DPV 368

DORE LAKE COMPLEX AND ITS IMPORTANCE TO CHIBOUGAMAU GEOLOGY AND METALLOGENY

Documents complémentaires

Additional Files

Licence

License

Énergie et Ressources naturelles
Québec

MINISTÈRE DE L'ÉNERGIE ET DES RESSOURCES

SERVICE DE LA GESTION DES DOCUMENTS

DIVISION DU MICROFILM

CE MICROFILM EST PRODUIT POUR LE

SERVICE DE LA GÉOINFORMATION

DPV

368

MICROFILMÉ PAR LA DIVISION DU MICROFILM

CAMÉRA: MODÈLE MRD-2-1

NUMÉRO DE SÉRIE

TAUX DE RÉDUCTION: 27x

DATE: 2 MARS 93

OPÉRATEUR(TRICE):

MINISTÈRE
DES RICHESSES
NATURELLES

DIRECTION GÉNÉRALE
DES MINES

DORÉ LAKE COMPLEX

and its importance to

Chibougamau geology and metallogeny

Gilles O. ALLARD

THE DORE LAKE COMPLEX AND ITS IMPORTANCE TO

CHIBOUGAMAU GEOLOGY AND METALLOGENY

by

Gilles O. Allard
Department of Geology
University of Georgia
Athens, Georgia 30602 U.S.A.

A final report on the field work done in the Chibougamau area

for the Quebec Department of Natural Resources during every

summer from 1966 to 1975.
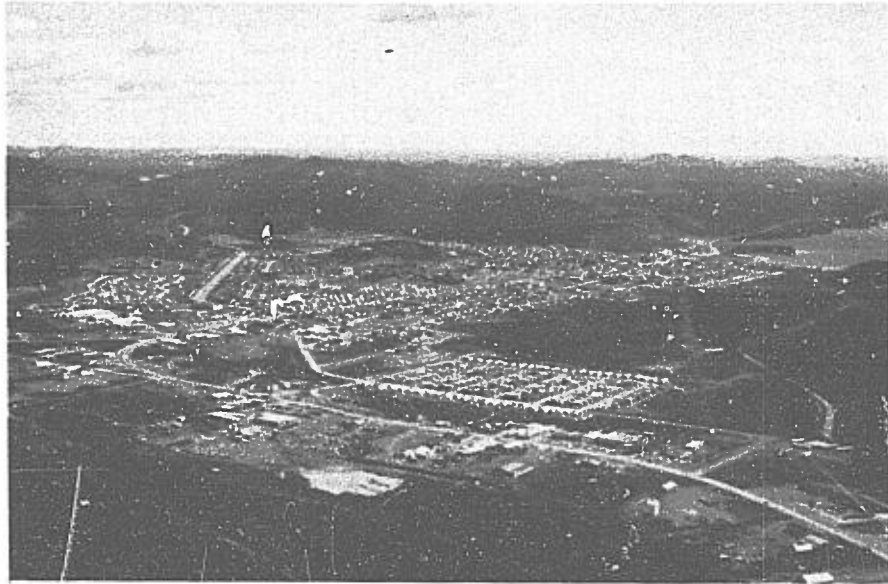
Aerial view of the town of Chibougamau taken
in 1972. Gilman Lake on the right. Looking
north-northeast across the Chibougamau syncline.
The hills behind the town are underlain by
the resistant Ventures and Bourbeau Sill.

PROVINCE DE QUEBEC

Baie d'Ungava

Baie d'Hudson

Océan Atlantique

Schefferville

R. La Grande

R. Eastmain

L. Mistassini

Matagami

Chibougamau

Noranda

Val d'Or

L. St-Jean

Fleuve St-Laurent

Terre-Neuve

N.B.

Québec

I.P.E.

ONTARIO

Ottawa

Montréal

U.S.A.

0 50 100 150 200
Milles

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Preliminary Note:

This report is a progress report on the ever changing geology of the Chibougamau area (it would be more accurate to say the everchanging interpretation of the geology). The increasing amount of exploration work in progress makes it impossible to present a truly final report or a completely up-to-date report.

For all practical purposes, the Chibougamau region is twenty five years old (1950-1975) and it is appropriate to pause and reflect on the accomplishments and on the future studies needed to complete the picture. I have attempted to present a summary of all the work done up to the present on the geology of the Chibougamau area. I have not included the region around Chapais except where the geological units extend as far as Chapais or further westward. A number of M.S. theses and Ph.D. dissertations have been done on Chibougamau and a great deal of unpublished chemical work is in the files of the Quebec Department of Natural Resources. I have attempted to review all this information and present a summary so that the geologist who is not familiar with the geology of Chibougamau can obtain in one single publication the data needed to orient his work. Space limitations have put constraints on the extent of the material included in this report. If I have slighted some of the work, it is either by ignorance or by a faulty judgment in the separation of the wheat from the chaff. An attempt has been made to present impartially the views of others and if I have misquoted or distorted their views, I deeply regret it and apologize for my mistake!

Common Abbreviations used in this Report

Q.B.M. - Quebec Bureau of Mines

Q.D.M. - Quebec Department of Mines

Q.D.N.R. - Quebec Department of Natural Resources

G.S.C. - Geological Survey of Canada

O.D.M. - Ontario Department of Mines

I.G.C. - International Geological Congress, 1972, Montreal.

D.L.C. - Dore Lake Complex

      LHZ - Lower Hidden Zone

      LMZ - Lower Magnetite Zone

      AZ - Anorthosite Zone

      LZ - Layered Zone

      FZ - Ferrodiorite Zone

      SGZ - Sodagranophyre Zone

      UBZ - Upper Border Zone

C.P. - Chibougamau Pluton

C.C.M. - Campbell Chibougamau Mines Ltd.

M.I.M.C. - Merrill Island Mining Corporation

P.M.L. - Patino Mines Ltd.

ABSTRACT

The Chibougamau mining district lies at the eastern extremity of the
Matagami-Chibougamau greenstone belt. The area has a relief above the normal
for glaciated Canadian Shield. The pre-Pleistocene topography was probably
quite similar to the present-day surface with bold ridges underlain by the
resistant gabbros of the Ventures and Bourbeau Sill and by the granophyric and
magnetite-rich rocks of the Dore Lake Complex. Deep valleys trending N 25 E
and N 45 E followed the weak zones of shearing and faulting. Pockets of
oxidation at the Henderson No. 2 mine and at the Copper Rand mine extended to
great depths (over 1300 feet - 390 m. - below the present level of Chibougamau
Lake). The area underlain by the Chibougamau   pluton was a saprolite-
covered lowland which is now Chibougamau Lake.

The volcanic rocks of the area constitute two mafic-to-felsic cycles (Roy
Group of Duquette, 1970). The Waconichi Formation is the first cycle and
culminated with porphyritic sodarhyolite and the exhalite-rich Lac Sauvage Iron
Formation (mostly finely-bedded pyrite and siderite). The Gilman and Blondeau
Formation constitute the second cycle. The volcanic assemblage is intruded by
numerous comagmatic mafic sills: The Dore Lake Complex, the Roberge, Ventures,
and Bourbeau Sills. The complete assemblage is folded into broad open folds:
the Chibougamau anticline occupied by the tonalitic and trondhjemitic
Chibougamau pluton bordered to the north by the Chibougamau syncline and to the
south by the Chapais syncline. The Chibougamau pluton is intrusive into the
lower part of the Anorthosite Zone of the Dore Lake Complex. The mafic portion
of each volcanic cycle has tholeiitic affinities and the felsic end-of-the-
cycle portions are calc-alkaline in nature. The Patino-Lemoine orebody is
located on a rhyolite dome at the top of the Waconichi Formation, on the south
limb of the Chibougamau anticline. On the north limb, the stratigraphically
equivalent rhyolite domes are located in Scott Township, north of David Lake.

Farther east, the Dore Lake Complex is intruded for many miles along the well-bedded siderite-pyrite iron formation hiding from observation the rhyolite domes and quartz-rich pyroclastics observed along the contact of the Dore Lake Complex on the south limb, in Rinfret and Lemoine Township. The Gilman Formation consists in pillowed metabasalts. The Blondeau Formation is made up of thinly bedded pyroclastics, cherty sediments, volcaniclastics, lenses of agglomerate, and pyritiferous graphitic argillites. The three mafic sills (Roberge, Ventures, Bourbeau) constitute a series of key horizons within the Blondeau Formation, extending from the Grenville Front westward for at least 50 miles (80 kms) and covering a post-folding north-south distance of at least 27 miles (43 kms). The Blondeau Formation contains many lenses of zinc-rich and copper-poor mineralization but no economic orebodies have been located within this formation at the present in the Chibougamau area.

The Chibougamau Formation is an Aphebian (2.1-2.3 b.y.) tillite and para-tillite lying unconformably on the folded volcanic rocks and sills of the Roy Group. It is preserved by faulting along the northwest side of the McKenzie Narrows Fault and Gwillim Lake-Waconichi Lake Fault and as isolated hills between these two faults within the axial zone of the Chibougamau syncline.

The Dore Lake Complex is the major geological curiosity of the Chibougamau area. It is a Bushveld-type layered complex folded into a large anticline and metamorphosed to the same degree as the enclosing volcanic rocks. It is coeval and comagmatic with the enclosing volcanic rocks and thus differ from the Bushveld in its regional setting. It is more similar to the gabbros and anorthosites reported by Engel and Fisher (1975) from oceanic ridges. All the major copper deposits of the area are located within the Anorthosite Zone of the Dore Lake Complex and this has been an added source of interest and information on the complex. From top to bottom, the complex has been divided into a number of zones: Upper Border Zone, Ferrodiorite Zone, Sodagranophyre Zone, Layered Zone, and Anorthosite Zone. Allard (1973) has postulated a Lower

Hidden Zone under the sill-like (laccolith?) Chibougamau pluton. The Complex
is metamorphosed to the greenschist facies except for a few small lenses of
fresh anorthosite in the Anorthosite Zone and ferrodiorite in the Ferrodiorite
Zone. The complex was 15,000 to 20,000 feet (4500-6000 m.) thick and possibly
thicker. Meta-anorthosite, gabbroic meta-anorthosite, and anorthositic
metagabbro are the most common rock types in the Anorthosite Zone. Very coarse
cumulus bytownite crystals, reaching 30 cms in places, are replaced by crystals
of albite speckled with zoisite. The intercumulus magnesium-rich pyroxenes are
replaced by chlorite and locally by actinolite. The small ilmenite grains are
pseudomorphed by sphene. The original textures are very well preserved.

The Layered Zone takes its name from the spectacular inch-scale layering
common on the south limb in Rinfret and Lemoine Township and in the Cache Lake-
David Lake area on the north limb. The Layered Zone has been subdivided into
five members (from bottom to top): P_1, A_1, P_2, A_2, and P_3 (Caty, 1970). The
P_1 member consists in meta-magnetitite, metaferrogabbro, and metaferropyroxenite.
Allard (1967) discovered commercial quantities of vanadium in the titaniferous
magnetite. Numerous metallurgical and feasibility studies have been conducted
on the potential vanadium ores of the P_1 member. A_1 and A_2 members consist in
coarse gabbroic meta-anorthosite similar to the rocks of the Anorthosite Zone.
P_2 is similar to P_1 but the magnetite-bearing layers show an increase in
titanium and a decrease in vanadium content. P_3 is a metaferropyroxenite rich
in ferrohastingstite. It is divided into submembers rich in ilmenite, ferro-
silicates, apatite, and quartz, in that ascending order. Within a small area
around Cache Lake and Gladstone Lake, a north-south crossfold is underlain by
most of the known Ferrodiorite Zone (Baskin, 1975). The rocks are fresher than
usual and primary ferropyroxene and andesine are common. The Sodagranophyre
Zone occurs along the entire south limb but is found only in the western end of
the north limb. The rock is white, made up of quartz and plagioclase, and forms

large rounded resistant hills. Locally, the rock displays spectacular grano-phyric texture but contains practically no potassium feldspar, hence the name Sodagranophyre. The Upper Border Zone forms thin discontinuous lenses varying from fine-grained gabbro (chilled zone ?) to coarse gabbroic anorthosite (floated up ?) and quartz-bearing gabbroic pyroxenite. The Upper Border Zone of the eastern portion of the north limb has not been restudied in detail at the present time.

The recent proposal by Irvine (1974, 1975) and McBirney (1974, 1975) on the origin of granophyres and layering in the Skaergaard and other complexes find direct support in the Dore Lake Complex where the granophyre zone is present only where the complex is in contact with felsic porphyritic soda-rhyolite and pyroclastics of the top of the Waconichi Formation. Facies changes take place where the complex is intruded into mafic rocks: the granophyre zone disappears, and the layered zone of the south limb gives way to the massive magnetite-rich ferrodunite and ferropyroxenite of the Sorcerer Mountain and Magnetite Bay zones. The titanium and vanadium content of these zones is much lower than on the south limb. Plagioclase and ferropyroxene common in the south limb give way to olivine and pyroxene on the north limb. The magnesium content is also much higher on the north limb.

The Chibougamau pluton is a complex multiphase intrusion varying from meladiorite to very felsic quartz porphyry. Some phases are metamorphosed and syntectonic while others have not been affected by metamorphism and deformation. We consider that the pluton has a laccolithic shape and is subvolcanic in character.

Dikes are very abundant throughout the area and most of the copper deposits are located along dikes and within dike swarms. The mine dikes are altered, metamorphosed, and vary from pristine to heavily sheared. The most common are the quartz (feldspar) porphyry dikes and the grey dikes (andesitic and dacitic in composition). The Gabbro Island dike and the Henderson

metapyroxenite dike cut across the area. The Line Island diabase dike is the easternmost dike of the Abitibi swarm dated by Fahrig et al., (1965) at 1230 m.y.

The Stella Formation is a sedimentary formation infolded and metamorphosed with the volcanic rocks of the Roy Group within the Chapais syncline and in a belt north of the Chibougamau syncline. It was recognized in the early days of the mapping in Chibougamau (Beach, 1940) and was called the Opemisca Series. Duquette (1970) included the sediments within the Blondeau Formation. Cimon (1975) coined the term Stella Formation from a small lake in Queylus Township. Caty (1975) is mapping a large belt of similar sediments in Richardson Township. The Stella Formation consists of a basal conglomerate, phyllitic schists, graphitic schists, conglomerates, greywackes and locally porphyritic andesite.

The regional structural geology of the area has already been outlined. The major folds of the area are well established thanks to hundreds of excellent top and bottom determinations. The major faults of the area were already recognized by Mawdsley and Norman (1935). As indicated earlier, the presence of flat-lying Chibougamau Formation tillites and paratillites on the northwest side of the major faults indicates a reverse southeast-side upward displacement, parallel to the displacement along the Grenville Front. The Mistassini Lake Fault is a recent addition to the main faults of the Chibougamau area. At the Icon copper mine (40 miles - 64 kms - northeast of Chibougamau, at the south end of the Mistassini Basin), the Mistassini Lake Fault is a reverse fault which has moved gneisses and amphibolites against the Mistassini dolomite (Proterozoic) and the enclosed Icon orebody. The fault can be traced southward as far as Dollier Township. The Chibougamau syncline fault is also a new addition to Chibougamau geology: it is a bedding fault required by the repetition of the Roberge and Ventures sills along much of the south limb of the Chibougamau syncline.

Age determinations indicate that the volcanics and intrusions of the Chibougamau area are older than the Kenoran metamorphism dated at ± 2.7 b.y.

The Chibougamau Formation, by correlation with the Gowganda Formation of western Quebec and Ontario is estimated at ± 2.3 b.y. The Mistassini Group is probably 1.7-1.8 b.y. (Fryer, 1972), and the Grenville orogeny has been dated around 950-1000 m.y.

The copper-gold deposits of the area have been labeled "shear zone replacement" deposits. The author is proposing a volcanogenic model to explain the deposits: veins of ore are deposited in fractures and dilation zones along dikes on top of a rising subvolcanic pluton. The veins are part of a network of channelways leading to the sea floor and to the stratified pyrite-sphalerite lenses found in the Blondeau Formation. The veins are surrounded by haloes of alteration. During the last stages of folding and metamorphism, the vein dike alteration zone system is transformed into the present sericite-chlorite-chloritoid-quartz-calcite/siderite "shear zones". The sulfide lenses of the original veins become foliated, brecciated, boudinaged, and chalcopyrite is preferentially mobilized to dilation zones, fractures, and pressure shadow zones. The essential point of this model explains both stratiform and cross-cutting orezones as a single volcanogenic episode. Both types are essentially synchronous and both types suffer the same metamorphism as the remainder of the volcanic assemblage of the Chibougamau district.

The Patino Lemoine deposit is a stratiform stratabound small lens of high grade copper-zinc ore on a rhyolite dome close to the top of a felsic unit marking the end of the Waconichi Formation (end of the first volcanic cycle). The discovery of this deposit in 1973, on the south limb of the anticline, 11 miles (17 kms) away from the deposits of the Dore Lake-Henderson area, has revived exploration efforts in the Chibougamau area for massive volcanogenic stratiform deposits.

The Roberge Lake asbestos deposit is contained within the serpentinized dunites and peridotites of the Roberge Sill.

The iron-titanium-vanadium content of the magnetitites of the Layered Zone in Rinfret and Lemoine Township has been explored and much research remains to be done to prove the feasibility of economic metallurgical separation of the iron, titanium, and vanadium from these rocks. The P_1 and P_2 members of the Layered Zone contain large volumes of magnetite-rich rocks. The vanadium tenor decreases gradually upward across the P_1 and P_2 members. A concomitant increase in titanium is noted across these two members. Numerous tables and figures synthesize the metallurgical research done so far on the magnetite.

CHAPTER 1

INTRODUCTION

The Chibougamau area has become well known in mining circles for its

copper deposits and in geological circles for the presence of an unusual

Bushveld-type Archean layered complex called the Dore Lake Complex.

Chibougamau is located about 320 miles (515 kms) north of Montreal (Fig. 1).

The Chibougamau district is bounded roughly by latitudes $49^{\circ}30'N$ and $50^{\circ}30'N$

and by longitudes $73^{\circ}45'W$ and $74^{\circ}45'W$. It comprises the town of Chibougamau

on the shores of Gilman Lake and the town of Chapais, 30 miles (50 kms) west

of Chibougamau, on the road linking Chibougamau and the Noranda-Val d'Or

district.

Geologically, the Chibougamau area lies at the eastern extremity of the

Matagami-Chibougamau greenstone belt (Fig. 2). Goodwin and Ridler (1970)

included Chibougamau within the "Abitibi orogenic belt". Allard and Oliveira

(1973) placed the Chibougamau area within the Matagami-Chibougamau greenstone

belt which extends in an east-west direction from the Kapuskasing "high" to

the Grenville Front east of Chibougamau, a distance of 265 miles (440 kms).

The belt averages 35 miles (55 kms) wide.

Previous Work

The Chibougamau area was visited during the 17th and 18th century by fur

traders and missionaries traveling north between Lac St. Jean and James Bay.

In 1870, James Richardson working for the Geological Survey of Canada found

the first traces of mineralization on the east shore of Portage Island in

Chibougamau Lake. In 1884, the Bignell-Low Mistassini expedition traversed the

area and in 1892 and 1905 A. P. Low did additional exploration in the Chibougamau

area. Following a series of discoveries of gold, asbestos, and copper, and the

publication of a few short notes, the Chibougamau Commission was appointed and

asked to report on the economic possibilities of the area and on the feasibility
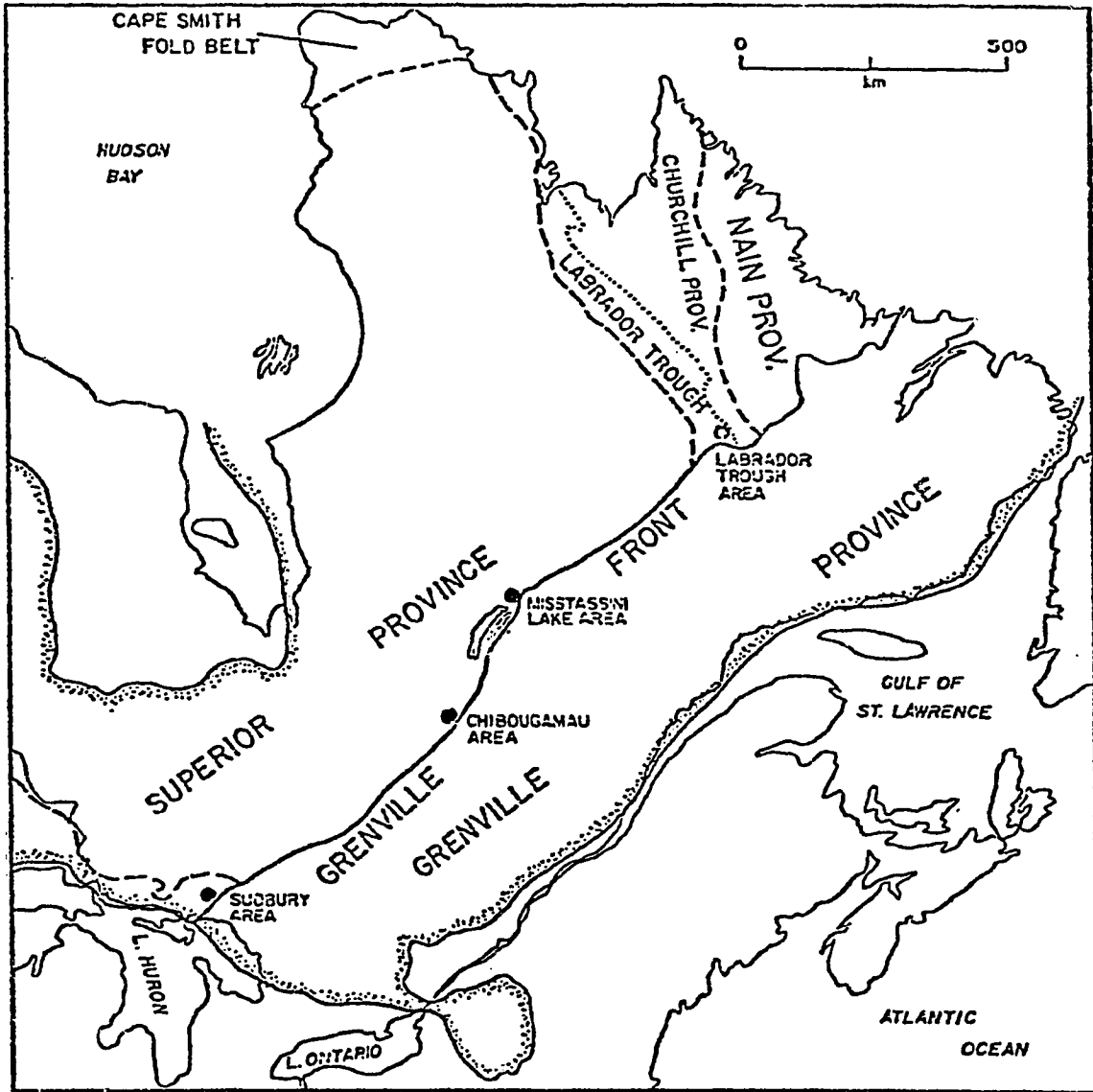
Figure 1. Geological location map of the Chibougamau area.
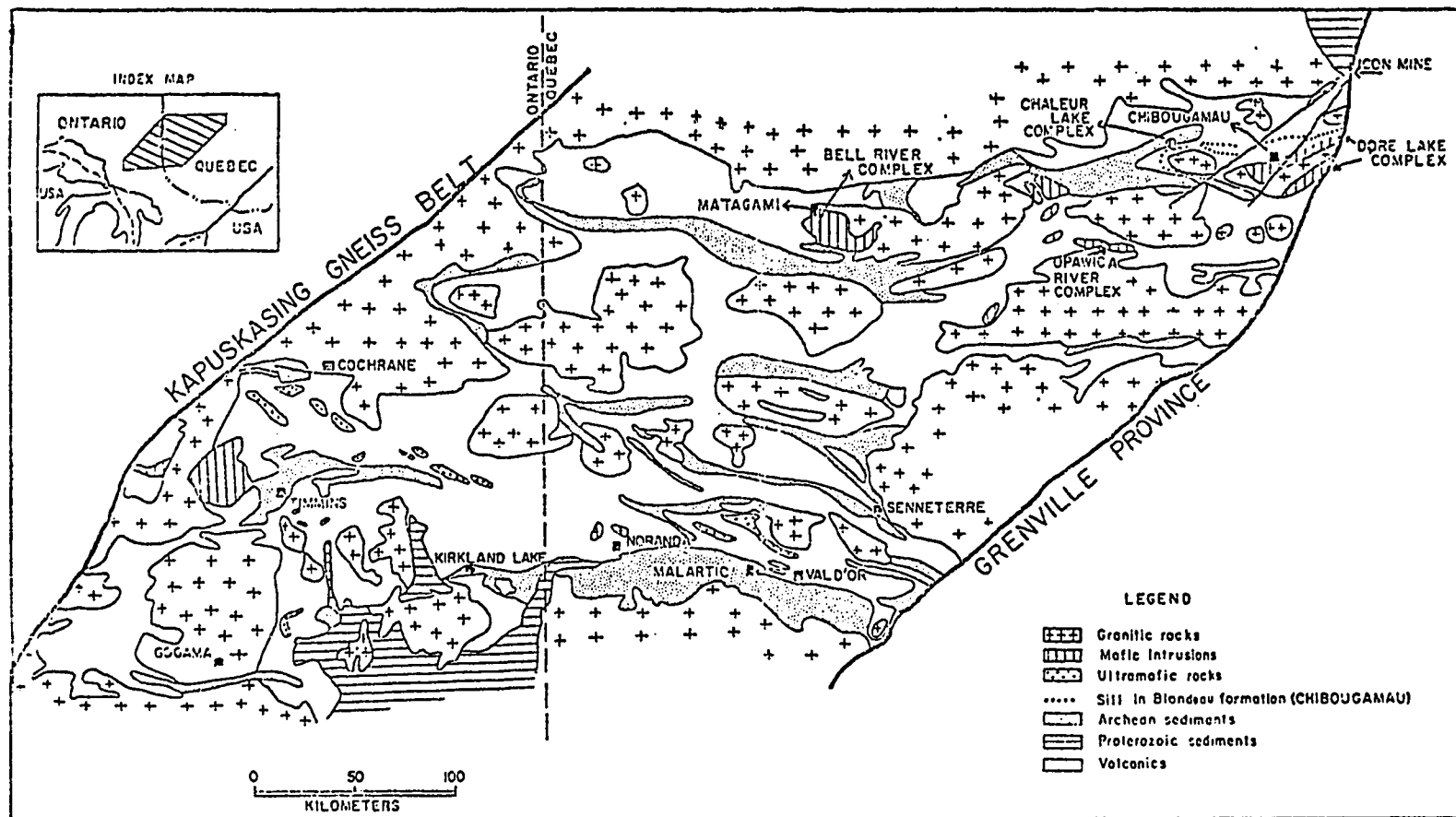
Figure 2. Generalized geologic map of the Chibougamau-Matagami greenstone belt and Abitibi Orogenic belt.
Note the four layered complexes (Dore Lake, Chaleur Lake, Opawica River, and Bell River) within the
Chibougamau-Matagami belt. (modified from Q.D.N.R. and O.D.M. published maps and from Goodwin
and Ridler, 1970)

of constructing a railway to Chibougamau. The report of the Commission was published in 1911 and its negative stand retarded exploration for many years. The discovery of the Noranda deposits in the late twenties brought back to Chibougamau a wave of prospectors who made a number of interesting finds between 1920 and 1935. Mawdsley (1927), Tolman (1930) and Retty (1930) conducted geological surveys in the area. Norman completed in 1934 the work started by Mawdsley in 1930. Their report and map (Mawdsley and Norman, 1935) have been the basis for all modern work in the area. Their study of Chibougamau was extended westward into the Opemisca Lake area (Norman, 1936, 1937, 1938), Michwacho Lake and Mechamego Lake areas (Beach, 1940). World War II brought exploration efforts to a standstill.

Work done and in progress for the present report

The construction of an all-weather gravel highway by the Quebec Department of Mines (Q.D.M.) in 1948 and 1949 between St. Félicien in the Lac St. Jean district and Chibougamau created a wave of exploration work which resulted in a number of mineral discoveries. In 1950, the Q.D.M. also initiated a program of detailed geological mapping at a scale of 1:12,000 which is still in progress and which has already covered most of the Chibougamau-Chapais area. The numerous airborne magnetic electromagnetic surveys done by the federal and provincial governments and by exploration companies have contributed a great deal to our present understanding of the geology of the area. Much remains to be done, especially in the field of mineralogy, and petrochemistry. The general stratigraphy of the volcanic complex has been outlined by Duquette (1967, 1970) following his mapping of a large part of the Chibougamau syncline (Plate 1). The petrography and petrology of the Dore Lake Complex has been investigated mostly by Allard and his students or students under his supervision in the field. The geology of the eastern end of the Chapais syncline (Plate 1) and the southwestern part of the Chibougamau Pluton has been investigated mostly by Cimon.

The present report is a progress report (1975) and should be considered as an effort to put together a comprehensive picture, far removed from the final picture which will require many more years of field and laboratory work.

The large quantity of confidential exploration work going on at the present time is bound to alter our understanding of Chibougamau geology and should add much to the next report.

Acknowledgments

VIENNE   BLAIKLOCK   RICHARDSON   BIGNELL

1   2   3   → 4   5   6

TO ALBANEL L

7 —BARLOW— —McKENZIE— —ROY— —McCORKILL—

7   8   9   10   11   12   13

CHIBOUGAMAU

14   15   16   17   18   19   20

CONSTRUCTION

27 —SCOTT— —OBALSKI— —LEMOINE— —RINFRET—

22   23   24

←TO CHAPAIS

LAC ST-JEAN

ROAD IN

25   25   26   26

TO

—HAUY— —QUEYLUS— —DOLLIER—

0 miles 4

List of Q.D.N.R. maps and reports covering the Chibougamau area. Township names given. ¼ township mapping credits indicated by numbers indexed below:

1. NW¼ McKenzie - 1968-Duquette PR 573-map 1661
4. NE¼ Roy - 1964-Mathieu PR 553-map 1614
7. SW¼ Barlow - 1973-Abramchev open file CM 28360
10. SE¼ McKenzie - 1960-Allard CR 95 - map 1253
13. SW¼ McCorkill- 1963-Pouliot PR 479-map 1418
16. NW¼ Obalski - 1956-Graham CR 71 -map 1091
19. NE¼ Lemoine - 1969-Allard PR 566-map 1687
22. SW¼ Obalski - 1970-Duquette PR 585-map 1710
25. NW¼ Queylus - 1971- Cimon open file p.r.
NE¼ Hauy

2. NE¼ McKenzie - 1966 - Duquette PR 551- map 1609
5. NW¼ McCorkill - 1968 - Duquette PR open file
8. SE¼ Barlow - 1960 - Gaucher PR 425 -map 1333
11. SW¼ Roy - 1958 - Horscroft PR 370 - map 1221
14. NW¼ Scott - 1971- Feuerbach PR open file
17. NE¼ Obalski - 1956- Graham CR 71 - map 1092
20. NW¼ Rinfret - 1967- Allard PR 567 - map 1649
23. SE¼ Obalski - 1970- Duquette PR 595 - map 1711
26. NE¼ Queylus - 1974- Cimon PR open file
NW¼ Dollier

3. NW¼ Roy - 1964 - Duquette PR 513 - map 1521
6. NE¼ McCorkill - 1972 - Abramchev PR open file
9. SW¼ McKenzie - 1960 - Smith CR 95 - map 1292
12. SE¼ Roy - 1959 - Gaucher PR 379 - map 1255
15. NE¼ Scott - 1973 - Allard PR 609 in press
18. NW¼ Lemoine - 1970 - Allard PR 589 - map 1707
21. S½ Scott - 1974 - Christmann open file DP 217
24. SW¼ Lemoine - 1960 - DeMontigny PR 437 - map 1360

Figure 3. Summary of detailed mapping (1:12,000) by the Quebec Department of Natural Resources in the Chibougamau area.

TABLE 1

Theses and dissertations on the Chibougamau area.

Allard, G.O.	Structure & Mineralization in the Chibougamau area M.A. thesis, Queen's University, 1953.
Allard, G.O.	The geology of a portion of McKenzie township, Chibougamau district, Quebec. Ph.D. dissertation, The John Hopkins University, Baltimore, Md., 1956.
Baskin, G.D.	The petrology and chemistry of a portion of the north limb of the Dore Lake Complex, Chibougamau, Quebec, Canada. M.S. thesis, University of Georgia, Athens, Georgia, 1975.
Blecha, M.	A study of the variation in chemical composition of certain dikes at the Campbell Chibougamau Mines Mine. M.S. thesis at McGill University, Montreal, 1966.
Caty, J.L.	Pétrographie et Pétrologie du flanc sud-est du complexe du Lac Doré. M.S. thesis, University of Montreal, Montreal, 1970.
Dorr, A.	Magnetite deposits in the northern part of the Dore Lake Complex, Chibougamau district, Quebec. M.S. thesis, McGill University, 1969.
Eckstrand, R.	Crystal chemistry of Chlorite. Ph.D. dissertation at Harvard University, Boston, Cambridge, 1963.
Gaucher, E.H.	The magnetic anomaly of the magnetite serpentinite at the Montagne du Sorcier, Chibougamau, Province of Quebec, Canada.
Hawkins, W.M.	A spectrochemical study of rocks associated with the sulphide ore deposits of the Chibougamau district, Quebec. Ph.D. dissertation, McGill University, Montreal, 1960.
Jeffery, W.G.	The geology of the Campbell Chibougamau Mines, Quebec. Ph.D. dissertation, McGill University, 1959.
Maybin, A.H.	The geology of the Opawica River Complex, Quebec, Canada. M.S. thesis, University of Georgia, Athens, Ga., 1976.
McMillan, R.H.	Petrology, geochemistry and wall rock alteration at Opemiska-a vein copper deposit crosscutting a layered Archean ultramafic-mafic sill. Ph.D. dissertation, University of Western Ontario, London, Ontario, 1972.
Miller, R.J.M.	Geology and ore deposits of the Cedar Bay mine and Chibougamau district. Ph.D. dissertation, Laval University, Quebec, 1957.
Moritz, H. W.	Muscovite-paragonite relationships in altered and mineralized meta-anorthosite at Chibougamau, Quebec. M.S. thesis, University of Georgia, Athens, Georgia, 1975.
Oliveira, J. A. L.	The petrology of the Chibougamau greenstone belt volcanics. M.S. thesis, University of Georgia, Athens, Georgia, 1973.
Raychaudhuri, S. K.	Trace elements with sulphide deposits of the Chibougamau district, Quebec. Ph.D. dissertation, McGill University, 1959.
Sutton, W.	Geology of the copper Rand Mine, Chibougamau, Quebec. M.S. thesis, University of Michigan, 1959.
Vollo, N. B.	The geology of the Henderson Copper deposit, Chibougamau region, Quebec. M.S. thesis, McGill University, 1959.
Wolhuter, L. E.	The Opemisca Lake Pluton. Ph.D. dissertation, McGill University, Montreal, 1968

Physical Geography

The Chibougamau area lies at the eastern extremity of Abitibi-East county within the Hudson Bay drainage basin. The height of land between the St. Lawrence River and Hudson Bay basins is the line separating Abitibi-East county and Lake St. John county and roughly following the Grenville Front on the Superior side.

Chibougamau is linked by road and railroad to the Lake St. John district to the southeast (150 miles (240 kms) to St. Félicien) and to the Senneterre-Val d'Or-Noranda area to the southwest (210 miles (340 kms) to Senneterre). Hydroplanes based at Caché Lake, 6 miles (10 kms) south of the town of Chibougamau, can be used to reach any part of the area. Nordair offers 4 direct flights a week between Montreal and Chibougamau. An excellent all-weather gravel highway joins Chibougamau with Lake Albanel, 120 miles (195 kms) to the north.

Haulage roads constructed by lumber companies facilitate the penetration of many areas with small vehicles. The Q.D.N.R. is constructing a secondary road circling Chibougamau Lake and passing by the new Patino-Lemoine mine and the Roberge Lake asbestos deposit.

Geomorphology

The Canadian Shield is characterized by its relatively flat glaciated surface dotted with innumerable swamps, lakes, and rivers. The Chibougamau area differs from most of the Shield by its much greater relief. The maximum relief is around 700 feet (210 meters): Mount Cummings has an elevation of 1950 feet

(585 meters) and Chibougamau Lake 1246 feet (374 meters). The topography

reflects the lithology and structure slightly modified by Pleistocene

glaciation. Allard and Cimon (1974, and paper in preparation) have postulated

a minumum of glacial erosion in the Chibougamau district. Young (1973) and

Long (1974) suggest an early Proterozoic glaciation covering an area nearly

coincident with that covered by the Pleistocene glaciation (Fig. 4). The

Chibougamau Formation is a witness to this early glaciation and occurs in four

isolated patches within the Chibougamau district. It will be discussed in a

later chapter. We can visualize a relatively flat glaciated surface over

northern Canada around 2 b.y. ago. North of Chibougamau, a large intracratonic

basin developed in which the Mistassini Group was deposited (dolomite, graphitic

argillite, iron formation). The lower dolomite grades downward into a regolith

showing an irregular sheeted gneiss surface cemented by dolomite. The Grenville

orogeny (around 1 b.y. ago) brought the Grenville Province upward and north-

westward against the Superior Province. A series of N 20 E steep reverse

faults sliced the eastern extremity of the Superior Province. The same

compressive forces caused a recurrence of movement along the major N 45 E

faults with an upward movement of the southeast side of the fault. Weathering

and erosion dissected the high range of hills along the Grenville Front. Fault

zones and incompetent lighologic units produce a N 20 E, N 45 E, and E-W system

of valleys. The competent rocks stood as resistant high blocks. The Paleozoic

seas probably covered most of the flat-lying lowlands to the west, and south

(Ambrose, 1964). A number of inliers of Paleozoic rocks are left within the

Shield, one at Waswanipi Lake, 100 miles (160 kms) west of Chibougamau, and a

large one around the south end of James Bay, 200 miles (320 kms) northwest of

Chibougamau. I suspect that the Chibougamau area was a positive large island

during this time but I have no direct evidence to support this opinion. During

the Mesozoic and Tertiary, weathering and erosion proceeded and in the

Chibougamau area reached great depths as evidenced by the oxidized zones found

HUDSON BAY

SUPERIOR PROVINCE

OTISH MOUNTAINS

MISTASSINI BASIN

CHIBOUGAMAU

ATLANTIC OCEAN

Dominant Paleocurrent Directions

★ Early Proterozoic (Aphebian) Tillite Occurrence

•••••• Limit of Areas last Affected by the Kenoran Orogeny

‾‾‾‾ Limit of Areas Covered by Early Proterozoic (Aphebian) Ice Cap

0   400
MILES

0   400
KM
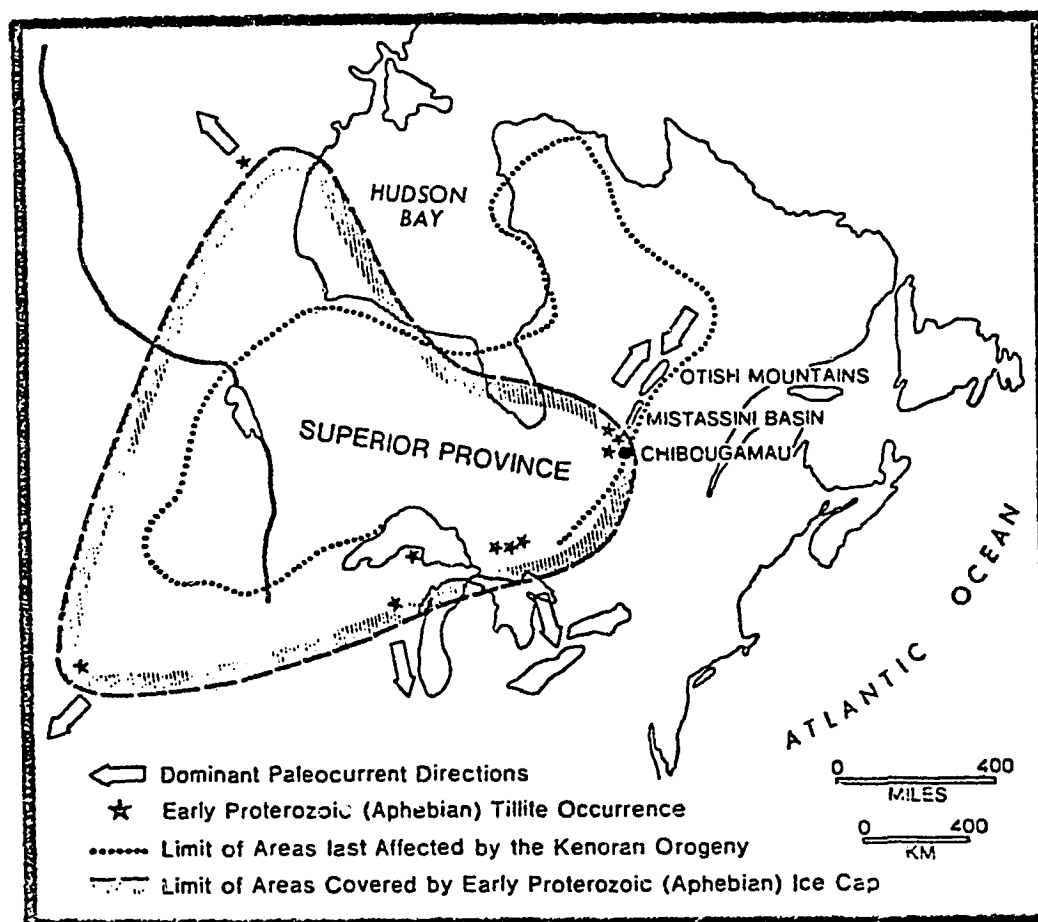
Figure 4. Sketch map showing the location of Chibougamau with respect to the postulated Early Proterozoic (Aphebian) ice sheet. (From Young, 1970, fig. 2, p. 100).
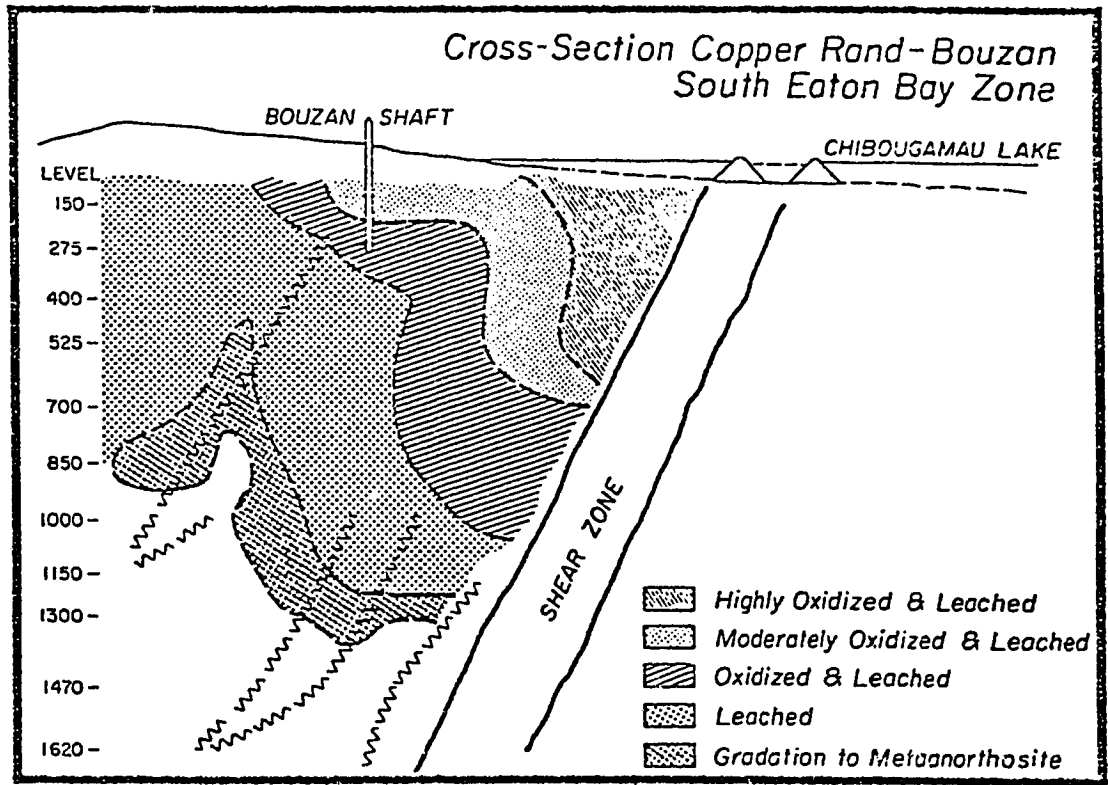
Fig. 5 Cross section at Copper Rand Mine showing the depth of the pre-Pleistocene oxidized zone.
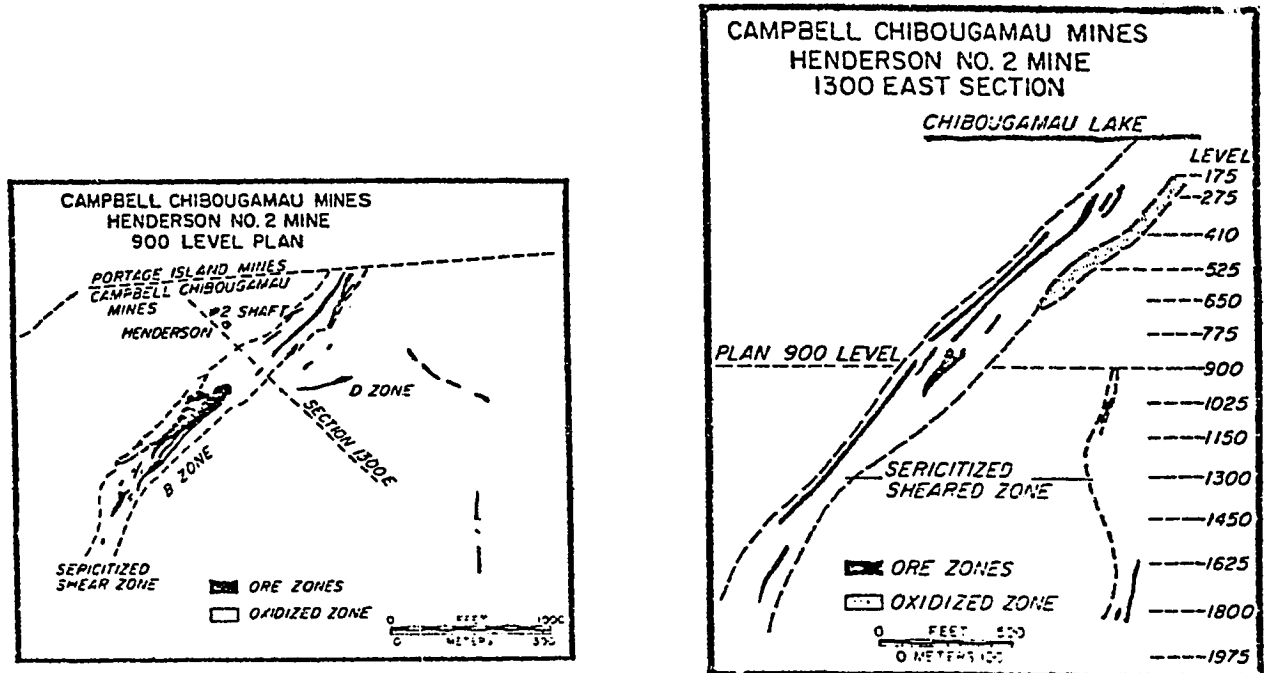
Fig. 6 Map of the 900-level (left) and cross section 1300-East (right) at the Henderson No. 2 Mine showing the extent and depth of the pre-Pleistocene oxidized orezone.

Figure 7. Islands in Chibougamau Lake showing the contrast
           between the polished glaciated outcrops on the
           north end (top) and the boulder-covered south
           shore (bottom).

at the Henderson mine and Copper Rand Main mine. At Copper Rand, the anorthosite has been altered to a spongy laterite which extends to a depth of 1300 feet (390 meters) below the actual level of Chibougamau Lake (Fig. 5). At the Henderson mine, the orezone has a rough N 45 E strike and dips 45-50° to the southeast. In the footwall of the orezone (Fig. 6), the oxidized zone extends to a depth of 1000 feet (300 meters) and the original chalcopyrite-pyrite-pyrrhotite ore has been converted to a vuggy spongy mass of malachite, azurite, etc. Allard and Cimon (1974) consider the preservation of these deep pockets of pre-Pleistocene oxidation as evidence for minimal erosion by the Pleistocene ice sheet.

Guha has started a detailed study of the mineralogy of the oxidized zones. At my request, he has forwarded the following note (personal communication, Jan. 27, 1975):

(his text)

"A part of the Henderson #2 and the Copper Rand deposits in the Chibougamau mining district shows pronounced oxidation. The oxidation in the Henderson #2 ore bodies, without exception, is restricted to or commenced from the footwall of the ore zones progressing towards the hangingwall. Whereas, in the Copper Rand deposit the oxidation developed from both the footwall and hangingwall zones leaving at places a band of "primary" sulfides in the middle. The extent of oxidation varies widely from incipient oxidation resulting in the formation of minor limonite to considerably oxidized areas with "secondary" sulfides, oxides and carbonates, native copper, remnants of "primary" sulfides, and much limonite, hematite and goethite. The oxidation did involve redistribution of copper and it wasn't solely a process in situ is corroborated, at the least, by the presence of tiny veinlets, flakes and grains of native copper in the adjacent wall rocks. The "secondary" minerals identified so far are chalcocite, djurleite, digenite(?), covellite, blanbleibender covellite(?), bornite, cuprite, tenorite, melaconite, malachite, azurite, goethite, limonite, hematite and gypsum. The work is continuing on the mineralogy as well as the physical and chemical factors controlling the formation of these oxidized zones and will form the substance of a future publication."

The predominant N 20 E topographic lineaments formerly ascribed to a glacial origin are caused by previously existing structural valleys slightly accentuated by the Pleistocene ice sheet which coincidentally moved in the same direction.

The pre-Pleistocene surface was marked by a series of high ridges under-
lain by competent gabbro sills, magnetite-rich rocks, and granophyres of the
Dore Lake Complex, and isolated large hills underlain by flat-lying Proterozoic
tillites of the Chibougamau Formation. The areas underlain by the anorthosite
of the Dore Lake Complex and by the trondhjemitic Chibougamau pluton were
undulating saprolite-covered lowlands. The Pleistocene ice sheet moved across
the Chibougamau area taking away the soils and saprolite and scouring the
bedrock surface but not greatly modifying the pre-Pleistocene surface, contrary
to White's (1972) views that the Pleistocene ice sheet has removed a very thick
slice of bedrock.

The retreat of the Pleistocene ice sheet left a blanket of morainic material
and a deranged drainage marked with swamps and innumerable lakes (Fig. 7)
connected by streams and rivers. Drumlins are abundant in the area. Eskers
are common but short and irregular. They provide excellent source of good-
quality gravel and sand for construction purposes. Northwest of David Lake and
south of Scott Lake, De Geer's moraines have been reported by Allard (1975) and
Christmann (1975). They are discontinuous low lenses of bouldery gravel lying
roughly perpendicular to the direction of ice movement.

The town of Chibougamau is built on a sand plain nested between hills
surrounding Gilman Lake. Similar sand plains are frequently observed through-
out the area and probably represent temporary glacial lakes and fluviatile
deposits formed in small lakes between recessional moraines and the ice front.

The drainage of the Chibougamau map-area is entirely via Chibougamau River
which drains Chibougamau Lake into a string of lakes (Doré, Merrill, Ledden,
David, Dulieux, Simon, Scott, Gwillim, Chevrillon, Barlow, Opemisca, Michwacho),
then merges with Waswanipi River to flow into Matagami Lake and drain northward
to James Bay via the Nottaway River. Chibougamau lies to the east of the "clay
belt" located within the limits of the former glacial lake Barlow-Ojibway which
covered a large area in western Quebec and northern Ontario (Flint, 1971).

CHAPTER 2

GENERAL GEOLOGY OF THE CHIBOUGAMAU DISTRICT

The Chibougamau area is located at the eastern extremity of the
Chibougamau-Matagami greenstone belt (Figs. 1 and 2) included by Goodwin and
Ridler (1970) in the Abitibi orogenic belt. The belt has a general easterly
strike and is truncated at its eastern extremity by the northeast-trending
crystalline rocks of the Grenville Province. The belt is 265 miles (440 kms)
long and varies between 15 and 60 miles (25 and 100 kms) in width.

The Chibougamau mining camp is essentially a copper-producing area with
minor gold. The Matagami camp is predominantly a zinc-producing area with
minor copper. A new discovery by Patino Mines Ltd. in 1973 carries high-grade
zinc and copper and is the first volcanogenic stratiform deposit in the area,
similar to the deposits of the Matagami and Noranda districts.

The Chibougamau greenstone belt resembles the classic model described by
Anhaeusser et al. (1969), Baragar (1972), Glikson (1970), Goodwin and Ridler
(1970), Goodwin and Shklanka (1967), and Wilson (1965) from the Archean shields
of Australia, Africa and Canada. It differs from the others by the presence
of the Dore Lake Complex (D.L.C), a thick stratiform igneous complex comagmatic
with enclosing volcanic rocks. Greenschist facies Kenoran metamorphism has
affected the volcanic rocks and the D.L.C.

Tectonically, the Chibougamau area consists of a large anticline flanked
to the north and south by major synclines. The axis of the anticline is
occupied by the Chibougamau pluton (C.P.), a complex zoned trondhjemitic
intrusion. Cimon (1973, 1975) recognized many phases of subvolcanic intrusive
porphyritic rocks within the southwest portion of the pluton. He was the first
to point out (1973) the possibility of porphyry copper deposits in Archean
plutonic rocks and his prediction is being tested successfully at the present
time (Cimon, 1975).

A few patches of Chibougamau Formation lie unconformably on the folded volcanic rocks. It represents the only vestiges of an Early Proterozoic glaciation (Long, 1974).

The Grenville orogeny has brought the Grenville Province against the rocks of the Chibougamau greenstone belt. This collision of two major cratonic blocks has sliced the eastern extremity of the Superior Province with a series of N 20 E reverse faults (southeast block upward) and raised the grade of metamorphism over a narrow zone on the Superior Province side.

Geology of the Roy Group volcanic rocks

The volcanic assemblage in the Chibougamau area has been mapped in detail over the last twenty five years. The discovery of the Patino Lemoine volcanogenic stratiform copper-zinc orebody in 1973 has sparked a number of exploration programs within the volcanic belts which are bound to improve our knowledge of the volcanic rocks of the area. The change in philosophy from the classical hydrothermalist views which were prevalent in the fifties and sixties to the currently popular volcanogenic theory has caused us to critically reexamine some of the earlier work in volcanic terrain.

Duquette (1968, 1970) after mapping a number of quarter townships north of Chibougamau (Fig. 3) established the stratigraphy of the Chibougamau volcanic assemblage:

$$
\text{Roy Group} \left\{ \begin{array}{l} \left. \begin{array}{l} \text{Blondeau Formation} \\ \text{Gilman Formation} \end{array} \right\} \quad \text{younger cycle} \\ \text{Waconichi Formation} \qquad \text{older cycle} \end{array} \right.
$$

This subdivision fits the classic model of Archean volcanism with repeated mafic-to-felsic cycles. The Waconichi Formation forms the lowermost cycle and the Gilman and Blondeau formations form the uppermost cycle.

Fig. 8

SIMPLIFIED STRATIGRAPHY of CHIBOUGAMAU

STELLA FORMATION
〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜〜

BLONDEAU FORMATION ⎫
                    ⎪ *SECOND VOLCANIC CYCLE*
GILMAN FORMATION   ⎭

WACONICHI FORMATION   *FIRST VOLCANIC CYCLE*

Waconichi Formation

The lowermost volcanic cycle in the Chibougamau area is the Waconichi Formation (Fig. 8). Duquette postulated a thickness of 40,000 feet (12,000 m.) and proposed a tentative type section along the Albanel Road. Recently, a new road between M.P. 9 of the Albanel road and Frotet Lake and lumbering roads in Richardson Township have opened different sections of the formation which show marked differences with the Albanel section. Caty (1975, pers. communication) is mapping a complete section of the Waconichi Formation in western Richardson Township and has confirmed the presence of an important and extensive post-Roy Group sedimentary sequence which had been recognized by early workers (Kindle, 1942; Riley, 1958; and Shaw, 1941; 1942), and lumped with the volcanic Waconichi Formation by Duquette (1970). It will be discussed in a later chapter (Chapter 6) titled Stella Formation.

The Waconichi Formation consists of mafic pillowed flows and gabbro sills, volcaniclastic and clastic rocks, tuffs, rhyolites, and a final end-of-the-cycle exhalative iron formation described separately below under "Lac Sauvage Iron Formation."

The basalts* and basaltic tuffs show the usual mineralogy, textures, and structures. The greenschist metamorphism has changed the original calcic plagioclase into albite and epidote and the pyroxene into chlorite and/or actinolite. Sphene replaces primary ilmenite grains. Magnetite is little affected by the metamorphism. The pillows show dark glassy rims with or without amygdules and/or varioles. Mafic tuffaceous horizons become chlorite schists difficult to differentiate from sheared metabasalts. The gabbro sills are identical to those found commonly in the Gilman Formation and will be described later. Table 2 to 6 present a number of chemical analyses of Waconichi Formation samples.

---

* In this report, rock names should be preceded by the prefix "meta" but in many instances it has been neglected to simplify the nomenclature.

The volcaniclastic portion of the Waconichi Formation is lensey and irregular in thickness and separates the basalts described above and the porphyritic rhyolites. They are well exposed along the Albanel highway between M.P. 18 and 12. The majority of the beds show excellent graded bedding and the grain size in each bed is proportional to the thickness of the bed.

Many of these rocks are crystal and crystal-lithic tuffs. The thickness of each bed varies from 3 meters to less than 30 cm. In each unit, the coarse pale-colored quartzofeldspathic and lithic portion grades into a darker very finely-bedded argillite. Shale-chip conglomerates are common at the base of some units. Similar rocks have often been called greywackes. Slump structures and other features indicative of penecontemporaneous deformation are common. Fiske (1963) and Fiske and Mats a (1964) described similar rocks from Japan and California and ascribed their origin to subaqueous pyroclastic flows. Our work is very reconnaissance in nature and much more work will be necessary to establish the origin of the thick section of lithic-crystal tuff of the Waconichi Formation and to distinguish rocks of this formation from the infolded younger sediments of the Stella Formation.

Agglomerate lenses consist of bombs and blocks of dacite, leucodacite, quartz felspar porphyry (sodarhyolite) and minor amounts of basaltic fragments in a matrix varying from a chloritic fine-grained tuffaceous material to the pale colored lithic tuff described above. The large clasts are commonly elongated and flattened in the plane of foliation, generally parallel to subparallel to the bedding planes.

Finely bedded tuffs vary from dark green chloritic types (basaltic) to pale-colored massive 'cherty' looking types grading in places to true cherts.

The quartz felspar porphyry (sodarhyolite) has been studied in detail by Oliveira (1973) who compared the various occurrences in the Chibougamau area (Fig. 9). The rocks weather to a chalky white surface dotted with glassy clear quartz phenocrysts. The rock is made up of plagioclase and quartz phenocrysts in a very fine-grained matrix made up of quartz, plagioclase, minor chlorite, zoisite, and carbonate. The quartz phenocrysts display excellent resorption features (Fig. 10). The matrix has a uniform appearance suggesting devitrified glass recrystallized during metamorphism. The grain size of the matrix increases as one approaches the Grenville Front in Lemoine and Rinfret Township but the phenocrysts are not affected (Fig. 11). Excellent exposures of the sodarhyolites of the Waconichi Formation can be found on the Albanel highway all around mile post 12, north of David Lake in Scott Township (Allard, 1975), and as a narrow band south of the Dore Lake Complex in Lemoine Township (Oliveira, 1973). The last two outcrop areas are very critical to the understanding of the Chibougamau stratigraphy and its application in exploring for volcanogenic stratiform copper-zinc ore deposits. These outcrops are on the north and south limb respectively of the Chibougamau anticline. They appear as thin lenses at the contact of the Dore Lake Complex and have led geologists in the fifties, when the mapping had been concentrated around the Dore Lake area, to state that Chibougamau was different from the other camps like Noranda, Val d'Or, and Matagami, in not having any rhyolites. We can state emphatically that the first volcanic cycle ended with a series of rhyolite domes, flows, and intrusives and the all-important exhalites horizon. Allard (1970, 1971, 1972) has compared this contact to the "key tuffite" of the Matagami mining district and has repeatedly urged exploration companies to concentrate their efforts along this favorable horizon.
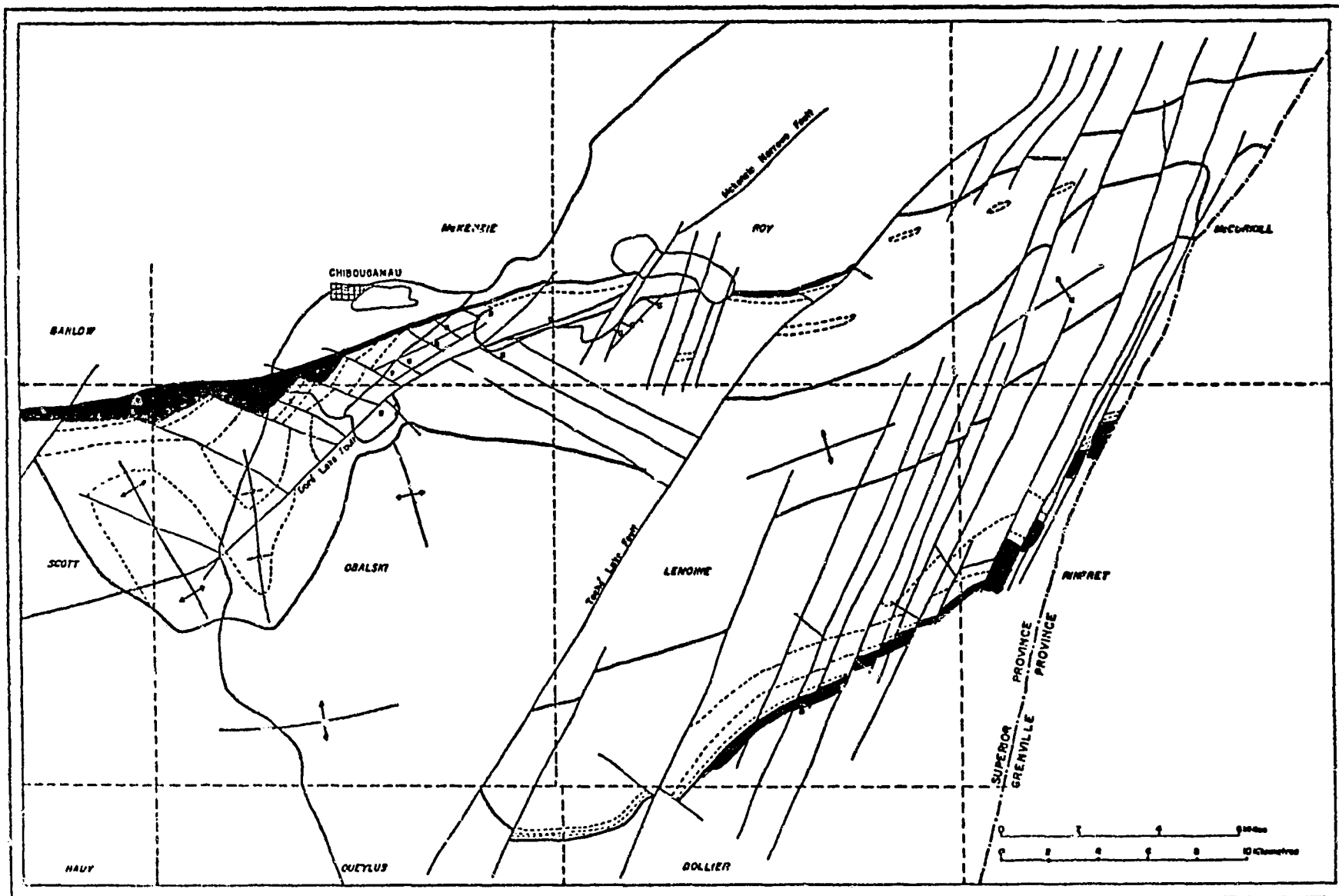
Fig. 9. Sketch map of the Chibougamau area (Dore Lake Complex in dark outline)
showing the distribution of the Waconichi Formation (dark pattern)

TABLE 2

CHEMICAL ANALYSES OF ROCKS FROM UNIT PORPHYRITIC RHYOLITE-WACONICHI-NORTH LIMB

ANALYSES CHIMIQUES DES ROCHES DE RHYOLITES POLPHYRITIQUES DU WACONICHI-BANDE NORD

Sample No. No. d'échantillon	J71-165	J71-209	J71-219	14-69-14
SiO_2	71.60	73.80	74.90	72.94
TiO_2	0.20	0.22	0.15	0.16
Al_2O_3	15.75	15.05	13.10	11.20
Fe_2O_3	0.48	0.36	0.42	0.42
FeO	1.45	1.07	1.25	0.82
MnO	0.02	0.02	0.03	
MgO	0.53	0.55	0.40	0.35
CaO	0.85	0.65	1.05	4.52
Na_2O	5.85	6.05	4.95	2.15
K_2O	2.15	1.65	1.78	2.44
P_2O_5				
H_2O+				
H_2O-				
CO_2				
S				
TOTAL	98.88	99.42	98.03	95.00
Norm wt%				
Qtz	25.83	29.47	35.65	42.37
Cor	2.25	2.13	1.12	
Or	12.70	9.75	10.52	14.42
Plag	53.72	54.42	47.07	31.90
Ab	49.50	51.19	41.89	18.19
An	4.22	3.22	5.21	13.70
Ne				
Wo				
Di				3.56
Wo				1.80
En				0.87
Fs				0.89
Hy	3.29	2.71	2.75	
En	1.32	1.37	1.00	
Fs	1.97	1.34	1.76	
Ol Fo				
Fa				
Mt	0.70	0.52	0.61	0.61
Il	0.38	0.42	0.28	0.30
Hm				
Ap				
Py				
Cal				
Data Wt%				
An/plag	7.8	5.9	11.1	43.0
Fa/ol				
En/hy	40.1	50.5	36.2	
Diff.i.	88.0	90.4	88.0	75.0
Qtz	29.3	32.6	40.5	56.5
Ab	56.2	56.6	47.5	24.2
Or	14.4	10.8	11.9	19.2
An	6.3	5.0	9.0	29.5
Ab	74.5	79.8	72.7	39.2
Or	19.1	15.1	18.2	31.1
A	76.4	79.5	76.4	74.2
F	18.4	14.8	19.0	20.0
M	5.0	5.7	4.5	5.7
Na+K/Al	75.9	78.0	76.9	55.2
Fe+Mn/FeMnMg	66.8	59.1	70.0	65.8
Na_2O/Na_2O+K_2O	73.1	78.5	73.5	46.8

TABLE 3

CHEMICAL ANALYSES OF ROCKS FROM UNIT PORPHYRITIC RHYOLITE -WACONICHI-RINFRET-LEMOIN

ANALYSES CHIMIQUES DES ROCHES DSS RHYOLITES PORPHYRITIQUES DU WACONICHI-RINFRET-
L.MOINE

Sample No. No. d'échantillon	J-71-2	J-71-70	J-71-71	J-71-180	J-71-74
SiO_2	73.80	71.60	71.10	75.10	59.14
TiO_2	0.42	0.40	0.48	0.35	0.49
Al_2O_3	12.98	12.35	12.70	12.40	13.05
Fe_2O_3	0.70	1.05	1.11	0.89	1.87
FeO	2.11	3.15	3.32	2.66	5.61
MnO	0.06	0.05	0.05	0.07	0.07
MgO	0.85	1.20	1.30	1.20	4.80
CaO	1.60	1.20	1.05	1.50	2.96
Na_2O	4.25	4.90	5.85	4.55	4.90
K_2O	1.08	1.00	0.78	0.65	0.80
P_2O_5					
H_2O+					
H_2O-					
CO_2					
S					
TOTAL	97.85	96.90	97.74	99.37	93.69
Norm wt%					
Qtz	39.01	32.93	27.86	39.46	11.14
Cor	1.91	1.02	6.32	1.48	
Or	6.38	5.91	4.61	3.84	4.73
Plag	43.90	47.42	54.71	45.94	52.71
Ab	35.96	41.46	49.50	38.50	41.46
An	7.94	5.95	5.21	7.44	11.25
Ne					
wo					
Di					2.81
Wo					1.43
En					0.82
Fa					0.55
Hy	4.83	7.34	7.72	6.69	18.66
En	2.12	2.99	3.24	2.99	11.14
Fs	2.71	4.35	4.48	3.70	7.52
Ol					
Fo					
Fa					
Mt	1.01	1.52	1.61	1.29	2.71
Il	0.80	0.76	0.91	0.66	0.93
Hm					
Ap					
Py					
Cal					
Data Wt%					
An/plag	18.0	12.5	9.5	16.2	21.3
Fa/ol					
En/hy	43.8	40.7	41.9	44.7	59.7
Diff.i.	81.3	80.3	82.0	81.8	57.3
Qtz	47.9	41.0	34.0	48.2	19.4
Ab	44.2	51.6	60.3	47.0	72.3
Or	7.8	7.3	5.6	4.7	8.2
An	15.8	11.1	8.8	14.9	19.5
Ab	71.5	77.7	83.4	77.3	72.1
Or	12.7	11.0	7.8	7.7	8.2
A	59.2	52.2	53.6	52.2	31.7
F	31.2	37.1	35.8	35.7	41.6
M	9.4	10.6	10.5	12.0	26.7
Na+K/Al	62.9	74.0	82.4	66.0	68.4
Fe+Mn/Fe+Mg	64.9	66.0	65.3	62.2	46.2
Na_2O/Na_2O+K_2O	79.7	83.0	88.2	87.5	86.0

TABLE 4

CHEMICAL ANALYSES OF ROCKS FROM UNIT PORPHYRITIC RHYOLITE -WACONICHI-RINFRET-LEMOIN

ANALYSES CHIMIQUES DES ROCHES DE S RHYOLITES PORPHYRITIQUES DU WACONICHI -RINFRET-LEMOINE

Sample No. No. d'échantillon	R10-68-19	DL-2818	DL-2133	R10-68-18
SiO_2	71.68	71.88	73.68	73.68
TiO_2	0.42	0.42	0.39	0.39
Al_2O_3	12.56	12.56	12.20	12.20
Fe_2O_3	1.00	2.00	2.00	0.97
FeO	3.00	3.88	3.77	2.92
MnO				
MgO	0.95	0.95	0.95	0.95
CaO	1.95	1.95	1.56	1.56
Na_2O	6.00	6.00	5.50	5.50
K_2O	0.20	0.20	0.27	0.27
P_2O_5				
H_2O+				
H_2O-				
CO_2				
S				
TOTAL	97.96	99.84	100.32	98.44
Norm wt%				
Qtz	29.44	29.08	33.75	34.11
Cor			0.02	0.02
Or	1.18	1.18	1.60	1.60
Plag	57.52	57.52	54.28	54.28
Ab	50.77	50.77	46.54	46.54
An	6.75	6.75	7.74	7.74
Ne				
W				
Di	2.46	2.48		
Wo	1.22	1.22		
En	0.46	0.42		
Fa	0.78	0.84		
Hy	5.11	5.89	6.99	6.28
En	1.90	1.95	2.37	2.37
Fs	3.21	3.94	4.63	3.92
Ol				
Fo				
Fa				
Mt	1.45	2.90	2.90	1.41
Il	0.80	0.80	0.74	0.74
Hm				
Ap				
Py				
Cal				
Data Wt%				
An/plag	11.7	11.7	14.2	14.2
Fa/ol				
En/hy	37.2	33.1	33.8	37.7
Diff.i.	81.3	81.0	81.9	82.2
Qtz	36.1	35.9	41.2	41.4
Ab	62.3	62.7	56.8	56.5
Or	1.4	1.4	1.9	1.9
An	11.5	11.5	13.8	13.8
Ab	86.4	86.4	83.2	83.2
Or	2.0	2.0	2.9	2.9
A	55.6	47.5	46.2	54.3
F	35.9	45.1	46.2	36.7
M	8.5	7.2	7.6	8.9
Na+K/Al	80.3	80.3	76.5	76.5
Fe+Mn/Fe+Mg	69.7	77.0	76.7	69.1
Na_2O/Na_2O+K_2O	95.8	96.8	95.3	95.3

TABLE 5

CHEMICAL ANALYSES OF ROCKS FROM UNIT C GABBRO SILLS IN UPPER PART OF WACONICHI VOLCANICS

ANALYSES CHIMIQUES DES ROCHES DE S SILLS DE GABBRO DANS LA PARTIE SUPERIEURE DU WACONICHI

Sample No. No. d'échantillon	J71-80	J71-185	J71-210	F69-165	14-69-13
SiO_2	47.20	49.30	49.70	47.59	49.50
TiO_2	0.86	1.20	1.10	0.98	2.13
Al_2O_3	12.70	13.80	12.55	15.00	12.59
Fe_2O_3	3.32	2.55	2.96	3.44	5.58
FeO	9.96	7.65	8.89	7.23	9.85
MnO	0.25	0.16	0.24		
MgO	8.05	8.45	7.55	7.60	4.22
CaO	9.80	7.60	8.15	11.52	4.72
Na_2O	2.05	2.70	2.90	1.58	4.00
K_2O	0.50	0.70	0.40	0.18	0.01
P_2O_5					
H_2O+					
H_2O-					
CO_2					
S					
TOTAL	94.69	94.11	94.44	95.12	92.60

Norm wt%					
Qtz		0.44	1.29	2.83	6.78
Cor					
Or	2.95	4.14	2.36	1.06	0.06
Plag	41.32	46.31	44.58	46.67	50.22
Ab	17.35	22.85	24.54	13.37	33.85
An	23.97	23.47	20.04	33.30	16.37
Ns					
Wo					
Di	20.18	11.52	16.65	19.27	5.82
Wo	10.29	5.94	8.51	9.96	2.94
En	5.72	3.75	4.88	6.35	1.48
Fs	4.17	1.83	3.25	2.96	1.40
Hy	21.19	25.73	23.18	18.43	17.59
En	12.26	17.30	13.92	12.57	9.03
Fs	6.92	8.43	9.26	5.86	8.56
Ol	2.61				
Fo	1.45				
Fa	1.16				
Mt	4.81	3.70	4.29	4.99	8.09
Il	1.63	2.28	2.09	1.86	4.05
Hm					
Ap					
Py					
Cal					

Data Wt%					
An/plag	58.0	50.7	45.0	71.3	32.6
Fa/ol	44.5				
En/hy	57.9	67.2	60.0	68.2	51.3
Diff.i.	20.3	27.4	28.1	17.2	40.7

Qtz		1.6	4.6	16.4	16.7
Ab	85.4	83.3	87.0	77.4	83.2
Or	14.5	15.0	8.3	6.1	0.1

An	54.1	46.5	42.7	69.8	32.5
Ab	39.1	45.2	52.2	28.0	67.3
Or	6.7	8.2	5.0	2.2	0.1

A	10.7	15.4	14.5	8.8	16.9
F	55.6	46.2	52.2	53.2	65.2
H	33.7	38.3	33.2	37.9	17.8

Na+K/Al	30.8	37.7	41.4	18.6	52.3
FeMn/FeMnMg	47.9	40.1	46.7	43.2	66.4
Na_2O/Na_2O+K_2O	80.3	79.4	87.9	89.8	99.7

Table 6A

GENERAL NOTE APPLICABLE TO TABLES 6,

16, 21, 28, 30, 36, 48, 54, 58, 64, 89, and 92.

a. In many analyses, a determination was made of the Fe_2O_3 and FeO. The results were used in the norm calculations. When the analyses were done by X-ray fluorescence and the Fe^{2+} was not distinguished from Fe^{3+}, a factor R was determined from known analyses on the same type of rocks or an arbitrary number was assigned to R if no known analyses were available. In many analyses, especially those of Oliveira and Gunn and Duquette on volcanic rocks, a factor of R = 0.30 was used. The R factor is used in the following equation:

$$Fe_2O_3{}' = \frac{Fe_2O_3}{1 + \dfrac{1.1113}{R}} \qquad \text{and} \quad FeO{}' = \frac{Fe_2O_3{}'}{R}$$

where $R = Fe_2O_3 / FeO$.

b. In all instances, when the data was available, we have given the analyst or the laboratory responsible for the analyses, the location of the sample, and the reference where all the data is presented.

c. The norms were calculated using a computer program modified by Stormer and in storage at the Computer Center of the University of Georgia.

d. The location of samples collected along the Albanel Highway are given in terms of mile post (M....). The zero point is the intersection of the Albanel Highway and the road to the Dore Lake mines, about 3 miles east of the town of Chibougamau.

On the main road between Chibougamau and St. Felicien, the mile post system is also used in many instances. The zero point is at St. Felicien and M.P. 144 is in the vicinity of the motel Alouette, at the south entrance to town.

e. C.M.S. stands for Chibougamau Mining and Smelting.

Table 6

Notes on samples of Tables 2 to 5.

TABLE 2. PORPHYRITIC RHYOLITE — WACONICHI FORMATION -- NORTH LIMB

X J-71-165 Oliveira, 1973, p. 86. Altered quartz feldspar porphyry (soda
            metarhyolite). Road to Roberge Lake asbestos deposit, close to the
            Albanel Highway intersection.

√ J-71-209 Oliveira, 1973, p. 86. Quartz feldspar porphyry (soda metarhyolite).
            Along Albanel Highway, close to M. 16.

  J-71-219 Oliveira, 1973, p. 86. Altered quartz feldspar porphyry. North of
            David Lake, NE 1/4 Scott Township.

  14-69-14 Allard, Q.D.N.R. Lab. ·Quartz feldspar porphyry. Drill hole Bar Le Duc
            No. 7, 485-495, north of David Lake, Scott Township.

TABLES 3 and 4. PORPHYRITIC RHYOLITE — WACONICHI FORMATION — RINFRET-LEMOINE TOWNSHIPS

  J-71-2   Oliveira, 1973, p. 86. Quartz feldspar porphyry. South of the Lemoine
            road, 1500 feet (450 m) west of the Rinfret-Lemoine township line.

  J-71-70   Oliveira, 1973, p. 86. Quartz feldspar porphyry. Lemoine Township, on
            Lemoine road, 4600 feet (1380 m) west of Rinfret-Lemoine township line.

  J-71-71   same as J-71-70

  J-71-180 Oliveira, 1973, p. 86. Quartz feldspar porphyry. Lemoine Township.
            Nine hundred feet (300 m) northwest of Camp Lake (north-northeast of
            Patino-Lemoine shaft).

  J-71-74   Oliveira, p. 87. Granophyric metadacite. Lemoine Township. South of
            Lemoine road, 4000 feet (1200 m) west of the Rinfret-Lemoine township
            line.

  R-10-68-19 Allard, Q.D.N.R. Lab. Lemoine Township. Quartz feldspar porphyry.
            Range line R 4-5, 3300 feet (990 m) west of Rinfret-Lemoine township
            line.

  Dl 2818   Caty, 1970, p. 67, Table 25, Lemoine Township. Granophyre No. 2.

  DL 2L33   Caty, 1970, p. 67, Table 25, Lemoine Township. Granophyre No. 2.

  R-10-68-18 id to 19 above but further west by a few feet.

TABLE 5. GABBRO SILLS IN THE UPPER PART OF THE WACONICHI FORMATION

X J-71-80   Oliveira, 1973, p. 89. Metagabbro. Albanel Highway, M. 11.1±.

  J-71-185 Oliveira, 1973, p. 89. Metagabbro. Lemoine Township. Just south of
            Camp Lake, south of Lemoine road.

X J-71-210 Oliveira, 1973, p. 89. Metagabbro. Roy Township. Albanel highway
            around M. 12.15.

  F 69-165 Allard, Q.D.N.R. Metagabbro. NE 1/4 Scott Township. Sample Feurbach
            F-165, northwest corner of the map (Allard, 1975).

  14-69-13 Allard, Q.D.N.R. Metagabbro. NE 1/4 Scott Township. Drill hole Bar
            le Duc No. 9, from 725 to 900 (north of David Lake).
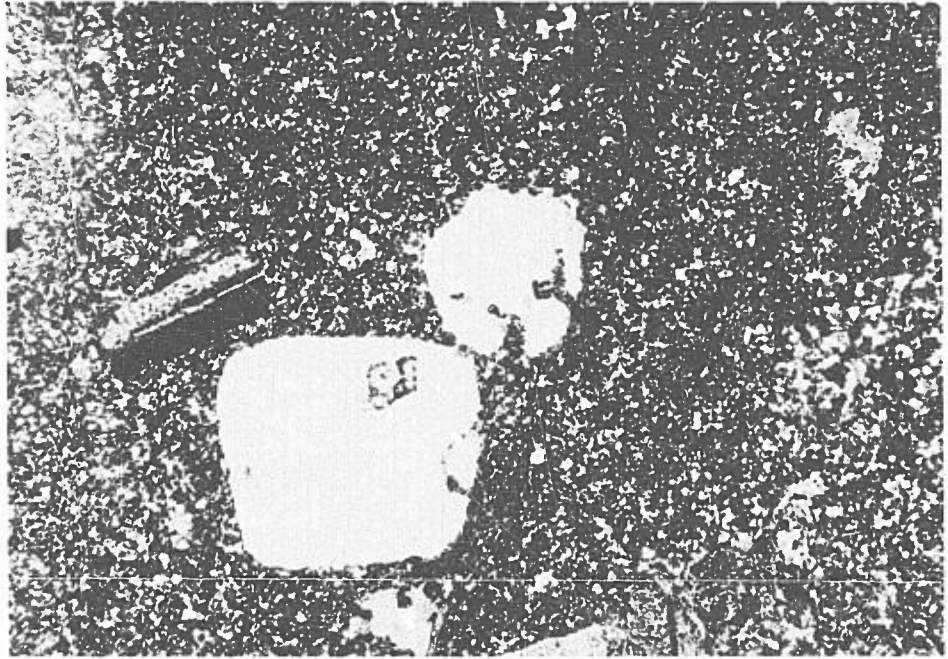
Fig. 10. Photomicrograph of porphyritic metasodarhyolite
from the Waconichi Formation. Sample J-71-152. Note the
resorbed quartz phenocrysts and the very fine-grained
matrix. Crossed nicols. Field: 2.8 mm.
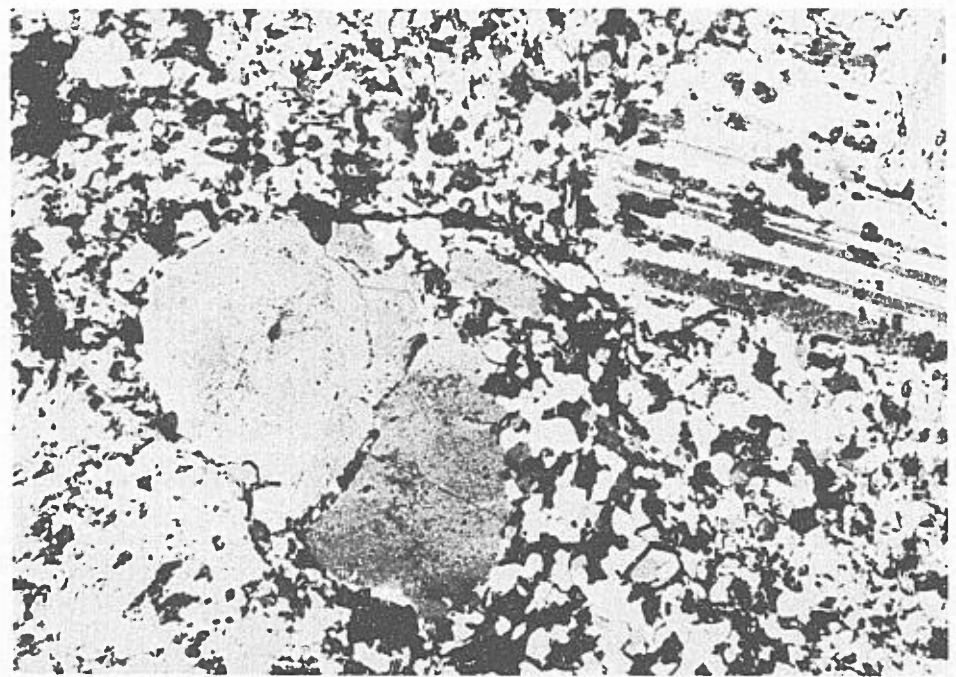
Fig. 11. Photomicrograph of porphyritic metasodarhyolite
from the Waconichi Formation. Sample J-71-180, southeast
Lemoine Twp. Note the coarser matrix as compared with Fig.10
due to Grenville metamorphism. Crossed nicols. Field: 2.4 mm.

Lac Sauvage Iron Formation

The exhalite sequence at the top of the Waconichi Formation is now called

the Lac Sauvage Iron Formation (Allard and Henry, 1974). It was first

described by Mawdsley and Norman (1935) who stated:

> "carbonatization occurs quite commonly, though not always, in the
> mineralized zones. It is particularly prevalent where the rocks
> are highly sheared and in schistose rocks in zone of intense
> movement along faults."

Allard (1956) influenced by peers and professors, recognized the fine

bedding features of much of the carbonate-rich horizon located at the contact

between the Dore Lake Complex and the Gilman pillowed metabasalts but also saw

much evidence for intense ankeritization of pillowed basalts and heavy shearing

in places within the zone rich in carbonate. The finely-bedded siderite and

ankerite was assumed to be a replacement of finely bedded tuff. The whole zone

was called the Lac Sauvage Fault Zone by Allard. Smith in his portion of

McKenzie Township (1960) describes very well the facts and inferences:

p. 24

> "Carbonate-chlorite schist is undoubtedly the result of replacement
> of carbonate (carbonatization) of older rocks. All rocks older
> than the Chibougamau series are in places so affected. In the
> Keewatin-type lavas circulation of the carbonatizing solutions
> through discontinuous channels afforded by interflow contacts,
> fragmental zones and thin, schistose flows resulted in mild
> carbonatization of the lavas in very narrow lenses. Wide,
> continuous zones of carbonate-chlorite schist must represent
> places where the solutions passed in greater quantity through
> channelways such as would be afforded by shear zones and faults;
> the presence of such zones is therefore contributory evidence of
> faulting. The cross-cutting nature of some of the zones confirm
> this conclusion."

Detailed studies of the contact zone between the Dore Lake Complex and the

volcanics on Sorcerer Mountain and on Portage Island led Allard (1973) to the

conclusion that the contact is not a major fault zone and that much of the

carbonate, sulfide, and chert found along this contact is volcanogenic in origin and is the culmination of a thick volcanic cycle, the Waconichi Formation. It is an exhalite similar to those described by Goodwin (1964) in Michipicoten, Ridler (1970) in Kirlkland Lake, and Fleisher (1971) in Brazil. In the core of the Chibougamau anticline, much of this horizon is hidden from view by the intrusion of the Dore Lake Complex and Chibougamau Pluton. This explains why the rhyolites in Scott and Lemoine Township are thin lenses and yet carry a very high economic importance. We have renamed this unit the Lac Sauvage Iron Formation. Henry is studying it for his M.S. thesis and a later separate report will be forthcoming. The discovery of the Patino-Lemoine high grade copper-zinc orebody in Lemoine Township in 1973 has reshaped the exploration philosophy of many companies. We visualize the end of the Waconichi volcanism as follows: an irregular underwater surface is broken by a few volcanic rhyolite spines and domes (some of them could rise above water as islands). This is a time of much chemical precipitation of large quantities of exhalative products coming up along fractures and dikes. Depending on the water depth and chemistry of the solutions coming to the sea floor, the various depressions on the surface contain variable thicknesses of well-bedded siderite (Fig. 12), ankerite, pyrite, minor chalcopyrite and sphalerite (except at the Lemoine orebody where the thickness is very small (± 10 feet (3 m.)) but the concentration very high), chert, and hematite. The soft oozes are periodically shaken by seismic and waning volcanic activity which explains slump features, intraformational breccias, tuffaceous and agglomerate lenses, etc. The Sorcerer Mountain zone and the Mile 11 (Albanel road) zone are mostly chert and sulfides with very minor carbonate. The thickest accumulation of iron formation is on Portage Island where Henry has measured up to 91 feet (27 m.) of the three facies of iron formation: 75 feet (22.5 m.) of siderite, 6 feet (1.8 m.) of pyrite, and ± 10 feet (3 m.) of bedded cherty magnetite.
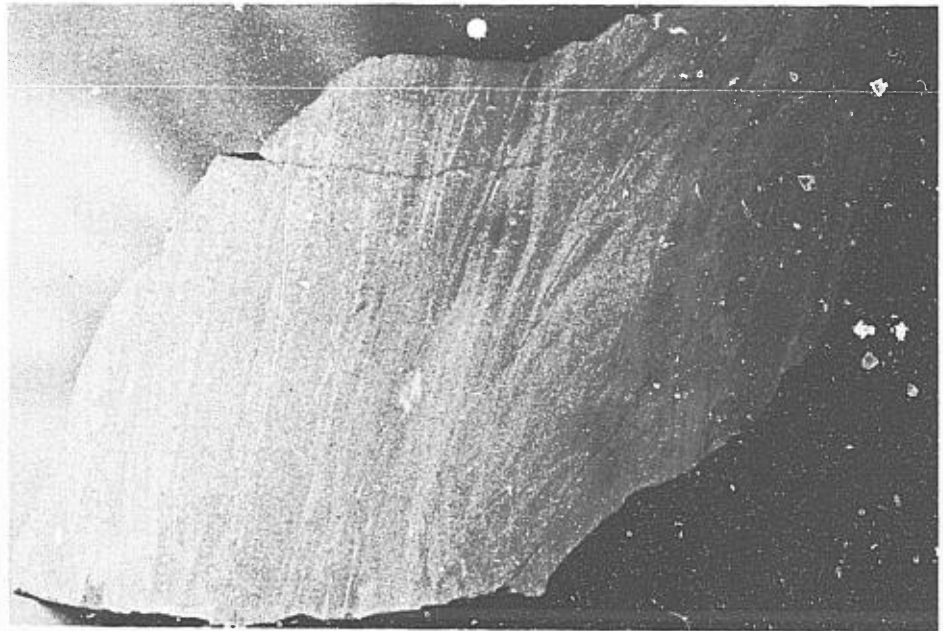
Fig. 12. Finely bedded carbonate-pyrite iron formation
from the Lac Sauvage Iron Formation. Sample RH-74-285
from Portage Island. Darker beds are fine-grained
siderite beds. Shiny white beds are pyrite-rich layers.
Height of the sample is 7.5 inches (16 cms).

Allard and Cimon (1972, unpublished map prepared for the International Geological Congress field trip A-C 41) and Jones et al. (1974) have extended the Waconichi Formation on the south limb much too far westward. Recent work by Cimon (1975), Christman (1975), and Feuerbach (1970), indicate that in Queylus, Hauy, and Scott Township, the Chibougamau pluton is intrusive into the Gilman and Stella Formations but there are no traces of the Waconichi Formation. As seen on Plate 1, the only Waconichi Formation on the south limb is a narrow strip of rhyolites, dacites, and pyroclastics in Lemoine and Rinfret Township south of the Dore Lake Complex. This is a mirror-image of the situation in Scott Township, north of David Lake, on the north limb of the anticline (Allard, 1975). The INPUT survey done by the Q.D.N.R. in 1972 shows this contact as a series of small punctual anomalies, similar to the Mile 11 contact zone as opposed to anomalies in the Blondeau or Stella Formations which are continuous and of very high intensity, because of the ubiquitous combination of pyrite and graphite. Cimon (oral presentation at the 1974 symposium and personal communication, 1975) believes that the rhyolites and the Patino-Lemoine ore deposit belong to the Blondeau Formation. Further mapping, research, and geochronological studies will be necessary to resolve this argument which has very important economic exploration implications.

Gilman Formation

The Gilman Formation lies conformably above the Waconichi Formation and forms the lower and main portion of the second volcanic cycle in the Chibougamau area (Fig. 8). It consists of 12,000 feet (3600 m.) (Duquette, 1970) of pillowed metabasalts and comagmatic gabbro sills. Flows can reach 200 feet (60 m.) in thickness. The majority of flows show well preserved pillow structures (Fig. 13). Scoriaceous flow tops and fragmental flow tops are common. A few horizons of pillow breccias and thin lenses of tuff between flows have been observed. In a few thick flows, accumulation of large

plagioclase phenocrysts close to the base (Fig. 14) suggest settling of crystals in a liquid magma that has come to rest. The base of the formation is more chloritic and mafic in character (Fig. 15). The top of the formation is more actinolitic and possibly more andesitic in composition. Table 7 to 18 give chemical and modal analyses of Gilman Formation rocks. A detailed petrochemical discussion will follow in a separate chapter. The pillows at the base of the formation (Fig. 13) tend to be larger and to contain much larger quantity of vesicles as compared to the small pillows north of the railroad station which show a thin glassy selvage hard to detect unless the outcrop is a good glaciated surface covered with wet moss which can be rolled off leaving a perfect etched surface. In a number of places, we have observed flows showing massive lower portion grading upward without a sharp contact into a pillowed upper portion.

The Gilman Formation takes its name from Gilman Lake and the best section would be along the main highway from the Hydro Quebec substation 3 miles (5 kms) south of Chibougamau to M.P. 4 on the Albanel highway. Regional considerations indicate that the Gilman Formation changes in character and thickness away from Chibougamau. It becomes thinner and more pyroclastic in nature to the east, west, and south. This might imply a submarine shield volcanic center around the location of Chibougamau with the pyroclastic debris further out on the flanks of the shield.

Hyaloclastite

In a few places, the top of the Gilman Formation is marked by a pale green actinolitic pillowed metabasalt with abundant varioles inside the pillows and a thick border of brown-weathering hyaloclastite between the pillows. The best outcrop is about 5600 feet (1680 m.) west of M.P. 4 on the Albanel highway (Figs. 17 and 18). The rock weathers to a dark brown color and the andesitic fragments stand out in relief above the glassy brown matrix and weather to a pale green color.

Volcanic breccia? Block tuff? Agglomerate?

An unusual lens of very coarse material is found in a former gravel pit just west of the railroad station. It is about 75-100 feet (22-30 m.) thick and a few hundred feet in length. However, Smith's map (1960) shows a series of similar lenses at about the same stratigraphic level across the area just north of the town of Chibougamau. The outcrop at the railroad station shows beds of large blocks, up to 1 m. in diameter (Figs. 19 and 20) of porphyritic pale grey andesitic lava grading upward into feldspathic crystal tuff. Some beds contain large quantities of slabby white chert fragments and small clasts of sulfides. This would indicate the proximity of a volcanic center with formation of an exhalite bed blown up and fragmented by volcanic explosions. The porphyritic andesitic nature of the blocks is difficult to explain since such lavas have not been found either below or above within the Gilman Formation. Tables 11 to 14 present chemical analyses and norms for a series of samples from the blocks and from the matrix (data courtesy of Dr. Fischer, International Nickel Co. of Canada).

It is interesting to note that a road cut in the northeast part of town exposed a breccia consisting of similar pale green andesitic fragments in a matrix of massive pyrrhotite. It was analyzed for precious and base metals with negative results. Further east, a bedded felsic pyroclastic unit has been identified in one traverse but further detailed work is necessary to determine its extent.

This horizon of felsic tuffs, agglomerate, and breccia with minor chert and sulfide may represent the end of a first phase of the second volcanic cycle. Detailed petrochemical and petrographic studies may show the need to make further subdivisions in the stratigraphy as outlined by Duquette (1970). The Waconichi cycle could be made into a group with further subdivisions into formations. The Gilman-Blondeau cycle might have to be subdivided.

North of Bruneau Mine, the upper contact of the Gilman Formation is exposed in a large hydraulicked outcrop. Large pillows of silicified (?) basalt (?) are surrounded by a thick brown-colored rusty rind caused by the weathering of sulfides (Figs. 21 and 22). Detailed chemical and petrographic work on that zone is in progress but the results are not available at the present.

Gabbro sills

Gabbro sills form an important part of the Gilman Formation. Of the 12,000 feet (3600 m.) of section measured across the town of Chibougamau, over 3000 feet (900 m.) are made up of gabbro sills. They range from tens of feet to more than 1000 feet (300 m.) in thickness. The thickest sills show good evidence of differentiation and the presence of variable amounts of quartz close to the top of the sill is one of the best top and bottom criterion used in the field. The sills form rounded smooth homogeneous outcrops as opposed to the hackly rough irregular surface of the flows. The sills are more competent and brittle than the enclosing volcanic rocks and give excellent traps for ore solutions as will be discussed in a chapter on structural geology and metallogeny. Modal analyses and chemical analyses of a few sills are presented in Tables 15 and 18.

