512-525.
- , 1946 - Major Faults, Abitibi Region, Quebec; *Canadian Institute Min. Metallurgy Trans.*, Vol. 49, pp. 129-144.
- Osborne, F.F., 1936 - Petrology of the Shawinigan Falls District; *Geol. Soc. America Bull.* Vol. 47, No. 1, pp. 197-227.
- , 1949 - Coronites, Labradorite, Anorthosite, and Dykes of Andesine Anorthosite, New Glasgow, P.Q.; *Trans. Roy. Soc. Canada*, Section IV, Vol. XLIII, pp. 85-112.
- , 1956 - Chemical Composition of the Grenville and the Southern part of the Timiskaming-Keewatin Sub-province in Quebec; *Trans. Roy. Soc. Canada*, III series, Vol. L., Section IV, pp. 65-83.
- Pfeffer, H.W., 1955 - Origin and Metamorphism of Keewatin-type Metadiabases ("Diorites") of the O'Sullivan Lake Area, Ontario; *Proceedings of the Geo. Assoc. Canada*, Volume 7, Part 1, pp. 83-101.
- Poldervaart, A., and Gilkey, A.K., 1954 - On Clouded Plagioclase; *Am. Mineralogist*, Vol. 39, No. 142, pp. 75-91.
- Quirke, T.T., 1926 - Huronian-Grenville Relations; *Am. Jour. Sci.*, 5th ser., Vol. 11, pp. 165-173.
- Quirke, T.T., and Collins, W.H., 1930 - The Disappearance of the Huronian; *Geol. Survey Canada*, Mem. 160.

- Richardson, J., 1872 - Report on the Country North of Lake St. John, Quebec; Geol. Survey Canada, Rept. Progress, 1870-1871, pp. 283-308.
- Rosenbusch, H., 1908 - Mikroskopische Physiographie, 4d. ed. p. 1290.
- Senft, F., 1857 - Die Felsarten, Breslau, pp. 148-149.
- Shand, S.J., 1945 - Coronas and Coronites; Geol. Soc. America Bull., Vol. 56, pp. 247-266.
- Smyth, G.H. Jr. - Report on the Crystalline Rocks of St. Lawrence Co.; N.Y., 15th Ann. Rept. of the State Geologist, p. 490.
- Tiphane, M., 1947 - Preliminary Map Shamus, Abitibi and Pontiac counties, Quebec, Marginal notes; Geol. Survey Canada, Paper 47-27.
- Turner, F.J., and Verhoogen, J., 1951 - Igneous and Metamorphic Petrology; McGraw-Hill.
- Tyrrell, G.W., 1949 - The Principles of Petrology; Methuen and Co. Ltd., pp. 310-311.
- Uytenbogaardt, W., 1954 - On the Opaque Constituents in a Series of Amphibolitic Rocks from Norra Storfjället, Västerbotten, Sweden; Arkit För Mineralogy, QCH Geologi Band 1 nr 19, pp. 527-543.
- Wahl, W.G., and Osborne, F.F., 1950 - Cawatose Map-area; Que. Dept. Mines, Geol. Rept. 44, 37 p.
- William, H., Turner, F.J., and Gilbert, C.M. - 1954 - Petrography, An Introduction to the Study of Rocks in Thin Sections; W.H. Freeman and Company, San Francisco.
- Wilson, J.T., 1949 - Some Major Structures of the Canadian Shield; Can. Min. Met. Bull., No. 450, pp. 543-554.
- , 1949a - The Origin of Continents and Precambrian History; Royal Soc. Canada Trans., 3rd series, Vol. 43, sec. 4, pp. 157-184.
- Wilson, M.E., 1913 - Kewagama Lake map-area, Quebec; Geol. Surv. Canada, Mem. 39, 134 p.
- , 1939 - The Canadian Shield in Geologie der Erde, Geology of North America I, pp. 232-311.
- , 1956 - Early Precambrian Rocks of the Timiskaming Region, Quebec and Ontario, Canada; Geol. Society of America, Bull., Vol. 67, No. 10, pp. 1397-1430.

- Yoder, R., 1952 - The $MgO - Al_2O_3 - SiO_2 - H_2O$ system and the Related Metamorphic Facies; Am. Jour. Science, Bowen volume, pp. 569-625.
- , 1955 - The Role of Water in Metamorphism; Geol. Soc., Amer. Special Paper 62, Crust of the Earth, pp. 505-525.