A small sill in Queylus Township was brought to our attention by Cimon. It is significant because the sill is only 400 feet thick (120 m.) and shows a spectacular accumulation of plagioclase at the base (Fig. 23) giving a gabbroic anorthosite similar to the Dore Lake Complex gabbroic anorthosite. Further up, the sill becomes a dark fine-grained gabbro with disseminated plagioclase phenocrysts gradually decreasing in quantity (Fig. 24). The sill is surrounded by pillowed metabasalts and tuffs all containing large quantities of coarse plagioclase phenocrysts. This supports strongly the idea that the sills are coeval and comagmatic with the enclosing flows. It could also explain the lack

TABLE 7

CHEMICAL ANALYSES OF ROCKS FROM UNIT GILMAN METABASALTS

ANALYSES CHIMIQUES DES ROCHES DE METABASALTES DU GILMAN

Sample No. No. d'échantillon	CH-506	CH-512	CH-513	CH-515	J-71-83	J-71-258
SiO_2	49.42	51.60	49.19	50.50	50.05	48.30
TiO_2	1.88	1.03	0.75	1.06	1.05	1.90
Al_2O_3	15.70	14.97	14.53	15.05	16.10	15.15
Fe_2O_3	4.05	2.82	3.09	3.06	2.67	3.43
FeO	12.16	8.53	9.38	9.27	7.92	10.31
MnO	0.21	0.22	0.21	0.20	0.16	0.20
MgO	5.44	5.01	9.77	7.28	8.25	5.65
CaO	8.26	12.83	9.86	10.73	7.10	5.85
Na_2O	1.30	1.87	1.81	1.36	3.08	2.85
K_2O	0.02	0.06	0.30	0.26	0.45	0.35
P_2O_5	0.18	0.10	0.08	0.21		
H_2O+						
H_2O-						
CO_2						
S						
TOTAL	98.62	99.04	98.96	98.97	96.83	93.99
Norm wt%						
Qtz	9.69	6.97		6.20		3.68
Cor						
Or	0.13	0.35	1.76	1.54	2.66	2.07
Plag	47.93	48.10	45.95	45.69	54.84	51.63
Ab	10.97	15.82	15.31	11.48	26.06	24.12
An	36.95	32.28	30.65	34.20	28.78	27.51
Ne						
Wo						
Di	2.37	25.39	14.41	14.46	5.23	1.25
Wo	1.19	12.83	7.40	7.37	2.69	0.63
En	0.54	6.39	4.47	4.11	1.66	0.32
Fa	0.64	6.17	2.54	2.97	0.88	0.30
Hy	28.65	11.96	29.70	24.16	26.47	26.79
En	13.01	6.09	18.94	14.02	17.29	13.75
Fs	15.64	5.87	10.76	10.14	9.17	13.03
Ol						
Fo			1.06 0.85		1.77 1.12	
Fa			0.41		0.65	
Mt	5.87	4.09	4.48	4.44	3.87	4.97
Il	3.56	1.96	1.42	2.01	1.99	3.61
Hm						
Ap	0.43	0.24	0.19	0.49		
Py						
Cal						
Data Wt%						
An/plag	77.1	67.1	66.7	74.9	52.4	53.2
Fa/ol			38.5		36.9	
En/hy	45.4	50.9	63.8	58.0	65.3	51.3
Diff.i.	20.8	23.1	17.0	19.2	28.7	29.9
Qtz	46.6	30.1		32.2		12.3
Ab	52.8	68.3	89.7	59.7	90.7	80.7
Or	0.6	1.5	10.3	8.0	9.2	6.9
An	76.9	66.6	64.2	72.4	50.0	51.2
Ab	22.8	32.7	32.0	24.3	45.3	44.9
Or	0.2	0.7	3.7	3.2	4.6	3.8
A	5.7	10.5	8.6	7.6	15.8	14.1
F	70.5	62.0	51.2	58.0	47.3	60.8
M	23.7	27.3	40.1	34.2	36.9	25.0
Na+K/Al	13.7	21.0	22.7	16.7	34.5	33.4
Fe+Mn/Fe+Mg	62.3	55.8	41.5	48.5	41.6	57.4

TABLE 8

CHEMICAL ANALYSES OF ROCKS FROM UNIT GILMAN METABASALTS

ANALYSES CHIMIQUES DES ROCHES DE   METABASALTES DU GILMAN

Sample No. No. d'échantillon	J-71-44	J-71-260	J-71-262	71-195	F-69-68	CH-516
SiO_2	50.80	48.20	50.10	44.20	46.34	56.80
TiO_2	1.15	1.16	1.35	1.75	1.50	1.59
Al_2O_3	14.90	14.85	14.80	13.00	11.40	15.36
Fe_2O_3	2.39	2.19	2.51	3.10	2.79	2.50
FeO	7.16	6.57	7.54	11.26	12.41	7.51
MnO	0.18	0.19	0.14	0.21		0.19
MgO	6.10	6.55	7.10	5.66	6.59	4.36
CaO	11.30	10.10	7.55	7.96	5.30	6.55
Na_2O	2.80	2.50	2.80	3.45	4.23	3.31
K_2O	0.60	0.40	0.50	0.01	0.13	0.82
P_2O_5				0.14		0.17
H_2O+				4.48		
H_2O-				0.15		
CO_2				4.60		
S				0.07		
TOTAL	97.38	92.73	94.39	100.04	90.49	99.16
Norm wt%						
Qtz	0.96	1.53	3.08	4.51		11.52
Cor				3.83		
Or	3.55	2.36	2.95	0.06	0.77	4.87
Plag	50.01	49.27	50.03	38.69	47.53	52.61
Ab	23.69	21.15	23.69	29.19	35.79	27.97
An	26.32	28.12	26.34	9.50	11.73	24.64
Ne						
Wo						
Di	24.25	17.83	9.03		12.09	5.54
Wo	12.42	9.18	4.64		6.08	2.81
En	7.25	5.65	2.82		2.84	1.46
Fs	4.58	3.00	1.56		3.17	1.27
Hy	12.97	16.32	23.10	29.57	9.05	17.58
En	7.95	10.66	14.86	14.10	4.27	9.40
Fs	5.03	5.66	8.24	15.47	4.78	8.18
Ol					14.54	
Fo					6.52	
Fa					8.02	
Mt	3.47	3.18	3.64	4.49	4.05	3.62
Il	2.18	2.24	2.56	3.32	2.47	3.03
Hm						
Ap				0.33		0.40
Py				0.13		
Cal				10.46		
Data Wt%						
An/plag	52.6	57.0	52.6	24.5	24.7	46.8
Fa/ol					55.1	
En/hy	61.2	65.3	64.3	47.7	47.2	53.4
Diff.i.	28.2	25.0	29.7	33.8	36.5	44.3
Qtz	3.4	6.1	10.3	13.3		26.0
Ab	84.0	84.4	79.7	86.4	97.9	63.0
Or	12.5	9.4	9.9	0.1	2.1	11.0
An	49.1	54.4	49.7	24.5	24.3	42.9
Ab	44.2	41.0	44.7	75.3	74.1	48.7
Or	6.6	4.5	5.5	0.1	1.5	8.4
A	17.8	15.9	16.1	14.7	16.7	22.3
F	50.1	48.1	49.1	61.2	58.1	54.1
M	32.0	36.0	34.7	24.1	25.2	23.5
Na+K/Al	35.2	30.6	34.8	43.7	62.2	41.2
Fe+Mn/Fe+Mn+Mg	46.6	43.0	44.0	58.5	55.9	56.1
Na_2O/Na_2O+K_2O	82.3	86.2	84.8	99.7	97.0	80.0

TABLE 9

CHEMICAL ANALYSES OF ROCKS FROM UNIT GILMAN METABASALTS

ANALYSES CHIMIQUES DES ROCHES DE   METABASALTES DU GILMAN

Sample No. No. d'échantillon	CH-517	CH-525	71-192	71-136	J-74-222
SiO_2	46.92	45.57	48.60	49.00	59.00
TiO_2	1.63	0.74	1.38	1.75	0.72
Al_2O_3	14.95	12.51	15.25	14.25	14.85
Fe_2O_3	3.87	2.89	2.67	2.42	1.07
FeO	11.60	8.75	7.46	9.59	3.22
MnO	0.19	0.20	0.24	0.28	0.10
MgO	6.86	13.13	6.46	6.34	4.95
CaO	7.78	9.48	11.84	8.84	5.55
Na_2O	4.46	5.61	2.43	3.83	4.50
K_2O	0.24	0.01	0.03	0.12	0.60
P_2O_5	0.21	0.14	0.12	0.13	
H_2O+			2.75	3.00	
H_2O-			0.10	0.12	
CO_2			0.94	0.54	
S			0.07	0.22	
TOTAL	98.71	99.03	100.34	100.43	94.56
Norm wt%					
Qtz			2.54		11.37
Cor					
Or	1.42	0.07	0.38	0.71	3.55
Plag	51.55	22.10	51.16	53.74	56.63
Ab	31.48	13.18	20.56	32.41	38.08
An	20.06	8.92	30.61	21.34	18.55
Ne	3.39	18.58			
Di	14.16	29.92	17.41	15.00	7.20
Wo	7.17	15.53	8.93	7.62	3.75
En	3.64	10.34	5.32	4.08	2.60
Fs	3.36	4.05	3.15	3.30	0.85
Hy			17.13	13.08	12.91
En			10.76	7.23	9.73
Fs			6.37	5.85	3.18
Ol	19.00	22.44		5.95	
Fo	9.42	15.67		3.14	
Fa	9.58	6.77		2.81	
Mt	5.61	4.19	3.87	3.51	1.55
Il	3.10	1.41	2.62	3.32	1.37
Hm					
Ap	0.50	0.33	0.28	0.31	
Py			0.13	0.41	
Cal			2.14	1.23	
Data Wt%					
An/plag	38.9	40.3	59.8	39.7	32.8
Fa/ol	50.4	30.1		47.1	
En/hy			62.8	55.2	75.3
Diff.i.	36.2	31.8	23.2	33.1	53.0
Qtz			10.9		21.4
Ab			88.3	97.9	71.9
Or			0.8	2.1	6.7
An	37.9	40.2	59.6	39.1	30.8
Ab	59.4	59.4	40.0	59.5	63.2
Or	2.7	0.3	0.3	1.3	5.9
A	17.3	18.5	12.9	17.8	35.5
F	57.2	36.3	53.1	53.9	29.9
M	25.3	43.2	33.9	28.4	34.5
Na+K/Al	50.8	73.9	26.4	45.1	54.2
Fe+Mn/Fe+Mn+Mg	55.5	33.0	46.7	51.6	32.7

TABLE 10

CHEMICAL ANALYSES OF ROCKS FROM UNIT GILMAN TUFF

ANALYSES CHIMIQUES DES ROCHES DE   TUF DE GILMAN

Sample No. No. d'échantillon	CH-514	CH-515	CH-522	CH-529	J-71-265	71-191
SiO_2	65.98	65.71	71.82	53.26	74.10	62.95
TiO_2	0.57	0.31	0.56	1.13	0.42	0.28
Al_2O_3	16.50	17.86	17.04	16.04	14.35	17.45
Fe_2O_3	1.39	0.96	0.77	3.03	0.84	1.35
FeO	4.17	2.87	2.32	9.09	2.52	2.15
MnO	0.08	0.06	0.03	0.18	0.02	0.07
MgO	1.77	2.12	2.76	6.01	1.40	1.19
CaO	4.60	4.08	0.75	8.37	0.95	5.05
Na_2O	2.35	1.36	2.07	2.67	3.50	5.84
K_2O	2.02	4.16	1.41	0.03	1.20	1.20
P_2O_5	0.10	0.21	0.21	0.17		0.09
H_2O+						1.36
H_2O-						0.07
CO_2						1.00
S						0.01
TOTAL	99.53	99.69	99.74	98.98	99.30	100.06
Norm wt%						
Qtz	29.74	28.72	48.00	6.32	43.53	13.71
Cor	2.31	4.20	11.24		5.57	
Or	11.94	24.58	8.31	0.18	7.09	7.09
Plag	42.10	30.38	19.89	54.29	34.33	67.27
Ab	19.90	11.48	17.52	22.59	29.62	49.42
An	22.19	18.90	2.38	31.69	4.71	17.86
Ne						
Wo						
Di				7.17		0.24
Wo				3.64		0.12
En				1.91		0.06
Fa				1.62		0.05
Hy	10.11	9.35	9.64	24.09	6.76	5.33
En	4.41	5.28	6.87	13.05	3.49	2.90
Fs	5.70	4.07	2.76	11.04	3.28	2.43
Ol Fo						
Fa						
Mt	2.02	1.39	1.12	4.39	1.22	1.96
Il	1.09	0.58	1.06	2.15	0.80	0.53
Hm						
Ap	0.23	0.49	0.49	0.40		0.21
Py						0.02
Cal						2.27
Data wt%						
An/plag	52.7	62.2	11.9	58.3	13.7	26.5
Fa/ol						
En/hy	43.6	56.4	71.3	54.1	51.5	54.4
Diff.i.	61.5	64.8	73.8	29.0	80.2	70.2
Qtz	48.2	44.3	65.0	21.7	54.2	19.5
Ab	32.3	17.7	23.7	77.8	36.9	70.3
Or	19.3	37.9	11.2	0.6	8.8	10.1
An	41.0	34.3	8.4	58.1	11.3	24.0
Ab	36.8	20.9	62.1	41.4	71.5	66.4
Or	22.1	44.7	29.4	0.3	17.1	9.5
A	37.3	48.1	37.2	13.0	49.7	24.0
F	47.5	33.4	33.1	58.1	35.5	66.4
K	15.1	18.4	29.5	28.8	14.8	9.5
Na+K/Al	36.7	37.7	28.9	27.5	49.1	62.5
Fe+Mn/Fe+Mn+	63.5	50.0	38.2	52.8	56.9	61.8
Na_2O/Na_2O+K_2O	53.8	24.6	59.5	98.9	74.4	82.9

TABLE 11

CHEMICAL ANALYSES OF ROCKS FROM UNIT ANDESITE BLOCKS IN GILMAN - RAILROAD STATION

ANALYSES CHIMIQUES DES ROCHES DES BLOCS D'ANDESITE DANS LA FORMATION GILMAN A LA
GARE

Sample No. No. d'échantillon	Inco 1	Inco 2	Inco 7	Inco 13	Inco 16	Inco 18
SiO_2	61.10	64.04	62.04	59.53	46.78	57.89
TiO_2						
Al_2O_3	16.79	16.77	14.65	12.53	17.36	17.17
Fe_2O_3	0.85	0.61	1.04	1.49	2.47	1.27
FeO	2.56	1.85	3.11	4.46	7.42	3.81
MnO						
MgO	2.01	1.61	3.09	4.11	5.90	3.11
CaO	3.94	4.06	5.15	9.66	3.43	2.41
Na_2O	7.52	6.55	5.67	3.88	5.51	7.97
K_2O	0.56	0.92	0.66			
P_2O_5						
H_2O+						
K_2O-	•					
CO_2						
S						
TOTAL	95.13	96.41	95.41	95.66	88.87	93.63
Norm wt%						
Qtz	4.90	11.41	11.49	13.69		
Cor						
Or	3.31	5.44	3.90			
Plag	73.24	69.06	60.55	49.60		78.51
Ab	61.94	55.42	47.98	32.83		67.44
An	11.30	13.64	12.57	16.77		11.07
Ne						
Wo						
Di	6.77	5.32	10.58	25.45		0.72
Wo	3.44	2.71	5.42	13.01		0.37
En	1.85	1.51	3.16	7.41		0.20
Fa	1.48	1.09	1.99	5.04		0.15
Hy	5.68	4.30	7.39	4.75		10.41
En	3.16	2.50	4.53	2.83		5.89
Fs	2.52	1.80	2.86	1.92		4.52
Ol						
Fo						2.15
Fa						1.16
						0.98
Mt	1.23	0.88	1.51	2.16		1.64
Il						
Hm						
Ap						
Py						
Cal						
Data Wt%						
An/plag	15.4	19.7	20.8	33.8		14.1
Fa/ol						45.8
En/hy	55.5	58.0	61.3	59.5		56.5
Diff.i.	70.1	72.2	63.3	46.5		67.4
Qtz	7.0	15.8	18.1	29.4		
Ab	88.3	76.7	75.7	70.5		100.0
Or	4.7	7.5	6.1			
An	14.8	18.3	19.5	33.8		14.1
Ab	80.9	74.3	74.4	66.1		85.9
Or	4.3	7.3	6.0			
A	59.2	64.7	46.6	27.8		49.3
F	25.6	21.3	30.5	42.7		31.4
M	15.1	13.9	22.8	29.4		19.2
Na+K/Al	75.3	70.1	68.5	50.9		76.3
Fe+Mn/Fe+Mn+Mg	48.1	45.5	42.3	44.9		47.1
Na_2O/Na_2O+K_2O	92.9	87.7	89.5	100.0		100.0

TABLE 12

CHEMICAL ANALYSES OF ROCKS FROM UNIT   GILMAN TUFF - RAILROAD STATION

ANALYSES CHIMIQUES DES ROCHES DE   TUF DE GILMAN A LA GARE

Sample No. No. d'échantillon	J-71-39	Inco 3	Inco 4	Inco 5	Inco 6	Inco 8
SiO_2	61.50	59.64	58.82	56.10	63.64	57.99
TiO_2	0.72					
Al_2O_3	16.20	15.95	15.42	16.05	9.84	15.68
Fe_2O_3	1.81	1.49	1.61	1.70	1.32	1.65
FeO	5.43	4.47	4.84	5.10	3.96	4.94
MnO	0.12					
MgO	4.45	3.56	3.50	4.47	3.29	4.54
CaO	4.60	3.18	4.16	2.01	13.45	2.56
Na_2O	2.90	3.95	4.34	6.08	2.17	3.35
K_2O	0.55	1.30	0.80		0.41	1.37
P_2O_5						
H_2O+						
H_2O-						
CO_2						
S						
TOTAL	97.83	93.54	93.49	91.51	98.08	92.08
Norm wt%						
Qtz	22.17	16.39	13.03	6.14	23.89	17.50
Cor	2.47	2.26		2.39		4.03
Or	3.25	7.68	4.73		2.42	8.10
Plag	47.36	49.20	56.95	61.42	34.26	41.05
Ab	24.54	33.42	36.72	51.45	18.36	28.35
An	22.82	15.78	20.23	9.97	15.90	12.70
Ne						
Wo					6.30	
Di			0.34		29.30	
Wo			0.17		14.92	
En			0.09		8.19	
Fa			0.08		6.18	
Hy	18.59	15.84	16.11	19.09		19.02
En	11.08	8.87	8.63	11.13		11.31
Fs	7.51	6.98	7.48	7.96		7.71
Ol Fo						
Fa						
Mt	2.62	2.16	2.33	2.46	1.91	2.39
Il	1.37					
Hm						
Ap						
Py						
Cal						
Data wt%						
An/plag	48.1	32.0	35.5	16.2	46.4	30.9
Fa/ol						
En/hy	59.6	56.0	53.5	58.3		59.4
Diff.i.	50.0	57.5	54.4	57.5	44.7	53.9
Qtz	44.3	28.5	23.9	10.7	53.4	32.4
Ab	49.1	58.1	67.4	89.3	41.1	51.5
Or	6.5	13.3	8.5		5.4	15.0
An	45.0	27.7	32.8	16.2	43.3	25.8
Ab	48.4	58.8	59.5	83.8	50.0	57.7
Or	6.4	13.5	7.7		6.5	16.4
A	22.8	35.5	34.0	35.0	23.1	29.8
F	47.8	40.3	42.7	39.1	47.3	41.5
M	29.3	24.1	23.1	25.8	29.5	28.6
Na+K/Al	33.1	49.5	51.9	62.3	40.8	44.6
FeMg/FeMg	47.5	47.8	50.2	45.4	46.7	44.2

TABLE 13

CHEMICAL ANALYSES OF ROCKS FROM UNIT GILMAN TUFF - RAILROAD STATION

ANALYSES CHIMIQUES DES ROCHES DE   TUF DE GILMAN A LA GARE

Sample No. No. d'échantillon	Inco 9	Inco 10	Inco 11	Inco 12	Inco 14
SiO_2	60.72	58.19	58.89	55.00	56.21
TiO_2					
Al_2O_3	16.16	13.69	13.95	14.64	16.38
Fe_2O_3	1.45	1.75	1.61	2.24	1.57
FeO	4.34	5.26	4.84	6.72	4.72
MnO					
MgO	3.88	4.42	4.45	5.46	3.80
CaO	1.78	6.02	2.43	2.24	1.64
Na_2O	3.68	3.69	5.25	3.79	6.83
K_2O	1.75	0.46		0.29	0.33
P_2O_5					
H_2O+					
H_2O-					
CO_2					
S					
TOTAL	93.76	93.48	91.42	90.38	91.68
Norm wt%					
Qtz	19.94	13.99	13.07	14.13	2.26
Cor	4.98		0.90	4.02	1.44
Or	10.34	2.72		1.71	1.95
Plag	39.97	50.66	56.48	43.18	66.92
Ab	31.14	31.22	44.42	32.07	57.79
An	8.83	19.43	12.06	11.11	9.13
Ne					
Wo					
Di		8.55			
Wo		4.36			
En		2.40			
Fs		1.79			
Hy	16.43	15.03	18.64	24.09	16.83
En	9.66	8.61	11.08	13.60	9.46
Fs	6.77	6.42	7.56	10.49	7.37
Ol					
Fo					
Fa					
Mt	2.10	2.54	2.33	3.25	2.28
Il					
Hm					
Ap					
Py					
Cal					
Data Wt%					
An/plag	22.0	38.3	21.3	25.7	13.6
Fa/ol					
En/hy	58.8	57.2	59.4	56.4	56.2
Diff.i.	61.4	47.9	57.4	47.9	62.0
Qtz	32.4	29.1	22.7	29.4	3.6
Ab	50.7	65.1	77.2	66.9	93.2
Or	16.8	5.7		3.5	3.1
An	17.5	36.4	21.3	24.7	13.2
Ab	61.9	58.5	78.7	71.4	83.9
Or	20.5	5.0		3.8	2.8
A	36.0	26.6	32.5	22.0	41.5
F	38.3	45.0	39.9	48.4	36.4
M	25.7	28.3	27.5	29.5	22.0
Na+K/Al	49.1	48.0	61.9	44.7	70.8
Fe+Mn/Fe+Mg	44.9	46.4	44.2	47.3	47.5
Na_2O/Na_2O+K_2O	67.8	88.9	100.0	92.9	95.3

TABLE 14

CHEMICAL ANALYSES OF ROCKS FROM UNIT GILMAN TUFF - RAILROAD STATION

ANALYSES CHIMIQUES DES ROCHES DE   TUF DE GILMAN À LA GARE

Sample No. No. d'échantillon	Inco 15	Inco 17	Inco 19	Inco 20	Inco 21
SiO_2	62.68	59.99	56.70	61.39	58.28
TiO_2					
Al_2O_3	14.32	14.98	15.84	15.49	13.47
Fe_2O_3	1.60	1.60	1.54	1.02	2.04
FeO	4.80	4.80	4.63	3.06	6.11
MnO					
MgO	3.52	3.74	4.07	3.01	5.82
CaO	2.88	4.06	3.99	3.81	2.99
Na_2O	4.40	4.74	5.06	5.33	3.56
K_2O	0.30	0.29	0.54	1.10	
P_2O_5					
H_2O+					
H_2O-					
CO_2					
S					
TOTAL	94.50	94.20	92.37	94.21	92.27
Norm wt%					
Qtz	21.11	13.93	7.48	12.17	18.15
Cor	1.52				2.18
Or	1.77	1.71	3.19	6.50	
Plag	51.52	58.85	61.73	60.19	44.45
Ab	37.23	40.11	42.82	45.10	30.12
An	14.29	18.74	18.91	15.09	14.63
Ne					
Ku					
Di		1.15	0.72	3.11	
Wo		0.58	0.37	1.59	
En		0.31	0.21	0.93	
Fa		0.25	0.15	0.59	
Hy	16.26	16.24	17.01	10.76	24.03
En	8.77	9.00	9.93	6.57	14.49
Fs	7.49	7.24	7.08	4.19	9.53
Ol					
Fo					
Fa					
Mt	2.32	2.32	2.23	1.48	2.96
Il					
Hm					
Ap					
Py					
Cal					
Data Wt%					
An/plag	27.7	31.8	30.6	25.0	33.0
Fa/ol					
En/hy	53.9	55.4	58.3	61.0	60.3
Diff.i.	60.1	55.7	53.4	63.8	48.2
Qtz	35.1	25.0	14.0	15.0	37.6
Ab	61.9	71.9	80.0	70.7	62.4
Or	2.9	3.0	6.0	10.1	
An	26.8	30.9	29.1	22.6	33.0
Ab	69.9	66.2	65.9	67.6	67.0
Or	3.3	2.8	4.9	9.7	
A	32.1	33.1	35.3	47.5	20.3
F	43.8	42.1	38.9	30.1	46.4
M	24.0	24.6	25.7	22.2	33.2
Na+K/Al	52.8	54.1	56.2	64.2	43.4
Fe+Mn/Felsic	49.9	48.3	45.3	42.5	43.3

TABLE 15

CHEMICAL ANALYSES OF ROCKS FROM UNIT GABBRO SILLS IN GILMAN VOLCANICS

ANALYSES CHIMIQUES DES ROCHES DES SILLS DE GABBRO DANS LES LAVES DU GILMAN

Sample No. No. d'échantillon	CH-523	J71-40	J71-42	J71-46	71-194
SiO_2	49.47	49.70	47.20	52.00	49.10
TiO_2	1.83	0.98	1.05	1.32	1.20
Al_2O_3	14.39	13.10	14.30	13.30	13.60
Fe_2O_3	4.31	2.33	2.51	3.14	3.90
FeO	12.91	6.98	7.54	9.41	8.55
MnO	0.24	0.22	0.17	0.21	0.20
MgO	5.40	8.10	8.30	4.90	7.72
CaO	8.81	10.70	10.70	6.80	9.16
Na_2O	0.40	2.85	2.50	3.28	2.06
K_2O	0.29	0.35	0.52	0.40	0.01
P_2O_5	0.37				0.13
H_2O+					3.70
H_2O-					0.10
CO_2					0.40
S					0.06
TOTAL	98.42	95.31	94.79	94.76	99.89

Norm wt%					
Qtz	13.16			6.53	5.58
Cor					
Or	1.71	2.07	3.07	2.36	0.06
Plag	39.99	46.03	47.42	48.14	45.26
Ab	3.38	24.12	21.15	27.75	17.43
An	36.62	21.92	26.26	20.39	27.83
Ne					
Ac					
Di	3.90	25.20	21.72	11.07	11.56
Wo	1.95	13.01	11.20	5.57	5.94
En	0.85	8.24	7.01	2.67	3.60
Fs	1.10	3.95	3.51	2.82	2.01
Hy	29.07	14.41	7.60	19.61	24.35
En	12.60	9.74	5.06	9.53	15.62
Fs	16.47	4.67	2.54	10.07	6.73
Ol		2.35	9.35		
Fo		1.54	6.03		
Fa		0.81	3.33		
Mt	6.25	3.38	3.64	4.55	5.65
Il	3.48	1.86	1.99	2.51	2.28
Hm					
Ap	0.88				0.31
Py					0.11
Cal					0.91

Data Wt%					
An/plag	91.5	47.6	55.3	42.3	61.4
Fa/ol		34.6	35.5		
En/hy	43.3	67.5	66.6	48.6	64.1
Diff.i.	18.2	26.1	24.2	36.5	23.0

Qtz	72.1			17.8	24.2
Ab	18.5	92.1	87.3	75.7	75.5
Or	9.4	7.9	12.6	6.4	0.2

An	87.8	45.5	52.0	40.3	61.4
Ab	8.1	50.1	41.9	55.0	38.4
Or	4.1	4.3	6.6	4.7	0.1

A	3.0	15.5	14.1	17.4	9.3
F	73.9	45.1	47.0	59.4	56.0
M	23.1	39.3	38.8	23.1	34.7

Na+K/Al	6.7	38.7	32.7	43.8	25.0
Fe+Mn/Fe+Mn+Mg	63.9	39.1	40.2	58.8	47.1
Na_2O/Na_2O+K_2O	57.9	89.0	82.8	89.1	99.5

Table 16

Notes on samples of Tables 7 to 15.

TABLES 7, 8, and 9. METABASALTS OF THE GILMAN FORMATION

NOTE: ALL GUNN AND DUQUETTE'S ANALYSES ARE IN THE FILES OF THE Q.D.N.R.

CH 506 Gunn and Duquette. Tholeiitic basalt. Roy Township. Near the Mistassini Park gate on the Albanel Highway, around M. 10.5.

CH 512 Gunn and Duquette. Metabasalt. Roy Township. 100 feet (30 m) southwest of the Park gate on Albanel Highway.

CH 513 Gunn and Duquette. Metabasalt. Roy Township. 1600 feet (480 m) southwest of the Park gate on Albanel Highway.

CH 515 Gunn and Duquette. Tuffaceous metasediment or altered dacite. Roy Township. 9600 feet (2880 m) southwest of the Park gate (M. 9 ±).

J-71-83 Oliveira, 1973, p. 87. Metabasalt. Roy Township. Albanel Highway close to the Park gate.

J-71-258 Oliveira, 1973, p. 90. Chlorite-rich metabasalt. McKenzie Township. St. Felicien Highway, M. 141.3.

J-71-44 Oliveira, 1973, p. 90. Metabasalt. McKenzie Township. Railroad cut north of the station.

J-71-260 Oliveira, 1973, p. 90. Metabasalt. McKenzie Township. 2.6 miles (4.2 kms) east of town of Chibougamau on main road.

J-71-262 Oliveira, 1973, p. 90. Metabasalt. Roy Township. M. 3.6 on Albanel Highway.

71-195 Allard, Q.D.N.R. Lab. Metabasalt. McKenzie Township. St. Felicien Highway at M. 142.9.

F-69-6B (14-69-2) Allard, Q.D.N.R. Lab. Metabasalt. NE 1/4 Scott Township. Sample of Fuerbach from northwest corner of the quarter township (see Allard, 1975).

CH 516 Gunn and Duquette. Tholeiitic pillow lava. Roy Township. 16,500 feet (4950 m) southwest of Park gate on Albanel Highway (± M. 7.8).

CH 517 Gunn and Duquette. Olivine tholeiite with flattened vesicles. Roy Township. 15,900 feet (4770 m) southwest of Park gate on Albanel Highway (± M. 7.5).

CH 525 Gunn and Duquette. Metabasalt. Roy Township. 16,600 feet (4980 m) southwest of Park gate on Albanel Highway (± M. 7.8).

71-192 Allard, Q.D.N.R. Lab. Metabasalt. Roy Township. Albanel Highway around M. 2.8.

71-136 Allard, Q.D.N.R. Lab. Pillowed Metabasalt. McKenzie Township. Railroad station.

J-71-222 Oliveira, 1973, p. 90. Metaandesite. McKenzie Township. Railroad station cut.

TABLE 10. TUFFS OF THE GILMAN FORMATION

CH 514 Gunn and Duquette. Tuffaceous black sediment with calcite. Roy Township. 6400 feet (1920 m) southwest of the Park gate, Albanel Highway, ± M. 9.4.

CH 522 Gunn and Duquette. Aluminous tuffaceous sediment. Roy Township. 2600 feet (780 m) of the park gate, Albanel Highway at M. 10 ±.

T A B L E   1 7

MODAL   ANALYSES   OF   METABASALTS   —   GILMAN   FORMATION

ANALYSES MODALES DE METABASALTES   —   FORMATION   GILMAN

Specimen No.	53-52	53-292	53-293	54-30	54-72	54-160	54-259	54-249	54-207
Albite	41	39.1	39.2	36	31.9	57.4	45.8	53.32	59.2
Actinolite	none	18.2	35.4	23	10.7	.16	16.8	none	none
Chlorite	32.8	12	13.6	10.3	7.8	30.2	12	32.7	36
Epidote	7.9	11.7	2.2	6.9	9.2	.11	5.6	none	none
Opaque	6.7	10.8	.11	16	.8	2.5	10.3	.06	.5
Leucoxene	5.9	8.2	6.7	8	8	6.6	6.2	7	4.6
Calcite	3.9	none	none	none	none	—	3	6.5	none
Quartz	1.6	none	2.8	none	none	.21	.25	.35	none
Number points	2173	1589	1794	1664	1668	1850	1938	1714	1813
Reproducibility	good	fair	very good	good	fair	fair	very good	poor	fair
Specific gravity	2.88	2.93	2.87	2.9	2.92	2.69	2.92	---	2.71
Index of artificial glasses formed by fusion & quenching	1.594	1.604	1.595	1.595	1.601	1.542	1.593	1.546	1.552

From Allard (1956, table 1, p. 36) .

—

TABLE 18

MODAL ANALYSES OF METAGABBRO SILLS - GILMAN FORMATION

ANALYSES MODALES DE SILLS DE METAGABBRO-FORMATION GILMAN

Specimen number	54-185	54-187	54-189
Height above base of sill	ca 40 feet	ca 150 feet	ca 300 feet
Clinozoisite	54.47	57.78	none
Clear plagioclase	11.3	tr	34.57
Actinolite	25.9	6.1	none
Chlorite	4.0	21	31.8
Opaque	.4	tr	11.2
Leucoxene	3.1	2.4	tr
Quartz	none	8.2	21.4
Calcite	.6	3.4	.5
Pyroxene	tr	none	none
Fine quartz & chlorite	none	.95	none
Number of points	1520	1470	1582
Specific gravity	3.03	2.94	2.89

From: Allard (1956, table 2, p. 59).
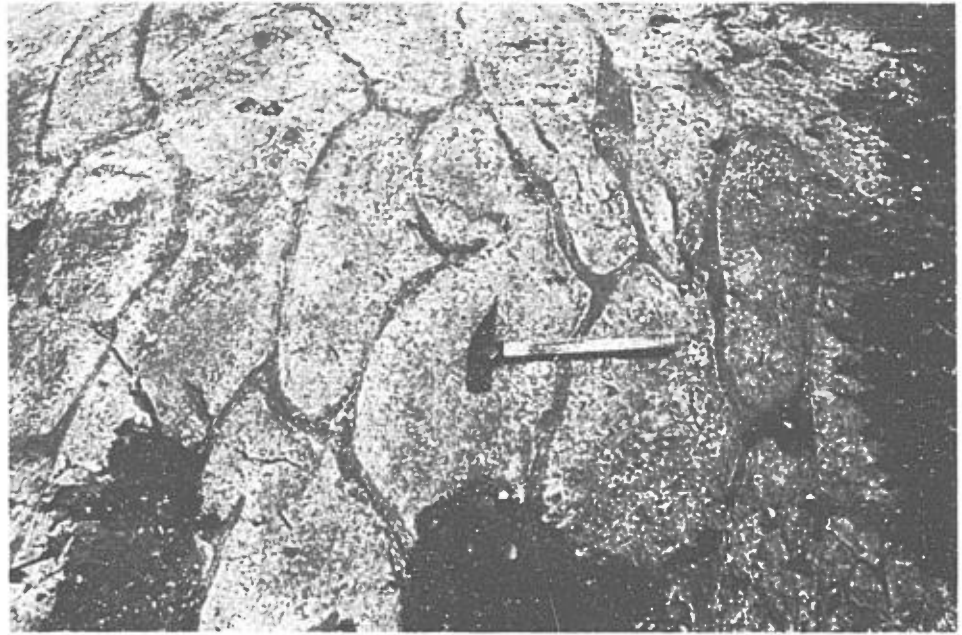
Fig. 13. Typical outcrop of pillowed metabasalt of the Gilman Formation (municipal garbage dump).

Fig. 14. Accumulation of plagioclase phenocrysts at the base of a metabasalt flow, Gilman Formation. The dark streak below the 6-inch (15 cms) scale is the chilled base of the flow. Intersection of Albanel Road and Henderson Road, 3 miles east of the town of Chibougamau.
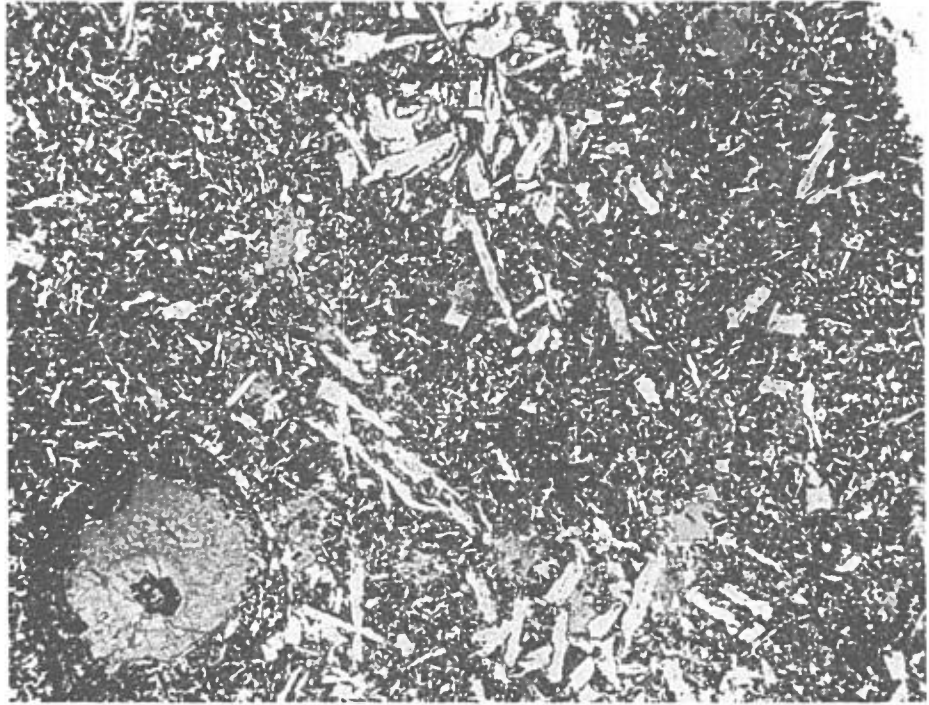
Fig. 15. Photomicrograph of a typical metabasalt from the Gilman Formation. Note the glomeroporphyritic texture and the chilled zone around the chlorite-filled amygdule. Sample 54-30. Field 1 cm.
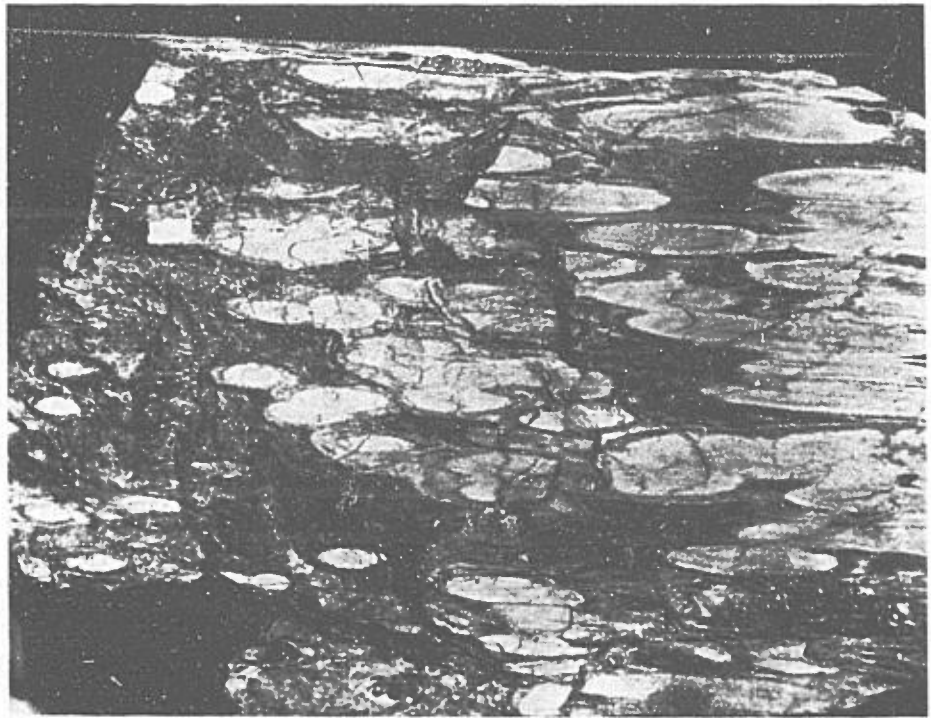
Fig. 16. Stretched varioles in metabasalt of the Gilman Formation. The plane of schistosity is vertical and the varioles are elongated in the vertical direction. Sample 53-110. Natural scale.
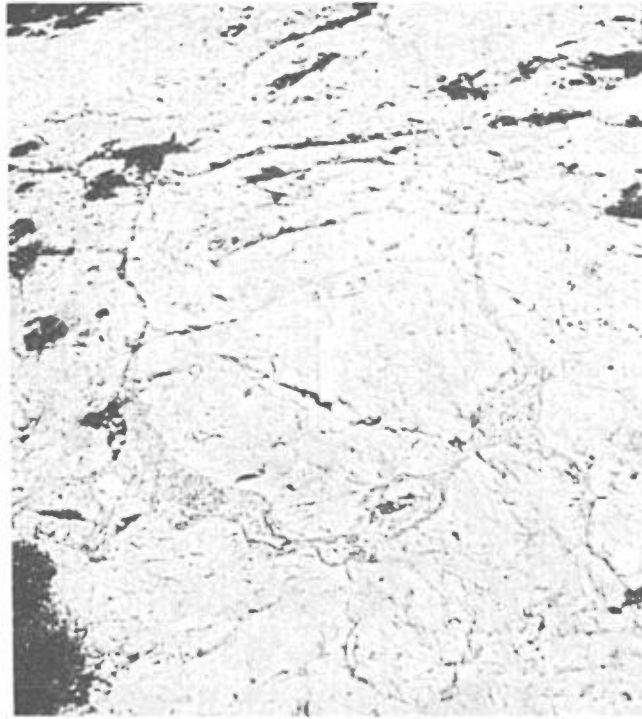
Fig. 17. Pillows of the Gilman Formation separated by
abundant hyaloclastite material. Top of the Gilman
Formation southwest of Cummings Lake. Scale is 6 inches
long (15 cms). Stratigraphic top to the left.
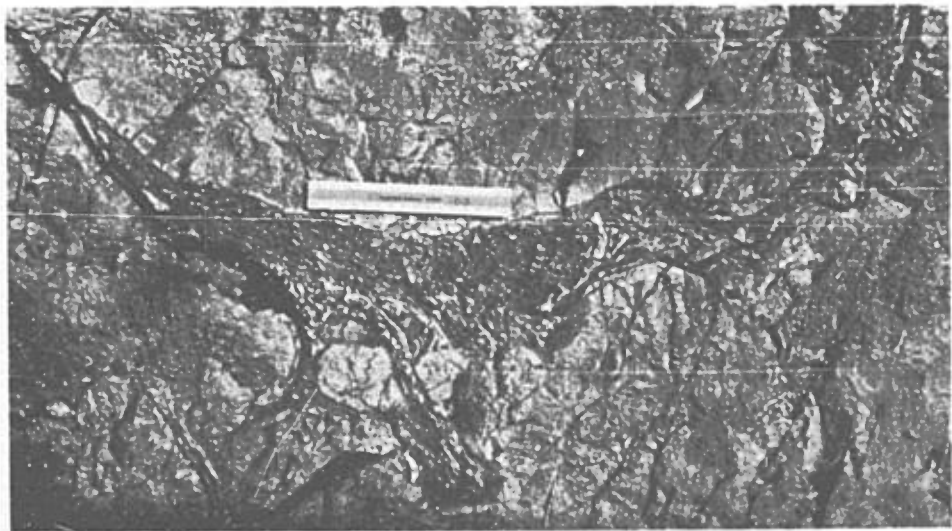
Fig. 18. Detail of interpillow hyaloclastite shown above in
Figure 17. Scale is 6 inches long (15 cms).

Fig. 19. Andesite breccia of the Gilman Formation at the
railroad station park. Angular fragments of andesite vary
from pale grey to medium grey. Some fragments are porphyritic.
Very few fragments are amyguloidal. Some fragments have a
narrow bleached halo around their outside rim. Scale is
6 inches long (15 cms).
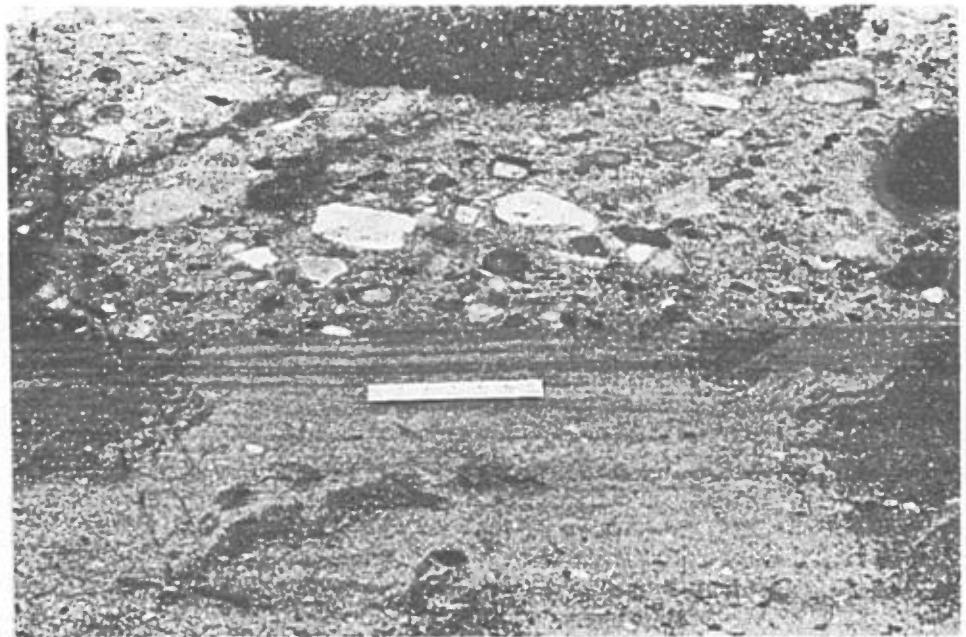
Fig. 20. Andesite breccia and tuff at the railroad station
park. Gilman Formation. Breccia fragments reach 3 feet (1 m.)
in diameter. Elongated narrow white slabs are chert fragments.
Most of the darker spots are rusty spots around small clasts of
pyrite. Scale is 6 inches long (15 cms).
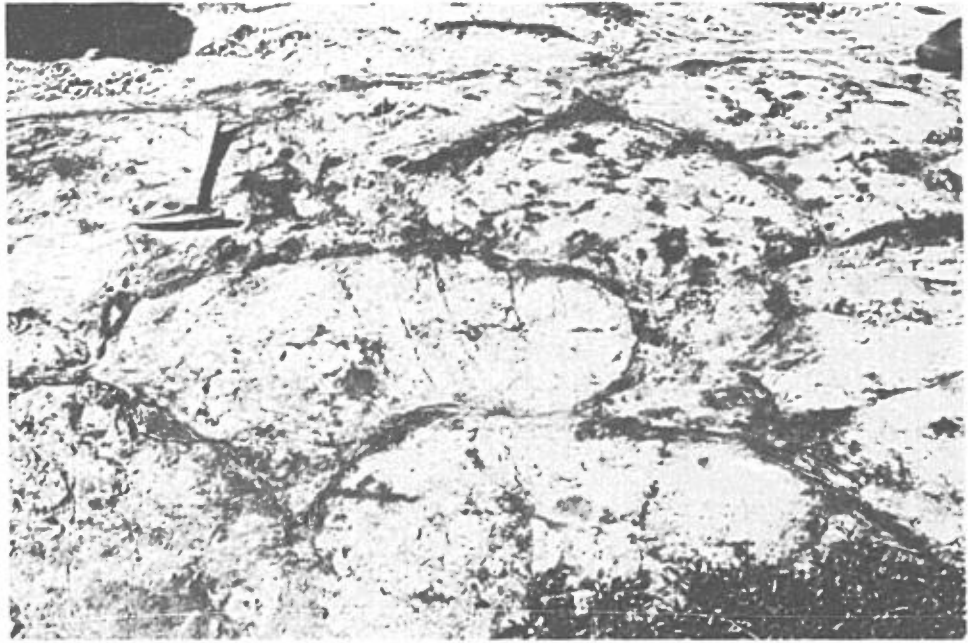
Fig. 21. Pale colored pillowed metabasalts (?) at the top
of the Gilman Formation. Each pillow is rimmed by a dark
brownish red rind caused by weathering of pyrite.
4300 feet (1300 m) northwest of Bruneau mine upper adit.
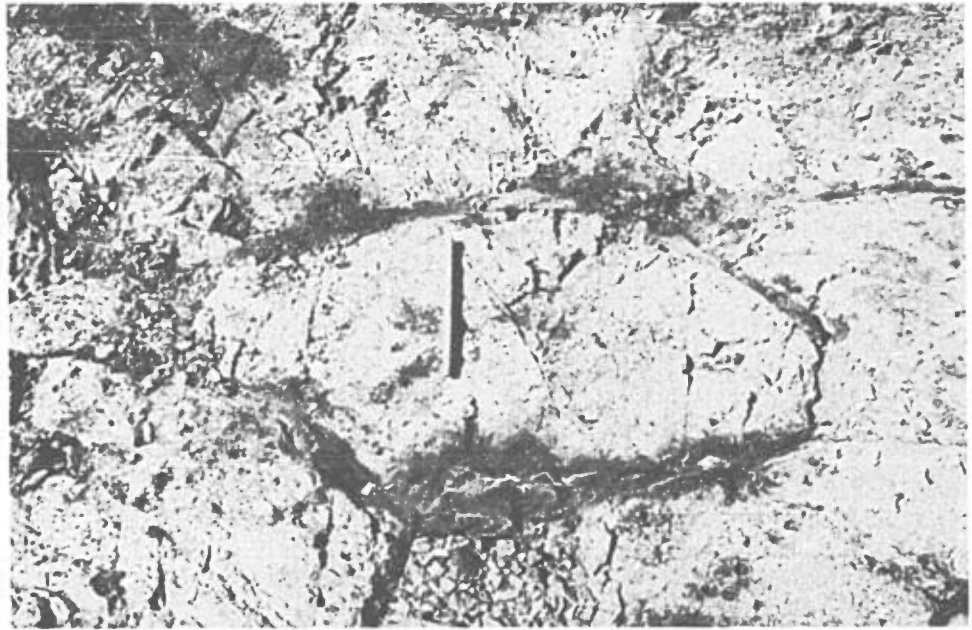
Fig. 22 Detail of pillows shown in figure 21 above.
Pen is 5.8 inches long (14.5 cms).
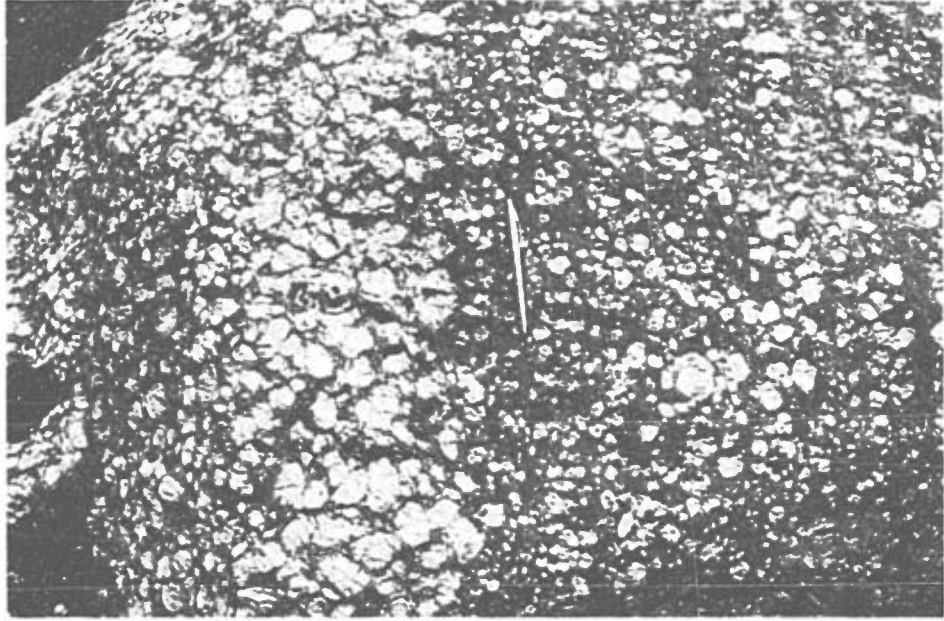
Fig. 23. Concentration of plagioclase phenocrysts at the base of a thin gabbro sill in Queylus Township, producing a gabbroic anorthosite similar to that found in the Dore Lake Complex. The sill is probably less than 400 feet (120 m) thick. South of road leading to sawmill at M.P. 123. Scale is a pen 5.8 (14.5 cms) inches long.
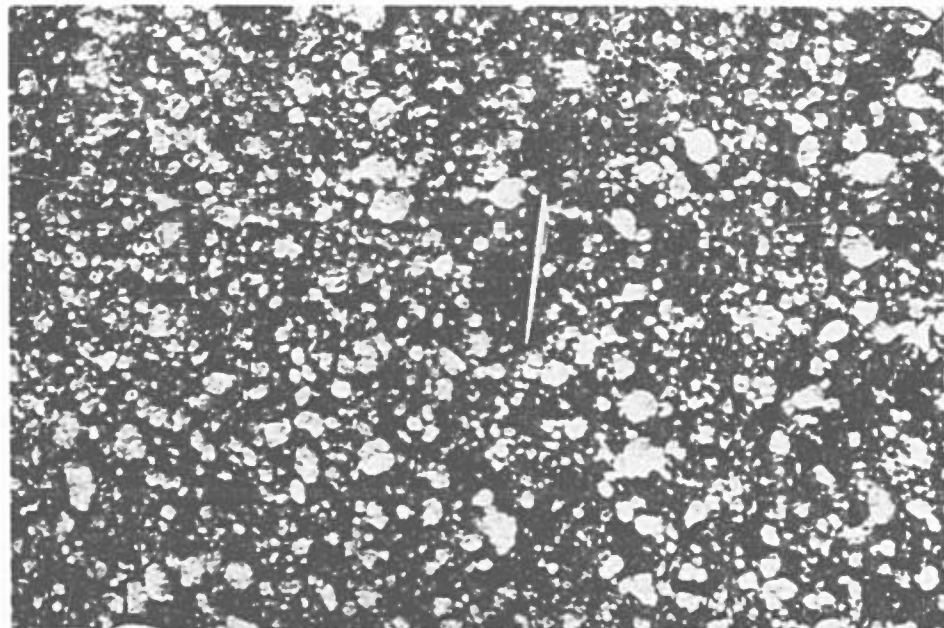
Fig. 24. Gabbro sill with abundant plagioclase phenocrysts evenly distributed throughout the field of view. Same location and scale as Fig. 23 above.
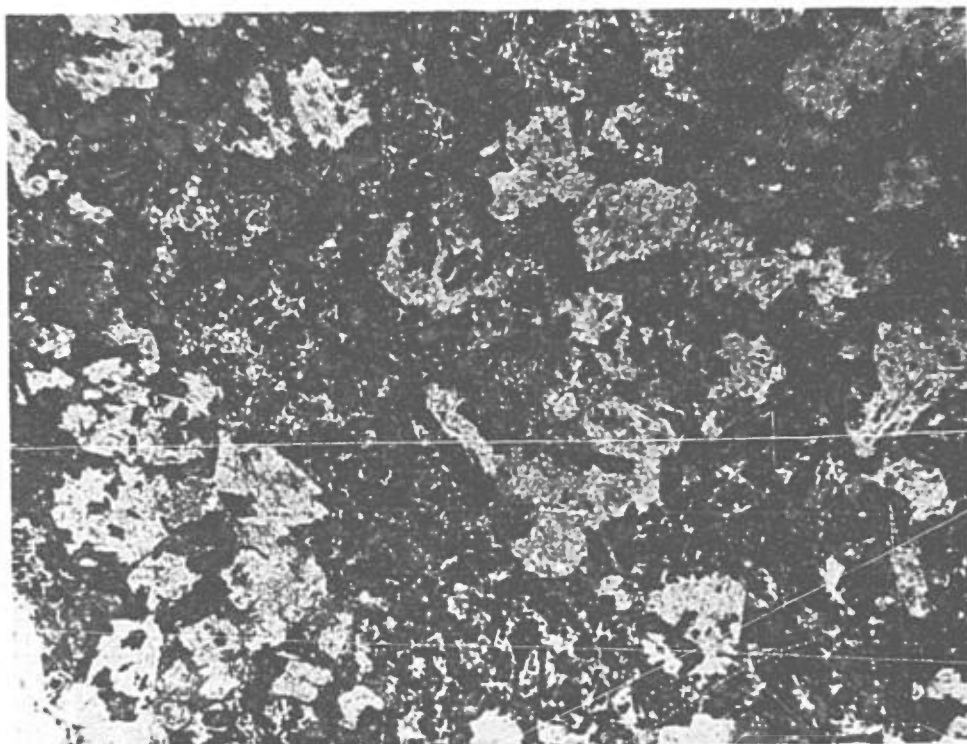
Fig. 25. Photomicrograph of gabbro sill from the Gilman Formation. Large grains are actinolite grains replacing an original pyroxene with ophitic texture. The dark matrix is a mixture of saussuritized plagioclase, chlorite, epidote, and minor actinolite. Field is 9mm. Sample 54-185. See a modal analysis of this sample in Table 17.
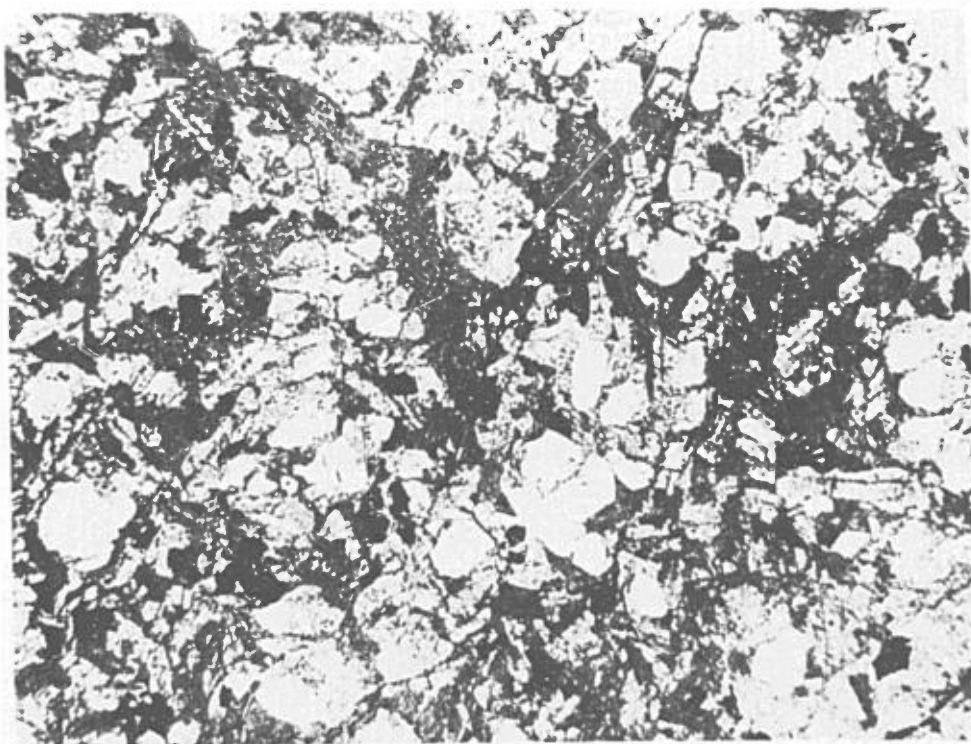
Fig. 26. Photomicrograph of the quartz-rich portion of the gabbro sill shown above in Fig. 25. Note clear twinned plagioclase and clear quartz. Matrix is rich in chlorite and iron oxide. Sample 54-189. Field is 9 mm. See a modal analysis of this sample in Table 17.

of a Lower Hidden Zone in the Dore Lake Complex (see chapter on LHZ of the
D.L.C.).

Blondeau Formation

The uppermost member of the Roy Group is the Blondeau Formation (Duquette,
1970). The Blondeau Formation around the Chibougamau district is 3000 feet
(900 m.) thick. The structural uplift caused by the Grenville Orogeny and the
subsequent erosion has left only the lowest part of the formation in the
Chibougamau syncline.

The Blondeau Formation is a mixture of chemical sediments, clastic, and
volcaniclastic rocks, and ubiquitous pyritic and graphitic argillite. It
resembles the upper part of the first cycle, i.e. the upper part of the
Waconichi Formation except for the presence of the argillites in the Blondeau.
The predominant rock type is a grey feldspathic crystal tuff. Chert beds,
tuffaceous cherts, cherty tuffs, and all intermediate types are common. Pyrite
beds and graphite-rich beds containing nodular and framboidal pyrite have been
reported in many drill holes. The pyritic graphitic member of the Blondeau
gives excellent anomalies on electromagnetic surveys and creates serious
problems to the exploration geologist in quest of stratiform copper-zinc deposits
within the Blondeau Formation.

Mafic-ultramafic sills in the Blondeau Formation

A good section of the Blondeau Formation is exposed in the axis of the
Chibougamau syncline along the Albanel road from M.P. 4 to M.P. 7. Chemical
analyses of the Blondeau rocks are presented in Tables 19 to 21.

The Blondeau bedded volcaniclastics and sediments are the host rocks for a
series of interesting mafic and ultramafic sills. Each sill is internally
differentiated and is also differentiated with respect to the sill below. The
following succession would apply to most of the Chibougamau district:

Blondeau {

Blondeau sediments and volcaniclastics

BOURBEAU SILL {
- 1200 feet (360 m.) quartz diorite, quartz gabbro
- 1100 feet (330 m.) leucogabbro
- 75 feet (23 m.) bronzite peridotite
}

Blondeau sediments and volcaniclastics

VENTURES SILL {
- minor granophyric quartz diorite
- 1500 feet (450 m.) Ventures gabbro
- 1800 feet (540 m.) Black and green pyroxenite
}

Blondeau sediments and volcaniclastics

ROBERGE SILL {
- pyroxenite and diopsidite
- peridotite and dunite
- gabbro
}

The sills are remarkable by their lateral extent when compared with the thickness. They have been mapped from the Grenville Front westward for more than 50 miles (80 kms) and they are found on both limbs of the Chibougamau anticline and the Chibougamau and Chapais synclines (Plate 1), a north-south post-folding distance of over 27 miles (43 kms).

The sills are competent brittle units making excellent hosts for orebodies as discussed in the chapter on metallogeny.

Roberge Sill

The lowermost major sill in the Blondeau Formation has been called the Roberge Sill by Duquette (1970). It is essentially ultramafic in composition, thoroughly serpentinized, and provides poor outcrops when compared with the Ventures and Bourbeau sills.

The Roberge Sill has been traced from the Grenville Front in McCorkill Township (Avramchev, 1975) westward as far as Cuvier Township (Gobeil, 1973), a distance of 50 miles (80 kms). The serpentinization of the original dunite and peridotite produces magnetite and serpentine which gives a distinct anomaly on airborne magnetic surveys. The sill has been identified by Caty (personal communication, 1975) in Richardson Township and by Baker (personal communication, 1974) in Rinfret Township, a north-south distance of 27 miles (43 kms). The Roberge Sill occurs all along the Chibougamau syncline but only outcrops in the vicinity of the Opemisca mine within the Chapais syncline and in a small area in Rinfret Township against the Grenville Front. The Roberge Sill is repeated by bedding faults (Figs. 126B and 126C) which have taken advantage of the graphitic beds in the Blondeau Formation and/or serpentinites of the sill itself. The sill is involved in tight folding and faulting within the axis of the Chibougamau syncline which explains the repetition and the peculiar dismembered outcrop pattern (Plate 1, and map of Smith and Allard, 1960). Duquette (1970) reports that the Roberge Sill is less than 1800 feet (540 m.) thick.

The main petrographic types found within the Roberge Sill are metadunite, metaperidotite, metapyroxenite, and a minor metagabbro chill zone which is well exposed on the large barren hill north of the Bruneau mine upper adit in McKenzie Township.

The serpentinized dunite and peridotite are dark colored rocks weathering to various shades of grey, brown, and white depending on composition. The original texture of the rock is very well preserved. The dunites show a cumulus texture and the original olivine is replaced by a mesh of isotropic serpentine in the core surrounded by fibrous birefringent serpentine. The interstices between former olivine grains consist of highly birefringent serpentine and fine dusty magnetite. The serpentinized peridotite in addition contains large poikilitic grains of unaltered augite and serpentinized

orthopyroxene which enclose the smaller grains of cumulate serpentinized olivine. Tiny veinlets of magnetite and seams of cross fiber crysotile are common. At Roberge Lake, the quantity of chrysotile reaches commercial quantities as described in the chapter on Economic Geology under Roberge Lake asbestos deposit.

The chemistry of the Roberge Sill is not well known. Gobeil (personal communication) in Cuvier Township has obtained a few chemical analyses (Table 22). No trace element work has been done. A few samples have been analyzed by exploration companies and they indicate a high nickel content which is to be expected in olivine-rich rocks. The chemical analyses of Table 22 have been plotted in Figure 27B.

Ventures Sill

The middle sill in the Blondeau Formation is called the Ventures Sill and takes its name from the name of the exploration company which formerly owned the Opemiska Mine where the sill forms the main host rock of most copper-bearing veins. A recent study by McMillan (1972) provides us with much detailed data on the Ventures Sill. McMillan compared a detailed section of the sill taken at the Opemiska Mine with a detailed section at Cummings Lake, north of Chibougamau.

The Ventures Sill has roughly the same geographic extent as the Roberge Sill. The thickness varies from ± 1000 feet to 3000 feet (300-900 m.) at the Opemiska Mine. It has been involved with the Roberge Sill in the fault which repeats part of the sequence from Cummings Lake westward (Figs. 126B and 126C).

The following petrographic subdivisions and descriptions have been suggested by McMillan (Figure 13 and Chapter 3 of McMillan, 1972).

Granophyre (upper quartzofeldspathic margin)

Ventures Gabbro (ophitic, subophitic, coarse texture)

Foliated Gabbro

Titaniferous magnetite-rich layer

Upper Green Pyroxenite

Black Pyroxenite

Lower Green Pyroxenite

The Lower Green Pyroxenite is about 100 feet (30 m.) thick and forms the lowermost unit. It is a greenish grey clinopyroxenite. Part of the clinopyroxene is altered to pale green actinolite with minor calcite and chlorite. Accessory quantities of chromite and skeletal ilmenite can be observed.

The Black Pyroxenite is 1200 feet (360 m.) thick at the Opemiska Mine and is composed of clinopyroxenite, wehrlite, and serpentinized dunite. The latter resembles the Roberge Sill metadunite. The rocks are olivine and clinopyroxene cumulates and show post-cumulus poikilitic clinopyroxene. Accessory chromite is common. Serpentine and magnetite replace the primary olivine.

The Upper Green Pyroxenite has a gradational contact with the Black Pyroxenite. It is about 200 feet (60 m.) thick at the mine. Except for the coarser grain size it resembles the Lower Green Pyroxenite. Gabbroic patches with up to 50% intercumulus plagioclase and up to 8% titaniferous magnetite have been observed.

The Foliated Gabbro is in sharp contact with the Upper Green Pyroxenite and displays a prominent igneous lamination. Some areas show pronounced rhythmic layering. Each layer has a pyroxene-magnetite-rich base and a plagioclase-rich top. The plagioclase is euhedral and saussuritized. The clinopyroxene is also cumulus and coarser than the plagioclase. Bands rich in cumulus titaniferous magnetite have been mapped at the mine. Apatite is a common accessory. Partial alteration of all the primary minerals is common.

The Ventures Gabbro is about 1200 feet (360 m.) thick at the mine. It has a characteristic coarse ophitic to subophitic texture which makes its identification very easy. The mineralogy is very similar to that of the Foliated Gabbro. Quartz constitutes up to 50% of the rock in the upper part of the unit. It occurs as small interstitial grains and as myrmekitic intergrowths in the outside rims of the plagioclase grains. Accessory minute zircons occur in some of the mafic minerals. A band up to 20 feet (6 m.) wide has been observed close to the top containing disseminated pyrrhotite and minor chalcopyrite.

The Granophyre has an irregular patchy distribution. It was found in the Lac Cummings area but was very poorly developed and very thin at the mine. It consists of medium-grained altered plagioclase and quartz. It also contains very minor skeletal ilmenite and altered pyroxene.

McMillan did detailed work on the sulfide and oxide content of the various rock types in the Ventures Sill and compared the mine section with the Cummings Lake section.

The chemical analyses of the various units reported by McMillan can be found in Tables 23 to 28 and Figure 27B. The Ventures Sill is a differentiated sill with a low alumina tholeiitic composition. The order of cumulus phases is olivine-clinopyroxene-plagioclase. Since magnetite, a late magmatic mineral, is present in the low-alumina Lower Green Pyroxenite, McMillan argues for the initial emplacement of a magma pool which gives rise, in situ, to the Roberge Sill, followed by the upward injection of the rest magma which produces the Ventures Sill. The Lower Green Pyroxenite, the lowermost unit, is the next phase to form and is followed by an influx of fresh basaltic magma which shifted the composition so that olivine can form a cumulus phase in the olivine-rich layer of the Black Pyroxenite. The layering and igneous lamination of the Foliated Gabbro indicates either a current in the magmatic chamber or a periodic change of conditions (P_{H_2O}, f_{O_2}, etc.) which produces the alteration

of cumulus phases. The ophitic texture of the Ventures Gabbro points to a static condition during the crystallization of this important member. McMillan does not believe that the "granophyre formed by crystallization of a residual liquid produced by extreme fractionation" because the K_2O content is low and many thin sections do not show granophyritic texture. The low K_2O content reflects the general chemistry of all the rocks of the Chibougamau greenstone belt which have a high Na_2O/K_2O ratio as most Archean greenstone belts of the world (Glikson, 1970).

The metalliferous veins at the Opemiska mine are located in the Ventures Sill and not in the enclosing volcanic rocks because of the marked competency difference between the sill and the volcanic rocks which control the creation of dilation zones along faults and fractures during deformation.

Bourbeau Sill

The Bourbeau Sill is the topmost sill within the Blondeau Formation. The sill is internally differentiated and is more felsic than the Ventures and Roberge Sills. It has roughly the same extent as the Roberge and Ventures Sill. The gabbroic part is a massive unit which is very resistant to erosion and commonly forms good ridges. The sill varies from 1500 to 2500 feet (450 to 750 m.) thick (Duquette, 1970). The following petrographic subdivisions are easy to identify in the field:

(top) ⎧ granophyric micropegmatite

⎪ quartz-rich melagabbro and meladiorite 1200 feet (360 m.)

⎪ leucometagabbro 1100 feet (330 m.)

⎩ bronzite metapyroxenite 75 feet (22.5 m.)

The bronzite metapyroxenite is a dark colored rock consisting of minor olivine, clinopyroxene, and large poikilitic blotches of bronzite. At first sight, the bronzite looks like biotite.

TABLE 19

CHEMICAL ANALYSES OF ROCKS FROM UNIT BLONDEAU TUFF

ANALYSES CHIMIQUES DES ROCHES DE TUFF DE BLONDEAU

Sample No. No. d'échantillon	CH-520	CH-560	CH-531	J71-255	J71-250A
SiO_2	58.61	75.02	74.04	74.30	61.10
TiO_2	1.67	0.27	0.48	0.20	0.90
Al_2O_3	16.10	14.51	13.70	15.10	13.72
Fe_2O_3	2.11	0.75	0.83	0.61	1.72
FeO	6.34	2.26	2.48	1.84	5.15
MnO	0.14	0.04	0.02	0.03	0.09
MgO	6.93	1.04	1.48	1.85	4.95
CaO	4.17	0.23	0.76	1.25	4.75
Na_2O	2.12	3.72	3.56	1.95	2.90
K_2O	1.02	1.74	2.26	1.38	0.50
P_2O_5	0.08	0.16	0.10		
H_2O+					
H_2O-					
CO_2					
S					
TOTAL	99.29	99.74	99.71	98.51	95.78
Norm wt%					
Qtz	19.97	43.69	39.71	51.06	21.84
Cor	4.12	6.47	4.25	8.13	
Or	6.03	10.28	13.35	8.15	2.95
Plag	38.10	31.57	33.24	22.70	47.48
Ab	17.94	31.48	30.12	16.50	24.54
An	20.16	0.10	3.12	6.20	22.94
Ne					
Ac					
Di					0.51
Wo					0.26
En					0.16
Fa					0.09
Hy	24.66	5.75	6.80	7.21	18.80
En	17.26	2.59	3.69	4.61	12.17
Fs	7.40	3.16	3.11	2.60	6.63
Ol					
Fo					
Fa					
Mt	3.06	1.09	1.20	0.88	2.49
Il	3.17	0.51	0.91	0.38	1.71
Hm					
Ap	0.19	0.38	0.24		
Py					
Cal					
Data Wt%					
An/plag	52.9	0.3	9.3	27.3	48.3
Fa/ol					
En/hy	70.0	45.0	54.2	63.9	64.7
Diff.i.	43.9	85.4	83.1	75.7	49.3
Qtz	45.4	51.1	47.7	67.4	44.2
Ab	40.8	36.8	36.2	21.8	49.7
Or	13.7	12.0	16.0	10.8	6.0
An	45.7	0.2	6.7	20.1	45.4
Ab	40.6	75.2	64.6	53.4	48.6
Or	13.7	24.5	28.7	26.4	5.9
A	16.9	57.4	54.8	43.6	22.3
F	45.6	31.6	31.2	32.1	45.1
M	37.4	10.9	13.9	24.2	32.5
Na+K/Al	28.5	55.1	60.6	31.1	38.7
Fe+Mn/Fe+Mg	40.4	61.6	55.1	42.3	43.4
Na_2O/Na_2O+K_2O	67.5	68.1	61.1	58.5	85.2

TABLE 20

CHEMICAL ANALYSES OF ROCKS FROM UNIT BLONDEAU TUFF

ANALYSES CHIMIQUES DES ROCHES DE TUFF DE BLONDEAU

Sample No. No. d'échantillon	J71-250B	J71-254	71-191	71-190
SiO_2	58.30	65.80	62.95	75.55
TiO_2	1.00	0.20	0.28	0.26
Al_2O_3	15.05	16.15	17.45	11.40
Fe_2O_3	2.03	0.97	1.35	0.54
FeO	6.09	2.91	2.15	1.03
MnO	0.12	0.06	0.07	0.04
MgO	5.15	1.05	1.19	0.53
CaO	5.90	3.75	5.05	1.75
Na_2O	3.10	5.50	5.84	5.10
K_2O	0.60	0.85	1.20	1.38
P_2O_5			0.09	0.07
H_2O+			1.36	0.77
H_2O-			0.07	0.04
CO_2			1.00	1.14
S			0.01	0.05
TOTAL	97.34	97.24	100.06	99.65
Norm wt%				
Qtz	14.81	19.36	13.71	38.92
Cor				1.14
Or	3.55	5.02	7.09	8.15
Plag	51.61	63.41	67.27	44.17
Ab	26.23	46.54	49.42	43.15
An	25.38	16.87	17.86	1.02
Ne				
Au				
Di	3.17	1.46	0.24	
Wo	1.63	0.72	0.12	
En	0.95	0.28	0.06	
Fa	0.60	0.46	0.05	
Hy	19.36	6.20	5.33	2.31
En	11.88	2.34	2.90	1.32
Fs	7.48	3.87	2.43	0.99
Ol				
Fo				
Fa				
Mt	2.94	1.41	1.96	0.78
Il	1.90	0.38	0.57	0.49
Hm				
Ap			0.21	0.17
Py				0.09
Cal				2.59
Data Wt%				
An/plag	49.1	26.6	26.5	2.3
Fa/ol				
En/hy	61.3	37.7	54.4	57.2
Diff.i.	44.5	70.9	70.2	90.2
Qtz	33.2	27.3	19.5	43.1
Ab	58.8	65.6	70.3	47.8
Or	7.9	7.0	10.1	9.0
An	46.0	24.6	24.0	1.9
Ab	47.5	68.0	66.4	82.4
Or	6.4	7.3	9.5	15.5
A	21.8	56.2	60.0	75.5
F	47.8	34.4	29.8	18.3
M	30.3	9.3	10.1	6.1
Na+K/Al	38.2	61.7	62.5	86.7
Fe+Mn/FeMnMg	46.7	67.2	61.8	62.2
K_2O/Na_2O+K_2O				

Table 21

Notes on the samples of Tables 19 and 20.

TABLES 19 AND 20.   TUFFS OF THE BLONDEAU FORMATION

CH 520   Gunn and Duquette. Fine grained dark bedded tuff. Roy Township.
            Albanel Highway around M. 6.9.

CH 560   Gunn and Duquette. Black tuff at the base of the Blondeau
            Formation. Roy Township. Albanel Highway. Exact location
            unknown.

CH 531   Gunn and Duquette. Rhyolite tuff below the Cummings Lake
            intrusive (Bourbeau Sill). 2200 feet (660 m) up radar station
            road at Cummings Lake.

J-71-255   Oliveira, 1973, p. 91. Cherty metatuff. Roy Township. Albanel
            Highway around M. 6.4.

J-71-250A   Oliveira, 1973, p. 91. Feldspathic metatuff. Roy Township.
            Albanel Highway around M. 4.2.

J-71-250B   Oliveira, 1973, p. 91. id to 250 A.

J-71-254   Oliveira, 1973, p. 91. Feldspathic metatuff with quartz. Roy
            Township. Albanel Highway around M. 7.05.

71-191   (J-71-254) Allard, Q.D.N.R. Lab. Feldspathic metatuff. Roy
            Township. Albanel Highway around M. 7.05.

71-190   (J-71-265) Allard, Q.D.N.R. Lab. Metatuff. Roy Township.
            Albanel Highway around M. 4.3.

Table 22

CHEMICAL ANALYSES OF METADUNITES FROM THE ROBERGE SILL

Analyses chimiques de métadunites du sill Roberge

	1	2	3
SiO_2	51.00	35.40	44.75
TiO_2	1.00	0.29	0.35
Al_2O_3	13.60	1.13	1.80
Fe_2O_3	2.90	12.45	8.94
FeO	10.30	2.20	3.90
MnO	0.16	0.21	0.15
MgO	5.55	35.50	23.00
CaO	8.18	0.23	11.64
Na_2O	3.96	0.00	0.11
K_2O	0.15	0.03	0.08
H_2O^+	3.17	10.95	4.20
H_2O^-	0.09	0.06	0.04
CO_2	0.10	0.15	0.61
S	0.01	0.03	0.08
P_2O_5	0.08	0.01	0.02
Total	100.25	98.64	99.67
Cu ppm	42	4	84
Ni	54	2030	1300
Cr	22	6620	3900
Co	66	160	100

1. Roberge pyroxenite.   Sample AG 37. Anal. Q.D.N.R.
   1974 for Andre Gobeil.

2. Roberge dunite.   Sample AG 55. Anal. Q.D.N.R.
   1974 for Andre Gobeil.

3. Roberge peridotite.   Sample AG 180. Anal. Q.D.N.R.
   1974 for Andre Gobeil.

TABLE 23

CHEMICAL ANALYSES OF ROCKS FROM UNIT   VENTURES SILL
ANALYSES CHIMIQUES DES ROCHES DU SILL VENTURES

Sample No. / No. d'échantillon	7	6	5	4	3	2	1
SiO_2	56.57	52.86	54.00	48.01	48.38	48.22	47.80
TiO_2	1.65	0.85	1.69	1.79	1.78	2.14	2.05
Al_2O_3	15.06	13.87	13.32	12.63	12.60	15.00	14.27
Fe_2O_3	2.85	4.17	4.15	3.90	3.86	3.96	4.10
FeO	8.65	12.64	12.57	11.83	11.69	11.99	12.42
MnO	0.17	0.26	0.27	0.25	0.25	0.23	0.26
MgO	2.33	3.24	3.21	3.70	3.70	2.42	5.74
CaO	5.25	4.62	3.18	11.19	11.27	10.00	7.12
Na_2O	5.94	5.04	5.08	4.21	4.21	3.05	3.76
K_2O	0.41	0.72	0.89	0.77	0.80	1.30	0.84
P_2O_5	0.16	0.33	0.24	0.40	0.16	0.36	0.26
H_2O+							
H_2O-							
CO_2							
S							
TOTAL	99.04	98.60	98.60	98.68	98.70	98.67	98.62
Norm wt%							
Qtz	3.66	0.06	2.93				
Cor							
Or	2.42	4.25	5.26	4.55	4.73	7.68	4.96
Plag	63.48	55.74	53.90	39.31	38.45	49.21	51.39
Ab	50.26	42.65	42.99	25.02	25.33	25.81	31.82
An	13.22	13.10	10.91	13.29	13.12	23.10	19.58
Ne				5.20	5.57		
Ac							
Di	9.96	6.53	2.80	33.39	35.17	20.37	11.68
Wo	4.92	3.20	1.38	16.54	17.43	9.96	5.86
En	1.73	1.00	0.45	6.16	6.54	2.89	2.70
Fa	3.31	2.33	0.97	10.69	11.21	7.51	3.12
Hy	11.88	23.59	23.94			9.30	6.40
En	4.07	7.07	7.55			2.59	2.97
Fs	7.81	16.52	16.39			6.71	3.43
Ol Fo				6.25 / 2.14	5.43 / 1.88	1.47 / 0.38	13.75 / 6.05
Fa				4.11	3.55	1.09	7.70
Mt	4.13	6.05		5.65	5.60	5.74	5.94
Il	3.13	1.61	6.02	3.40	3.38	4.06	3.89
Hm							
Ap	0.38	0.78	3.21	0.95	0.38	0.85	0.62
Py							
Cal							
Data wt%							
An/plag	20.8	23.4	20.2	33.8	34.1	47.5	38.0
Fa/ol				65.7	65.4	74.0	56.0
En/hy	34.2	30.0	31.5			27.8	46.3
Diff.i.	56.3	47.0	51.1	35.8	35.6	33.4	36.8
Qtz	6.4	0.1	5.7				
Ab	89.2	90.8	84.0			77.0	86.5
Or	4.3	9.0	10.2			22.9	13.5
An	20.0	21.8	18.4	30.3	30.3	41.1	34.7
Ab	76.2	71.0	72.7	59.3	58.7	45.3	56.4
Or	3.7	7.0	8.9	10.3	10.9	13.5	8.8
A	31.4	22.3	23.0	20.4	20.6	19.1	17.1
F	57.0	65.1	64.5	64.4	64.1	70.2	61.5
M	11.5	12.5	12.3	15.1	15.2	10.6	21.3
Na+K/Al	67.8	65.4	70.0	61.4	61.8	42.8	49.7
Fo+lin/Feldsp	73.2	74.2	74.3	70.2	70.0	78.5	61.5
Na_2O/Na_2O+K_2O	93.5	87.5	85.0	84.5	84.0	70.1	81.7

TABLE 24

CHEMICAL ANALYSES OF ROCKS FROM UNIT VENTURES SILL

ANALYSES CHIMIQUES DES ROCHES DU SILL VENTURES

Sample No. No. d'échantillon	15	14	13	12	11	10.	9	8
SiO_2	51.23	50.40	44.72	50.22	50.23	41.67	46.25	45.84
TiO_2	0.49	0.56	0.40	0.52	0.65	2.02	1.54	1.13
Al_2O_3	3.92	3.23	2.08	2.45	3.27	12.26	14.00	9.47
Fe_2O_3	2.10	2.51	3.06	2.23	2.44	4.63	4.31	6.23
FeO	6.35	7.60	9.28	6.77	7.40	14.03	13.07	18.88
MnO	0.16	0.23	0.30	0.19	0.22	0.19	0.26	0.38
MgO	17.82	18.52	29.57	20.39	18.35	9.16	6.40	6.10
CaO	16.10	14.85	8.92	15.95	15.84	9.29	7.26	6.60
Na_2O	0.88	0.98	0.01	0.01	0.43	4.09	4.17	1.98
K_2O	0.10	0.13	0.04	0.05	0.17	0.95	0.63	1.01
P_2O_5	0.08	0.07	0.09	0.10	0.10	0.15	0.26	0.28
H_2O+								
H_2O-								
CO_2								
S								
TOTAL	99.30	99.15	98.97	99.24	99.18	98.44	98.55	97.90
Norm wt%								
Qtz								
Cor								
Or	0.59	0.77	0.24	0.30	1.00	5.61	3.72	5.97
Plag	13.90	12.32	5.60	6.58	10.13	18.88	48.02	30.72
Ab	7.45	8.29	0.08	0.08	3.64	6.59	30.39	16.75
An	6.45	4.03	5.51	6.49	6.49	12.29	17.62	13.97
Ne						15.18	2.65	
Wo								
Di	57.91	55.10	30.26	57.09	56.86	26.99	13.86	14.32
Wo	30.44	28.89	15.93	30.06	29.83	13.70	6.97	7.07
En	22.61	20.98	11.98	22.60	21.79	7.26	3.26	2.53
Fa	4.86	5.24	2.35	4.44	5.24	6.03	3.63	4.72
Hy	13.52	12.73	15.44	22.19	17.35			31.39
En	11.13	10.18	12.91	18.54	13.99			10.95
Fs	2.39	2.54	2.53	3.64	3.37			20.44
Ol Fo	9.23	13.36	41.55	8.22	8.80	20.89	19.76	3.68
Fo	7.46	10.48	34.16	6.76	6.95	10.90	8.88	1.20
Fa	1.77	2.88	7.39	1.46	1.84	9.98	10.88	2.48
Mt	3.04	3.64	4.44	3.23	3.54	6.71	6.25	9.03
Il	0.93	1.06	0.76	0.99	1.23	3.84	3.68	2.15
Hm								
Ap	0.19	0.17	0.21	0.24	0.24	0.36	0.62	0.66
Py								
Cal								
Data Wt%								
An/plag	46.4	32.7	98.4	98.7	64.0	65.0	35.7	45.4
Fa/ol	19.1	21.5	17.8	17.8	21.0	47.8	55.0	67.2
En/hy	82.3	80.0	83.6	83.5	80.6			34.9
Diff.i.	8.0	9.0	0.3	0.3	4.6	27.3	36.8	22.7
Qtz								
Ab	92.6	91.5	26.3	22.2	78.3			73.7
Or	7.3	8.4	73.6	77.7	21.6			26.2
An	44.5	30.8	94.5	94.4	58.3	50.1	34.0	38.0
Ab	51.4	63.3	1.4	1.2	32.7	26.9	58.7	45.7
Or	4.0	5.9	4.0	4.3	9.0	22.9	7.2	16.2
A	3.6	3.7	0.1	0.2	2.0	15.3	16.8	8.7
F	31.0	34.0	29.4	30.5	34.1	56.8	60.8	73.4
M	65.3	62.2	70.4	69.2	63.7	27.9	22.3	17.8
Na+K/Al	39.7	54.2	2.9	2.9	27.2	63.2	53.9	45.9
Fe+Mn/Fe+Mn+Mg	20.9	23.4	19.0	19.8	23.0	53.0	60.1	69.5
Na_2O/Na_2O+K_2O	89.8	88.2	20.0	16.7	71.7	81.1	85.9	66.2

TABLE 25

CHEMICAL ANALYSES OF ROCKS FROM UNIT   VENTURES SILL

ANALYSES CHIMIQUES DES ROCHES DU   SILL VENTURES

Sample No. No. d'échantillon	CH-549	CH-548	CH-547	CH-543
SiO_2	41.48	51.20	50.26	39.70
TiO_2	0.25	0.44	0.64	0.71
Al_2O_3	1.66	2.40	3.78	8.45
Fe_2O_3	4.56	2.21	2.95	2.82
FeO	13.70	6.65	8.86	8.47
MnO	0.30	0.16	0.19	0.19
MgO	34.50	18.90	14.72	10.93
CaO	1.86	16.76	16.50	27.53
Na_2O	0.11	0.39	0.57	0.09
K_2O	0.03	0.03	0.50	0.01
P_2O_5	0.02	0.03	0.03	0.16
H_2O+				
H_2O-				
CO_2				
S				
TOTAL	98.47	99.17	99.00	99.06

Norm wt%				
Qtz				
Cor				
Or	0.18	0.18	2.95	
Plag	4.68	8.01	11.10	22.62
Ab	0.93	3.30	4.82	
An	3.95	4.71	6.28	22.62
Ne				0.41
Wo				
Di	4.10	62.13	60 51	24.55
Wo	2.15	32.67	31.48	12.69
En	1.56	24.32	21.38	8.15
Fs	0.39	5.14	7.66	3.71
Hy	23.65	17.73	14.05	
En	18.91	14.63	10.34	
Fs	4.74	3.10	3.70	
Ol	58.54	7.02	4.83	20.08
Fo	45.87	5.69	3.46	13.37
Fa	12.67	1.33	1.37	6.71
Mt	6.61	3.20	4.28	4.09
Il	0.47	0.84	1.22	1.35
Hm				
Ap	0.05	0.07	0.07	0.38
Py				
Cal				

Data Wt%				
An/plag	80.9	58.8	56.5	100.0
Fa/ol	21.6	18.9	28.3	33.4
En/hy	80.0	82.5	73.6	
Diff.i.	1.1	3.4	7.8	0.4

Qtz				
Ab	84.0	94.9	62.0	
Or	16.0	5.1	38.0	

An	78.0	57.5	44.7	100.0
Ab	18.4	40.3	34.3	
Or	3.5	2.1	21.0	

A	0.2	1.4	3.9	0.4
F	34.5	31.4	42.8	50.5
M	65.2	67.0	53.3	49.0

Na+K/Al	12.9	26.0	39.1	1.9
Fe+Mn/Fe+Mn+Mg	22.7	20.7	30.8	36.5
Na_2O/Na_2O+K_2O	78.5	92.9	53.2	90.0

TABLE 26

CHEMICAL ANALYSES OF ROCKS FROM UNIT VENTURES SILL

ANALYSES CHIMIQUES DES ROCHES DU SILL VENTURES

Sample No. / No. d'échantillon	CH-598	CH-593	CH-592	CH-544	CH-550
SiO_2	47.63	53.66	55.62	64.71	73.57
TiO_2	1.69	1.12	0.79	0.62	0.74
Al_2O_3	5.55	14.09	13.97	14.47	12.26
Fe_2O_3	4.26	3.37	3.32	0.70	1.84
FeO	12.79	10.13	9.96	2.10	5.52
MnO	0.21	0.19	0.15	0.10	0.07
MgO	12.22	2.11	2.41	3.65	1.09
CaO	13.55	13.67	12.05	8.79	0.72
Na_2O	0.52	0.15	0.28	3.52	1.06
K_2O	0.08	0.19	0.03	0.99	2.07
P_2O_5	0.06	0.17	0.30	0.12	0.03
H_2O+					
H_2O-	、				
CO_2					
S					
TOTAL	98.56	98.85	98.88	99.77	99.37

Norm wt%					
Qtz	0.94	41.95	23.24	20.16	53.37
Cor					7.04
Or	0.47	1.12	0.18	5.85	12.23
Plag	16.97	38.48	39.14	50.54	12.35
Ab	4.40	1.27	2.37	29.79	8.97
An	12.57	37.21	36.77	20.76	3.38
Ne					
Wo					
Di	44.11	25.21	17.93	17.60	
Wo	22.65	12.32	8.79	9.21	
En	13.60	3.46	2.67	6.61	
Fs	7.85	9.44	6.47	1.77	
Hy	26.54	6.68	11.38	3.14	10.24
En	16.83	1.79	3.33	2.48	2.71
Fs	9.71	4.88	8.05	0.67	7.52
Ol Fo					
Fa					
Mt	6.18	4.89	4.81	1.01	2.67
Il	3.21	2.13	1.50	1.18	1.41
Hm					
Ap	0.14	0.40	0.71	0.28	0.07
Py					
Cal					

Data Wt%					
An/plag	74.0	96.7	93.9	41.0	27.3
Fa/ol					
En/hy	63.4	26.8	29.2	78.8	26.5
Diff.i.	5.8	22.3	25.8	55.8	74.5

Qtz	16.1	89.2	90.1	36.1	71.5
Ab	75.7	5.7	9.1	53.3	12.0
Or	8.1	5.0	0.7	10.4	16.4

An	72.0	94.0	93.5	36.8	13.7
Ab	25.2	3.2	6.0	52.8	36.4
Or	2.7	2.8	0.4	10.3	49.8

A	2.0	2.1	1.9	41.1	27.0
F	57.0	84.6	83.0	25.5	63.5
M	40.9	13.2	15.0	33.3	9.4

Na+K/Al	17.0	3.2	3.5	47.4	32.5
Fe+Mn/Fe+Mn+Mg	43.6	78.0	75.3	30.3	78.9
Na_2O/Na_2O+K_2O	86.7	44.1	90.3	70.0	33.9

TABLE 27

CHEMICAL ANALYSES OF ROCKS FROM UNIT VENTURES SILL

ANALYSES CHIMIQUES DES ROCHES DU SILL VENTURES

Sample No. No. d'échantillon	CH-546	CH-545	CH-594	CH-595	CH-597
SiO_2	44.22	51.64	50.42	51.46	41.33
TiO_2	2.35	1.73	1.00	1.52	2.55
Al_2O_3	12.89	13.16	16.36	14.87	12.79
Fe_2O_3	5.15	4.67	3.52	3.32	5.30
FeO	15.47	14.00	10.57	9.96	15.90
MnO	0.18	0.27	0.13		0.21
MgO	5.34	2.51	2.77	3.23	7.85
CaO	8.76	7.08	13.74	14.26	12.06
Na_2O	2.79	2.71	0.14	0.12	0.13
K_2O	1.01	0.42	0.03	0.02	0.03
P_2O_5	0.10	0.25	0.14	0.12	0.06
H_2O+					
H_2O-					
CO_2					
S					
TOTAL	98.26	98.44	98.82	98.88	98.21
Norm wt%					
Qtz		9.56	14.48	16.19	
Cor					
Or	5.97	2.48	0.18	0.12	0.18
Plag	42.10	45.43	45.11	40.99	35.35
Ab	22.44	22.93	1.18	1.02	1.14
An	19.66	22.50	43.92	39.98	34.20
Ne	0.63				
Di	19.43	9.43	19.81	25.22	20.93
Wo	9.66	4.59	9.74	12.52	10.54
En	3.83	1.18	3.16	4.84	5.01
Fa	5.94	3.67	6.91	7.85	5.38
Hy		20.91	11.92	8.38	26.12
En		5.08	3.74	3.20	12.60
Fs		15.83	8.18	5.18	13.53
Ol	17.96				2.98
Fo	6.63				1.36
Fa	11.33				1.61
Mt	7.47	6.77	5.10	4.81	7.68
Il	4.46	3.29	1.90	2.89	4.84
Hm					
Ap	0.24	0.59	0.33	0.28	0.14
Py					
Cal					
Data Wt%					
An/plag	46.7	49.5	97.3	97.5	96.8
Fa/ol	63.0				54.2
En/hy		24.2	31.3	38.1	48.2
Diff.i.	29.0	35.0	15.8	17.3	1.3
Qtz		27.3	91.4	93.4	
Ab		65.5	7.4	5.9	86.5
Or		7.1	1.1	0.7	13.4
An	40.9	47.0	97.0	97.2	96.2
Ab	46.7	47.9	2.6	2.4	3.2
Or	12.8	5.1	0.3	0.2	0.5
A	12.8	12.9	1.0	0.8	0.5
F	69.2	76.8	82.7	79.8	72.5
M	17.9	10.3	16.2	19.4	26.9
Na+K/Al	44.0	37.3	1.6	1.4	2.0
FeMn/FeMg	68.0	80.5	73.7	69.2	59.9
Na_2O/Na_2O+K_2O	73.4	66.5	62.3	85.7	7?.8

Table 28

Notes on samples of Tables 23 to 27.

TABLES 23 and 24. VENTURES SILL

Samples 1 to 15 are from McMillan, 1972, Figure 27, p. 43.

 1 - sample 8470-983 Ventures gabbro

 2 - sample 8470-930 Ventures gabbro

 3 - sample 8470-890 Ventures gabbro

 4 - sample 8470-890A Ventures gabbro

 5 - sample 8470-715 Ventures gabbro

 6 - sample 8470-620 Ventures gabbro

 7 - sample 8607-370 Ventures gabbro

 8 - sample 8607-359 Foliated gabbro

 9 - sample 8607-328 Foliated gabbro

10 - sample 8607-140 Foliated gabbro

11 - sample 8621-10 Upper Green Pyroxenite

12 - sample 8621-165 Black Pyroxenite

13 - sample 8621-290 Wehrlite

14 - sample 8583-340 Lower Green Pyroxenite

15 - sample 8583-270 Lower Green Pyroxenite

CH 543 Gunn and Duquette. Ventures sill, Upper Pyroxenite. Location unknown.

CH 547 Gunn and Duquette. Ventures sill, Lower Green Pyroxenite. Location unknown.

CH 548 Gunn and Duquette. Ventures sill, Black Pyroxenite. Location unknown.

CH 549 Gunn and Duquette. Ventures sill, Peridotite. Location unknown.

CH 550 Gunn and Duquette. Ventures sill, granophyre. Location unknown.

CH 544 Gunn and Duquette. Ventures sill, unit and location unknown.

CH 592 Gunn and Duquette. Ventures gabbro, 60 feet (18 m) below the granophyre at the Cummings Lake radar station road.

CH 593 Gunn and Duquette. Ventures gabbro, 105 feet (31.5 m) below granophyre at the Cummings Lake radar station road.

CH 598 Gunn and Duquette. Ventures coarse pyroxenite, 200 feet (60 m) below the granophyre at the Cummings Lake radar station road.

CH 546 Gunn and Duquette. Ventures foliated gabbro. Location unknown.

CH 545 Gunn and Duquette. Ventures gabbro. Location unknown.

CH 594 Gunn and Duquette. Coarse Ventures gabbro at the gate to Cummings Lake radar station.

CH 595 Gunn and Duquette. Ventures gabbro. Location unknown.

CH 957 Gunn and Duquette. Coarse Ventures gabbro, 135 feet (40.5 m) below granophyre at Cummings Lake radar station road.

TABLE 29

CHEMICAL ANALYSES OF ROCKS FROM UNIT BOURBEAU SILL

ANALYSES CHIMIQUES DES ROCHES DU SILL BOURBEAU

Sample No. No. d'échantillon	CH-533	CH-534	CH-535	CH-537	CH-540	CH-536	CH-539	CH-538
SiO_2	49.99	49.75	50.05	49.71	52.76	57.20	49.13	55.73
TiO_2	0.63	0.51	0.78	2.84	2.68	1.44	5.67	2.40
Al_2O_3	9.38	14.70	19.00	11.88	12.59	14.79	13.36	14.89
Fe_2O_3	2.23	1.88	2.78	4.65	3.66	3.13	4.31	3.99
FeO	6.73	5.63	8.33	13.96	11.00	9.39	12.92	11.98
MnO	0.16	0.14	0.16	0.28	0.24	0.16	0.26	0.17
MgO	13.04	9.15	7.41	4.25	2.79	4.16	4.39	3.75
CaO	15.53	15.52	6.34	8.99	9.82	3.88	6.74	1.99
Na_2O	1.21	1.75	3.30	1.61	2.19	4.10	1.51	2.77
K_2O	0.17	0.20	0.77	0.04	0.78	0.10	0.10	0.61
P_2O_5	0.14	0.13	0.15	0.23	0.26	0.59	0.17	0.37
H_2O+								
H_2O-								
CO_2								
S								
TOTAL	99.21	99.36	99.07	98.44	98.77	98.94	98.56	98.65
Norm wt%								
Qtz				11.10	11.91	14.40	14.95	21.62
Cor			1.57			2.30		6.94
Or	1.00	1.18	4.55	0.24	4.61	0.57	0.59	3.60
Plag	29.90	46.47	58.40	38.69	40.75	50.09	42.16	30.89
Ab	10.24	14.81	27.92	13.62	18.53	34.69	12.78	23.44
An	19.66	31.66	30.47	25.07	22.22	15.39	29.38	7.46
Ne								
Wu								
Di	45.15	35.71		15.19	20.97		2.44	
Wo	23.58	18.57		7.53	10.35		1.23	
En	16.58	12.60		2.87	3.66		0.60	
Fa	4.99	4.54		4.78	6.95		0.61	
Hy	12.64	7.25	23.94	20.55	9.53	22.94	21.01	24.40
En	9.71	5.33	14.50	7.71	3.29	10.36	10.34	9.34
Fs	2.92	1.	9.44	12.84	6.25	12.58	10.67	15.06
Ol	5.77	4.	4.75					
Fo	4.33	3.41	2.77					
Fa	1.44	1.35	1.99					
Mt	3.23	2.73	4.03	6.74	5.31	4.54	6.25	5.79
Il	1.20	0.97	1.48	5.39	5.09	2.73	10.77	4.56
Hm								
Ap	0.33	0.31	0.36	0.54	0.62	1.40	0.40	0.88
Py								
Cal								
Data Wt%								
An/plag	65.8	68.1	52.1	64.8	54.5	30.7	69.7	24.1
Fa/ol	24.9	28.4	41.8					
En/hy	76.9	73.5	60.5	37.5	34.4	45.1	49.2	32.2
Diff.i.	11.2	16.0	32.4	25.0	35.0	45.7	28.3	48.7
Qtz				44.4	34.0	29.0	52.8	44.4
Ab	91.0	92.6	86.0	58.6	52.9	69.8	45.1	48.1
Or	8.9	7.3	14.0	0.9	13.1	1.1	2.0	7.4
An	63.6	66.4	48.4	64.4	49.0	30.3	66.7	21.6
Ab	33.1	31.0	44.3	35.0	40.8	68.4	29.9	67.9
Or	3.2	2.4	7.2	0.6	10.1	1.1	1.3	10.4
A	5.9	10.4	18.0	6.7	14.5	20.1	6.9	14.6
F	38.3	40.3	49.1	75.9	71.8	60.0	74.1	69.1
M	55.8	49.1	32.8	17.3	13.7	19.9	16.9	16.2
Na+K/Al	23.1	21.0	33.0	22.7	35.3	46.3	19.4	35.0
Fe+Mn/Fe+Mn+Mg	27.7	31.4	45.4	70.9	74.5	62.5	68.5	70.2
Na_2O/Na_2O+K_2O	87.7	89.7	81.0	97.5	73.7	97.7	93.8	81.9

Table 30

Notes on samples of Table 29.

TABLE 29:   BOURBEAU SILL

CH 533   Gunn and Duquette.   Olivine pyroxenite at base of norite sill.   Roy
Township.   900 feet (300 m) north of Cummings Lake radar station
road.

CH 534   Gunn and Duquette.   Olivine gabbro.   Roy Township.   1100 feet (330 m)
north of Cummings Lake radar station road.

CH 535   Gunn and Duquette.   Feldspathic norite.   Roy Township.   1300 feet
(390 m) north of Cummings Lake radar station road.

CH 537   Gunn and Duquette.   Roy Township.   Hypersthene gabbro at the base
of sill.   2100 feet (630 m) north of Cummings Lake radar station
road.

CH 540   Gunn and Duquette.   Quartz-bearing gabbro.   Roy Township.   100
feet (30 m) below CH 539.

CH 536   Gunn and Duquette.   Quartz-bearing norite.   Top of norite sill.
Roy Township.   1700 feet (510 m) north of Cummings Lake radar
station road.

CH 539   Gunn and Duquette.   Titaniferous norite.   Main road cut at the
center of the sill, north of the Radar road intersection.

CH 538   Gunn and Duquette.   Quartz rich norite, upper part of the sill.
Roy Township.   2700 feet (810 m) north of the Cummings Lake radar
station road.

The leucogabbro is a medium-grained rock consisting of a large quantity of saussauritized plagioclase and altered pyroxene. The grain size is uniform and the rock very homogeneous and massive, forming good ridges. A few grains of altered titaniferous magnetite can be observed.

The leucogabbro grades upward into a dark rock made up of chlorite, ferroactinolite, saussuritized plagioclase, altered titaniferous magnetite, and clear quartz eyes. Locally, the rock has an ophitic texture. The quartz and chlorite content gradually increases upward with a concomitant decrease in ferroactinolite. A granophyric texture can be observed in a few thin sections.

The Bourbeau Sill is the host rock for the auriferous quartz veins of the Norbeau Mine. It has the same mechanical properties as the Ventures Sill when compared with the enclosing pyroclastics and volcanic rocks. It forms an excellent marker horizon in regional stratigraphic and structural studies. No detailed petrographic and chemical studies have been done on this sill but a number of chemical analyses are reported in Tables 29 and 30 and on Figure 27A.

Petrochemistry of the volcanic rocks of the Roy Group

The petrochemistry of Archean greenstone belts has been well studied within the last decade and many efforts made to identify the unique chemistry of the lavas associated with volcanogenic copper-zinc deposits. Barragar (1966, 1968) studied the Yellowknife and Noranda greenstone belts, Viljoen and Viljoen (1969) the Barberton belt in South Africa, and Glikson (1970) compared Australian, South African, Rhodesian, and Canadian greenstone belts. The advent of plate tectonics sparked a rush to analyze volcanic rocks from every possible environments and ages in order to recreate paleoenvironments for older volcanic rocks. It became fashionable to use the information from Archean belts to conclude that plate tectonics was or was not operative in Archean time (Glikson, 1969; Anhaeuser et al., 1969). The recent popularity and successes of the volcanogenic theory of ore formation led many workers to

compare volcanic rocks associated with ore deposits with those that are barren.

Fonteilles (1967, 1968) found that metallogenitic provinces in Japan are

associated with calc-alkaline orogenic magmatic suites while alkalic and

tholeiitic volcanic provinces are barren. The Miocene "greentuff" province of

Japan and its numerous Kuroko-type deposits (Tatsumi, 1970) is the best studied

example of this association of copper ores with calc-alkaline volcanic rocks.

We should remind the reader, at this point, that these ideas are not

entirely new and strictly a product of the plate tectonic concepts. Tilley

(1950) and Kuno (1959) already suggested the recycling of continental crustal

material in the making of calc-alkaline magmas. Routhier (1963, p. 661) also

expressed the same idea very clearly and extended it to ore deposits:

> "Au total, si l'on cherche les liaisons les plus évidentes, les
> plus directes, peutêtre les plus fréquentes, entre concentrations
> métallifères et volcanisme, c'est en particulier du côté du
> volcanisme post-orogénique, calco-alcalin et andésitique, qu'il faut
> les chercher. Or ce volcanisme implique l'utilisation de matériaux
> sialiques antérieurs, par 'palingenèse', de la même manière que la
> 'granitisation' progresse sur du Sial antérieurement consolidé. Ce
> rapprochement mérite d'être souligné; il montre que la source la
> plus proche des métaux n'est pas seulement la Sima basaltique mais
> également le Sial."

Alsac et al., (1971, 1973, 1974) and his Canadian coworkers have applied

Fonteille's concepts and methods to the Val d'Or (Archean) and Weedon-Thetford

greenstone belts (Paleozoic). They concluded that the Val d'Or lavas have a

spilitic tendency (high Na_2O, very low K_2O, and low CaO). The basalts are

subalkaline with high alumina content in many instances. Alsac also found an

association of calc-alkaline rocks, rhyolite, granodiorite stocks, and

mineralization. It might be best to quote Alsac directly (1974, p. 12):

> "Le volcanisme de Val d'Or présente des compositions à tendance
> spilitique, ce caractère étant variable d'un échantillon à l'autre.
> Si l'on compare ces laves aux lignées magmatiques définies dans le
> volcanisme récent, les compositions observées s'apparentent à celles
> des séries tholéiitiques et calco-alcalines. Les laves du premier
> type sont présentes dans toutes les formations, les calco-alcalines
> se rencontrent essentiellement dans le Malartic supérieur, niveau
> dans lequel se trouvent les minéralisations."

Gunn and Duquette (1969) did a large number of chemical analyses on samples collected in the Chibougamau area. The analyses are in open file documents in the Q.D.N.R. files and we have used many of them. Unfortunately, the sample collecting was not done in the systematic fashion of Barragar or Alsac. Moreover, some samples attributed to the Waconichi Formation by Duquette may belong to the post-Roy Group Stella Formation as indicated by Caty in Richardson Township (personal communication). For this reason I have eliminated all analyses of samples from a doubtful stratigraphic position.

Gunn and Duquette (1969, p. 135) classified the predominant lavas of the Chibougamau area as a "low potassium olivine tholeiite similar to present-day oceanic tholeiite". Tables 2 to 16 and 19 to 21 give the analyses of volcanic rocks from all sources. Figures 27 and 27A present in a diagrammatic fashion the data contained in the numerous chemical analyses of Chibougamau volcanic rocks.

Using the 1.75% TiO_2 limit which Chayes (1965) recommends to separate oceanic from circumoceanic basalts, we see in Tables 2 to 16 that 87% of the analyses of metabasalts (DI $>$ 50 and $<$ 54% SiO_2) contain less than 1.75% TiO_2, and the maximum value is only 1.90% which is well below the average of 3.05% for oceanic basalts. On this basis, we could say that the basalts of the Chibougamau area are of the circumoceanic types.

The AFM diagrams (Figures 27 and 27A) show that the lavas of the Chibougamau district have a pronounced calc-alkaline affinity using Kuno (1954) and Aramaki (1963) curves to separate the tholeiitic field from the calc-alkaline field. The majority of true tholeiites are metabasalts of the lower part of the Gilman Formation. The andesitic rocks of the pyroclastic lenses found in the Gilman Formation at the railroad station are all well in the calc-alkaline field. A detailed study of the petrochemistry of each formation of the Roy Group is planned for the coming field seasons.
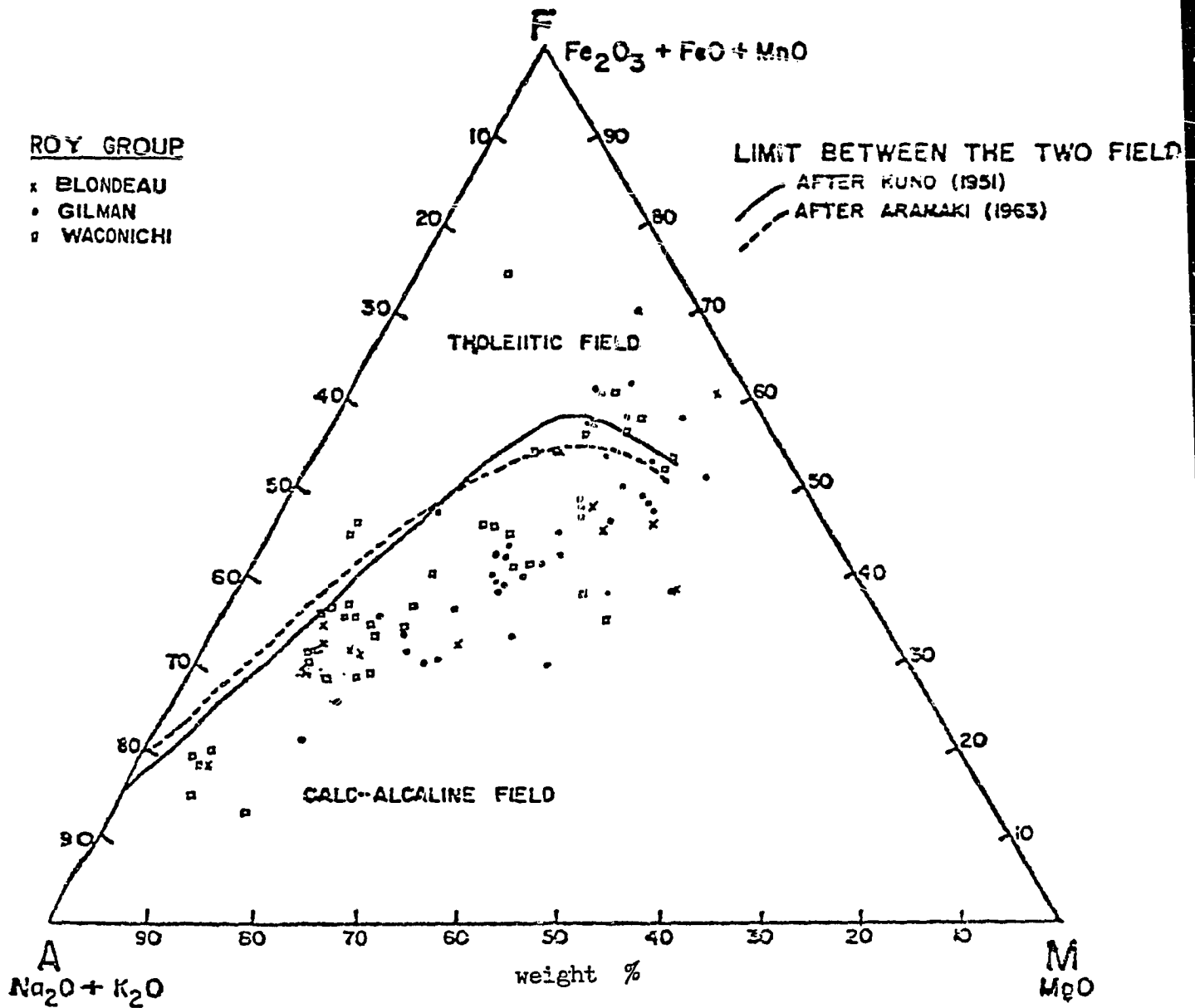
Fig. 27. AFM diagram of the volcanic rocks of the Roy Group.
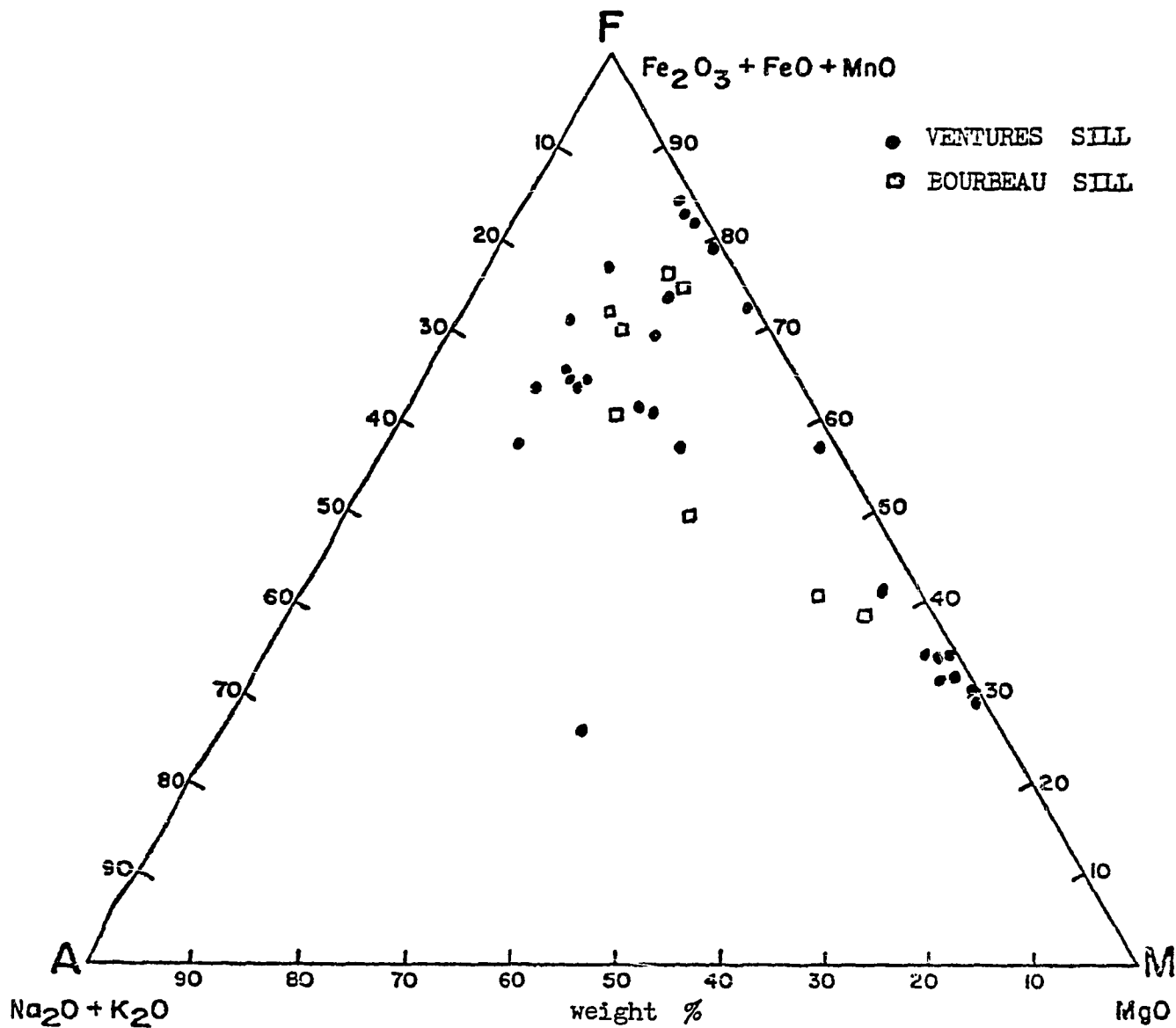
Fig. 27 A. AFM diagram of the Ventures Sill and Bourbeau Sill.
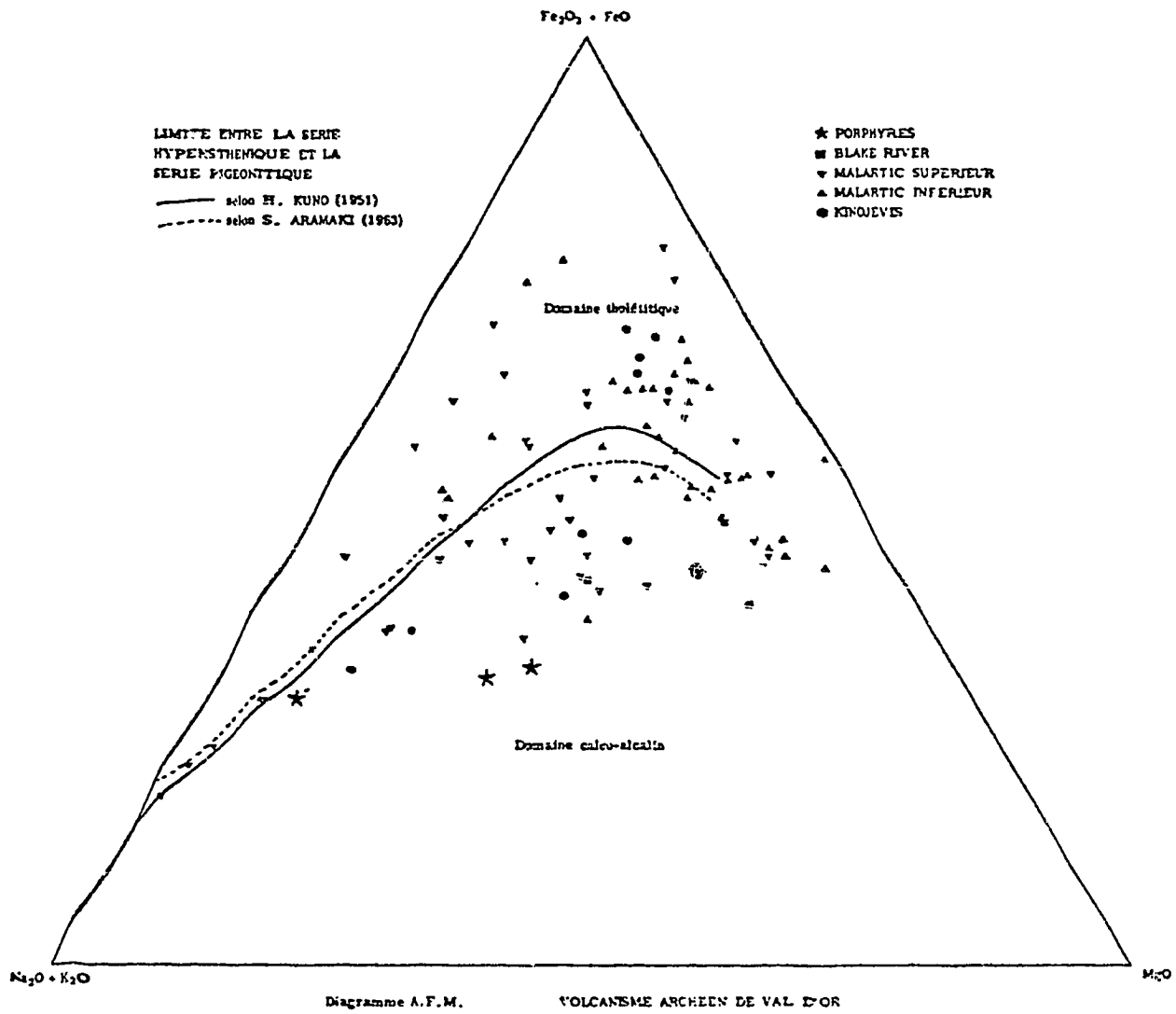
Fig. 28. AFM diagram of the volcanic rocks of the Val d'Or area
(from Alsac et al, 1974, fig. 9)

High-alumina basalts are distinguished by an alumina content of 17% or greater and thought by Juno to be a fundamental magma type. None of our analyses of metabasalts and comagmatic gabbro sills fall within this group.

Application to exploration

The calc-alkaline nature of most of the analyses of volcanic rocks in the Chibougamau area is a promising feature for the exploration geologist, if we accept Fonteille's premise that copper-zinc mineralization is more likely associated with calc-alkaline volcanism than with tholeiitic volcanism, especially in the upper felsic end-of-the-cycle portion. This aspect will be considered in more details in the chapter on the metallogeny of Chibougamau.

Chibougamau Formation

The Chibougamau Formation lies unconformably on the greenstones of the Roy Group. It consists of a sequence of terrigenous clastic rocks ranging from conglomerates to mudstones. It attracted the attention of the first geologists in the area since it underlies some of the highest hills of the area and the shore of the well-traveled canoe route to Waconichi Lake at the north end of Chibougamau Lake.

A detailed study of the formation has been done by Long and much of the information presented here is taken from his papers (Long, 1972, 1973, 1974). The Chibougamau Formation was formerly called Chibougamau Series by Mawdsley and Norman (1935) and by Smith and Allard (1960).

Deposits of the Chibougamau Formation have been variously interpreted as the products of igneous activity (Low, 1906), littoral and shallow marine deposits (Faribault et al., 1911), and glacial deposits (Retty, 1929). Long interpreted the Chibougamau Formation as

> "a sequence of rocks formed in a glacial to periglacial
> environment as the products of syn- and paraglacial alluvial
> fans. Deposits also include tillites, aquatillites, and normal
> lake deposits."

The Chibougamau Formation occurs as five isolated erosional remnants of relatively undisturbed and unmetamorphosed sediments in an east-west belt in Barlow and McKenzie Township. It also forms an elongated lens along the northwest side of McKenzie Narrows Fault in Roy Township. Similar patches are found on the northwest side of the Campbell Lake-Gwillim Lake-Waconichi Lake Fault in Richardson Township north of the Chibougamau area proper.

The lower contact of the Chibougamau Formation is a sharp surface with no apparent chemical weathering developed in the steeply dipping Archean rocks of the Roy Group. A local relief up to 100 meters has been suggested by Long. On the road to the Radar Hill at Bourbeau Lake where the conglomerate is in contact with serpentinized dunite of the Roberge Sill, calcium metasomatism has produced a rodingite zone consisting of hydrogarnet, vesuvianite, and diopside.

The sedimentary rocks of the Chibougamau Formation include orthoconglomerates, wackes, arenites, mixtites, and graded laminites with dropstones. Facies changes are very rapid. The conglomerate beds contain abundant 'granitic' and 'gneissic' pebbles and cobbles which can be matched to similar lithologies in the gneissic complex lying 25-30 kms to the north, suggesting a distal provenance. Sorting of the mixtite and wackes is very poor. The petrology suggests a mixed provenance from "gneissic" and greenstone type rocks. Graded laminites (called varves in Pleistocene glacial sediments) with dropstones constitute one of the best evidence for a glacial origin of the Chibougamau Formation. Long also adds that a

> "true englacial origin is however indicated by the presence of
> aggregate sediment clasts of similar texture of the mixtite matrix.
> Such pellets, which were soft at the time of incorporation into
> the lake sediment can only be produced and emplaced by ablation
> of a terrestrialy based ice mass."

Many authors have suggested a correlation between the Chibougamau Formation and the Gowganda Formation of Huronian age located 400 kms to the southwest. Young (1970, 1973) has outlined a continental ice sheet which

covered a large part of Canada 2.1-2.3 billion years ago. In Young's paleo-
geographic map (Fig. 4) Chibougamau is at the extreme northeastern corner of
the Proterozoic (Aphebian) ice sheet. The following is a conclusion by
Long (1972):

> "the Chibougamau Formation is considered to be deposited in a
> glacial and periglacial environment. The ice sheet, which is of
> equivalent age to the Gowganda Formation of Ontario was of
> continental dimensions (see Young 1970). The ablation of this
> ice mass produced as a direct result, the mixtite units, and
> indirectly (by calving and ablation of ice-bergs) the graded
> laminite units. The formation of the latter probably took place
> in a non-saline water mass. Alluvial fans and associated mass-
> flow deposits are a result of the increased runoff due to
> (seasonal ?) ablation of the ice mass. Most of the material in
> these fans is probably reworked till and outwash which had been
> laid bare by the retreating ice mass. Several readvances of
> this ice sheet are possible within the time spanned by deposits
> of the Chibougamau Formation, though deposits in McKenzie
> Township are probably the result of one glacial advance. The
> local provenance of much of the clastic detritus, and the lack
> of a well developed stratigraphy (compared with the Gowganda
> Formation) are probably due to a more 'mountainous' topography
> than that encountered beneath the Huronian Gowganda Formation
> in Ontario and western Quebec."

THICKNESS OF SEQUENCE IN EACH SUB-AREA GIVEN IN METRES.

A = SECTIONS LACKING GRADED LAMINITE AND MIXTITE MEMBERS.

B = SECTIONS INCLUDING GRADED LAMINITE AND/OR MIXTITE MEMBERS.

STIPPLED PATTERN DENOTES SUPPOSED ABUNDANCE OF MASSIVE ORTHOCONGLOMERATES IN EACH
SUB-AREA.
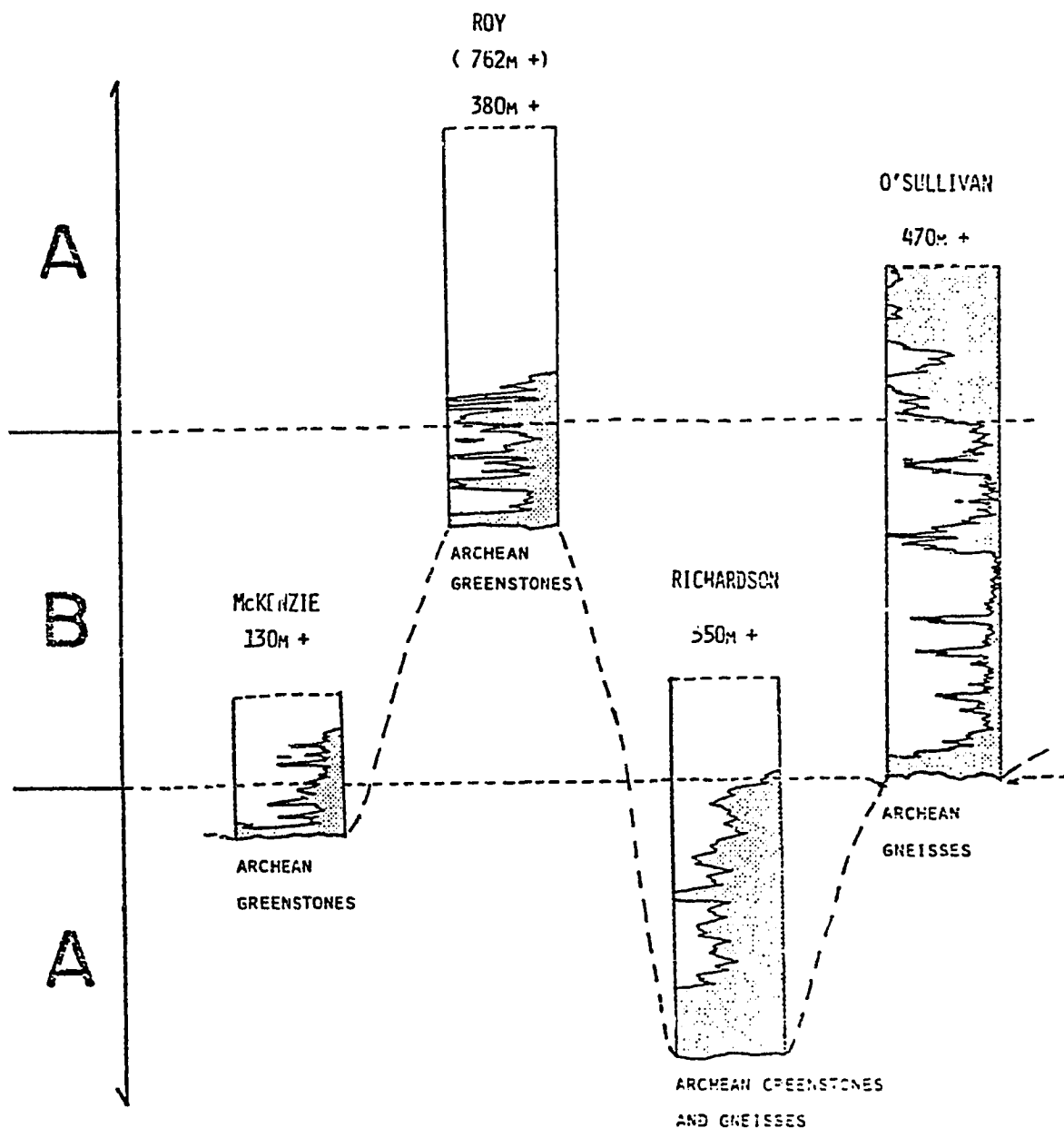
Fig. 29. Stratigraphic correlation of Chibougamau Formation rocks
proposed by Long (1973, fig. 5.1, p. 280) for the McKenzie, Roy,
Richardson, and O'Sullivan Township sub-areas.

CHAPTER 3

GEOLOGY OF THE DORE LAKE COMPLEX

INTRODUCTION

The Dore Lake Complex is a stratiform igneous intrusion similar to other well known stratiform complexes such as the Bushveld in South Africa, the Stillwater in Montana, the Skaergaard in Greenland, the Dufek in Antarctica, the Muskox in the N.W.T. of Canada, and many others discussed in length in the classic study of Wager and Brown (1967) and in the Pretoria symposium proceedings (Visser and Von Gruenewaldt, 1970).

The Dore Lake Complex differs from other complexes by the low grade regional metamorphism which has affected most of the complex, by its general tectonic setting in a volcanic greenstone belt, and by its Archean age. The presence of epigenetic copper-gold ore deposits of the Chibougamau mining area is a fortunate coincidence which has provided us with an incentive to study the complex and some fantastic underground exposures coupled with millions of feet of drill cores which would not have been available otherwise since all the mines are located under the waters of Dore Lake and Chibougamau Lake.

Previous Work

The Dore Lake Complex is a relatively recent addition to the list of well-known layered complexes. The Chibougamau Commission (1911) found an interesting white rock around Dore Lake and stated:

p. 64

> "In addition, a rock which seems peculiar to this area has been
> called "anorthosite", because although it is of gabbroic type,
> there is usually a marked absence of paucity of ferromagnesian
> minerals, which are present and sometimes quite abundant in
> typical gabbros. The prevalent phases of this rock highly
> resemble the highly feldspathic gabbro to which the term anorthosite
> was first applied, and which is characteristic of the formation
> formerly classified as Upper Laurentian.

"The Keewatin formation is made up of a series of decomposed and deformed basic magnesian rocks, which may in general be described as greenstones and green schists. These are the oldest rocks of the district. They are penetrated by the batholithic mass of the anorthosite already mentioned."

One can readily recognize the influence of Adams' work (1893) on anorthosite from the Grenville Province massifs which was only 18 years old.

Retty (1930) described the "oligoclase anorthosite" but does not comment on the presence of genetically related gabbros.

Mawdsley and Norman (1935) stated:

p. 27

"The northern mass of anorthosite forms a belt, 2 to $2\frac{1}{2}$ miles wide, that extends in a direction slightly north of east almost continuously across the central part of the map-area from lake David to Nepton bay. Anorthosite is the predominant rock of this belt. The Associated gabbro occurs as a narrow marginal phase along the northern side of the anorthosite belt and occurs with serpentine both as marginal phases and as small masses within the anorthosite northeast of lake Chibougamau. The associated gabbro is most widely developed at Caché lake. It underlies a large, irregularly shaped area there and separates the anorthosite at lake David from the main anorthosite mass on lakes Doré and Chibougamau.
"The anorthosite mass southeast of lake Chibougamau may have been originally part of the northern mass and have been separated from it by intrusive granite. Gabbroic phases are associated with the anorthosite and are very approximately separated from it on the map."

p. 29

"Gabbroic rocks composed either in part or entirely of dark ferromagnesian minerals and their alteration products are closely associated with the anorthosite. They are believed to be closely related to the anorthosite in origin and to be of approximately the same age."

p. 29

"The associated gabbro marginal to the anorthosite west of Bear bay, in places shows a transition into anorthosite. Away from the anorthosite these rocks for the most part grade into highly altered ones that have little resemblance to the anorthosite and closely resemble rocks described as gabbro, diorite, quartz diorite, and their altered equivalents."

From these excerpts, Mawdsley and Norman give the impression that the different rock types and the anorthosite mass are genetically related. They do not

mention layered complex but Hall's famous Memoir on the Bushveld (1932) was

very new and little known outside of South Africa. Wager (1934) was just

beginning to publish notes on the Skaergaard.

Graham (1951) divided the rocks in the northwest quarter of Obalski

Township in two groups: the Dore Lake Group and the David Lake Group. Graham

reports gradations between many of the rocks of both groups. He stated:

p. 5

> "the transition rock (gabbroic anorthosite, anorthositic gabbro) is
> the result of the anorthosite intruding the gabbro and may be due
> to replacement."

But in his final report (1956) Graham states:

p. 10

> "it would appear that this zone represents a true transition phase
> between gabbro and anorthosite derived from the same magnetite-
> bearing basaltic magma."

His David Lake Group included some rocks belonging to the Dore Lake Complex

and some rocks belonging to the Chibougamau pluton.

Allard (1956) was the first to recognize the layered nature of the

intrusion and to compare it with the Bushveld and other well known layered

intrusives (Fig. 30). Many authors contributed in the detailed mapping of the

complex between 1950 and the present. Some investigators (Table 1) (Miller,

Sutton, Raychaudhuri, Hawkins, Vollo) were concerned with alteration studies

around ore deposits and indirectly contributed to our knowledge of the complex,

especially of the Anorthosite Zone.

Allard (1967) and Allard and Caty (1969) first established a detailed

stratigraphy of the complex (Table 31, Fig. 30), especially outcrops in Rinfret

and Lemoine Township on the south limb of the Chibougamau anticline. Baskin

(1975) studied the area around Cache Lake and identified and described a

localized Ferrodiorite Zone (FZ). Allard (1973) speculated on the existence of

a Lower Hidden Zone (LHZ). A summary of the stratigraphy of the complex can be

found in Table 31.

Table 31

STRATIGRAPHY OF THE DORR LAKE COMPLEX

Zone	NORTH LIMB - western portion	NORTH LIMB - eastern portion	SOUTH LIMB
UPPER BORDER ZONE	Metadiabase Anorthositic metagabbro	Metapyroxenite - metadiabase	Metadiabase - metagabbro Anorthositic metagabbro
SODAGRANOPHYRE ZONE	Sodagranophyre		Sodagranophyre
FERRODIORITE ZONE	F_3 Ferrodiorite III F_2 Ferrodiorite II F_1 Ferrodiorite I		
LAYERED ZONE	NP_3 Metapyroxenite III- quartz bearing NP_2 Metapyroxenite II- apatite-ilmenite bearing NP_1 Metapyroxenite I- metagabbro magnetite-bearing	Metapyroxenite-metaferropyroxenite Metaferrodunite	P_3 member - metaferropyroxenite-metagabbro A_2 member - meta-anorthosite-gabbroic meta-anorthosite P_2 member - metaferropyroxenite -magnetitites-metagabbro A_1 member - meta-anorthosite-gabbroic meta-anorthosite P_1 member metaferropyroxenite-metaferrogabbro-magnetitite
ANORTHOSITE ZONE	Anorthositic metagabbro Meta-anorthosite	anorthositic metagabbro gabbroic meta-anorthosite meta-anorthosite	Metagabbro Anorthositic meta gabbro Gabbroic meta-anorthosite Meta-anorthosite
INTRUSIVE CONTACT	Intruded by Chibougamau Pluton	Intruded by Chibougamau Pluton	Intruded by Chibougamau Pluton
LOWER HIDDEN ZONE	?	?	?

Data from Allard (1969), Dorr (1969), Caty (1970), Allard (1973), Baskin (1975).
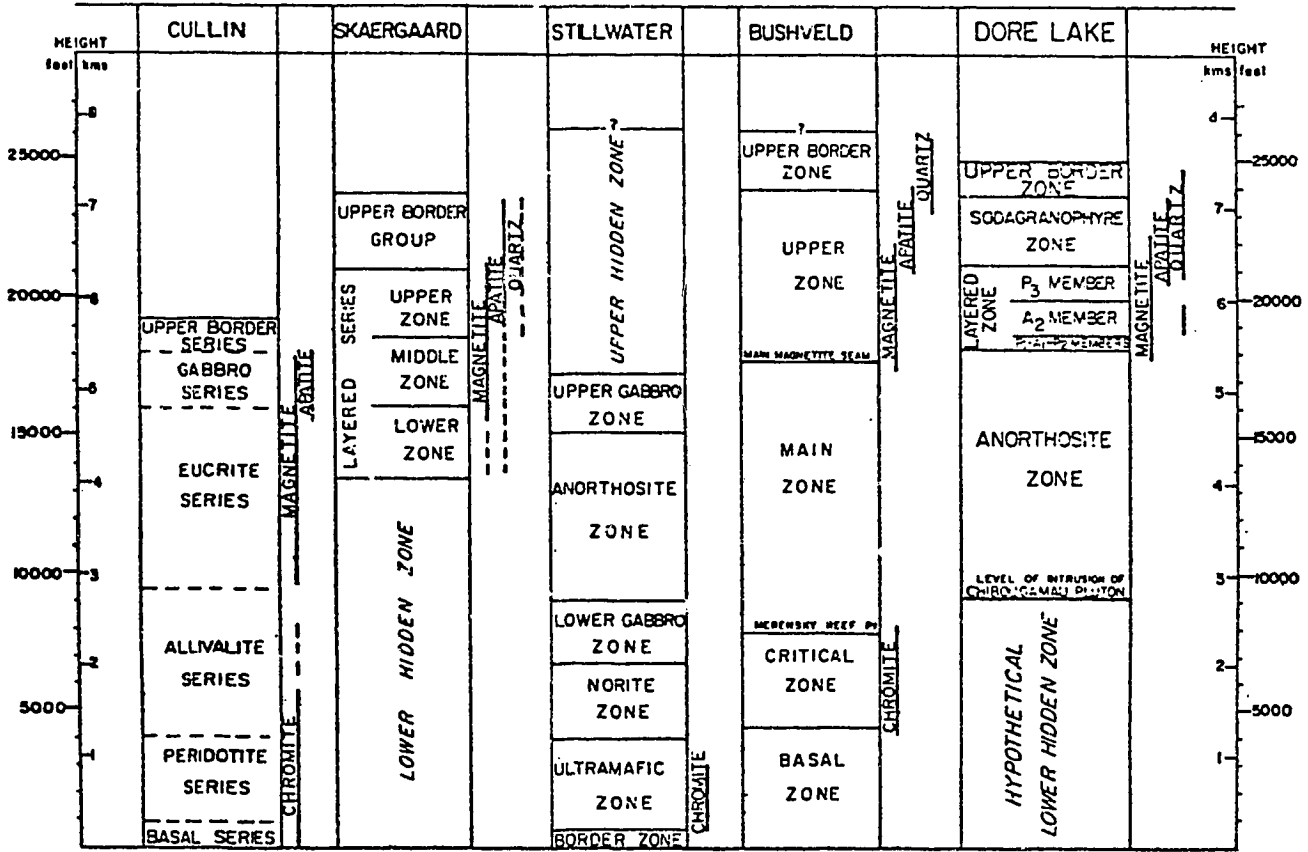
Fig. 30. Comparison between major layered complexes and the Dore Lake Complex showing the similarity in stratigraphy, petrography, and mineralogy (from Allard, 1973, fig. 4, p. 723).

Detailed microprobe studies of the various minerals involved in the Dore Lake Complex are in progress but the results are not available at the present. Chemical analyses of samples from the complex can be found in Tables 33 to 36, 42, 46, 51, 52, 53, 55, 56, 57, 60-68, 70 and 77. Figures 46, 71, 80, 120, 121, 122, 123, and 124 summarize the chemical information contained in the tables of chemical analyses.

ANORTHOSITE ZONE

The Anorthosite Zone (AZ) is the lowermost exposed zone of the complex. The Chibougamau pluton is intruded within the lower.part of the zone. Allard (1973) postulated a Lower Hidden Zone (LHZ) which will be discussed later. The An content of the plagioclase in the unmetamorphosed patches of anorthosite and the total thic`ness of the AZ (8,000-12,000 feet, 2,400-3,600 m.) suggest that the pluton is intrusive at or very near the bottom of the AZ. Ic is possible that a physical discontinuity existed at that level in the D.L.C. similar to the sharp contact observed between the AZ and LZ; such a break would be mechanically favorable for the intrusion of the sill-like Chibougamau pluton.

The original rocks within the AZ varied from anorthosite to gabbro. Table 32 gives the scheme of classification used by Caty (1970) in Lemoine and Rinfret Township. Within the Chibougamau area, many rocks which would be classified as gabbro have been called "anorthositic" if they are within the AZ and have the very coarse texture of most of the rocks within the zone (Figs. 31 to 34). This local usage was necessary in correlating our work with the work of numerous mining and exploration geologists who extended the term anorthosite and anorthositic because of the early belief that Chibougamau ore deposits could be found only in this type of rocks. For that reason, it became 'promotionally' better to log many gabbros and gabbroic rocks as anorthosite and gabbroic anorthosite.

Table 32

CLASSIFICATION SCHEME FOR ROCKS OF THE LAYERED ZONE (LEMOINE AND RINFRET TOWNSHIPS)
(FROM TABLE 7 IN CATY, 1970)

CLASSIFICATION DES ROCHES DE LA ZONE RUBANEE (CANTONS LEMOINE ET RINFRET)
(ADAPTE DU TABLEAU 7 DE CATY, 1970)

A) Rocks with less than 20% of magnetite and ilmenite	A) Roches contenant moins de 20% de magnétite et d'ilménite
90 - 100% plagioclase* : meta-anorthosite	90 - 100% de plagioclase* : méta-anorthosite
70 - 90% plagioclase* : gabbroic meta-anorthosite	70 - 90% de plagioclase* : méta-anorthosite gabbroique
50 - 70% plagioclase* : anorthositic metagabbro	50 - 70% de plagioclase* : métagabbro anorthositique
30 - 50% plagioclase* : metagabbro	30 - 50% de plagioclase* : métagabbro
05 - 30% plagioclase* : melametagabbro	05 - 30% de plagioclase* : métagabbro mélanocrate
00 - 05% plagioclase* : metapyroxenite	00 - 05% de plagioclase* : métapyroxénite
B) Rocks with more than 20% of magnetite and ilmenite	B) Roches contenant plus de 20% de magnétite et d'ilménite
Most abundant cumulate mineral first	Minéraux "cumulus" par ordre d'importance
Plagioclase*, magnetite, pyroxene* metacumulate	Métacumulite à : plagioclase*, magnétite, pyroxène*
Magnetite, plagioclase*, pyroxene* metacumulate	Métacumulite à : magnétite, plagioclase*, pyroxène*
Magnetite, pyroxene*, plagioclase* metacumulate	Métacumulite à : magnétite, pyroxène*, plagioclase*
Plagioclase* and magnetite metacumulate	Métacumulite à : plagioclase* et magnétite
Magnetite and plagioclase* metacumulate	Métacumulite à : magnétite et plagioclase*
Magnetite and pyroxene* metacumulate	Métacumulite à : magnétite et pyroxène*
Pyroxene* and magnetite metacumulate	Métacumulite à : pyroxène* et magnétite
Magnetite metacumulate	Métacumulite à : magnétite
* plagioclase means the metamorphic pseudomorph of the original plagioclase	* plagioclase : pseudomorphe de plagioclase
* pyroxene means the metamorphic pseudomorph of the original pyroxene	* pyroxène : pseudomorphe de pyroxène.

The major characteristic of this zone is the very coarse grain size (Figs. 31 to 34). Single blastocumulus plagioclase up to 4-5 inches (10-12 cms) are not uncommon. Patches of plagioclase up to 12 inches (30 cms) have been observed but the crystalloblastic nature of the zoisite made it impossible to determine whether it was a single crystal or a glomeroporphyritic assemblage of crystals.

Unmetamorphosed anorthosite has been observed in only a few places. Drill cores from Duvex drilling shows an adcumulate of bytownite (An_{80}) (Fig. 35) with a grey color. Very minor zoisite needles and grains can be found at grain boundaries. Veinlets of clear albite cross the rock and stand out by their different positions of extinction with respect to the bytownite (Fig. 35).

Meta-anorthosite is the common rock type in the lower part of the zone. The rock weathers to a chalky white color with a knobby surface caused by the cumulus plagioclase greater resistance to erosion than the intercumulus chlorite. The fresh surface varies from dead white to spotty greenish white depending on the quantity of green chlorite blotches in the gabbroic anorthosites. The intercumulus pyroxene is replaced by chlorite and the cumulus plagioclase by large crystals of albite irregularly speckled with a brownish mat of poorly crystalline zoisite (Figs. 36, 37, 39, 40, 41). The ratios of albite to zoisite reflect the composition of the original plagioclase. In bright sunlight, the Albite twinning and Carlsbad twinning of the albite can be seen through the veil of saussuritization products. The primary intercumulus grains of ilmenite (Figs. 39, 40, 42) have been replaced by orange to purple leucoxene (in thin section, it appears to be mostly fine-grained poorly crystalline sphene). The lowermost layers of anorthosite consist of cumulus bytownite and a Mg-rich pyroxene (orthopyroxene ?). The very low total iron content of the rock explains the very pale color of the chlorite and the pure white color of the zoisite-albite. Proceeding upwards in the AZ, the iron content increases

and the chlorite becomes darker green and the plagioclase yellowish green with
an increase in iron in the zoisite-clinozoisite-epidote minerals. Detailed
microprobe studies of the chlorites and epidote family minerals are in progress.

Contact metamorphic effects

The contact between the Chibougamau pluton and the meta-anorthosite is a
zone of contact metamorphism and breccia with blocks of anorthosite of all
sizes in a matrix of hornblende meladiorite and melatonalite (Fig. 125).
Excellent exposures of the breccia zone can be seen along the Opemisca highway
at mileage 206.1, just west of the Chibougamau river in Scott Township and
along the shores of the islands in Chibougamau Lake. The breccia zone grades
into a white hornfels consisting of granoblastic clear zoisite (Fig. 38). The
brownish mat of saussuritized plagioclase changes to a crystalline granoblastic
clear zoisite with minor clear albite and quartz.

Layering

In the early days of mapping in the D.L.C., variations from outcrops to
outcrops in texture and mineralogy pointed to the probability of a crude
layering in the anorthosite. The very large grain size of the plagioclase
precludes development of a spectacular inch-scale layering like that of the
Layered Zone. The variations in grain size and in the relative proportions of
pyroxene, ilmenite, and plagioclase produce the rhythmic layering in the AZ.
In the early days of the mining camp, mine geologists kept looking for a favorable
horizon (mechanical or chemical) which might provide a structural control for
the ore zones. Terms like "brecciated anorthosite" (Figs. 31 and 32), "spotted
anorthosite" (Fig. 34), "tombstone anorthosite", "polka dot anorthosite" (Fig.
34), "sandstone anorthosite", "reverse texture anorthosite", etc., were coined
by mine geologists in logging core and in underground mapping. Unfortunately,
no good layering attitudes could be determined although it was clear that the
variety of textures and structures was due to rhythmic layering. In the late

sixties, excellent layering in the upper portion of the AZ was observed in the underground drift joining the Jaculet and Bateman shafts, underground at Copper Rand Main mine, and underground at both Cedar Bay and Henderson mines (Figs. 44 and 45). The variable quantities of ilmenite and magnetite in the upper portion of the AZ is more conducive to good development of layering than the plagioclase adcumulates of the base of the zone.

Large areas of Rinfret and McCorkill Township are underlain by gabbroic anorthosite with a distinct brownish weathered surface: the plagioclase is fresh, averaging around An_{63} (Allard and Simmons, 1969), and the original pyroxene is replaced by actinolite. Excellent examples of blastopoikilitic texture were observed (Fig. 43). The actinolite megacrysts are made up of narrow blades of actinolite tightly packed along either the cleavage or exsolution lamellae direction of the original intercumulus pyroxene.

The resistance of plagioclase to low grade metamorphic changes increases with the Na content of the plagioclase. As mentioned earlier, most of the original plagioclase has been replaced by albite during metamorphism. The calculated An content of the normative plagioclase (Tables 33 to 36) can be used to determine the changes in the original plagioclase across the Dore Lake Complex. Table 72 shows the calculated averages of the plagioclase composition in the various rocks of the complex. The plagioclase varies from around An_{95} in the lower part to An_{72} in the upper part of the AZ. Since the rocks are cumulates, one cannot use the AFM diagram (Fig. 46) to determine the composition of the crystallizing liquid in equilibrium throughout the AZ but microprobe data on the Mg/Fe ratios of chlorites and/or actinolite would be a good indication of the changing composition of the intercumulus liquid during the formation of the AZ.

The AZ shows a cyclic repetition of anorthosite, gabbroic anorthosite, and anorthositic gabbro with a concomitant gradual upward increase in the amount of intercumulus chlorite and iron-titanium oxide. At the same time, the original

pyroxenes become richer in iron; this is reflected in the darkening colors of the chlorites and epidotes. The amount of iron oxides increases markedly in the upper 500 feet of the AZ. The high content of vanadium makes some of those rocks an important potential ore of vanadium. A few thin beds of magnetitite can be observed in the upper part of the AZ.

Block structure

Throughout the D.L.C., 'boulders' of one rock type in another are very common. White blocks of anorthosite in black magnetitite are common and spectacular in the LZ but blocks of anorthosite-gabbroic anorthosite within rocks of nearly the same composition are also common but difficult to recognize on the weathered surface (Figs. 31 and 32). Similar structures have been described from the Bushveld and the Stillwater (Hess, 1960; Coertze, 1970, p. 12). Igneous petrologists ascribe these blocks to sedimentary slumping and brecciation during crystallization of cumulates. These features will be discussed at greater length in a separate chapter on sedimentary features.

The Anorthosite Zone—host rock to the orebodies
of the Chibougamau district

The rocks of the D.L.C., and especially the anorthosite forms the host rock for all the ore deposits discovered so far in the Chibougamau area, except for the Grandroy deposit in a satellitic pluton of the Chibougamau pluton and the recently discovered Patino deposit in Lemoine Township which is a stratiform volcanogenic deposit located in the volcanics of the Roy Group.

The ore deposits consist of massive sulfide lenses (chalcopyrite, pyrite, pyrrhotite, rare sphalerite) enclosed in sericite-paragonite-carbonate-quartz (chloritoid) schist. The ore deposits within the Dore Lake basin have a close relationship to dikes while those of the Henderson Portage area do not share this association. The meta-anorthosite becomes gradually richer in white mica

TABLE 33

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. ANORTHOSITE ZONE

ANALYSES CHIMIQUES DES ROCHES DE LA ZONE D'ANORTHOSITE DU C.L.D.

Sample No. No. d'échantillon	S-4-328	S-4-743	S-5-187	E-1-356	G-204	G-199	G-201
SiO_2	44.97	44.43	45.79	46.12	47.39	48.76	47.69
TiO_2	0.13	0.05	0.13	0.03			
Al_2O_3	28.92	30.14	30.08	27.72	25.47	22.84	31.09
Fe_2O_3	0.??	3.71	4.00	0.72	1.16	1.57	0.63
FeO	0.53	1.66	1.79	0.25	2.66	4.21	0.43
MnO					0.05	0.09	0.02
MgO	0.43	0.52	0.90	0.27	4.52	5.23	0.57
CaO	21.03	17.16	15.78	18.32	15.79	13.50	14.53
Na_2O	0.53	1.76	2.24	1.42	1.53	1.81	2.86
K_2O	0.01	0.04	0.06	0.18	0.12	0.28	0.35
P_2O_5							
H_2O+						1.43	1.30
H_2O-						0.08	0.11
CO_2							
S						0.01	0.02
TOTAL	96.73	99.47	100.77	97.03	98.69	99.81	99.82

Norm wt%							
Qtz	1.88			4.3		0.38	
Cor							
Or	0.06	0.24	0.35	1.06	0.71	1.65	2.07
Plag	80.99	86.60	88.11	80.7	75.22	68.69	91.55
Ab	4.48	12.38	16.26	12.0	12.95	15.32	20.68
An	76.50	74.22	71.84	68.7	62.27	53.37	70.87
Ne		7.36	1.46				2.00
Wo	9.84	3.06	0.10	8.47			
Di	3.46	2.79	4.83	1.45	12.89	11.02	0.96
Wo	1.78	1.50	2.59	0.78	6.71	5.68	0.51
En	1.07	1.30	2.24	0.67	4.56	3.55	0.38
Fa	0.61				1.63	1.79	0.07
Hy					5.87	14.27	
En					4.33	9.48	
Fs					1.54	4.79	
Ol Fo					2.32		0.58 0.73
					1.06		
Fa					0.65		0.15
Mt	0.26	5.20	5.39	0.72	1.68	2.28	0.91
Il	0.25	0.09	0.25	0.06			
Hm		0.12	0.28	0.22			
Ap							
Py						0.01	0.03
Cal							

Data wt%							
An/plag	94.5	85.7	81.5	85.1	82.8	77.7	77.4
Fa/ol					28.2		17.3
En/hy					73.7	66.4	
Diff.i.	6.4	13.9	18.1	17.4	13.7	17.4	24.7

Qtz	29.2			24.7		2.2	
Ab	69.8			69.1	94.8	88.3	
Or	0.9			6.1	5.2	9.5	

An	94.4	85.5	81.2	84.0	82.0	75.9	75.7
Ab	5.5	14.3	18.4	14.7	17.0	21.8	22.1
Or	0.1	0.3	0.4	1.3	0.9	2.3	2.2

A	32.1	23.4	25.6	56.3	16.5	15.9	66.5
F	42.3	69.8	64.4	34.1	38.2	44.1	21.8
M	25.6	6.8	10.0	9.5	45.2	39.9	11.7

Na+K/Al	3.0	9.7	12.5	9.1	10.4	14.4	16.5
Fe+Mn/Fe+Mn+Mg	47.4	84.4	77.1	65.1	31.8	38.0	50.0
Na_2O/Na_2O+K_2O	98.2	97.8	97.4	88.7	92.7	86.6	89.2

TABLE 34

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. ANORTHOSITE ZONE

ANALYSES CHIMIQUES DES ROCHES DE LA ZONE D'ANORTHOSITE DU C.L.D.

Sample No. No. d'échantillon	71-87	DL1002	Queylus
SiO_2	46.60	48.25	48.0
TiO_2	0.18	1.46	0.16
Al_2O_3	27.00	21.65	28.80
Fe_2O_3	1.60	4.89	0.52
FeO	0.90	5.30	1.57
MnO	0.06	0.11	
MgO	1.35	2.92	0.43
CaO	15.30	13.21	13.66
Na_2O	3.45	1.80	3.00
K_2O	0.57	0.37	0.42
P_2O_5	0.01	0.03	
H_2O+	2.13		
H_2O-	0.16		
CO_2	0.28		
S	0.02		
TOTAL	99.61	99.99	96.56

Norm wt%			
Qtz		5.54	
Cor			
Or	3.37	2.19	2.48
Plag	72.80	65.13	87.67
Ab	16.30	15.23	23.80
An	56.50	49.90	63.88
Ne	6.98		0.86
Wo	3.35		
Di	7.45	12.48	3.30
Wo	3.98	6.45	1.62
En	3.36	4.08	0.55
Fa	0.10	1.96	1.12
Hy		4.72	
En		3.19	
Fs		1.53	
Ol			
Fo			1.19 / 0.37
Fa			0.82
Mt	2.32	7.09	0.75
Il	0.34	2.77	0.30
Hm			
Ap	0.02	0.07	
Py	0.04		
Cal	0.64		

Data Wt%			
An/plag	77.6	76.6	72.9
Fa/ol			69.3
En/hy		67.6	
Diff.i.	26.6	22.9	27.1

Qtz		24.1	
Ab		66.4	
Or		9.5	

An	74.2	74.1	70.8
Ab	21.4	22.6	26.4
Or	4.4	3.2	2.7

A	51.1	14.2	57.6
F	31.8	66.7	35.2
M	17.1	19.1	7.2

Na+K/Al	23.3	15.5	18.7
Fe+Mn/Fe+Mg	49.9	65.3	72.7
Na_2O/Na_2O+K_2O	85.8	83.0	87.7

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. SHEARED & ALTERED A - ANORTHOSITE ZONE

ANALYSES CHIMIQUES DES ROCHES DES ZONES D'ALTERATION ET CISAILLEMENT - ZONE
D'ANORTHOSITE C.L.D.

Sample No. No. d'échantillon	S-5-1163	J-1-500	U66-1175	U149-55	U157-075	U698-157
SiO_2	41.88	45.59	42.49	42.78	44.43	42.15
TiO_2	0.18	0.05	0.86	0.43	0.68	0.51
Al_2O_3	30.78	34.21	25.00	24.99	26.28	26.32
Fe_2O_3	0.37	0.50	1.96	1.53	1.09	1.92
FeO	1.11	0.42	3.22	9.39	6.53	6.08
MnO			0.07	0.12	0.09	0.15
MgO	0.79	0.24	0.07	3.04	2.48	2.92
CaO	10.92	10.88	8.71	4.52	4.46	7.32
Na_2O	3.85	4.18	3.51	2.00	3.32	2.61
K_2O	0.16	0.35	1.15	2.00	1.41	1.57
P_2O_5			0.01	0.02	0.01	0.01
H_2O+			4.18	5.49	5.03	4.78
H_2O-						
CO_2		2.47	7.37	3.39	3.38	5.37
S						
TOTAL	90.04	98.99	98.40	99.75	99.2	101.71
Norm wt%						
Qtz		2.88	16.0	11.6	11.1	11.5
Cor	4.42	12.90	17.98	19.2	19.0	19.5
Or	0.95	2.07	6.80	11.8	8.33	9.3
Plag	74.88	73.73	29.70	17.8	28.81	24.4
Ab	20.70	35.37	29.70	16.9	28.09	22.1
An	54.17	38.36		0.9	0.71	2.3
Ne	6.43					
Wo						
Di						
Wo						
En						
Fa						
Hy		0.87	3.18	22.98	16.31	16.29
En		0.60	0.17	7.57	6.2	7.3
Fs		0.28	3.00	15.41	10.1	9.0
Ol	2.49					
Fo	1.38					
Fa	1.11					
Mt	0.54	0.72	2.84	2.22	1.58	2.78
Il	0.34	0.09	1.63	0.91	1.29	0.97
Hm						
Ap			0.02	0.05	0.02	0.02
Py						
Cal		5.62	15.53	7.71	7.69	12.21
Data wt%						
An/plag	72.3	52.0		4.8	2.5	9.4
Fa/ol	44.6					
En/hy		68.4	5.5	32.9	37.9	44.6
Diff.i.	28.1	40.3	52.5	40.3	47.5	42.9
Qtz		7.1	30.5	28.7	23.4	26.8
Ab		87.7	56.6	42.0	59.1	51.5
Or		5.13	12.9	29.3	17.5	21.6
An	71.4	50.6		2.9	1.9	6.8
Ab	27.3	46.7	81.4	57.2	75.6	65.6
Or	1.2	2.7	18.6	39.9	22.4	27.5
A	63.8	79.6	47.0	22.3	31.9	27.7
F	23.6	16.2	52.3	60.8	51.4	53.0
M	12.6	4.2	0.7	16.9	16.7	19.3
Na+K/Al	21.1	21.2	28.1	21.8	26.6	22.8
FeMn/FeMg	50.6	67.0	97.6	66.8	63.2	60.5
Na_2O/Na_2O+K_2O	96.0	92.3	75.3	50.0	70.2	62.4

Table 36

Notes on samples of Tables 33 to 35.

TABLES 33 and 34. DORE LAKE COMPLEX ANORTHOSITE ZONE

S-4-328   Meta-anorthosite. Lemoine Township. Drill hole C.M.S. S-4 at 328';
          north tip of Annie Island in northwest corner of NW 1/4 Lemoine.

S-4-743   Meta-anorthosite. Lemoine Township. Drill hole C.M.S. S-4 at 743';
          north tip of Annie Island in northwest corner of NW 1/4 Lemoine.

S-5-187   Meta-anorthosite. Lemoine Township. Drill hole C.M.S. S-5 at 187'.
          Northeast tip of Lorenzo Island in northwest corner of NW 1/4 Lemoine.

E-1-356   Meta-anorthosite. Scott Township. Drill hole C.M.S. E-1 at 356'
          2700 feet (540 m) from the southeast corner of the NE 1/4 of Scott
          Township (Allard, 1975).

G-204, G-199, G-201 Pouliot samples done in the Q.D.M. Lab. (Pouliot, 1963)
          Southwest McCorkill Township. Exact location unknown.

71-87   Allard, Q.D.N.R. Lab. Lemoine Township. 14,000 feet (4200 m) west of
          the Rinfret-Lemoine Township line and 7000 feet (2100 m) south of R5-6
          range line.

DL 1002   Caty, 1970, p. 209. Anorthositic metagabbro. Lemoine Township. Visual
          estimates: 60% plagioclase (and metamorphic derivatives), 35% chlorite
          and 2% opaques.

Queylus   Cimon J 69-29. NE 1/4 of Queylus Township. Fresh anorthosite.

TABLE 35. ALTERED AND SHEARED META-ANORTHOSITE FROM THE DORE LAKE COMPLEX

S-5-1163 Cimon J 69-29. NE 1/4 of Queylus Township. Sheared meta-anorthosite.

J-1-500   Sheared meta-anorthosite. Scott Township. Drill hole C.M.S. J-1 at
          500 feet. Point of land west of the entrance to Berthe Bay (Allard, 1975).

U-66-1175 Sheared meta-anorthosite. Jeffery, 1959, Table 1, p. 86B. Anal. Q.D.M.
          Lab. Drill hole underground at Campbell Main Mine, No. 66 from 1175 to
          1180. From a barren shear zone 1200 feet (360 m) away from the ore-
          bearing shear.

U-149-55 Sheared meta-anorthosite. Jeffery, 1959, Table 5, p. 167B. Anal. Q.D.M.
          Lab. Drill hole underground at Campbell Main mine. No. 149 from 55 to
          75. Fifty feet (15 m) along strike from orezone.

U-157-075 Sheared meta-anorthosite. Jeffery, 1959, Table 5, p. 167B. Anal. Q.D.M.
          Lab. Drill hole underground at Campbell Main mine, No. 157 from 0 to
          7.5 feet. In footwall of the shear zone and 75 feet along strike from
          the orezone.

U-698-157 Sheared meta-anorthosite. Jeffery, 1959, Table 5, p. 167B. Anal. Q.D.M.
          Lab. Drill hole underground at Campbell Main mine. No. 698 from 157 to
          162. 350 feet (105 m) along strike from orezone.
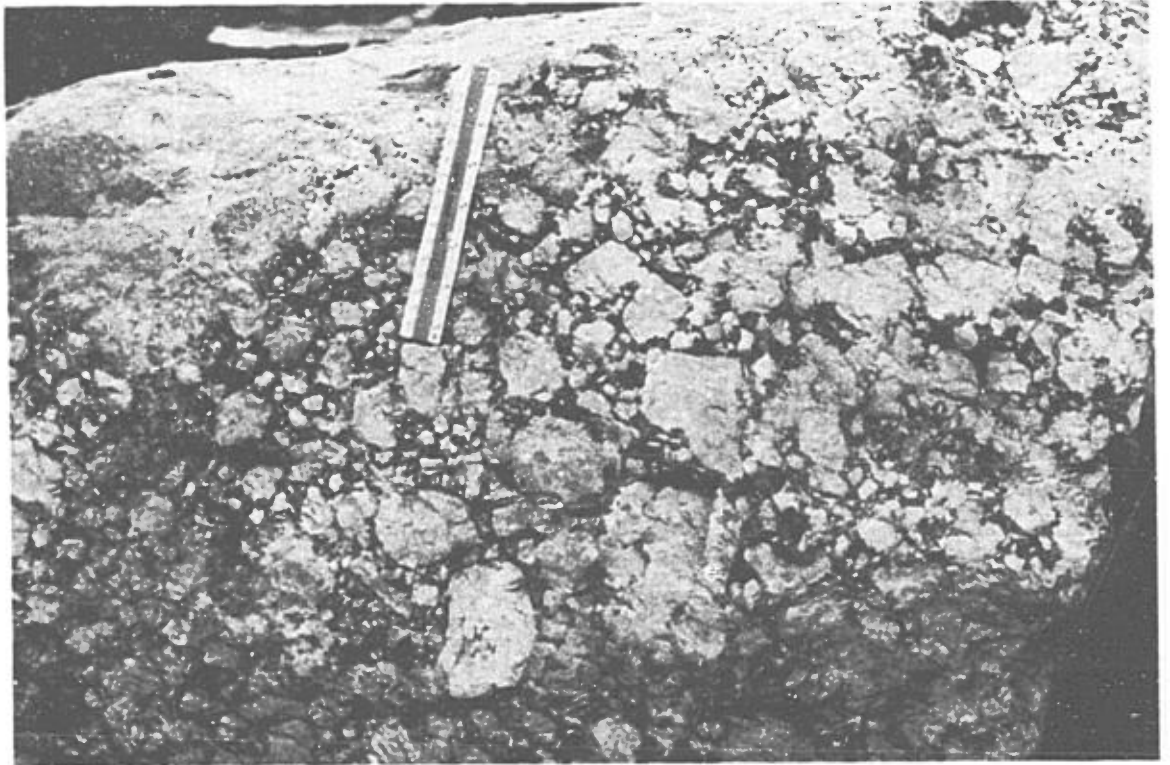
Fig. 31. Gabbroic meta-anorthosite of the Anorthosite Zone of the Dore Lake Complex. Layering in the upper left hand corner and very coarse cumulus texture in the lower part. White cumulus crystals are plagioclase (albite + zoisite) and intercumulus is chlorite replacing original pyroxene and leucoxene replacing ilmenite and titaniferous magnetite. Scale is 6 inches long (15 cms). Kokko Creek mine.
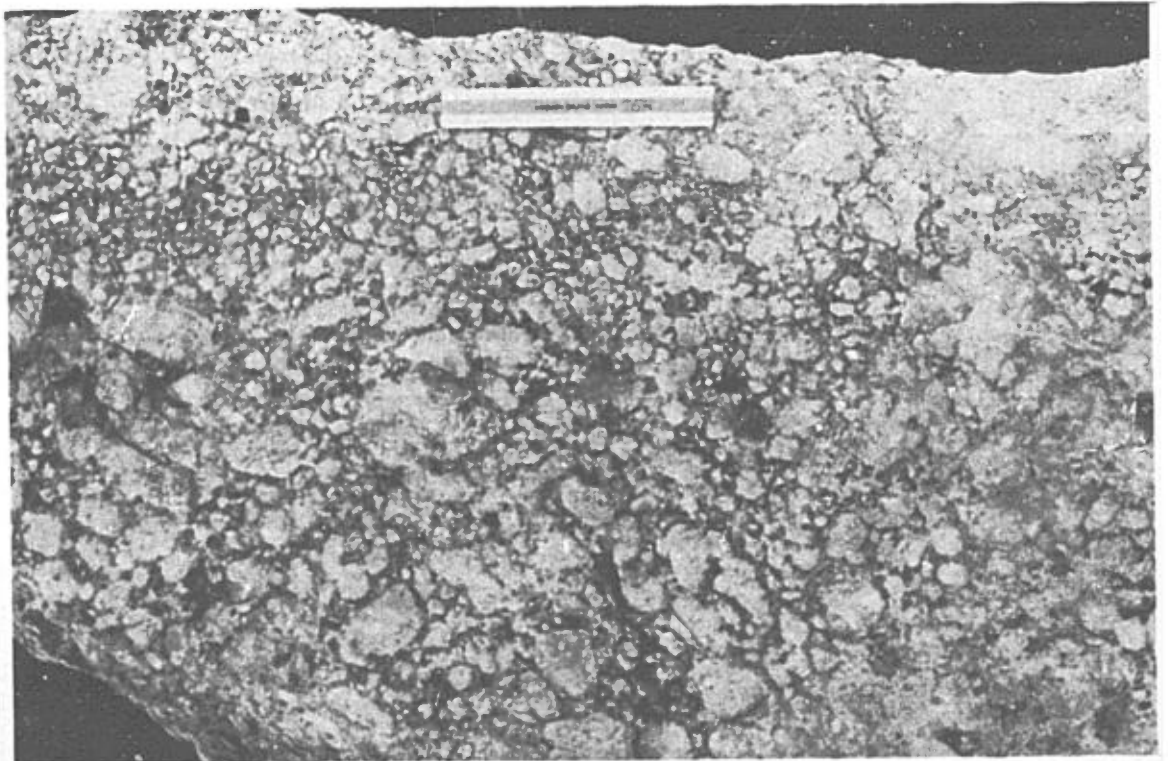
Fig. 32. Same as above in Fig. 31.
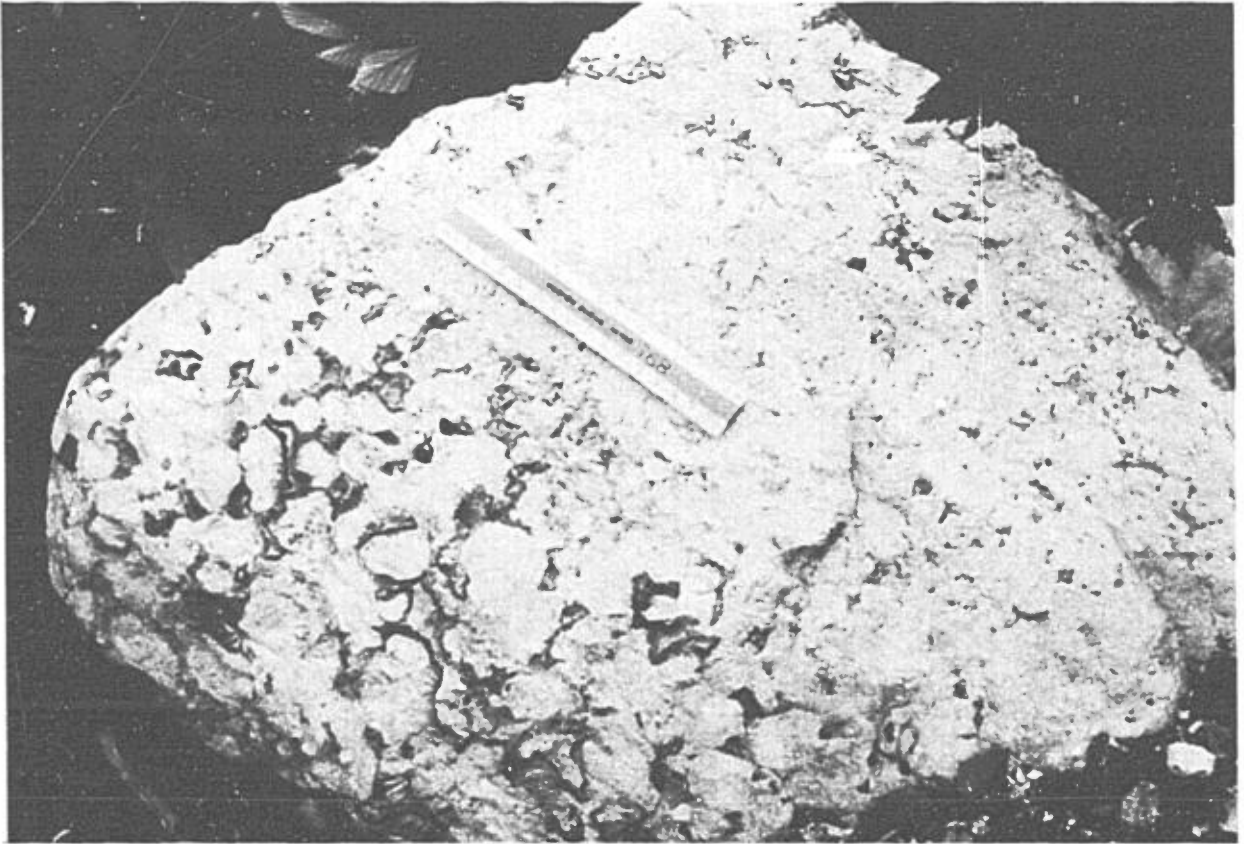
Fig. 33. Layer of meta-anorthosite (AZ) at the top and gabbroic meta-anorthosite at the bottom. Same remarks as in Fig. 31.
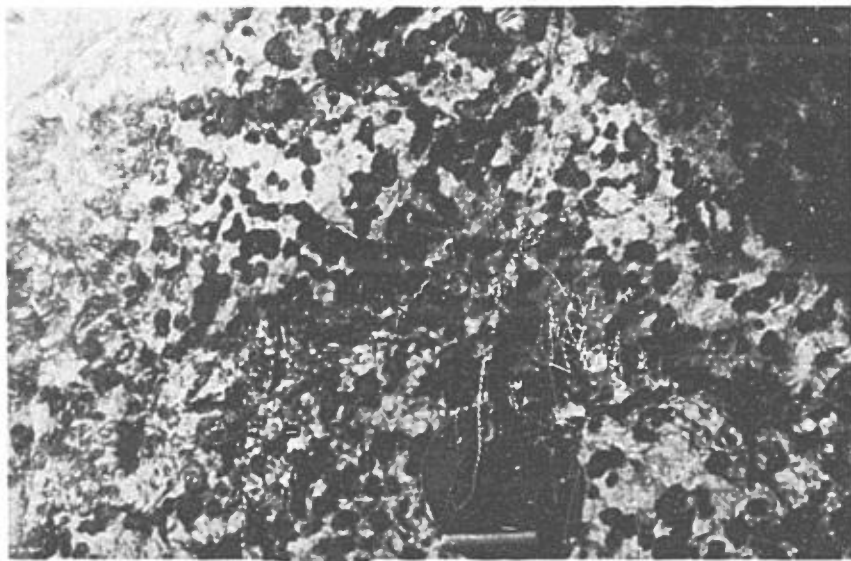
Fig. 34. "Polka dot" gabbroic meta-anorthosite (AZ). Cumulus orthopyroxene (?) replaced by dark chlorite in a matrix of albite and zoisite. Magnet is one inch (2.5 cms) across.
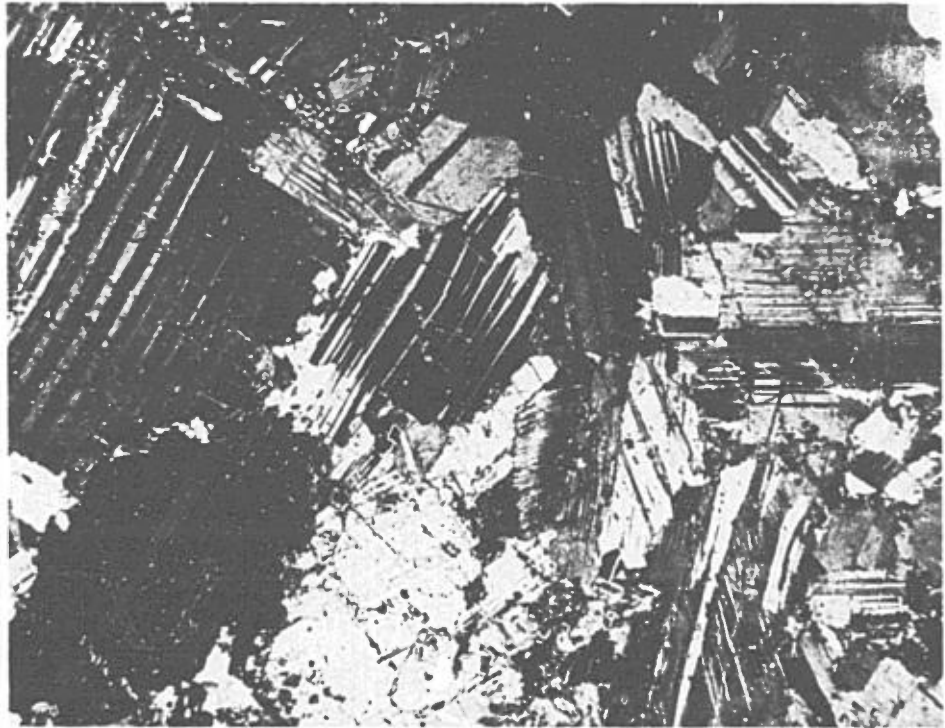
Fig. 35. Photomicrograph of fresh anorthosite, bottom of AZ. A few grains of zoisite at grain boundaries. Very narrow albite veinlets cut across the bytownite (An_{80}) showing a difference in the extinction position. Crossed nicols. Field: 15 mm. Sample 15-357 from Duvex drilling. (223)
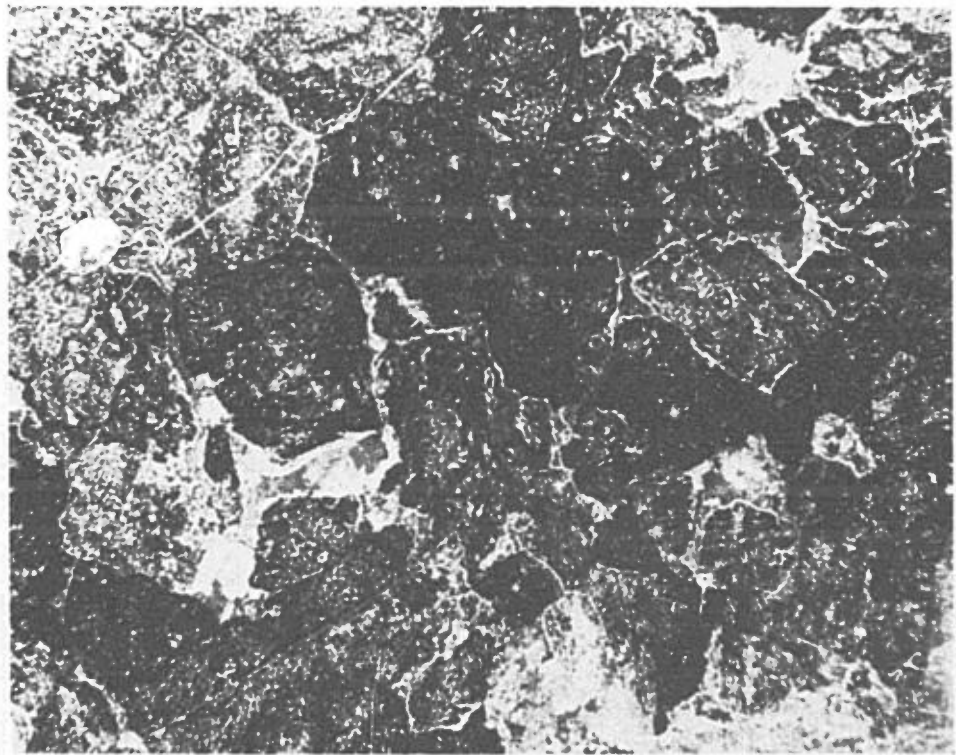
Fig. 36. Photomicrograph of heavily saussuritized anorthosite(AZ). Many grains have a rim of clear albite. Veinlets of albite in optical continuity with the host grains cut across the rock. Influence of grain boundaries during metamorphism clearly visible. Field: 1 cm. Sample 54-200 (160).
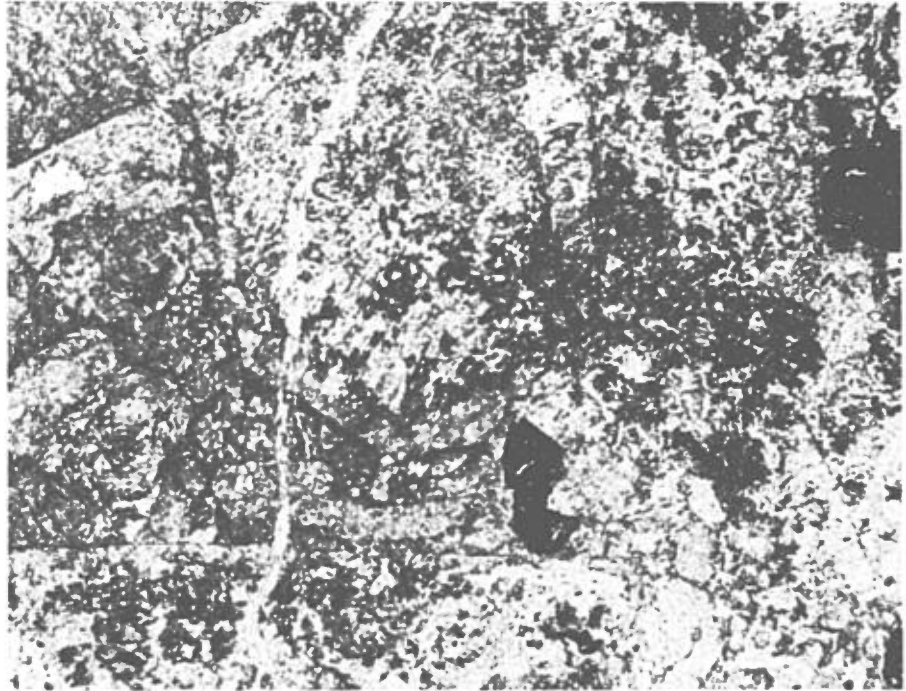
Fig. 37. Photomicrograph of gabbroic meta-anorthosite (AZ). Large plagioclase euhedral grain (top center) is replaced by albite and zoisite in core and epidote on the outside where plagioclase was in contact with pyroxene(now chlorite). Opaque is ilmenite grain replaced by unrecrystallized sphene. Veinlet of albite cuts across the rock. Field: 6 mm. Sample 53-501.
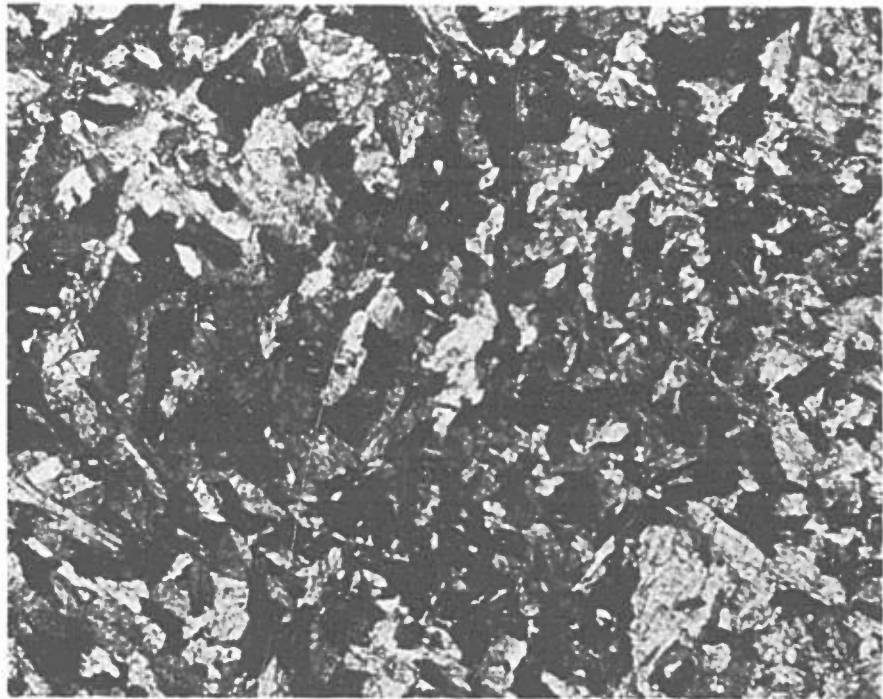
Fig. 38. Photomicrograph of meta-anorthosite (AZ) recrystallized to a mosaic of zoisite at the contact of the Chibougamau pluton. Field is 8 mm. Crossed nicols. Sample Duvex B.
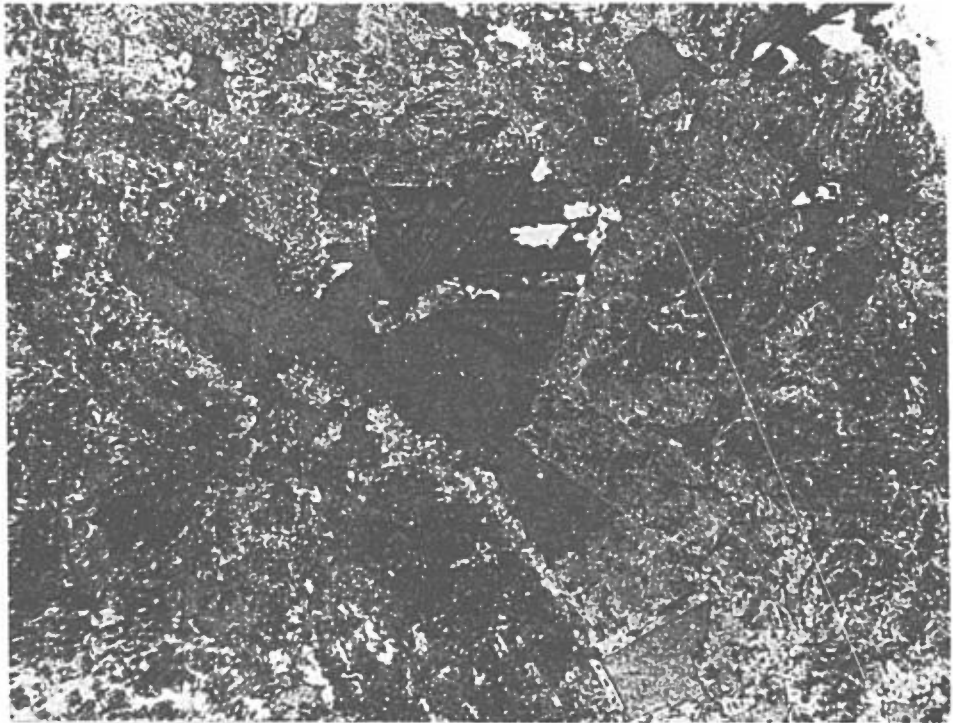
Fig. 39. Photomicrograph of gabbroic meta-anorthosite (AZ).
Large grain of intercumulus pyroxene is replaced by chlorite(C).
A grain of titaniferous magnetite with well preserved E Widmanstatten
texture is replaced by chlorite and blades of leucoxene.
Note the sharp boundaries of the chlorite against the plagioclase
and the preservation of the texture in spite of the intense
metamorphism and folding of the rocks. Sample 53-13.Field 4.8 mm.
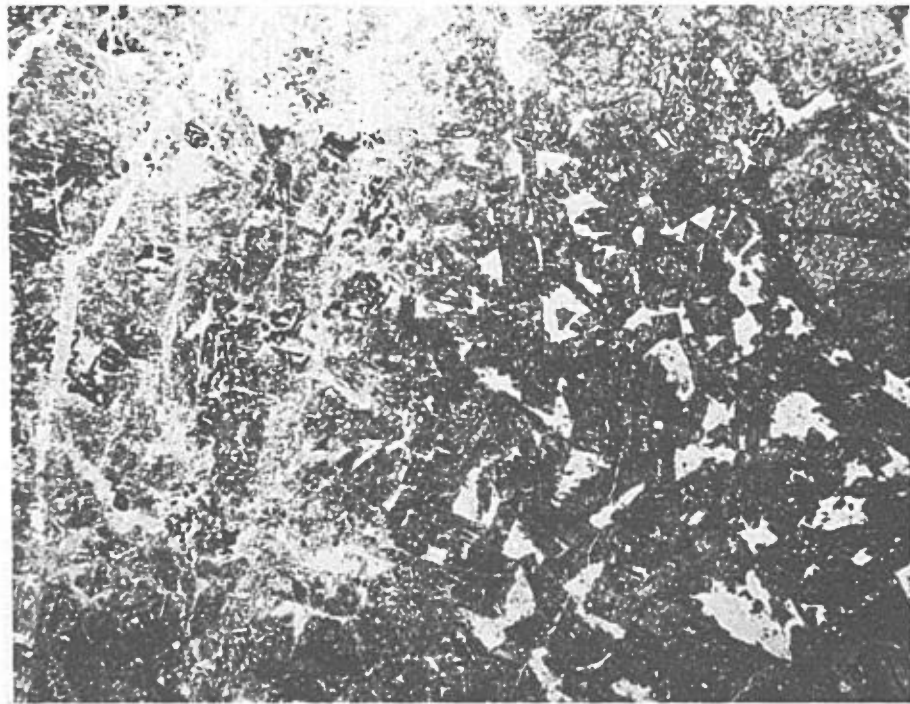
Fig. 40. Photomicrograph of gabbroic meta-anorthosite (AZ).
The white patches are Mg-rich chlorite replacing the original
Mg-rich intercumulus pyroxene. Grains of titaniferous magnetite
are replaced by chlorite and leucoxene. Veinlet of albite+chlorite
cuts across the rock. Field: 15 mm. Sample 54-97(118).
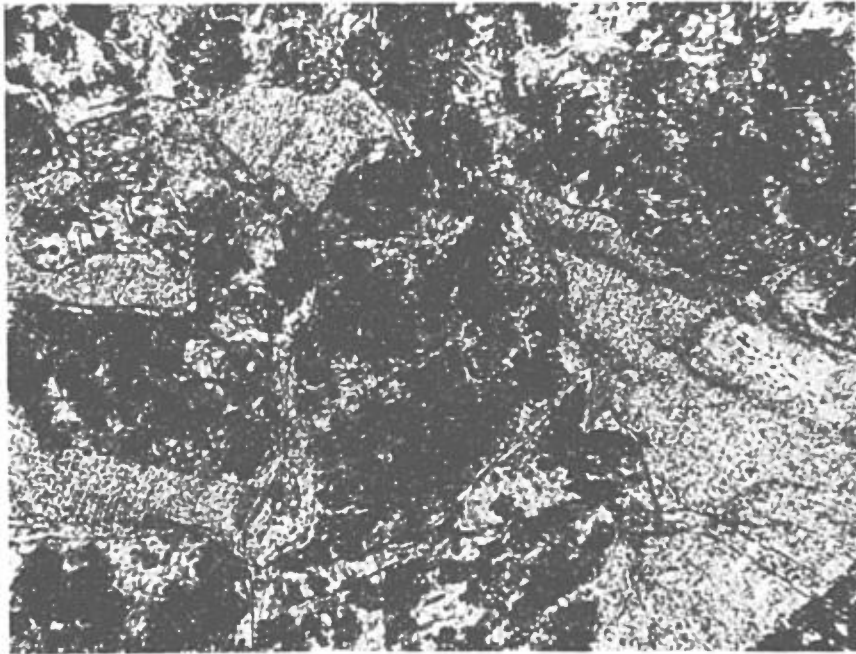
Fig. 41. Photomicrograph of gabbroic meta-anorthosite (AZ).
Plagioclase cumulus is replaced albite and zoisite(dark) and
intercumulus poikilitic pyroxene by chlorite (pale). All the
chlorite patches have the same orientation. Field: 3 mm.
Sample 54-280 (195).

Fig. 42. Enlarged photograph of a piece of drill core of anortho-
sitic metagabbro (AZ) with a large patch of titaniferous magnetite.
The magnetite is replaced by chlorite (grey and white) and the
lamellae of ilmenite by a pale orange-colored leucoxene(sphene)
(pale grey). Core is 15 mm diam.
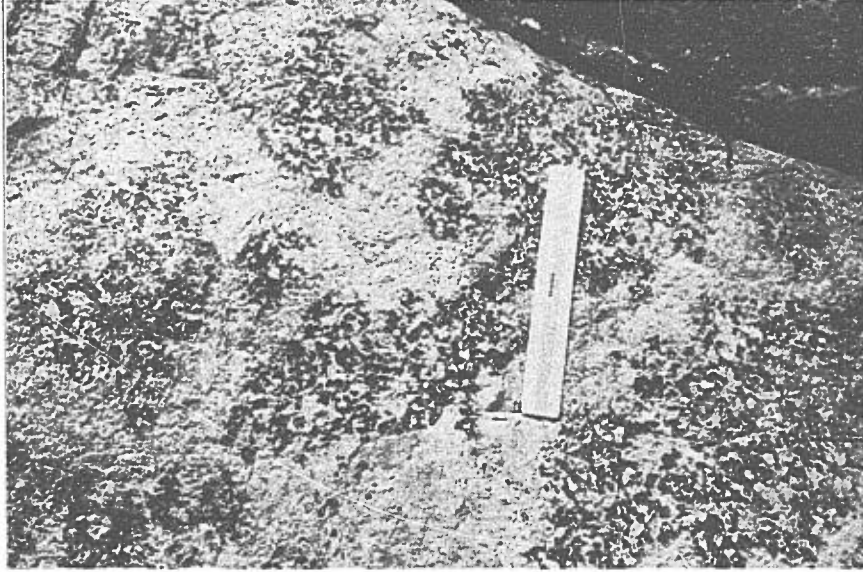
Fig. 43. Blastopoikilitic texture in gabbroic anorthosite from Rinfret Township. M The plagioclase is fresh labradorite and the large dark-colored actinolite patches are pseudomorph of primary poikilitic pyroxene crystals. Scale is 6 inches (15 cms) long.
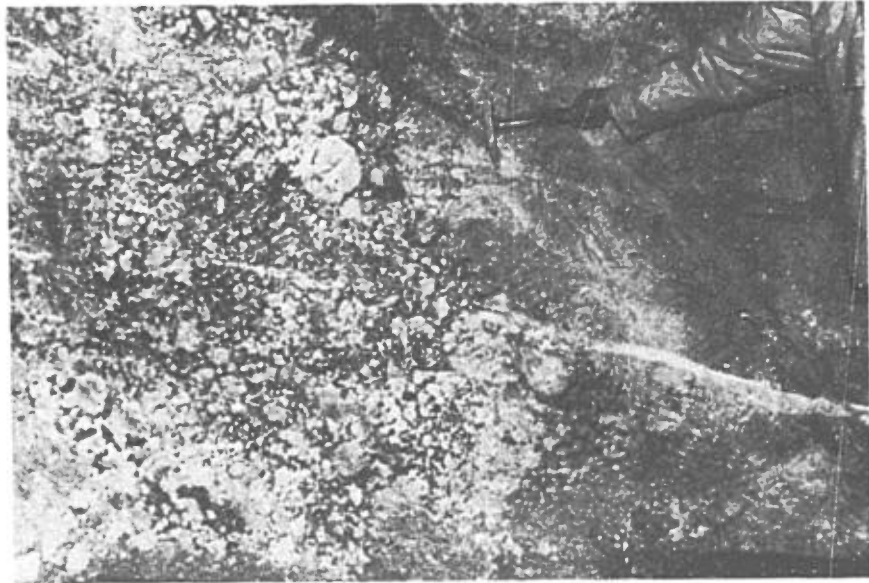
Fig. 44. Layering in gabbroic meta-anorthosite (AZ).
Bottom layer is very coarse-grained and more gabbroic than the
top layer. Plane of layering dips to the right of the
photo. Underground in drift between Jaculet and Bateman shafts.

Fig. 45. Layering in gabbroic meta-anorthosite (AZ).
Note the very thin layer under the head of the hammer.
(top) Underground in drift between Jaculet and Bateman shafts.
Bottom: underground in drift at Cedar Bay, 20-level.
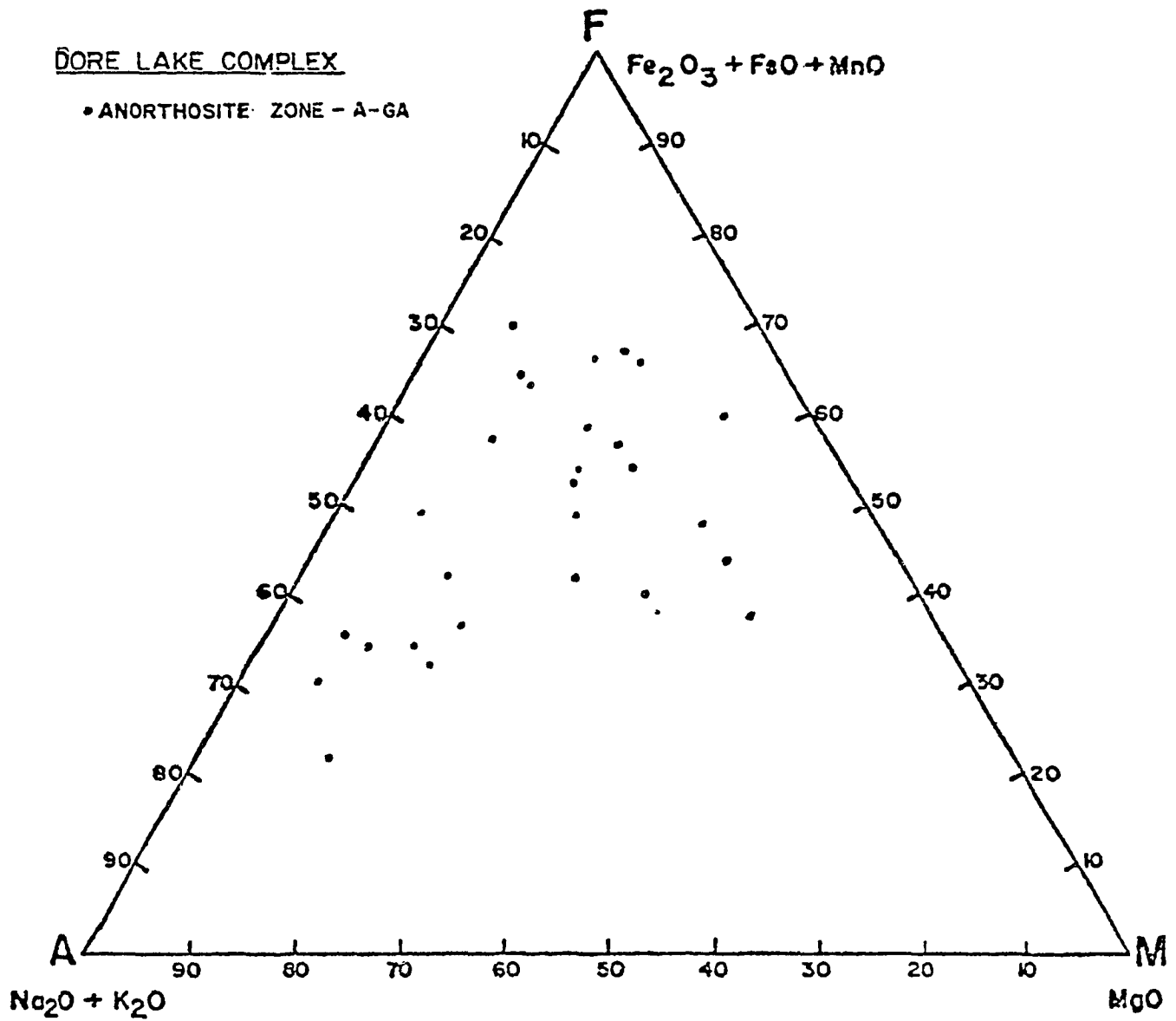
Fig. 46. AFM diagram of samples from the Anorthosite Zone of the Dore Lake Complex (wt %).

and chlorite along the walls of the orebodies. Moritz (1975) has shown that the white mica is essentially paragonite in barren shear zones and muscovite in the vicinity of ore deposits. The rock maintains the very coarse cumulus texture of the original anorthosite even when the mineral substitution is nearly complete. The shearing produces an irregular foliation wrapping around the large tan-colored cumulus plagioclase grains producing pseudo-augens of sericitized and carbonatized plagioclase in a chloritic matrix. The foliation becomes better developed closer to the orebody and the original texture eventually loses its characteristics. Dikes vary in composition from "greenstones" (metadiabase) to quartz feldspar porphyry (sodarhyolite) and occur within the shears in all states of deformation and alteration, from unaltered dikes with sharp chilled contacts to sheared, mineralized, and altered dikes unrecognizable from the enclosing schists.

Some orebodies in the upper part of the AZ and lower part of the LZ contain siderite and chloritoid instead of the common chlorite-calcite assemblage found in the iron-poor meta-anorthosite of the lower part of the complex. This suggests that the mineralizing solutions brought in CO_2, H_2O, K_2O, S, etc., but borrowed the Fe, Al, Na, from the enclosing rocks. Some geologists (Vollo, 1959) would get the Cu from the same source. We prefer to associate the copper with the hydrothermal solutions which caused the alteration and brought in large quantities of CO_2, H_2O, and CO_2.

LAYERED ZONE

The Layered Zone (LZ) takes its name from the spectacular layering displayed on the south limb in Rinfret and Lemoine Township (Figs. 47 to 52). It is also well exposed in the area of Cache Lake on the north limb (Plate 1). It contains hundreds of millions of tons of low grade titaniferous vanadiferous magnetite (Allard, 1967; Allard and Assad, 1968; Kish, 1971; Avramtchev, 1975). Allard (1967), Allard and Caty (1969), and Caty (1970) established in Rinfret and

Lemoine Township a detailed stratigraphy of the LZ (Table 31 and 37). Facies changes take place in both NE-SW and NW-SE direction across the complex and will be discussed later. The economic importance of these facies changes is evident since it affects the ratios of Fe/Ti/V in the magnetites.

Mawdsley and Norman (1935) did not map the south limb. Two reconnaissance traverses were done but no mention was made of the magnetitites. An airborne magnetometer survey by Dominion Gulf Company in 1953 followed by preliminary surface work revealed the presence of a thick LZ exposed over a strike length of 15 miles (24 kms). Jalore Mining Company, a subsidiary of Jones and Laughlin Steel Company, drilled six holes in 1958 in Rinfret Township across the bottom of the LZ and abandoned its exploration efforts because of the high tenor in TiO_2 in magnetite. Using the Bushveld Complex as a model (Willemse, 1969) Allard postulated the possibility of vanadium in the magnetitites. Analyses of a number of samples confirmed the presence of vanadium in commercial quantities in the magnetitites. The main part of the zone was staked by the Q.D.N.R. in 1966. Additional geological and geophysical work and diamond drilling have been done and the results embodied in reports by Kish (1971), Avramchev (1975), Astier et al., (1970). The summary of their work can be found in Tables 106 to 118 and Figures 149 to 160 in Chapter 9.

On the north limb of the Chibougamau anticline (Fig. 53), Grand Chibougamau Mines Ltd. drilled seven holes on the high hill south of Cache Bay in 1952. Chibougamau Mining and Smelting drilled eight holes in 1956 on the southern extension of the same zone east of Cache Lake.

The stratigraphic equivalent of the LZ appears on the north side of Portage Island and is repeated by faulting on the south of Portage Island, just north of Portage Lake. It was drilled by Portage Island Mines Ltd. in 1958. Sorcerer Mountain, one of the boldest ridges in the Chibougamau area, east of Portage Island, is underlain by the magnetite-rich layer at the top of the Dore Lake Complex. The Magnetite Bay zone, south of the bay of the same name and of

the Sorcerer Mountain zone, is similar in lithology and composition. Both belong to Campbell Chibougamau Mines Ltd. who has done 41,380 feet (12,414 m.) of drilling and reports 270 million tons averaging 27.6% Fe and 1.1% TiO_2. At the time of writing the Q.D.N.R. is pursuing metallurgical research and feasibility studies on the south limb deposit and Campbell Chibougamau Mines Ltd. is looking for financial partners in order to develop their property. Details on the analyses of the ore and metallurgical tests will be found in a separate section in Chapter 9.

Studies of the LZ have been done by Graham when he mapped the north half of Obalski Township (1956), De Montigny (1960) in his mapping of the southwest portion of Lemoine Township, Caty (1970) who did a M.S. thesis on the Lemoine-Rinfret LZ, Dorr (1969) who studied the Sorcerer Mountain-Magnetite Bay zones, and Gaucher (1960) who studied the paleomagnetism of the Sorcerer Mountain zone.

Graham (1956, p. 21) said:

"The essentially disseminated rather than vein-like nature of the magnetite, its concentration at the base of the gabbro and the gradually decreasing magnetite content away from the base of the gabbro suggest that the magnetite formation is a product of differentiation in situ within the gabbro."

De Montign y (1960, p. 9) on the other hand believes that:

"the magnetite was emplaced in these rocks after their intrusion."

His conclusion was based on the presence of veinlets of magnetite cutting across the schistosity of the gabbro.

The LZ rich in Fe, Ti P_2O_5 and V_2O_5, is in the normal position within layered complexes (Fig. 30) i.e., in the upper portions of the complex above a thick zone of anorthosite and gabbro and below a thin zone of granophyre.

In the present report, the LZ is divided into two parts: (a) the LZ proper found all along the south limb and in the western part of the north limb; (b) the stratigraphic equivalent found on Portage Island, Sorcerer Mountain, and at Magnetite Bay.

Layered Zone Proper

The Layered Zone proper occurs along the southern limb of the Chibougamau anticline from the Grenville Front to the northeast corner of Queylus Township where it is cut off by the Chibougamau pluton, a distance of 17 miles (27 kms). It also occurs along a seven-mile N-NE segment east of Cache Lake, west of Cache Bay and northward as far as the edge of the Dore Lake Complex against the volcanics south of Gilman Lake, and around the nose of a cross fold at David Lake (Plate 1). The thickness of the zone and its magnetite content decreases markedly going westward on both limbs.

The thickness of the LZ is quite variable and very difficult to define accurately, since it is intensely faulted. In the best studied area in Rinfret and Lemoine Township, it varies between 1500 and 3300 feet (450 m. to 990 m.). Table 31 shows the proposed stratigraphic subdivisions arrived at by Allard and Caty (1969) in the south and Baskin (1975) in the northern zone. The zone is subdivided into members. The lack of detailed information and drilling across the P_3 member does not allow as complete a breakdown of this horizon as for the others where abundant outcrop information has been supplemented by drilling. The nomenclature uses simple letters "P" for metapyroxenite and "A" for gabbroic anorthosite.

P_1 Member

The lowermost member of the Layered Zone is the P_1 member. It varies between 100 and 300 feet (30-90 kms) in Rinfret Township gradually thinning westward. It is best exposed on a large hill in Rinfret Township about 3000 feet (900 m.) east of the Rinfret-Lemoine Township line. Caty (1970) subdivided the P_1 member in a low-grade and a high-grade submember (grade refers here to the abundance of titaniferous vanadiferous magnetite). This member displays all the features expected in a magmatic sediment (Wadsworth, 1973): cross lamination, slump folds, graded bedding, load cast, blocks, trough bending,

etc. The major characteristic is the spectacular inch-scale layering (Figs. 49 and 50). The main rock types are metaferrogabbro, metaferropyroxenite, and metamagnetitite. The lower contact of the Layered Zone is very sharp. The upper part of the AZ gradually becomes more gabbroic and contains some disseminated titaniferous magnetite. A few thin layers of magnetitite and magnetite-rich gabbro can be observed in the topmost portion of the AZ. Within a couple of inches (cms) the coarse anorthositic gabbro gives way to much finer-grained well-laminated and well-layered rocks of the LZ (Figs. 49 and 50). Table 37 gives the major subdivisions of the LZ. An attempt was made to measure the number of layers within P_1 in Rinfret Township along a trench with near-continuous exposures. A total of 289 layers was identified and many of them could be further subdivided into fractions. The upper contact of the P_1 member is a layer of gabbroic meta-anorthosite containing no magnetite. Tables 38 and 39 give the chemical analyses of large bulk samples (four tons from blasted trenches) from the P_1 member in Rinfret Township. Table 40 gives the assays of many samples in drill hole no. 12 (Q.D.N.R.) and a complete chemical analysis of a composite sample from the same samples assayed for Fe, TiO_2, and V_2O_5. One can see the similarity between these chemical analyses which represent a good average of the P_1 member. The contacts between layers can be sharp on both sides, sharp on either the upper or lower side, gradational on either the upper or lower side, and sharp on one side but gradational on the other. Where both contacts are gradational, it is common to find in the center of a layer an horizon rich in magnetite. A strong magmatic foliation (also called igneous lamination) due to the alignment of original plagioclase and/or pyroxene parallels the layering (Fig. 54). The textures of the rocks are spectacularly displayed on smooth glaciated surfaces where the moss has been peeled off: the magnetite and amphibole stand out in relief above the epidotized plagioclase and chlorite. The identification of the cumulus vs the

intercumulus phases is rendered very easy on such etched polished surfaces.

The gabbroic layers have a distinct yellowish white to greenish white rough

weathered surface while the pyroxenitic layers have a very smooth surface

varying from dark green to pale green.

Mineralogy

The primary cumulate phases were calcic plagioclase, titaniferous magnetite,

ortho- and clinoferropyroxene. The labradorite laths are pseudomorphed by minor

albite and aggregates of epidote/clinozoisite (Fig. 54). The pyroxenes are

pseudomorphed by actinolite, ferrochlorite, ferrohastingsite, and other iron-

rich amphiboles (Fig. 53). The magnetite has been little affected by regional

metamorphism (Figs. 57 and 58). A border of small grains of sphene is commonly

observed around magnetite grains in rocks rich in plagioclase and poor in

magnetite. In other rocks, small fractures filled with chlorite can be noted

across magnetite grains. Actinolite and related species of amphibole replace

the primary pyroxenes. The actinolite can be an exact pseudomorph of the

original grain but can also be found as small needles growing at grain

boundaries and projecting into other minerals, especially chlorite. The

actinolite has a 2V of $\pm$ 80° and the following pleochroic formula: N_z = bluish

green, N_y = pale green, N_x = pale green to colorless. Chlorite replaces a

primary cumulus and more commonly intercumulus pyroxene. It is very pleochroic

and dark green with the following pleochroic formula: N_z = pale yellow, N_x =

N_y = deep green. The interference colors are tints of purplish blue. The

chlorite is length slow. The exact chemistry of the chlorites and amphiboles

has not yet been determined.

Accessory metamorphic calcite, leucoxene (sphene), sericite, and scapolite

have been identified in many thin sections.

Caty (1970) developed a detailed classification scheme for these rocks.

It is reproduced in Table 32. Table 41 gives a summary of estimated visual

modes.

Fe-TiO$_2$-V$_2$O$_5$ in the P$_1$ member

The importance of the P$_1$ member lies in its vanadium and iron content. A strong cryptic layering is superimposed on the inch-scale layering mentioned above. Hundreds of samples have been analysed over the years and a great deal of information is summarized in Chapter 9 under iron-titanium-vanadium deposits. In general, samples have been analysed for total Fe and TiO$_2$. A portion of the sample is then ground to -200 mesh and passed through the Davis Tube in order to produce a magnetic concentrate. Analyses are made on the magnetic concentrates for Fe, TiO$_2$, V$_2$O$_5$ and P$_2$O$_5$. The weight % of magnetic concentrate is also recorded. The degree of grinding is very important in comparing between samples, as evidenced by the difference in TiO$_2$ and V$_2$O$_5$ of concentrates analyses (Tables 110 and 111) using a -200 mesh grind as opposed to a grind of -325 mesh. The finer grinding liberate many individual grains of ilmenite and cleans many grains of magnetite of the silicate inclusions which explains why the TiO$_2$, MgO, Al$_2$O$_3$, etc. of the concentrate drops markedly when one uses a finer grind. This is more evident on the Sorcerer Mountain ore which is serpentine-rich.

The major effects of the cryptic layering of the P$_1$ member is the gradual decrease in V$_2$O$_5$ in the magnetite from the base to the top and the concomitant increase in TiO$_2$. This is especially striking in Figures 149 to 160 and in Tables 112 and 114. The trend and magnitude of changes is very similar to those observed in the Bushveld by Willemse (1969) in the Main Magnetite Seam. Figure 61 is a reproduction from Willemse (1969) and Molyveux (1970).

A$_1$ Member

The A$_1$ member separates the P$_1$ and P$_2$ members of the LZ. It varies from 20 to 150 feet (6 to 45 m.) in thickness. It consists of a very coarse-grained gabbroic meta-anorthosite and anorthositic metagabbro. It contains a very small quantity of iron oxides. A crude layering can be observed in a few places.

Good blastopoikilitic texture was observed along the IGC traverse in Lemoine

Township (Figs. 59 and 60). The A_1 member consists in cumulate calcic plagio-

clase, up to one cm in diameter, replaced by albite and epidote and intercumulus

pyroxene replaced by antinolite and/or chlorite. Minor accessories are

titaniferous magnetite, leucoxene, sphene, calcite, sericite, and scapolite.

Thin magnetite and pyroxene cumulates displaying inch-scale layering indicate

the top of A_1 and the bottom of the P_2 member. Table 42 gives two chemical

analyses of A_1 and Table 43 gives modal analyses. Analysis in Table 44

represents a length of 12.4 feet (3.7 m.) of split core in Q.D.N.R. hole no. 12

in Rinfret Township. This analysis gives a better average of the A_1 member

since the other samples were punctual samples.

P_2 Member

The P_2 member is very similar in all respects to the P_1 member except for

its tenor in vanadium, titanium, and iron. It displays spectacular inch-scale

layering (Figs. 47 and 48) and sedimentary features. The lower surface is

moulded on the irregular upper surface of the A_1 member. Thin beds of

magnetitite, magnetite-rich metagabbro and metapyroxenite fill in the irregular

surface and give way to regular and continuous thin layers (Fig. 106). The

thickness of the member varies between 30 and 200 feet (9 and 60 m.). The

rocks show a pronounced primary foliation. In the lowest part of the P_2

member, metagabbro, anorthositic metagabbro, and magnetite metacumulate are

predominant. In the upper part, metapyroxenite and magnetite metacumulate are

the most common rock types.

The main minerals are actinolite, ferroactinolite, chlorite, titaniferous

magnetite, ilmenite, minor albite, and epidote. The actinolite-ferroactinolite

is a very dark green pleochroic species evidently rich in Fe but not studied

in detail with the microprobe at the present. Actinolite replaces a primary

cumulus pyroxene. Chlorite is the most common silicate phase in P_2. It

replaces the intercumulus ferropyroxene. The extreme pleochroism indicates a high Fe content but no quantitative data are available. Albite and epidote pseudomorph the original laths of calcic plagioclase and are especially abundant in the lower portion of P_2. Leucoxene (sphene) grains around titaniferous magnetite and ilmenite grains are common in rocks with sufficient CaO and SiO_2 to react with the available TiO_2. Table 46 shows 4 analyses of P_2 rocks and Table 45 gives modal analyses of P_2 rocks taken from Caty (1970).

$Fe-TiO_2-V_2O_5$ in P_2

The magnetite content of the P_2 member is sufficient to warrant detailed investigation of its Fe, Ti, and V content. The vanadium content is considerably lower than the P_1 member and for this reason very few drill holes are available across the entire P_2 member. The data from Jalore hole no. 2 is taken from Caty (1970) and reproduced in Figure 149 and in Table 114. Similar data can be seen in Tables 115 and 116 and in Figure 153 from Jalore hole no. 3. The general trend in the distribution of Fe-Ti-V values is a continuation of the trend established previously for the P_1 member, i.e., a general decrease in V_2O_5 and a concomitant increase in TiO_2. The figures from Caty for Jalore hole no. 2 are punctual analyses and differ from continuous samples but the trend is clearly evident in both cases.

Further metallurgical research on the recovery of $Fe-TiO_2-V$ will determine whether P_2 can be considered ore.

A_2 Member

The rocks of this member are coarse gabbroic meta-anorthosite and anorthositic metagabbro nearly identical to the rocks of the A_1 member except for a minor quartz content. The upper and lower contacts are sharp and undulating (Fig. 63). The rocks consists in cumulus plagioclase, up to one centimeter in diameter, altered to albite and epidote-clinozoisite, actinolite replacing the original

pyroxene which is intercumulus in the anorthositic rocks and cumulus in the gabbroic phases, and chlorite which pseudomorphs the intercumulus pyroxene. Chlorite predominates as a mafic mineral in the anorthositic rocks. Quartz grains form distinct intercumulus patches but the distribution is very spotty and many outcrops do not show appreciable quartz on first inspection. The thickness of the A_2 member varies from a few feet to 1500 feet (m. to 450 m.) but the lack of outcrops in critical areas and the evident repetition due to faulting make it impossible to obtain a good measure of the true thickness.

Two analyses of typical A_2 rocks are on Table 42 and Table 49 gives a series of modal analyses taken from Caty (1970, p. 51).

P_3 Member

The P_3 member is the topmost member of the Layered Zone and is much thicker than either P_1 or P_2 varying between 600 and 1200 feet (180-360 m.). The major rock type is a dark green metaferropyroxenite and interlayered thin bands of metaferrogabbro. The rocks are finer grained in general than in the other members, at the exception of lenses of coarse gabbroic meta-anorthosite observed at the base of the P_3 member along the IGC traverse.

A faint primary foliation is commonly noticed but is not as clearly displayed as in the P_1-P_2 members. The P_3 member contains much ferrochlorites and is much more prone to shearing than the other more brittle metagabbroic units.

The rocks throughout the P_3 member show the effect of rhythmic and cryptic layering (Figs. 51 and 52). The iron content of the rocks is very high but is located mostly in the silicate phases. The information available on this member is rather meagre since no drill holes have cut this unit. Tables 50 to 54 give chemical and modal analyses of P_3 rocks.

A four-fold subdivision of P_3 can be established:

(top) — quartz-rich metaferropyroxenite

apatite-rich metaferropyroxenite

ilmenite and ferrosilicate rich metaferropyroxenite

magnetite-bearing metaferropyroxenite

An interesting feature is the number of outcrops showing auto-injection and brecciation due to the intrusion of the granophyre liquid magma into the rocks already crystallized but still hot and plastic of the subjacent P_3 member (Fig. 65).

Magnetite-bearing submember

The magnetite-bearing submember appears at the base of P_3 and varies from a few feet to a maximum of 100 feet (30 m.) in thickness. The rock is finely layered and resembles P_1 and P_2 but the layering is on a finer scale, the grain size is finer, and the magnetite content is rather low. Moreover, the TiO_2 content of the magnetic concentrate is much increased and the V_2O_5 content greatly reduced, as one would predict from comparisons made with other layered complexes.

Ilmenite-bearing submember

This submember consists of metaferropyroxenite with variable amounts of ilmenite. Since ilmenite is present throughout the P_3 member, the use of such nomenclature is not the most correct but it helps in field investigations of this horizon to have the submembers listed as above. The thickness varies between 200 and 800 feet (60 to 240 m.). The most common rock is a dark green to greenish black metaferropyroxenite and thin layers of melanocratic metaferrogabbro. The layering is excellent (Figs. 51 and 52) and very regular. Blocky structures so common in the AZ and LZ is practically unknown in this member. The ilmenite content varies between 10 and 20%.

Apatite-bearing submember

The apatite-bearing submember differs little from the adjacent rocks except for the presence of 10-20% euhedral to subhedral small crystals of glassy apatite with a milky whitish tan weathered surface (Fig. 64). This submember varies between 200 and 800 feet (60 to 240 m.) in thickness. The apatite does not reach sufficient concentration to make this rock commercially interesting for its phosphate content. A partial analysis was published by Allard and Caty (1969) and gave 2.80% P_2O_5 for a sample very rich in apatite.

Quartz-bearing submember

The upper part of P_3 is marked by a rapid increase in the quantity of quartz present. It is 25-200 feet (7.5-60 m.) in thickness. Quartz has first appeared in small quantity in the A_2 member below P_3 and reappears in large quantities in the upper part of P_3. Excellent layering was observed close to the top of P_3 a short distance from the Five-Mile Lake road (Fig. 85). Within this submember, a poorly known stilpnomelane-rich horizon has been identified on both limbs of the anticline. The gradation between this submember and the Sodagranophrye Zone varies from the sharp contact observed on the Five-Mile Lake road to the more gradational transition from ferropyroxenite to quartz gabbro to gabbroic granophyre and finally to leucosodagranophyre observed on the IGC traverse.

Mineralogy of P_3

The ferropyroxenite and ferrogabbro of the P_3 member were made up of ortho- and clinoferropyroxenes, fayalite (?), ilmenite, apatite, and minor plagioclase. These primary minerals have been replaced by a variety of amphiboles (actinolite, ferroactinolite, ferrohastingsite (Baskin and Allard, 1974), cummingtonite (?)); ferrochlorite, ferroepidote, and minor albite, sphene, and stilpnomelane. The apatite and minor zircons have not been affected by

metamorphism. Ilmenite may remain intact or show a halo of small grains of sphene. Color zoning of amphiboles is common (Fig. 56). Much microprobe work on the minerals of P_3 remains to be done. The extremely high iron content of the original silicate phases has given rise to an unusual assemblage of metamorphic minerals, commonly found in metamorphosed iron formation (Gunderson et al., 1962; Morey et al., 1972).

Baskin (1975) and Baskin and Allard (1974) discovered ferrohastingsite in the rocks of the NP_2 and NP_3 members. It was identified in many thin sections from both limbs. Most observers have previously called it hornblende or riebeckite because of the bluish green tint. It is described in a separate chapter on mineralogy.

Baskin (1975) also identified grunerite from one sample (B 70-127, p. 34) of metaferropyroxenite. The texture suggests that the Fe-rich olivine has been replaced by grunerite and magnetite.

Sorcer Mountain-Magnetite Bay magnetite-rich metaferrodunites

The magnetite-rich rocks of the Layered Zone found on the south limb and on the western part of the north limb give place to an unlayered or very poorly layered magnetite-rich metaferrodunite, metaferropyroxenite, and metaferro-peridotite. The facies changes taking place within this horizon has important commercial applications since the magnetite contains much less TiO_2 and lesser amounts of V_2O_5. The Sorcerer Mountain and Magnetite Bay deposits (Fig. 66) belong to Campbell Chibougamau Mines Ltd. who has done extensive drilling on the zones and given us much of the necessary data for this report. The company reports (1975) 270,000,000 tons of ore averaging 27.6% Fe and 1.1% TiO_2. Grinding tests to -325 mesh produce a concentrate averaging 66.3% Fe, 1.2% TiO_2.

Tables 124 to 128 summarize the data obtained by Campbell Chibougamau and by Dorr (1969) on these two zones.

Large quantities of serpentine as opposed to the chlorites and amphiboles found on the south limb constitute the main petrographic differences. The rocks are anomalous in that they contain large quantities of Mg which one would expect in a lower ultramafic zone and the high $Fe-FiO_2-V$ that one finds in the upper part of complexes (Fig. 30).

The magnetite-bearing rocks are underlain by gabbroic anorthosite of the AZ. Dorr (1969) reports 3 analyses from this horizon (Table 56). We note that the calculated normative An content of the plagioclase varies between 97 and 75 which is higher than one would find at the same stratigraphic level on the south side. An interesting observation is that the total Fe + Ti + V content reported by C.C.M. from Sorcerer and Magnetite-Bay is roughly the same as that reported by the Q.D.N.R. in Rinfret and Lemoine Township. However, the TiO_2 and V content in Rinfret-Lemoine is much higher than that of the north limb.

Metapyroxenite with variable quantities of magnetite is a major rock unit within this zone. The rock weathers to a brownish red to grey color depending on the iron content. The rock is made up of tremolite-actinolite and/or chlorite replacing the original pyroxene and variable amounts of serpentine replacing the primary olivine. Table 57 gives chemical analyses of metaferro-pyroxenites and metaferrodunites from the Magnetite Bay zone. Large amphibole rosettes and clusters are common (Fig. 68). Dorr (1969) reports that they reach 18 inches (54 cms) in length but usually range from one to 6 cms. Titaniferous magnetite and ilmenite occur in clots of small irregular intercumulus blotches (Figs. 67, 69, and 70).

Magnetite-rich metaferrodunite forms the main part of the Sorcerer Mountain zone. The rock is typically a fine-grained black to dark green rock weathering to a greyish white surface showing the typical mesh texture with cumulate olivine and "intercumulate" magnetite (Figs. 69 and 70). Asbestos veinlets are common in the metadunite. The magnetite content varies from 20 to

MEMBERS	SUB-MEMBERS	UNITS	MEMBRES	SOUS-MEMBRES	UNITES
METAPYROXENITE III (500'-1400')	quartz apatite	Metapyroxenite, metagabbro Metapyroxenite Melametagabbro	METAPYROXENITE III (500'-1400')	quartz apatite	Métapyroxénite, métagabbro Métapyroxénite Métagabbro mélanocrate
	magnetite	Metapyroxenite Melametagabbro		magnétite	Métapyroxénite Métagabbro mélanocrate
	ilmenite	Metapyroxenite		ilménite	Métapyroxénite
META-ANORTHOSITE II (1000'-1400')		Anorthositic metagabbro (AG) Gabbroic meta-anorthosite (GA) more or less quartz	META-ANORTHOSITE II		Métagabbro anorthositique (GA) Méta-anorthosite gabbroique (AG) plus ou moins de quartz
METAPYROXENITE II (30'-75')	ilmenite	Metagabbro, metapyroxenite Plagioclase and magnetite metacumulate	METAPYROXENITE II (30'-75')	ilménite	Métagabbro, métapyroxénite Métacumulites à plagioclase et magnétite
	magnetite	Metagabbro, metapyroxenite Plagioclase and magnetite metacumulate		magnétite	Métagabbro, métapyroxénite Métacumulites à plagioclase et magnétite
META-ANORTHOSITE I (20'-150')		Metagabbro Anorthositic metagabbro (AG) Gabbroic meta-anorthosite (GA)	META-ANORTHOSITE I		Métagabbro Métagabbro anorthositique (GA) Méta-anorthosite gabbroique (AG)
METAPYROXENITE I (100'-200')	high grade in Fe+Ti	Magnetite metacumulate Magnetite and plagioclase metacumulate Fe-Ti oxide rich metapyroxenite Fe-Ti oxide rich metagabbro Fe-Ti oxide rich meta-anorthosite	METAPYROXENITE I	haute teneur Fe-Ti	Métacumulites à magnétite Métacumulites à magnétite et plagioclase Métapyroxénite à oxydes de Fe-Ti Métagabbro à oxydes de Fe-Ti Méta-anorthosite à oxydes de Fe-Ti
	low grade in Fe+Ti	Metagabbro with Fe-Ti oxides Anorthositic metagabbro Meta-anorthosite Metapyroxenite Magnetite metacumulate Plagioclase and magnetite metacumulate		basse teneur Fe-Ti	Métagabbro plus oxydes Métagabbro anorthositique Méta-anorthosite Métapyroxénite Métacumulites à magnétite Métacumulites à magnétite et plagioclase

Table 37. SUBDIVISIONS OF THE LAYERED ZONE (LEMOINE & RINFRET TOWNSHIPS))FROM TABLE 6 IN CATY,1970) SOUS-DIVISIONS DE LA ZONE RUBANEE (CANTONS LEMOINE & RINFRET) (ADAPTE DU TABLEAU NO. 6 DE CATY, 1970).

TABLE 38

Chemical Analyses of 5 bulk samples of magnetitites from Rinfret twp. (IRSID)
Analyses chimiques de 5 échantillons de magnétitites du canton Rinfret (IRSID)

	I(line 0)	II(line 22E)	III(line 43E)	IV(line 29E)	V(line 11E)
S_1O_2	17.4	17.6	12.6	13.8	12.2
TiO_2	9.9	10.6	12.7	12.0	13.9
Al_2O_3	10.5	10.4	8.9	9.3	8.6
Fe Total	37.7	36.7	41.1	40.5	40.4
Fe^{++}	17.7	18.1	20.6	20.1	20.8
Mn	0.19	0.20	0.313	0.189	0.241
MgO	3.0	3.5	2.6	2.7	2.9
CaO	4.4	3.8	2.7	3.1	2.65
Na_2O	0.63	0.68	0.42	0.52	0.44
K_2O	0.12	0.11	0.04	0.05	0.04
H_2O	2.94	3.12	2.73	2.74	3.15
CO_2	0.15	0.18	0.31	0.14	0.15
S	0.08	0.17	0.19	0.17	0.26
P	0.033	0.029	0.011	0.016	0.016
V_2O_5	0.75	0.70	0.71	0.71	0.52
* Pb	0.018	0.014	0.020	0.021	0.021
* Zn	0.030	0.032	0.048	0.032	0.038
* Cu	0.010	0.005	0.005	0.005	0.007
* Cr	0.054	0.049	0.043	0.037	0.024
Forrer Index	30.2	29.6	34.1	35.1	30.35

* semiquantitative analyses
  Forrer index = ratio of magnetization of sample compared to a standard sample
  (single crystal of pure magnetite from Sweden)
  Indice Forrer = rapport des aiman tations à saturation de l'échantillon à un
  étalon (monocristal de magnétite pure suédoise)
  Adapted from Gerbe et al - 1970 (Table 15 + 16)
  Adapté de Gerbe et al - 1970 - (Tableau 15 et 16)

TABLE 39

Chemical analyses of mill fractions on 4 bulk samples of magnetitite (P1) from Rinfret twp.   IRSID

Analyses chimiques des produits de traitement de 4 échantillons du canton Rinfret IRSID

Wt. %	Feed alimentation		Magnetic concentrate Concentré magnétique		Ilmenite concentrate Concentré d'ilménite		Middlings Fins à retraiter		Tailings Stériles	
	max	min	max	min	max	min	max	min	max	min
SiO2	17.6	12.6	2.35	1.9	4.3	2.7	29.7	24.3	35.1	31.0
TiO2	12.7	9.9	12.4	9.5	43.5	39.8	9.5	6.6	4.0	2.9
Al2O3	10.5	8.9	2.55	1.9	3.2	2.0	18.1	17.2	20.8	18.6
Fe Total	41.1	38.7	61.4	58.8	35.2	34.2	23.2	20.9	18.5	16.1
Fe ++	20.6	17.7	25.7	24.2	24.2	17.8	18.5	15.2	13.9	11.3
Mn	0.313	0.189	0.272	0.158	0.900	0.585	0.303	0.187	0.20	0.12
MgO	3.5	2.6	0.9	0.7	0.75	0.5	6.4	5.25	5.2	4.65
CaO	4.4	2.7	0.3	0.2	1.6	0.8	6.5	5.25	10.0	8.2
Na2O	0.68	0.42	0.14	0.08	0.15	0.09	1.05	0.68	1.39	1.12
K2O	0.12	0.04	0.02	0.01	0.02	0.01	0.11	0.06	0.17	0.09
H2O	3.12	2.74	1.15	0.99	0.98	0.71	5.71	5.38	4.96	4.18
Cu2	0.31	0.14	0.07	0.03	0.05	0.02	0.53	0.27	0.47	0.15
S	0.19	0.08	0.08	0.03	1.01	0.51	0.28	0.13	0.17	0.06
P	0.033	0.011	0.015	0.01	0.02	0.019	0.032	0.022	0.03	0.019
V2O5	0.75	0.70	1.39	1.16	0.32	0.285	0.27	0.20	0.21	0.16
Pb	0.021	0.014	0.012	0.007	0.013	0.009	0.052	0.031	0.031	0.015
Zn	0.048	0.030	0.041	0.02	0.023	0.015	0.070	0.036	0.039	0.027
Cu	0.010	0.005	0.002	0.001	0.010	0.004	0.012	0.011	0.009	0.005
Cr	0.054	0.037	0.081	0.047	0.014	0.011	0.023	0.014	0.015	0.013
Torrer Index	35.1	29.6	71.3	64.6	4.45	3.1	1.6	1.2	1.85	1.1
Recovery % Fe	100.0	100.0	74.5	66.0	7.6	6.6	16.9	12.5	10.0	6.4
% TiO2	100.0	100.0	51.7	39.5	34.4	26.2	20.3	18.1	6.8	4.0
% V	100.0	100.0	86.9	78.3	3377	3.2	11.2	6.2	7.0	3.6

adapted from Gerbe et al - 1970 - Tableau 19
adapté de Gerbe et al - 1970 - Tableau 19
(Samples are no. I-II-III and IV of table 38
Echantillon no. I, II III, et IV du tableau.

Table 4U

CHEMICAL ANALYSES OF P_1 MEMBER (LZ) - RINFRET TOWNSHIP - HOLE NO. 12 Q.D.N.R.

Analyses chimiques du membre P_1 (ZL) - Canton Rinfret - Trou No. 12 Q.D.N.R.

Interval	length (feet)	Fe	TiO_2	V_2O_5	% wt.	Fe	TiO_2	V_2O_5	Chemical analysis of the composite of all the samples analyse on the left.	
									Analysis of the magnetic concentrate	
20.2 - 25.2	5.0	39.3	14.1	0.51	40.20	60.0	13.5	0.99		
25.2 - 33.0	7.8	46.4	16.3	0.65	54.47	61.6	13.3	1.02		
33.0 - 37.6	4.6	24.0	7.2	0.29	14.07	61.2	9.7	1.09	SiO_2	15.30
48.4 - 53.7	5.3	45.6	16.3	0.70	56.53	59.6	14.6	1.06	TiO_2	11.70
75.6 - 85.6	10	47.4	16.6	0.79	60.80	60.2	14.5	1.14	Al_2O_3	9.89
85.6 - 95.6	10	44.9	14.9	0.71	54.07	59.7	14.5	1.17	Fe_2O_3	24.30
95.6 - 103	7.4	41.4	13.7	0.69	45.77	60.2	13.2	1.21	FeO	28.05
103 - 113	10	38.1	11.4	0.61	40.20	60.3	12.8	1.18	MgO	2.32
113 - 123	10	41.1	13.0	0.79	47.13	60.4	13.0	1.18	CaO	2.83
123 - 133	10	39.1	12.0	0.67	44.73	60.1	12.5	1.21	Na_2O	0.56
133 - 143	10	39.0	11.7	0.66	41.13	61.9	12.1	1.29	K_2O	0.08
143 - 153	10	38.5	11.0	0.68	42.47	61.1	11.7	1.27	H_2O	2.84
153 - 163.2	10.2	39.6	11.3	0.74	45.73	61.6	12.3	1.27	CO_2	0.73
166 - 174.5	8.5	40.7	11.5	0.75	44.93	64.1	9.2	1.40	P_2O_5	0.01
174.5 - 184	9.5	40.7	11.4	0.79	47.33	61.2	11.5	1.34	V_2O_5	0.79
191.3 - 201.3	10.0	41.0	11.3	0.76	48.27	62.5	10.9	1.36	Cr_2O_3	0.08
201.3 - 211	9.7	41.8	11.4	0.87	52.60	61.9	11.6	1.37	NiO	0.02
231.3 - 241.3	10	43.5	11.4	0.85	49.0	62.8	8.6	1.47	As	0.01
241.3 - 251.3	10	39.4	10.1	0.75	40.73	63.7	7.4	1.53	S	0.15
251.3 - 255.5	4.2	38.4	9.7	0.74	37.93	65.3	5.6	1.65	Total	99.66
255.5 - 264.3	8.8	40.8	10.5	0.79	45.27	62.2	8.6	1.47	(data from Richard, 1975)	
271.8 - 276.0	4.2	43.6	10.7	0.86	41.13	68.0	1.9	1.78		
280.0 - 284.2	4.2	31.8	7.5	0.59	24.07	66.4	2.3	1.71		
290.0 - 300.1	10.1	41.0	10.0	0.82	38.27	67.6	2.8	1.75		
305.7 - 312	6.3	35.6	8.6	0.67	31.47	66.7	2.7	1.73		
318.9 - 328.6	9.7	44.8	11.2	0.90	55.33	61.9	10.2	1.45		
weighted average	215.5	40.78	11.87	0.73	45.36	62.1	10.5	1.34		

Avramtchev's weighted average for complete set of analyses

273.5		37.2	10.5	0.66	39.58	63.16	10.7	1.33

(Date from Avramtchev, 1975)

TABLE 41

MODAL ANALYSES OF ROCKS FROM THE P_1 MEMBER (VISUAL ESTIMATE) - D.L.C.

ANALYSES MODALES DES ROCHES DU MEMBRE P_1 (ESTIMATION VISUELLE) - C.L.D.

Rock Type / Type de roches	Magnetite cumulate / Cumulite à magnétite	Plagioclase + magnetite cumulate / Cumulite à plagioclase + magnétite	Plagioclase + magnetite + pyroxene cumulate / Cumulite à plagioclase + magnétite + pyroxène
Magnetite Ilmenite	80 75 60 75 70	20 35 25 25 25 25 35 30 30 30	40 20 30 35
Chlorite	20 15 30 20 30	05 10 10 25 15 20 20 20 15 10	12 25 15 15
Actinolite	10	10 05	03 15 15 03
Albide Epidote	10	65 50 55 45 55 55 45 50 50 60	45 40 40 45
Muscovite		10	

Rock Type / Type de Roches	Magnetite + plagioclase + pyroxene cumulate / Cumulite à plagioclase + magnétite + pyroxène	Meta-anorthosite, metagabbro, anorthositic metagabbro, gabbroic meta-anorthosite / Méta-anorthosite, métagabbro, métagabbro anorthositique, méta-anorthosite gabbroïque
Magnetite Ilmenite	45 70 50	03 10 15 15 10 02 07 05 15 15 07
Chlorite	30 30 15	06 08 20 10 10 10 10 20 20 15 23
Actinolite		35 35 10 20 15 13
Albide Epidote	25 35	90 90 35 40 65 60 80 80 85 65 80 70 70
Muscovite		

From Caty (1970, table 8 to 13

Tiré de Caty (1970), tableaux 8 à 13

TABLE 42

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. MEMBERS A$_1$ A$_2$ - LAYERED ZONE

ANALYSES CHIMIQUES DES ROCHES DES MEMBRES A$_1$ A$_2$ DE LA ZONE RUBANÉE C.L.D.

Sample No. No. d'échantillon	DL-1003	DL-1004	DL-1005	DL-1006
SiO_2	48.68	52.54	49.54	49.35
TiO_2	2.39	1.19	1.71	1.66
Al_2O_3	16.18	22.64	21.92	19.11
Fe_2O_3	3.76	2.97	3.60	3.59
FeO	10.60	3.20	5.00	7.80
MnO	0.21	0.09	0.11	0.17
MgO	4.63	1.05	1.66	2.83
CaO	10.66	10.84	11.62	12.44
Na_2O	2.66	4.23	4.63	2.71
K_2O	0.14	1.20	0.20	0.23
P_2O_5	0.29	0.01	0.01	0.08
H_2O+				
H_2O-				
CO_2				
S				
TOTAL	100.20	99.96	100.00	99.97
Norm wt%				
Qtz	2.06	0.96		2.72
Cor				
Or	0.83	7.09	11.18	1.36
Plag	54.30	75.04	71.06	62.23
Ab	22.51	35.79	32.63	22.93
An	31.79	39.24	38.44	39.30
Ne			3.55	
Wo		1.38	0.05	
Di	15.94	8.70	15.67	18.26
Wo	8.01	4.46	7.94	9.14
En	3.75	2.62	4.13	4.02
Fs	4.17	1.62	3.59	5.10
Hy	16.41			6.86
En	7.78			3.03
Fs	8.63			3.84
Ol Fo				
Fa				
Mt	5.45	4.31	5.22	5.21
Il	4.54	2.26	3.25	3.15
Hm				
Ap	0.69	0.02	0.02	0.19
Py				
Cal				
Data Wt%				
An/plag	58.5	52.3	54.1	63.1
Fa/ol				
En/hy	47.4			44.1
Diff.i.	25.4	43.8	37.4	27.0
Qtz	8.1	2.2		10.1
Ab	88.6	81.6		84.9
Or	3.3	16.2		5.0
An	57.7	47.8	53.2	61.8
Ab	40.8	43.6	45.2	36.1
Or	1.5	8.6	1.6	2.1
A	12.8	42.9	32.0	17.1
F	65.9	48.8	57.0	66.4
M	21.2	8.3	11.0	16.5
Na+K/Al	28.0	36.5	35.7	24.6
Fe+Mn/Fe+Mn+Mg	63.2	76.1	73.8	68.9
Na_2O/Na_2O+K_2O	95.0	77.9	95.8	92.2

TABLE 43

MODAL ANALYSES OF ROCKS FROM THE A_1 Member
(VISUAL ESTIMATE)   LAYERED ZONE   D.L.C.

ANALYSES MODALES DES ROCHES DU MEMBRE A_1
(ESTIMATION VISUELLE)   ZONE RUBANEE   C.D.L.

	J1 134	J1 145	J1 153	J1 157	J2 112	J2 135	C67 159
Opaques		"	30	35	20	55	05
Chlorite		"		15			
	45		20		30	40	50
Actinote		"		50			
Albite Epidote	55	"	50		40	—	45
Séricite	—						
Muscovite		—	—				—
Scapolite			—				
Quartz					—		
Augite					—		
Sphène					—	—	
Leucoxène						—	—
Biotite						—	—
Calcite					—		—

From Caty (1970) table 14, p. 39 .

J-1-134 = anorthositic metagabbro

J-1-153 & J-2-112 = plagioclase and magnetite metacumulate

J-157 = pyroxene and magnetite metacumulate

J-2-135 magnetite and pyroxene metacumulate

C67-159 metagabbro

Table 44

CHEMICAL ANALYSIS OF GABBROIC META-ANORTHOSITE (A_1 MEMBER)
FROM HOLE NO. 12 Q.D.N.R.

ANALYSES CHIMIQUES DE META-ANORTHOSITE GABBROIQUE DU
MEMBER A_1, TROU NO. 12 Q.D.N.R.

SiO_2	46.25	H_2O^+	2.84
TiO_2	0.25	H_2O^-	0.03
Al_2O_3	24.12	CO_2	0.97
Fe_2O_3	4.05	P_2O_5	0.03
FeO	2.85	F_2O_5	0.06
MgO	0.81	Cr_2O_3	0.04
CaO	14.40	NiO	0.01
Na_2O	3.46	As	0.01
K_2O	0.63	S	0.01

Total 100.82

(data from Richard, 1975)

Table 45

MODAL ANALYSES OF ROCKS FROM THE P_2 MEMBER LAYERED ZONE D.L.C. (VISUAL ESTIMATE)

ANALYSES MODALES DES ROCHES DU MEMBRE P_2 (ESTIMATION VISUELLE) ZONE RUBANEE C.D.L.

	Magnetite + pyroxene metacumulate Métacumulite à pyroxène et magnétite		Pyroxene + magnetite metacumulate Métacumulite à pyroxène et magnétite			Anorthositic metagabbro Métagabbro anorthositique
Magnetite + ilmenite	25	65	35	20	20	05
Chlorite	20	25	20	15	20	25
Actinolite	02	10	45	60	50	15
Albite + epidote	05					55
Sphene	40					
Calcite	05					
Garnet					10	
	J-2-18	J-2-103	J-2-38 C67-183		C67-207	J-1-89

traces of sphene, leucoxene, garnet, apatite, calcite, and epidote.

From Caty (1970) table 17, p. 45.

TABLE 46
CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. MEMBER P_2 - LAYERED ZONE

ANALYSES CHIMIQUES DES ROCHES DE MEMBRE P_2 - ZONE RUBANEE C.L.D.

Sample No. No. d'échantillon	DL1031	DL1032	DL1030	DL1013	14-69-16	14-69-18	14-69-19
SiO_2	36.07	28.34	35.91	24.48	48.56	42.08	44.86
TiO_2	5.12	9.50	5.58	10.17	1.25	2.74	0.56
Al_2O_3	8.14	10.92	3.92	8.87	11.79	12.72	9.47
Fe_2O_3	12.28	14.52	18.19	19.64	2.20	4.27	2.61
FeO	20.40	25.50	19.80	27.00	9.85	11.08	11.49
MnO	0.31	0.27	0.24	0.32			
MgO	7.45	3.37	9.44	4.65	6.94	7.28	18.90
CaO	9.22	6.05	6.47	3.92	8.98	11.56	7.07
Na_2O	0.71	0.98	0.34	0.76	2.63	1.17	0.25
K_2O	0.22	0.43	0.02	0.08	0.55	0.19	0.08
P_2O_5	0.07	0.10	0.06	0.11			
H_2O+							
H_2O-							
CO_2							
S							
TOTAL	99.99	99.98	99.97	100.00	92.75	93.09	95.2?
Norm wt%							
Qtz			5.25		0.67		
Cor				0.67			
Or	1.30	2.54	0.12	0.47	3.25	1.12	0.47
Plag	24.38	32.42	11.99	25.16	40.99	38.79	26.60
Ab	6.01	8.29	2.88	6.43	22.25	9.90	2.12
An	18.37	24.13	9.11	18.73	18.74	28.89	24.48
Ne							
Wo							
Di	22.30	4.45	18.33		21.22	23.25	8.52
Wo	11.24	2.19	9.43		10.78	11.88	4.42
En	5.40	0.68	5.80		5.73	6.77	2.96
Fa	5.66	1.59	3.10		4.71	4.59	1.13
Hy	17.00	7.60	27.18	16.73	21.05	17.10	39.03
En	8.30	2.27	17.71	6.74	11.55	10.19	28.22
Fs	8.70	5.32	9.47	9.99	9.50	6.91	10.80
Ol	7.32	13.65		8.93		1.43	15.83
Fo	3.40	3.81		3.39		0.82	11.13
Fa	3.92	9.83		5.54		0.61	4.70
Mt	17.80	21.05	26.37	28.48	3.19	6.19	3.78
Il	9.72	18.04	10.60	19.32	2.37	5.20	1.06
Hm							
Ap	0.17	0.24	0.14	0.26			
Py							
Cal							
Data Wt%							
An/plag	75.4	74.4	76.0	74.4	45.7	74.5	92.1
Fa/ol	53.6	72.1		62.0		42.8	29.7
En/hy	48.8	29.9	65.2	40.3	54.9	59.6	72.3
Diff.i.	7.3	10.8	8.2	6.9	26.2	11.0	2.6
Qtz			63.7		2.6		
Ab	82.2	? 5	34.9	93.2	85.0	89.8	81.7
Or	17.8	?.4	1.4	6.8	12.4	10.2	18.3
An	71.5	69.0	75.3	73.1	42.4	72.4	90.4
Ab	23.4	23.7	23.8	25.1	50.3	24.8	7.8
Or	5.0	7.3	1.0	1.8	7.4	2.8	1.8
A	2.3	3.1	0.8	1.6	14.3	5.7	1.0
F	79.6	89.3	79.5	89.5	54.4	64.0	42.3
M	18.1	7.5	19.7	8.9	31.3	30.3	56.7
Na+K/Al	17.3	19.0	14.8	15.1	41.7	16.7	5.3
Fe+Mn/Fe+Mg	70.5	86.6	68.4	84.4	48.9	53.5	29.1
Na_2O/Na_2O+K_2O	76.3	69.5	94.4	90.5	62.7	86.0	75.7

TABLE 47

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. NP_2

ANALYSES CHIMIQUES DES ROCHES DU MEMBRE NP_2 du C.L.D.

Sample No. No. d'échantillon	B-70-392	B-70-244
SiO_2	44.90	45.00
TiO_2	2.43	3.16
Al_2O_3	9.46	13.54
Fe_2O_3	5.69	4.90
FeO	20.33	17.50
MnO	0.57	0.39
MgO	3.66	2.87
CaO	8.07	9.50
Na_2O	3.83	4.18
K_2O	0.43	0.33
P_2O_5		2.22
H_2O+		
H_2O-		
CO_2		
S		
TOTAL	99.40	103.96
Norm wt%		
Qtz		
Cor		
Or	2.54	1.95
Plag	34.77	50.82
Ab	27.42	33.61
An	7.35	17.21
Ne	2.70	0.95
Ns		
Di	28.13	14.04
Wo	13.67	6.82
En	3.40	1.68
Fs	11.06	5.54
Hy		
En		
Fs		
Ol	18.38	17.76
Fo	4.01	3.83
Fa	14.37	13.93
Mt	6.25	7.10
Il	4.62	6.00
Hm		
Ap		5.26
Py		
Cal		
Data wt%		
An/plag	21.1	33.9
Fa/ol	78.2	78.4
En/hy		
Diff.i.	32.7	36.5
Qtz		
Ab		
Or		
An	19.7	32.6
Ab	73.5	63.7
Or	5.8	3.7
A	12.5	15.1
F	76.7	75.2
M	10.8	9.6
Na+K/Al	71.5	53.4
Fe+Mn/Fe+Mg	80.0	81.3
Na_2O/Na_2O+K_2O	90.0	92.7

Table 48
Notes on samples of Tables 42, 42, 46 and 47

TABLE 42. MEMBERS A_1 AND A_2 OF THE LAYERED ZONE OF THE DORE LAKE COMPLEX

DL-1003 Caty, 1970, p. 209. Anorthositic metagabbro. Lemoine Township. Field sample C67-184. Base of the A_1 member. Visual estimate: 60% plagioclase, 35% chlorite, and 2% opaque.

DL-1004 Caty, 1970, p. 209. Gabbroic meta-anorthosite. Lemoine Township. Field sample C67-AN1. Top of the A_1 member. Visual estimate: 75% plagioclase and 25% chlorite.

DL-1005 Caty, 1970, p. 211. Gabbroic meta-anorthosite. Lemoine Township, Range 6. Field sample C67-AN2. Visual estimate: 80% plagioclase and 20% chlorite, trace opaque.

DL-1006 Caty, 1970, p. 210. Anorthositic metagabbro. Lemoine Township, Range 6. Field sample C67-153. Visual estimate: 65% plagioclase, 20% actinolite, 15% chlorite, trace magnetite and ilmenite.

TABLE 44. A_1 MEMBER FROM DRILL HOLE NO. 12, Q.D.N.R. RINFRET TOWNSHIP VANADIUM ZONE FROM 53.7 TO 66.1 (LENGTH OF 12.4 FEET) (3.7 m)

TABLE 46. MEMBER P_2 OF THE LAYERED ZONE OF THE DORE LAKE COMPLEX

DL-1031 Caty, 1970, p. 209. Melametagabbro. Lemoine Township, Range 6. Base of the P_2 member. Field sample C67-182. Visual estimate: 40% actinolite, 30% plagioclase, 20% chlorite, 10% opaque.

DL-1032 Caty, 1970, p. 209. Pyroxene and magnetite metacumulate. Lemoine Township, Range 6. Field sample C67-183. Visual estimate: 60% actinolite, 20% magnetite and ilmenite, 15% chlorite.

DL-1030 Caty, 1970, p. 210. Pyroxene and magnetite metacumulate. Lemoine Township, Range 6. Field sample: C67-157. Visual estimate: 60% actinolite, 20% magnetite and ilmenite, 15% chlorite.

DL-1013 Caty, 1970, p. 210. Pyroxene and magnetite metacumulate. Lemoine Township, Range 6. Field sample C67-207. Visual estimate: 50% actinolite, 20% magnetite and ilmenite, 20% chlorite, 10% garnet.

14-69-16 Allard, Q.D.N.R. Lab. Scott Township. Millkirk drill cores close to the north shore of David Lake (Allard, 1975).

14-69-18 Allard, Q.D.N.R. Lab. Metagabbro. Scott Township. Millkirk drill cores close to the north shore of David Lake (Allard, 1975).

14-69-19 Allard, Q.D.N.R. Lab. Coarse metapyroxenite. Scott Township. Millkirk drill cores close to the north shore of David Lake (Allard, 1975).

TABLE 47. MEMBER P_2 OF THE LAYERED ZONE OF THE DORE LAKE COMPLEX

B-70-392 Baskin, 1975, anal. 1, p. 123. Pyroxenitic metagabbro. Obalski Township. Nine hundred feet (270 m) south of Cache Bay.

B70-244 Baskin, 1975, anal. 2, p. 124. Metagabbro. Obalski Township. 1800 feet (540 m) south of Cache Bay.

Table 49

MODAL ANALYSES OF ROCKS FROM THE A_2 MEMBER (VISUAL ESTIMATE) LAYERED ZONE D.L.C.

ANALYSES MODALES DES ROCHES DU MEMBRE A_2 (ESTIMATION VISUELLE) ZONE RUBANEE C.D.L.

Magnetite + ilmenite	10	1 - 3	1 - 3	1 - 3		1 - 3
Chlorite + actinolite	1 - 3	40	40	30	40	20
Albite + clinozoicite epidote	75	55	55	68	55	75
Quartz	10		1 - 3			1 - 3
Pyroxene		3				
Orthoclase	3					

From Caty (1970) Table 19, p.51.

Table 50

MODAL ANALYSES OF ROCKS FROM THE P$_3$ MEMBER (VISUAL ESTIMATE) LAYERED ZONE D.L.C.

ANALYSES MODALES DES ROCHES DU MEMBRE P$_3$ (ESTIMATION VISUELLE) ZONE RUBANEE C.D.L.

	C67 202	C67 201	C67 134	C67 200	C67 186	C67 192	C67 206	C67 205	C67 204	C67 95	C67 197	C67 203	C67 199
Ilmenite + magnetite	10	10	5	10	5	7	15	12	15	5	10	6	5
Chlorite	15	5	tr	20	5	10	20	7	15	10	10	6	15
Albite + epidote	30	tr	tr		30	tr	4	30	20			45	35
Plagioclase		45	20			17				5	5		
Actinolite	40	25	30	50	30	40	60	40	40	50	70	43	45
Cummingtonite		tr								1	tr		
Stilpnomelane biotite			tr		10	tr							
Ferrohastingsite (hornblende)		5	15	5	10	10		10	10	15			
Apatite	1	5	3	15	10	3	tr	tr		10			
Quartz	5				2								tr
Sphene-leucoxene			tr		tr	tr				tr	tr	tr	
Zircon						tr							
Calcite	tr						tr					tr	tr
Muscovite													
Garnet		5	20	tr	10	10				5			
Augite									tr	tr			

From Caty (1970) table 23 + 24, p.62-63.

TABLE 51

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. NP₃

ANALYSES CHIMIQUES DES ROCHES LU MEMBRE NP₃ DU C.L.D.

Sample No. / No. d'échantillon	B70-400	B70-242	B70-401	B70-235	B70-481	B70-468	B70-513
SiO_2	49.80	45.30	55.00	67.80	55.60	50.50	58.20
TiO_2	2.36	1.25	0.99	0.74	1.86	2.04	0.95
Al_2O_3	9.69	23.59	14.42	10.93	11.43	11.50	12.37
Fe_2O_3	5.26	2.35	3.69	3.03	4.29	4.34	3.39
FeO	18.78	8.40	13.20	10.43	14.79	14.96	11.67
MnO	0.43	0.19	0.30	0.19	0.42	0.48	0.30
MgO	1.67	3.08	1.25	1.33	2.45	2.45	0.76
CaO	7.27	16.04	7.00	0.76	6.83	7.39	4.56
Na_2O	1.84	1.70	5.00	4.43	3.00	3.10	5.00
K_2O	0.66	0.08	0.83	0.11	0.60	0.32	1.16
P_2O_5		0.49					
H_2O+							
H_2O-							
CO_2							
S							
TOTAL	97.81	102.52	101.71	99.77	101.32	97.13	98.39

Norm wt%

	B70-400	B70-242	B70-401	B70-235	B70-481	B70-468	B70-513
Qtz	10.47		1.09	30.79	11.95	6.35	8.93
Cor				2.12			
Or	3.90	0.47	4.90	0.65	3.55	1.89	6.85
Plag	31.80	69.28	56.76	41.31	41.33	42.75	50.19
Ab	15.57	12.78	42.31	37.49	25.39	26.23	42.31
An	16.23	56.50	14.45	3.82	15.95	16.52	7.88
Ne		0.87					
Wo							
Di	17.36	16.75	17.74		16.20	17.41	12.98
Wo	8.30	8.33	8.49		7.84	8.44	6.18
En	1.21	3.32	1.24		1.70	1.99	0.66
Fs	7.84	5.09	8.01		6.67	6.98	6.15
Hy	22.12		13.97	19.09	18.38	18.53	12.59
En	2.95		1.87	3.31	3.73	4.11	1.23
Fs	19.17		12.09	15.78	14.65	14.42	11.46
Ol		8.19					
Fo		3.05					
Fa		5.14					
Mt	7.63	3.41	5.35	4.39	6.22	6.29	4.92
Il	4.48	2.37	1.68	1.41	3.53	3.87	1.80
Hm							
Ap		1.16					
Py							
Cal							

Data Wt%

	B70-400	B70-242	B70-401	B70-235	B70-481	B70-468	B70-513
An/plag	51.0	81.5	25.5	9.3	38.6	38.6	15.7
Fa/ol		62.8					
En/hy	13.3		13.4	17.3	20.3	22.2	9.7
Diff.i.	29.9	14.1	48.3	68.9	40.9	34.5	58.1

	B70-400	B70-242	B70-401	B70-235	B70-481	B70-468	B70-513
Qtz	35.0		2.2	44.7	29.2	18.4	15.4
Ab	52.0		87.6	54.4	62.1	76.1	72.8
Or	13.0		10.1	0.9	8.7	5.5	11.6

	B70-400	B70-242	B70-401	B70-235	B70-481	B70-468	B70-513
An	45.5	81.0	23.4	9.1	35.5	37.0	13.8
Ab	43.6	18.3	68.6	89.3	56.6	58.8	74.2
Or	10.9	0.7	8.0	1.5	7.9	4.2	12.0

	B70-400	B70-242	B70-401	B70-235	B70-481	B70-468	B70-513
A	8.9	11.4	24.3	23.5	14.5	13.6	28.0
F	85.2	68.9	70.5	69.6	76.7	76.7	68.5
M	5.9	19.7	5.2	6.9	8.8	9.7	3.5

	B70-400	B70-242	B70-401	B70-235	B70-481	B70-468	B70-513
Na+K/Al	38.6	12.2	63.3	67.8	48.9	47.4	76.6
FeMn/FeMnMg	88.9	66.1	88.3	84.9	83.1	81.6	91.7
Na_2O/Na_2O+K_2O	73.6	95.5	85.8	97.6	83.3	90.6	81.2

TABLE 52

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. MEMBER P₃ – LAYERED ZONE

ANALYSES CHIMIQUES DES ROCHES DU MEMBRE P₃ DE LA ZONE RUBANEE – C.L.D.

Sample No. / No. d'échantillon	DL1010	DL1012	DL1016	DL1022	14-69-15	DL1023	DL1015
SiO_2	39.83	41.67	44.83	42.45	38.29	45.74	45.53
TiO_2	4.82	3.54	2.26	3.52	2.69	1.99	2.36
Al_2O_3	11.29	11.86	13.00	11.53	10.90	12.61	12.02
Fe_2O_3	4.74	3.94	3.72	9.16	3.87	5.58	4.22
FeO	23.10	22.10	19.60	14.60	22.99	19.30	19.40
MnO	0.33	0.29	0.35	0.25		0.40	0.39
MgO	4.03	6.46	2.98	3.58	2.27	1.47	2.09
CaO	8.02	8.11	9.93	8.55	10.12	9.03	10.19
Na_2O	2.09	1.73	2.07	3.05	1.64	2.77	2.44
K_2O	0.19	0.14	0.15	0.24	0.44	0.33	0.22
P_2O_5	1.54	0.11	1.09	0.14		0.76	1.13
H_2O+							
H_2O-							
CO_2							
S							
TOTAL	99.98	99.95	99.98	100.07	93.21	99.98	99.99
Norm wt%							
Qtz						0.15	0.29
Cor							
Or	1.12	0.83	0.89	1.42	2.60	1.95	1.30
Plag	38.55	38.82	43.25	51.06	32.69	44.44	41.84
Ab	17.68	14.64	17.52	25.81	11.61	23.44	20.65
An	20.86	24.18	25.74	25.25	21.08	21.00	21.20
Ne					1.23		
wo							
Di	7.60	12.98	14.17	13.65	25.39	16.48	19.12
Wo	3.70	6.40	6.85	6.79	12.16	7.86	9.18
En	0.95	2.20	1.46	2.68	1.86	0.99	1.51
Fs	2.95	4.38	5.66	4.18	11.37	7.63	8.43
Hy	20.25	14.12	27.98	6.99		23.33	24.23
En	4.93	4.72	5.57	2.73		2.67	3.69
Fs	15.32	9.40	22.40	4.26		20.66	20.54
Ol	12.86	20.51	1.49	6.66	20.58		
Fo	2.91	6.42	0.27	2.45	2.66		
Fa	9.95	14.09	1.21	4.21	17.92		
Mt	6.87	5.71	5.39	13.28	5.61	8.09	6.12
Il	9.15	6.72	4.29	6.69	5.11	3.78	4.48
Hm							
Ap	3.65	0.26	2.58	0.33		1.80	2.68
Py							
Cal							
Data Wt%							
An/plag	54.1	62.3	59.5	49.5	64.5	47.3	50.7
Fa/ol	77.4	68.7	81.6	63.2	87.0		
En/hy	24.4	33.4	19.9	39.1		11.5	15.2
Diff.i.	18.8	15.5	18.4	27.2	15.4	25.5	22.2
Qtz						0.6	1.3
Ab	94.0	94.6	95.2	94.8		91.8	92.9
Or	6.0	5.4	4.8	5.2		7.6	5.8
An	52.6	61.0	58.3	48.1	59.7	45.3	49.1
Ab	44.6	36.9	39.7	49.2	32.9	50.5	47.9
Or	2.8	2.1	2.0	2.7	7.4	4.2	3.0
A	6.7	5.4	7.8	10.7	6.7	10.5	9.4
F	81.5	75.8	81.8	77.6	86.1	84.5	83.3
M	11.8	18.8	10.4	11.7	7.3	5.0	7.4
Na+K/Al	32.3	25.3	27.4	36.3	29.1	39.0	35.4
Fe+Mn/Felsic	79.4	69.3	81.4	73.3	86.7	90.4	86.4
Na_2O/Na_2O+K_2O	91.7	92.5	93.2	92.7	78.8	89.4	91.7

TABLE 53

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. MEMBER P₃ - LAYERED ZONE

ANALYSES CHIMIQUES DES ROCHES DE MEMBRE P₃ DE LA ZONE RUBANEE - C.L.D.

Sample No. No. d'échantillon	DL1011	DL1020	71-133	14-69-3	69-181	71-98	DL1014	71-63
SiO_2	44.73	45.24	31.20	50.73	52.54	58.15	55.25	59.10
TiO_2	4.47	3.20	1.50	1.82	0.97	1.36	1.92	1.26
Al_2O_3	11.94	11.04	10.90	11.40	16.81	10.95	8.33	11.30
Fe_2O_3	4.44	5.31	15.02	4.43	4.74	3.79	5.10	5.41
FeO	19.51	18.30	21.39	16.80	8.71	12.96	17.50	15.34
MnO	0.32	0.34	0.33			0.42	0.48	0.32
MgO	4.37	2.85	3.28	0.69	3.08	0.17	0.78	1.28
CaO	7.68	8.83	7.36	8.71	10.44	6.20	8.24	5.35
Na_2O	1.94	2.58	0.78	0.99	0.13	2.43	0.99	2.50
K_2O	0.30	0.40	0.05	0.40	0.02	0.74	0.52	0.42
P_2O_5	0.29	1.88	2.87			0.30	0.86	0.46
H_2O+			4.50			1.63		1.90
H_2O-			0.10			0.10		0.15
CO_2			0.67			0.41		0.35
S			0.02			0.02		0.13
TOTAL	99.99	99.97	99.97	93.21	97.44	99.63	99.97	100.27
Norm wt%								
Qtz	1.45	2.71	4.37	16.56	21.39	22.92	23.43	26.66
Cor			4.61					
Or	1.77	2.36	0.30	2.36	0.12	4.37	3.07	2.48
Plag	39.40	39.19	20.13	33.86	46.32	37.35	25.13	39.53
Ab	16.42	21.83	6.60	8.38	11.0	20.56	8.38	21.15
An	22.99	17.36	13.53	25.48	45.22	16.78	16.75	18.37
Ne								
Wu								
Di	11.25	12.19		15.64	5.49	8.37	16.32	2.55
Wo	5.52	5.91		7.40	2.74	3.93	7.73	1.23
En	1.72	1.41		0.55	1.16	0.10	0.60	0.26
Fa	4.01	4.87		7.69	1.59	4.34	7.98	1.05
Hy	30.52	25.39	33.13	17.67	15.40	15.15	19.00	14.54
En	9.16	5.69	8.17	1.17	6.51	0.33	1.34	2.92
Fs	21.36	19.70	24.97	16.50	8.89	14.82	17.66	11.71
Ol								
Fo								
Fa								
Mt	6.44	7.70	21.78	6.42	6.87	5.50	7.39	7.84
Il	8.49	6.08	2.85	3.46	1.84	2.58	3.65	2.39
Hm								
Ap	0.69	4.45	6.80			0.71	2.04	1.09
Py			0.04			0.04		0.24
Cal			1.50			0.93		0.80
Data Wt%								
An/plag	58.3	44.3	67.2	75.3	97.6	44.9	66.7	46.5
Fa/ol								
En/hy	30.0	22.4	24.6	6.6	42.3	2.2	7.0	20.0
Diff.%.	19.6	26.9	11.3	27.3	22.6	47.8	34.9	50.3
Qtz	7.4	10.1	38.8	60.7	94.6	47.9	67.2	53.0
Ab	83.6	81.1	58.6	30.7	4.9	42.9	24.0	42.1
Or	9.0	8.8	2.6	8.7	0.5	9.1	8.8	4.9
An	55.8	41.8	66.2	70.4	97.4	40.2	59.4	43.7
Ab	39.9	52.5	32.3	23.1	2.4	49.3	29.7	50.4
Or	4.3	5.7	1.4	6.5	0.2	10.5	10.9	5.9
A	7.3	10.1	2.1	6.0	0.9	15.8	6.1	14.6
F	78.4	80.2	89.9	91.1	80.6	83.4	90.8	79.0
M	14.3	9.7	8.1	2.9	18.5	0.8	3.1	6.4
Na+K/Al	29.4	42.4	12.3	18.1	1.4	43.8	26.3	40.4
Fe+Mn/FeMnMg	75.4	82.2	85.8	94.4	70.3	98.7	94.2	87.2
Na_2O/Na_2O+K_2O	86.6	86.6	94.0	71.2	90.8	76.7	65.6	85.6

Table 54

Notes on samples of Tables 51, 52, and 53.

TABLE 51. NP$_3$ MEMBER OF THE LAYERED ZONE, DORE LAKE COMPLEX

B-70-400 Baskin, 1975, anal. 3, p. 125. Metaferrogabbro. Obalski Township. On
hundred feet (30 m) south of Cache Bay.

B-70-242 Baskin, 1975, anal. 4, p. 126. Metagabbro. Obalski Township. 2000
feet (600 m) south of Cache Bay.

B-70-401 Baskin, 1975, anal. 5, p. 127. Metagabbro. Obalski Township. One
hundred feet (30 m) south of Cache Bay.

B-70-235 Baskin, 1975, anal. 6, p. 128. Quartz-bearing metagabbro. Obalski
Township. One thousand feet (300 m) west of the north tip of Cache Lak

B-70-481 Baskin, 1975, anal. 7, p. 129. Quartz-bearing metagabbro. Obalski
Township. Three hundred feet (90 m) west of the western tip of Cache B

B-70-468 Baskin, 1975, anal. 8, p. 130. Quartz-bearing metagabbro. Obalski
Township. 1200 feet (360 m) north of Cache Bay.

B-70-513 Baskin, 1975, anal. 9, p. 131. Quartz-bearing metagabbro. Obalski
Township. Eight hundred feet (240 m) west of the north tip of Cache La

TABLES 52 AND 53. P$_3$ MEMBER OF THE LAYERED ZONE, DORE LAKE COMPLEX

DL-1010 Caty, 1970, p. 212. Metapyroxenite. Lemoine Township, Range 5, Field
sample C 67-200. Visual estimate: 55% actinolite, 20% chlorite, 10%
apatite, 10% ilmenite.

DL-1012 Caty, 1970, p. 211. Melametagabbro. Lemoine Township, Range 5. Field
sample C 67-204, base of P$_3$ member. Visual estimate: 20% plagioclase
An$_{44}$, 50% actinolite, 15% chlorite, 15% ilmenite.

DL-1016 Caty, 1970, p. 213. Melametagabbro. Lemoine Township, area of Five
Mile Lake. Field sample C 67-5M8. Visual estimate: 50% actinolite,
20% plagioclase, 20% chlorite, 3% apatite and 5% ilmenite.

DL-1022 Caty, 1970, p. 211. Metagabbro. Lemoine Township, Range 5. Field
sample C 67-203. Visual estimate: 35% plagioclase, 45% actinolite, 15
chlorite, 5% ilmenite.

14-69-15 Allard, Q.D.N.R. Lab. Ilmenite-bearing metaferropyroxenite. Scott
Township. Drill cores from Millkirk, north of David Lake (Allard, 1975

DL-1023 Caty, 1970, p. 213. Melametagabbro. Lemoine Township, Range 5. Field
sample C 67-134. Visual estimate: 20% plagioclase, 50% actinolite-
ferrohastingsite, 15% garnet, 5% apatite, 5% ilmenite, trace biotite.

DL-1015 Caty, 1970, p. 214. Melametagabbro. Lemoine Township, area of Five
Mile Lake. Field sample C 67-5M6. Visual estimate: 20% plagioclase,
50% actinolite-ferrohastingsite, 15% garnet, 5% apatite, 5% ilmenite,
trace biotite.

DL-1011 Caty, 1970, p. 212. Melametagabbro. Lemoine Township, Range 5. Field
sample C 67-202. Visual estimate: 25% plagioclase, 45% actinolite,
10% ilmenite, 15% chlorite, 5% quartz, 2% apatite.

DL-1020 Caty, 1970, p. 213. Melametagabbro. Lemoine Township, Range 5. Field
sample C 67-186. Visual estimate: 20% plagioclase, 45% actinolite-
ferrohastingsite (?), 5% chlorite, 15% apatite, 10% garnet, 1% quartz,
5% ilmenite, 5% biotite.

71-133 Allard, Q.D.N.R. Lab. Apatite and ilmenite-bearing metaferropyroxenite
6700 feet (2010 m) north of the Lemoine Township center line and 800
feet (240 m) southeast of Five Mile Lake shore.

14-69-3 Allard, Q.D.N.R. Lab. Quartz-bearing metapyroxenite. Lemoine Town-
ship, road to Five Mile Lake very close to the contact between the P$_3$
member and the Sodagranophyre Zone.

69-181 (14-69-5) Allard, Q.D.N.R. Lab. Quartz-bearing metapyroxenite. Scott
Township. North of David Lake (Allard, 1975).

71-98 Allard, Q.D.N.R. Lab. Quartz-bearing metagabbro. Lemoine Township,
19,500 feet (5850 m) west of the Rinfret-Lemoine township line and
10,700 feet (3210 m) south of R5-6 range line.

DL-1014 Caty, 1970, p. 214. Transition between P$_3$ and granophyre. Lemoine
Township, area of Five Mile Lake. Field sample C 67-5M3. Visual
estimate: 35% quartz, 30% actinolite, 25% chlorite, traces of ilmenite
and garnet.

71-63 Allard, Q.D.N.R. Lab. Quartz-bearing metagabbro. Lemoine Township.
8500 feet (2550 m) west of the Rinfret-Lemoine Township line and 7000
feet (2100 m) south of R5-6 range line.

TABLE 55

Chemical analyses of the Sorcerer Mountain magnetite zone - Roy township - D.D.H. SC-74-3
Analyses chimiques de la zone de magnétite de la montagne du Sorcier - canton de Roy - Trou de sondage SC-74-3

Sample No. Echantillon no.	74-3-1	74-3-2	74-3-3	74-3-4	74-3-5	74-3-6	74-3-7	74-3-8	74-3-9	Weighted Average
D.D. Hole interval Profondeur	782.2 - 791.0	791.0 - 881.7	881.7 - 980.0	980.0 - 1030.0	1030.0 - 1075.9	1075.9 - 1170.0	1170.0 - 1259.0	1259.0 - 1302.0	1302.0 - 1323.5	782.2 - 1323.5
Footage Pieds de carotte	8.8	90.7	98.3	50.0	45.9	94.1	89.0	43.0	21.5	541.3
SiO_2	34.43	22.79	25.16	28.48	31.44	23.90	29.73	36.35	41.08	27.80
TiO_2	0.36	0.82	1.18	1.30	0.79	1.45	1.09	0.99	0.98	1.09
Al_2O_3	17.33	11.37	9.57	11.61	11.42	4.36	3.09	10.09	15.80	8.66
Fe_2O_3	3.92	26.52	22.90	16.06	13.00	29.60	23.63	9.48	2.49	21.13
FeO	17.86	16.18	16.71	19.40	15.83	16.58	13.03	11.25	12.91	15.60
MnO	0.19	0.14	0.19	0.25	0.25	0.23	0.19	0.24	0.21	0.20
MgO	24.14	18.72	20.47	17.08	21.40	20.54	25.70	24.18	17.56	21.05
CaO	0.79	1.58	2.41	4.36	4.64	2.39	2.65	6.72	7.15	3.18
Na_2O	0.22	0.21	0.17	0.19	0.15	0.16	0.15	0.17	1.29	0.22
K_2O	0.16	0.51	0.08	0.08	0.06	0.08	0.05	0.05	0.14	0.15
P_2O_5	0.16	0.25	0.15	0.17	0.12	0.01	0.07	0.02	0.001	0.11
V_2O_5	0.12	0.29	0.31	0.32	0.19	0.38	0.27	0.11	0.10	0.27
Cr_2O_3	0.07	0.08	0.06	0.11	0.07	0.08	0.11	0.09	0.11	0.08
S	0.23	0.52	0.63	0.58	0.62	0.23	0.22	0.23	0.16	0.41
Total Fe %	14.84	29.20	26.80	23.84	20.00	30.75	25.00	14.60	10.68	
1974 Fe analysis % analyse Fe 1974	15.2	28.5	26.7	24.5	21.5	32.1	25.9	14.0	10.3	
Concentrate grind Concentré (broyé- 325 mailles)	99.0%	99.0	98.0	99.0	96.0	96.0	99.0	96.0	97.0	
Concentrate weight % % poids concentré	no sample	33.2	31.4	21.9	115.1	39.2	30.1	6.7	no sample	
Concentrate Concentré	%Fe	–	67.2	67.7	68.4	68.9	69.1	68.0	68.1	–
	%TiO_2	.	0.97	2.24	3.36	2.96	1.32	0.94	2.65	–
	%V_2O_5	–	0.55	0.67	0.87	0.64	0.68	0.57	0.37	–
	%S	–	0.14	0.91	0.65	1.03	0.08	0.20	1.33	–
	%SiO_2	–	2.84	2.08	1.30	1.22	2.56	2.68	2.14	–
	%MgO	–	2.16	1.56	0.50	0.72	1.81	2.26	1.00	–
	%Al_2O_3	–	1.01	0.85	0.80	0.76	0.40	0.40	0.52	–

Analyses done in the laboratories of the Q.D.N.R. in 1975
Samples submitted for Fe analyses and magnetic concentrate analyses by Campbell Chib. Mines Ltd in 1974

Analyses faites aux laboratoires du M.R.N. en 1975
Echantillons soumis pour analyses de Fe et tests de concentration magnetique par Campbell Chib. Mines Ltd en 1974

TABLE 56

CHEMICAL ANALYSES OF GABBROIC META-ANORTHOSITE
AND ANORTHOSITIC METAGABBRO FROM THE
SORCERER MOUNTAIN AND MAGNETITE BAY ZONES

	A-1	A-2	A-3
SiO_2	45.67 %	42.50 %	39.14 %
Al_2O_3	18.05	16.74	13.36
Fe_2O_3	0.50	0.39	0.60
FeO	11.47	8.75	13.33
MgO	6.30	10.05	17.56
CaO	10.08	15.64	5.85
Na_2O	1.59	0.13	0.04
K_2O	0.04	0.03	0.00
Cr_2O_3	0.01	0.108	0.03
TiO_2	0.64	0.30	0.04
V_2O_5	0.035	0.07	0.035
NiO	0.014	0.015	0.025

Trace elements in ppm.			
Ag	0.9	0.7	1.2
Cu	44	38	14
Zn	42	135	141
Pb	20	22	30
Pt	0.02	0.02	0.02
Sn	20	15	15

TOTAL (%)	93.860	94.742	89.971

C I P W NORMS weight percent

Quartz	0.00	0.00	0.00
Orthose	0.24	0.18	0.00
Anorthite	42.00	45.00	29.02
Albite	13.45	1.00	0.34
Diopside	3.17	17.35	0.00
Hedenbergite	3.52	9.18	0.00
Enstatite	10.63	1.57	13.49
Ferrosilite	13.53	0.95	10.12
Forsterite	2.52	10.81	17.69
Fayalite	3.53	7.23	10.66
Magnetite	0.07	0.57	0.87
Ilmenite	1.22	0.57	0.08
Chromite	0.01	0.16	0.04

Data from Dorr (1969), table 3 & 4, p. 14-15.

TABLE 57

CHEMICAL ANALYSES OF METAPYROXENITES AND METAFERRODUNITES FROM SORCERER MOUNTAIN AND MAGNETITE BAY ZONES

From Dorr (1969) tables 5 to 8, p. 23-24 and 29-30.

	A-4	A-5	A-6	A-7	A-8	A-9	A-10
SiO_2	45.13 %	36.12 %	39.15 %	33.41 %	21.59 %	22.10 %	21.96 %
Al_2O_3	1.42	0.21	1.49	0.72	2.00	4.57	6.80
Fe_2O_3	0.30	0.55	1.42	17.01	42.23	30.25	34.90
FeO	14.78	12.15	9.12	0.76	1.90	16.64	1.58
MgO	25.58	34.78	34.49	32.97	20.23	22.64	22.61
CaO	2.07	0.41	0.21	0.14	0.14	0.84	1.04
Na_2O	0.03	0.02	0.02	0.02	0.04	0.02	0.02
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr_2O_3	0.058	0.146	0.035	0.087	0.00	0.02	0.03
TiO_2	0.61	2.78	1.93	1.30	1.90	1.25	1.37
V_2O_5	0.071	0.035	0.035	0.107	0.464	0.028	0.214
NiO	0.007	0.029	0.022	0.009	0.015	0.036	0.019
	Trace elements in ppm.			Trace elements in ppm.			
Ag	1.1	1.1	0.8	1.1	1.3	0.8	1.3
Cu	13	10	19	21	23	16	48
Zn	107	151	37	21	32	115	40
Pb	12	15	17	17	23	22	22
Pt	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Sn	15	15	20	25	15	20	20
TOTAL (%)	91.072	87.245	87.947	87.170	90.641	98.484	90.675

C I P W NORMS (weight per cent)

Anorthite	3.74	0.48	1.04	0.69	0.69	4.17	5.16
Albite	0.25	0.17	0.17	0.17	0.00	0.00	0.00
Diopside	3.88	0.99	0.00	0.00	0.00	0.00	0.00
Hedenbergite	1.37	0.00	0.00	0.00	0.00	0.00	0.00
Enstatite	44.13	31.42	43.08	28.15	0.00	0.00	0.00
Ferrosilite	17.89	0.00	0.00	0.00	0.00	0.00	0.00
Forsterite	12.47	38.36	30.01	37.82	35.31	39.51	39.46
Fayalite	5.57	0.00	0.00	0.00	34.26	30.63	28.64
Magnetite	0.43	0.00	1.03	18.46	27.72	24.42	23.02
Ilmenite	1.16	5.13	3.67	2.47	3.61	2.37	2.50
Chromite	0.09	0.22	0.04	0.13	0.00	0.03	0.04
Hematite	—	—	—	10.43	0.00	0.00	0.00

Table 58

Notes on samples of Tables 55, 56, and 57.

TABLE 55. ANALYSES OF DRILL CORES FROM HOLE SC-74-3 SORCERER MOUNTAIN ZONE

The drill hole was drilled by Campbell Chibougamau Mines Ltd. in 1974 to obtain a continuous sample across the magnetite-rich zone at Sorcerer Mountain. The hole is located on line 5E at 1790 N and was drilled south at $40°$. The dips obtained were $39°$ at 200', $37°$ at 400', $35°$ at 600', $35°$ at 800', $32°$ at 1000', and $27°$ at 1392', the total depth of the hole. The footage of each sample and the magnetic concentrate analyses are given in Table 55. We thank R. Hinse of FERCHIB for the information. The weighted average of the 9 samples is given in Table 55 and the average of the magnetite-bearing part of the zone is given in the chapter on ore deposits "vanadium-titanium-iron" section.

TABLE 56. GABBROIC META-ANORTHOSITE AND ANORTHOSITIC METAGABBRO FROM SORCERER
MOUNTAIN AND MAGNETITE BAY ZONES

All data on Tables 56 and 57 is from Dorr, 1969, Tables 3 to 8.

A-1 Gabbroic meta-anorthosite, Sorcerer Mountain zone, L 44E, 50 feet (15 m) south.

A-2 Gabbroic meta-anorthosite, Magnetite Bay Zone, L 84 E, 400 feet (120 m) north.

A-3 Anorthositic metagabbro, Magnetite Bay zone, L 92 E, 200 feet (60 m) and 600 feet (180 m) north of base line.

TABLE 57. METAPYROXENITES AND METAFERRODUNITES FROM SORCERER MOUNTAIN AND
MAGNETITE BAY ZONES

A-4 Metapyroxenite, Magnetite Bay zone, Line 44E, 200 feet (60 m) and 75 feet (22 m) north of base line.

A-5 Metapyroxenite, Magnetite Bay zone, line 52E, 600 feet (180 m) south.

A-6 Metapyroxenite, Magnetite Bay zone, line 76E, 150 feet (45 m) west and 150 feet (45 m) north of base line.

A-7 Metadunite, Sorcerer Mountain Zone, line 56E, 340 feet (102 m) north.

A-8 Metadunite, Sorcerer Mountain Zone, line 72E, 100 feet (30 m) west and 1250 feet (375 m) north of base line.

A-9 Metadunite, Magnetite Bay Zone, line 84E, 220 feet (66 m) north.

A-10 Metadunite, Sorcerer Mountain Zone, line 4W, 550 feet (165 m) north.
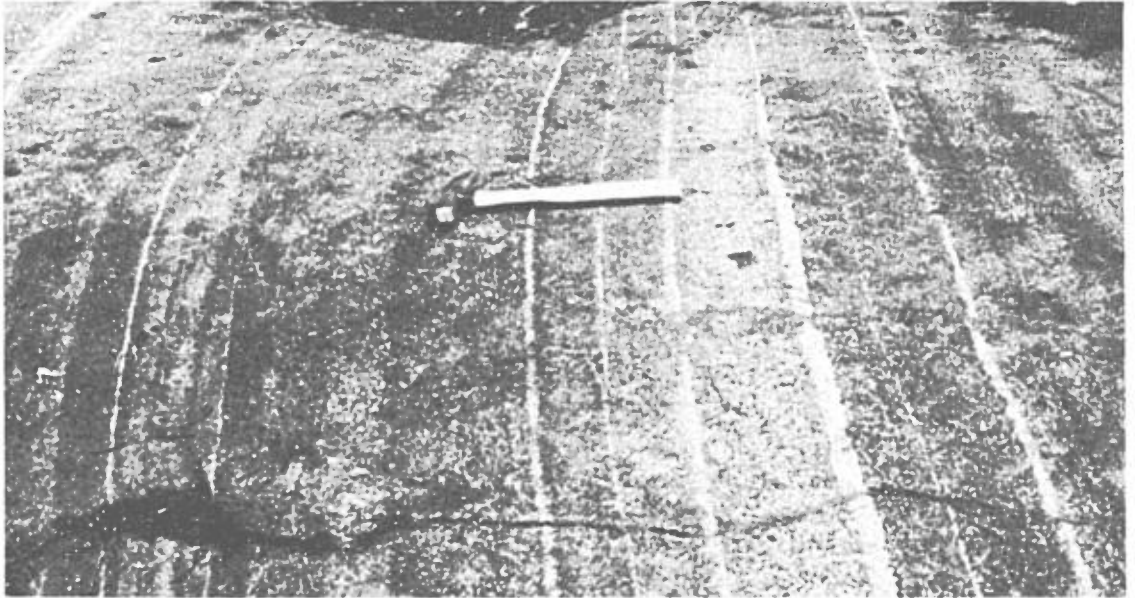
Fig. 47. Inch-scale layering in P_2 (LZ) in Rinfret Township.
Light layers are feldspathic metagabbro and dark layers are
magnetitite and magnetite-rich metapyroxenite.

Fig. 48. Irregular inch-scale layering at the base of P_2 (LZ)
in Rinfret Township (L 36 E). Light layers are metagabbro and
dark layers are magnetitite.
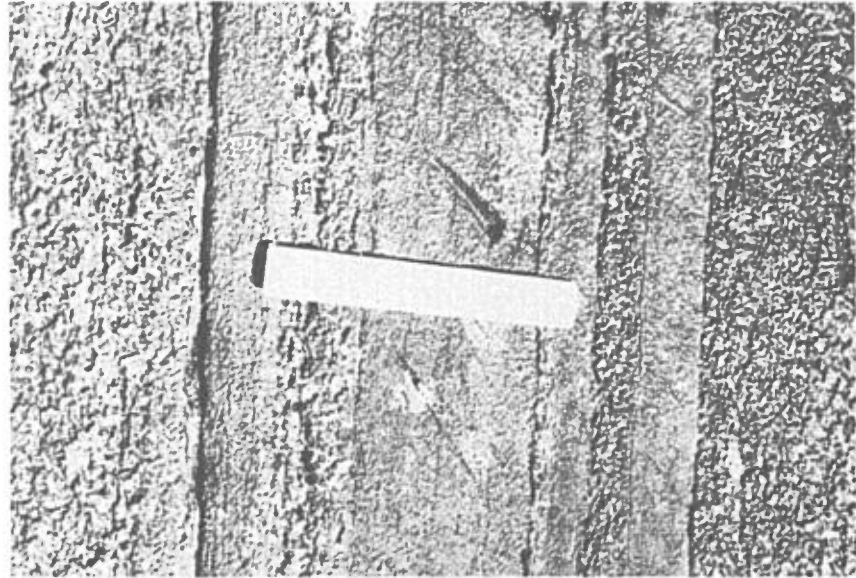
Fig. 49. Typical regular inch-scale layering in P₁ (LZ). Smooth layers are metapyroxenite and rough-surfaced layers are magnetitite. Scale is 6 inches (15 cms) long.
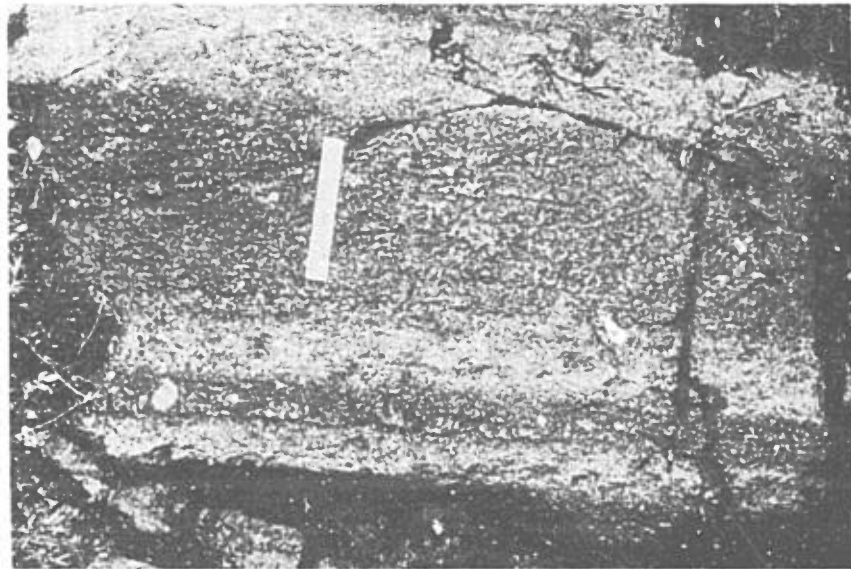
Fig.50. Layering in the P₁ member, Rinfret Township. Layer under the scale is a magnetitite layer. Note the next dark layer below contains fragments of plagioclase in the magnetitite. Scale is 6 inches (15 cms) long.

Fig. 51. Excellent inch-scale layering in P$_3$ member (LZ) on
the road to Five Mile Lake in Lemoine Township. Pale layers
are anorthositic gabbro and dark layers are green metaferro-
pyroxenite. The large pick in center of photograph :
3 feet long (90 cms).

Fig. 52. Inch-scale layering in the P$_3$ member (LZ). White
layers are feldspathic metagabbro and dark layers are dark
green metaferropyroxenite.
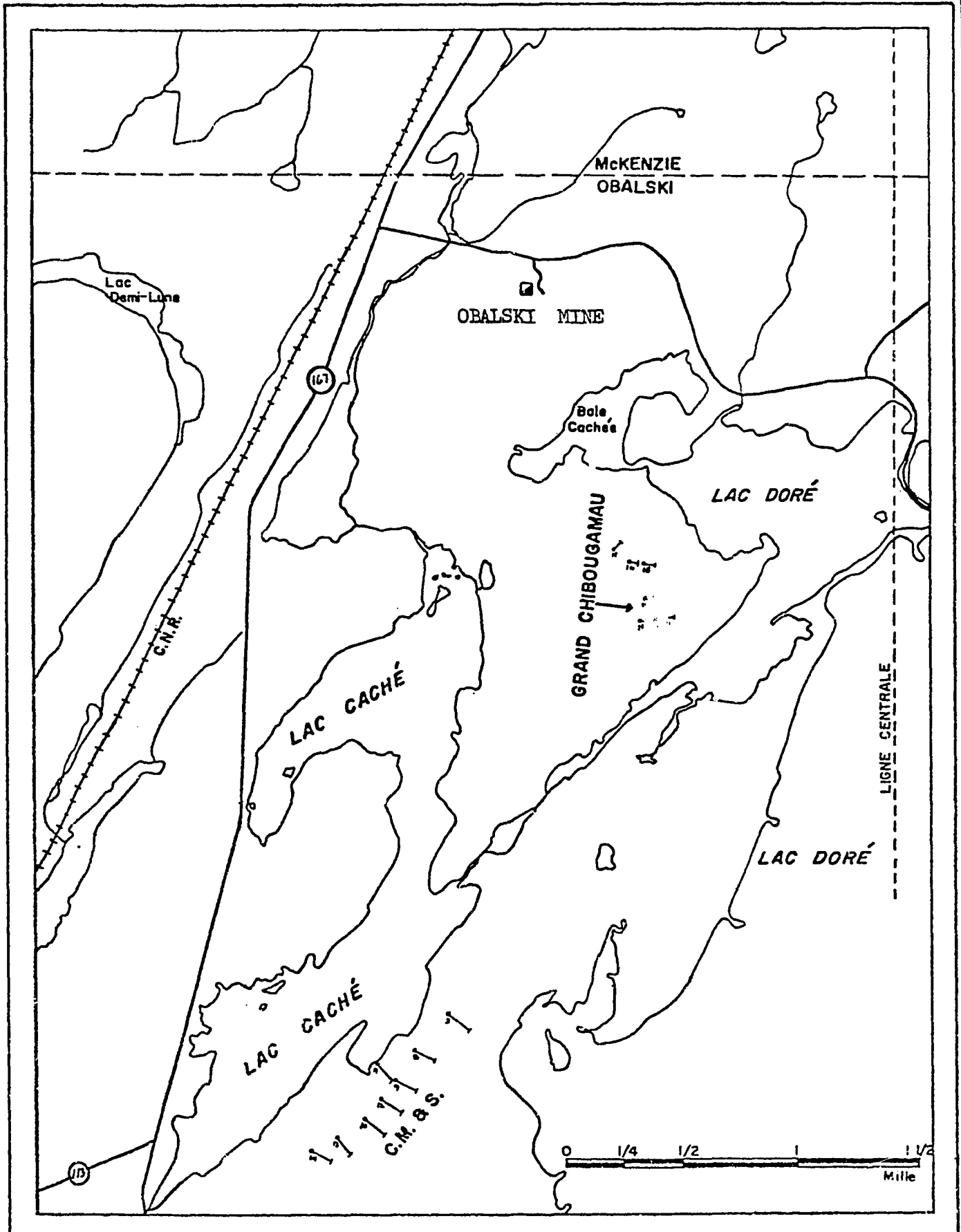
Fig. 53. Sketch map showing the location of drill holes in the Layered Zone around Cache Lake, Obalski Township.

Fig. 54. Photomicrograph across the contact of a metagabbro (right) and magnetite-rich metaferropyroxenite (left) (LZ). The elongation of the plagioclase and pyroxene grains in the gabbro is preserved and imparts a distinct igneous lamination to the rock parallel to the layering. Small pyroxene grains are left in the cores of amphiboles at the left side. The Widmanstatten texture of the titaniferous magnetite is also well preserved. The magnetite is partly replaced by chlorite and minor carbonate. The opaque lamellae have a border of very small grains of sphene. Sample 12-283(220). Field is 2.5 cm wide.
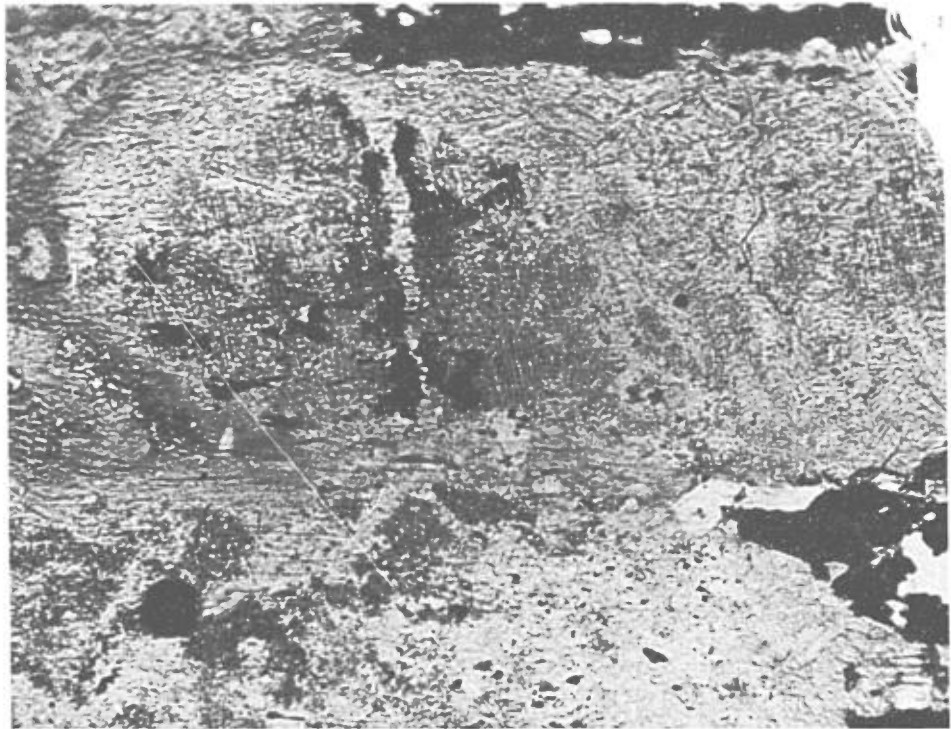
Fig. 55. Photomicrograph of a relict pyroxene in the core of a large amphibole grain (ferrohastingsite?). The pyroxene patches have a common optical orientation. Detail from the left side of Fig. 54. Field is 1.1 mm. Sample 12-283 (220).
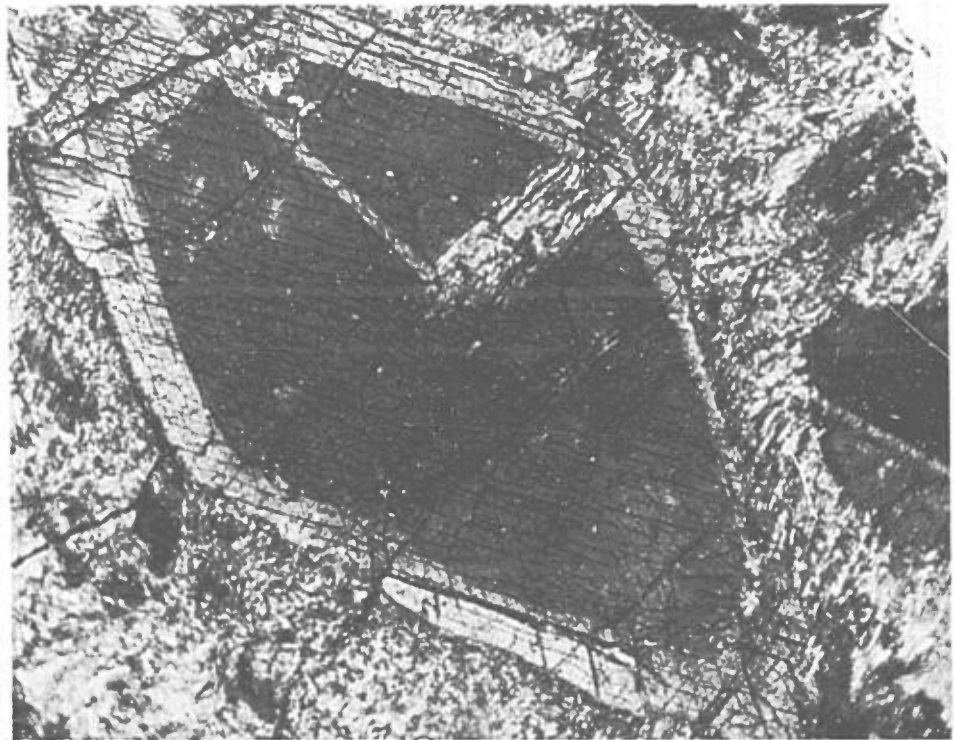
Fig. 56. Photomicrograph of a metapyroxenite or metaperidotite. Large zoned colored amphibole are in a matrix of fine tremolitic amphibole. The center of the large grain is dark green and the rim is much paler green. The square termination at the upper left corner is probably a relict pyroxene termination. Sample 54-237(175). Field is 1 mm. Gouin Peninsula, near south shore, 4000 feet west of Roy-McKenzie township line.
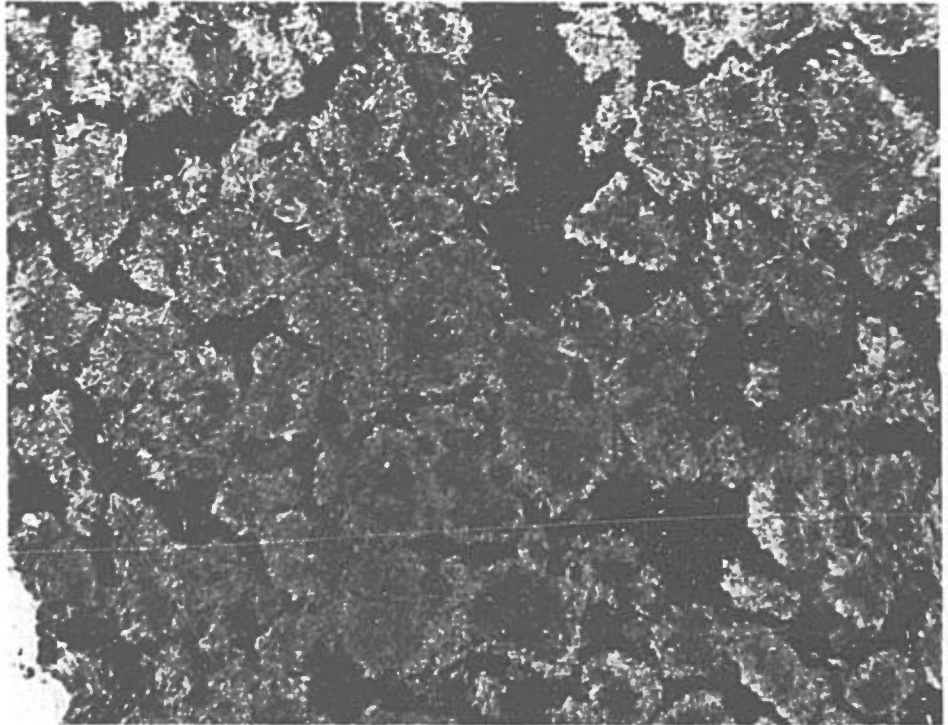
Fig. 57. Magnetite-rich metapyroxenite. The primary pyroxene is the cumulus phase and is replaced by amphibole and a dust of fine-grained magnetite. The primary magnetite is intercumulus . Field is 1.1 cm. Sample 13-225 (221).
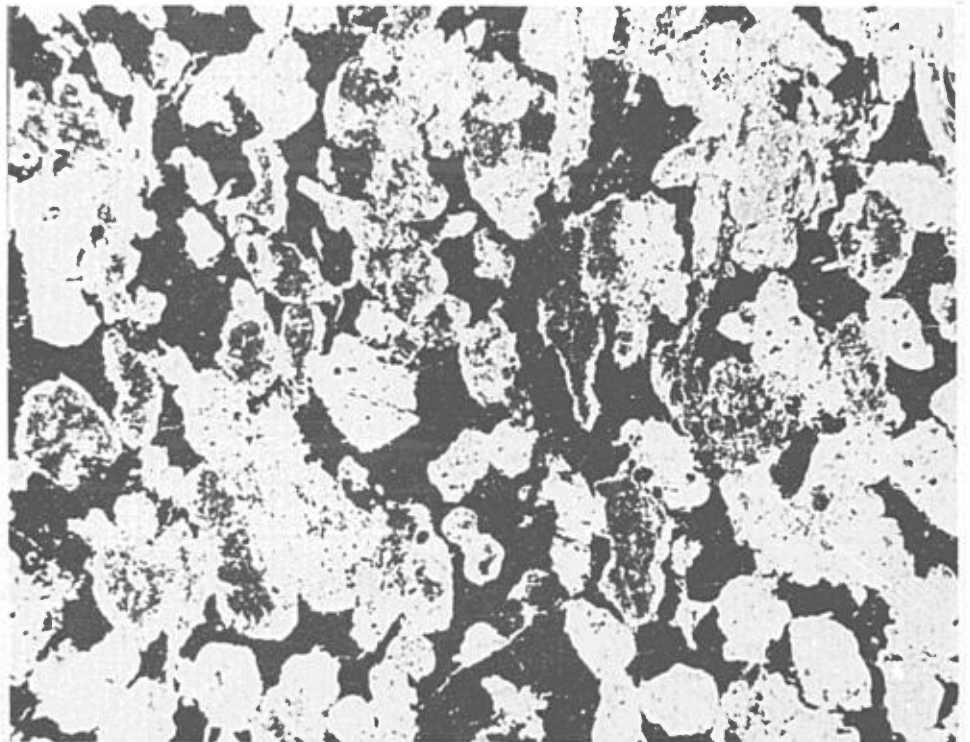
Fig. 58. Photomicrograph of magnetite-rich metapyroxenite. Same remarks as for the figure 57 above. Field : 1.2 cms.
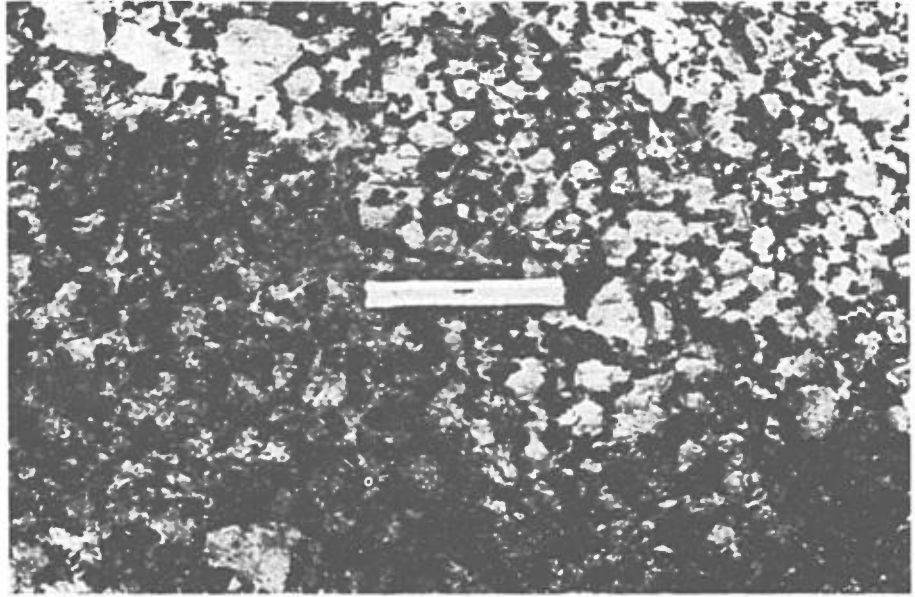
Fig. 59. Typical cumulus-intercumulus texture of the A$_2$
member (LZ). Gabbroic meta-anorthosite. Plagioclase
forms the cumulus phase and chlorite+actinolite the
intercumulus phase. Rinfret Township, L 24E, 1300S.
Scale is 6 inches long (15 cms).
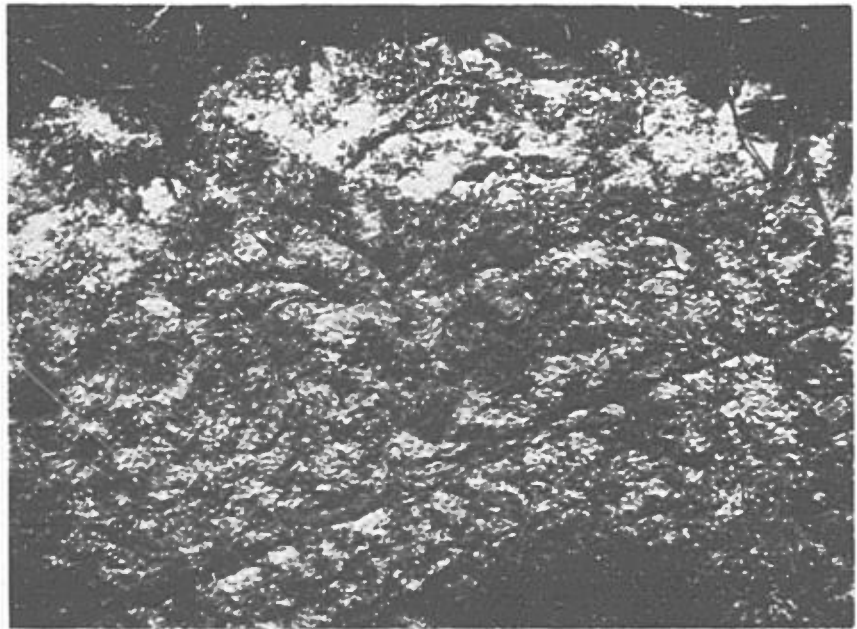
Fig. 60. Blastopoikilitic texture in gabbroic
meta-anorthosite of the A$_2$ member (LZ), Lemoine Township,
I.G.C. traverse. Field: about 12 inches (30 cms) long.

Zones	Subzones	Magnetic iron ore		V_2O_5 content of magnetite	Elevation above (+) or below (-) Main Magnetitite Seam	Country rock	Thickness in feet
Upper	D					Ferrodiorite, in places diorite	1000
	C		Upper seams 15-21	0.5%	+3600 to +4200 ft.	Ferrodiorite, gabbro, pyroxenite rare, anorthosite and troctolite	4000
	B	Plugs rare	Upper seams 8-14	0.55-0.75%	+1410 to +2620 ft.		
	A		Upper seams 1-7	1.35-1.6%	0 to 560 ft.		
		Main Magnetitite Seam					
Main	D	Lower seams 1-4; plugs rare		1.9-2.1% in seams	-400 to -1000 ft.	Gabbro and anorthosite, troctolite subordinate	1000
	C - A	Plugs subordinate. Within 3000 ft. of base Buffelshoek-Kennedy's Vale plugs and impersistent seams		0.48 to 2.35%		Gabbro, norite and anorthosite; pyroxenite very subordinate	9000
		Merensky Reef					
Critical		Plugs of magnetite diallagite pegmatoid within about 1500 ft. from base, elsewhere rare				Anorthosite, norite, pyroxenite and chromitite	3500
		Main Chromitite Seam					
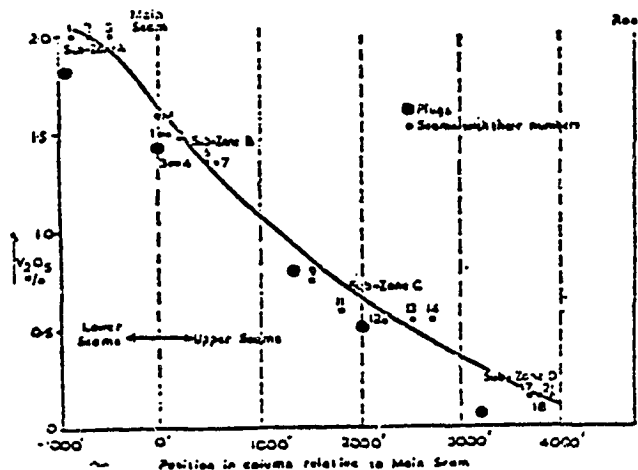
Fig. 20. Available V₂O₃ analyses of Bushveld Magnetitite seams and plugs from the Magnet Heights area.

Fig. 61. (Upper) Variation of vanadium content in magnetites from the Bushveld Complex.

Reproduced from Willemse (1969), p. 189

(Lower) same from Molyneux (1970), p. 240

Fig. 62. Pegmatitic metagabbro "pipe" cutting the P_2 member (LZ). Rinfret Township, L 24E, 1160 S. Pen scale is 5.7 inches (14 cms) long.

Fig. 63. Contact between poikilitic gabbroic meta-anorthosite of the A_2 member (LZ) and the P_3 member metaferropyroxenite. Rinfret Township, L 34E, 550S.
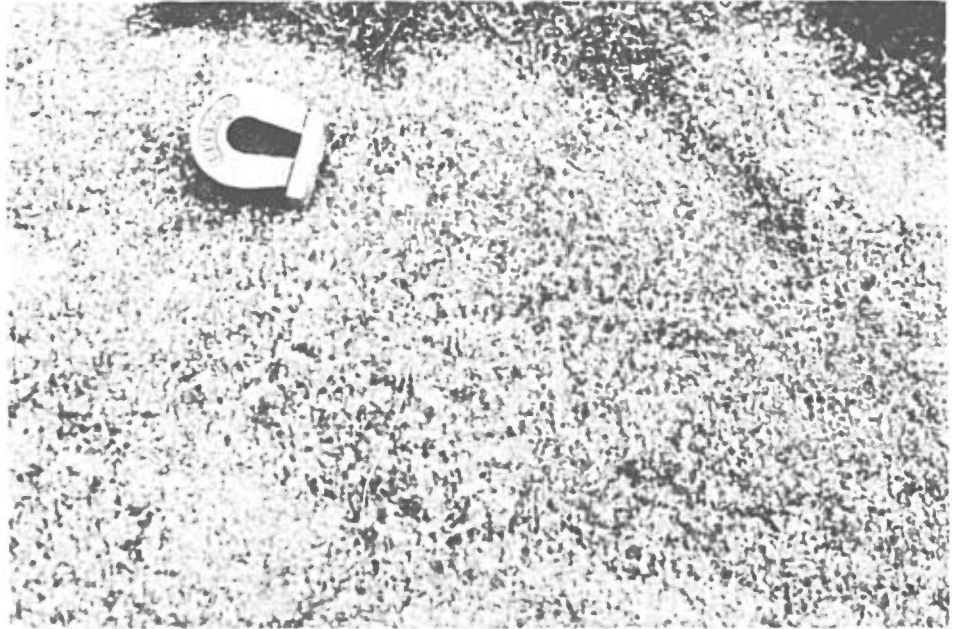
Fig. 64.   Apatite-rich submember of the P$_3$ member(LZ).
The very small white grains are apatite. Lemoine Township,
I.G.C. traverse. Magnet is 1 inch wide (2.5 cms).

Fig. 65. Metaferropyroxenite of the P$_3$ member (LZ) brecciated
by the granophyre in the vicinity of the contact between the
Layered Zone and the Sodagranophyre Zone. Lemoine Township.
Scale is 6 inches long (15 cms).

LEGEND

☐ Ore Zone

○ Diamond Drill Holes

PLAN

SCALE : 1" = 2000 Feet

SECTION   A - A

SCALE : 1" = 1000 Feet
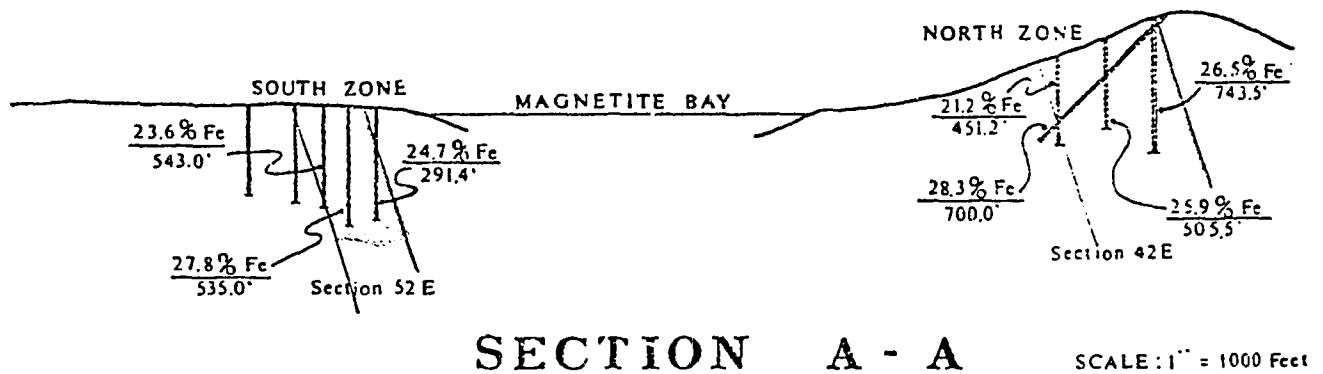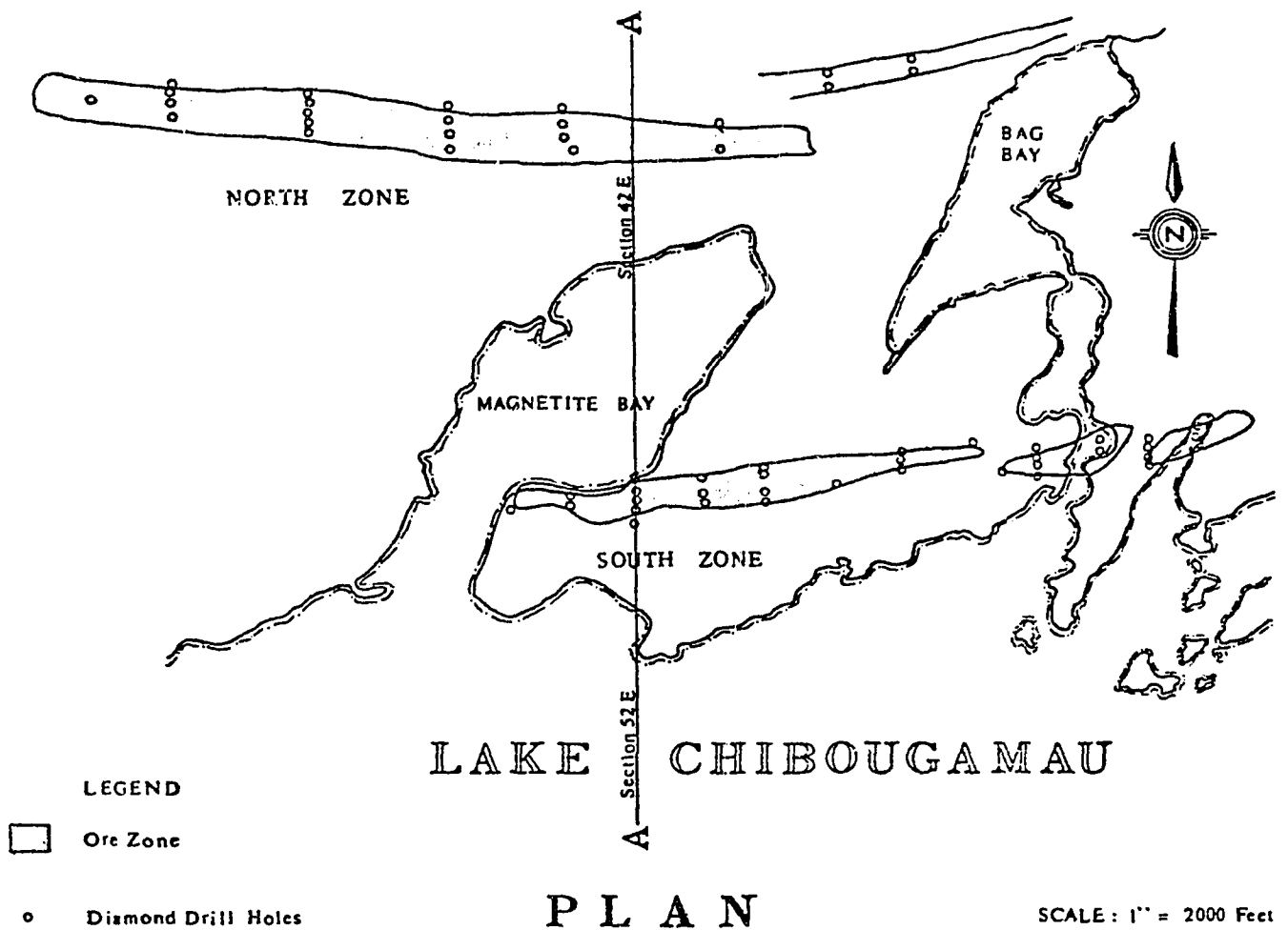
Fig. 66.   Sketch map and cross section of the Campbell
Chibougamau Mines Ltd Sorcerer Mountain (north zone) and
Magnetite Bay (south zone) deposits.

(from FERCHIB report)

Fig. 67. Rough weathered surface of the magnetite-rich metaferrodunite at Sorcerer Mountain. The magnetite forms black clots standing on relief in a matrix of serpentine. Sample is 4.5 inches long (11 cms).
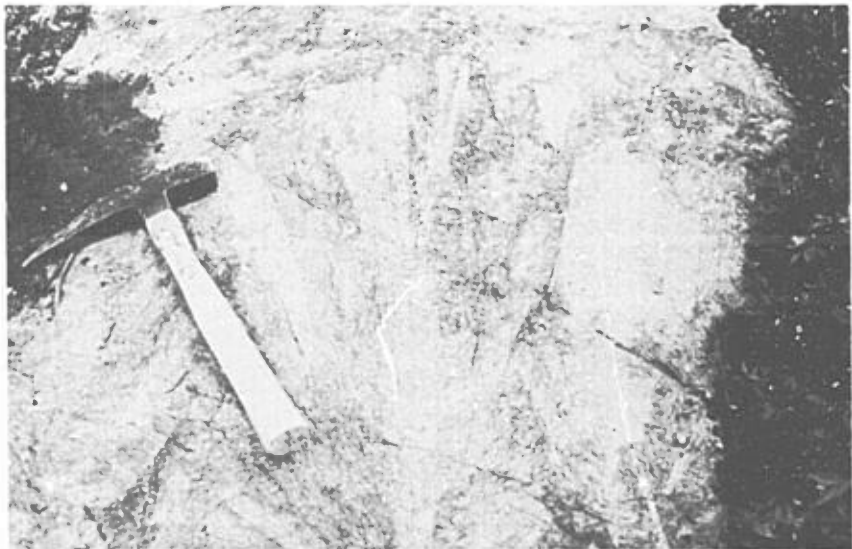
Fig. 68. Large amphibole crystals in serpentine from the Magnetite Bay magnetite zone. Some crystals are more than 15 inches long (37 cms).
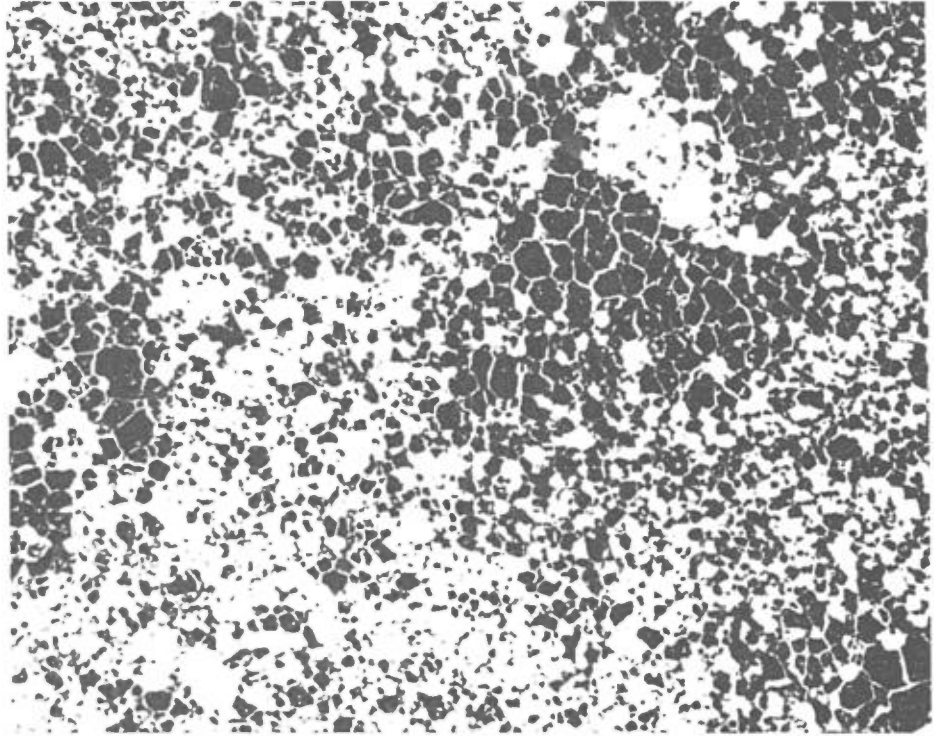
Fig. 69. Photomicrograph of magnetite-rich metaferrodunite
from d.d.hole Fe-5 on line 68E Magnetite Bay zone.
(reverse print: white is magnetite and black is serpentine).
The magnetite forms narrow rims around serpentine grains
and individual clots . Field is 2 cms long.
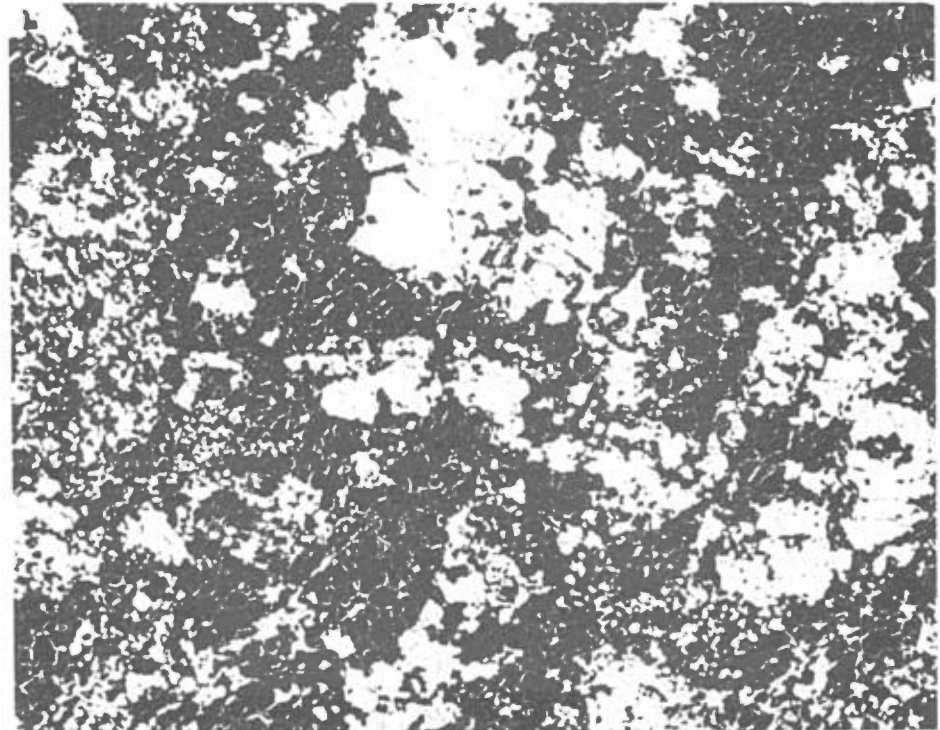
Fig. 70. Photomicrograph of magnetite-rich metaferrodunite.
Sample Dorr's C-25. (reverse print: white is magnetite
and black is serpentine). Same remarks as above. Field is
3 cms long.
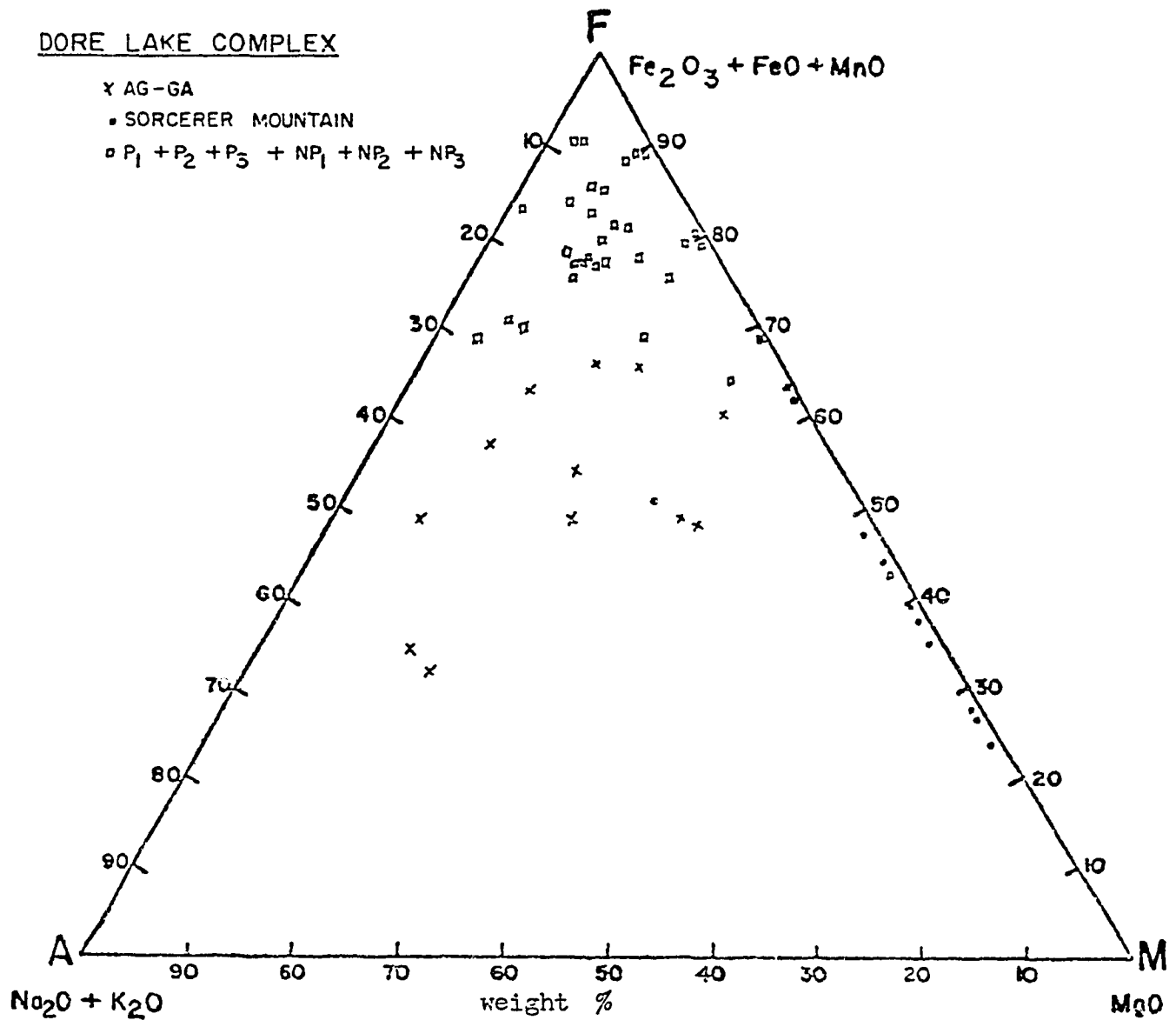
Fig. 71. AFM diagram for magnetite-rich rocks and associated gabbroic meta-anorthosite and anorthositic metagabbro of the Dore Lake Complex.

40% of the rock. No olivine has been found in the serpentines of Sorcerer

Mountain but Gaucher (1960) reported a composition of $Fo_{64}Fa_{36}$ for olivine from

a similar rock 3 miles (5 kms) east of Sorcerer Mountain. Much magnetite was

primary and occupies the intercumulus portion of the rock. Microprobe studies

would likely reveal that some of the magnetite is primary and rich in TiO_2 and

V while the magnetite derived from the breakdown of the fayalite during

metamorphism is probably very low in TiO_2 and V. More detailed studies are in

progress and will be reported later.

Table 55 presents nine chemical analyses done on split core across the

entire Sorcerer Mountain zone. The weighted average is thus an excellent

chemical average of the whole Sorcerer Mountain Zone. We are grateful to C.C.M.

for the information on this drill hole and for their permission to use the core

for the complete analyses which were done in the laboratories of the Q.D.N.R.

Table 59 contains the calculated norms and pertinent data calculated from the

analyses using Stormer's computer program on file with the University of Georgia

Computer center.

FERRODIORITE ZONE

The Ferrodiorite Zone (FZ) is located between the Layered Zone and the

Sodagranophyre Zone. Geographically, it is restricted to a crossfold in the

area of Cache Lake-Gladstone Lake in Obalski Township on the north limb and to

a very small patch in Lemoine Township, on the south limb. The latter has not

been studied in detail. Baskin (1975) just completed a study of the FZ.

Mawdsley and Norman (1935, map 304A) recognized an area around Cache Lake and

Cache Bay consisting of dioritic and gabbroic rocks related in part to the

anorthositic rocks and in part to what they called granite at Half Moon Lake

and Williams Lake. This band of granite is now recognized as the Sodagranophyre

Zone and is part of the Dore Lake Complex and not the Chibougamau pluton, a

distinction they did not make on their map. Graham (1956) mapped some of the

rocks of the Ferrodiorite Zone as parts of the Dore Lake Group (now Dore Lake

Complex) and parts of the David Lake Group (now reassigned to the Dore Lake

Complex and Chibougamau pluton). The main difficulty lies in the petrographic

similarity between the maladiorite of the border of the pluton and the dark

ferrodiorite of the Dore Lake Complex. Baskin has shown that the rocks of the

FZ are well layered, gradational into rocks of the LZ below and Granophyre Zone

above, and have mineralogical and geochemical characteristics which place them

without a doubt in the Dore Lake Complex.

Baskin (1975) divided the FZ into three members called F_1, F_2, and F_3.

F_1 Member

The F_1 member consists of metaferrogabbro, metaferropyroxenite, metaferro-

peridotite (?), leucometagabbro and metaferrodiorites. The rocks are medium

grained and light grayish green to black in hand specimen. Excellent inch-

scale layering has been observed. Primary foliation and cumulus texture can be

seen on most outcrops and specimens. Many rocks of this zone contain a primary

plagioclase much less calcic than the lower zones and hence more stable during

regional metamorphism, which explains the presence of fresh plagioclase

(An_{51-54}) in the rocks of this member. The main minerals present are plagioclase,

augite, chlorite, ferrohastingsite, clinozoisite, magnetite and ilmenite. Minor

constituents are sphene, apatite, calcite, and sericite. Quartz and grunerite

have also been observed (Fig. 77).

F_2 Member

The F_2 member consists of fine-to-medium grained pyroxene ferrodiorite

(Figs. 72 and 73) and ferronorite and coarse-grained apatite-bearing pyroxene

ferrodiorite. The coarse-grained rocks lie above the fine-grained ones. The

rocks are very fresh, dense, massive, and hardly show any signs of metamorphism

or alteration. The stable mineralogy and very dense impermeable physical

characteristics explain the lack of water and metamorphic reactions. The

chemistry of the ferrodiorite (Tables 60 to 64) is very similar to the ferro-diorites of the Skaergaard.

The fine-grained ferrodiorite-ferronorite are grey and dense. In thin sections, they show an adcumulus texture (Figs. 72 and 73). Microlayers of different grain size are evident in one thin section. The coarse-grained ferrodiorite is grayish black in hand specimen. The rocks are poorly layered and commonly exhibit a primary foliation. Some magnetite-rich layers are locally present.

The main minerals present are plagioclase (An_{48-55}), ferroaugite, inverted pigeonite (Fig. 74), ferrohypersthene, ilmenite, and magnetite. Accessory minerals are chlorite, actinolite (Fig. 75), sphene, apatite, ferrohastingsite, and calcite (Figs. 78 and 79).

F_3 Member

The F_3 member consists in roughly the same lithologies as the F_1 member. Fresh pyroxene was not observed.

Analyses of rocks from the FZ can be found in Tables 60 to 64. On the AFM diagram (Fig. 80) they plot very close to the F corner of the diagram reflecting their unusually high Fe content and very low Mg content.

SODAGRANOPHYRE ZONE

The Sodagranophyre Zone (SZ) lies stratigraphically between the Upper Border Zone (UBZ) and either the LZ or the FZ. Mawdsley and Norman (1935, p. 35) called the layer of granophyre north of David Lake granite and thought that it was the eastward extension of a tongue of granite related to the Chibougamau pluton. They mentioned the similarity of the dark colored phases of this mass to the Cache Bay Complex and to the quartz-bearing gabbroic phases marginal to the anorthosite. Smith (1953 and 1960, part 1) thought that some of the chlorite-rich quartz-bearing rocks found in the southeast corner of the

SW quarter of McKenzie Township were metasomatized volcanic rocks. Allard

(1956) recognized in thin section the excellent granophyric texture and in the

field the gradation from gabbros of the D.L.C. He called it granophyre. De

Montigny (p. 4-5, 1960) in Lemoine Township, on the south limb, states:

> "A sill-like body of altered granitic rocks, averaging nearly
> half a mile in width, is present between the pyroxenite and the
> older sedimentaries that lie to the east. The sill extends north-
> eastward from the southern boundary of the area for a distance of
> four and a half miles and disappears under a thick mantle of
> glacial deposits near the northeast corner of the map-area.
> "The rock is rather coarse grained and characterized by 30
> to 50 per cent of milky blue quartz. The occurrence of such
> material as dykes in the pyroxenite shows that it is intrusive
> into the pyroxenite. Nowhere, however, has a sharp contact been
> observed between the pyroxenite and the main body of granite;
> rather, there seems to be a transitional zone probably produced
> by contact metamorphism. Near the southern boundary of the
> area, ordinary pyroxenite grades into a black rock which contains
> 10 to 15 per cent of blue quartz, but which otherwise still looks
> like pyroxenite. The percentage of quartz, together with feld-
> spar, increases gradually eastward until the rock becomes granitic
> in composition.
> "The writer thus concludes that the sill was intruded after
> complete emplacement of the pyroxenite and probably represents a
> late phase in the differentiation of the Dore Lake complex. It
> may be contemporaneous with the granite batholith underlying lake
> Chibougamau, but no sign of this was recorded in the field."

In the SE corner of Lemoine Township, Allard (1969) identified two zones

of granophyres called granophyre I and II. This was based on two small

outcrops of porphyritic quartz-bearing rock with a granophyric texture on top

of the gabbro-pyroxenite of the UBZ. Logging operations opened scores of

excellent outcrops and Allard (1970) and Oliveira (1973) identified granophyre

II as a porphyritic rhyolite and interlayered crystal tuff forming the country

rocks of the D.L.C. and belonging to the Waconichi Formation.

The term Granophyre Zone was changed to Sodagranophyre Zone at the suggestion

of E. D. Jackson during a discussion at the Pretoria meeting where it was held

that the 5-6% Na_2O and very minor quantity of K_2O did not correspond to the

average granophyre found in other layered complexes (Table 69).

As mentioned earlier under P_3, a quartz-rich submember in the P_3 member marks the second appearance of quartz in the complex, the lower one being at the A_2 member level. The problem of the origin of the granophyre will be discussed below. The D.L.C. offers one of the best examples of a zone of granophyre with clear relationships to the rest of the complex.

The rocks of the SZ are not layered and look much like a normal granite. The rock is very rich in quartz (up to 35%) and very resistant to erosion forming rounded knobs (Fig. 81) all along the crest of the south limb ridge which coincides with the divide between the St. Lawrence River and the James Bay-Hudson Bay drainage system. The thickness varies from 500 to 3,000 feet (150 to 900 m.) on the south limb where the zone extends from one extremity to the other. An identical rock is found on the north limb from Williams Lake to Half Moon Lake forming a series of high ridges. In the northeast-trending sliver north of Cache Bay (Plate 1), the quartz-bearing granophyric rocks are dark green and differ markedly from the leucocratic granophyre of the south limb. Chemical analyses from the sodagranophyre rocks are listed in Table 65.

The main minerals in the rocks of the SZ are quartz, plagioclase, chlorite, minor actinolite and epidote. Accessories are zircon, apatite, magnetite, and pyrite. Quartz and plagioclase occur as individual grains and as granophyric intergrowth (Figs. 82 to 84). In some specimens, the near totality of the quartz and plagioclase (Fig. 84) show mutual granophyric intergrowths while in others only a few large blue-color red quartz eyes show granophyric intergrowths. Nuclei of quartz and/or plagioclase have been observed in the center of some intergrowths (Fig. 83). Sericitization (paragonite ?) of the plagioclase is very common but epidote-clinozoisite are rare alteration products reflecting the low An content of the original plagioclase and the small amount of K_2O in the rock. Chlorite is the most common mafic mineral and occurs as disseminated flakes throughout the plagioclase and as clusters pseudomorph of a primary

unknown mineral. The extremely low K_2O content of the rock eliminates biotite and leaves ferropyroxene and/or amphibole as potential candidates.

In the melanocratic granophyre, the chlorite content increases markedly and much of it results from chloritization of plagioclase. This pervasive hydrothermal alteration may be linked to the presence of many dikes and plugs of quartz feldspar porphyry found between the Obalski shaft and the area north of the Quebec Chibougamau shaft.

Origin of granophyric texture

Vogt (1930) explained granophyric texture as a result of simultaneous crystallization of quartz and feldspar in a magma composition on the cotectic line. Barker (1970) states that granophyre intergrowths are products of rapid crystallization on a few nuclei. The field evidence indicates that the rest liquid after formation of the top of the FZ was a liquid with ability to intrude the already partly consolidated P_3 ferropyroxenite (Fig. 65) underneath and sufficiently fluid to allow sinking of broken blocks of the Upper Border Zone (Fig. 86).

UPPER BORDER ZONE

The Upper Border Zone, as its name implies, is the zone of rocks above the Sodagranophyre Zone and in contact with the volcanic country rocks. It is poorly known and highly variable from one place to the other. It is discontinuous and lensey. In Rinfret and Lemoine Township, the following rock types have been observed:

   a. fine to medium-grained metagabbro

   b. gabbroic quartz-bearing metaferropyroxenite

   c. quartz-bearing coarse metagabbro

   d. very coarse gabbroic meta-anorthosite and anorthositic metagabbro.

TABLE 60

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. FERRODIORITE ZONE -F$_2$-

ANALYSES CHIMIQUES DES ROCHES DE LA ZONE DE FERRODIORITE -F$_2$- DU C.L.D.

Sample No. No. d'échantillon	B-70-27	B-70-72	B-70-62	B-70-85	B-70-259
SiO_2	45.10	49.40	46.80	43.90	45.90
TiO_2	3.93	1.40	2.02	3.31	3.05
Al_2O_3	15.23	13.30	12.16	12.84	14.51
Fe_2O_3	3.55	3.27	3.73	3.46	3.18
FeO	16.13	14.85	17.00	15.85	14.45
MnO	0.31		0.34	0.31	0.29
MgO	2.35		6.34	4.82	4.08
CaO	10.93	9.42	8.19	13.34	13.17
Na_2O	4.56		1.94	2.30	2.60
K_2O	0.23	0.45	0.17	0.18	0.13
P_2O_5		0.49			
H_2O+					
H_2O-					
CO_2					
S					
TOTAL	102.36	92.58	98.74	100.34	101.40
Norm wt%					
Qtz		20.59			
Cor					
Or	1.36	2.66	1.00	1.06	0.77
Plag	40.27	34.96	40.39	37.78	46.60
Ab	19.86		16.42	13.60	19.07
An	20.41	34.96	23.97	24.18	27.54
Ne	10.14			3.18	1.59
Wo					
Di	29.19	7.64	14.08	35.48	32.03
Wo	14.15	3.58	6.99	17.56	15.82
En	3.31		2.72	6.45	5.57
Fa	11.73	4.06	4.37	11.47	10.64
Hy		18.19	33.62		
En			12.88		
Fs		18.19	20.73		
Ol	8.76		0.37	11.52	9.98
Fo	1.78		0.14	3.89	3.22
Fa	6.98		0.24	7.63	6.77
Mt	5.15	4.74	5.41	5.02	4.61
Il	7.46	2.66	3.84	6.29	5.79
Hm					
Ap		1.16			
Py					
Cal					
Data Wt%					
An/plag	50.7	100.0	59.3	64.0	59.0
Fa/ol	79.6		63.9	66.2	67.8
En/hy			38.3		
Diff.i.	31.3	23.2	17.4	17.8	21.4
Qtz		88.5			
Ab			94.2		
Or		11.4	5.8		
An	49.0	92.9	57.9	62.2	58.1
Ab	47.7		39.7	35.0	40.2
Or	3.2	7.0	2.4	2.7	1.6
A	17.9	2.4	7.2	9.3	11.1
F	73.3	97.5	71.0	72.5	72.1
M	8.8		21.7	18.1	16.7
Na+K/Al	50.9	3.7	27.8	31.0	30.4
Fo+Mn/Fe+Mg	82.4	100.0	64.7	69.1	70.8
Na_2O/Na_2O+K_2O	95.2		91.9	92.7	95.2

TABLE 61

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. FERRODIORITE ZONE $-F_2-$

ANALYSES CHIMIQUES DES ROCHES DE LA ZONE DE FERRODIORITE $-P_2-$ DU C.L.D.

Sample No. No. d'échantillon	B-70-84	B-70-277	B-70-570	B-70-567
SiO_2	53.90	37.80	48.70	51.10
TiO_2	0.84	2.92	0.91	0.70
Al_2O_3	18.34	11.02	15.90	16.65
Fe_2O_3	1.54	4.74	2.13	1.46
FeO	7.01	21.56	9.68	6.65
MnO	0.18	0.34	0.25	0.16
MgO	5.00	5.55	6.22	5.62
CaO	10.92	11.03	12.56	10.97
Na_2O	3.50	1.03	3.89	3.06
K_2O	0.18	0.46	0.14	0.16
P_2O_5		0.76		
H_2O+				
H_2O-				
CO_2				
S				
TOTAL	101.98	97.15	100.44	96.58
Norm wt%				
Qtz	1.45			1.18
Cor				
Or	1.06	2.72	0.83	0.95
Plag	63.42	32.80	46.47	57.12
Ab	29.62	8.71	20.96	25.89
An	33.80	24.09	25.51	31.22
Ne			6.48	
w				
Di	17.59	21.89	30.50	19.08
Wo	8.93	10.75	15.41	9.73
En	4.72	3.40	7.68	5.42
Fa	3.94	7.74	7.41	3.93
Hy	14.17			14.79
En	7.73			8.57
Fs	6.44			6.21
Ol Fo		25.63	11.30	
		7.30	5.48	
Fa		18.33	5.83	
Mt	2.23	6.87	3.09	2.12
Il	1.60	5.55	1.73	1.33
Hm				
Ap		1.80		
Py				
Cal				
Data Wt%				
An/plag	53.3	73.4	54.9	54.7
Fa/ol		71.5	51.5	
En/hy	54.5			58.0
Diff.i.	32.1	11.4	28.2	25.0
Qtz	4.5			4.1
Ab	92.1			92.4
Or	3.3			3.3
An	52.4	67.8	53.9	53.6
Ab	45.9	24.5	44.3	44.6
Or	1.6	7.6	1.7	1.6
A	21.3	4.4	18.2	19.0
F	49.6	78.9	53.5	47.8
M	29.0	16.6	28.2	33.1
Na+K/Al	32.4	19.9	41.2	31.2
Fe+Mn/Fe+Mg	49.0	72.5	51.7	44.8
Na_2O/Na_2O+K_2O	95.1	69.1	96.5	95.0

TABLE 62

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. FERRODIORITE ZONE -P-

ANALYSES CHIMIQUES DES ROCHES DE LA ZONE DE FERRODIORITE -P- DU C.L.D.

Sample No. / No. d'échantillon	B70-557	B70-127	B70-102	B70-122	B70-141	B70-211A	B70-214	B70-96
SiO_2	46.40	34.40	40.10	55.70	40.70	34.10	42.90	50.10
TiO_2	3.42	4.11	3.65	0.36	3.29	3.40	4.18	0.71
Al_2O_3	13.98	6.21	11.45	18.88	12.22	9.85	10.47	19.03
Fe_2O_3	3.45	6.65	4.22	1.19	4.38	5.50	4.47	1.52
FeO	15.68	30.23	19.16	5.39	19.90	24.98	20.30	6.90
MnO	0.15	0.58	0.34	0.13	0.45	0.47	0.39	0.15
MgO	4.18	3.95	3.00	5.80	2.79	3.22	4.65	4.43
CaO	6.11	5.31	11.35	11.11	7.92	9.57	9.16	11.04
Na_2O	5.48	1.16	3.76	4.30	2.38	1.64	1.72	4.60
K_2O	0.35	0.19	0.15	0.36	0.41	0.41	0.14	0.51
P_2O_5			0.49				0.22	
H_2O+								
H_2O-								
CO_2								
S								
TOTAL	99.23	92.82	97.70	103.28	94.48	93.17	98.65	99.28

Norm wt%								
Qtz								
Cor								
Or	2.07	1.12	0.89	2.13	2.42	2.42	0.83	3.01
Plag	46.20	20.99	25.46	67.54	41.59	21.03	34.99	55.57
Ab	33.69	9.82	11.54	36.39	20.14	2.72	14.55	26.70
An	12.51	11.18	13.92	31.15	21.45	18.30	20.43	28.87
Ne	6.87		10.98			6.04		7.54
Lc								
Di	15.13	13.18	33.78	19.59	15.49	25.32	20.13	21.49
Wo	7.47	6.36	16.38	10.05	7.48	12.20	9.68	10.86
En	2.58	1.24	3.85	5.99	1.58	2.36	3.05	5.42
Fa	5.09	5.59	13.55	3.54	6.43	10.76	7.21	5.20
Hy		17.18		6.56	6.98		24.78	
En		3.12		4.12	1.38		7.36	
Fs		14.06		2.44	5.61		17.41	
Ol	17.45	22.88	12.38	5.01	15.38	23.91	2.96	8.09
Fo	5.49	3.84	2.54	3.04	2.80	3.97	0.82	3.93
Fa	11.96	19.04	9.84	1.98	12.58	19.94	2.14	4.16
Mt	5.00	9.64	6.12	1.73	6.35	7.97	6.48	2.20
Il	6.50	7.81	6.93	0.68	6.25	6.46	7.94	1.35
Hm								
Ap			1.16				0.52	
Py								
Cal								

Data Wt%								
An/plag	27.1	53.2	54.7	46.1	51.6	87.0	58.4	52.0
Fa/ol	68.5	83.2	79.5	39.5	81.8	83.4	72.3	51.4
En/hy		18.2		62.8	19.7		29.7	
Diff.1.	42.6	10.9	23.4	38.5	22.6	11.2	15.4	37.2

Qtz								
Ab		89.7		94.5	89.3		94.6	
Or		10.3		5.5	10.7		5.4	

An	25.9	50.5	52.8	44.7	48.7	78.1	57.0	49.3
Ab	69.8	44.4	43.8	52.2	45.8	11.6	40.7	45.6
Or	4.3	5.1	3.4	3.0	5.5	10.3	2.3	5.1

L	20.0	3.2	12.9	27.3	9.3	5.7	5.9	29.2
F	65.6	87.4	77.2	38.6	81.3	85.3	79.2	46.4
M	14.3	9.4	9.9	34.0	9.3	9.0	14.9	24.4

Na+K/Al	67.2	34.0	55.4	39.5	35.7	32.0	28.5	44.4
FeMn/FeMnMg	71.7	83.9	81.3	38.9	83.0	84.1	74.9	51.7
Na_2O/Na_2O+K_2O	96.0	90.3	93.4	92.3	85.3	80.0	92.5	90.4

TABLE 63

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. FERROJIORITE ZONE -F-

ANALYSES CHIMIQUES DES ROCHES DE LA ZONE DE FERROJIORITE -F- DU C.L.D.

Sample No. No. d'échantillon	B70-97	B70-338	B70-227	B70-107	B70-301	B70-39	B70-10	B70-7
SiO_2	38.40	51.80	49.10	36.90	42.60	51.10	46.90	38.20
TiO_2	2.82	0.65	0.70	3.08	3.17	0.55	4.41	5.21
Al_2O_3	11.96	16.48	13.45	10.91	13.45	16.54	16.93	13.18
Fe_2O_3	4.65	2.23	3.00	4.50	3.05	1.50	3.49	4.43
FeO	21.17	10.14	13.63	20.50	13.85	6.85	15.86	20.14
MnO	0.35	0.31	0.30	0.39	0.29	0.12	0.28	0.43
MgO	3.13	7.30	6.36	4.27	6.28	5.33	1.61	3.08
CaO	10.63	9.55	9.26	10.80	16.66	9.44	8.03	6.95
Na_2O	3.40	3.52	2.34	1.96	1.82	2.38	5.24	2.39
K_2O	0.79	1.01	0.91	0.19	0.11	0.11	0.23	0.21
P_2O_5	2.40		0.31	1.18				1.00
H_2O+								
H_2O-								
CO_2								
S								
TOTAL	99.74	103.02	99.41	96.72	101.32	93.97	103.02	97.26

Norm wt%								
Qtz						6.54		
Cor								
Or	4.67	5.97	5.38	1.12	0.49	0.65	1.36	1.24
Plag	27.55	55.97	43.31	36.49	28.21	54.26	54.55	44.84
Ab	12.51	29.79	19.80	16.08		20.14	32.56	20.22
An	15.04	26.18	23.51	20.41	28.21	34.12	21.99	24.61
Ne	8.81			0.27	8.34		6.38	
Wo								
Di	19.08	17.45	17.14	21.85	45.37	10.53	15.55	11.46
Wo	9.23	8.84	8.55	10.66	22.78	5.35	7.48	5.57
En	1.98	4.55	3.60	2.96	10.44	2.87	1.38	1.36
Fs	7.88	4.07	4.98	8.22	12.16	2.30	6.69	4.53
Hy		0.55	21.27			18.74		1.80
En		0.29	8.92			10.40		0.42
Fs		0.26	12.35			8.34		1.38
Ol	21.95	18.57	5.88	21.85	8.33		11.72	19.27
Fo	4.08	9.35	2.33	5.38	3.65		1.84	4.13
Fa	17.87	9.22	3.55	16.48	4.68		9.87	15.14
Mt	6.74	3.23	4.35	6.52	4.42	2.17	5.06	6.42
Il	5.36	1.23	1.33	5.85	6.02	1.04	8.38	9.89
Hm								
Ap	5.68		0.73	2.79				2.37
Py								
Cal								

Data Wt%								
An/plag	54.6	46.8	54.3	55.9	100.0	62.9	40.3	54.9
Fa/ol	81.4	49.6	60.4	75.4	56.2		84.3	78.6
En/hy		52.8	41.9			55.5		23.1
Diff.i.	26.0	35.7	25.2	17.5	9.0	27.3	40.3	21.5

Qtz						23.9		
Ab		83.3	78.6			73.7		94.2
Or		16.7	21.4			2.4		5.8

An	46.7	42.3	48.3	54.3	98.3	62.1	39.3	53.4
Ab	38.8	48.1	40.7	42.8		36.7	58.2	43.9
Or	14.5	9.6	11.0	3.0	1.7	1.2	2.4	2.7

A	12.6	18.7	12.4	6.8	7.7	15.4	20.7	8.6
F	78.0	51.1	63.4	79.6	67.3	51.6	73.2	81.2
M	9.4	30.2	24.2	13.6	25.0	33.0	6.1	10.1

Na+K/Al	54.0	41.8	35.9	31.4	23.1	24.4	52.4	31.6
FeMn/FeMnMg	82.1	48.9	59.5	76.6	60.1	46.7	87.0	81.7
Na_2O/Na_2O+K_2O	81.1	77.7	72.0	91.2	94.3	95.6	95.8	91.9

Table 64

Notes on samples of Tables 60, 61, 62, and 63.

TABLES 60 AND 61. F_2 MEMBER OF THE FERRODIORITE ZONE OF THE DORE LAKE COMPLEX

B-70-27 Baskin, 1975, anal. 26, p. 148. Ferrodiorite. Obalski Township. 150 feet (45 m) west of the main road, 13,000 feet (3900 m) south of the old road to Campbell mine.

B-70-72 Baskin, 1975, anal. 27, p. 149. Ferrodiorite. Obalski Township. 400 feet (120 m) east of the north end of Gladstone Lake.

B-70-62 Baskin, 1975, anal. 28, p. 150. Ferrodiorite. Obalski Township. 400 feet (120 m) east of the north end of Gladstone Lake.

B-70-85 Baskin, 1975, anal. 29, p. 151. Ferrodiorite. Obalski Township. A little north of samples 72 and 62.

B-70-259 Baskin, 1975, anal. 30, p. 152. Ferrodiorite, Obalski Township. 800 feet (240 m) east of the north end of Gladstone Lake.

B-70-84 Baskin, 1975, anal. 31, p. 153. Ferrodiorite, Obalski Township. Roughly the same as for sample 85.

B-70-277 Baskin, 1975, anal. 32, p. 154. Ferropyroxenite. Obalski Township. 700 feet (210 m) east of the north end of Gladstone Lake.

B-70-570 Baskin, 1975, anal. 33, p. 155. Ferrodiorite. Obalski Township. 1800 feet (540 m) north-northwest of the north tip of Gladstone Lake.

B-70-567 Baskin, 1975, anal. 34, p. 156. Ferrodiorite. Obalski Township. 1200 feet (360 m) northeast of the north end of Gladstone Lake.

TABLES 62 AND 63. FERRODIORITE ZONE OF THE DORE LAKE COMPLEX

B-70-557 Baskin, 1975, anal. 10, p. 132. Ferrodiorite. Obalski Township. West shore of the central part of Cache Lake.

B-70-127 Baskin, 1975, anal. 11, p. 133. Ferroperidotite, Obalski Township. Middle of the peninsula between the two arms of Cache Lake.

B-70-102 Baskin, 1975, anal. 12, p. 134. Ferrodiorite, Obalski Township. Very close to sample 127 above.

B-70-122 Baskin, 1975, anal. 13, p. 135. Leucodiorite, Obalski Township. Western part of the peninsula between the two arms of Cache Lake.

B-70-141 Baskin, 1975, anal. 14, p. 136. Ferropyroxenite, Obalski Township. Western part of the peninsula between the two arms of Cache Lake.

B-70-211A Baskin, 1975, anal. 15, p. 137. Ferropyroxenite, Obalski Township. East of the main road, 16,200 feet (4820 m) south of the old road to Campbell mine.

B-70-214 Baskin, 1975, anal. 16, p. 138. Ferrodiorite, Obalski Township. East of the main road, 16,200 feet (4820 m) south of the old road to Campbell mine.

B-70-96 Baskin, 1975, anal. 17, p. 139. Ferrodiorite, Obalski Township. 1000 feet (300 m) east of the southwest tip of the western arm of Cache Lake on peninsula.

B-70-97 Baskin, 1975, anal. 18, p. 140. Ferrodiorite, Obalski Township. 1000 feet (300 m) east of the southwest tip of the western arm of Cache Lake on peninsula.

B-70-338 Baskin, 1975, anal. 19, p. 141. Ferrodiorite, Obalski Township. 300 feet (90 m) west of the northwest corner of Cache Lake.

B-70-227 Baskin, 1975, anal. 20, p. 142. Ferrodiorite, Obalski Township. 300 feet (90 m) west of the northwest corner of Cache Lake.

B-70-107 Baskin, 1975, anal. 21, p. 143. Ferrodiorite, Obalski Township. Three hundred feet (90 m) west of shore on peninsula between arms of Cache Lake.

B-70-301 Baskin, 1975, anal. 22, p. 144. Ferropyroxenite, Obalski Township. Half way between Gladstone Lake and south tip of the west arm of Cache Lake.

B-70-39 Baskin, 1975, anal. 23, p. 145. Ferrodiorite, Obalski Township. 1000 feet (300 m) east of Gladstone Lake.

B-70-10 Baskin, 1975, anal. 24, p. 146. Ferrodiorite, Obalski Township. Four hundred feet (120 m) west of the main road, 13,700 feet (4110 m) south of the old road to Campbell mine.

B-70-7 Baskin, 1975, anal. 25, p. 147. Ferrodiorite, Obalski Township. Four hundred feet (120 m) west of the main road, 13,700 feet (4110 m) south of the old road to Campbell mine.

TABLE 65

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. SODAGRANOPHYRE   - OBALSKI

ANALYSES CHIMIQUES DES ROCHES DE LA ZONE DE SODAGRANOPHYRE - OBALSKI

Sample No. / No. d'échantillon	B70-5	B70-383	B70-60	B70-59	B70-188	B70-133	B70-483	B70-591
SiO_2	76.00	79.70	74.30	68.90	68.70	64.90	62.80	65.80
TiO_2	0.19	0.38	0.49	0.53	0.69	1.21	1.21	0.64
Al_2O_3	11.76	11.93	10.29	12.23	11.61	13.12	15.00	10.96
Fe_2O_3	0.56	0.47	1.19	1.87	2.55	2.80	1.98	2.55
FeO	1.82	1.52	4.80	6.00	8.22	9.03	6.38	8.22
MnO	0.04	0.08	0.07	0.09	0.10	0.13	0.16	0.21
MgO	0.06	0.10	0.15	0.73	1.54	1.35	1.39	0.54
CaO	0.26	0.36	2.36	2.23	0.76	1.99	3.78	6.43
Na_2O	6.20	6.48	6.00	4.34	2.60	5.28	4.48	1.40
K_2O	2.29	1.00	0.33	0.19	1.15	0.38	0.33	0.10
P_2O_5								
H_2O+								
H_2O-								
CO_2								
S								
TOTAL	99.20	102.04	100.31	97.12	97.94	100.21	97.53	96.88
Norm wt%								
Qtz	31.45	36.65	32.19	33.06	39.75	20.74	21.47	38.91
Cor				0.82	4.69	0.38	0.38	
Or	13.53	5.91	1.95	1.12	6.80	2.25	1.95	0.59
Plag	47.74	55.34	50.94	47.81	25.82	54.60	56.71	35.17
Ab	47.74	54.83	50.77	36.72	22.00	44.68	37.91	11.85
An		0.51	0.17	11.09	3.82	9.93	18.81	23.33
Ne								
Wo								
Di	1.19	1.16	10.27					7.59
Wo	0.56	0.55	4.85					3.61
En	0.03	0.07	0.28					0.39
Fs	0.60	0.54	5.14					3.59
Hy	2.62	1.57	1.86	10.58	15.87	15.87	11.84	9.69
En	0.12	0.18	0.10	1.82	3.84	3.36	3.46	0.95
Fs	2.50	1.39	1.76	8.77	12.03	12.51	8.38	8.73
Ol Fo								
Fa								
Mt		0.68	2.16	2.71	3.70	4.06	2.87	3.70
Il	0.36	0.72	0.93	1.01	1.31	2.30	2.30	1.22
Hm								
Ap								
Py								
Cal								
Data Wt%								
An/plag		0.9	0.3	23.2	14.8	18.2	33.2	66.3
Fa/ol								
En/hy	4.6	11.5	5.1	17.2	24.2	21.2	29.2	9.8
Diff.i.	92.7	97.4	84.9	70.9	68.5	67.7	61.3	51.3
Qtz	33.9	37.6	37.9	46.6	58.0	30.6	35.0	75.8
Ab	51.5	56.3	59.8	51.8	32.1	66.0	61.8	23.1
Or	14.6	6.1	3.3	1.6	10.0	3.3	3.2	1.1
An		0.8	0.3	22.7	11.7	17.5	32.1	65.2
Ab	77.9	89.5	96.0	75.0	67.4	78.6	64.6	23.1
Or	22.1	9.6	3.7	2.3	20.8	3.9	3.3	1.6
A	77.7	78.2	49.6	34.5	23.3	30.0	33.0	11.7
F	21.8	20.8	49.3	59.9	67.1	62.8	57.4	84.1
M	0.5	1.0	1.2	5.5	9.6	7.2	9.5	4.2
Na+K/Al	107.8	98.4	99.4	60.1	47.6	69.3	51.5	22.0
Fualis/Felsic	95.7	91.9	95.9	85.7	79.5	82.9	77.1	91.8
Na_2O/Na_2O+K_2O	73.0	86.8	94.8	95.8	69.3	93.3	93.1	93.3

Fig. 72. Photomicrograph of pyroxene ferrodiorite (FZ).
Pyroxene is fresh except for a very narrow rim of chlorite.
White is fresh plagioclase. Field: 2.8 mm. Sample B-70-62.
from Baskin(1975) fig. 17, p. 42.
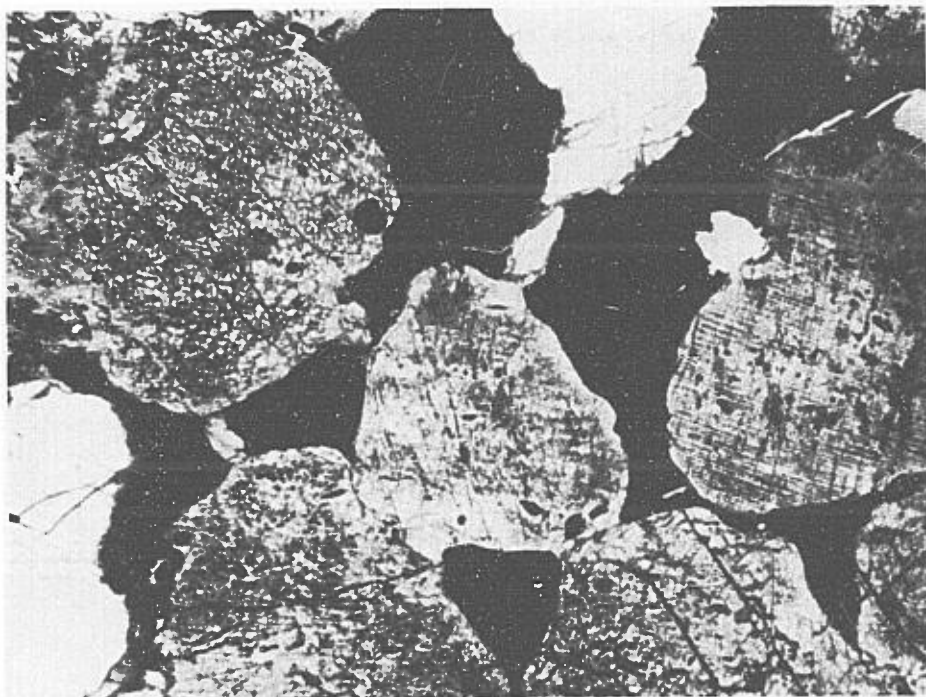
Fig. 73. Photomicrograph of pyroxene ferrodiorite (FZ).
Cumulus fresh pyroxene, plagioclase, and apatite (not seen in
the photo but present in quantity in the thin section).
Intercumulus Fe-oxide. Field is 7 mm. Baskin(1975) fig. 16,p.41.
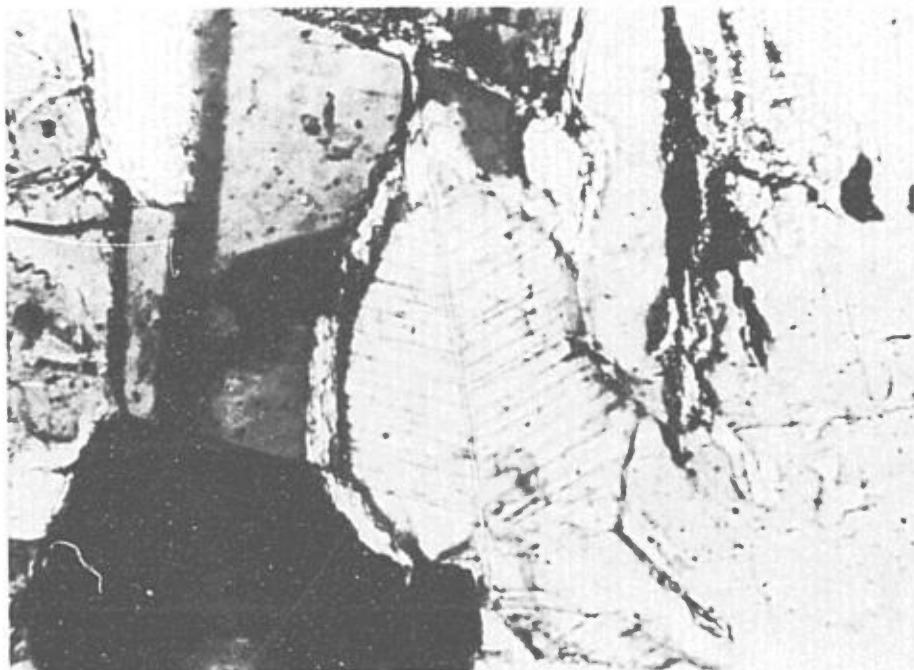
Fig. 74. Photomicrograph of pyroxene diorite from the F_2 member (FZ). Center grain is inverted pigeonite. The herringbone pattern is a result of exsolution of augite parallel to (001) of a twinned pigeonite prior to its inversion from a monoclinic structure. Broad lameallae are augite. Baskin (1975)fig.18,p43. Sample B-70-72.
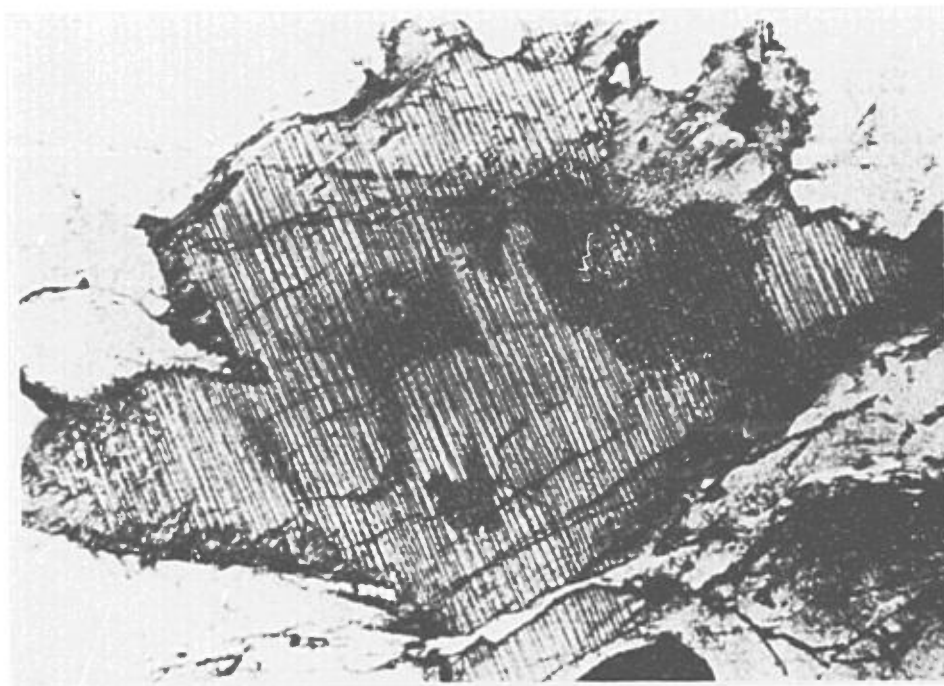
Fig. 75. Photomicrograph of pyroxene ferrodiorite (FZ). Exsolution of opaque needles gives the schiller texture of the clinopyroxene. The rim of the pyroxene is altered to fibrous actinolite. Sample B 70-27. Field: 2.8 mm. Baskin (1975) fig. 22, p. 50.

Fig. 76. Photomicrograph of gabbroic metaferropyroxenite (FZ).
Two types of magnetite are present: on the left, an n intercumulus
primary magnetite and on the right, magnetite intergrown with
amphibole resulting from the release of Fe as the ferropyroxene
is altered to amphibole. Sample B-70-127. Field is 5.5 mm.
From Baskin(1975), fig. 14, p. 36.
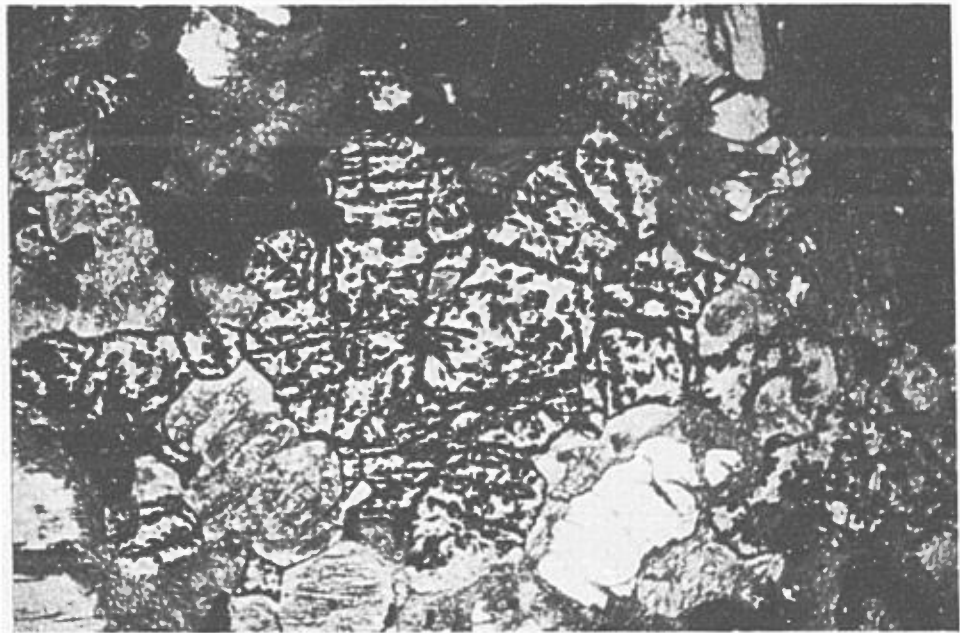
Fig. 77. Photomicrograph of gabbroic metaferropyroxenite
(metaperidotite?) from the F_1 member (FZ). Grunerite and
magnetite replace an original Fe-rich olivine.
Sample B-70-127. Field: 7 mm. From Baskin(1975) fig.12,p.34.
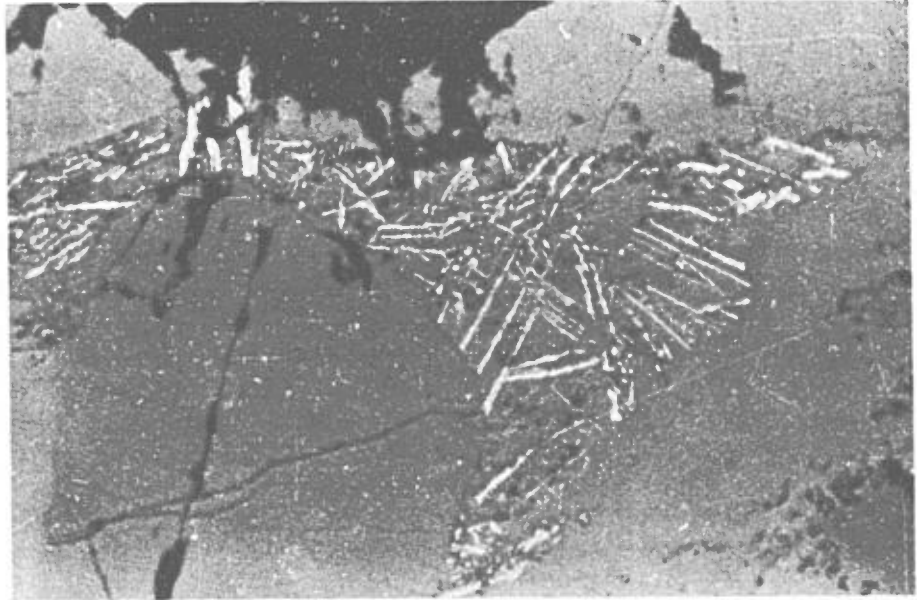
Fig. 78. Photomicrograph (reflected light) of ferrodiorite (FZ)
The intercumulus (?) oxide grains are replaced by chlorite and
the ilmenite remains intact. The multiple orientation of the
ilmenite blades suggests a series of small cumulus grains
instead of a large patch of intercumulus oxide. Sample
B-70-259. Field: 6 mm. From Baskin(1975), fig.25, p. 53.
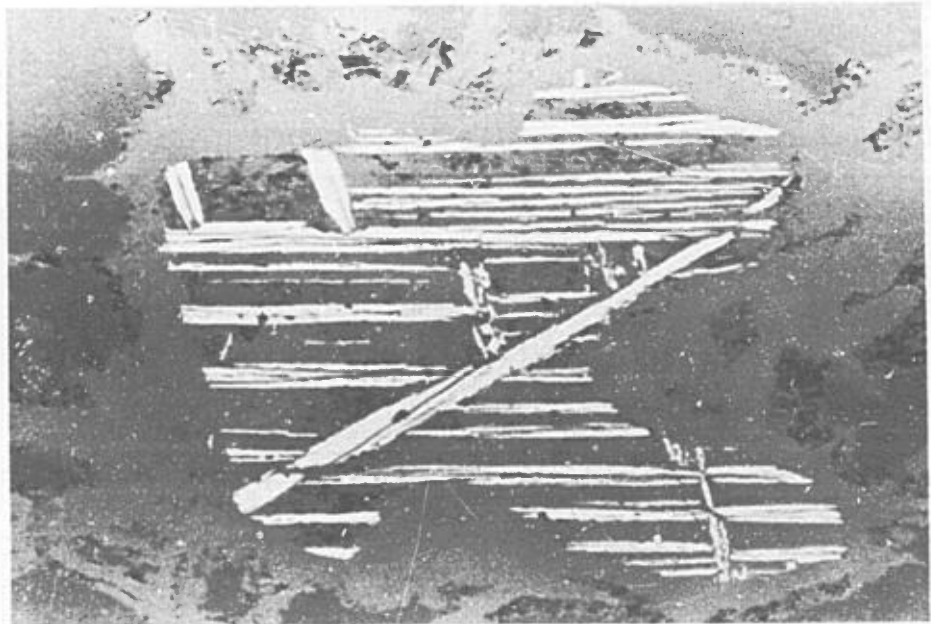
Fig. 79. Photomicrograph (reflected light) of pyroxene
ferrodiorite(FZ). Oxidation of the ulvospinel produces
ilmenite lamellae parallel to (111) of magnetite.
The magnetite is replaced by chlorite and amphibole but
the ilmenite is left intact. Compare with Fig.42 where the
ilmenite is altered to sphene. Sample B-70-259. f Field:.6 mm.
From Baskin (1975), fig. 24, p. 52.
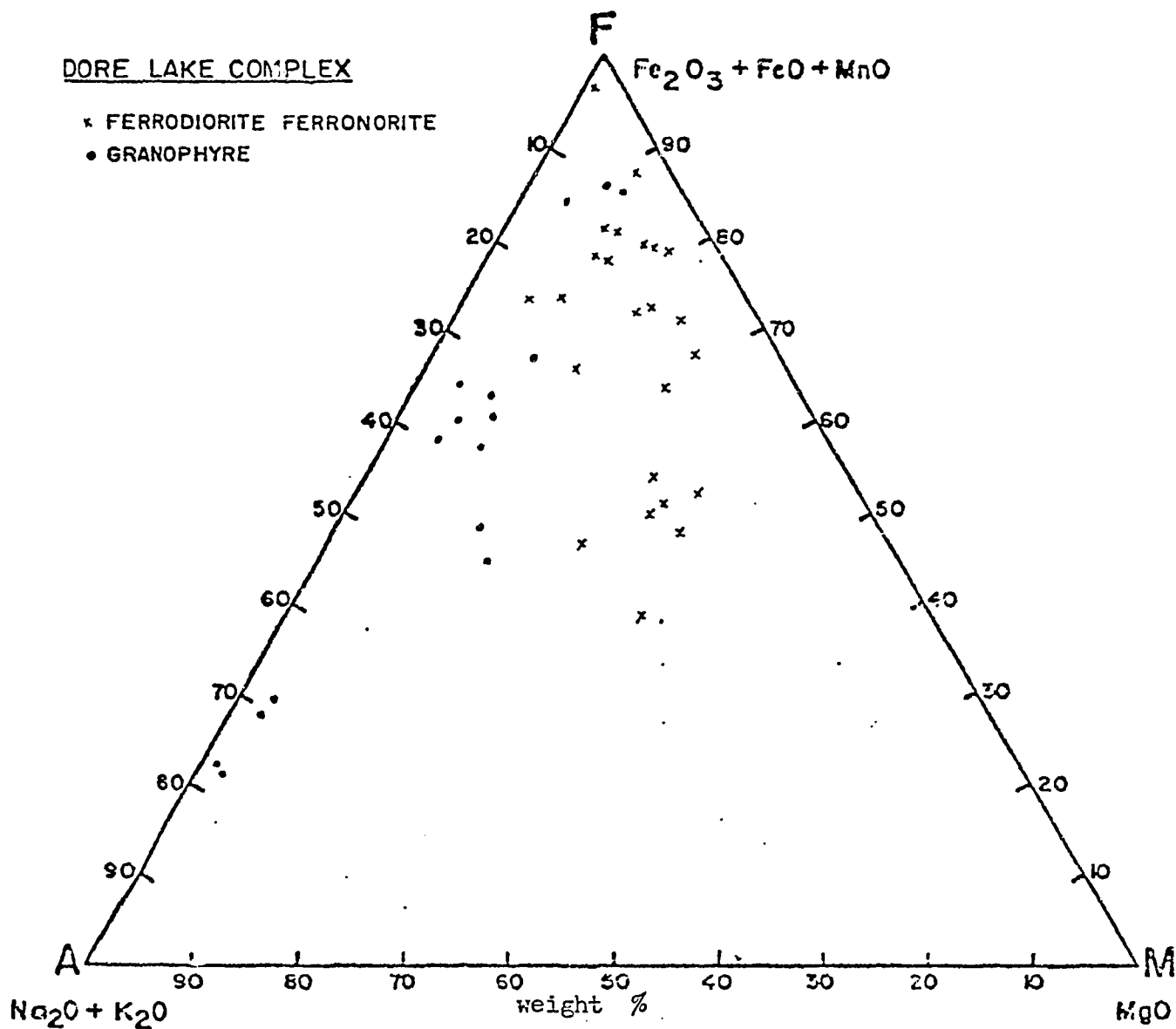
Fig. 80. AFM diagram for the Ferrodiorite and Sodagranophyre Zone

Fig. 81. Typical glaciated outcrop of sodagranophyre (SZ).
Lemoine Township by the old camp at the Five Mile Lake
road intersection.
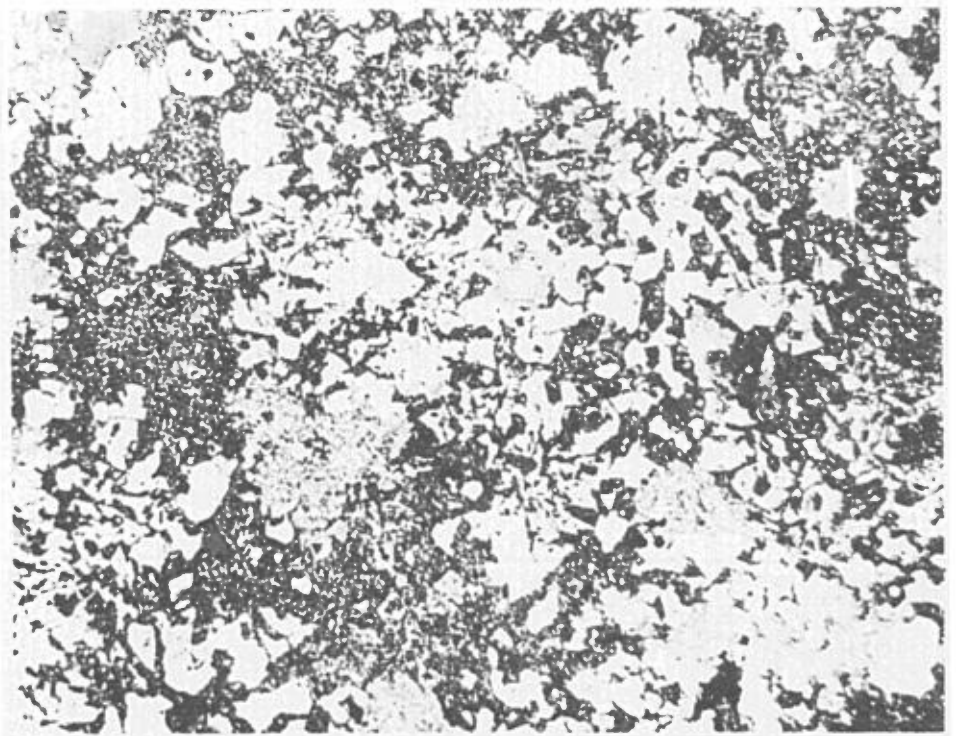
Fig. 82. Photomicrograph of sodagranophyre. Clear
quartz grains are composite grains with the same
optical orientation over large areas of the slide.
The matrix consists in plagioclase, sericite, chlorite,
and minor zircon, opaque, and apatite. Field: 1.1 cm.
Sample 53-205 (52).
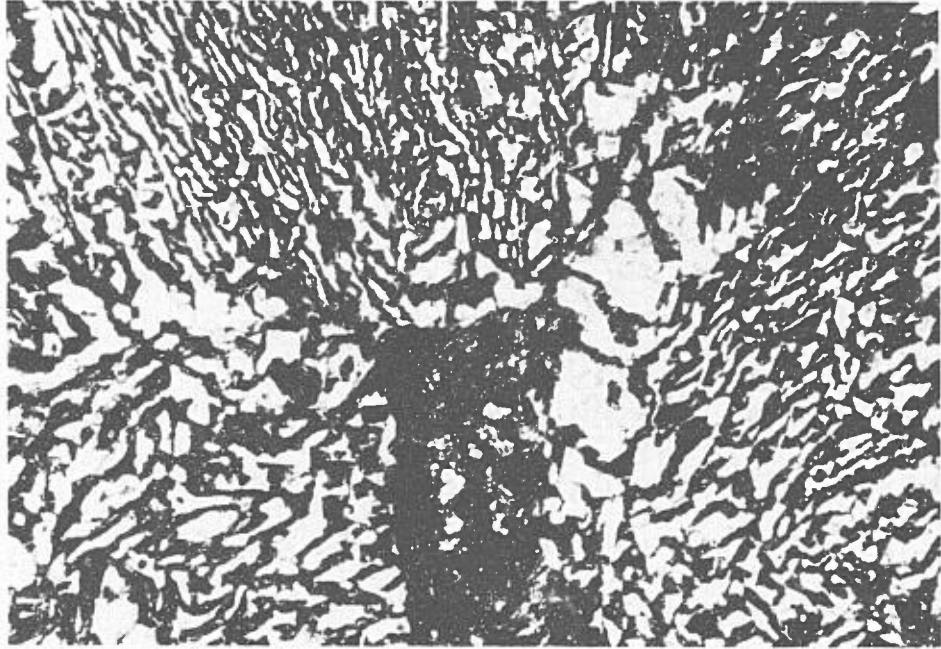
Fig. 83. Photomicrograph of a chlorite-rich sodagranophyre (SZ).
Euhedral plagioclase crystal serves as a nucleation center for
the granophyric intergrowth. The plagioclase is altered to
albite, chlorite, and clinozoisite. Field: 2.8 mm.
Sample B-70-468. From Baskin (1975), fig. 33, p.65.
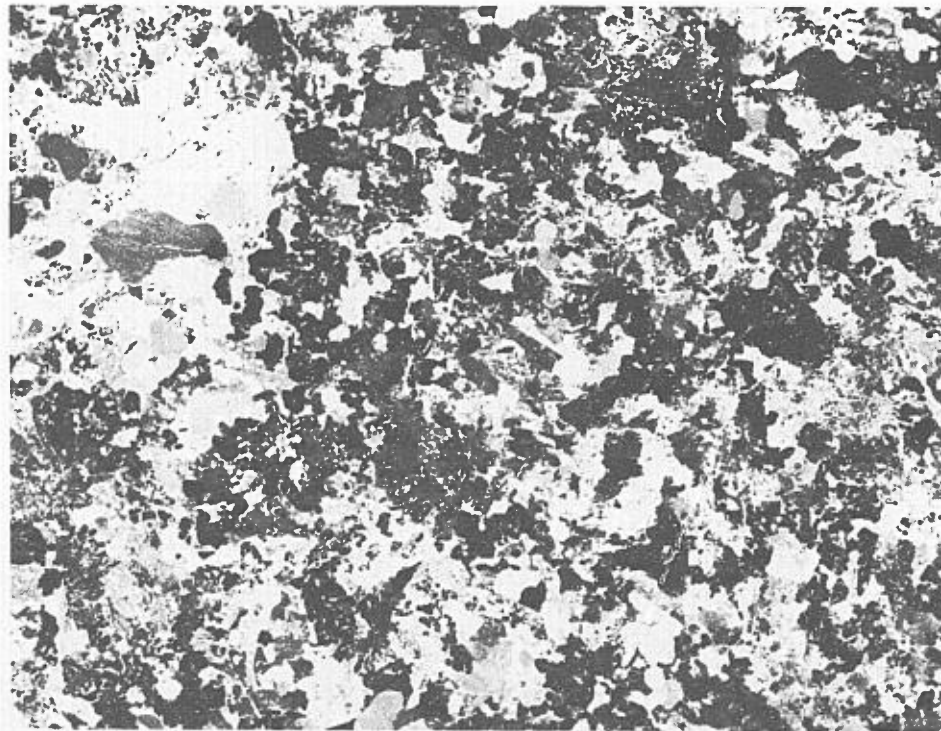
Fig. 84. Photomicrograph of a chlorite-poor sodagranophyre(SZ).
The rock consists of quartz, plagioclase, and minor sericite,
opaque, and zircon. Sample B-70-5. Field: 3 cms.

Fig. 85. Inch-scale layering in quartz-rich metaferropyroxenite from the top of P$_3$ (LZ) very close to the contact with the Sodagranophyre Zone. The light-colored layers are rich in quartz and plagioclase. Close to the Five Mile Lake road. Scale is 6 inches   long(15 cms).
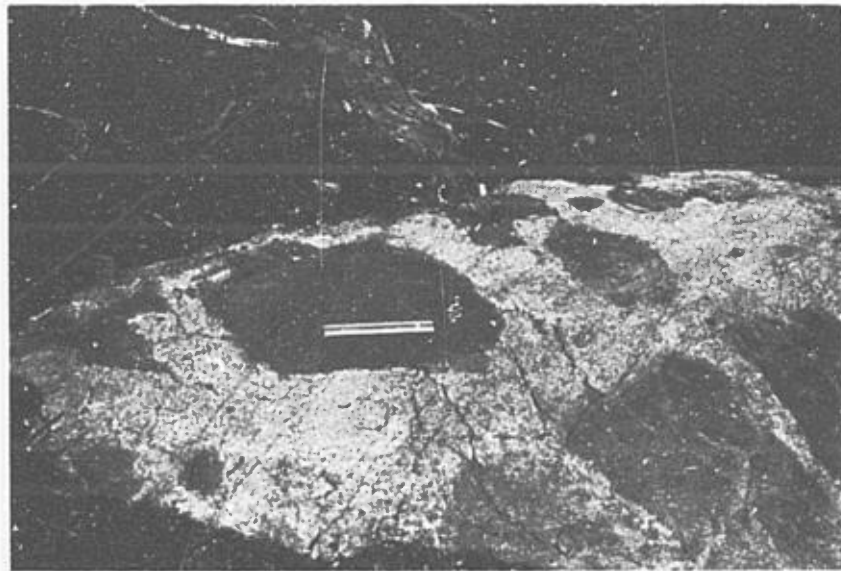
Fig. 86. Blocks of fine-grained metagabbro from the Upper Border Zone in sodagranophyre. Outcrop at the junction of the Rinfret road and the Five Mile Lake road. Scale is 6 inches long (15 cms).
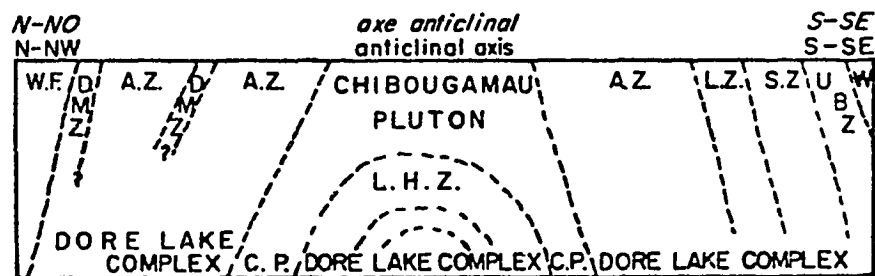
Fig. 87. Idealized cross-section of the Dore Lake
Complex east of Portage Island showing the position
of the postulated Lower Hidden Zone. Section is
roughly 12 miles (19 kms) long.
WF: Waconichi Formation; DMZ: magnetite-rich
Ferrodunite Zone; AZ: Anorthosite Zone;
LZ: Layered Zone; SZ: Sodagranophyre Zone;
UBZ: Upper Border Zone.
LHZ: Lower Hidden Zone.
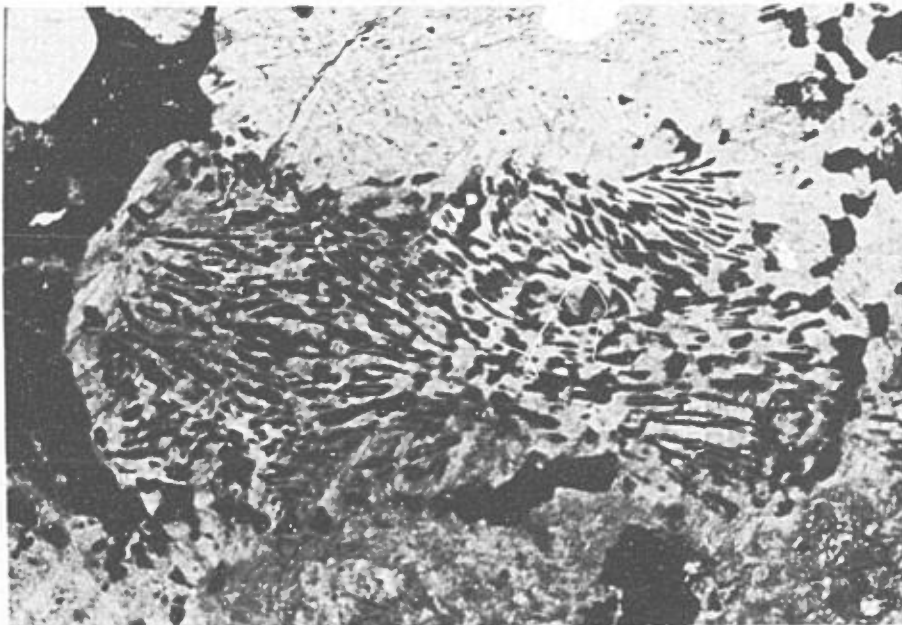
Fig. 88. Symplectic intergrowth of magnetite and amphibole in metaferropyroxenite or metaferroperidotite(FZ), replacing an original ferropyroxene. Sample B-70-277. Field: 2.8 mm. From Baskin (1975), fig. 29, p. 58.
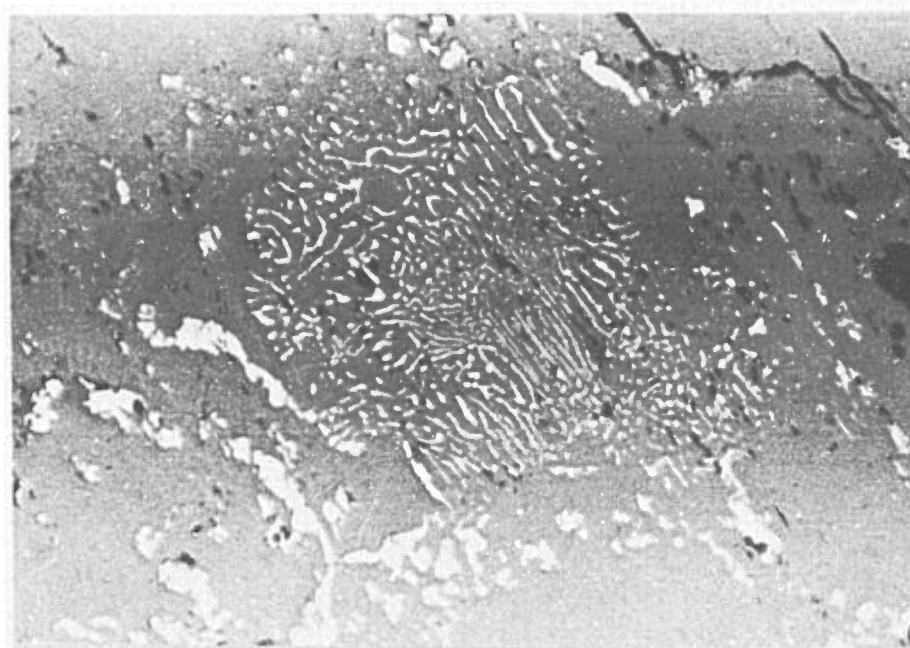
Fig. 89. Photomicrograph (reflected light) of a symplectic intergrowth of magnetite and amphibole in pyroxene ferrodiorite (FZ). This is the product of metamorphism of a ferropyroxene. Field: .6mm. Sample B-70-259. From Baskin(1975), fig.27,p.56.

In Scott and Obalski Township, at the west end of the north limb, the following rocks have been observed:

a. coarse anorthositic metagabbro and gabbroic meta-anorthosite

b. fine-grained metagabbro

c. metadiabase

d. metaferropyroxenite with small amounts of quartz, ilmenite, and magnetite.

Chemical analyses of rocks from the Upper Border Zone are found in Tables 66 and 67.

The mineralogy of the rocks listed above is similar to that of other rocks of the same nature already discussed in the other zones. The coarse gabbroic anorthosite rocks are very similar to A_1 and A_2 rocks of the Layered Zone. They consist of clinozoisite albite aggregates replacing original calcic plagioclase, actinolite, chlorite, and minor Fe-Ti oxides, sphene, calcite, and sericite. The texture is cumulus-intercumulus but the chemical and petrographic nature of the rocks and their stratigraphic position lead us to the conclusion that they have floated to the top of the magma chamber, probably at the time of formation of the Layered Zone. Whether they floated directly upwards or were carried upward by convecting currents and became stuck in a crystallizing liquid cannot be ascertained.

LOWER MAGNETITE-BEARING LAYERED ZONE

A lower magnetite-bearing zone was discovered in 1975 by SELCO in drilling an anomaly at the northeast corner of Lac des Iles in Lemoine Township (Plate 1). A weak airborne magnetic anomaly indicates that this zone extends for 13 miles (21 kms) and is very close to the contact between the Chibougamau pluton and Dore Lake Complex.

The information we have is limited to a single short (131 feet, 39 m.) drill hole (small core), 12 thin sections, and 7 partial chemical analyses and

TABLE 66

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. UPPER BORDER ZONE

ANALYSES CHIMIQUES DES ROCHES DE LA ZONE DE BORDURE SUPÉRIEURE DU C.L.D.

Sample No. / No. d'échantillon	71-140	J71-203	W29-208	W29-218	W-16-10
SiO_2	47.35	53.80	49.50	49.94	48.56
TiO_2	0.33	0.95	0.94	0.93	0.95
Al_2O_3	27.10	15.40	17.90	14.77	19.03
Fe_2O_3	2.32	2.18	1.82	2.12	2.04
FeO	1.30	6.54	6.63	7.73	6.25
MnO	0.06	0.14			
MgO	1.52	5.05	5.80	7.40	6.04
CaO	11.44	7.35	11.27	11.76	11.62
Na_2O	3.62	2.05	3.11	1.95	2.89
K_2O	1.90	0.45	0.07	0.04	0.15
P_2O_5	0.05				
H_2O+	2.47				
H_2O-	<0.10				
CO_2	0.40				
S	0.01				
TOTAL	99.97	93.91	97.04	96.64	97.53
Norm wt%					
Qtz		13.90		3.06	
Cor					
Or	11.23	2.66	0.41	0.24	0.89
Plag	71.37	48.84	60.99	47.93	62.96
Ab	19.29	17.35	26.32	16.50	24.45
An	52.08	31.49	34.67	31.43	38.51
Ne	6.15				
Wo					
Di	1.41	4.07	17.31	21.90	15.53
Wo	0.76	2.08	8.87	11.24	7.99
En	0.65	1.17	5.18	6.70	4.88
Fa		0.83	3.27	3.96	2.67
Hy		19.48	10.63	18.68	7.19
En		11.41	6.52	11.73	4.65
Fs		6.07	4.11	6.94	2.54
Ol Fo	2.21		3.27		6.20
Fo	2.20		1.93		3.87
Fa	0.01		1.34		2.33
Mt	3.36	3.16	2.64	3.07	2.96
Il	0.63	1.80	1.79	1.77	1.80
Hm					
Ap	0.12				
Py	0.02				
Cal	0.91				
Data Wt%					
An/plag	73.0	64.5	56.8	65.6	61.1
Fa/ol	0.48		44.0		37.5
En/hy		58.5	61.3	62.8	64.7
Diff.i.	36.7	33.9	26.7	19.6	25.3
Qtz		41.0		15.4	
Ab		51.1	98.4	83.3	96.5
Or		7.8	1.55	1.2	3.5
An	63.0	61.1	56.5	65.2	60.3
Ab	23.3	33.7	42.9	34.3	38.3
Or	13.6	5.2	0.7	0.5	1.4
A	51.8	15.4	18.2	10.3	17.5
F	34.0	53.6	48.5	51.2	47.7
M	14.3	31.0	33.3	38.5	34.8
Na+K/Al	29.6	25.1	29.0	22.0	25.8
Fe+Mn/Fe+Mg	56.0	49.0	44.4	42.2	42.9
Na_2O/Na_2O+K_2O	65.6	82.0	97.8	98.0	95.0

TABLE 67

CHEMICAL ANALYSES OF ROCKS FROM UNIT D.L.C. UPPER BORDER ZONE

ANALYSES CHIMIQUES DES ROCHES DE LA ZONE DE BORDURE SUPERIEURE DU C.L.D.

Sample No. No. d'échantillon	OB-202-235	OB-195-380	B70-497	B70-130	70-62
SiO_2	58.00	60.10	44.10	48.40	62.60
TiO_2	1.05	1.19	0.49	0.63	0.96
Al_2O_3	11.25	11.70	23.12	22.80	11.62
Fe_2O_3	1.29	3.70	2.65	2.23	2.43
FeO	11.53	9.00	7.65	6.36	11.06
MnO	0.26	0.22	0.15	0.13	0.35
MgO	1.19	1.10	3.86	4.00	0.87
CaO	4.70	3.82	13.82	10.55	2.99
Na_2O	3.76	4.34	4.46	4.40	4.12
K_2O	0.08	0.10	0.36	0.63	0.28
P_2O_5	0.37	0.38			
H_2O+	2.76	2.10			
H_2O-	0.09	0.05			
CO_2	3.49	1.75			
S	0.05	0.04			
TOTAL	99.87	99.59	100.72	100.17	97.30
Norm wt%					
Qtz	25.51	25.11			22.47
Cor	4.98	2.47			
Or	0.47	0.59	2.13	3.72	1.65
Plag	31.82	42.13	46.02	64.72	47.25
Ab	31.82	36.72	4.02	24.12	34.86
An		5.41	42.00	40.60	12.39
Ne			18.27	7.10	
Wo					
Di			22.19	9.75	2.19
Wo			11.13	4.93	1.04
En			5.08	2.52	0.13
Fa			5.97	2.59	1.02
Hy	21.72	14.57			18.39
En	2.96	2.74			2.04
Fs	18.75	11.83			16.35
Ol Fo			7.30	10.42	
			3.18	5.21	
Fa			4.12	5.21	
Mt	1.87	5.36	3.84	3.23	3.52
Il	1.99	2.26	0.93	1.20	1.62
Hm					
Ap	0.88	0.90			
Py	0.09	0.07			
Cal	7.52	3.98			
Data wt%					
An/plag		12.8	91.3	62.7	26.2
Fa/ol			56.4	50.0	
En/hy	13.6	18.8			11.1
Diff.i.	57.8	62.4	24.4	34.9	59.0
Qtz	44.1	40.2			38.0
Ab	55.0	48.8			59.1
Or	0.8	0.9			2.8
An		12.6	87.2	59.3	25.3
Ab	98.5	86.0	8.3	35.2	71.3
Or	1.5	1.4	4.4	5.4	3.4
A	21.5	24.3	25.4	28.5	23.4
F	71.8	69.6	54.2	48.7	71.9
M	6.7	6.0	20.3	22.7	4.6
Na+K/Al	55.7	61.9	33.4	34.7	60.9
Fe+Mn/Fe+Mn+Mg	85.9	86.5	59.7	54.4	89.8
Na_2O/Na_2O+K_2O	92.0	97.7	92.5	87.5	93.6

Table 68

Notes on samples of Tables 65, 66, and 67.

TABLE 65. SODAGRANOPHYRE ZONE OF THE DORE LAKE COMPLEX--OBALSKI TOWNSHIP

B-70-5   Baskin, 1975, anal. 35, p. 157. Sodagranophyre, Obalski Township. West of the south end of Half Moon Lake.

B-70-383 Baskin, 1975, anal. 36, p. 158. Sodagranophyre, Obalski Township. West of the center of Half Moon Lake.

B-70-60   Baskin, 1975, anal. 37, p. 159. Sodagranophyre, Obalski Township. South of the west end of Half Moon Lake.

B-70-59   Baskin, 1975, anal. 38, p. 160. Sodagranophyre, Obalski Township. South of the west end of Half Moon Lake.

B-70-188 Baskin, 1975, anal. 39, p. 161. Sodagranophyre, Obalski Township. South of the western tip of Half Moon Lake.

B-70-133 Baskin, 1975, anal. 40, p. 162. Sodagranophyre, Obalski Township. 4200 feet (1260 m) west-southwest of the western tip of Half Moon Lake.

B-70-483 Baskin, 1975, anal. 41, p. 163. Sodagranophyre, Obalski Township. South of Obalski shaft.

B-70-591 Baskin, 1975, anal. 42, p. 164. Sodagranophyre, Obalski Township. Road cut in curve at top of the hill on old road to Campbell mine.

TABLES 66 AND 67. UPPER BORDER ZONE OF THE DORE LAKE COMPLEX.

71-140   Allard, Q.D.N.R. Lab. Anorthositic metagabbro. Lemoine Township. 4100 feet (1230 m) north of Lemoine Township center line and 5000 feet (1500 m) east of Armitage River.

J-71-203 Allard, Q.D.N.R. Lab. Metagabbro. Lemoine Township. On Lemoine road, about 1400 feet (420 m) west of the Rinfret-Lemoine Township line.

W-29-208 Allard, Q.D.N.R. Lab. Anorthositic metagabbro. Scott Township. Drill hole 29 from 208 to 215. Chibougamau Copper at Williams Lake.

W-29-218 Allard, Q.D.N.R. Lab. Gabbro with coarse diabasic texture. Scott Township. Drill hole W 29 from 218 to 228, Chibougau Copper at Williams Lake.

W-16-10   Allard, Q.D.N.R. Lab. Gabbroic meta-anorthosite. Scott Township. Drill hole W 16 from 10 to 15, Chibougamau Copper at Williams Lake.

OB-202-235 Allard, Q.D.N.R. Lab. Metadiabase, Obalski Township. Drill hole OB 202, from 235 to 243, Obalski mine near shaft.

OB-195-380 Allard, Q.D.N.R. Lab. Metadiabase, Obalski Township. Drill hole OB 195, from 380 to 387, Obalski mine near shaft.

B-70-497 Baskin, 1975, anal. 43, p. 165. Anorthositic metagabbro, Obalski Township. Northeast of sample 130 below.

B-70-130 Baskin, 1975, anal. 44, p. 166. Anorthositic metagabbro, Obalski Township. 5100 feet (1530 m) west-southwest of the western tip of Half Moon Lake.

B-70-62   Baskin, 1975, anal. 45, p. 167. Metadiabase, Obalski Township. Four hundred feet (120 m) east of the northern part of Gladstone Lake.

Table 69

Comparison between the sodagranophyres of the Dore Lake Complex and other intrusions.

Comparison entre les sodagranophyres du complexe du Lac Doré et d'autres intrusions.

	1	2	3	4	5	6	7
SiO_2	70.14	73.86	67.0	66.21	61.65	58.78	73.66
TiO_2	0.67	0.38	0.86	1.11	1.20	1.29	0.22
Al_2O_3	12.11	13.16	12.30	11.92	14.11	11.45	13.45
Fe_2O_3	1.78	1.24	3.80	5.95	2.80	5.48	1.25
FeO	5.75	1.69	5.10	4.40	7.85	10.08	0.75
MnO	0.11	0.03	0.14	0.13	0.15	0.24	0.03
MgO	0.73	0.15	0.84	0.58	0.87	0.68	0.32
CaO	2.27	1.25	3.60	3.53	5.87	4.99	1.13
Na_2O	4.60	4.13	2.60	2.75	2.75	3.77	2.99
K_2O	0.72	3.55	3.40	3.08	2.46	2.01	5.35
H_2O^+	--	0.47	--	--	--	0.76	0.78
H_2O^-	--	0.11	--	--	--	0.15	--
P_2O_5	--	0.033	0.37	0.34	0.30	0.44	0.07

1. Sodagranophyres of the Dore Lake Complex (average of 8 analyses in Table 65).

2. Acid granophyre, Tinden sill, Skaergaard intrusion (Wager & Brown, 1967, Table 9, aver. of 2 samples).

3. Granophyres of the Dufek intrusion, Antarctica (Ford, 1970, p. 506, anal. A).

4. Granophyres from Tasmania (aver. of 3 anal., McDougall reported by Ford, 1970, p. 506, anal. E).

5. ayalite granophyres from Tasmania (aver. of 4 analyses, McDougall reported by Ford, 1970, p. 506, anal. D).

6. Melanogranophyres from the Skaergaard intrusion (Wager & Brown, 1967, Table 9, p. 159, aver. of 3 samples).

7. Calc-alkali rhyolite (average of 22 analyses, Nockolds, 1954, p. 1012, anal. II).

magnetic concentrate analyses. Portions of the core were split and sent to the
Q.D.N.R. laboratories for analyses and magnetite concentrate testing (we
acknowledge the loan of the core by Mr. Downey of SELCO's Chibougamau office).
The results are summarized in Table 70.

The lower magnetite zone is around 100 feet thick (30 m.) but could be a
little thicker since we do not know the relationship between the top of the
drill hole and the stratigraphic top of the zone. The rocks are layered, fine-
to medium-grained, and generally highly foliated. The zone has all the
characteristics in miniature of the Layered Zone: a decrease of the vanadium
content upward, an irregular distribution followed by a gentle increase in
titanium content, a marked drop in MgO content upward, the presence of abundant
apatite in the upper thin sections, and minor zircons in two thin sections at
the top of the drill hole. By comparing Table 70 with Tables 106 to 112, one
can readily see the very low TiO_2 content of the concentrates from this zone as
compared with the main Layered Zone.

Mineralogically, the Lower Magnetite Zone differs from all others by the
complete lack of epidote and amphibole. Carbonatization and silicification are
evident in nearly every slide. A very pale phlogopitic (?) biotite was observed
in four thin sections. In some slides, the magnetite is clearly intercumulus
to a cumulus silicate phase now replaced by chlorite, carbonate, and quartz.
The chlorite is strongly pleochroic with greenish yellow interference colors in
the upper part and bluish purple in the lower part. Pyrrhotite was abundant in
the upper portion. It was analyzed for Ni, Cu, and Pt with negative results.

The intense carbonatization and silicification, the development of biotite,
and the presence of pyrrhotite is probably genetically linked to the intrusion
of the Chibougamau pluton. Narrow felsic dikes associated with the pluton were
noted in the core.

This zone of magnetite may be the result of magmatic differentiation of a
small precursor phase of the Dore Lake Complex followed by the major pulse of

TABLE 70

Partial chemical analyses D.D. Hole SELCO-1-Lemoine

Analyses chimiques partielles Trou SELCO-1-Lemoine

Sample No. Echantillon No.	Footage Pieds de carotte	Fe total %	MgO %	Ni %	Pt oz/t	Magnetic concentrate (95%-325 mesh) Concentré magnétique (95%-325 mailles)									
						Wt % % en poids	Fe %	TiO_2 %	V_2O_5 %	P_2O_5 %	Cr_2O_3 %	Mn %	Ni %	Cu %	S %
75-1	35' – 38'6"	34.6	1.67	0.01	nil	38.42	69.1	1.78	0.02	<0.01	<0.01	0.10	0.02	<0.01	4.12
75-2	39'3" – 42'6"	31.3	1.61	0.02	.004	22.32	64.9	0.95	<0.02	<0.01	<0.01	0.09	0.18	<0.01	12.1
75-3	42'6" – 51'6"	35.6	1.29	0.01	nil	52.43	69.8	0.58	<0.02	<0.01	<0.01	0.06	0.02	<0.01	5.33
75-4	53'6" – 58'8"	36.0	1.52	0.01	nil	65.27	67.8	0.59	0.02	<0.01	<0.01	0.10	0.01	<0.01	4.43
75-5	58'4" – 58'6"			0.02		–	–	–	–	–	–	–	–	–	–
75-6	81 – 87'8"	18.5	4.24	0.01		12.50	68.1	1.41	0.29	<0.01	<0.01	0.04	0.01	<0.01	0.06
75-7	97'6" – 101'-6"	29.1	4.51	0.01		34.29	67.6	3.63	0.64	<0.01	<0.01	0.07	0.02	<0.01	0.32
75-8	109' – 118'	23.6	4.28	0.01	.008	19.11	68.7	2.86	1.08	<0.01	<0.01	0.09	0.02	<0.01	0.10
Weighted Average Moyenne pondérée	40'7"	29.1	2.84	0.01	nil		68.35	1.66	0.36	<.01	<0.01	0.07	0.03	<0.01	3.13

Hole drilled in 1975 by Selco Mining Corp.
Trou sondé en 1975 par Selco Mining Corp.

Samples from Gilles O. Allard
Echantillon de Gilles O. Allard

Analyses done in the laboratories of the Q.D.N.R. in 1975
Analyses faites dans les laboratoires du M.R.N. du Québec en 1975

magma which gave rise to the most of the Complex. Much more remains to be done

on this zone and a short drill hole is clearly insufficient to allow much

speculation on the nature of the zone and its relationship to the rocks of the

pluton and of the D.L.C.

LOWER HIDDEN ZONE

The Dore Lake Complex stratigraphy (Table 31) is incomplete when compared

with well-studied complexes like the Bushveld and the Stillwater (Hess, 1960;

Jackson, 1961; and Wager and Brown, 1967) (Fig. 30). The lower unit of the

D.L.C. is the AZ which is intruded by the Chibougamau pluton in the core of the

Chibougamau anticline. Duquette (1972, fig. 14, p. 65) indicated, without

comments, an unexposed section of the D.L.C. under the Chibougamau pluton.

Allard (1973) expanded this concept and showed chemical analyses (Table 71) and

petrographic reasons to postulate a Lower Hidden Zone (LHZ) (Fig. 87). Allard

stated:

> "The postulated Lower Hidden Zone of the Dore Lake Complex,
> when compared with the Stillwater and Bushveld Complexes, should
> consist of the Ultramafic Zone and the Lower Border Zone (Fig. 87).
> "An estimate of the chemical composition of the Lower Hidden
> Zone can be made using analyses of typical exposed rocks averaged
> over mapped thicknesses of the different members. The southern
> limb is better exposed and better known and has been used in the
> calculations of Table 71. The marked facies changes which take
> place from one limb to the other and from the southwest to the
> northeast portion of either limb (Allard, in prep) would not
> significantly alter the total average composition. The average
> composition of the exposed part of the Dore Lake Complex is shown
> in column 6 of Table 71. Comparisons with the analyses of chilled
> zones of other complexes (column 1 to 4, averaged in column 5)
> readily reveal a pronounced deficiency in Cr_2O_3 and MgO and an
> excess of Al_2O_3 and CaO. Column 7 represents the average of 26
> samples of the Ultramafic Zone of the Stillwater Complex (Wager
> and Brown, 1967). Columns 8, 9, and 10 are combinations of 15,
> 20, and 25 percent of the average of the Ultramafic Zone of the
> Stillwater Complex compared with 85, 80, and 75 percent, respec-
> tively, of the average analysis of the exposed Dore Lake Complex.
> The best fit is 20 percent of Hidden Zone and 80 percent of the
> exposed portion of the Dore Lake Complex. Considering the exposed
> thickness this would indicate roughly 4,000 ft. of Lower Hidden
> Zone. A thicker Anorthosite Zone would require a thicker Lower
> Hidden Zone."

Table 71.. CHEMICAL ANALYSES USED IN ESTIMATING THE THICKNESS OF THE LOWER HIDDEN ZONE

	1 Bushveld	2 Bushveld	3 Stillwater	4 Skaergaard	5 Average	6 D.L.C. exposed	7 Ultramafic Stillwater	8 15% hidden	9 20% hidden	10 25% hidden
SiO_2	50.58	51.53	50.95	48.52	50.40	48.55	50.54	48.86	48.95	49.04
TiO_2	0.66	0.34	0.45	1.18	0.66	1.09	0.13	0.95	0.90	0.85
Al_2O_3	15.24	18.70	17.74	17.38	17.27	23.13	5.10	20.43	19.52	18.62
Fe_2O_3	1.04	0.28	0.26	1.33	0.73	4.27	3.11	4.10	4.04	3.98
FeO	10.08	9.05	9.93	8.53	9.40	5.33	6.93	5.57	5.65	5.73
MgO	8.30	6.85	7.75	8.?	7.90	1.84	30.69	6.16	7.61	9.05
CaO	11.31	10.97	10.52	11.48	11.07	13.43	2.58	11.81	11.25	10.72
Na_2O	2.24	1.58	1.88	2.39	2.02	2.21	0.20	1.91	1.81	1.71
K_2O	0.19	0.14	0.24	0.25	0.21	0.15	0.02	0.13	0.12	0.12
P_2O_5	0.12	0.09	0.09	0.08	0.09	tr	0.01	?	?	?
MnO	0.23	0.47	0.15	0.16	0.25	..	0.18	?	?	?
Cr_2O_3	0.01	..	0.04	..	?	..	0.51	0.08	0.11	0.13

1. Fine-grained hypersthene gabbro, Marginal Group, Bushveld. Wager and Brown, 1967, anal. 1 on Table 26 (all analyses are recalculated on a water- and CO_2-free basis).

2. Fine-grained hypersthene gabbro, Marginal Group, Bushveld (same reference as a .1. 1).

3. Hypersthene dolerite, Border Zone, Stillwater. Hess, 1960, Table 12.

4. Chilled olivine gabbro, Marginal Border Group, Skaergaard. Wager and Brown, 1967, anal. on Table 26.

5. Average of analyses 1, 2, 3, and 4.

6. Average of the exposed portion of the Dore Lake Complex (analyses done by the Quebec Dept. of Natural Resources and by Caty, 1970).

7. Composite sample of 26 specimens from the ultramafic zone of the Stillwater Complex (Hess, 1960, Table 31).

8. Composite analysis made up of 15% of anal. 7 and 85% of anal. 6.

9. Composite analysis made up of 20% of anal. 7 and 80% of anal. 6.

10. Composite analysis made up of 25% of anal. 7 and 75% of anal. 6.

The comparison between the D.L.C. LHZ and the well known Cullin, Stillwater, and Bushveld complexes (Fig. 30) brings out the enormous economic potential of such a zone under the Chibougamau pluton. The chromite and platinum deposits of the Bushveld are too well known to deserve more than a casual mention here. The nickel-copper deposits at the base of the Insizwa, Stillwater, and Duluth complexes bring out another important possibility for potential economic deposits. The difficulty lies in proving the point that the Chibougamau pluton was intruded as a sill which separates the LHZ from the AZ and in establishing at reasonable costs estimates of the depth of plutonic rocks under Chibougamau Lake.

MINERALOGY

A complete discussion of the mineralogy of the Dore Lake Complex is not possible at this point since much research with the microprobe remains to be done on all the minerals involved in the rocks of the complex. The work is also rendered difficult by all the metamorphic reactions which have partly obliterated the original minerals and created new species of exotic compositions. For the sake of the mineralogists and petrographers who are interested in layered complex mineralogy and metamorphic petrology, we will give a few notes on most of the minerals known in the complex up to now, with the understanding that much work is in progress and many changes will be forthcoming within the next few years.

Plagioclase

Plagioclase is the dominant mineral in the D.L.C. It is found in every zone and is missing only in a few ferropyroxenitic layers of the LZ. Allard (1956) reported a fresh anorthosite with An_{80} from a small island in Nepton Bay on the north limb in a drill hole from Duvex Mines Ltd. (Fig. 35). Other patches of fresh plagioclase have been found in McCorkill and Rinfret where compositions

of An$_{63}$ have been reported (Allard and Simmons, 1969). In the Layered Zone,
fresh plagioclase was noted in a sample of magnetitite from Rinfret Township.
In the Ferrodiorite Zone, Baskin determined much fresh plagioclase ranging in
composition from An$_{44}$ to $_{55}$. In the Sodagranophyre Zone, the original compo-
sition was probably around An$_{20}$.

In most of the complex, plagioclase is a cumulus phase. A few pyroxenitic
layers have been observed in the Anorthosite Zone and Layered Zone where
plagioclase is distinctly intercumulus in nature (some of the so-called 'reverse
texture anorthosite' are coarse gabbroic rocks in which the plagioclase is
intercumulus).

The low grade greenschist metamorphism is essentially isochemical (if we
exclude H$_2$O and CO$_2$). Tables 33-36, 38-40, 42, 46-48, 51-68, and 70 give
chemical analyses of the many samples analysed throughout the complex and the
normative computer calculations. It is clear from Table 72 and Figure 96 that
the recalculated An content of the plagioclase is a good measure of the
composition of the original plagioclase across the Dore Lake Complex. The
metamorphic conversion of calcic plagioclase results in albite plus a sprinkling
of small grains of zoisite-clinozoisite-epidote depending on the amount of Fe
available from the intercumulus metamorphosed pyroxenes (Figs. 36, 37, and 40).
The main characteristic of the plagioclase is the extremely coarse-grained size
within the anorthosite and gabbroic anorthosite. We have observed what looked
like single large crystals up to 18 inches (45 cms) in diameter but they are
made up of an aggregate of zoisite and minor albite and one could not establish
whether they were single crystals or not. However, in many instances, by
reflections on good cleavage planes, in a strong light source, single crystals
up to 6 inches (15 cms) can easily be located. No zoning has been observed in
any thin sections of fresh anorthositic rocks. The faint zoning in the
distribution of zoisite vs albite in some thin sections could be due to the

TABLE 72

NORMATIVE An CONTENT (WT %) OF PLAGIOCLASE ACROSS THE DORE LAKE COMPLEX

% NORMATIF DE An (EN POIDS) DANS LE PLAGIOCLASE DU COMPLEXE DE LAC DORE

Zone		% An (wt %) % en poids de An	Number of analyses Quantité d'analyses
Upper Border zone		63	8
Granophyre zone		13	7
Ferrodiorite {	Quartz gabbro	25	4
	Ferrodiorite	53	19
Layered zone (north) {	NP$_3$	52	3
	NP$_2$	27	2
	NP$_1$	73	5
Layered zone (south)	P$_3$	61	16
	A$_1$+A$_2$	59	6
	P$_1$+P$_2$	70	6
(Magnetite Bay)		[90	5]
Anorthosite zone			
Dore Lake Mines		73	6
McCorkill twp.		79	3
Lower portion		86	8

replacement of an original zoned crystal but it could also be due to a
preferential leaching away of the zoisite by the circulating metamorphic fluids
which used the intercumulus spaces to circulate through the rocks during the
low grade metamorphism. We do not have any data on the structural state of the
fresh or altered plagioclase.

Retty (1930), Mawdsley and Norman (1935), and other authors using extinction
angles, which can be ambiguous in certain compositions, identified oligoclase
and called the rocks around Dore Lake an "oligoclase anorthosite". Allard
(1956) identified either fresh plagioclase in the labradorite-bytownite range,
or albite varying from An_0 to An_7. From a study of many thin sections, we
believe that either the plagioclase is fresh and has its original composition,
or it is very nearly pure albite. We exclude here the eastern zone where
Grenville metamorphism has been superimposed on the original Kenoran greenschist
metamorphism and the plagioclase composition varies from An_{15} to An_{70} depending
on the bulk chemistry of the original rock.

Wager and Brown (1967) discussed at length the problem of zoning in
orthocumulate and adcumulate rocks. We cannot add much to their discussion
from our study of the Dore Lake metamorphosed rocks.

The very large grain size of the plagioclase grains in the Anorthosite
Zone need an explanation. Maybin (1975) and Durocher (1975, personal
communication) report similar grain sizes in the Opawica River and Chaleur Lake
Complexes respectively. The enormous thickness of the magma chamber at the
time of formation of the lower part of the Anorthosite Zone could account for
the large grain size: plagioclase nucleii formed in the upper part of the
chamber slowly sank and simultaneously grew to their final grain size. The
specific gravity of bytownite is 2.72-2.75 and is very close to the specific
gravity of the postulated liquid (Hess, 1960; Wager and Brown, 1967) suggesting
a very long settling time and the possibility for excessive growth of the

plagioclase crystals. By comparison, olivine, pyroxenes, ilmenite, and magnetite have a much higher specific gravity and would have settled very rapidly, reaching only a small proportion of the size of the plagioclase crystals.

Zoisite-clinozoisite-epidote

This family of mineral is extensively represented with the plagioclase in the D.L.C. In some meta-anorthosite close to the contact with the Chibougamau pluton, crystalline zoisite makes up more than 90% of the rock (Fig. 38). Moving away from the contact, the granoblastic texture of the hornfels gives place to the usual blastocumulus texture where each individual plagioclase crystal is replaced by a large single crystal of albite speckled with a brownish dust-like aggregate of zoisite-clinozoisite grains (the typical "saussurite" of many authors). Some samples of meta-anorthosite display very narrow veinlets of albite (Fig. 36) in optical and crystallographic continuity with the host crystals. This indicates a minor amount of soda metasomatism in the late phase of the metamorphism. Similar veinlets in fresh anorthosite (Fig. 35) are in crystallographic continuity but not in optical continuity since their composition is very different.

The distinction between clinozoisite and epidote has not always been done. Much microprobe work remains to be done on this family of minerals. In the gabbroic anorthosite the mineral is colorless, non pleochroic, and has anomalous interference colors. In the Layered Zone, the amount of iron available for diffusion within the epidote has given rise to epidote and ferroepidote with a strong yellowish green color in hand specimen and good clear high-birefringence and weak but discernible pleochroism. The epidote family minerals, like the others, reflect the chemistry of the minerals they replace and the bulk chemistry of the rocks.

Magnetite-ilmenite

Magnetite and ilmenite are intimately linked in the rocks of the complex. Much work remains to be done to fully understand the trace element behavior of all magnetites. As a rule, magnetite is relatively stable under conditions of low grade metamorphism.

The magnetite contains most of the vanadium found in commercial quantities in Lemoine and Rinfret Township. It also contains much of the TiO_2. The few polished sections studied by Caty (1970) on the south limb, Dorr (1969) on the Sorcerer Mountain-Magnetite Bay Zone, Allard (1953, 1956) on the Cache Lake Grand Chibougamau zone, reveal the existence of titaniferous magnetites and ilmenite in the rocks of the Dore Lake Complex. Tables 106 to 128 and Figures 149 to 169 show the change in the ratios of Fe/Ti/V from east to west and north to south which accompany facies changes discussed in a separate chapter.

The lowest magnetite-bearing horizon in the Anorthosite Zone, discovered in a SELCO drill hole in Lemoine Township in 1975 was analyzed in the Q.D.N.R. laboratories. The results are tabulated in Table 70. Forty feet of magnetite-bearing cores were studied in 7 samples. The tenor of the magnetic concentrates indicates that the zone behaves as in independent layered zone showing the same differentiation trends as the main Layered Zone. The bottom of the zone (samples 75-6, 7, 8) is much richer in V_2O_5 than the top of the zone. It also contains an average of 2.63% TiO_2 which drops off higher up (0.71% TiO_2) and increases again as one would expect towards the top (1.78% TiO_2). The surprisingly low Cr_2O_3 content is difficult to explain.

Within the Anorthosite Zone, the minor accessory minerals are ilmenite and titaniferous magnetite. The grains are always small, in an intercumulus position, altered to 'leucoxene' varying in color from orange to purple. The original Widmanstatten texture is commonly well preserved (Figs. 39 and 40). The magnetite host is either preserved, partially preserved, or completely replaced

by chlorite (Figs. 78 and 79). The orange exsolved lamellae consist of cryptocrystalline sphene.

In the upper part of the AZ, the magnetite becomes more abundant. If the rock is rich in plagioclase, part of the Ti content is converted to a rim of very small grains of sphene. With an increase in the amount of magnetite and a concomitant decrease in the amount of plagioclase available to release CaO and SiO_2 during metamorphism, the magnetite gradually loses its halo of sphene grains and retains its primary aspect. In the magnetitites of Rinfret and Lemoine Township, tiny fractures develop along cleavages in magnetite and ferrochlorite is commonly present along the fractures. In a few thin sections, fresh plagioclase is separated from magnetite by a corona of amphibole.

In all the rocks of the D.L.C. a distinction must be made between primary magnetite (cumulus or intercumulus) and magnetite released during the metamorphism of pyroxenes to amphiboles or chlorites (Figs. 39, 40, 57, 58, 73,76-79, 88 and 89). Caty (1970), like Vincent and Phillips (1954) concluded that ilmenite became a cumulus phase before magnetite. He found that magnetite with exsolution lamellae of ilmenite constitute 70% of the oxide minerals while ilmenite with hematite lamellae forms 30% of the oxide minerals. Figures 141 to 148 are from Caty (1970) and illustrate the various textures observed in P_1 and P_2 members.

Caty (1970) found 4 types of ilmenite:

    a. ilmenite exsolution lamellae in the (111) direction of magnetite

    b. graphic intergrowths of ilmenite in titaniferous magnetite

    c. exsolved individual grains of ilmenite

    d. cumulus ilmenite grains.

Following Buddington and Lindsey (1964, p. 717) Caty concluded that the original exsolution was one of ulvospinel from magnetite and later oxidation of the ulvospinel into ilmenite. The degree of oxidation seems to increase

towards the top of the LZ based on the types of textures obtained by Caty in comparison with Buddington and Lindsley.

Chemistry of magnetite and ilmenite

Various laboratories have worked for many years on the magnetites of the D.L.C. following the discovery by Allard in 1966 of the high vanadium content of some magnetites of the LZ. Most of the results are discussed in the chapter on ore deposits in the section on iron-titanium-vanadium deposits.

The analyses done by the Q.D.N.R. laboratories are done for metallurgical purposes and not for research per se. Hence the results cannot be directly compared in precision and accuracy to the research done by Vincent and Phillips on the Skaergaard magnetites or to the work done by Caty in his thesis. Caty's results on 7 samples from the P_1 and P_2 members of the Lemoine-Rinfret Layered Zone are reproduced here in Figure 90. The SiO_2-MgO-Al_2O_3 values are not entirely reliable due to a slight contamination by chlorite flakes located within fractures in the magnetite. Figures 91 and 92 graphically show the chemical variations given in Tables 73 and 74. The remainder of the values are significant since the chlorite content is very low and the elements involved are more likely to be found in magnetite than chlorite. The values obtained by Caty are very similar to those obtained by Vincent and Phillips (1954) on magnetites from the Skaergaard (Tables 73 and 74).

Vanadium

The most important trace element in the magnetite is vanadium since it occurs in potential economic quantities. All the work done over the last few years has confirmed the conclusions of Allard and Assad (1968) that roughly six times more vanadium goes to the magnetite than to the ilmenite. As in other layered complexes (Wager and Brown, 1967; Willemse, 1969) the quantity of vanadium decreases rapidly upward (Figs. 61 and 90). This is the most important
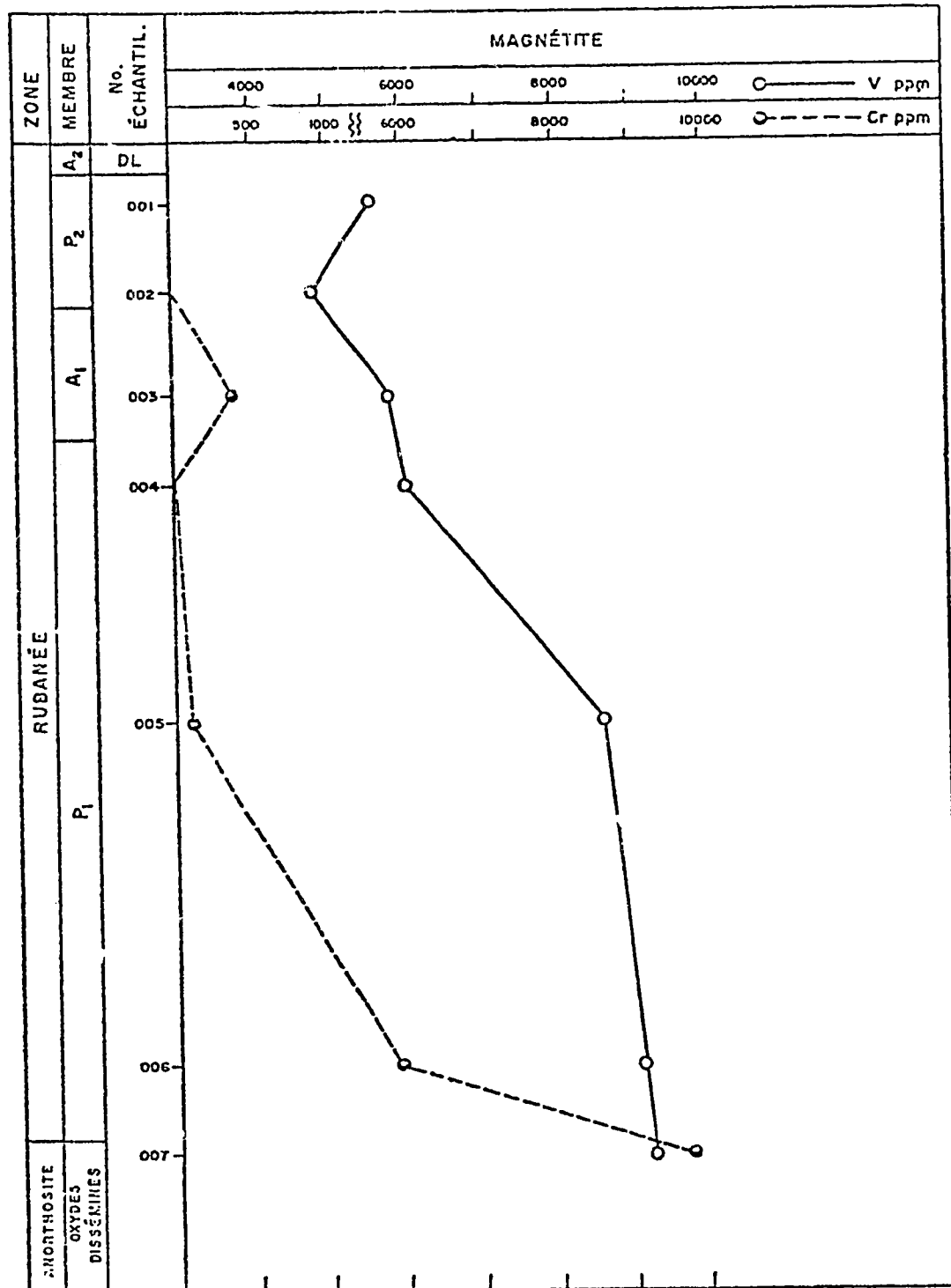
Fig. 90. Changes in V and Cr content of magnetites from Rinfret
Township in function of their stratigraphic height.

From Caty (1970), fig. 10, p 116. Sample are from DDH 2, Jalore,
at 37 (C01),103,167,227,395,621. and 007 is C-67-129

T A B L E   73

ANALYSES OF ILMENITES FROM LAYERED ZONE -- RINFRET TOWNSHIP

	2001	2002	2003	2004	2005	2006	2007
FeO	45.13	45.22	40.88	44.90	45.74	40.40	38.36
H_2O	.17	.18	.07	.08	.20	.43	.23
MnO	1.24	1.18	1.03	1.01	1.08	.97	.93
CaO	.21	.08	.09	.09	.15	.44	.39
Fe_2O_3	3.63	5.78	6.46	3.15	3.41	5.50	11.94
Al_2O_3	1.30	.95	.39	.84	.99	1.68	1.28
V_2O_3	nil	nil	nil	nil	nil	.34	.03
TiO_2	47.35	45.99	50.13	48.89	47.21	46.08	44.65
SiO_2	.98	.58	.92	1.04	1.20	4.15	2.16
Ni ppm	12.2	24.2	165.3	26.8	27.4	23.0	72.5
Cu ppm	45.7	5.3	172.0	25.1	34.4	75.6	265.3
Zn ppm	109.4	149.1	138.7	116.8	164.8	44.8	165.7
Cr ppm	nil	nil	nil	nil	nil	379.0	931.0
Total:	99.99	99.99	99.99	99.99	99.99	99.99	99.99
$\frac{Fe_2O_3}{FeO}$:	.08	.12	.15	.07	.08	.13	.31

From Caty.(1970), table 28, p. 103.

ANALYSES OF ILMENITES FROM SKAERGAARD INTRUSION

% poids.	2308	3661	2569	4147	4142
FeO	39.64	40.39	42.72	43.30	42.18
H_2O	3.27	2.27	1.48	0.62	0.46
MnO	0.47	0.41	0.62	0.65	1.44
CaO	0.37	0.34	0.48	0.46	0.71
TiO_2	51.19	49.89	51.97	50.31	50.02
SiO_2	0.09	0.14	0.23	0.57	0.51
Fe_2O_3	4.25	6.26	2.58	3.92	4.19
Al_2O_3	0.17	0.02	-	tr	-
V_2O_3	0.32	0.18	-	-	-
Cr_2O_3	-	-	-	-	-
Zn, ppm	120	140	120	220	-
Cu, ppm	70	130	400	150	-

From Vincent and Phillips (1954), table 4, p. 15

T A B L E 74

ANALYSES OF TITANIFEROUS MAGNETITES FROM LAYERED ZONE - RINFRET TOWNSHIP

	3001	3002	3003	3004	3005	3006	3007
FeO	34.06	37.14	36.37	39.04	36.72	34.93	28.47
MgO	.24	.53	.19	.20	.23	.21	.60
MnO	.07	.35	.26	.30	.15	.08	.12
CaO	.09	.11	.12	.10	.09	.10	.31
Fe_2O_3	60.27	41.61	46.65	41.13	52.45	55.82	59.86
Al_2O_3	.79	1.47	1.16	1.24	1.15	.95	1.68
V_2O_3	.82	.73	.88	.89	1.27	1.33	1.36
TiO_2	2.67	16.84	13.39	16.26	7.02	4.65	5.72
SiO_2	.57	1.20	.95	.83	.92	.91	2.37
Ni ppm	35.0	38.5	37.6	58.8	81.5	275.0	350.0
Cu ppm	167.0	13.2	18.8	110.8	63.4	19.6	8.6
Zn ppm	181.8	135.2	490.2	517.4	169.6	102.0	118.4
Cr ppm	nil	nil	398.0	nil	204.0	5950.0	12234.0
Total:	99.99	99.99	99.99	99.99	99.99	99.99	99.99
$\dfrac{Fe_2O_3}{FeO}$:	1.77	1.15	1.29	1.05	1.42	1.62	2.08

From Caty (1970), table 27, p. 102.

ANALYSES OF TITANIFEROUS MAGNETITES FROM SKAERGAARD INTRUSION

	2308	3661	2569	4147	4142
FeO	43.07	35.68	41.69	35.69	37.01
MgO	1.93	1.19	1.21	0.77	0.06
MnO	0.33	0.27	0.45	0.25	0.64
CaO	0.42	0.30	tr	0.93	0.81
Fe_2O_3	32.27	42.95	31.26	45.86	39.53
Al_2O_3	0.78	1.16	0.91	0.67	0.41
V_2O_3	1.74	1.61	0.40	-	-
Cr_2O_3	0.13	-	-	-	-
TiO_2	19.28	16.28	23.74	15.08	19.68
SiO_2	0.24	0.35	0.23	0.63	1.80
P_2O_5	0.03	0.02	0.02	0.04	0.04
Zn, ppm	1200	950	750	1300	650
Cu, ppm	100	100	350	400	200

From Vincent and Phillips (1954), table 2, p. 12.
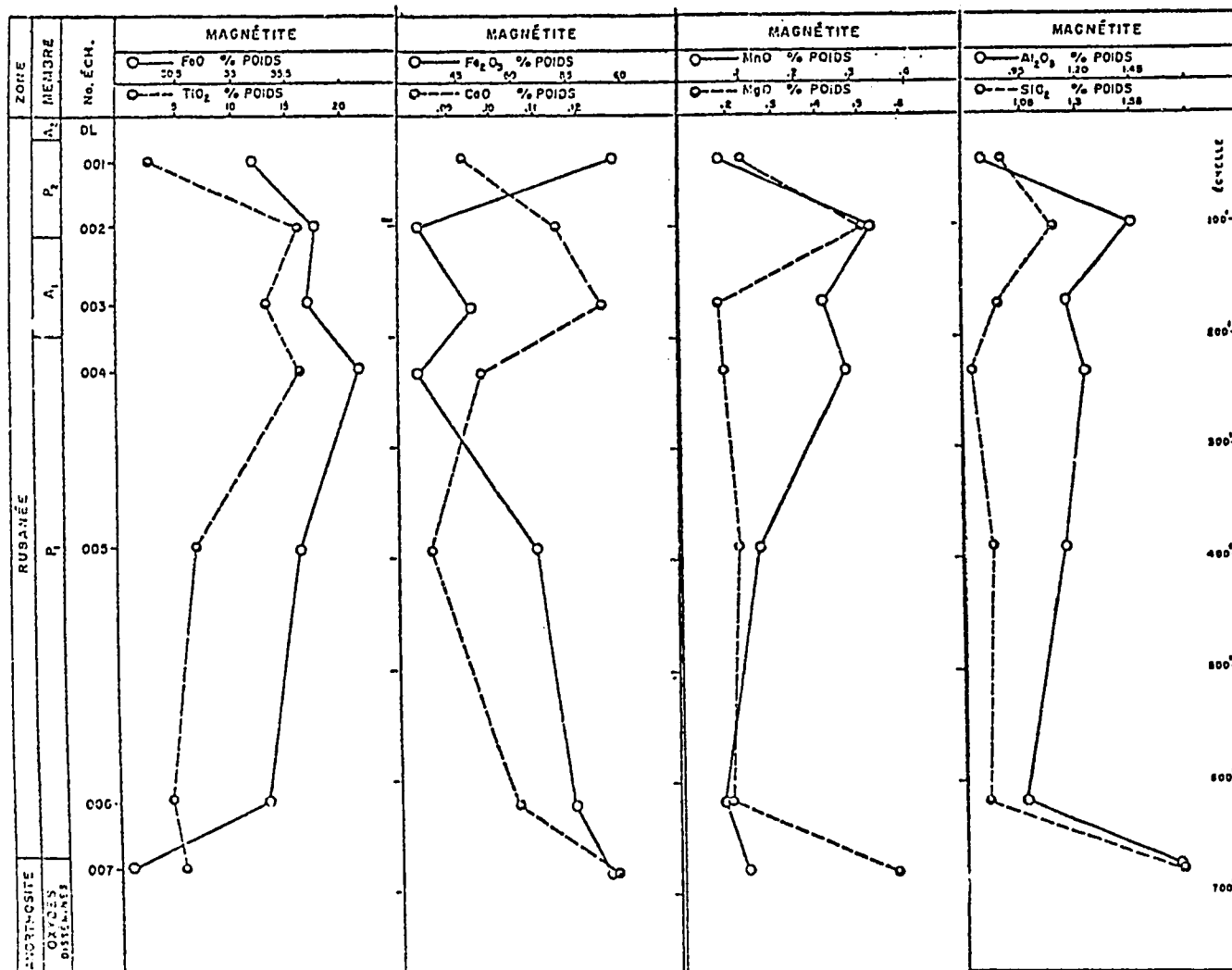
Fig. 91. Variation in FeO, TiO$_2$, Fe$_2$O$_3$, CaO, MnO, MgO, Al$_2$O$_3$ and SiO$_2$ of magnetite in function of stratigraphic height, Layered Zone, Rinfret Township (from Caty, 1970, fig. 5 to 8).
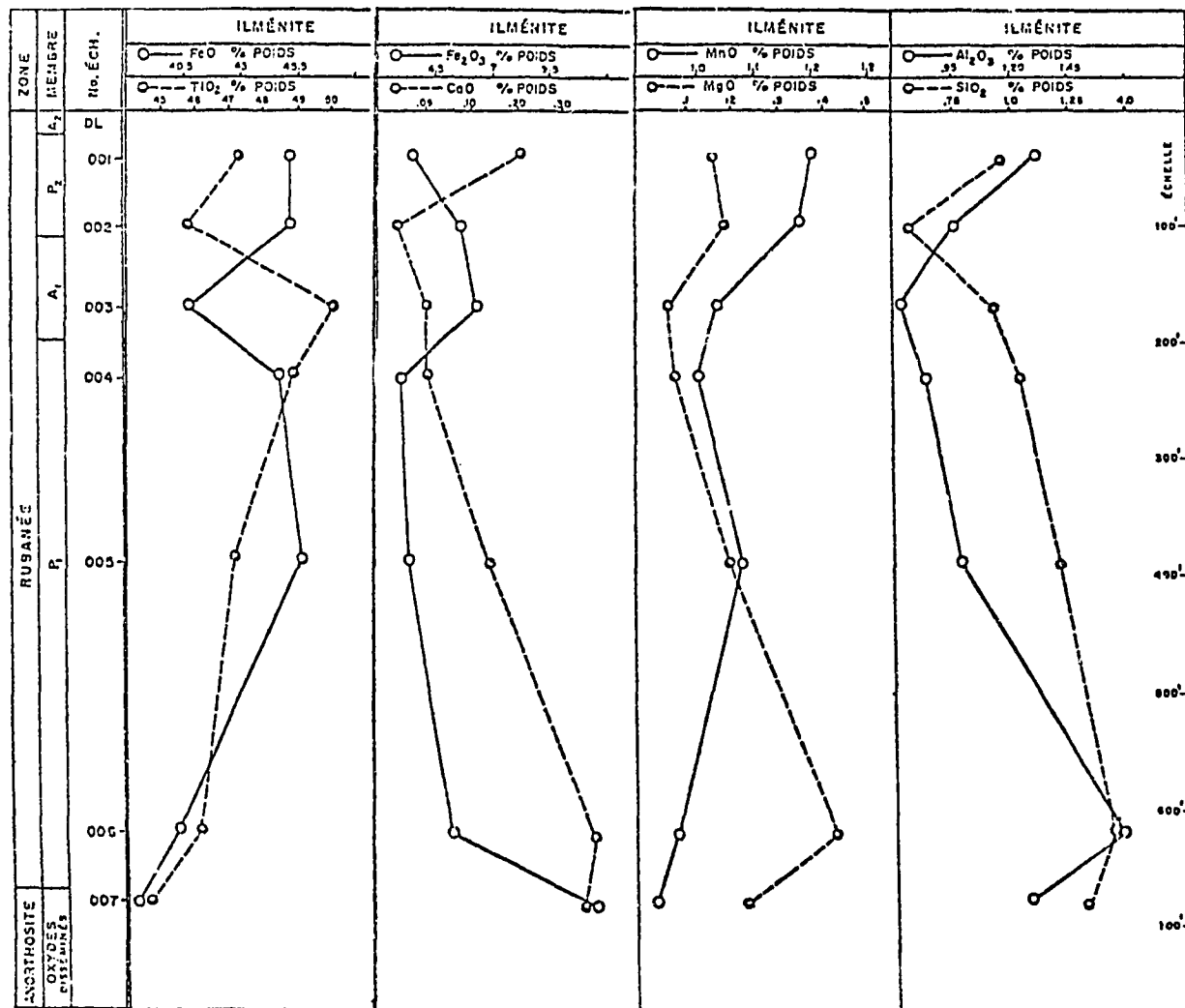
Fig. 92. Variation in FeO, TiO$_2$, Fe$_2$O$_3$, CaO, MnO, MgO, Al$_2$O$_3$, and SiO$_2$ of ilmenite in function of stratigraphic height, Layered Zone, Rinfret Township (from Caty, 1970, fig. 5 to 8)

consideration in working out potential mining tonnages and grades since it will determine the cutoff point in mining the magnetite if vanadium is the most important portion of the saleable product. On the other hand, if a titanium concentrate could be marketed, the increase in ilmenite upward could become an important factor in determining mining limits.

Chromium

The chromium content of magnetites is very low and detectable only in the samples from the lower part of the Layered Zone. This follows the expected trend since most of the chromium should have come out with the early-formed ultramafic rocks of the Lower Hidden Zone (Allard, 1973).

Nickel

Nickel substitutes for Mg in the early olivines of the ultramafic rocks. A very minor amount is left in the magma forming the Layered Zone and it substitutes for Fe^{2+} in the magnetite. It decreases rapidly upward. Four times more Ni is taken in the magnetite than in the coexisting ilmenite.

Copper-zinc

Copper and zinc in magnetite tends to increase upward but decreases in the ilmenite.

Magnetite-ilmenite - Cumulus or intercumulus?

The magnetite-ilmenite in many of the D.L.C. rocks occupy a clear and unmistakable intercumulus position (Figs. 39, 40, 54, 57, 58, 72, 73, and 78). In some rocks of the LZ, the magnetite is clearly a cumulus phase. A detailed study of this problem has not been done as yet. Cameron (1969, p. 754) suggested that post cumulus recrystallization can change the grain size and habit of some minerals. One could conceive of a magma of density ± 2.7 with crystals of plagioclase of density 2.71-2.72 and magnetite of specific gravity 4.6-5.1. The

plagioclase settles through the magma at very slow speed increasing in size as it settles. The magnetite small grains settle very rapidly and do not have time to grow to the extent of the co-precipitating plagioclase. Their small size causes them to fit neatly in the intercumulus space between the plagioclase. Post-cumulus recrystallization could change a series of very small grains into a few larger grains adapted perfectly to the intercumulus space and giving the false impression that they are intercumulus in origin.

Magnetite-ilmenite - Geothermometer and geobarometer

Caty (1970) attempted to utilize the method suggested by Buddington and Lindsley (1964) to determine f_{O_2} and T and P of formation of the magnetite-ilmenite pair in rocks of the D.L.C. He recasted the impurities into chlorite and recalculated the analyses into magnetite and ulvospinel and ilmenite and hematite respectively. Using Lindsley (1963) (Fig. 93), Caty determined the oxygen fugacity (f_{O_2}) and the temperature of formation of the magnetite (Table 76). The range of temperature obtained (600° C - 900° C) is lower than expected for crystallization temperature of mafic magmas. Similar results were obtained by Buddington and Lindsley on Skaergaard magnetite ($700-900^{\circ}$C) (Table 75). Textural evidence points to a simultaneous crystallization of the oxide and silicate phases. The difference of temperature of formation is explained by postcumulus recrystallization and subsolidus exsolution and oxidation. We have mentioned above the possibility on textural grounds for postcumulus recrystallization. The magnetite-ilmenite temperatures obtained by Caty offer an added line of evidence to support postcumulus recrystallization. Since the rocks of the D.L.C. have been subjected to lower greenschist meta-morphic conditions, we can assume (Winkler, 1967; 1974) that the temperature of metamorphism was below 550° C and that the temperatures obtained in Table 76 are primary pre-metamorphic temperatures.
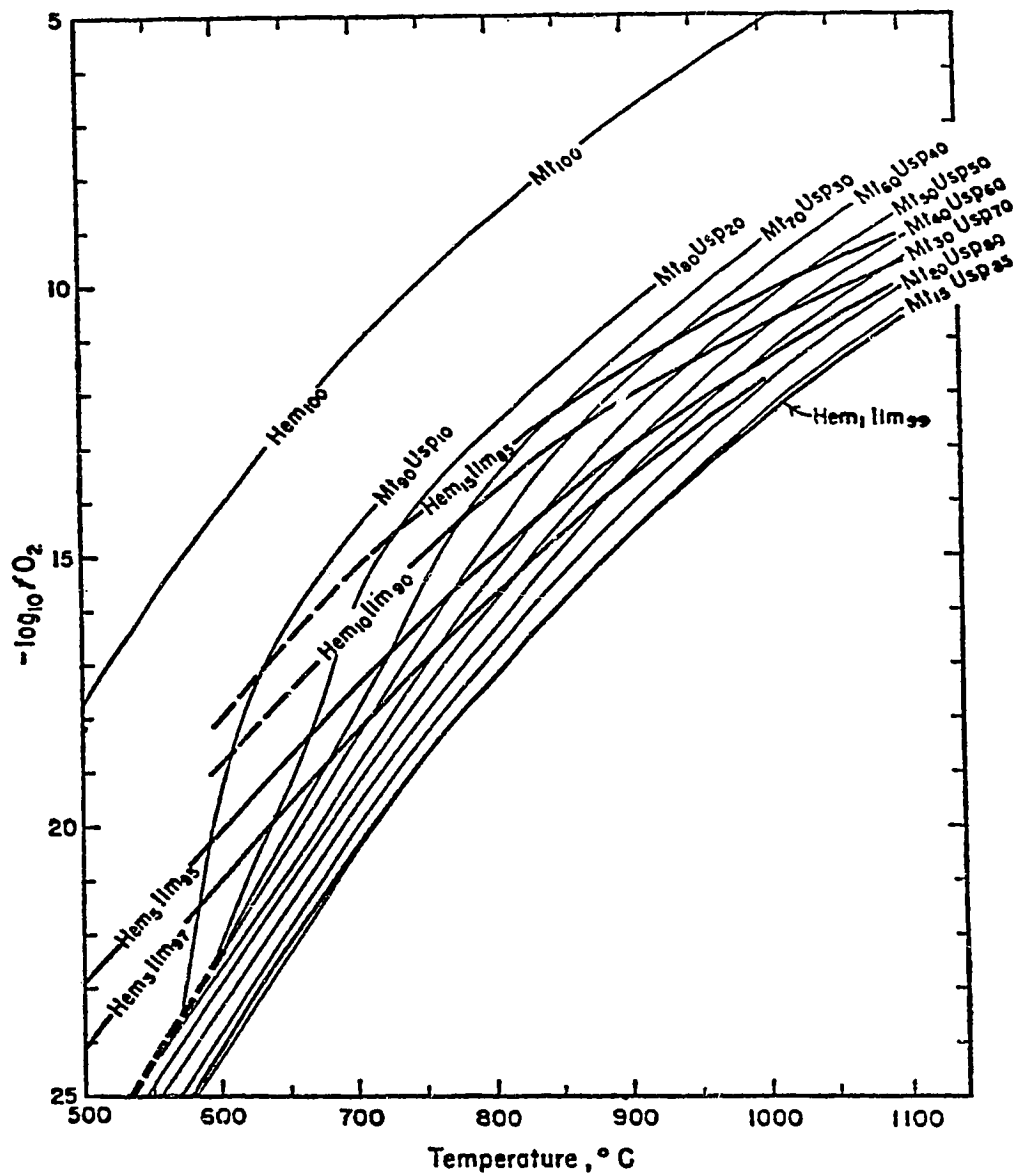
Fig. 93. Diagram of $-\log_{10} f\, O_2$ vs temperature of formation of coexisting magnetite-ilmenite .

From Lindsley (1963), fig. 5, p. 64.

TABLE 75

TEMPERATURE OF FORMATIONS OF MAGNETITES FROM SKAERGAARD INTRUSION AND ANORTHOSITE MASSIFS

Compositions of titaniferous magnetite and ilmenite-hemo-ilmenite minerals from oxide mineral-rich concentrations, together with estimated temperature and f_{O_2} of formation based on experimental data

Ref. no. and field no.	Rock and locality	Magnetite Wt% TiO2	Magnetite Mole% Fe3O4	Fe2TiO4	FeTiO3	Fe2O3	Equivalent Fe2TiO4	Ilmenite-hemo-ilmenite Mole% FeTiO3	Fe2O3	TiO2	Estimated T. °C =50	log10 fO2 (atm) =1.0
1 (2569)	Melanocratic titaniferous magnetite-rich (21.4%) hortonolite gabbro with ilmenite (5.8%). Skaergaard; Vincent & Phillips, 1954	24.6	43.0	23.0	34.0	—	69.3	89.2	2.4	8.4	860	−14.6
2 (2308)	Melanocratic oxide mineral-rich layer (36.3% magnetite, 13.8% ilmenite) in hypersthene-olivine gabbro, Skaergaard; Vincent & Phillips, 1954	20.4	45.2	54.8	—	—	58.3	82.8	4.0	13.2	870	−13.7
3 (SM-1106)	Oxide mineral-rich ferro-gabbro, Ovre Roddal, Norway; Gjelsvik, 1957	14.6	60.4	26.1	13.5	—	41.3	94.3	2.4	3.3	710	−18.1
4 (65)	Ilmeno-magnetite (60%)-ilmenite (22%) ore body in anorthosite, Sanford Hill, Adirondacks	13.0	62.0	—	32.6	5.4	36.8	83.5	4.8	11.7	750	−16.1
5 (203)	Ilmeno-magnetite (70%)-ilmenite (17%) ore body in anorthosite, Sanford Hill, Adirondacks	9.0	71.1	—	23.6	5.3	25.8	82.8	6.2	11.0	710	−16.7
6 (SR-153)	Melanocratic oxide mineral-rich noritic pyroxenite layer in anorthosite, Derrick, Adirondacks; Davis, 1962	—	71.3	1.4	27.3	—	31.9	80.9	9.4	9.7	810	−13.6
7 (230)	Feldspathic oxide mineral-rich (20% magnetite, 30% ilmenite) pyroxenitic rock, N. of Calamity Mill, Adirondacks	8.0	73.5	—	20.6	5.9	22.9	75.0	8.4	16.6	710	−16.0
8	Titanomagnetite gabbro, Tsaginsk gabbro-labradorite massif, USSR; Yudin, 1960	—	65.2	—	33.8	1.0	38.0	88.0	6.4	5.6	790	−14.6
9 (204)	Oxide mineral-rich norite (12% magnetite, 12% ilmenite) in anorthosite, Sanford Hill, Adirondacks	6.0	80.8	16.9	—	2.3*	17.1	82.8	6.2	11.0	650	−18.2
10 (H-213) (H-265)	Oxide mineral- and apatite-rich norite sheet in anorthosite, Allard Lake, Quebec; Hargraves (personal communication)	—	93.2	—	6.7	—	6.7	76.9	18.4	4.8	600	17.0
11 (A-128)	Oxide mineral-rich diorite in anorthosite, Sualt-aux-Cochons complex, Quebec; Anderson, 1963	3.94	85.9	—	10.8	3.3	11.3	98.3	9.1	12.6	615	−13.5
12	Oxide mineral-rich crustified zoned vein with bronzite borders within anorthosite, Hayes prospect, western Newfoundland	3.16	—	—	—	—	9	—	18	—	650	−15.8

From Buddington and Lindsley (1964), table 4, p. 335

T A B L E   76

TEMPERATURE   OF   FORMATION   AND   f O_2 OF MAGNETITE-ILMENITE

COEXISTING   PAIRS   FROM   LAYERED   ZONE - RINFRET TOWNSHIP

Sample No.	Case 1 %mol.	T° C ± 50	f O2 -10atm	Case 2 %mol	T° C ± 50	f O2 -10atm	Case 3 %mol	T° C ± 50	f O2 -10atm
3001	M 95			M 94			M 95		
	U 05			U 06			U 05		
2001	I 94			I 95			I 98		
	H 06			H 05			H 02		
3002	M 50	930	12.0	M 52	900	12.5	M 50		
	U 50			U 48			U 50		
2002	I 91			I 92			I 99		
	H 09			H 08			H 01		
3003	M 71	700	17.8	M 65	696	18.3	M 71	700	17.8
	U 29			U 35			U 29		
2003	I 96			I 97			I 96		
	H 04			H 03			H 04		
3004	M 55	730	17.4	M 57	720	17.20	M 55	810	14.7
	U 45			U 43			U 45		
2004	I 97			I 97			I 93		
	H 03			H 03			H 07		
3005	M 85	620	18.3	M 85	620	18.3	M 85		
	U 15			U 15			U 15		
2005	I 94			I 94			I 99		
	H 06			H 06			H 01		
3006	M 90	590	20.8	M 90	586	21.4	M 90		
	U 10			U 10			U 10		
2006	I 96			I 97			I 98		
	H 04			H 03			H 02		
3007	M 85	620	20.2	M 86	606	20.3	M 85	620	19.5
	U 15			U 14			U 15		
2007	I 96			I 96			I 95		
	H 04			H 04			H 05		

case 1:   analyses recalculated forming chlorite
case 2:   analyses recalculated using only the major elements
case 3:   % ilmenite and % hematite determined by diffraction

M: magnetite   U: ulvospinel (solid solution)
I: ilmenite   H: hematite   (solid solution)

From Caty (1970), table 33, p. 131.

Olivine-serpentine

Olivine is a rare mineral in the D.L.C. but serpentine derived from olivine during regional metamorphism is common. The LHZ, if it exists, should contain a large proportion of olivine-serpentine (see the separate chapter on the Hidden Zone).

Anorthosite Zone

A very thin layer of metaperidotite has been located in the Anorthosite Zone on the shore of a small island in David Lake (Plate 1), on the shore of David Lake by the entrance to Berthe Bay, in the road cut on the Opemisca highway 3,150 feet (1 km) west of the intersection with the St. Félicien-Chibougamau highway, and at a curve in the main highway to St. Félicien south of the Chibougamau River bridge. It was also located in drill hole E-1 of Chibougamau Mining and Smelting in Scott Township.

The unit shows excellent inch-scale layering (Figs. 94 and 95). The shore exposures are deeply pitted and rough because of the weathering of the carbonate which is common in this rock. The metaperidotite unit consists of serpentine, chlorite, small amount of magnetite, and variable amounts of needles of very pale green tremolite. Large saussuritized plagioclase grains become more abundant as the peridotite gives way to gabbroic anorthosite. Table 77 gives chemical analyses of samples from this unit. We have not located this horizon in the Dore Lake or Chibougamau Lake area but its limited thickness, and its very poor resistance to erosion would not favor the preservation of outcrops in the lake basins. Some dark green altered chloritic shear zones found in some drill cores may be the remnant of similar serpentine-chlorite-carbonate metaperidotitic layers in the anorthosite.
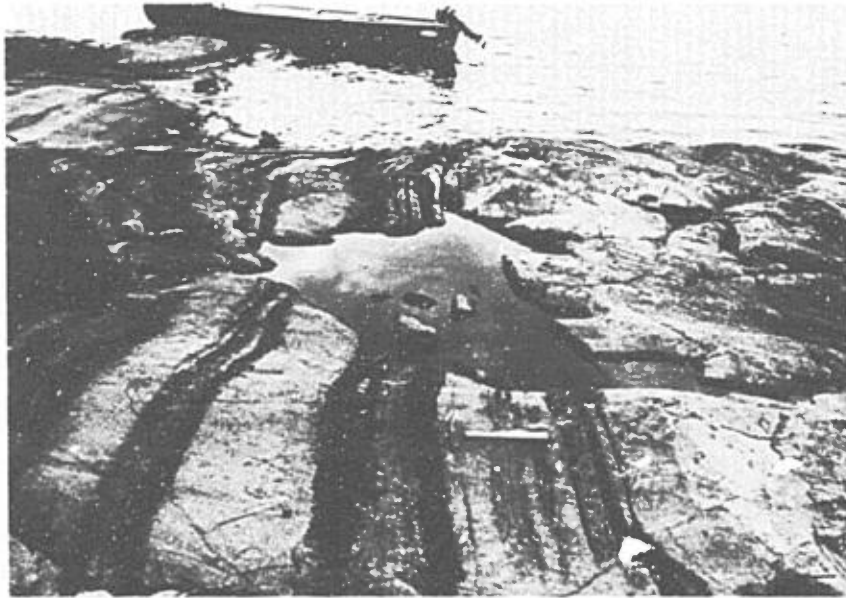
Fig. 94. Inch-scale layering in metaperidotite layer within the Anorthosite Zone. Shore of island in center of David Lake. Dark pitted layers consist of chlorite, serpentine, tremolite, and carbonate. White massive layers are gabbroic meta-anorthosite.
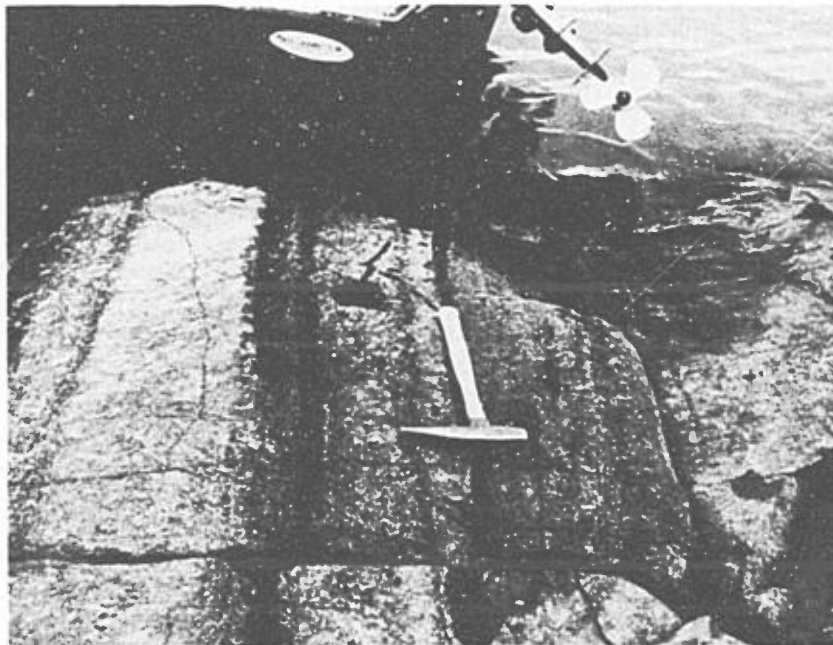
Fig. 95. Detail of photo above in fig. 94.

Table 77

CHEMICAL ANALYSES OF METAPERIDOTITES FROM ANORTHOSITE ZONE - D.L.C.

ANALYSES CHIMIQUES DE METAPERIDOTITES DE LA ZONE ANORTHOSITE C.L.D.

	75-522	75-523
SiO_2	30.25	39.25
TiO_2	1.17	0.13
Al_2O_3	5.90	11.40
Fe_2O_3	8.31	1.35
FeO	7.46	13.55
MgO	28.75	19.00
CaO	3.71	6.05
Na_2O	0.00	0.11
K_2O	0.06	0.01
H_2O total	9.80	7.85
CO_2	3.59	0.30
S	0.08	0.001
Total	99.08	99.00
Ni ppm	180	490
Cr_2O_3 ppm	39	44

Analyses done in laboratory of the Q.D.N.R. 1975

75-522: Roadcut at bend in road about 1500 feet (450 m) south of the bridge on the Chibougamau River, Southwest quarter Obalski Township.

Dark green metaperidotite consisting of serpentine, chlorite, and minor amounts of carbonate and magnetite.

75-523: Roadcut on highway to Chapais about   feet west of the intersection with the St. Felicien highway.

Dark green metaperidotite consisting in chlorite and tremolite (pale green needles) with very minor carbonate and magnetite.

Table 78

NORMATIVE Fa CONTENT (WT %) OF OLIVINE ACROSS THE DORE LAKE COMPLEX

% NORMATIF DE Fa (EN POIDS) DANS L'OLIVINE DU COMPLEXE DE LAC DORE

Zone	% Fa (wt %) % en poids de Fa	Number of analyses Quantité d'analyses
Upper Border zone	37	5
Granophyre zone	- -	- -
Ferrodiorite zone	68	16
Layered zone (north & south) P_3	61	7
$P_1 + P_2 + NP_2$	75	10
Sorcerer Mtn	37	4
Magnetite Bay $\begin{cases} 30 \\ 21 \end{cases}$	30 21	2 5
Anorthosite zone	32	6

Fig. 96. Changes in normative composition of plagioclase and olivine
with height.
From Caty (1970), fig. 1, p. 76.

Sorcerer Mountain-Magnetite Bay zones

The iron deposit at Sorcerer Mountain and Magnetite Bay is predominantly a metaferrodunite and not a ferroperidotite. The cumulus phases were olivine and titaniferous magnetite (Figs. 69 and 70). The olivine is replaced by serpentine and a dust of fine-grained magnetite. No fresh olivine has been noticed by Gaucher (1960), Dorr (1969), or Allard (1956). About three miles (5 kms) east of Sorcerer Mountain, Gaucher (1960, p. 13) reports fresh olivine with a composition of Fa_{36} from a lens of metaperidotite lying at the same stratigraphic level as the Sorcerer Mountain zone. Analyses of rocks from this unit can be found in Tables 55, 56, and 57. Table 78 and Figure 96 presents the variations in recalculated olivine compositions across the Dore Lake Complex (see also tables of chemical analyses under Fa/ol).

Ferrodiorite zone

Baskin (1975, p. 109) has not observed primary olivine in his area but has found a thin section (B 70-127) from the Ferrodiorite Zone containing grunerite and magnetite replacing what appears to be an original fayalite grain. Some ferrochlorite and iron-rich amphibole may be derived from fayalite but no fresh fayalite has been observed.

Pyroxene

Pyroxenes were the second most abundant group of minerals in the D.L.C. after plagioclase. Fresh unaltered pyroxene is very rare. Throughout the Anorthosite Zone, no fresh pyroxene has ever been observed. Even in rocks with fresh plagioclase (Allard, 1956; Allard and Simmons, 1969), the pyroxene has been replaced by amphibole or chlorite. The lens of fresh rock southeast of Copper Rand shaft is a special case not well known or understood and is under study.
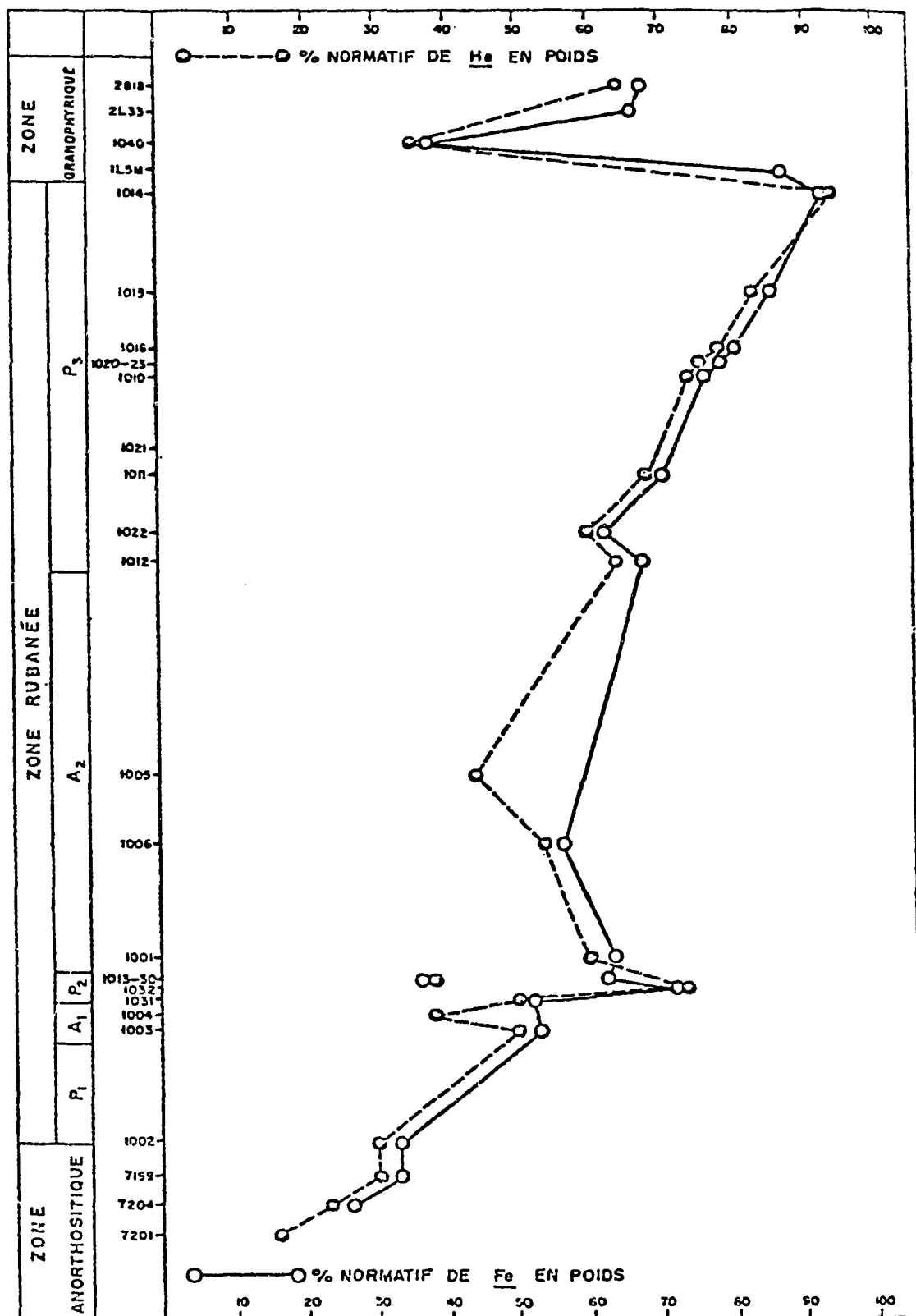
Fig. 97.   Changes in normative composition of pyroxenes with height.
(He: hedenbergite;   Fe: ferrosilite)
From Caty (1970), fig. 2, p. 80.

PARTIAL ELECTRON PROBE ANALYSES OF PYROXENES FROM THE   FZ OF THE D.L.C.

ANALYSES PARTIELLES A LA MICROSONDE DES PYROXENES DE LA ZF DU C.L.D.

An. No.	1	2	3	4	5	6	7	8	9	10
FeO	16.8	25.4	12.9	20.9	11.7	17.6	32.2	17.5	11.9	28.5
MgO	10.5	10.6	9.9	8.8	9.7	9.1	13.2	11.3	13.1	15.8
CaO	20.5	10.5	19.4	23.7	16.4	20.3	1.3	13.2	20.8	.9
Al_2O_3	.6	.9	.6	.5	.5	tr	tr	1.2	.9	.1
Na_2O	.1	.1	tr	tr	.1	.1	tr	.1	.1	0
TiO_2	0	0	0	tr	0	tr	0	tr	0	0
Subtotal	48.5	47.5	42.8	53.9	38.4	47.1	46.7	43.3	46.8	45.3

Analysis No.

1. Sample B70-259, augite lamellae in pyroxene from coarse-grained ferrodiorite of the Ferrodiorite Zone.

2. Sample B70-259, fine lamellae in pyroxene from coarse-grained ferrodiorite.

3. Sample B70-259, augite in same sample as above.

4. Sample B70-27, augite lamellae in pyroxene from coarse-grained ferrodiorite.

5. Sample B70-107, pyroxene (augite) remnant in metagabbro from F_1 of the Ferrodiorite Zone.

6. Sample B70-127, ferroaugite in metaperidotite from F_1 of the Ferrodiorite Zone.

7. Sample B70-85, ferropyersthene in coarse-grained ferrodiorite of the Ferrodiorite Zone.

8. Sample B70-85, clinopyroxene coexisting with orthopyroxene in Analysis 7.

9. Sample B70-72, augite in fine-grained member of F_2 from the Ferrodiorite Zone.

10. Sample B70-72, ferrohypersthene coexisting with clinopyroxene in Analysis 9.

From Baskin (1975), table 3, p. 32.

A general increase in the Fe/Mg ratio of pyroxenes (both ortho- and clino-) due to magmatic differentiation and crystal fractionation is one of the major mineral characteristics which facilitate the comparison of the Dore Lake Complex with other well known layered complexes (Wager and Brown, 1967).

In the LZ, (Allard, 1956, p. 103) has identified cores of clinopyroxene in the centers of actinolite within a metagabbro (Fig. 55). Caty showed the calculated normative changes in pyroxenes (Fig. 97). The tables containing chemical analyses show the calculated normative En (enstatite) content in the orthopyroxene.

Relict pyroxenes are never found in chlorite but always in the cores of amphibole. Sauvé (1957, p. 168) has observed the same feature. This may be due to the high content of water in chlorite (13%) as opposed to the amphiboles (± 2%). It could also be due to a difference in the Al_2O_3 content of chlorite when compared with amphiboles and with the original pyroxene. This would explain why pyroxenes are never found in anorthositic rocks but only in gabbroic and dioritic rocks of the complex.

The major occurrence of pyroxenes is in the Ferrodiorite Zone (Baskin, 1975). Baskin found augite, ferroaugite, and ferrohypersthense in the LZ and FZ of the north limb around Cache Lake. Table 79 gives the partial electron probe analyses of pyroxene from the FZ as reported by Baskin.

Amphibole

The variety of amphiboles found in the Dore Lake Complex probably exceeds any other body of rocks in the world. Unfortunately, much microprobe work remains to be done in order to ascertain the exact composition of each amphibole. The strong changes in Mg/Fe content of the primary pyroxenes (both ortho- and clino-) is reflected in the composition of the amphibole.

In the anorthositic rocks, large intercumulus poikilitic actinolites replace an original Mg-rich pyroxene. In the LZ, the actinolite takes on

deeper hues due to the increasing Fe/Mg ratio of the rock and of the original

pyroxene. The typical metaferrogabbro and metaferropyroxenite contains two or

three amphiboles, a very dark green strongly pleochroic species, a very pale

green species, and in some instances in between species not well understood at

the present time. Zoning is common with dark rims around pale cores a common

feature (Fig. 56). A bluish tint to the green of the amphibole is common and

has caused many authors to refer to them as riebeckite and other related alkalic

amphiboles. All of the amphiboles are the metamorphic result of greenschist

metamorphism of ferropyroxenes. Locally, the amphiboles are patchy with a

fairly uniform host speckled with smaller grains of a slightly different color.

Caty (1970) has reported some cummingtonite with actinolite.

Baskin (1975) and Allard and Baskin (1974) discovered the presence of

ferrohastingsite as an abundant variety of amphibole in the LZ and FZ (Fig. 99).

Table 80 gives a number of partial analyses of ferrohastingsites reported by

Baskin. This mineral has not been reported previously from such an environment.

It is strongly pleochroic with the formula: X= straw yellow

$$Y = \text{olive green}$$

$$Z = \text{deep bluish green}$$

2V varies from 5° to 40°. It exhibits very strong dispersion with r v. Some

grains have rims showing darker pleochroic blue green tints than their interiors.

Baskin states (1975, p. 22):

> "Electron probe microanalysis of these grains revealed that from
> the center to the edge of some grains, there is an increase in wt%
> of Al_2O_3, Na_2O, and CaO and a decrease of MgO. Contrary to
> previously held ideas, total Fe (as FeO) varies little."

However, the probe gives total Fe and not the ratio Fe^{+3}/Fe^{+2}. Since we know

from a regional study of all the rocks of the complex that the general color

of the chlorites and amphiboles vary in proportion to the Fe/Mg content of the

rock and of the primary pyroxene, we have to assume that the oxidation state

of the Fe may be an important factor in the coloration of the ferrohastingsite.

PARTIAL ELECTRON PROBE ANALYSES OF AMPHIBOLES FROM THE LZ AND FZ OF THE D.L.C.

ANALYSES PARTIELLES A LA MICROSONDE DES AMPHIBOLES DE LA ZR ET ZF DU C.L. D.

Analysis No.	1	2	3	4	5	6	7	8	9	10	11
Σ Fe as FeO	8.3	11.3	19.7	23.3	29.0	26.1	26.2	25.3	27.2	27.8	26.9
MgO	19.5	16.5	10.1	7.3	4.8	6.2	9.1	6.2	5.7	6.4	5.5
CaO	11.6	10.7	8.7	9.8	10.5	11.7	9.6	13.0	11.1	10.4	11.6
Al_2O_3	.05	5.0	6.1	6.5	8.4	13.3	7.9	17.7	15.5	12.0	13.6
Na_2O	tr	1.0	.8	1.1	1.3	1.9	1.0	2.7	2.3	1.8	2.0
TiO_2	0	.4	tr	.2	.4	.2	tr	tr	.2	.5	.5
Subtotal	39.4	46.9	45.4	48.2	54.4	59.4	53.8	64.9	62.0	58.9	60.1

Analysis No.

1. Sample B70-122, colorless fibrous actinolite in a leucodiorite from F_1 of the Ferrodiorite Zone.

2. Sample B70-122, brown pleochroic amphibole (hastingsite?).

3. Sample B70-85, dark green pleochroic ferrohastingsite in coarse-grained ferrodiorite from F_2 of the Ferrodiorite Zone.

4. Sample B70-353, dark green pleochroic ferrohastingsite (2V=40°) in quartz metagabbro NP_3 of the Layered Zone.

5. Sample B70-242, dark bluish green pleochroic ferrohastingsite (2V≤5°) in quartz metagabbro from NP_3 of the Layered zone.

6. Sample R3-564, ferrohastingsite in metagabbro from NP_2 of the Layered Zone.

7. Sample R3-323, center of ferrohastingsite grain in metagabbro from NP_2 of the Layered Zone.

8. Sample R3-323, edge of ferrohastingsite grain in metagabbro from NP_2 of the Layered Zone.

9. Sample R3-564, ferrohastingsite (2V=10°) in metagabbro from NP_2 of the Layered Zone.

10. Sample R3-479, center of ferrohastingsite grain in metagabbro from NP_2 of the Layered Zone.

11. Sample R3-479, edge of ferrohastingsite grain in Analysis 10. (2V=10°, α = 1.695, γ = 1.724).

From Baskin (1975), table 2, p. 23-24.
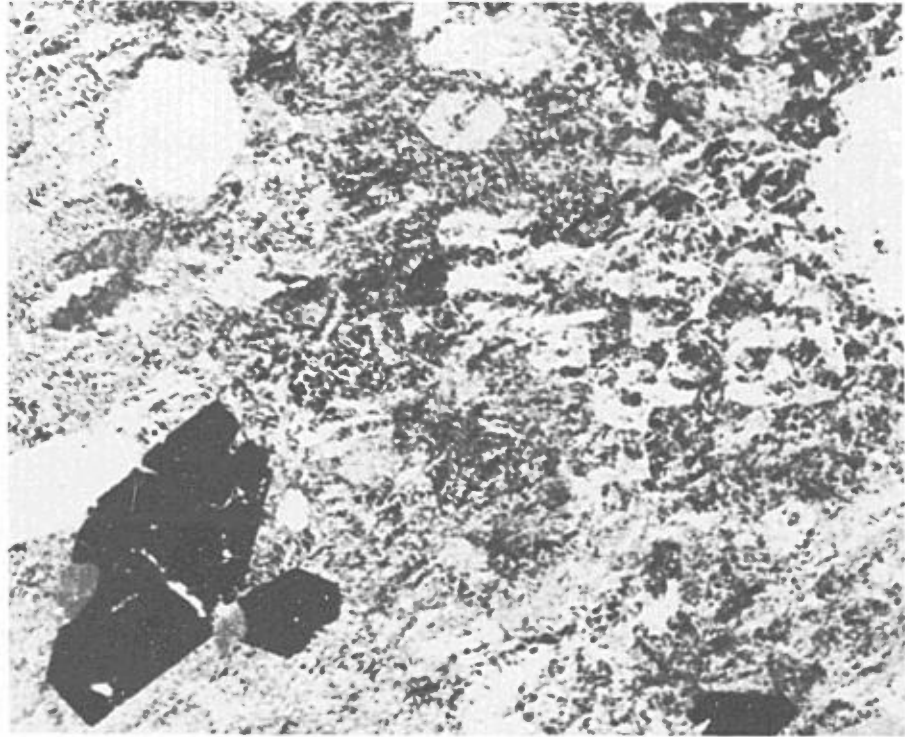
Fig. 98. Euhedral tremolite porphyroblasts in serpentine from Portage Island south magnetite zone extension under Commencement Bay. Clear area to the right is chlorite. Small hook-shape intercumulus magnetite grains are present throughout the serpentine in individual patches not visible in the photo. Field:1 cm. Section 6675 from d.d.Hole Bateman Bay 151 at 574°.
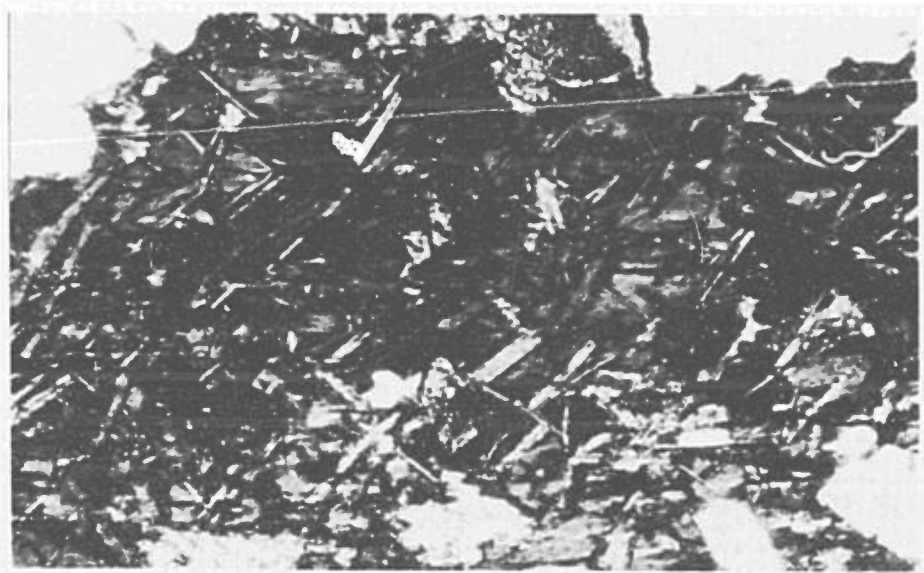
Fig. 99. Photomicrograph of ferrohastingsite with inclusions of stilpnomelane in quartz-bearing metagabbro of the NP_3 member(LZ). The stilpnomelane grains are oriented along four distinct crystallographic directions. Field: 2.8 mm. Sample B-70-401. From Baskin (1975), fig. 10, p. 28.

In some thin sections, the darker greenish-blue hue on the outside rim was observed when the amphibole was in contact with plagioclase which might indicate some diffusion of Al_2O_3 and Na_2O from the plagioclase to the ferrohastingsite.

In some rocks of the NP_2 and NP_3 members, actinolite and ferroactinolite are rimmed by dark ferrohastingsite. The actinolite cores vary from green to very pale green to colorless or neutral.

In all the serpentine-bearing rocks of the complex, certain metaferro-dunites and metaperidotites contain porphyroblastic needles of pale green to white tremolite. Figure 98 shows that these needles have replaced the cumulus olivine-derived serpentine but not the intercumulus magnetite. The calcium necessary for the growth of tremolite comes from saussuritized calcic plagioclase in the rock itself or in the vicinity of the ultramafic layers.

Baskin (1975) reported grunerite from one thin section (B 70-127). It is intimately laced with a mesh of magnetite grains. The outline of the grains suggest fayalite as the original mineral although a ferropyroxene remains a possibility. The rock is a gabbroic metaferropyroxenite from the F_1 member of the Ferrodiorite Zone. Grunerite is commonly found in metamorphosed iron formation (Moret et al., 1972), but the ferrodiorite containing the grunerite contains 34.4% SiO_2, 6.21% Al_2O_3, 6.65% Fe_2O_3, and 30.23% FeO which is not very far from many analyses of typical low grade taconitic iron formations containing grunerite.

Chlorite

Chlorite is one of the most common minerals in the Dore Lake Complex. It is found in rocks of every zone and seems to replace orthopyroxene and possibly clinopyroxene. We do not have data on the detailed chemistry of the chlorites but the optical properties suggest that they vary from magnesian species in the lower part of the Anorthosite Zone to extremely iron-rich ferrochlorites in the ferrogabbros and ferropyroxenites of the Layered Zone and Ferrodiorite Zone.

The chlorite in the Anorthosite Zone pseudomorphs the intercumulus pyroxene. It commonly shows sharp boundaries with the surrounding cumulus plagioclase (Figs. 39, 40, and 41) now converted to a mixture of albite and zoisite. In a few thin sections, the chlorite patches form single crystals with unique crystallographic orientation over large areas and enclosing many plagioclase grains. This is a relict poikilitic texture common in anorthositic rocks. Within the chlorite grains, a number of very small unidentified grains resembling sphene are alined along an original cleavage or exsolution lamellae of the primary pyroxene (Fig. 41). The chlorite varies from very pale yellowish green in hand specimen to medium green. In thin section, it varies from colorless with very weak pleochroism at the base of the zone to apple green at the top. The birefringence color is a pale olive grey green. Detailed microprobe analyses will probably reveal as many chlorites as amphiboles in the Dore Lake Complex. From chemical and petrological evidence, we have concluded that chlorite replaces orthopyroxenes while actinolite replaces clinopyroxenes. Olivine, on the other hand, is replaced by serpentine and magnetite. The major chemical difference between orthopyroxene and chlorite is that the pyroxene has twice the amount of SiO_2 but nearly no Al_2O_3 and a large quantity of water. The Al_2O_3 is easy to obtain from the transformation of bytownite into albite and zoisite and the excess SiO_2 is probably involved in the formation of quartz grains and quartz veinlets common throughout all the rocks of the area.

Stilpnomelane

The mineral stilpnomelane has been identified in a number of samples from the David Lake area, Half Moon Lake-Cache Lake (Baskin, 1975) and in Lemoine Township on the south limb. Stilpnomelane $(K, Na, Ca)_{0-1.4}(Fe^{3+}, Fe^{2+}, Mg, Al, Mn)_{5.9-8.2}Si_8O_{20}(OH)_4(O, OH, H_2O)_{3.6-8.5})$ optically resembles biotite. It has a talc-like structure. It contains much less K_2O (1-2%) than biotite (8-9%) but more silica and iron than most biotites (Deer, Howie, and Zussman, 1962).

In the D.L.C., the stilpnomelane occurs in granophyric rocks at the transition between LZ and SZ. The rocks have a deep brown "rotten" appearance and contains bluish quartz which stands out in relief on the weathered surface. The D.L.C. as mentioned in ano ther chapter has an unusually high Na_2O/K_2O content. The stratigraphic position of the stilpnomelane indicates a high Fe/Mg ratio, a high SiO_2 content, and sufficient K_2O to give rise to the formation of stilpnomelane instead of biotite. In the Cache Lake-Half Moon Lake area, Baskin found that the stilpnomelane occurs as needles growing in three or four preferred orientations within ferrohastingsite (Fig. 99).

Sphene

Sphene is a common mineral throughout the complex as one would expect in a calcium-titanium rich body which has undergone low grade regional metamorphism.

Sphene is generally associated with ilmenite or replaces what was ilmenite. In the AZ, large grains of titaniferous magnetite and ilmenite are replaced by an orange-to-purple colored mineral called leucoxene by most geologists. In thin sections, it has all the characteristics of poorly crystallized sphene. In some rocks, the original Widmanstatten texture is well preserved (Figs. 39, 40, and 42): the host magnetite is either preserved or replaced by chlorite, ferrohastingsite or carbonate or epidote; the lamellae of ilmenite, oriented parallel to the (111) direction of the magnetite host are replaced by the "leucoxene" which turns out to be mostly sphene when examined with X-ray or in thin section. In the upper part of the AZ and in the LZ and FZ, the proportions of $TiO_2/CaO/SiO_2$ are such that a narrow rim of small grains of sphene commonly borders ilmenite or titaniferous magnetite if the rock does not contain too large a proportion of oxides, but in rocks with a high oxide content (e.g., the magnetitites of P_1 and P_2), no sphene is present due to an insufficient quantity of CaO and SiO_2. None of the sphene in the rocks of the Dore Lake Complex has the usual idiomorphic shape common in plutonic granitic rocks. It occurs as

poorly crystalline brownish mass of very small grains pseudomorphing the original grains.

Apatite

Apatite occurs over a very narrow stratigraphic range in the D.L.C. It is found in quantities in a portion of the P_3 member of the LZ on both limbs. It is also an accessory in some rocks of the FZ and SZ.

One sample (67-85) analysed by the Q.D.N.R. laboratories gave the following results (Castonguay, 1968):

TiO_2 = 8.5%   V = 0.04%

P_2O_5 = 2.80%   F = 0.27%

Fe sol. = 20.70%   rare earths = 0.04%

The Davis Tube tests (95% -325 mesh) gave only 1.2% magnetic concentrate confirming the lack of magnetite noted in the field. A Jones magnetite separation test produced a concentrate with 26.8% TiO_2 and 0.12% P_2O_5, whereas the rejects contained 4.60% P_2O_5, which represents 97.09% of all the apatite.

The apatite is a cumulus phase and is closely associated with the ilmenite. The apatite seems immune to the effects of regional metamorphism which has completely altered the original silicates of the same rock. We have no data yet on the detailed chemistry of the apatite but microprobe work will be done shortly.

Zircon

The only zircons observed in thin sections were from granophyric rocks close to the top of the complex. Some thin sections from Range 9 in Scott Township, north of David Lake, contained many zircons. A couple of grains of zircon were observed in the lower magnetite-rich layered zone.

Scapolite

Scapolite has only been found in the anorthosite-gabbroic anorthosites in the vicinity of the Grenville Front. It occurs as a minor accessory partly replacing the plagioclase and the intercumulus grains. It is too fine grained to obtain optical and chemical data. Its geographic distribution indicates a genetic relationship with the Grenville metamorphism which will be discussed in a separate chapter.

Garnet

Garnets are limited to a narrow zone up to 4 miles (6.4 kms) wide west of the Grenville Front. It is found in all rock types but the bulk chemistry of each rock type determines the quantity of garnet produced and the maximum distance it can be found away from the Grenville Front. For example, anorthosites and magnetitites with garnets up to 1 inch (2.5 cm) in diameter have been found in Rinfret Township in the immediate vicinity of the front but some P_3 metaferropyroxenite contains small garnets at a distance of $\pm$ 4 miles (1.4 kms) from the Grenville Front in Lemoine Township, along the road to Five Mile Lake. No detailed work has been done on the composition of the garnet.

Chloritoid

Chloritoid was first identified by Allard in 1952 in the area around the Siderite Hill and Copper Cliff showings (Plate 1). A sample from the wall rock at Siderite Hill was given to Halferdahl for study and he expanded the study into a Ph.D. dissertation (1961).

Chloritoid ($SiO_2.FeO.Al_2O_3.H_2O$) is a mineral generally found in regionally metamorphosed pelitic rocks within the greenschist facies. Harker (1950) thought that chloritoid is a stress mineral. Allard (1956) found abundant evidence (post kinematic porphyroblasts, carbonate veinlets with randomly oriented chloritoid crystals, etc.) that chloritoid is not a stress mineral.

It can form in many environments provided the composition of the rocks and fluid phases has the proper ratios of components. Chloritoid has been reported as a hydrothermal alteration product along ore zones in many deposits throughout the world. In Chibougamau, it has been found in metabasalt, metagabbro, gabbroic meta-anorthosite, felsic and intermediate dikes, and in all sorts of associations around orezones. A common factor to all occurrences is the presence of iron carbonate (ankerite to siderite) in the immediate vicinity. The following assemblages were reported by Allard (1956, p. 141) with chloritoid:

carbonate (ankerite and/or siderite)-quartz-opaque-

carbonate (ankerite and/or siderite)-chalcopyrite- (or pyrite)

quartz-opaque-

quartz-muscovite-carbonate-opaque- (& leucoxene)

quartz-muscovite-opaque-

quartz-chlorite-opaque-muscovite-

pyrite-

The most common assemblage is chloritoid-quartz-carbonate-muscovite. A few specimens of extreme types have been observed like massive pyrite and disseminated chloritoid, massive siderite and chloritoid, quartz and chloritoid.

The chloritoid occurs as dark green pseudohexagonal plates resembling biotite in cross sections and needles of amphibole on polished cores. It varies in size from tiny grains hardly noticeable on the foliation planes up to prisms 3 mm long and .5 mm wide. It occurs as individual porphyroblasts (Fig. 100) and as rosettes. The grain size and habit varies with the host rock. In muscovite schist, the porphyroblasts are large, well developed, and very variable in size. In metamorphosed fine-grained dikes, the grains of chloritoid are small and roughly equal in size throughout. In thin section, the pleochroic formula is:

Z = pale yellow to green yellow

X = dark to medium green

Y = bluish to pale green.

Halferdahl (1961, p. 82) reports the following optical and crystallographical parameters for the Chibougamau chloritoid:

a = 9.50 Å   α = 96° 53'   cell volume = 462.99 Å^3

b = 5.48 Å   β = 101° 49'   Z (number of formula units $H_2FeAl_2SiO_7$

c = 9.16 Å   γ = 90° 2'   in the cell) = 4

The calculated specific gravity is 3.56 and the measured one is 3.58 ± 0.02. The mineral is triclinic (many chloritoid samples from other localities analysed by Halferdahl are monoclinic).

Halferdahl (p. 88) gives the following direction angles between the normal to the (001) cleavage and the optical directions (determinations made in sodium light)

⊥ (001) ∧ X   average = 75°   ⊥ (001) ∧ Y   average = 77°   ⊥ (001) ∧ Z   average = 20°

range = 67–84°   range = 79–87°   range = 17–24°

The $2V_z$ averages 124° (one of the rare places where chloritoid is negative) with a range of 122–125°.

The observed indices are α' = 1.725   The calculated indices are α = 1.725

β' = 1.729   β = 1.720

γ = 1.730

Table 81 is taken from table 15 of Halferdahl (1961, p. 78-79).

The chemical analysis is taken from Halferdahl, table 8, p. 61:

SiO_2	24.30			
TiO_2	0.18			
Al_2O_3	39.92	atomic proportions:	Si	2.02
Fe_2O_3	1.80		Al	3.92
FeO	25.63		Fe^{+3}	0.11
MnO	0.41		Fe^{+2}	1.78
MgO	0.77		Mn	0.03
CaO	0.09		Mg	0.10
Na_2O	0.01		OH	3.81
K_2O	0.06		F	0.01
H_2O^+	6.86		O	10.00
H_2O^-	0.07			
F	0.05			
	100.15			
less O = F	0.02			
	100.13			

Some samples of chloritoid show excellent hour-glass structure. In general, chloritoid porphyroblasts are not broken and show no signs of deformation. They do contain helicitic inclusions of sericite, opaque, quartz, etc.

Chloritoid in the mines

An interesting and probably significant aspect of the distribution of chloritoid is its absence in the mines located within the lower portion of the AZ and its abundance in the rocks and ore deposits located within the upper part of the AZ and the LZ or its equivalent. This reflects the low Fe content and high Mg/Fe ratio in the lower anorthosite and gabbroic anorthosites of the D.L.C. We have mentioned previously the gradual increase in Fe of the rocks of the complex until a maximum is reached in the magnetitites and ferrogabbros of the LZ and FZ. The carbonate which accompanies the ore deposits also vary in relation to the stratigraphic height within the complex. Mines like Campbell,

Merrill, and Kokko Creek have an abundance of calcite in the ore and in the wall rock around the deposits. Deposits like Copper Cliff, Quebec Chibougamau, Siderite Hill, and Jaculet have abundant ankerite and siderite. From this broad generalization, we conclude that the ore solutions bring in a number of elements, especially K_2O, CO_2, S, Cu, but take from the enclosing rocks a portion of its Ca, Al_2O_3, and Fe. Detailed quantitative geochemical balance studies have not been done yet and are necessary to provide us with a better understanding of the exchanges between ore solutions and wall rocks.

Sutton (1959) agreed with Allard's conclusions regarding the distribution and habit of chloritoid at the Copper Rand mine. Vollo (1959, p. 53) at the Henderson main shear does not agree with Allard's views that chloritoid is not a stress mineral. He suggests that chloritoid forms from iron-rich chlorite. In our studies, there are too many rocks with absolutely no signs of iron-rich chlorite to limit the formation of chloritoid to this mechanism. We believe that chloritoid will form in any rock which has the proper composition in SiO_2, FeO, Al_2O_3, H_2O and under the proper P, T, P_{O_2}, and P_{CO_2} conditions.

It is interesting to note that Vollo does not find any ankerite and chloritoid in the "A" zone at Henderson but finds them in the main shear a few feet away from the eastern limit of the "A" zone.

Miller (1957) did not report chloritoid from Cedar Bay. Jeffrey (1959) noted a few grains of chloritoid in six thin sections from dikes next to massive ore and from altered shear zones at Campbell. Abundant chloritoid is found at Quebec Chibougamau, Copper Cliff, Siderite Hill, Jaculet, Bateman Bay, and Copper Rand Main mine.

DENSITY OF ROCKS FROM THE DORE LAKE COMPLEX

A number of density measurements of the rocks of the Dore Lake Complex have been done either for gravity surveys interpretation or for tonnage and average grade calculations. The results are presented in Table 83.

TABLE 81

X - RAY DIFFRACTION POWDER DATA FOR TRICLINIC CHLORITOID FROM CHIBOUGAMAU

$2\theta_{obs}$	d	$Q_{obs}\times10^3$	$\Delta Q\times10^3$	hkl	I	$2\theta_{obs}$	d	$Q_{obs}\times10^3$	$\Delta Q\times10^3$	hkl	I
22.77	4.419	5,052	3	002	1	72.43	1.6395	37,203	−21	133	1
23.55	4.747	4,438	3	ī10	1	73.00	1.6283	37,707	−19	3ī4	2
24.10	4.640	4,645	{−11, −5}	{200, 110}	1	75.60	1.5804	40,037	{−37, −1, 45}	{33ī, 025, 225}	8
b {24.87	4.498	4,942	{−45, −43, −43}	{11ī, 20ī}	>10	76.45	1.5655	40,803	{−36, −33, 69}	{602, 332, 5ī2}	
25.15	4.449	5,052	3	002		b{		41,010	{−39, 27, 42}	{132, 424, 5ī4}	3
29.49	3.806	6,904	{−6, 7}	{201, 111}	2	76.91	1.5575	41,223	{−69, −24, 4}	{331, 331, 205}	
31.15	3.608	7,683	{−2, 7}	{112, 202}	1	77.45	1.5484	41,709	{1, 48}	{600, 330}	2
34.71	3.247	9,483	{−8, 22}	{1ī2, ī12}	6	78.10	1.5375	42,303	53	314	1
38.14	2.965	11,377	−3	003	8	79.98	1.5072	44,021	−14	134	1
38.69	2.924	11,695	{−6, 14}	{202, 112}	2	81.59	1.4826	45,494	3	006	4
40.92	2.771	13,022	−12	203	4	82.98	1.4620	46,785	{−30, 51}	{404, 224}	2
42.12	2.696	13,762	{2, 9}	{021, 311}	7	83.90	1.4490	47,628	−58	3ī6	1
42.69	2.661	14,120	−7	310	3	85.76	1.4235	49,350	{−38, 47}	{133, 425}	2
45.32	2.514	15,820	{−27, 11}	{021, ī13}	1	86.46	1.4142	50,001	{−66, −25, 53}	{603, ī16, 3ī5}	4
46.45	2.456	16,574	{−34, −4}	{022, 312}	9	87.31	1.3968	51,254	−35	333	1
47.63	2.399	17,377	7	311	5	88.69	1.3858	52,071	−32	406	1
48.28	2.369	17,818	{−16, −10}	{40ī, 22ī}	3	90.25	1.3669	53,521	{−53, −38}	{5ī5, 622}	
49.31	2.322	18,545	{−8, 14}	{400, 220}	1	b{		53,705	0	62ī	3
49.94	2.295	18,993	{−5, 14, 25, 42}	{221, 203, 221, 113}	5	90.81	1.3605	54,042	{−48, 16}	{620, 040}	
50.78	2.259	19,596	{−11, −2}	{222, 402}	3	91.90	1.3477	55,057	−3	042	2
52.10	2.206	20,555	{−17, 44}	{312, 022}	3	93.38	1.3312	56,430	24	620	1
53.85	2.139	21,854	{−53, −17, −9, 43}	{401, 221, 023, 313}	6	97.41	1.2892	60,167	{−38, −1, 14, 54, 56, 58, 58}	{405, 241, 134, 533, 334, 225, 713}	2
55.07	2.095	22,775	{−11, 49}	{222, 222}	2	99.51	1.2690	62,098	−18	603	1
55.57	2.078	23,161	21	312	1	100.82	1.2569	63,299	27	226	2
56.59	2.044	23,935	{−45, −21}	{223, 403}	2	102.70	1.2403	65,005	{−57, −18, 60}	{316, 242, 713}	2
57.44	2.016	24,610	15	114	1	104.23	1.2273	66,389	{−4, 24}	{227, ī17}	1
b 59.74	1.945	26,437	−62	314	1	109.63	1.1833	71,418	{−23, −2, 52}	{335, 801, 44ī}	2
b {61.15	1.904	27,576	{15, 66}	{402, 272}	2	119.79	1.1197	79,762	{8, 18, 53}	{227, 713, 5ī7}	1
61.45	1.896	27,830	19	3ī3		121.07	1.1118	80,900	−17	008	3
63.02	1.853	29,111	{−43, 47}	{223, 223}	2	137.61	1.0382	92,776	−47	624	1
63.77	1.834	29,737	{−60, 14}	{024, 314}	7	156.70	0.98835	102,372	{−4, 29}	{009, 4ī5}	2
65.84	1.782	31,491	{10, 21}	{131, 4ī1}	3						
68.23	1.727	33,529	{−48, 16}	{421, ī31}	1						
70.18	1.6850	35,221	−17	423	1						
70.96	1.6688	35,908	1	403	3						

From Halferdahl (1961) table 15, p. 78-79.

$2\theta_{hkl}$ in degrees FeK_β 0°–23° $\lambda = 1.75654$ Å.
FeK_α 23°–120° $\lambda = 1.9373$ Å.
$FeK_{\beta1}$, 120°–160° $\lambda = 1.93597$ Å.
d = interplanar spacing in Å.

$Q = 1/d^2$.
$\Delta Q = Q_{calc} - Q_{obs}$.
b = broad line or band.
I = relative intensity based on visual comparison.
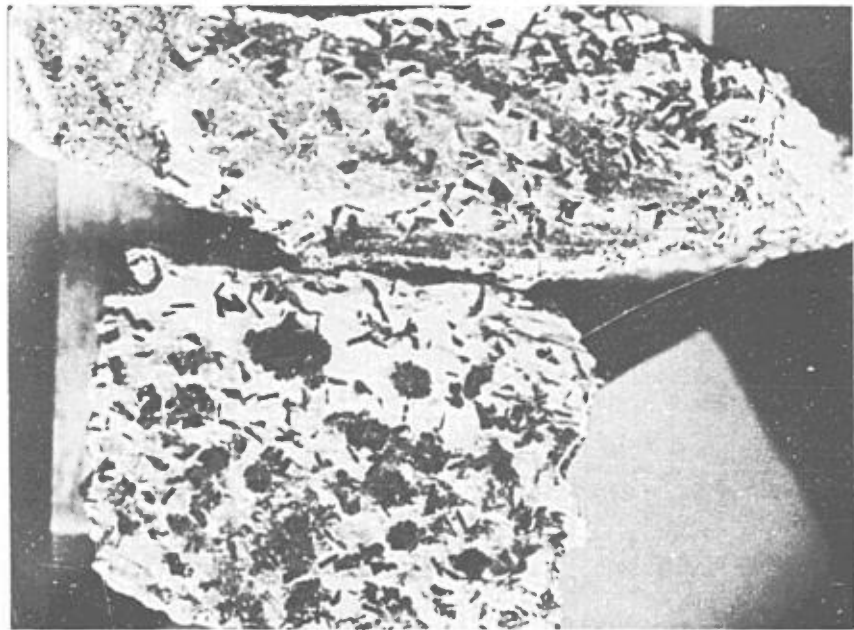
Fig. 100. Chloritoid porphyroblasts in a sericite-carbonate schist. Wallrock of the Copper Cliff Siderite Hill showing, McKenzie Township (Patino). Sample at the top is 4 inches (10 cms) long.

TABLE 82

DENSITY OF ROCKS FROM CHIBOUGAMAU DISTRICT

DENSITE DES ROCHES DU DISTRICT DE CHIBOUGAMAU

(MEASURED BY GILLES LAVERDURE - 1974)

(MESUREES PAR GILLES LAVERDURE - 1974)

Unit Unité	No. of measures No. des mesures	Range Rang	Average density Density moyenne
Chibougamau Formation	12	2.616 - 2.708	2.656
Blondeau	29	2.706 - 2.977	2.768
Bourbeau Sill			
Upper part	10	2.787 - 3.019	2.862
leucogabbro	15	2.874 - 3.069	2.994
lower pyroxenite	6	2.958 - 3.012	2.969
Ventures Sill			
Ventures gabbro	1	2.868	2.868
Foliated gabbro	3	2.915 - 3.10	3.015
Green pyroxenite	1	3.24	3.24
Black pyroxenite	1	2.792	2.792
			(aver. 2.991)
Roberge Sill			
diopsidite	6	3.219 - 3.265	3.242
serpentinized dunite	15	2.655 - 2.773	2.713
Gilman			
Upper part	7	2.813 - 3.057	2.874
lower part	7	2.954 - 3.18	3.039
sills	5	2.968 - 3.13	3.055
Chibougamau Pluton			
meladiorite	9	2.849 - 2.998	2.942
tonalite	11	2.663 - 2.839	2.738
Grandroy metatonalite	4	2.692 - 2.729	2.719
Quartz feldspar porphyry	3	2.700	2.700
Dikes	4	2.898 - 3.052	2.990

TABLE 83

DENSITY OF ROCK SAMPLES FROM DORE LAKE COMPLEX

DENSITE DES ROCHES DU COMPLEXE DE LAC DORE

MEASURED BY (L) - LAVERDURE M.R.N. 1974
MESUREES PAR (A) - AVRAMTCHEV M.R.N. 1974
          (K) - KISH   M.R.N. 1971

Unit Unité	No. of measures No. des mesures	Range Rang	Average density Density moyenne
(L) Upper Border Zone			2.96
Granophyre zone			
Ferrodiorite zone			
Layered zone			
(A) (holes 11-19)			
Magnetite $P_1 + P_2$ members	32	3.41 - 4.46	3.91
Magnetite bearing $P_1 + P_2$	12	3.27 - 3.88	3.61
Metagabbro with low mag.	6	2.68 - 3.28	3.14
Average of ore computed in reserves			3.72
Meta-anorthosite	7	2.94 - 3.15	3.02
Metapyroxenite	2	2.99 - 3.03	3.01
Gabbroic anorthosite	9	2.94 - 3.17	3.04
Anorthositic gabbro	8	2.87 - 3.29	3.04
Gabbro	8	2.93 - 3.31	3.11
Dyke	5	2.68 - 2.95	2.79
	89		
(K) (holes 7-8-9)			
Magnetite rich $P_1 + P_2$ members	8	4.36 - 4.93	4.58
Average ore	19	3.40 - 4.00	3.70
Meta-anorthosite	8	2.80 - 3.01	2.93
Metagabbro metapyroxenite	8	3.03 - 3.46	3.19
Schist	8	2.86 - 3.03	2.94
	51		
Anorthosite Zone			
(L) Meta-anorthosite - gabbroic anorthosite	9	3.019 - 3.138	3.094
" " " " " "	36	2.824 - 3.106	3.005
Sericitized and altered meta- anorthosite	7	2.851 - 3.002	2.897
" " " " " " "	7	297 - 3.131	3.012

SEDIMENTARY FEATURES IN THE DORE LAKE COMPLEX

Many authors have described in detail the sedimentary features found in layered igneous intrusives. Wadsworth (1973) has the most complete review of the subject.

Rhythmic layering refers to the small scale stratification so well displayed in the LZ and FZ. Phase layering is on a larger scale and is due to the abrupt appearance or disappearance of certain minerals. For example, the abrupt appearance of magnetite and ferropyroxene at the base of the LZ is a type of phase layering which facilitates the subdivision of the Complex in major zones. It cannot be illustrated except on cross-sections and general maps of the whole complex. Typical rhythmic layering is illustrated in Figures 47 to 52.

Igneous lamination is due to the preferred orientation of tabular crystals (Fig. 54), especially plagioclase and pyroxene in the LZ. It has not been observed in the coarse-grained rocks of the AZ because of the blocky irregular morphology of the plagioclase crystals. It is an interesting but unexplained observation that all the coarse gabbroic anorthosite have blocky plagioclase but the medium-grained ferrogabbro, ferrodiorite, magnetitites, etc., display good tabular plagioclase.

Graded bedding or gravity stratification is present in a few layers of the LZ but as many or more layers show reverse graded bedding or irregular central concentration of the magnetite. This feature and other evidence points to strong current activity during much of the sedimentation of the Layered Zone.

Cross bedding in the Layered Zone was observed in a few outcrops only. In Range 5 of Lemoine Township on line 82W (8200 feet west of the Rinfret-Lemoine Tornship line) just south of the central township line, good clear cross-bedding was observed. The sketch in Figure 101 is drawn from a colored slide. Another case of cross-bedding was seen in P_2 along the tractor road in Rinfret Township,

2200 feet east of the township line. It is reporduced in Figure 102 from a series of color slides.

Cut-and-fill structures and trough cross-bedding have been observed in a few places (Figs. 103, 104, and 105). Within the LZ, the top of a gabbroic anorthosite-anorthositic gabbro layer is everywhere a rough undulated surface (Fig. 106). The magnetite-rich layers which follow fill in the irregularities and after the troughs have been filled, thin layers of magnetitite or gabbro become regular over the length of the outcrop and probably beyond. Detailed work will bring out many more features like this. For example, Figure 105 shows an outcrop observed for the first time in 1975 and it is one of the best examples of trough cross-bedding.

Load casts were seen on the IGC traverse in Lemoine Township (Figs. 109 and 110). There can be no doubt that they are load casts since the tabular plagioclase laths are standing parallel to the finger-shaped protrusion (Fig. 110). It would be near impossible to deposit a thin tabular plagioclase lath and keep it suspended in a fluid in a near vertical position. However, a small fracture in the upper layer while both layers are still unconsolidated could lead to a certain flowage of the laminated magnetite-rich fine-grained layer into the fracture of the upper bed causing the shape seen in Figure 110 and the preservation of the lamination parallel to the walls of the load cast.

Slump folds are common in sandstone (Pettijohn et al., 1972, p. 125). Many folds have been recorded in the Layered Zone (Figs. 111 and 112) but in most instances it is virtually impossible to ascertain whether the folds are tectonic drag folds or slump folds. In a few instances we could find no evidence of tectonic disturbances but a glaciated outcrop is a two-dimensional observation plane and one cannot completely eliminate the possibilities of fault underneath the surface.

The occurrence of pebbles, cobbles, and boulders of all types in the rocks of the D.L.C. is more a rule than an exception, especially in the south limb LZ

where most detailed work has been done. The foreign blocks vary from rounded
to extremely angular (Figs. 50, 104, and 105). They vary in size from small
blocks one centimeter in diameter to a block observed in the summer of 1975
(found by André Goeeil, line 49E, Rinfret Township, 11 + 60 north, 50' west of
the line) which is 10 feet (3 m.) wide, 8 feet (2.4 m.) high and unknown in the
other dimension. The block is striking by its white color (anorthosite) in a
black magnetite-rich portion of P_1. Figure 113 is a rough sketch made from
slides. The arrangement of the magnetite beds at either end of the block
indicate a fair amount of current depositing the magnetite on both sides of the
block but sweeping the top clean until the time when the whole thickness of the
block has been deposited and the subsequent layers drape over the block.

Some blocks have not affected the bedding planes on which they rest
(Fig. 50) and we assume that they settle very gently on the lower partly
consolidated bed. In other instances (Fig. 107) the blocks have drastically
disturbed the layering of the partly consolidated material in which they landed.

Coertze (1969) used the presence of blocks of one type of rock in another
as evidence of multiple injection of magmas. Hess (1960), Cameron (personal
communication), and many others have observed such blocks in every major mafic
layered intrusion. The evidence in the D.L.C. is clearly against the idea of
multiple injection of magmas, at least in the number of injections which would
be required to explain the variety of blocks across the whole complex. Slumping
of soft sediment or partly consolidated sediment due to faulting current, cut
and fill, deposition on unstable slopes close to the outside walls, etc., can
produce all the observed features described above.

The injection of granophyre in the partly consolidated layer of P_3 below
it (Fig. 65) simulates sandstone dikes in shales and siltstones. The lower bed
of ferropyroxenite is fractured and brecciated and the overlying hot liquid
(granophyre) under pressure tends to follow the fractures and brecciate the
ferropyroxenite around the fractures.
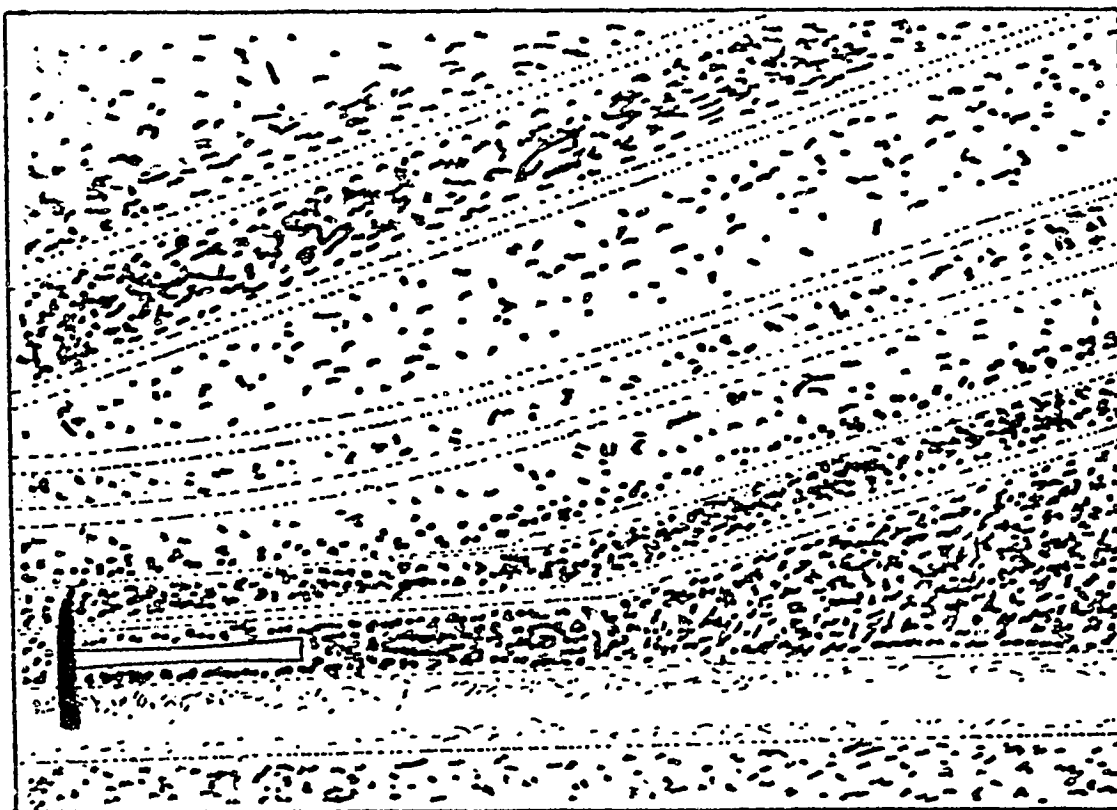
Fig. 101. Cross bedding in magnetitite and magnetite-rich
metagabbro of the P_2 member (LZ) in Rinfret Township. Outcrop
is on the ,main road to the 'trench', about 2740 feet (822 m)
east of the Lemoine-Rinfret township line. Hammer for scale.
The intensity of the dots reflects the quantity of magnetite.
Thin layers of feldspathic metagabbro stand out on the dark-
colored outcrop. From colored slide.
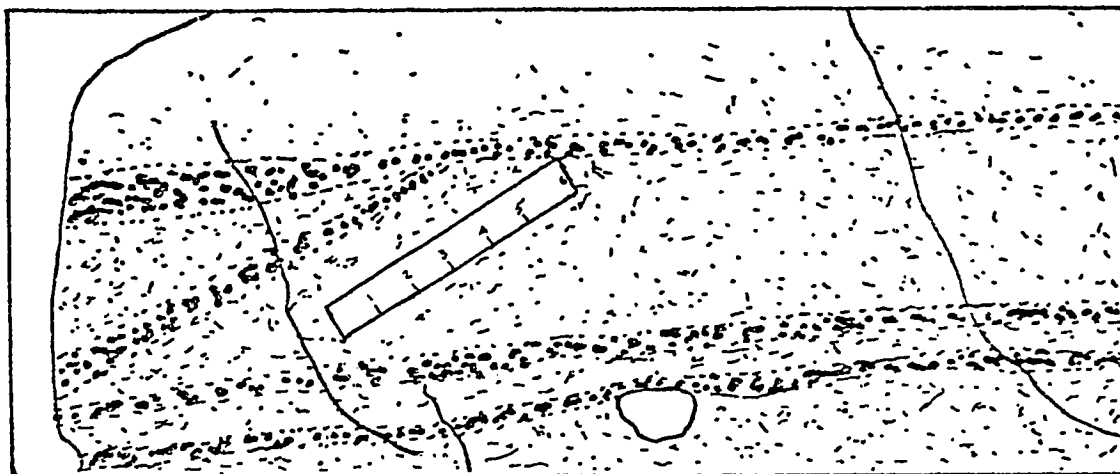
Fig. 102. Cross bedding in magnetite-poor metagabbro. Intensity
of dots indicate concentration of magnetite. Rest of the rock is
a coarse metagabbro. At the top of the sketch, gabbroic
meta-anorthosite. Note a small bouder of meta-anorthosite in
the lower part of the outcrop. Scale is 6 inches (15cms) long.
From colored slide.
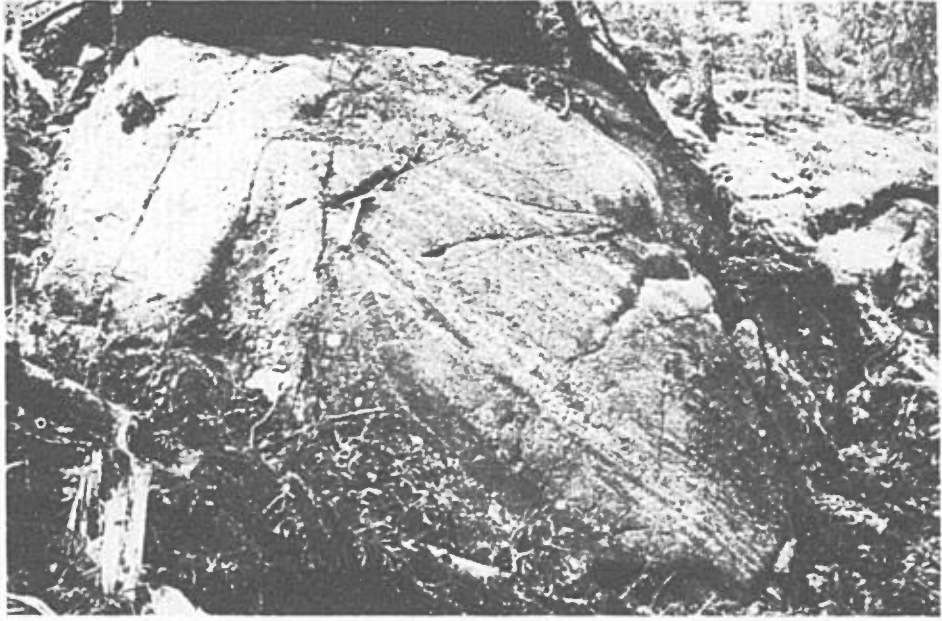
Fig. 103. Trough banding and inch-scale layering in the layered zone north of the Obalski adit. Left of the hammer, the layering is nearly vertical and the rock is a gabbroic meta-anorthosite. To the right of the hammer and below, the rock is well layered consisting of metagabbro and feldspathic metagabbro.
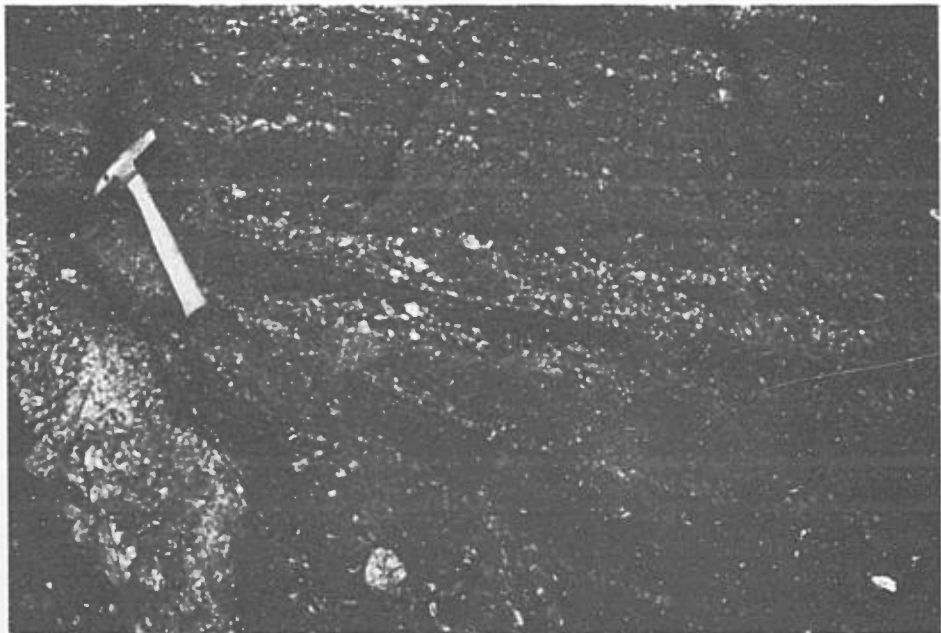
Fig. 104. Detail from the same outcrop shown above in fig. 103. The layers pinch out to the left as they approach the gabbroic anorthosite. Note the clasts of plagioclase which attain 8 cms in diameter.
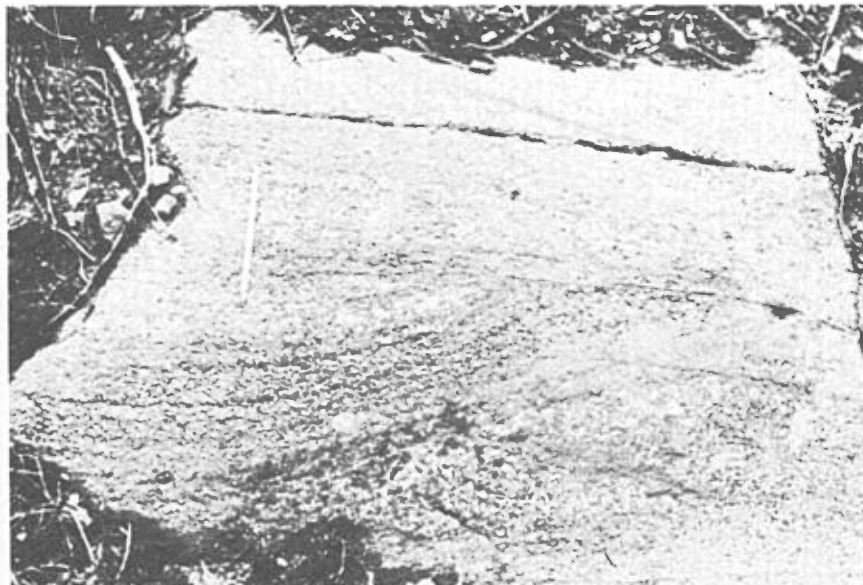
Fig. 105. Trough cross-bedding in P_2 member (LZ). The layer of metagabbro and metapyroxenite at the bottom of the photograph has been cut by a channel filled with magnetite-rich metapyroxenite and magnetite-poor metagabbro. The top of the photograph shows a sequence of finely-layered magnetite-rich metagabbro and metapyroxenite deposited across the whole outcrop. Pencil is 5.5 inches long (14 cms). Rinfret Township, L.12E, 1400 N of B.L.2,45' west.

Fig. 106. Irregular upper surface of the gabbroic meta-anorthosite of the A_1 member (LZ) in the lower left hand corner. Note the filling of the irregularities by fine-grained magnetite. The upper layers of magnetitite(under scale) go across the whole outcrop regardless of the irregularities of the lower surface. Lemoine Township, I.G.C. traverse.
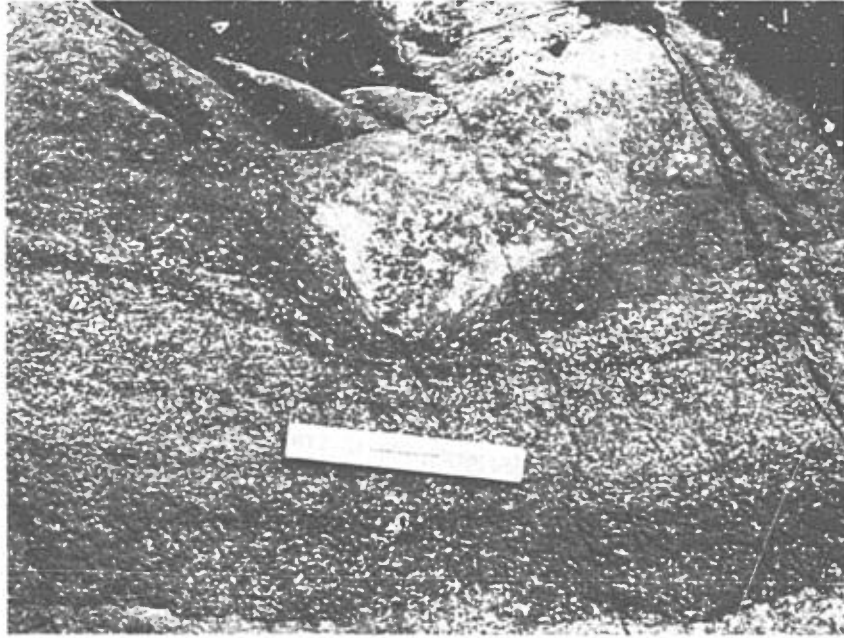
Fig. 107. Large block of anorthositic meta-gabbro in layered P_1 member (LZ). The dark layers are magnetitite beds. Pale layers are metagabbro $\pm$ magnetite. Note the imprint made by the boulder on the magnetitite layer. Scale is 6 inches (15cms) long. Lemoine Township, I.G.C. traverse.

Fig.108. Disrupted and irregular layering in the P_1-A_1 members (LZ). The dark layers are magnetite-rich and the white layers are gabbroic meta-anorthosite. Rinfret Township. Scale is 6 inches (15 cms) long.
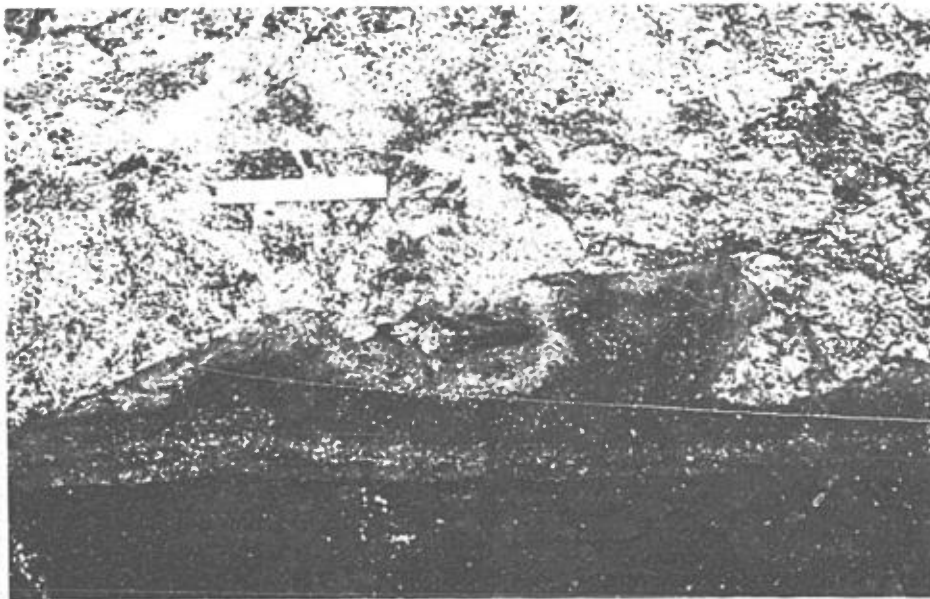
Fig. 109. Load cast in P$_2$ (LZ). Bottom dark layer is a magnetitite layer. The top layer is a coarse gabbroic anorthosite. The slightly feldspathic magnetitite which was deposited horizontally has pushed its way upward into the younger layer causing the load cast effect. Scale is 6 inches (15 cms) long. Lemoine Township, I.G.C. traverse.
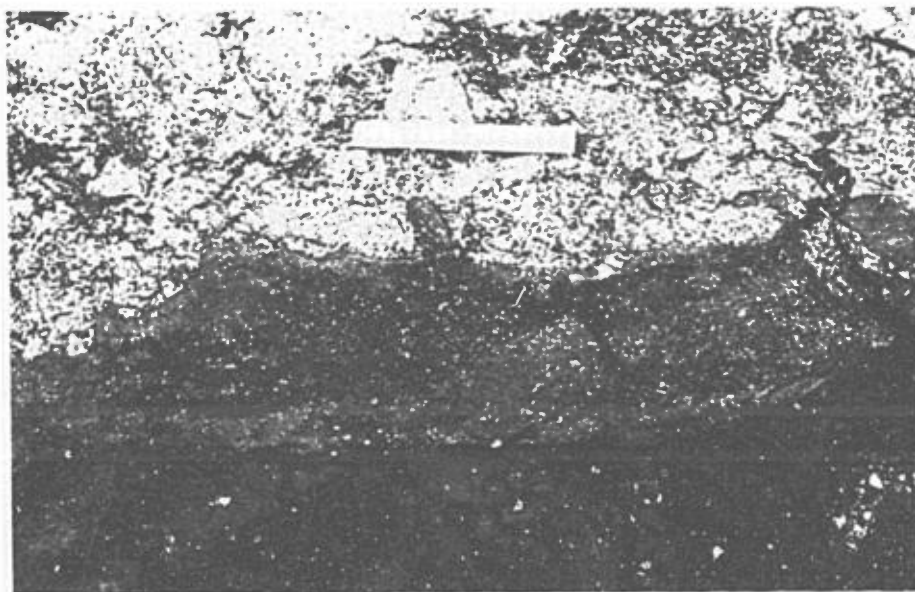
Fig. 110. Same as above but smaller. The plagioclase laths in the dark load cast are alined parallel to the walls of the cast (steep) and could not have been deposited in that position.
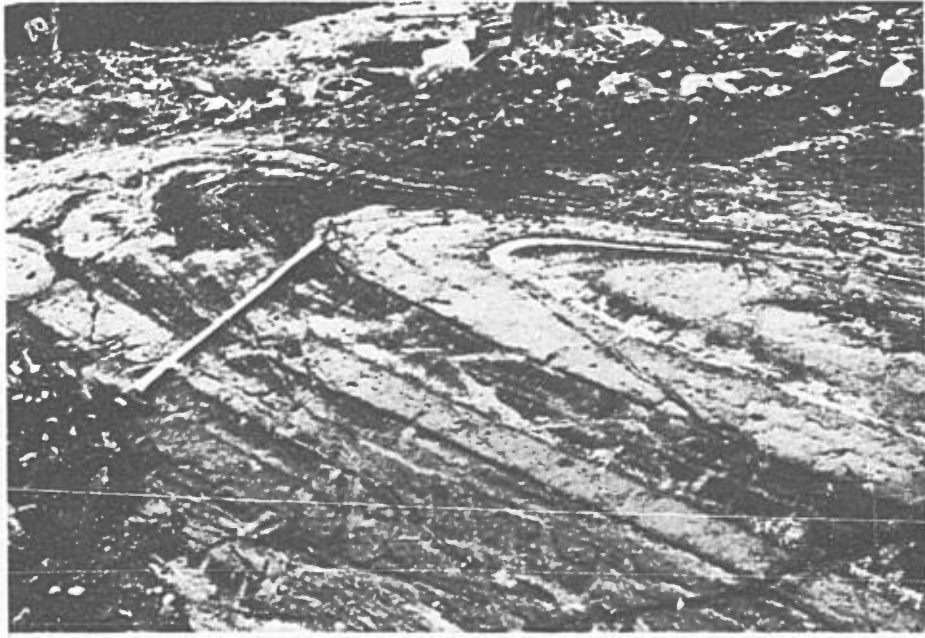
Fig. 111. Fold in P_1 member (LZ). Dark layers are magnetitite. Light layers are gabbroic in composition. Hammer is 3 feet (1 m.) long. It is not known whether the fold is due to soft sediment slumping or to tectonic deformation. Rinfret Township at the large trench where 1000-ton sample was blasted.

Fig. 112. Fold in P_2 (?) member of the Layered Zone. Dark layers are magnetitite and light layers are gabbroic meta-anorthosite. The light layers are cut by a well-developed fracture cleavage. Rinfret Township, L 49E, 400 N.
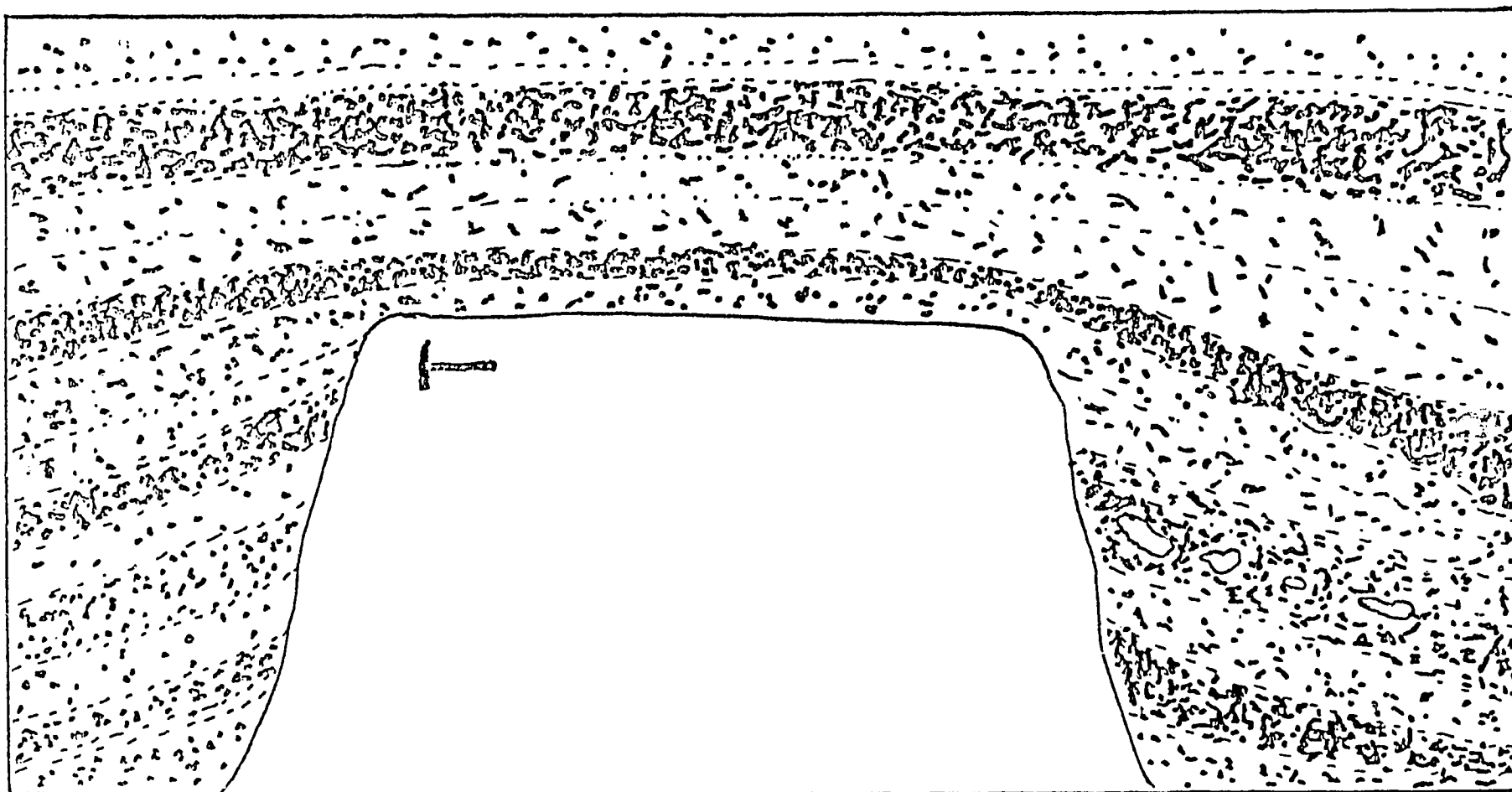
Fig. 113   Sketch of a large block of meta-anorthosite in the well-layered
magnetite-rich P_1 member of the Layered Zone in Rinfret Township.
(L 49E, 1160 N, 50° west of line).   Density of dots roughly indicates
concentration of magnetite.   Hammer for scale. From slides.

The blocks of fine-grained gabbro (UBZ) in the granophyre on the south limb (Fig. 86) are also easy to explain. The crust of chilled zone UBZ is caught between fused felsic rocks (if we adopt Irvine's model, see Figure 116 reproduced here from his paper) and liquid granophyre. Tectonic disturbances, earthquakes, and just plain shrinking cooling fractures can develop and produce shattering of this rind of poorly consolidated fine-grained gabbro and falling of blocks until they are stopped by the viscosity of the granophyre. Wager and Brown report similar blocks up to 100 meters thick (1967, Fig. 46-47, p. 77-79).

ORIGIN OF LAYERING

A complete review of theories proposed to explain the layering in igneous rocks is clearly beyond the scope of this report. Many ideas have been discussed in Wager and Brown (1967), Hess (1960), Poldervaart and Taubeneck (1960), etc. Wager and Brown (1967) start their authoritative book with a quote from Darwin (1844, p. 118) which merits repeating:

> "The sinking of crystals through a viscid substance like molten rock, as is unequivocally shown to have been the case in the experiments of M. Drée, is worthy of further consideration, as throwing light on the separation of the trachytic and basaltic series of lavas."

Bowen (1915) experimented with crystallization in laboratory crucibles and observed crystal settling. Bowen in his famous paper on the problem of anorthosite (1917), von Eckerman (1938) and many others have tried to explain the origin of layering in stratiform igneous bodies. Wager and Deer (1939) and later Wager and Brown (1967) in their work on the Skaergaard showed magnificant photographs of glaciated barren outcrops showing layering and other sedimentary features which rekindled the interest of petrologists in finding a solution to the problem of the origin of layering. Recently, a series of abstracts and short papers on the Skaergaard has put into doubt many of Wager's conclusions and, at the same time, have brought new ideas which are very interesting to us because the D.L.C. is particularly well suited to serve as a

test case for these new concepts. The D.L.C. has been mapped in detail. The folding and subsequent erosion has exposed an excellent cross-section of the two limbs of the complex permitting us a good look not only at the complex but especially at the roof which is so commonly eroded away in undeformed complexes like the Bushveld, Great Dyke, Skaergaard, Stillwater, etc.

The rocks of the LZ, FZ, and the upper part of the AZ show well-developed layering (Figs. 44, 45, 47-52, and 85). In most of the rocks of the LZ and FZ, igneous lamination due to the alignment of tabular crystals of plagioclase and pyroxene is superimposed on the layering and parallel to it. In the coarse grained anorthosite, the plagioclase is blocky and no lamination was observed (Figs. 31, 32, and 33.

The layering is caused by a change in mineral composition and/or texture. Other sedimentary features have been discussed in a separate chapter. An homogeneous large magma body could produce at any instant a number of nucleii of the different mineral species in equilibrium under the conditions acting on the body at that time. The minerals lighter than the magma could float (Bowen, 1917; Morse, 1968) and the heavier ones would sink under the influence of gravity. If a mineral has nearly the same density as the magma, as is the case for plagioclase (Hess, 1960), the sinking velocity would be influenced by the viscosity and would be small enough to give ample time for growth of very large crystals, a situation described in the chapter on the AZ and illustrated in Figures 31, 32, and 33. The situation described above could lead to a layer of smaller grains of high density (pyroxenite, ilmenite) interlayered with coarse anorthosite. However, after the initial layers have been formed, static conditions would lead to a bimodal shower of crystals which would settle and form a gabbroic anorthosite showing no distinct layering. If the conditions change (P, T, P_{H_2O}, f_{O_2}, etc.) a new mineral species could crystallize and formation of a new layer would take place. If convection currents act on the magma, the differential velocity between crystals of different size and density

could create layers. In this case, we should observe a lineation in the plane

of foliation. However, this process must stop and a new set of nucleation

conditions could cause a cyclic repetition of layers. The changing composition

of the magma due to crystal fractionation forces a gradual change in the

composition of the new crystal formed. The change of conditions of crystallization

of the magma may be internal and strictly tied with differentiation of the

magma. It could also be due to injection of a new magma pulse or to contamination

by fused country rocks.

Many authors have supported multiple injection of magma in layered

complexes (Lombard, 1934; Cooper, 1936; Coertze 1969). But the gradational

changes in mineral composition tied to the cryptic layering (Figs. 90, 91, and

92, for Ti, Fe, and V of the D.L.C. LZ) argue against this possibility unless

the new pulses of magmas are differentiated themselves to the same degree as

the original magma of the complex. Turner and Verhoogen (1951, p. 223) pointed

out that coincidental differentiation of this type is not very probable.

The internal changes of magma composition due to crystal fractionation and

differentiation are evident in all layered complexes. Bowen (1913) laid down

a theoretical background which has been much expanded over the last 60 years

in laboratories throughout the world (Carmichael, Turner, and Verhoogen, 1974).

More recently, a restudy of the Skaergaard and a series of theoretical studies

has brought a convergence of ideas which can be used to explain the layering in

the D.L.C., the particular distribution of the granophyres (Plate 1), and the

facies changes discussed previously.

Taylor (1968) using oxygen isotope studies suggested that the Skaergaard

granophyres might not represent a pure differentiation product of the basaltic

magma but might result from a contamination due to fusion of country rock

gneisses and/or circulation of meteoric waters in the cooling magmatic body.

Leeman et al., (1973) using Sr^{87}/Sr^{86} ratios showed that the differences between

the interior gabbro and the granophyre pointed to (p. 711):

"complex interaction between the gabbroic magma and the host
granite gneiss."

McBirney (1975) reevaluated the data of Wager and Deer, did additional work on

new samples, and much-needed geophysical surveys. He concludes that the

volume of the Hidden Zone is much smaller than that postulated by Wager and

Brown (1967). Moreover, he feels that at a late stage, the magma separated

into two immiscible liquids, one rich in iron and phosphorus, and the other

rich in silica and alkalies.

At the same time, Irvine (1970, 1974, 1975a, 1975b) who has vast experience

in the Duke Island and Muskox layered intrusions, advanced a theoretical

explanation, supported by new laboratory work, for the origin of the chromitite

beds in the Bushveld, Stillwater, and Great Dyke: the chromite crystallizes in

a cyclic manner when (p. 300)

"the parental magma deviated from its normal course of crystal-
lization because of contamination by granitic melts derived from
the roof of the intrusion."

Yoder first recognized the importance of changes in P_{H_2O} and f_{O_2} and showed

that cyclic changes in these variables could lead to layering in igneous rocks.

The contamination and assimilation suggested by Irvine does provide a mechanism

to introduce oxygen (e.g., in H_2O) and modify the oxidation state of the magma.

Irvine (1974) also suggested that this mechanism could explain layers of

magnetite, sulfides, and perhaps other kinds of magmatic ores. Irvine's

critical figures are reproduced here with their original legends to help the

reader of this report.

Figure 116 shows the geometry of the magma chamber, the convection cell,

and the zone of roof rocks melted to create the necessary contamination. The

distribution of the granophyre within the Dore Lake Complex (Fig. 117) compared

to the composition of the country rocks is extremely interesting in function of

what has been proposed by Taylor, Irvine, and McBirney. The roof rocks of the

D.L.C. can be divided into three parts:

a. the south limb where the D.L.C is in contact with porphyritic rhyolite and quartzofeldspathic pyroclastics of the Waconichi Formation (Allard, 1970 and Oliveira, 1973). A thick zone of granophyre is present throughout the full extent of the south limb of the complex, reaching thicknesses of ± 3000 feet (900 m.).

b. the western portion of the north limb is also in contact with porphyritic rhyolite and felsic pyroclastics of the Waconichi Formation (Allard, 1975). The rocks of the LZ and FZ underneath the granophyre are well layered.

c. the eastern portion of the north limb from Cedar Bay eastward is in contact with the Lac Sauvage Iron Formation and the pillowed metabasalts of the Gilman Formation. This portion has no granophyre and lacks a well layered zone.

FACIES CHANGES IN THE DORE LAKE COMPLEX

The differences between the well-layered Layered Zone of the south limb and western north limb and the magnetite-rich serpentinites of the Sorcerer Mountain and Magnetite Bay zones has been described in a separate chapter. Looking again at Figure 117, one is apt to conclude that the ideas of Taylor, Irvine, and McBirney can be applied together in explaining the rock distribution of the complex. McBirney (1975) ends his paper with the following statement:

> "A further complication arises from the recent discovery that the
> phase layering of the Layered Series transgresses structural and
> stratigraphic horizons. The sequence of appearance of mafic
> phases is displaced upward in the eastern part of the intrusion
> relative to a section on the west side, so that cumulus clino-
> pyroxene and magnetite appear and olivine disappears at levels that
> rise toward the east relative to distinctive horizons, such as the
> conspicuous Triple Group. The fact that the composition of
> plagioclase does not seem to be affected by this phenomenon
> suggests that the liquidus temperatures of iron-bearing minerals
> reflected a difference in oxygen fugacity from one side of the
> intrusion to the other. This feature was only recognized very
> recently and requires more study."

We recognize here a duplication of the Dore Lake Complex situation with ferro-pyroxene, magnetite, and plagioclase cumulus minerals in the well-layered south limb while the eastern part of the north limb is a ferrodunite displaying very

crude and poor layering and olivine and magnetite (Figs. 69 and 70) cumulus

minerals but without ferropyroxene and plagioclase. McBirney suggests

differences in oxygen fugacities to explain these facies changes and it could

well be that such differences are tied in with Irvine's suggestions of a

contamination by fusion of the felsic country rocks. Cyclical breaking up of

the Upper Border Zone and admixing of the melted country rock could change the

oxygen fugacity and the composition and cause the layering and the major facies

changes observed in the Dore Lake Complex.

If this is the case, one cannot envision a large convection cell acting on

the whole extent of the complex, but a series of smaller cells acting indepen-

dently from one another.

DIFFERENTIATION TREND OF THE DORE LAKE COMPLEX

The changes in composition of the Dore Lake Complex magma as it crystallizes

have been demonstrated in previous pages. The isochemical metamorphism has

left the textures intact and the resultant metamorphic mineralogy indicates that

the bulk chemistry of the present rocks, if we exclude H_2O and CO_2, is identical

to the original chemistry of the magmatic rocks. One difficulty in evaluating

chemical analyses is the percentage of cumulate minerals vs intercumulus material

which may or may not represent the crystallizing magma at the time of formation

of the rock. The only good index of composition is the cryptic variation in

minerals as explained in the chapter on petrography and mineralogy of the Dore

Lake Complex. The changes in composition of plagioclase, pyroxene, olivine,

oxides, and the appearance of apatite and quartz correspond very well with the

observed sequences reported in complexes like the Skaergaard, Bushveld,

Stillwater, and Duluth complexes (Wager and Brown, 1967, figs. 131 and 132,

p. 237 and 238).

Figure 118 shows the information on the Skaergaard and Figure 119 summarizes

the information on the Duluth, Stillwater, and Bushveld complexes. Figure 120
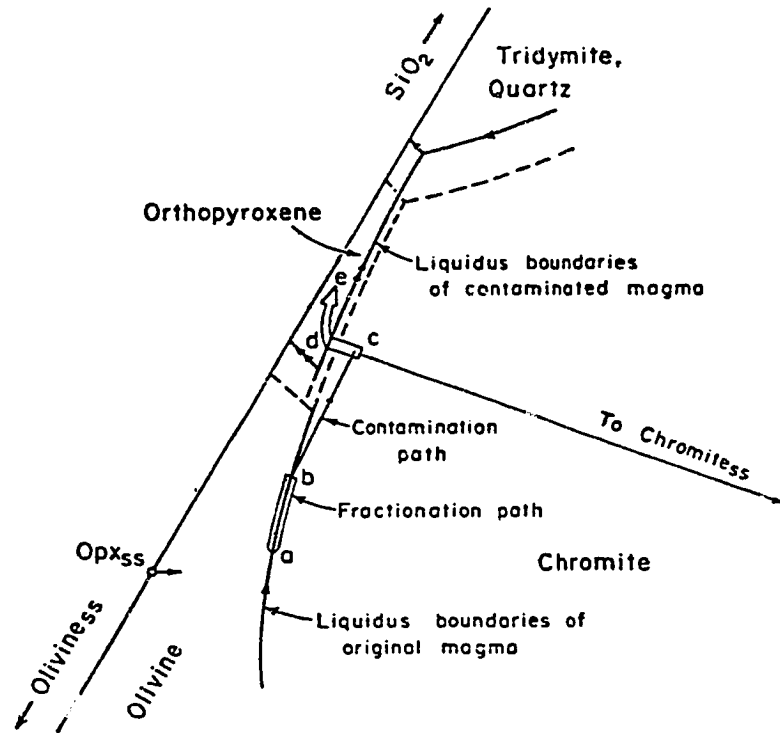
Fig. 59. Phase diagram model illustrating the formation of the lower parts of the Muskox cyclic units containing chromite-rich layers by a combination of fractional crystallization and contamination. The model is the same as in Fig. 55.

Fig. 114.Diagram of Irvine illustrating a mechanism to produce layering of chromite-rich rocks in a differentiating mafic magma.

From Irvine (1974), fig. 59, p. 310.
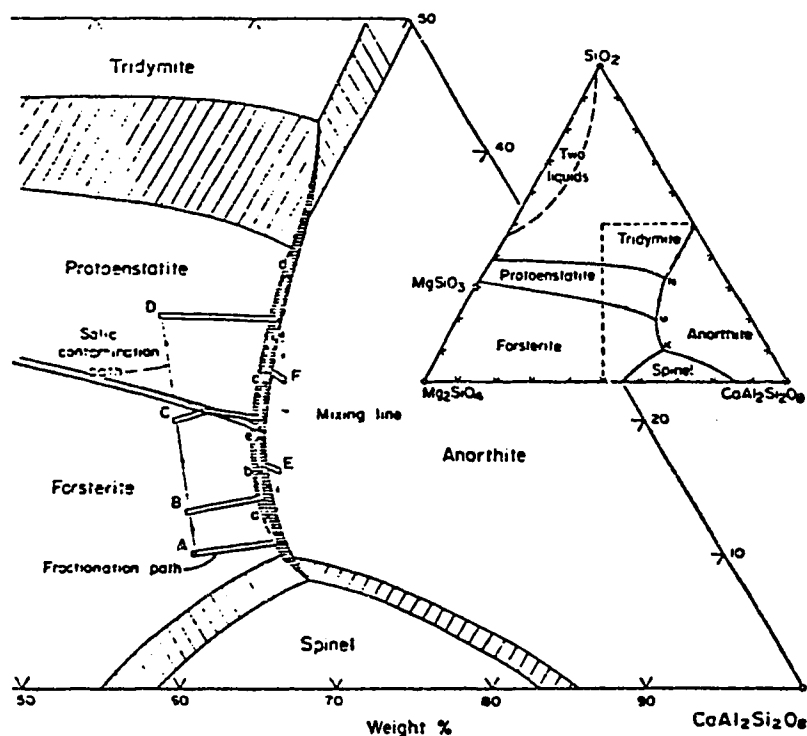
Fig. 66. Liquidus diagram of part of the system Fo-An-Or-Q, showing the crystallization orders that can be developed from a haplobasaltic liquid at A by the combined effects of salic contamination, fractional crystallization, and magma mixing. The diagram is not quantitative in detail but may be regarded as a projection from about $Or_{\sim}Q_{\sim}$. The extent of contamination and mixing has been exaggerated for purposes of illustration. If the various precipitates are equated with rock types (e.g., forsterite with peridotite, protoenstatite with orthopyroxenite, anorthite with anorthosite), the indicated fractionation paths give the following sequences of rock layers: Aa and Bb, peridotite, troctolite (and, eventually, norite); Cc, peridotite, orthopyroxenite, norite; Dd, orthopyroxenite, n_rite; Ee, anorthosite, troctolite (and, eventually, norite); Ff, anorthosite, norite. Note that a given path length in the anorthite field yields much more crystalline material than an equivalent path length in the olivine or pyroxene field.

Fig.115.   Diagram of Irvine illustrating a mechanism to explain layering in mafic complexes.

From Irvine (1975), fig. 66, p. 499.
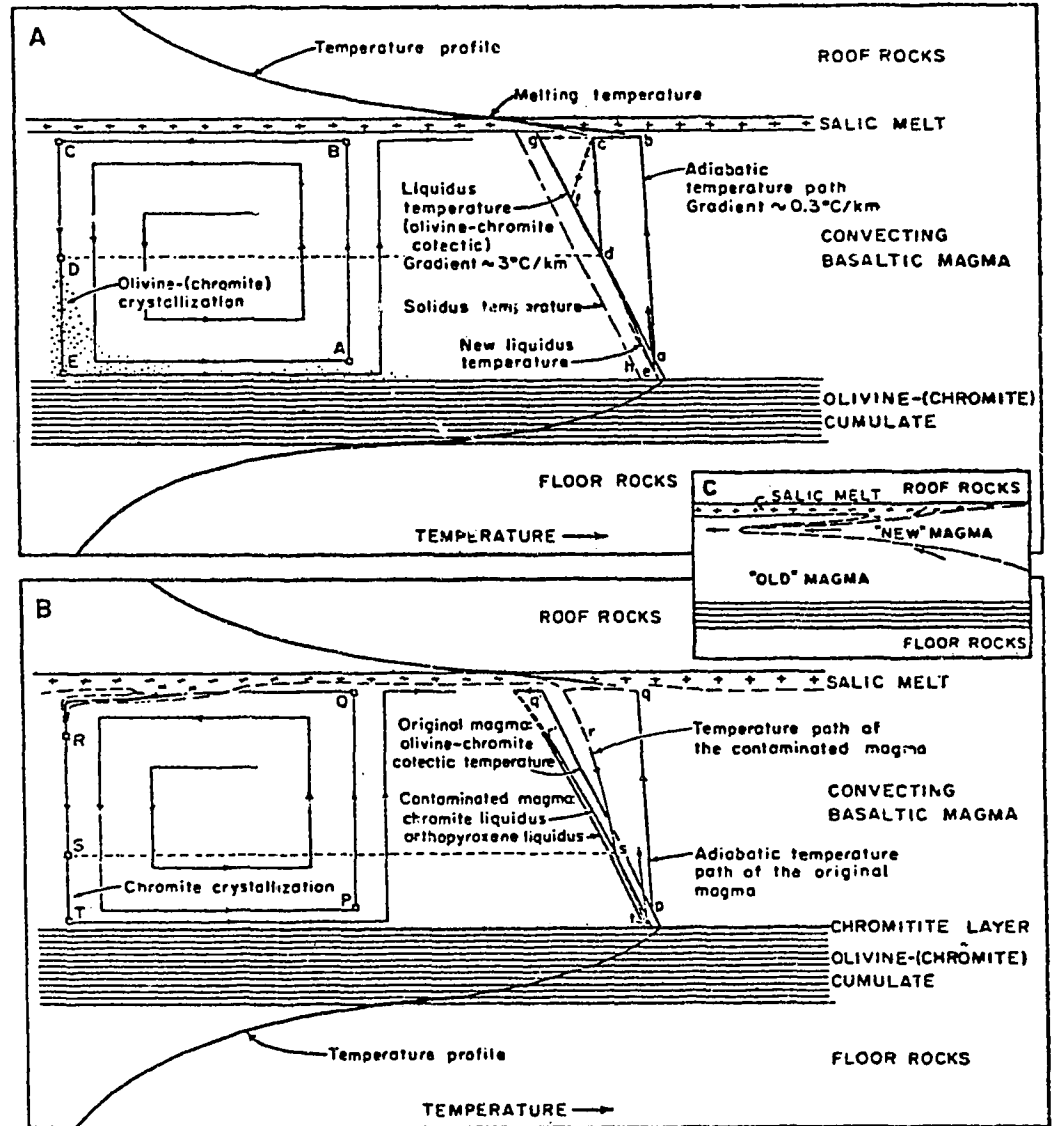
Fig. 61. Diagrams illustrating the physical processes postulated for the formation of chromitite layers. It is assumed that the intrusion roof comprises a substantial proportion of rocks such as pelitic schists and granite that will yield salic melt at temperatures well below the liquidus of the basic magma. The tendency of H_2O to accumulate at the top of intrusions would facilitate the melting process. For further discussion, see text.

Fig. 116.   Diagram of Irvine showing the relationship of the intrusive body and country rocks during crystallization of the differentiating mafic magma.

From Irvine (1974), fig. 61, p. 313.
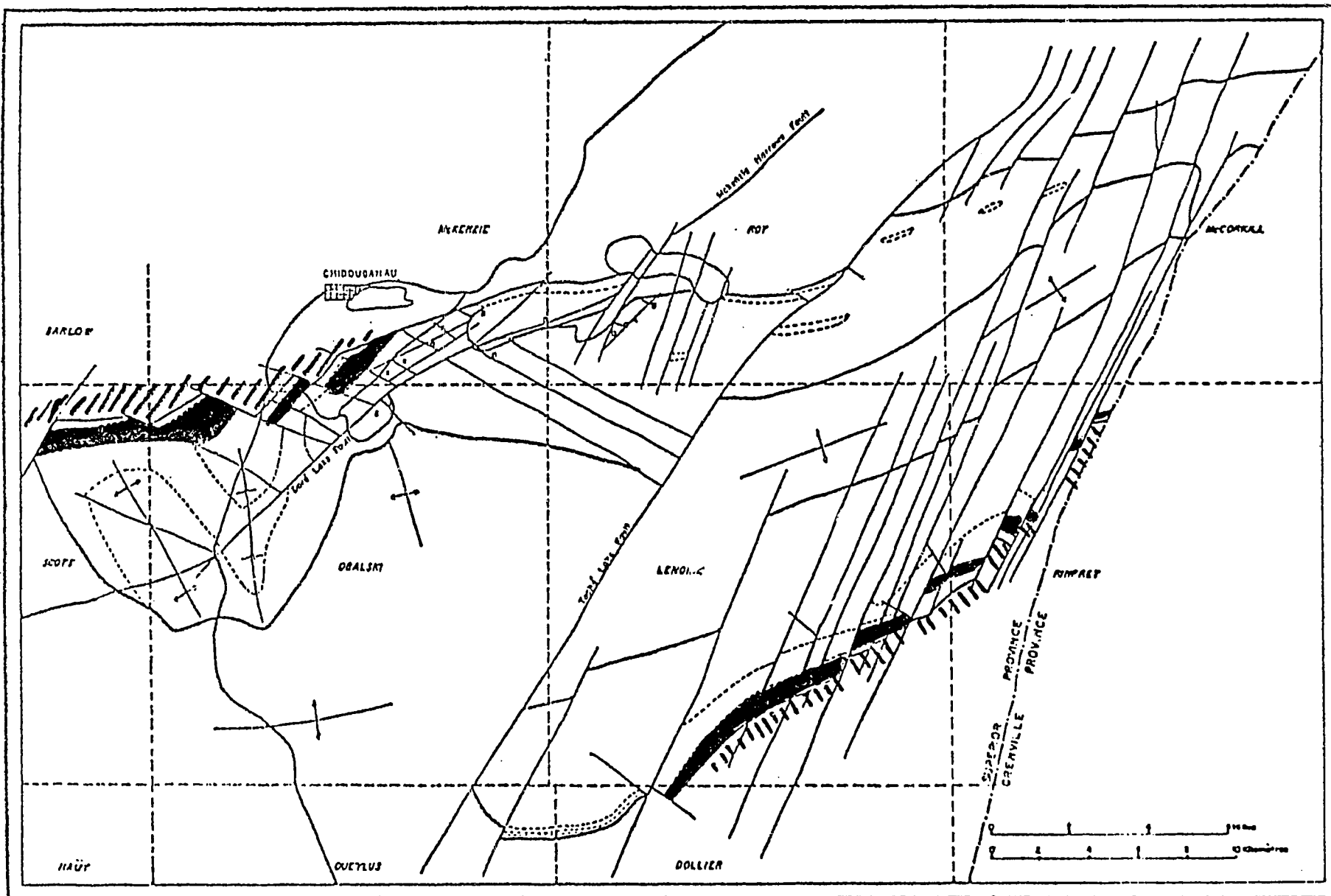
Fig. 117 - Sketch map of the Dore Lake Complex showing the extent of the Sodagranophyre Zone (black) and the porphyritic sodarhyolite and felsic crystal tuffs of the Waconichi Formation (cross hatched pattern).
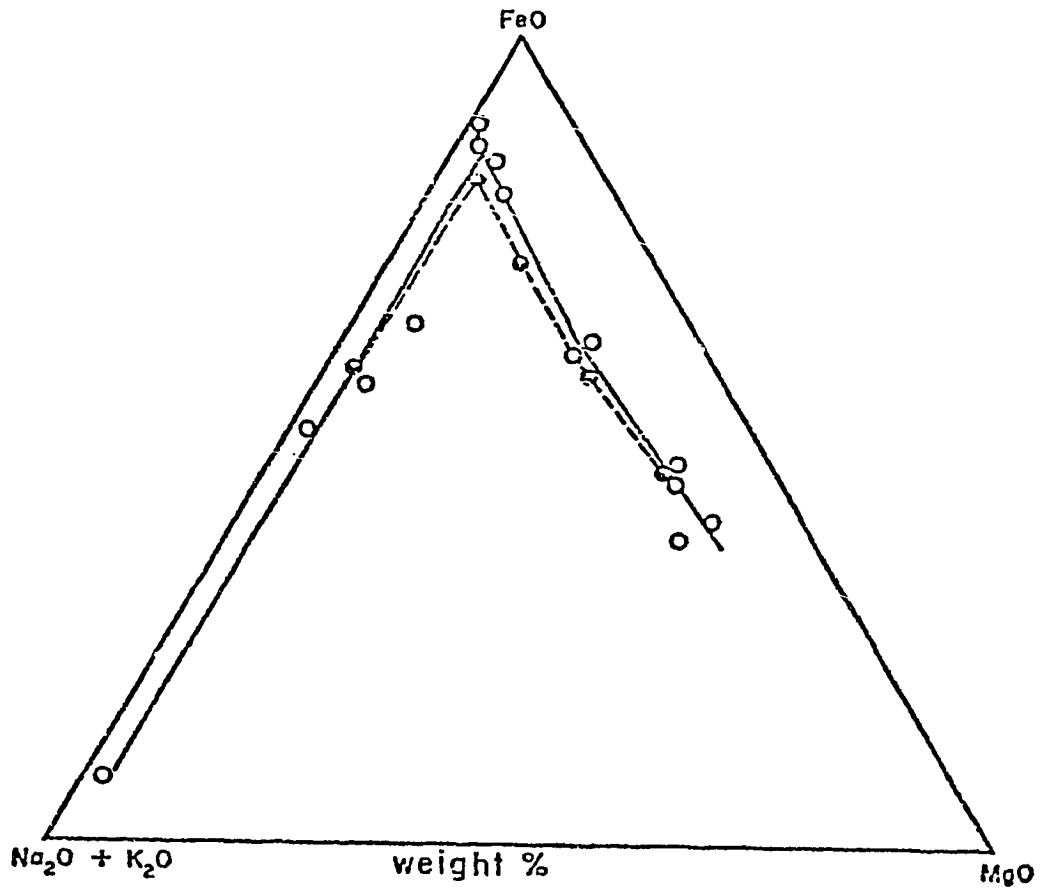
Fig. 118. AFM diagram for the Skaergaard Complex after
          Wager and Deer (1939)

    ⊕ Skaergaard Liquid
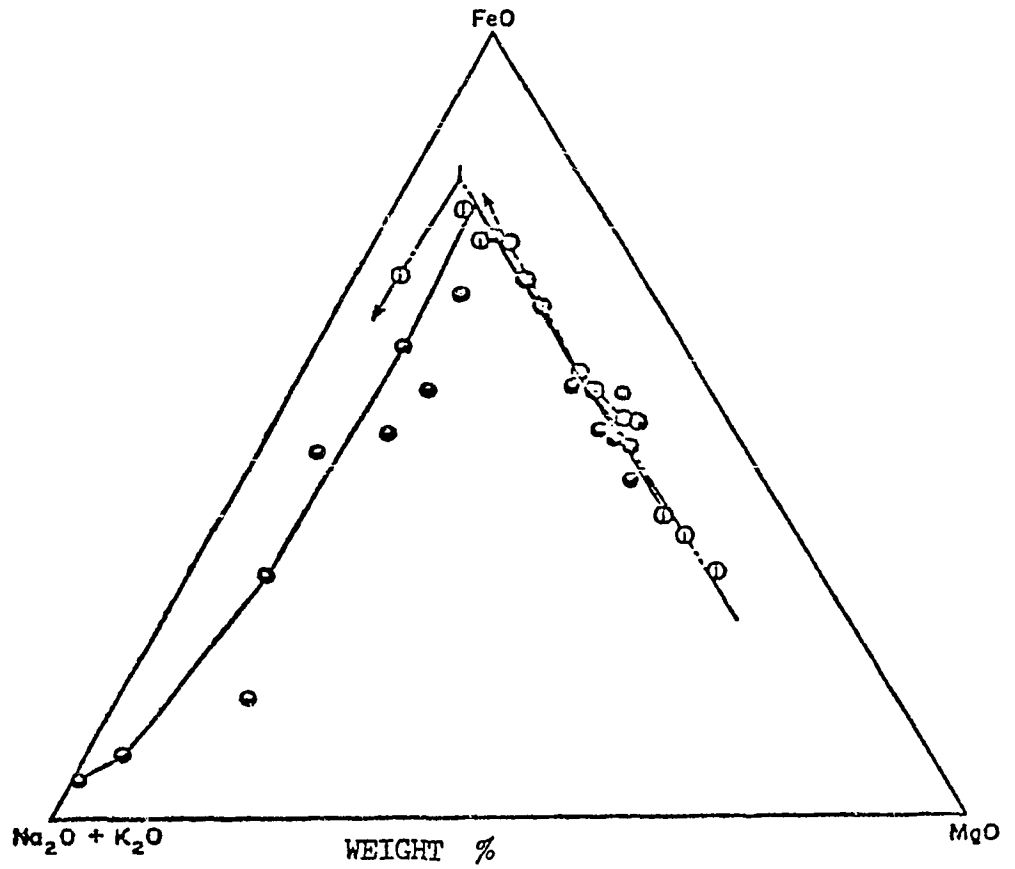
    ○ Skaergaard Rocks

Fig. 119. AFM diagram for rocks of the Stillwater, Bushveld, and Duluth complexes after Hess (1960, plate 11).

FeO + Fe$_2$O$_3$

Na$_2$O + K$_2$O

MgO

WEIGHT %
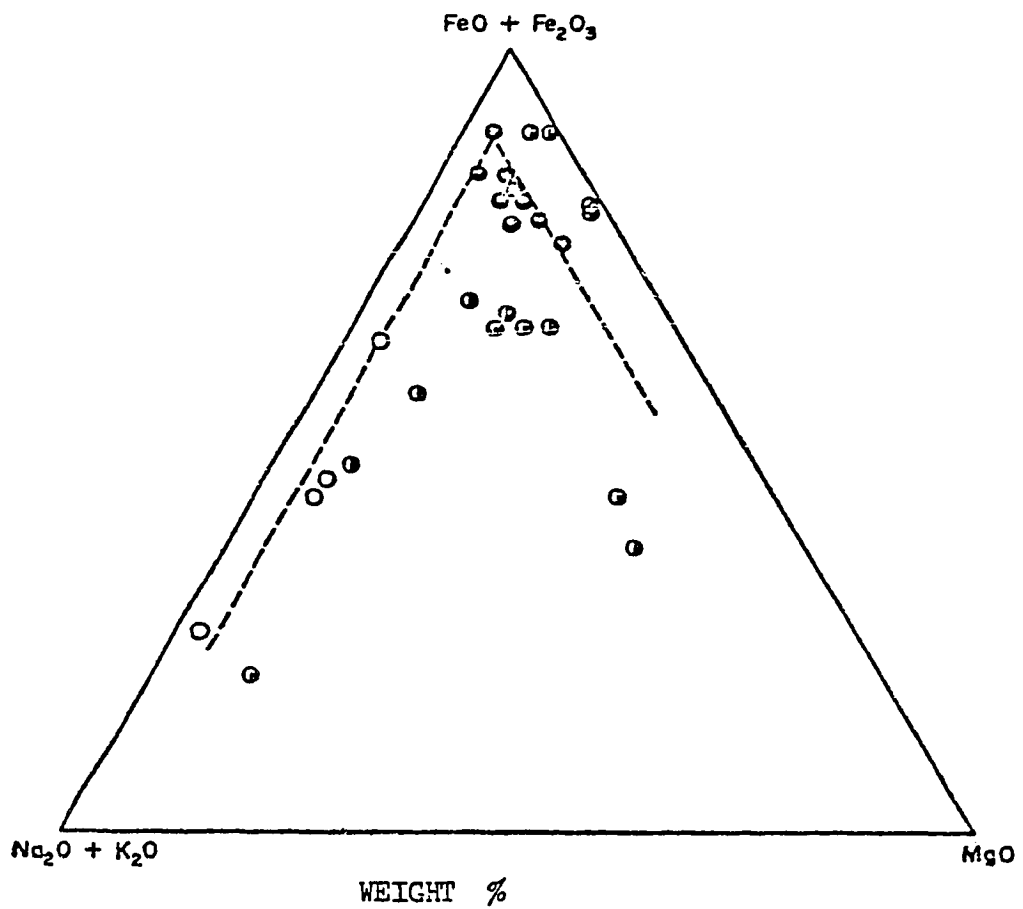
   ◒   Metagabbro, metapyroxenite P$_3$ member
           (homogeneous rocks)

   ◯   Metasodagranophyres

   ◐   Metacumulates (plagioclase, pyroxene, magnetite)

Fig. 120.   AFM diagram for the rocks of the south limb of
              the D.L.C. (from Caty, 1970, fig. 29, p.167)
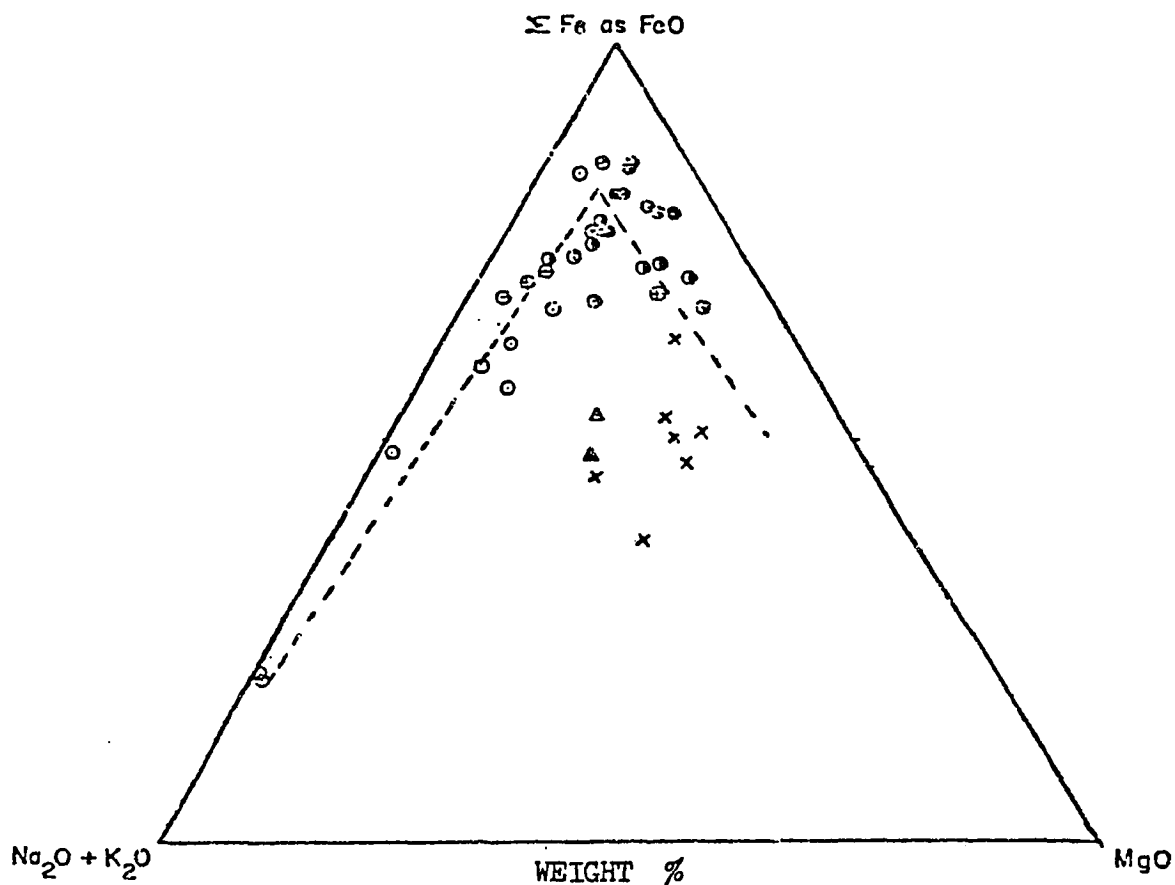
Fig. 121. AFM diagram for rocks from the western portion of the North limb of the Dore Lake Complex (from Baskin, 1975, fig. 38, p. 78)
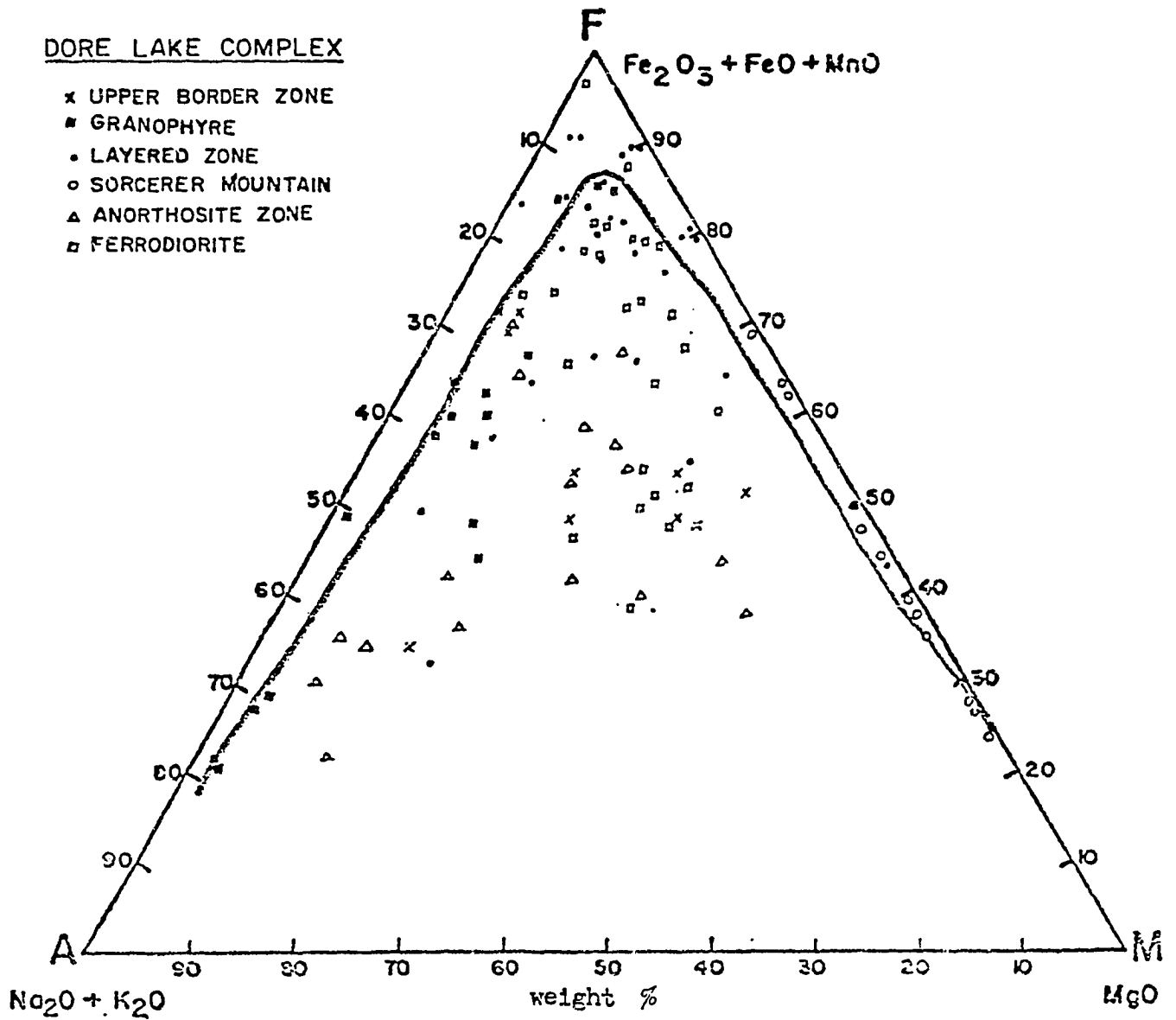
Fig.   122.   AFM diagram for all analyses from the Dore Lake Complex
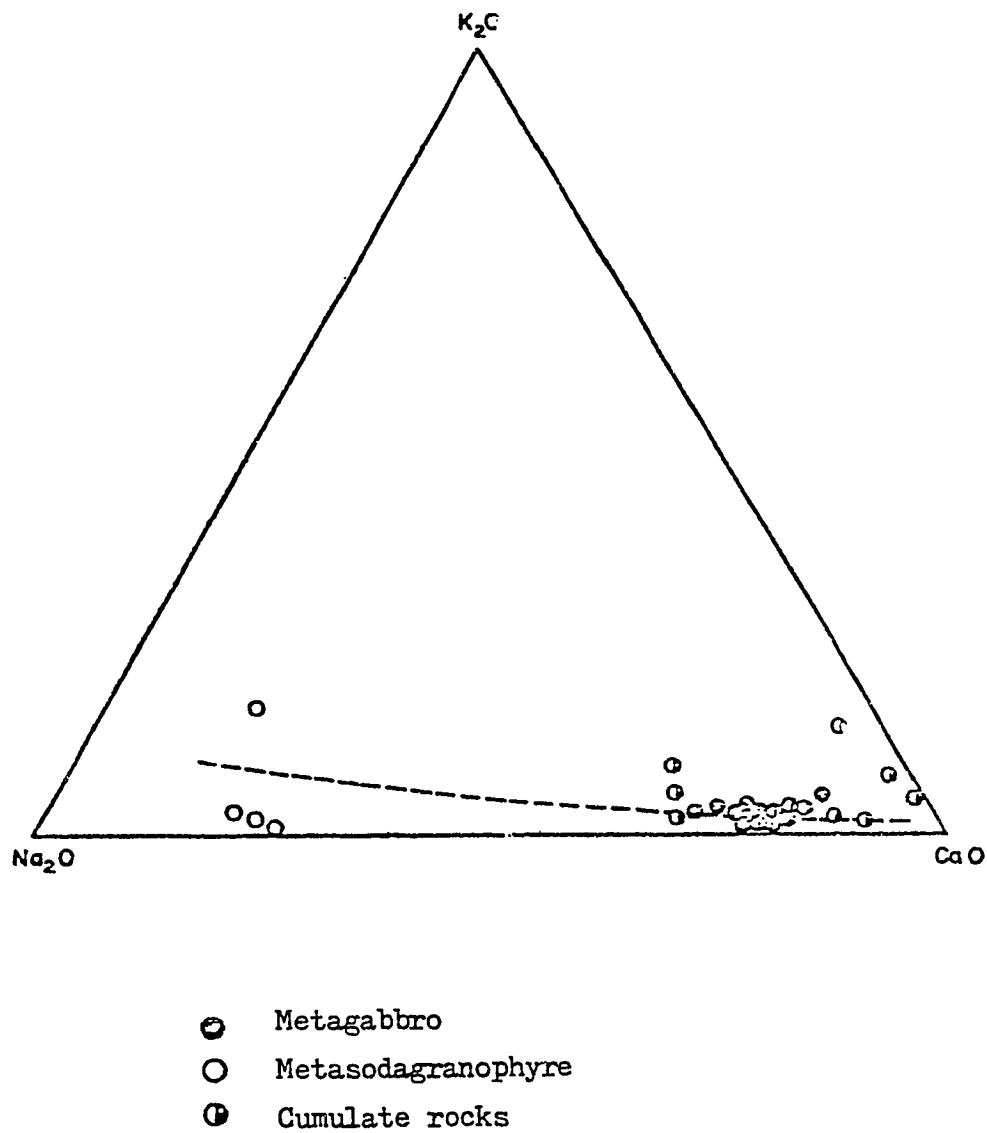
Fig. 123. Na$_2$O - K$_2$O - CaO diagram for rocks from the south limb of the Dore Lake Complex

(from Caty,1970, fig. 30, p. 168)
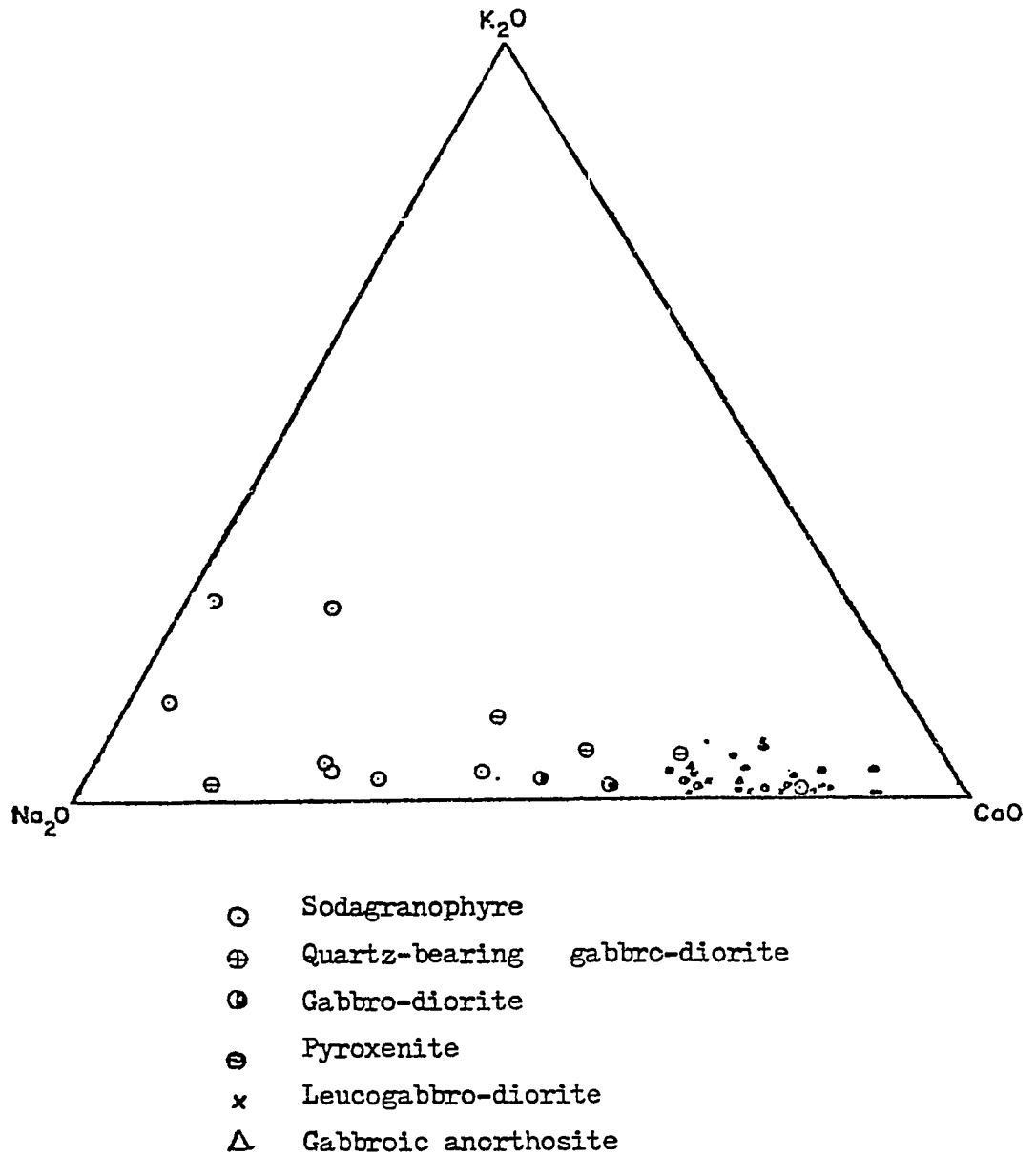
Fig. 124. Na_2O-K_2O - CaO diagram for rocks from the western portion of the north limb of the Dore Lake Complex (from Baskin, fig.41,p.82)

is a diagram prepared by Caty for rocks of the south limb of the D.L.C. Figure 121 was done by Baskin for the western portion of the north limb of the D.L.C. Figure 122 shows all the analyses known from the D.L.C. The difficulty in using the diagram is the large number of analyses of cumulates which cannot be compared with the magma composition at the time of formation of the rock. The Na_2O-K_2O-CaO diagram (Fig. 123 for the south limb and Fig. 124 for the north limb) also indicate similarity between the D.L.C. and other complexes except for the lower K_2O content of the D.L.C. which corresponds to a world-wide tendency for Archean rocks (Glickson, 1970).

The similarities shown in all these diagrams between the D.L.C. and the well known layered complexes suggest that the D.L.C. is the result of extreme fractionation of a basaltic magma with tholeiitic affinities.

The oxidation state of the initial magma must have been very low resulting in the formation of silicates and a long delay in the appearance of magnetite. The increasing oxidation state became overpowering at the top of the AZ resulting in the production of large quantities of magnetite and at the same time an increase in the Fe-content of the pyroxenes and/or olivines. We have suggested earlier that the assimilation of fused wall rock pyroclastics and sodarhyolites (Waconichi Formation) may be a cause of the layering and may control the distribution of granophyre (Fig. 117) within the D.L.C. It could also bring in O_2 in the form of H_2O which would explain this rapid increase upward in the state of oxidation of the magma.

CHAPTER 4

GEOLOGY OF THE CHIBOUGAMAU PLUTON

INTRODUCTION

The Chibougamau pluton, formerly called Lake Chibougamau mass by Mawdsley

and Norman (1935, p. 38), part of the David Lake Group by Graham (1956), and

Chibougamau Lake pluton by Allard (1956) is a large and very complex

trondhjemitic intrusive. Unfortunately, the detailed mapping of the pluton has

been done by eleven different geologists in the period 1950-1975, without

counting the numerous exploration company geologists who also worked within the

pluton. One can easily compile a map of the pluton taken as a whole but to

differentiate between all the various phases of the pluton becomes an impossible

task. We desperately need a complete restudy of the pluton by one single

geologist, not an easy task since the pluton covers an area of 172 square miles

(445 square kilometers), much of it under the waters of Chibougamau, Dore,

David, Scott, Simon, Merrill, and Ledden lakes, and large areas of glacial drift.

As mentioned in the chapter on Pleistocene geology, the large plutons in this

part of the Superior Province were evenly saprolitized and low lying before

Pleistocene glaciation producing large irregular amoeba-shape lakes dotted with

innumerable islands (Chigougamau Lake on Chibougamau pluton, Opemiska Lake on

Opemisca pluton, Obatogamau Lake on the La Dauversière pluton, etc., etc.).

Much of the Chibougamau pluton is pretectonic. A few phases found in the

core and in the southwest bulge are syn- or late-kinematic showing only minimal

deuteric alteration and no metamorphic or tectonic foliation.

The pluton is zoned and trondhjemitic in composition. Like many of its

Archean brothers, it is highly sodic and very low in K_2O. A few chemical

analyses of various phases are shown in Tables 84 to 89. A complete chemical

study would surely reveal many other types but as far as we know the K_2O content

of all rock types is very low except in the halo of intense hydrothermal

alteration around some porphryitic phases in Queylus Township. Cimon (1973)

has discovered in Queylus Township evidence for porphyry-type copper minerali-

zation and recent work has shown that type of mineralization is more widespread

in Queylus and Obalski Townships than formerly recognized and is associated with

many phases of porphyritic intrusions (dikes and plugs) accompanied by

tourmaline breccia pipes and very intense red potassic alteration. Cimon (1974)

reports rocks containing up to 5% K_2O, an exceptionally high content of K_2O for

the Chibougamau area.

The following rock types have been described over the years from the pluton.

Remapping by a single individual would likely eliminate some rock types and

group together lithologies described as different rock types in the papers

published so far.

DIORITE-QUARTZ DIORITE-MELADIORITE

The northern flank of the Chibougamau pluton is intrusive in the

Anorthosite Zone of the Dore Lake Complex. In most places, except in the area

south of the Campbell-Merrill ore deposits, the rock is a dark green fine- to

medium-grained meladiorite, diorite, hornblende diorite, gradually becoming

richer in quartz and biotite going south, away from the contact. This border

zone is marked by an abundance of xenoliths of anorthosite-gabbroic anorthosite-

gabbro (Fig. 125) and by a network of veinlets of pale grey tonalitic rocks

linked with the more felsic phases of the pluton. The easiest place to observe

this rock is in a roadcut on the Chapais road about 2000 feet (600 m.) west of

the bridge on the Chibougamau River.

The meladiorite (Allard, 1975, p. 7) is a dense medium-grained dark green

rock consisting of saussuritized plagioclase, hornblende, and small amounts of

epidote. Quartz is a minor constituent and increases gradually to the south.

The weathered surface is a dull greenish grey and is characterized by a fine

network of very narrow veinlets of epidote and quartz-albite standing in relief

on the surface. This criterion is one of the best to differentiate the mela-
diorite from similar rocks in the Ferrodiorite Zone of the Dore Lake Complex.
The meladiorite is also cut by anostomosing veinlets of tonalite, aplite, and
pegmatite derived from the more felsic portions of the pluton. The meladiorite
is probably genetically linked to the numerous dikes found in the anorthosite
close to the contact. Some of the dikes have a porphyritic texture marked by
an abundance of small euhedral dark yellow saussuritized plagioclase. Chemical
analyses of the meladiorite can be found in Table 88. The high TiO_2 content may
indicate contamination of a tonalitic magma by the anorthosite rocks of the Dore
Lake Complex.

It is interesting to quote here the description of identical rocks in
McCorkill Township at the eastern extremity of the pluton (Pouliot, 1963, p. 7):

> "Rocks of dioritic composition occur at the contact of the
> granitic complex with the meta-anorthosite east of lake Forest,
> in the west central part of the area, and similarly as a larger
> body, in the northeast corner of the map-area. A smaller mass
> of diorite intrudes the meta-anorthosite south of Forest lake.
> "The diorite is well exposed on the line between ranges II
> and III, approximately 2,100 feet east of Forest lake. The
> northern part of the exposure consists of dark green, fine-
> grained diorite containing abundant inclusions of meta-anorthosite.
> The diorite is characterized by a network of film-like feldspathic
> veinlets filling the fractures in the rock. Southward along the
> exposure, the diorite becomes coarser and more feldspathic; on the
> range line, it approximates the composition of a quartz syenite
> containing 20 percent hornblende and a little biotite. The network
> of feldspathic veinlets is still visible in the syenite, but
> disappears farther south. The diorite from the northeast corner
> of the area is a dark green to black medium-grained rock, composed
> of 60 percent hornblende and grey feldspars. Dykes of leucocratic
> granite cut both occurrences of diorite."

The diorite-meladiorite rocks which are so common all along the northern
contact of the Chibougamau pluton are not present on the south contact where
lighter-colored quartz-rich tonalites are in contact with the anorthosites.

GRANODIORITE-QUARTZ SYENITE-HORNBLENDE TONALITE-HORNBLENDE METATONALITE

The long list of terms above has been applied to different phases of the pluton by Graham (1956), Gaucher (1959), Pouliot (1963), Allard (1967), Allard and Caty (1969), Duquette and Mathieu (1970), and De Montigny (1960). A gradual coarsening of the grain size, decrease in quantity of hornblende, and increase in quartz content marks the transition from the meladiorite-diorite previously described to the rocks considered here. In most localities, especially in the eastern part of the pluton, a pronounced foliation is readily visible.

The rocks of this group weather to a light pinkish color speckled with dark green spots of hornblende making up to 30% of the rock. The quartz content varies from 5 to 30% forming tiny flattened lenses within the foliation plane. The feldspar is a saussuritized and sericitized oligoclase-andesine. A few flakes of chloritized biotite are generally present. A small quantity of pinkish feldspar is assumed to be potash feldspar. Chemical analyses of some samples are listed in Tables 84 and 85.

METALEUCOTONALITE-TRONDHJEMITE-GRANITE-BIOTITE GRANITE

The rocks listed here form the core of the Chibougamau pluton. The rocks are foliated in the eastern part of the pluton. The rocks are very sodic and should not be called granite in the classical sense. They are pale colored on the fresh surface and weather to a chalky white color with small elongated curvey lenses of quartz sticking out on the surface. Many of the rocks within this group have less than 10% mafic minerals, mostly chlorite derived from biotite. The plagioclase is saussuritized and sericitized and potash feldspar is in very small quantity explaining the low K_2O content of the rocks as shown in Tables 86 and 87. De Montigny (1960), Mawdsley and Norman (1935), Pouliot (1963), and Graham (1956) called some of the rocks granite. Biotite tonalite, biotite granodiorite, biotite hornblende granodiorite and hornblende biotite granodiorite are the most common types. All of these rocks have a trondhjemitic tendency.

Pouliot (1963) in the northeastern part of McCorkill Township mapped a separate facies which he called "grey biotite-rich granite." He states that:

> "it is composed of 50% to 80% glassy grey and white feldspar, quartz, and small flakes of biotite. The biotite content ranges from 15 to 45 per cent."

QUEYLUS-OBALSKI TOWNSHIP "PORPHYRY" INTRUSIVES

The southwest corner of the Chibougamau pluton is a hodgepodge of felsic intrusives not completely understood because of a severe lack of outcrops. In that area, the rocks of the pluton are intrusive into volcanic rocks of the Roy Group   and not in the Dore Lake Complex (Plate 1). Cimon (1971, 1973, 1974, 1975) recognized a series of facies which he called metatonalite, carbonatized quartz porphyry, and aplitic tonalite. At the same time, he recognized an unusual amount (for Chibougamau) of potassic alteration (one analysis in Table 85 gives over 6% K_2O) and an abundance of disseminated sulfides, mostly chalcopyrite with some pyrite, molybdenite, tourmaline, and magnetite. Cimon (1973) put forward the idea of Archean porphyry copper deposits in the Chibougamau area. Geologists were reluctant at first to accept his proposition but recent work by exploration companies have vindicated his suggestion. No copper deposits have yet been located (at the time of writing, December 1975) but ample traces of copper mineralization have been reported. Cimon (1974) suggests late satellitic diapiric and dike-like intrusives of very felsic and porphyritic rocks into the already solidified tonalite and diorite of the Chibougamau pluton. A vague west-northwest structural trend controls the late phase intrusives. Hydrothermal alteration, explosive brecciation, and copper-molybdenum mineralization are closely related to the porphyritic intrusives.

Two types of breccia can be observed (Cimon, 1974). One is made up of subangular to subrounded fragments of pebble-cobble size in a matrix of finely crushed rock. Most fragments are tonalitic in composition and a few have a

felsic porphyry composition. Some fragments of magnetite and magnetite-bearing metapyroxenite are reported by Cimon. They would be brought in from the Dore Lake Complex. Another type of breccia is a fragmented rock where the fragments are all of the same type and cemented by a fine mixture of black tourmaline, quartz, and rock particles. Similar breccias are common in Mesozoic and Tertiary porphyry copper districts.

GRANDROY SATELLIC INTRUSIVE

A satellic intrusion of metatonalite is located under most of Portage Bay and extends as far as the western end of Sorcerer Mountain and the northern tip of Marguerite Island. It has been intersected in a number of drill holes and its extent is shown in Plate 1. Two chemical analyses in Tables 86 and 87 are from unaltered drill cores in the Grandroy pluton. The Grandroy copper deposit was discovered on the mainland within the Grandroy intrusive, a few hundred feet north of Portage Bay. Formerly known as the Grandines sulfide zone, it contains ± 500,000 tons averaging 2-2.5% Cu and 0.03 oz. of gold per ton. The deposit occurs in a network of fractures in the metatonalite. Pink potassic alteration is common along mineralized veinlets. The main ore minerals are chalcopyrite, pyrite, molybdenite, magnetite, and specularite. Campbell Chibougamau Mines has mined 385,047 tons by open pit and has gone underground with a spiraling ramp. The stockwork of mineralized fractures resemble many porphyry copper deposits but the tonnage is small and the grade higher than the average porphyry deposit. K. Beckman is studying the Grandroy deposit for his M.S. thesis (see chapter on ore deposits for more details).

BRECCIA ZONES IN NORTHEAST LEMOINE TOWNSHIP

Allard (1969) has located a series of outcrops of breccia in the northeast quarter of Lemoine Township. The outcrops are located along Armitage River and on the shores of islands in Chibougamau Lake. They are not continuous

enough to permit the mapping of the exact shape of the breccia bodies. The breccias consist in subangular blocks of hornblende-rich metadiorite and metagabbro (?). The matrix varies from a pale metaleucotonalite to a pinkish granitic rock. This breccia should not be confused with the border breccia zone at the contact between the Chibougamau pluton and the Anorthosite Zone of the Dore Lake Complex; the latter is recognizable by its position and the xenoliths of meta-anorthosite and metagabbro in the dark green meladiorite.

The origin and significance of the Lemoine breccia bodies remains an unsolved problem while awaiting detailed studies.

TABLE 84

CHEMICAL ANALYSES OF ROCKS FROM UNIT   CHIBOUGAMAU PLUTON

ANALYSES CHIMIQUES DES ROCHES DU PLUTON DE CHIBOUGAMAU

Sample No. No. d'échantillon	GC-42	GC-43	GC-44	GC-46	GC-47
SiO_2	67.07	56.73	70.33	72.68	68.72
TiO_2	0.45	0.63	0.37	0.23	0.41
Al_2O_3	15.27	17.94	14.81	14.32	14.84
Fe_2O_3	1.14	1.96	0.82	0.65	1.05
FeO	3.42	5.88	2.47	1.95	3.15
MnO	0.06	0.10	0.04	0.05	0.07
MgO	1.85	3.62	1.09	0.84	1.20
CaO	5.39	7.42	4.19	3.57	4.54
Na_2O	4.07	3.91	4.39	4.30	4.18
K_2O	0.75	0.97	1.06	1.12	1.34
P_2O_5	0.15	0.17	0.14	0.06	0.14
H_2O+					
H_2O-					
CO_2					
S					
TOTAL	99.62	99.33	99.71	99.77	99.64
Norm wt%					
Qtz	25.49	7.22	29.51	33.58	26.99
Cor					
Or	4.43	5.73	6.26	6.62	7.92
Plag	55.62	61.62	54.72	52.85	53.14
Ab	34.44	33.09	37.15	36.39	35.37
An	21.18	28.54	17.57	16.46	17.77
Ne					
Ac					
Di	3.79	5.91	1.91	0.71	3.22
Wo	1.91	2.99	0.96	0.36	1.60
En	0.93	1.52	0.43	0.15	0.66
Fs	0.95	1.40	0.53	0.20	0.96
Hy	7.44	14.42	5.08	4.49	5.75
En	3.68	7.50	2.29	1.94	2.33
Fs	3.76	6.92	2.80	2.55	3.41
Ol					
Fo					
Fa					
Mt	1.65	2.84	1.19	0.94	1.52
Il	0.85	1.20	0.70	0.44	0.78
Hm					
Ap	0.36	0.40	0.33	0.14	0.33
Py					
Cal					
Data Wt%					
An/plag	38.0	46.3	32.1	31.1	33.4
Fa/ol					
En/hy	49.4	52.0	45.0	43.1	40.6
Diff.i.	64.3	46.0	72.9	76.5	70.2
Qtz	39.6	15.7	40.4	43.8	38.4
Ab	53.5	71.9	50.9	47.5	50.3
Or	6.9	12.4	8.5	8.6	11.2
An	35.2	42.3	28.8	27.7	29.1
Ab	57.3	49.1	60.9	61.1	57.9
Or	7.3	8.5	10.2	11.1	13.0
A	42.9	29.9	55.4	61.1	50.5
F	40.6	48.0	33.4	29.3	38.4
M	16.4	22.1	11.0	9.4	11.0
Na+K/Al	49.1	41.7	56.5	57.9	56.1
Fe+Mn/Fe+Mn+Mg	57.7	54.5	62.5	63.3	66.0
Na_2O/Na_2O+K_2O	84.4	80.1	80.5	79.3	75.7

TABLE 85

CHEMICAL ANALYSES OF ROCKS FROM UNIT   CHIBOUGAMAU PLUTON

ANALYSES CHIMIQUES DES ROCHES DU PLUTON DE CHIBOUGAMAU

Sample No. No. d'échantillon	GC-48	GC-50	GC-51	GC-52	GC-53
SiO_2	68.96	72.82	70.64	76.55	68.45
TiO_2	0.26	0.04	0.32	0.10	0.34
Al_2O_3	14.99	14.25	13.58	12.64	15.54
Fe_2O_3	0.74	0.16	0.78	0.38	0.83
FeO	2.21	0.49	2.34	1.14	2.50
MnO	0.08	0.21	0.06	0.04	0.04
MgO	1.29	0.19	1.15	0.44	1.52
CaO	4.00	0.54	4.17	2.54	3.71
Na_2O	4.77	4.61	4.62	4.40	4.71
K_2O	2.37	6.56	1.99	1.55	1.95
P_2O_5	0.09	0.08	0.08	0.08	0.13
H_2O+					
H_2O-					
CO_2					
S					
TOTAL	99.76	99.95	99.73	99.86	99.72
Norm wt%					
Qtz	21.92	20.69	26.35	38.80	22.63
Cor					
Or	14.00	38.76	11.76	9.16	11.52
Plag	52.85	36.78	49.53	47.39	55.36
Ab	40.36	36.78	39.09	37.23	39.85
An	12.49		10.44	10.16	15.50
Ne					
Wo					
Di	5.59	1.84	8.08	1.61	1.69
Wo	2.82	0.90	4.06	0.80	0.86
En	1.40	0.26	1.89	0.32	0.44
Fs	1.37	0.68	2.13	0.49	0.40
Hy	3.61	0.76	2.08	1.98	6.37
En	1.82	0.21	0.98	0.78	3.35
Fs	1.79	0.55	1.10	1.20	3.02
Ol Fo					
Fa					
Mt	1.07		1.13	0.55	1.20
Il	0.49	0.08	0.61	0.19	0.65
Hm					
Ap	0.21	0.19	0.19	0.19	0.31
Py					
Cal					
Data Wt%					
An/plag	23.6		21.0	21.4	28.0
Fa/ol					
En/hy	50.3	27.9	46.9	39.3	52.5
Diff.i.	76.2	96.2	77.2	85.1	74.0
Qtz	28.7	21.5	34.1	45.5	30.5
Ab	52.9	38.2	50.6	43.7	53.8
Or	18.3	40.2	15.2	10.7	15.5
An	18.7		17.0	18.0	23.1
Ab	60.3	48.7	63.8	65.8	59.5
Or	20.9	51.3	19.1	16.2	17.2
Q	62.7	93.0	60.7	75.2	57.9
F	25.9	5.4	28.7	19.2	28.9
M	11.3	1.5	10.5	5.5	13.2
Na+K/Al	69.4	103.05	71.8	70.5	63.4
Fe+Mn/FeMnMg	56.2	71.4	60.2	66.0	54.8
Na_2O/Na_2O+K_2O	66.8	41.2	69.9	73.9	70.7

TABLE 86

CHEMICAL ANALYSES OF ROCKS FROM UNIT   CHIBOUGAMAU PLUTON TONALITE

ANALYSES CHIMIQUES DES ROCHES DE   TONALITE DU PLUTON DE CHIBOUGAMAU

Sample No. No. d'échantillon	68-174	68-145	68-0-1	20-70-1	G20-183
SiO$_2$	68.83	69.03	73.60	74.20	68.00
TiO$_2$	0.28	0.20	0.10	0.09	0.15
Al$_2$O$_3$	15.53	15.58	14.76	14.35	16.35
Fe$_2$O$_3$	1.11	0.67	0.27	0.69	1.23
FeO	3.32	2.00	0.82	0.50	2.38
MnO				0.03	0.05
MgO	1.04	0.95	0.51	0.35	1.61
CaO	3.86	4.11	2.27	1.42	2.01
Na$_2$O	4.30	4.30	5.20	5.32	2.62
K$_2$O	0.85	1.04	1.39	1.45	2.40
P$_2$O$_5$				0.02	0.12
H$_2$O+				0.85	1.88
H$_2$O-				0.04	0.06
CO$_2$				0.32	0.77
S				0.01	0.01
TOTAL	99.12	97.88	98.92	99.63	99.64
Norm wt%					
Qtz	28.60	28.60	31.90	34.96	37.86
Cor	0.52		0.57	2.24	7.86
Or	5.02	6.15	8.21	8.57	14.18
Plag	55.53	56.52	55.26	49.91	26.49
Ab	36.39	36.39	44.00	45.02	22.17
An	19.15	20.14	11.26	4.89	4.32
Ne					
Wo					
Di		0.21			
Wo		0.11			
En		0.05			
Fa		0.06			
Hy	7.31	5.05	2.39	1.12	7.19
En	2.59	2.32	1.27	0.87	4.01
Fs	4.72	2.73	1.12	0.24	3.18
Ol Fo					
Fa					
Mt	1.61	0.97	0.39	1.00	1.78
Il	0.53	0.38	0.19	0.17	0.28
Hm					
Ap				0.05	0.28
Py				0.01	0.02
Cal				0.73	1.75
Data Wt%					
An/plag	34.4	35.6	20.3	9.8	16.3
Fa/ol					
En/hy	35.4	45.9	53.2	78.0	55.8
Diff.i.	70.0	71.1	84.1	88.5	74.2
Qtz	40.8	40.2	37.9	39.4	51.0
Ab	52.0	51.1	52.3	50.8	29.9
Or	7.1	8.6	9.8	9.7	19.1
An	31.6	32.1	17.7	8.3	10.6
Ab	60.0	58.0	69.3	77.0	54.5
Or	8.2	9.8	12.9	14.6	34.9
A	48.4	59.6	80.4	81.4	49.0
F	41.7	29.8	13.3	14.3	35.2
M	9.8	10.6	6.2	4.2	15.7
Na+K/Al	51.4	52.6	68.1	71.9	42.2
Fe+Mn/Fe+Mg	70.0	60.5	53.9	64.9	55.2
Na$_2$O/Na$_2$O+K$_2$O	83.5	80.5	78.9	78.5	52.1

TABLE 87

CHEMICAL ANALYSES OF ROCKS FROM UNIT   CHIBOUGAMAU PLUTON TONALITE

ANALYSES CHIMIQUES DES ROCHES DE TONALITE DU PLUTON DE CHIBOUGAMAU

Sample No. No. d'échantillon	R-4-347	20-70-2	68-F197	K21-270	0-2-320
SiO_2	66.13	66.65	68.24	67.65	68.00
TiO_2	0.27	0.15	0.27	0.19	0.38
Al_2O_3	16.34	16.25	17.00	15.85	12.86
Fe_2O_3	0.74	1.42	0.52	1.50	1.79
FeO	2.22	1.51	1.56	1.46	1.83
MnO		0.04		0.03	
MgO	1.45	1.52	0.90	1.17	6.08
CaO	4.60	3.03	3.38	3.06	2.54
Na_2O	4.50	5.06	5.40	4.96	4.43
K_2O	2.08	1.80	1.04	1.60	0.44
P_2O_5		0.12		0.10	
H_2O+		1.66		1.60	
H_2O-	`	0.05		0.05	
CO_2		0.65		0.34	
S		0.01		0.01	
TOTAL	98.33	99.92	98.31	99.57	98.35
Norm wt%					
Qtz	19.59	23.04	23.36	25.05	25.47
Cor		2.26	0.85	1.42	0.48
Or	12.29	10.64	6.15	9.45	2.60
Plag	56.32	52.96	62.46	54.35	50.09
Ab	38.08	42.82	45.69	41.97	37.49
An	18.24	10.14	16.77	12.38	12.60
Ne					
Wo					
Di	3.77				
Wo	1.91				
En	1.01				
Fa	0.84				
Hy	4.78	5.20	4.23	4.08	16.40
En	2.60	3.79	2.24	2.91	15.14
Fs	2.18	1.41	1.99	1.17	1.25
Ol Fo					
Fa					
Mt	1.07	2.06	0.75	2.17	2.60
Il	0.51	0.28	0.51	0.36	0.72
Hm					
Ap		0.28		0.24	
Py		0.01		0.01	
Cal		1.48		0.77	
Data Wt%					
An/plag	32.3	19.1	26.8	22.8	25.1
Fa/ol					
En/hy	54.4	72.8	53.0	71.3	92.3
Diff.i.	70.0	76.4	75.2	76.4	65.5
Qtz	28.0	30.1	31.0	32.8	38.8
Ab	54.4	56.0	60.8	54.9	57.1
Or	17.5	13.9	8.1	12.3	4.0
An	26.5	15.9	24.4	19.4	23.9
Ab	55.5	67.3	66.6	65.8	71.1
Or	17.9	16.7	9.0	14.8	4.9
A	59.9	60.6	68.3	61.3	33.4
F	26.9	25.9	22.0	27.7	24.8
H	13.1	13.4	9.5	10.9	41.7
Na+K/Al	59.0	63.2	58.9	62.4	60.3
Fe+Mn/Fe+Mn+Mg	52.8	51.0	55.8	57.7	24.1
Na_2O/Na_2O+K_2O	68.3	73.8	83.8	75.6	91.0

TABLE 88

CHEMICAL ANALYSES OF ROCKS FROM UNIT   CHIBOUGAMAU PLUTON MELADIORITE

ANALYSES CHIMIQUES DES ROCHES DE MELADIORITE DU PLUTON DE CHIBOUGAMAU

Sample No. / No. d'échantillon	0-2-311	69-192	A-1-254	A-1-153	68-D109	68-P283	68-137	G-29-320
SiO_2	48.13	52.34	52.07	60.16	44.77	50.14	53.06	50.80
TiO_2	1.47	1.39	1.07	0.70	1.73	1.06	0.83	1.40
Al_2O_3	15.61	15.03	16.76	16.86	18.31	17.47	19.06	12.70
Fe_2O_3	3.99	2.09	2.85	2.57	3.11	2.25	1.89	4.22
FeO	8.18	9.35	6.85	3.29	9.33	4.65	5.69	10.71
MnO								0.36
MgO	4.36	5.70	5.50	2.36	4.70	4.72	3.66	6.09
CaO	9.03	8.60	8.31	5.75	10.04	9.20	8.46	6.84
Na_2O	4.37	3.00	3.00	4.02	3.80	3.45	3.65	2.56
K_2O	0.46	0.34	0.29	0.85	0.20	0.47	0.38	0.10
P_2O_5								0.15
H_2O+								3.25
H_2O-								0.08
CO_2								0.35
S								0.10
TOTAL	95.60	97.85	96.70	96.56	95.99	93.41	96.68	99.71
Norm wt%								
Qtz		4.15	5.77	17.09		2.49	4.98	8.34
Cor								
Or	2.72	2.01	1.71	5.02	1.18	2.78	2.25	0.59
Plag	55.84	51.93	56.79	59.46	55.97	59.99	65.39	44.53
Ab	34.22	25.39	25.39	34.02	23.66	29.19	30.89	21.66
An	21.62	26.54	31.41	25.45	32.31	30.79	34.50	22.97
Ne	1.49				4.60			
Di	19.08	13.31	8.00	2.49	14.48	11.96	6.14	6.50
Wo	9.68	6.73	4.10	1.28	7.31	6.20	3.12	3.29
En	5.06	3.41	2.41	0.82	3.59	4.06	1.66	1.65
Fa	4.34	3.16	1.49	0.38	3.59	1.70	1.37	1.56
Hy		20.79	18.26	7.44		10.92	13.61	26.28
En		10.78	11.29	5.06		7.69	7.46	13.51
Fs		10.00	6.97	2.38		3.23	6.15	12.77
Ol Fo	7.89				11.96			
Fa	4.06				5.69			
	3.83				6.27			
Mt	5.79	3.03	4.13	3.73	4.51	3.26	2.74	6.12
Il	2.79	2.64	2.03	1.33	3.29	2.01	1.58	2.66
Hm								
Ap								0.36
Py								0.19
Cal								0.80
Data Wt%								
An/plag	38.7	51.1	55.3	42.8	57.7	51.3	52.8	51.3
Fa/ol	48.5				52.4			
En/hy		51.8	61.8	68.0		70.4	54.8	51.4
Diff.i.	38.4	31.5	32.9	56.1	29.4	34.4	38.2	30.5
Qtz		13.1	17.5	30.4		7.2	13.0	27.2
Ab		80.4	77.2	60.6		84.7	81.0	70.8
Or		6.3	5.2	8.9		8.0	5.9	1.9
An	36.9	49.2	53.7	39.4	56.5	49.0	51.0	50.7
Ab	58.4	47.0	43.3	52.7	41.4	46.5	45.7	48.0
Or	4.6	3.7	2.9	7.8	2.0	4.4	3.3	1.3
A	22.6	16.3	17.8	37.2	18.9	25.2	26.3	11.2
F	57.0	55.9	52.4	44.8	58.8	44.4	49.6	63.0
M	20.4	27.8	29.7	18.0	22.2	30.3	24.0	25.7
Na+K/Al	29.2	35.2	31.3	44.7	35.3	35.4	33.7	34.0
Fe+Mn/Fe+Mn+Mg	60.2	52.5	49.0	57.1	59.1	44.2	53.1	57.8
Na_2O/Na_2O+K_2O	90.4	89.8	91.1	82.5	95.0	88.0	90.5	96.2

Table 89

Notes on samples of Tables 84 to 88.

TABLES 84, 85, AND 86. CHIBOUGAMAU PLUTON

GC-42, 43, 44, 46, 47, 48, 50, 51, 52, 53. All samples of Gunn and Duquette.
Location unknown.

68-174　(R 10-68-11) Allard, Q.D.N.R. Lab. Biotite poor tonalite. Lemoine
Township, southwest shore of Granite Island.

68-145　(R 10-68-4) Allard, Q.D.N.R. Lab. "Biotite cluster" tonalite. Small
island east of Granite Island.

68-D-1　(R 10-68-9) Allard, Q.D.N.R. Lab. Leucotonalite. Lemoine Township.
Shore of Chibougamau Lake, 12,000 feet (3600 m) north of the southeast
corner of the NW 1/4 (Allard, 1970).

20-70-1　Allard, Q.D.N.R. Lab. Leucotonalite. Obalski Township. Main Highway
300 feet (90 m) north of the Queylus-Obalski Township line.

G 20-183　Allard, Q.D.N.R. Lab. Hornblende tonalite, Roy Township. Drill hole
Grandines 20 from 183 to 187.

TABLE 87. CHIBOUGAMAU PLUTON TONALITE

R-4-347　Allard, Q.D.N.R. Lab. Hornblende tonalite. Lemoine Township. Drill
hole R-4 of C.M.S. close to the northeast corner of the NW 1/4 Lemoine
(Allard, 1970).

20-70-2　Allard, Q.D.N.R. Lab. Hornblende tonalite. Obalski Township. Main
highway, 600-700 feet (180-210 m) north of 20-70-1 above.

68-P197　Allard, Q.D.N.R. Lab. (R 10-68-8) Leucotonalite. Lemoine Township.
Lookout Island.

K-21-270　Allard, Q.D.N.R. Lab. Hornblende tonalite. Roy Township. North tip of
Marguerite Island. Drill hole C.M.S. K-21 from 250 to 251 and 269 to 272.

0-2-320　Allard, Q.D.N.R. Lab. Leucotonalite dike cutting hornblende diorite.
Scott Township. Drill hole 0-2 of C.M.S. on L 47 W, 400 N, west of David
Lake (Allard, 1975) from 320 to 324.

TABLE 88. CHIBOUGAMAU PLUTON MELADIORITE

0-2-311　(14-69-28) Allard, Q.D.N.R. Lab. Scott Township. Drill hole 0-2 of
C.M.S. from 311 to 318. Location above.

69-192　(14-69-20) Allard, Q.D.N.R. Lab. Meladiorite. Scott Township. Opemisca
main road at first curve west of the bridge on the Chibougamau river.

A-1-254　(14-69-22) Allard, Q.D.N.R. Lab. Meladiorite. Scott Township. Drill
hole A-1 from 254 to 260 on north tip of Deschenes Island, Simon Lake
(Allard, 1975).

A-1-153　(14-69-21) Allard, Q.D.N.R. Lab. Meladiorite, Scott Township. Drill
hole A-1 from 153 to 157, location as above.

68-D-109　(R 10-68-2) Allard, Q.D.N.R. Lab. Meladiorite. Lemoine Township. West
shore of the small island north of Line Island (Allard, 1970).

68-P-283　(R 10-68-1) Allard, Q.D.N.R. Lab. Meladiorite. Lemoine Township. East
shore of small island south of Arthur Island (Allard, 1970).

68-137　(R 10-68-3) Allard, Q.D.N.R. Lab. Hornblende diorite, Lemoine Township.
Northeast shore of Line Island (Allard, 1970).

G-29-320　Allard, Q.D.N.R. Lab. Hornblende diorite. Roy Township. Drill hole
G 29 of Grandines Mines Ltd., from 320 to 332.5.
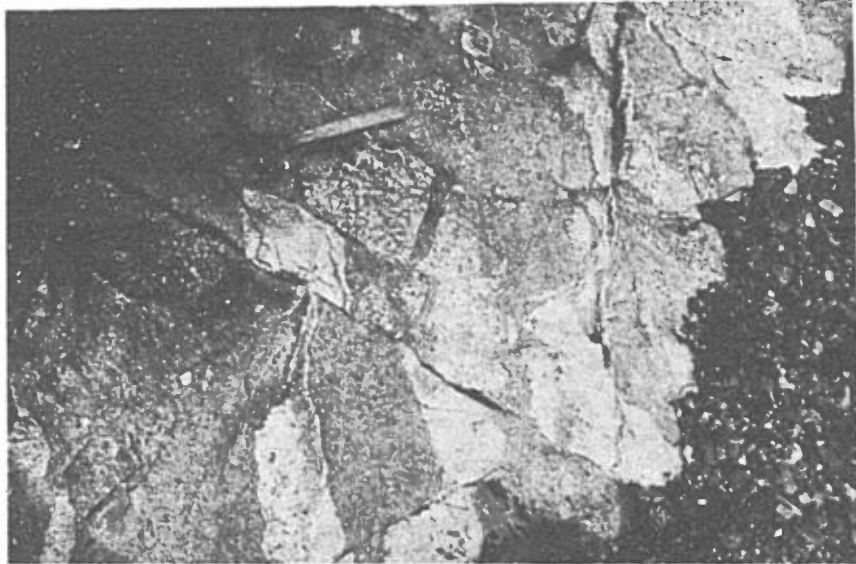
Fig. 125. Blocks of meta-anorthosite, anorthositic metagabbro, and metagabbro in quartz diorite-meladiorite of the Chibougamau pluton. Part of the intrusive breccia zone which separates the Dore Lake Complex and the pluton. Small faults cross the outcrop. Shore of island in Chibougamau Lake.

CHAPTER 5

DIKES

INTRODUCTION

The economic importance of dikes in the Chibougamau mining camp has been recognized by all the workers in the district. The range of composition extends from the most mafic (Henderson I pyroxenite) to the quartz porphyry common throughout the area. Unfortunately, their small size and the scale of mapping allows very few dikes to appear on the published maps. We badly need a regional study of all dikes with good statistics on the orientation, size, distribution, concentration, etc., of every dike type but such a study is physically impossible without remapping in great detail the whole Chibougamau district.

Published reports and theses discuss dikes and we will attempt to bring together all the important data in this chapter. Table 90 lists the dikes and their general relationships.

MINE DIKES

The Chibougamau area is a large composite volcanic center consisting of two major volcanic cycles and an abundance of intrusions varying from the most mafic to the most felsic and from dikes inches wide to the giant Dore Lake Complex.

The lower part of the Anorthosite Zone of the complex is in contact with the Chibougamau pluton and is intruded by a large number of dikes varying in composition from granitic to gabbroic. The dikes are related to the many phases of the pluton and to the volcanism which produced the Blondeau Formation. Dikes vary from a few inches to 100 feet (30 m.) in width. They commonly show chilled zones against the host rocks. Some dikes show sharp contacts with enclosing rocks, others show internal foliation parallel to the contact and others show sheared contact zones accompanied of stringers of quartz, carbonate, and/or sulphides. Dikes commonly contain xenoliths of the wall rocks but very rarely

Table 90

Important dikes in the Chibougamau area.

Dikes dans la region de Chibougamau.

Dike	Host rocks
Dike	Roches encaissantes

Line Island diabase dike	every rock type of the area
Metadiabase dikes	Chibougamau Formation (Henderson)
Lamprophyre dikes	Chibougamau pluton and Stella Formation
Gabbro Island dike	Roy Group, D.L.C. and C.P.
Henderson I metapyroxenite dike	D.L.C. and C.P.

Volcanic dikes	Q.F.P.	
	Q.P.	Roy Group, D.L.C., and C.P.
	F.P.	

	"greenstone" (metadiabase) dike
	older diorite dike
	grey dike
	feldspar porphyry dike
Mine dikes	quartz feldspar porphyry dike
	diorite porphyry dike
	quartz diorite dike
	granitic dikes
	"black dike"

show amygdules. Subparallel offshoots from the dikes have been noted in many mines. Some dikes are completely sheared and very heavily altered and difficult to identify since they look identical to the sheared and altered country rocks. The color contrast and grain size differences makes it easy to detect dikes in the meta-anorthosite but very difficult in the metabasalts. Quartz feldspar porphyry dikes are easy to spot in the basalts and are commonly reported. Dikes can be multiple and/or composite. The importance of dikes as ore controls in the Dore Lake area has been mentioned earlier. No ore deposit has been found in the Dore Lake area which is not in a shear zone alongside a swarm of dikes. The Henderson-Portage deposits seem to be an exception to this rule since no good dikes were identified parallel to either the "A" or "G" zones at Henderson.

The place and time of dike emplacement with respect to ore varies with the philosophy of each geologist. This will be discussed in the chapter on metallogenesis.

Every thesis on mines in the Chibougamau area discussed the petrography of dikes and their role in localizing ore deposits. Blecha (1966) did a thorough study of dikes at the Campbell Chibougamau Main mine. He studied 80 samples from seven dikes branches covering a vertical extent of 3050 feet (550-3600 level) and a lateral distance of 1500 feet (1100 W to 400 E).

Campbell Chibougamau Main Mine Dikes

The Campbell orebody consists in many lenticular ore lenses within a major composite shear zone-dike system. The average strike is N 70 W and the dip varies from 60° south to 80° north with an overall general steep dip to the south. The orebodies extend to a depth of 3900 feet. They occur along the footwall of steeply dipping dikes in meta-anorthosite. The general trend of dikes is N 70 W, parallel to the average shear zone. A few dikes with other directions have been noted but the N 70 W is predominant. In the center of the main Campbell shear, Blecha reports that dikes constitute about 30 per cent of the rocks.

Blecha recognized the following dikes:

a. older diorite dike

b. common dikes, important mine dikes

(the dikes underlined are those identified by most mine geologists)

grey dikes

Quartz diorite porphyry dikes

diorite dikes

granitic dikes

quartz porphyry dikes

feldspar porphyry dikes

quartz feldspar porphyry dikes

c. amphibolite dike

The petrography of the dikes is taken from Blecha (1966), Jeffery (1959), and Allard (1960). Considering the wide range of rock names applied to the dikes by mine geologists, it is surprising to see how limited is the mineralogy of the dikes: the main constituents are plagioclase, quartz, sericite, chlorite, carbonate, clinozoisite-epidote, minor sphene, and zircon. Veinlets of secondary quartz, calcite, and epidote are common. Fine disseminations of sulfides, mostly pyrite, are also very common.

Older diorite dike

The older diorite dike forms a tabular body 500 feet (150 m.) long and 50 feet (15 m.) wide on the footwall of the orebody at the 1000-level. The dike is dark green and consists of 35-60 per cent chlorite with minor associated quartz, plagioclase, sericite, and calcite. It is cut by some of the mine dikes. It is rarely seen in the mine and has little significance in its relation to the ore deposit.

Amphibolite dike

The amphibolite dike strikes almost parallel to the orezone but dips 50° north intersecting the orebody close to the 1900-foot level. It can be correlated with a metagabbro dike mapped at surface by Graham (1956, p. 20) in the vicinity

of the Kayrand oreshoot. Jeffery studied the dike in detail and his petro-
graphic description fits that of a metamorphosed diabase. The dike consists of
actinolite, zoisite-clinozoisite, chlorite, and quartz. Jeffery favours a pre-
ore origin mainly on the basis of a high-grade copper ore lens located in the
footwall of the dike on the 1750-foot level. The contact of the dike with
sulfides is sharp but locally tongues and veins of ore extend into the dike.

"Mine" or "common" dikes

The mine dikes form a complex swarm conformable to the main ore-bearing
shear zone. Within the shear, the dikes are both massive and sheared and
locally broken and separated into isolated lenses and blocks. The alteration
of the dikes varies from very intense to nil. The regional and local appearance
and distribution of the dikes point to injection of a fluid magma along
fractures produced under extension (not necessarily tension since updoming by a
granitic subvolcanic pluton would also produce extension). The presence of
meta-anorthosite xenoliths in many dikes indicate a certain amount of stoping
along the walls. The dikes show very little effects on the meta-anorthosite.
Polished and slickensided dike walls indicate that one movement took place
along dike contacts. Minor shearing and narrow lenses of quartz, carbonate,
chlorite, sericite, and sulfides are commonly located along the walls of dikes.
The relative age of the dikes with respect to mineralization is difficult to
establish. In places, the sulfides are in sharp contact with unmineralized
dikes. In other places, the dikes are sheared, altered, and mineralized.
However, no dikes have been noted cutting sharply across an ore zone which seems
to indicate the dike emplacement was pre- and syn-mineralization.

The relationship between the seven distinct types of dike rocks at Campbell
are equally problematic. Jeffery did not observe rapid variations in the
composition of dikes but Graham (1956, p. 15) "notes local fading of phenocrysts
resulting in gradational transitions between porphyritic and equigranular dikes."

Blecha studied 80 samples over a vertical range of 3050 feet and a strike length of 1600 feet. His study investigated the possibility of correlating the dikes on the basis of chemical compositions. After extensive statistical tests on the results of his analyses, Blecha found that the internal variations within one branch of a dike was larger than the differences between branches. He concluded (p. 58) that:

> "none of the investigated dikes has a sufficiently characteristic composition to make it distinguishable from any other dyke branch without further statistical tests."

He also states (p. 59):

> "one of the more striking results of the analyses is the wide variation in the chemical composition of samples taken from single dike intersections within relatively short distances."

A decrease in Na_2O and V was noted by Blecha in the altered dikes. The few samples done by outside laboratories indicate an increase in K_2O in altered dikes. Regretfully, Blecha did not analyze his samples for K_2O. Blecha could not establish a paragenetic order of dike intrusions. He did conclude to the close similarity of the dikes and proposed:

> "that some of the later dikes were emplaced while the consolidation of the earlier dike material was still incomplete. The resulting mixture of chemically similar differentiates would leave little trace of the contact zones between the various dyke rock types, particularly if later obscured by shearing, and hydrothermal alteration. This mode of emplacement would account for the puzzling observation that individual dyke branches may be composed of more than one rock type. It would explain the local fading of phenocrysts, and the gradational relationship between the various dyke rock types. It would explain why neither the chemical nor the petrological character of the dykes form a reliable criterion for the correlation of the individual dyke branches."

Grey Dikes

This common variety of dikes around all the mines of the Dore Lake area is a fine-grained equigranular grey rock without phenocrysts. Blecha (1966) describes them (p. 19-20):

> "Relatively unaltered grey dikes consists of 50 to 80 per cent of fine anhedral quartz grains and scattered clusters of zoisite (20-50 per cent) in a quartz-sericite-chlorite matrix.

Only minor amounts of fine grained, subhedral plagioclase of un-
known composition are present. Sphene and epidote are accessory
minerals comprising 1-2 per cent of the rock ..."

"A gradation between grey and feldspar porphyry dykes has
been observed both megascopically and in thin section. The
gradation is marked by the appearance of fine highly sericitized
grains of feldspar, barely exceeding the size of the minerals
constituting the matrix. In several specimens clusters of
zoisite and sericite may have formed from the complete alteration
of feldspar phenocrysts."

Feldspar porphyry dikes

Blecha (p. 20) describes these dikes as follows:

"Feldspar porphyry dykes are grey, fine-grained rocks, consisting
of 20-60 per cent pale grey, subhedral plagioclase phenocrysts,
embedded in a fine, slightly darker grey matrix. The plagioclase
is albitic, ranging in composition from An7 to An10, and is
commonly sericitized, even in specimens megascopically described
as fresh.

"The matrix consists of a fine grained aggregate of quartz,
plagioclase, sericite and chlorite, with minor epidote and sphene.
As with the grey dykes, traces of pyrite, secondary carbonate,
quartz and epidote have been observed in all specimens. Because
of the fine grained nature of the plagioclase present in the
matrix, its composition could not be determined."

Quartz feldspar porphyry dikes

Blecha (p. 22) states:

"This rock differs from the feldspar porphyry only by the
presence of quartz, which comprises up to 25 per cent of the
phenocrysts. The quartz phenocrysts are rounded or subhedral,
and show a wide range in size, attaining up to 6 mm. in
diameter.

"Gradation to feldspar porphyry has been noted in dykes in
which quartz phenocrysts are less prominent, being only slightly
larger than the grains comprising the matrix."

Diorite porphyry dike

Blecha (p. 23) has the following description:

"The diorite porphyry, often logged as 'grey' dyke in drill
core, is, nevertheless a very distinct rock type in thin section.
It differs from all other dykes by total absence of quartz, and
is characterized by a matrix that consists of 75-90 per cent
interlocking subhedral phenocrysts of plagioclase which constitute
5-20 per cent of the rock. The phenocrysts, commonly twinned, are
albitic in composition, and often contain minute inclusions of
epidote. The plagioclase laths comprising the matrix range in

size from 0.05 mm. to 0.2 mm., occasionally approaching the size of the phenocrysts. As in all other dykes sericitization of the plagioclase is extensive."

Quartz diorite dike

According to Jeffery, it is a variety of the diorite porphyry, and differs from it only by the presence of quartz in the matrix, and by a decrease in the amount of phenocrysts.

Granitic dike

According to Jeffery, the rock is characterized by a medium grained granitic texture, and is composed of plagioclase and quartz phenocrysts, embedded in a matrix of quartz, sericite and chlorite. The granitic dykes appear to be a variety of the quartz feldspar porphyry, with a large proportion of quartz and feldspar phenocrysts.

Black Dike at Cedar Bay and Quebec Chibougamau Mines

An unusual dike called by many different names by mining geologists has been studied by Miller (1957) at Cedar Bay mine and was noted at Quebec Chibougamau by the writer. The rock is bluish black and most commonly referred to as "Black dike." It is commonly sheared and so highly altered that the original rock cannot be identified. For all purposes, it is a chlorite-sericite schist dark grey to graphite black on a fresh surface. Chloritized anorthosite can be very similar to the black dike but it has a greenish cast not noted in the black dike. Miller (1957, p. 54) states:

> "The weathered surface of the black dyke is dark brown to black and
> is commonly stained with iron oxide. It is usually rough because
> of the presence of quartz grains and veinlets which stand in relief
> against the chlorite and sericite-rich background..... In thin
> section the black dikes are seen to consist essentially of mica
> and chlorite in various proportions usually with mica predominating.
> Accessory minerals are quartz, leucoxene, and sphene, apatite,
> carbonate, and the ore minerals, especially pyrite and chalcopyrite."

Mine Dikes in the Henderson Area

Vollo (1959, p. 30) states that dikes of quartz feldspar porphyry have not been located in his study of Henderson "A" orezone and such "dioritic or greenstone" dikes as have been found are very narrow and have no apparent structural influence on the location of ore. Vollo had no access to underground openings. Since then, the Henderson mine and its extension to the north, the Portage mine of Patino, have opened miles of underground openings. J. L. Simard, J. Patel, and R. Fournier (personal communication) concur with Vollo's opinion that dikes are rare, small, not continuous, and seem to bear no direct relationship to orezones in the Henderson-Portage area.

GABBRO ISLAND DIKE

A large dike of metagabbro composition runs in a rough N 25 E direction from the northern part of McCorkill Township to Queylus Township. Its presence on the west shore of Gabbro Island led early workers to name the island from the rock type and we have used the island to name the whole dike. Similar dikes in the southern part of Queylus Township may be correlated but too many large gaps between outcrops make it impossible to ascertain continuity. The dike varies in width between 200 and 500 feet (60-150 m.). It is quite irregular in width and seems to lens out and reappear along a general line in a N 25 E direction. Some segments are displaced by faults and others seem to be offset without any apparent faults. It cuts all rock types of the Roy Group, Dore Lake Complex, and Chibougamau pluton.

The dike is very massive and forms well rounded ridges standing in relief above the surrounding terrain. The dike has a good chilled margin against the host rocks. The grain size increases inward very rapidly and at the center the crystals of actinolite and saussuritized plagioclase may reach eight millimeters. Granophyric quartz is abundant in the center of the dike indicating slow inward cooling and differentiation. Table 91 gives two analyses from the dike. The

marked increase in quartz content from the edges to the center makes it difficult to choose representative samples for analyses. The uralitization of the original pyroxene the replacement of ilmenite by sphene and the saussuritization of the plagioclase indicate a pre-metamorphic age for this dike but its orientation indicate a post-folding age.

HENDERSON I METAPYROXENITE DIKE

A metapyroxenite dike extends from the shaft of Henderson I in a S 50 E direction for about 9 miles (15 kms). The dike cuts rocks of the Dore Lake Complex and Chibougamau pluton. The dike dips 70° northeast and varies between 30 and 80 feet (9-24 m.) in width. It was first discovered in the drilling of the Henderson "A" zone and was later identified in Lemoine Township (Allard and Caty, 1969; Allard, 1970). The dike, or a similar one, was identified by Vollo (1959, p. 30) in a drill hole north of Portage Lake, 3000 feet (900 m.) northwest of the Henderson orebody. It shows clear chilled margins against the meta-anorthosite. Vollo (1959) studied it in the Henderson drill holes. The grain size varies from aphanitic at the margins through medium grained at the center.

The rock consists in stumpy partially altered titanaugite crystals in a fine grained matrix of actinolite and chlorite. The alteration of the pyroxene varies from a thin margin of actinolite and fine needles of ilmenite and/or magnetite to a complete replacement by actinolite and chlorite. Coarse ilmenite is also present in the matrix. The dike is not magnetic and could not be detected in a magnetometer survey done on Lake Chibougamau. Table 91 gives an analysis of the dike.

Vollo (1959, p. 22) describes the contact metamorphic effects of the dike on meta-anorthosite at the Henderson mine:

"weak contact metamorphism of the meta-anorthosite is present for distances up to 20 feet (6 m.) from the pyroxenite. Megascopically this is shown by the development of a greenish cast to the meta-anorthosite due to alteration of colorless magnesian chlorites to

green ferrian chlorites and of colorless clinozoisite to light
green epidote. A diffusion of iron from the pyroxenite to the
meta-anorthosite has apparently occurred. Needles of actinolite
may also develop within the meta-anorthosite near its contact
with pyroxenite."

The exact age of the dike is unknown. It cuts both the complex and the

pluton. The petrography of the dike indicates some metamorphism after the

emplacement of the dike. The intersection between the Gabbro Island dike,

the Line Island diabase dike, and the Henderson pyroxenite dike is under water

and we cannot determine their relative ages. However, the very fresh nature

of the diabase dike indicates that it is definitely younger than the other two.

LAMPROPHYRE DIKE

A very small lamprophyre dike was noted by Allard (1960, p. 8) on the

northeast shore of Granite Island in Chibougamau Lake. The dike is very narrow

and weathered into a deep trench. It is made up of olivine, phlogopite, and

abundant carbonate. Similar dikes and sills have been observed in Richardson

Township cutting the sediments of the Stella Formation. They show good chilled

zones against country rocks. Caty is preparing a detailed study of Richardson

Township and will obtain a K-Ar age on the dikes. Similar dikes could have

been overlooked in the Chibougamau mining district since they alter and shear

very readily because of their olivine and carbonate content.

LINE ISLAND DIABASE DIKE

A large unmetamorphosed northeast-trending diabase dike cuts across the

center of the Chibougamau district. It extends in a N 45 E direction from the

Obalski-Scott Township line to the Lemoine-Roy Township line, a distance of 17

miles (27 kms). It is well exposed on the shore of Dore Lake, Chibougamau Lake,

and on many small islands in Chibougamau Lake. It is particularly well exposed on Lin

Island in the center of Chibougamau Lake, hence its name. It has been traced across

Chibougamau Lake by magnetometer surveys (work of Chibougamau Mining and Smelting

under the supervision of the writer). Its magnetic susceptibility is very low and

the dike hardly shows on the published airborne magnetometer survey sheets (G.S.C.

542G). Duquette (1970) used regional airborne magnetic survey maps to extend the Line Island dike southwest across Hauy, Brongniart, Rasles, Lescure, Gradis, De Guesclin, Morin, Picquet, and Prevert townships, a total distance of roughly 100 miles (160 kms). The dike is much less magnetic than those at La Treve Lake and those between Chibougamau and Mistassini Lake.

The dike has a very fine grained chilled zone and coarsens within a few inches to a coarse-grained black diabase displaying the typical diabasic texture. It consists of labradorite, pyroxene, minor olivine and biotite, and traces of apatite and magnetite. Small branches subparallel to the main dike and offshoots from the main dike have been reported by Mawdsley and Norman (1935, p. 48) and Graham (1956, p. 15).

The Line Island diabase dike is the easternmost dike in the Superior Province and belongs to the "Abitibi swarm" of Fahrig et al., (1965). Fahrig has not obtained a date on the Line Island dike proper but he dates the Abitibi swarm at 1230 m.y.

TABLE 91

CHEMICAL ANALYSES OF ROCKS FROM UNIT   POST TECTONICS

ANALYSES CHIMIQUES DES ROCHES DE   DYKES POST-TECTONIQUES

Sample No. No. d'échantillon	68-105	68-123	68-139	T-50-300	68-D96
SiO_2	49.41	47.68	42.05	43.70	44.49
TiO_2	0.43	0.69	4.00	3.55	3.62
Al_2O_3	16.05	14.53	15.64	7.32	8.18
Fe_2O_3	2.23	2.57	3.83	1.36	3.94
FeO	6.68	7.71	11.50	13.18	11.83
MnO					
MgO	7.68	7.40	5.94	13.36	12.47
CaO	9.37	11.04	9.20	9.02	9.01
Na_2O	2.36	1.80	3.70	0.55	1.00
K_2O	2.24	1.14	0.98	0.03	0.04
P_2O_5					
H_2O+					
H_2O-					
CO_2					
S					
TOTAL	96.45	94.56	95.84	92.07	94.58
Norm wt%					
Qtz					0.77
Cor					
Or	13.24	6.74	5.79	0.18	0.24
Plag	46.55	43.43	41.58	22.07	26.17
Ab	19.97	15.23	18.40	4.65	8.46
An	26.58	28.20	23.17	17.42	17.71
Ne			6.99		
Ku					
Di	16.12	21.62	14.36	22.15	21.72
Wo	8.31	11.09	7.31	11.41	11.27
En	5.18	6.61	3.99	7.08	7.46
Fa	2.63	3.91	3.06	3.66	3.00
Hy	4.53	14.90		36.86	33.09
En	3.00	9.37		24.29	23.60
Fa	1.52	5.54		12.57	9.49
Ol Fo	11.96	2.84	13.97	2.09	
	7.67	1.72	7.57	1.33	
Fa	4.29	1.12	6.40	0.76	
Mt	3.23	3.73	5.55	1.97	5.71
Il	0.82	1.31	7.60	6.74	6.88
Hm					
Ap					
Py					
Cal					
Data Wt%					
An/plag	57.1	64.9	55.7	78.9	67.7
Fa/ol	35.9	39.4	45.8	36.3	
En/hy	66.3	62.8		65.9	71.3
Diff.i.	33.2	22.0	31.1	4.8	9.4
Qtz					8.0
Ab	60.1	69.3		96.3	89.4
Or	39.9	30.7		3.7	2.5
An	44.4	56.2	48.9	78.2	67.0
Ab	33.4	30.3	38.8	20.9	-32.0
Or	22.1	13.4	12.2	0.8	0.9
A	21.7	14.2	18.0	2.0	3.5
F·	42.0	49.8	59.0	51.0	53.9
M	36.2	35.9	22.9	46.9	42.5
Na+K/Al	39.3	28.9	45.7	12.8	20.6
FeMn/FeMnMg	38.8	43.1	58.5	37.7	40.9
Na_2O/Na_2O+K_2O	51.3	61.2	79.0	94.8	96.1

Table 92

Notes on samples of Table 91

TABLE 91. POST TECTONIC DIKES

68-105   (R 10-68-5) Allard, Q.D.N.R. Lab. Lemoine Township. Gabbro
          Island metagabbro 9000 feet (3000 m) and 1600 feet (480 m) north
          of the southeast corner of the NW 1/4 Lemoine (Allard, 1970).

68-123   (R 10-68-6) Allard, Q.D.N.R. Lab. Lemoine Township. Gabbro
          Island dike a short distance north of previous sample.

68-139   (R 10-68-7) Allard, Q.D.N.R. Lab. Lemoine Township. Line
          Island diabase. Line Island (Allard, 1970).

T 50-300 (14-69-24) Allard, Q.D.N.R. Lab. Roy Township. Metapyroxenite.
          Drill hole T-50 of C.M.S. at Henderson No. 1 mine, from 300
          to 325.

68-D96   (R 10-68-17) Allard, Q.D.N.R. Lab. Lemoine Township. Meta-
          pyroxenite. Southeast tip of Stanislas Island, Henderson Dike.

CHAPTER 6

SEDIMENTARY GROUP

STELLA FORMATION

This newcomer to Chibougamau geology bears a new name but its identification as a post volcanic sedimentary regional unit goes back to Norman (1936, 1937, 1938), Beach (1940), and Riley (1956) who named the volcanic rocks the "pre-Opemisca Group" (now called the Roy Group by Duquette, 1970) and the sedimentary group the "Opemisca Group." Figure 126 shows the original postulated extension of this group, confined mostly to the Chapais syncline and to a fold belt north of the Chibougamau syncline. Duquette in his compilation grouped these sediments with either the Waconichi or Blondeau Formation. Recent mapping by Cimon in Queylus and Hauy Township positively established the existence of a basal conglomerate filling in a depression within the UBZ and SZ of the D.L.C. Neale (1959, p. 24) had previously reported blocks of anorthosite in the conglomerate on the Lemoine-Dollier Township line. Cimon's findings confirm that the D.L.C. was exposed during the formation of the Stella Formation. Cimon named it from the small lake in Queylus Township where it is well exposed. Caty (1975, personal communication) mapped a wide section of the same formation in the band north of the Chibougamau syncline in Richardson Township.

The Stella Formation consists in basalt conglomerates, phyllitic schists, graphitic schists, conglomerates and greywackes of various compositions. The rocks are metamorphosed to the greenschist facies and are infolded with the volcanics. In places the sedimentary rocks are conformable to the underlying volcanic rocks and in other places, looking at published geological maps, one can see a marked angular unconformity between the Stella Formation sediments and the Roy Group volcanics. Caty and Cimon are studying the formation and will report later on their findings.
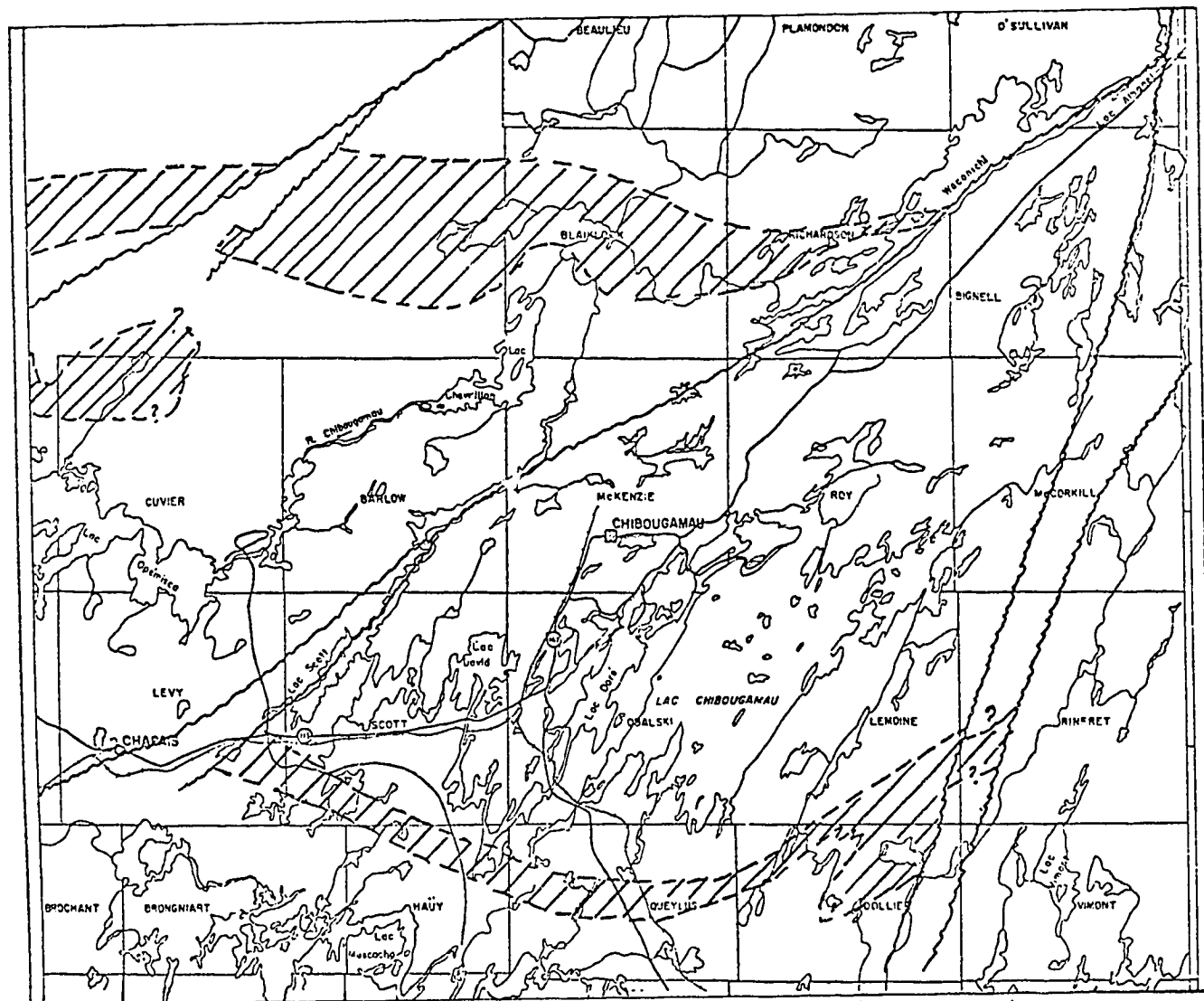
Fig. 126. Sketch map showing the postulated extent of the Stella Formation (cross hatched) based on old 4mile-to-the-inch maps. Since the formation has only been named in 1975, this sketch map is schematic and will surely change a great deal, especially within the northern belt.

CHAPTER 7

STRUCTURAL GEOLOGY OF THE CHIBOUGAMAU AREA

INTRODUCTION

The Archean Roy Group metavolcanic rocks and the sedimentary Stella

Formation are part of a large synclinorium bordered by little-known gneisses,

granites, and amphibolites typical of the so-called "basement" in the Superior

Province. The synclinorium can be divided into three major units:

a. Chibougamau anticline across the central part of the area

b. Chibougamau syncline, north of the Chibougamau anticline

c. Chapais syncline, south of the Chibougamau anticline

The Chibougamau greenstone belt terminates eastward against rocks of the

Grenville Province. Folds and faults are very abundant and important as usual

in most mining districts. The recent discoveries of stratiform volcanogenic

ores augment the importance of good stratigraphic and structural knowledge of

the area for the exploration geologist.

HISTORICAL REVIEW

The Chibougamau Commission (1911) report does not have a separate chapter

on structure and very little mention is made of structural features within the

geological chapter.

Mawdsley and Norman (1935) clearly recognized (p. 17-19) many flow tops

criteria and proposed a major synclinal axis from Lake Antoinette to McKenzie

Bay (the Chibougamau syncline of Duquette, 1970). The two reconnaissance

traverses southeast of Chibougamau Lake were insufficient to prove the existence

of Dore Lake Complex lithologies south of the pluton. Mawdsley and Norman

described in great detail the evidence they had accumulated for the numerous

major faults of the area.

Graham (1957) recognized the major anticline along the axis of the

Chibougamau pluton.

Smith and Allard (1960) identified a large number of top and bottom criteria in the volcanics of the Gilman and Blondeau formation and intrusive coeval gabbro sills.

Gaucher (1965, p. 763) shows a cross section with a major synclinal axis along the core of the pluton. This interpretation cannot be correct considering the irrefutable evidence afforded by the lithologies of the Dore Lake Complex (see chapter on D.L.C.).

Duquette (1967, 1970) established the stratigraphy of the Roy Group and interpreted the structure as shown on his map 1686 and cross sections. He coined the terms Chibougamau anticline, Chibougamau syncline, and Chapais syncline. He added a number of parasitic folds on the limbs of the major folds. Allard and Cimon (1972) and the present map (Plate 1) eliminated many of these folds. On the south limb of the Chibougamau anticline, the petrography and petrochemistry of the Dore Lake Complex show the gradual change upward expected in layered complexes (Wager and Brown, 1967) and does not allow room for the minor folds shown on Duquette's compilation map. The mechanical properties of a thick competent sill like the D.L.C. do not favor the idea of short wave tight folds like those shown on Duquette's cross section. In the Chibougamau and Chapais syncline, on the other hand, this kind of tight folding is possible and does exist but not with the same intensity as Duquette has shown on his map, especially east of the Dore Lake-McKenzie Narrows Fault. On the other hand, within the northern margin of the Chibougamau syncline and the southern margin of the Chapais syncline, more complex folding than shown on Duquette's map has been demonstrated by Cimon (1973), Baker and Allard (1974) in Dollier Township, and by Caty (1975, personal communication) in Richardson Township. We are awaiting Caty's final map to complete our cross-sections.

TOP AND BOTTOM CRITERIA

The determination of major structures in the area is the result of hundreds of good top and bottom determinations. The major criteria used are the following:

1. pillow shapes in metabasalts (Figs. 13, 21, and 22)

2. scoriaceous flow top (fragmental in places) in metabasalts

3. zones of cumulate crystals in the lower portion of thick flows and sills

4. graded bedding in pyroclastics, tuffs, volcaniclastics, and sediments

5. cross-bedding in pyroclastics, tuffs, volcaniclastics, and sediments

6. cryptic differentiation and crystal fractionation in sills. The presence of quartz-rich granophyric horizons in gabbro sills is common and one of the best methods of determining top and bottom in volcanic terrains.

The criteria listed above require few comments since they are commonly used by field geologists. The combination pillows in flows+granophyric portions of sills+graded bedding in tuffs has been so extensively applied within the Chibougamau area that it leaves practically no room for additional folds. For example, from the Dore Lake Complex contact to the axis of the syncline, Smith and Allard (1960) mapping on the south limb of the Chibougamau syncline found hundreds of excellent top determinations well distributed over the ± 15,000 feet (4500 m.) of Gilman-Blondeau volcanics, volcanoclastics, and comagmatic sills. Duquette (1964, 1968) and Duquette and Mathieu (1966, 1968) found the same type of evidence on the northern limb of the Chibougamau syncline.

The recognition of a few grains of quartz in the upper portion of sills is relatively easy since they stand out in relief on the weathered surface and is often neglected by field geologists working in volcanic terrains. It is one of the easiest and most useful top and bottom criteria in the Chibougamau area.

RHEOLOGICAL PROPERTIES OF ROCKS

The mechanical properties of rocks are very important in determining the location and type of structures which will affect an assemblage of folded and faulted metamorphosed rocks. The exploration and mining geologists are constantly looking for clues which will facilitate the search and mining of ore deposits.

The Chibougamau area offers the structural geologist a wide variety of rocks. Unfortunately, no detailed studies of rock mechanics have been published yet. Archambault (personal communication) has a research program underway but we do not have access to his results at the present time. The relative age of metamorphism, folding, and fracturing is import at in determining some types of fractures. For example, an original coarse pyroxenite layer is probably much more similar in rheological properties to adjacent gabbro layers than the post-metamorphic metagabbro (saussuritized plagioclase and actinolite) vs meta-pyroxenite (chlorite and amphibole). The metagabbro has preserved the diabasic-ophitic texture and is not very dissimilar from the original gabbro. On the other hand, the metapyroxenite consists in actinolite crystals floating in a chlorite matrix. The crystallographic properties of chlorite, as opposed to the original pyroxene, render the metapyroxenite prone to the development of a pervasive foliation; a foliated rock becomes a natural locus for shearing and faulting and replacement by carbonate and quartz. This is observed very commonly in Rinfret and Lemoine Township within the Layered Zone of the D.L.C.

A similar difference in mechanical properties exist between fine-grained dikes and surrounding Dore Lake rocks. The dikes are commonly shattered and criss-crossed by veinlets of quartz, carbonate, albite, epidote, or tonalitic material while the adjacent country rock does not show the same features. The same remarks could be made for the pair of fine-grained meladiorites of the Chibougamau pluton as compared to the coarser trondhjemites and tonalites of the C.P.

WACONICHI LAKE-GWILLIM LAKE-CAMPBELL LAKE-BACHELOR LAKE FAULT

This major regional fault was recognized by Mawdsley and Norman (1935, p. 51) who remarked:

> "A third major fault with a northeasterly trend may be along Gwillim Lake. Its presence is suggested by the shape of the lake and by northeasterly shearing of the rocks at places along the lake shore."

Allard (1952) in his compilation extended the fault as far as the Bachelor Lake area, giving the fault a length of 150 miles (240 kms). The northeastern 75 miles (120 kms) has been well established by detailed mapping, numerous geophysical surveys, and drilling. Opemiska Copper Mine has crossed the fault in its underground workings. Lavoie (1972) indicates a dip of 85° to the southeast. He states (p. 12):

> "the geological and magnetic data indicate that the nose of the antiform was offset by this faulting event."

and (p. 15):

> "the horizontal left hand displacement measured on the fault is a little over 2 miles."

Gaucher (1960, p. 10) states:

> "The Gwillim Lake fault, recognized by many geologists who have worked in the area, is reported to cut diagonally across the north half of the map-area. A strong schistosity is present at many places along the shores of the lake, but the shear direction is generally oriented in a more easterly direction than the proposed strike of the fault. Moreover, the rocks of the ultra-basic complex appear to continue without interruption underneath the lake and no appreciable offset along the strike of the proposed fault plane is indicated (see p. 6 of this report). In effect, no positive indications of such a fault were found and it is difficult to imagine that the fault predates the injection of the ultrabasic sill complex."

However, his map indicates the possibility of a drag and a considerable displacement, supported by the published aeromagnetic map.

Duquette (1968, p. 10) remarked:

> "An extension of the Gwillim Lake fault is inferred to lie northeastwardly across the south half of the map-area. This fault, which is believed to be a regional break, was first recognized on the property of Opémiska Copper Mines in Lévy township [8] where

it appears to have a genetic relationship with the copper ore deposition. Direct evidence for its presence in the map-area is lacking but its assumed location coincides with the Gwillim Lake depression and the sand plain east of the fault."

Shaw (1938), Gilbert (1958), and Caty (personal communication, 1975) recognized that a major fault runs along the southeast shore of Waconichi Lake. The fault has caused the preservation on its northwest side of two large outcrop belts of flat-lying Chibougamau Formation sediments indicating an upward movement of the southeast side of the fault.

Gilbert (1958, p. 28) reports:

"The second major fault branches from the Mistassini Lake fault near the outlet of Waconichi Lake. It extends southwest-ward beyond the western limit of the map-area, closely paralleling the south side of Waconichi lake. Its general strike is S.60°W., and its dip is 75° south. The only evidence that this fault may extend east of the Mistassini Lake fault is a small shear zone, also with northeast strike, in gneiss about 5,000 feet southwest of the northeast corner of the area.
"Along part of the south shore of Waconichi lake this fault is marked by a zone a few hundred feet wide of intensely sheared Early and Late Precambrian rocks. Along Bignell river, evidence of northwesterly movement is seen near the mouth in mylonitized Chibougamau rocks and, upstream for about two miles, in grooves, slickensides, and intense deformation within the Keewatin-type greenstones."

The Bachelor Lake-Campbell Lake-Gwillim Lake-Waconichi Lake Fault is truncated by the north-trending Mistassini Lake Fault.

MCKENZIE NARROWS-DORE LAKE FAULT

Mawdsley and Norman (1935, p. 51-55) described in detail the field evidence for the McKenzie Narrows Fault. At the type locality the fault separates a narrow sliver of Chibougamau Formation sediments from Roy Group volcanic rocks and sills (Plate 1). They suggested that the fault may extend southwestward across Portage Island and along Dore Lake and Cache Lake. Allard (1960) and Duquette (1970) realizing the difficulty in passing the fault through Portage Island preferred to call the segment of the fault in Dore Lake and Cache Lake the Dore Lake Fault, and continue to use McKenzie Narrows Fault for the northern segment north of Portage Bay. The two faults may be one and

the same but the geological and geophysical evidence do not unequivocally support this conclusion.

Graham (1956, p. 17) reported observing the Dore Lake Fault in the creek bed which flows from Cache Lake to Dore Lake. It was observed in the 400-level and 800-level drive between Campbell Chibougamau Main mine shaft and the Kokko Creek orebody on the north shore of Dore Lake. It was also indicated in underground diamond drilling at the Cedar Bay mine and observed on the 1300-level at the Copper Rand Main mine. It must be present at the contact between the narrow band of volcanics and the anorthosite of the D.L.C. which extends along the shore of Gouin Peninsula from a point slightly north of the Copper Rand causeway to the center of Portage Island. In the Dore Lake area, the fault has a northwest dip while the McKenzie Narrows Fault has a southeast dip direction. Detailed work on Portage Island supported by detailed aeromagnetic surveys (Chibougamau Mining and Smelting survey of 1955) indicate that the structural picture shown on Plate 1 is very complex, and much more complex in reality than can be shown at the scale of the compilation map.

Duquette (1970) failed to show the band of volcanic rocks along Gouin Peninsula on his compilation but this must be a drafting oversight since excellent outcrops showing pillows, scoriaceous flow tops, amygduloidal zones, etc., are easily reached from the road to the Henderson-Portage mines, and the band of volcanics was clearly outlined on the map of Smith and Allard (1960) and Horscroft (1958). A detailed study of the Dore Lake Fault would be interesting but the outcrops are too limited to allow the necessary observations.

TACHÉ LAKE FAULT

The Tache Lake Fault was well observed and described by Mawdsley and Norman (1935, p. 55-57). No additional information can be added to their discussion. The aeromagnetic map indicates a fault between Tache Lake and Bag Bay but the Magnetite Bay megnetic anomaly indicates that the fault either splits in two

branches or deviates in strike around the western end of the magnetite zone.
The latter option was chosen in our compilation map. We have extended the
fault across Chibougamau Lake. Graham (1957) traced the fault as far south as
Windy Lake, a total distance of 60 miles (100 kms).

The Tache Lake Fault is parallel to the McKenzie Narrows Fault, 3-1/4
miles to the northwest. The fault seems to have a southeast dip. The offset
of the gabbroic anorthosite of the D.L.C. indicates 6000-7000 feet (1800-
2100 m.) of left-hand separation. On the other hand, the separation on the
Roberge Sill is either negligible or slightly right-handed. This difference
can be explained by an upthrust of the southeast side of a faulted syncline.
South of Chibougamau Lake, the area offers few outcrops and the fault is
poorly known.

MISTASSINI LAKE FAULT

The Mistassini Lake Fault is a major fault in the area; it extends from
the southern tip of Albanel Lake, past the Icon Mine, southward as far as
Dollier Township. At the Icon Mine (top right hand corner of Fig. 2) the fault
was plainly visible in the open pit No. 2 when the mine was in operation. It
dips to the southeast at 65-70° and has brought up gneisses and amphibolites in
contact with the drag folded and faulted Mistassini Group sediments and the
orebody at the Icon Mine.

Gilbert (1958) clearly identified the fault across O'Sullivan, Bignell,
and part of McCorkill townships. The fault is the eastern boundary of the Lac
Frances pluton.

Pouliot (1963, p. 10) and Allard (1967) did not identify the fault per se
but Pouliot identified in the northeast corner of his area and further south a
strong zone of shearing which lines up very well with the Mistassini Lake Fault
of Gilbert. Since then, Avramtchev (1975) has mapped the northern part of
McCorkill Township and has identified the continuation of the fault. Allard

(1967) in Rinfret Township mapped a series of faults. One of the faults has over 3000 feet (900 m.) of displacement and lines up remarkably well with those of Gilbert, Avramtchev, and Pouliot. As seen on Plate 1, we have extended the fault southward into Dollier Township where an aeromagnetic anomaly outlines a block of Ventures and Roberge Sill lithologies between the Mistassini Lake Fault and the Grenville Front proper. Further detailed mapping will be necessary to extend the fault southward.

Many authors (Troop and Darcy, 1973; Collins et al., 1974) either confuse the Mistassini Lake Fault with the Grenville Front or assume that the rocks east of the fault are Grenville gneisses. Allard (1972) using aeromagnetic evidence and the mapping of Avramtchev in McCorkill Township pointed out that the true Grenville Front, or at least the easternmost fault separating Superior Province rocks and Grenville rocks, is much further east and the triangle of rocks between the two faults is either Roy Group volcanics of Superior basement which has been affected by the Grenvillian metamorphism. This distinction is important since sulfide deposits could be found in this area if it is underlain by Roy Group volcanic rocks. The possibilities for locating sulfide deposits would decline drastically if the rocks were true Grenville rocks.

CHIBOUGAMAU SYNCLINE FAULT

This fault was first recognized by Allard and Cimon (1972) when preparing field stop handouts for the IGC field excursion. It is not exposed but is required by the constant repetition of the Roberge and Ventures sills in the Blondeau-mafic sills sequence which underlies the axis of the Chibougamau Syncline, from Cummings Lake to the western boundary of Cuvier Township, a distance of 31 miles (50 kms). The Blondeau volcaniclastics between the sills contain thick beds of pyritiferous graphitic argillites. In the tight folding of the Chibougamau syncline, the competent trio of sills could not bend as tightly as the well-bedded volcaniclastics and the easiest release was by a

COUPE DU LAC CUMMINGS
LAKE CUMMINGS SECTION

SW

M4

NE

LAC CUMMINGS

BOURBEAU SILL

TOP

BLONDEAU

TOP

BLONDEAU

VENTURES SILL

ROBERGE SILL

TOP

BLONDEAU

BLONDEAU

VENTURES SILL

TOP

BLONDEAU

ROBERGES SILL

BLONDEAU

VOLCANIC GILMAN

HORIZONTAL SCALE: 1000' = 1"
VERTICAL SCALE: 10X

ALLARD & CIMON 1972
IGC A41-C41
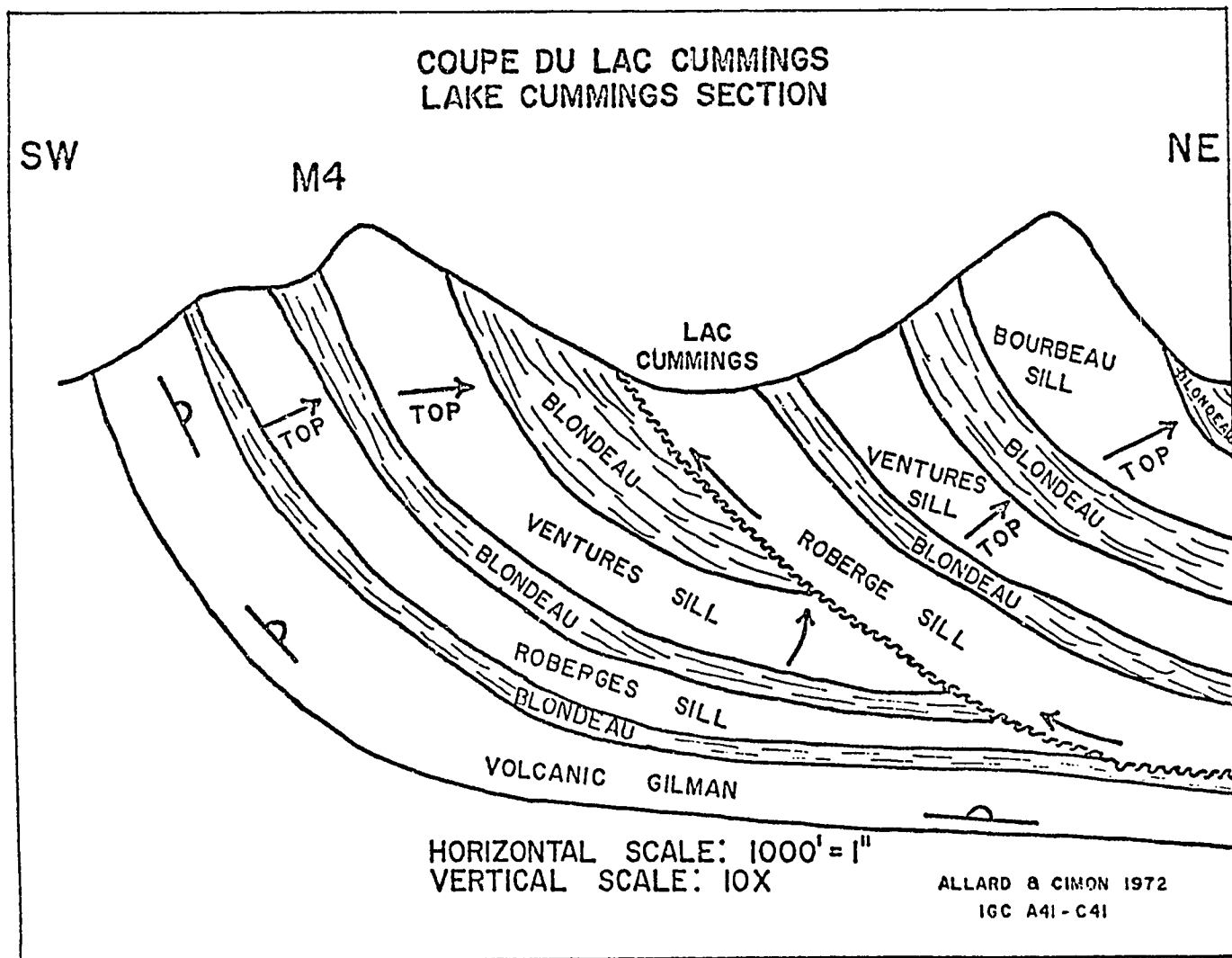
Fig. 126 A. Cross section at Cummings Lake showing the repetition of sills by a bedding fault. (from Allard and Cimon, 1972, handout for IGC excursion)

COUPE DU LAC CUMMINGS
LAKE CUMMINGS SECTION

SW

M4

NE

VOLCANIC GILMAN

SILL ROBER-GE

B

SILL VENTURES

TOP →

BLONDEAU

LAC CUMMINGS

SILL ROBERGE

GILMAN

SILL VENTURES

BLONDEAU

SILL BOURBEAU

TOP →

TOP →

TOP →

BLONDEAU

P

HORIZONTAL SCALE: 1000'=1"
VERTICAL SCALE: 10X

ALLARD 1972
IO CA41-C41
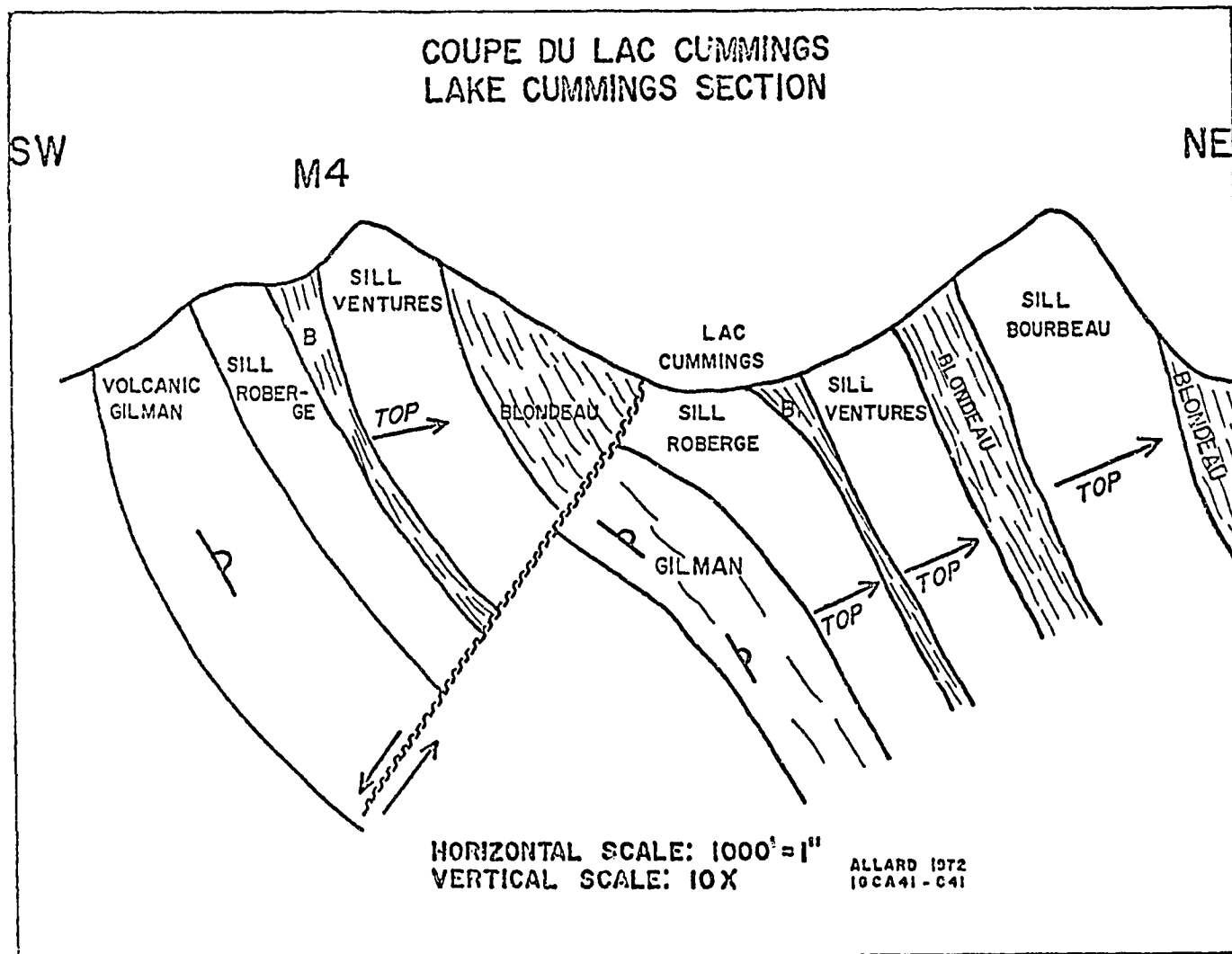
Fig. 126 **B.**   Cross section at Cummings Lake showing the repetition of sills by a normal fault.
(from Allard, 1972, handout for IGC excursion)

bedding fault which probably behaves in places as a longitudinal fault and in others as a thrust fault. The section postulated at Cummings Lake (Fig. 126A) along the Albanel Highway could be applied with minor modifications to the whole extent of the fault. Another possibility suggested by Allard (1972) and Avramtchev (1973) (Fig. 126B) is a steep-dipping normal fault cutting across the limb of the syncline and causing the repetition mentioned above. We favor the idea of a flat bedding fault which has used the graphitic beds and/or the serpentinites of the Roberge Sill as a plane of easiest rupturing and gliding. The normal fault interpretation (Fig. 126B) is unlikely in the compressional stress field produced in a tight synclinal fold.

MINE "SHEAR ZONES"

The economic ore deposits of the Chibougamau area are lenses of sulfides in shear zones (see chapter on Economic Geology and Metallogeny). The terms shear zones and fault zones have been used loosely in the Chibougamau area. The shear zones are planar features, finite in length, and marked by a strong foliation caused by the preferred orientation of micaceous minerals (paragonite-sericite-chlorite). Some of the shears are true faults with measurable displacements. Most of the shear zones within the Dore Lake-Henderson-Portage area might be fault zones but the lack of recognizable horizons on either side makes it impossible to ascertain whether they are faults or not.

The very coarse anorthosite-gabbroic anorthosite of the D.L.C. is the rock type most commonly involved in the so-called shear zones. In the vicinity of the shear zones, the plagioclase megacrysts become fractured and progressively altered to sericite-paragonite. The mineral changes took place in a static mode. Further in, the fractures become narrow well-defined slip planes (microfaults) cutting across the whole body of rock. The fractures become more closely spaced and the swarm of fractures take the appearance of slaty cleavage. The alteration becomes more intense and the original cumulus-intercumulus

boundaries between original grains poorly defined and irregular. Some of the plagioclase cumulus grains become augen-shaped with closely spaced foliation planes wrapping around them and cutting across the larger ones. In the core of the shear zones, the original textures is completely lost and the rock is described by mine geologists logging core as "paper schists." Lenses of massive sulfides, calcite, quartz, and blocks of relatively unaltered and unsheared anorthosite and blocks of altered and/or sheared dikes are common within major shear zones such as the Campbell-Merrill, Copper Rand, Cedar Bay shears, etc.

We have not conducted microfracture analyses of any shear zone. One good outcrop across Dore Lake from the Campbell Chibougamau mine (Allard, 1972) shows a 6" shear zone with a foliation inside the zone at an angle to the general direction of the shear. The shear is bounded by two distinct zones of intense foliation. This angular difference between the foliation planes inside the block of sheared ground and the walls of the shears fit the model of Ramsay and Graham (1970, p. 803). On that same outcrop known to visitors as the "Miniature Dore Lake camp", the fracture systems found within the mines and within the Chibougamau area are well represented. The N 45 E set (Dore Lake Fault direction) and the N 55-75 W set (mine shears) are common. Locally, the northeast set seems to cut and displace the northwest set, but the opposite can also be observed.

THE NATURE OF THE GRENVILLE FRONT IN THE CHIBOUGAMAU AREA

The Grenville Front is a major tectonic and metamorphic feature separating the low-grade east-trending greenstone belt of the Superior Province from the northeast-striking high grade rocks of the Grenville Province. It has been traced from the Labrador coast to Lake Huron, a distance of 1185 miles (1900 kms).

In the Chibougamau area, the Grenville Front can be divided into two segments: one in McCorkill-Rinfret township where the Front separates rocks of

the Chibougamau Pluton and Dore Lake Complex from Grenville rocks; and the
other in Lemoine-Dollier Township where volcanic and volcaniclastic rocks are
in contact with gneisses and amphibolites of the Grenville Province. The
difference in behaviour seems to be controlled by the competency and rheological
properties of the rocks.

In the McCorkill and Rinfret areas, (Avramchev, 1975; Pouliot, 1963;
Allard, 1967), the Grenville Front is a set of closely-spaced senestral narrow
fault zones trending N 25-30 E and dipping 65-75° southeast. The spacing
between the faults increases gradually westward away from the Grenville Front.
The blocks of rocks between the faults are more or less strongly foliated in a
N 25-30 E direction depending on the grain size, and mineralogical composition
of the rock; for example, the quartz-rich sodarhyolite is so strongly foliated
that we had originally called the rock a quartz plagioclase mica schist and we
thought of the whole zone in Rinfret Township as a wide shear zone. However,
in the adjacent magnetitites, the original layering is well preserved, large
garnets are present, the rock is coarsely crystalline, and the northeast
schistosity is very weakly developed. One large block caught between two
faults retains an unusual southeast trend as if it had been rotated from the
common N 70 E direction (Plate 1). A penetrative deformation has imparted to
all the rocks between fault zones a pronounced secondary foliation.

The rocks in the zone between the Grenville and Superior Provinces have a
strong lineation due to mineral alignment and microcrinkles. The lineation
plunges 60 to 75 degrees in a southeast direction. Some folds axes have a steep
plunge parallel to the mineral alinement indicating lateral horizontal movement.
Other fold axes are nearly horizontal with indications of an upward movement of
the southeast side relative to the northwest side.

The thrusting of Grenville rocks against Superior rocks was accompanied by
a rise in temperature and pressure over a width varying from hundreds of feet to
± 5 miles within the Superior Province. This set of conditions created by

Grenvillian metamorphism (around one billion years ago) is deduced from the mineralogical changes which have not been studied in detail. The presence of pink-red garnets in the rocks of the Superior Province is easily observed in the field. The changes in plagioclase, chlorite, and actinolite compositions are not readily determined in the field and will be investigated by Baker for his Ph.D. dissertation. Baker and Allard (1974) reported kyanite-grade metamorphism in Dollier Township. Baker is completing an exhaustive study of the front in Dollier, Rinfret, and McCorkill Townships and his data is forthcoming.

CHAPTER 8

PALEOMAGNETISM OF THE CHIBOUGAMAU GREENSTONE BELT

The only detailed paleomagnetic work done in the Chibougamau area has been

done by Ueno and Park of the Earth Physics Branch of the Department of Energy,

Mines, and Resources. Their sample collection around the Chibougamau area

proper was guided by the author. Ueno and Irving (1976) reported their findings

and we quote directly their abstract (we thank Dr. Irving for a pre-publication

copy of the manuscript and permission to quote his abstract):

> "A paleomagnetic survey (34 sites, 200 core samples) of an
> Archean greenstone belt just north of the Grenville Front is
> described. Sixty per cent of the samples have blocking
> temperatures less than $400^{\circ}C$ and remanent coercive forces pre-
> dominantly below 100 Oe, and they provide no information about
> the Precambrian geomagnetic field. The other samples contain
> many magnetizations of which two (CS and CH) can be clearly
> recognized. The CS magnetization occurs in basic sills, and has
> high blocking temperature (550 to $650^{\circ}C$) and remanent coercive
> force (often exceeding 1000 Oe) and a direction (186°, -38°) that
> is not significantly different from that in Matachewan diabase
> dikes (2690 m.y.). CS is thought to have been caused by uplift
> following the Kenoran orogeny and its age is probably about 2600
> m.y. No older magnetization has been found. The CH magnetization
> occurs in several different bodies and has a direction (119°, $+51^{\circ}$)
> similar to that observed in rocks from other places close to the
> Grenville Front. CH has more variable blocking temperatures
> (200 to $650^{\circ}C$) and remanent coercive forces (200 to 1000 Oe) and
> is considered to have been acquired by heating during uplift of
> the highly metamorphosed Grenville Province to the south. Uplift
> occurred about 1000 m.y. ago, and the CH magnetization is
> considered to be of this age. Evidence is presented to support
> the suggestion that there was an extensive magnetization episode
> both within and adjacent to the Grenville Province at that time."

GEOCHRONOLOGY OF THE CHIBOUGAMAU AREA

A number of authors have determined the age of rock samples and rock units

in the Chibougamau area. Progress has been made but much work remains to be

done since so many results are discordant. The author's lack of expertise in

isotope geology may be the factor responsible for the confusion of numbers

presented in Table 93 but one cannot study the data without hesitation on the

interpretation. To start with, the constants used in Rb-Sr work differ between

TABLE 93 - Age determination from the Chibougamau area.   Age (x 10^6 y).

$\lambda 87_{Rb} = 1.47 \times 10^{-11}$ yr^{-1} for Wanless and Jones ; $\lambda 87_{Rb} = 1.39 \times 10^{\overline{1}1}$ yr^{-1} for Dallmeyer, Johnston, Jäger.

Sample no Identifies Stockwell C.S.C. (1973)	Location location	Rock type Roche	Mineral mineral	K-Ar mineral	K-Ar whole rock	Rb-Sr mineral	Rb-Sr whole rock	U-Pb Pb-Pb	References References	K-Ar mineral	K-Ar whole rock	Rb-Sr mineral age	Rb-Sr Isochron
(1) 63-136	7.88 miles north of C.P.	Granodiorite	muscovite	X					Wanless 64-17 p.96	2295		2535	
63-137	id	id	biotite	X		X			id	2085			
64-143	id	id	whole rock		X				id 65-17 p.88		1855		
(2)	7.87	id	biotite	X					id 1970,p.350	1965		1830	
(3)	4.97	Quartz monzonite	biotite	X		X	(X)		id 1970,p.350	1520		845	
	id	id	muscovite	X		X			id	2035		2375	all of Wanless
(4)	id	Gneissic quartz monzonite	whole rock			X	(X)		id				Rb-Sr
(5) 62-153	4.91	Granodiorite	biotite	X				X	id	1815			whole
62-154	id	id	muscovite	X					Wanless 63-17 p.97	2340			rocks
64-145	id	id	whole rock				(X)		Wanless 65-17 p.88		1690		
(6)	3.23	Quartz monzonite	whole rock						Wanless 1970,p.350				
(7) 63-163	3.0	Granite	biotite	X			(X)		Wanless 64-17 p.99	2485			2610 $\tilde{+}$ 175 m.y.
63-164	id	id	muscovite	X					id p.100	2025			
64-147	id	id	whole rock		X		(X)		Wanless 65-17 p.87		706		
(8)	2.79	gneissic granite	biotite	X					Wanless 1970,p.350	3680		1000	
	id	id	muscovite	X		X	(X)		id	1550			
(8)	id	id	biotite	X		X			id	3825			
	id	id	muscovite	X					id	1740			
(9) 63-146	2.25	id	biotite	X					Wanless 64-17 p.101	3330			
63-145	id	id	muscovite	X					id	1630			
(10)	1.41	Quartz monzonite	biotite	X		X	(X)		Wanless 1970,p.350	2345		930	
(11)	1.35	diabase	whole rock			X	(X)		id				
(12)	1.35	Quartz monzonite	biotite	X		X	(X)		id	2715		910	
(13)	1.05	Hornblende schist	hornblende	X					id	2050			
(14) 63-107	0.70	gneissic granodiorite	biotite	X					Wanless 61-17 p.63	2580			
64-168	id	id	whole rock		X				Wanless 65-17 p.90	1840		1305	
(15) 62-144	0.28	paraschist	biotite	X		X			Wanless 63-17 p.92	1313		935	
62-147	id	id	muscovite	X					id	1060			
62-149	id	paraschist	whole rock		X				Wanless 65-17 p.90		982		
(16)	0.10 south	gneiss	muscovite	X		X			Wanless 1970,p.350	960		1040	
(17)	0.30	gneiss	muscovite	X		X	(X)		id	975		830	
(18) 62-148	0.43	id	biotite	X		X			Wanless 63-17 p.94	1050		920	
62-149	id	id	muscovite	X					p.93	1010			
62-150	id	id	whole rock		X		(X)		65-17 p.90		915		
(19)	0.80	id	whole rock						1970,p.350				
(20) 63-108	1.3	id	biotite	X			(X)		61-17 p.64	1270			
61-152	id	id	muscovite	X					62-17 p.7	960			
62-131	id	id	whole rock		X		(X)		65-17 p.91		1075		
(21) 63-141	3.27	id	biotite	X					64-17 p.98	985			
63-142	id	id	muscovite	X					64-17 p.99				
64-137	id	id	whole rock		X		(X)		65-17 p.91		1265		
62-130	9a	orthogneiss	biotite	X					63-17 p.93	1105			
62-131	40	paragneiss	biotite	X					63-17 p.96	950			
64-133	id	id	whole rock		X				65-17 p.92			882	
64-132	id	id	muscovite	X			(X)		63-17 p.96	980			
64-139	Copper Rand Mine	sericite schist	muscovite		X				Wanless 67-2A p.212	1790			
67-113	Granite Island	Biotite tonalite	biotite		X				69-2A p.63	2010			
67-126	Mauy twp 49°41'40"N 74°29'W	Diabase	Biotite		X				69-2A p.67	2045			
72-91	Cedar Bay Mine	wall rock alteration	actinolite		X				73-7 p.68	2035			
										2706			
(Krough 7052)	Merrill Island	Granite-C.P.	zircon					(U-Pb)	Krough 1971,p.242	2780			
	Campbell Chib. Mine PMI - U 148-46'	ore	galena					(Pb-Pb)	Wilson et al,1956 p.535	(2000 $\pm$ 200)			

					^{40}Ar/^{39}Ar	R-Ar	
		Biotite Hornblende gneiss	biotite	Dallmeyer,1974	2108		
Road to Janini	id	hornblende	2517	2504		
north of Chibougamau	id	biotite	2333			
	id	hornblende	2610	2607		

							Rb-Sr
Lac Doro Complex	11 samples	whole rock	(X)	Jones et al, 1974			2573
Chibougamau pluton	9 samples	whole rock	(X)	id			2414
Roy Group volcanics	10 samples	whole rock	(X)	id			2706
Albanel iron formation			(Y)	Fryer, 1972			1787
Huronian sediments (Gowganda-Cobalt) - 10 samples (correlated with Chibougamau formation,Long 1774)			(X)	Fairbairn et al -			2268
Nipissing diabase sill at Gowganda - (11 samples)			(X)	id			2162

the U. S. and the Canadian laboratories ($\lambda_{87_{Rb}}$ = 1.39 x 10^{-11} yr^{-1} in Canada and 1.47 x 10^{-11} yr^{-1} in the U. S.) and the differences are not negligible as shown by Dallmeyer (1974): Wanless' 2610 m.y. date becomes 2761 m.y. using the American constant. Jones et al., (1974) Rb-Sr ages give a younger age for the host rock volcanics of the Roy Group than for the intrusives Dore Lake Complex and Chibougamau Pluton indicating a major problem with the use of this method in metamorphosed fine-grained volcanics. Wilson et al., (1956) using Pb-Pb ages on Canadian ores obtained wide variations, including a negative age (future ores) for the Archean Quemont ores in the Noranda area. Wanless et al., (1965 to 1973) studies across the Grenville Front a decade ago showed the need for extreme caution in K-Ar work in the vicinity of the Grenville Front. Their Rb-Sr work (Wanless et al., 1970) also indicates that the width of the zone of influence of Grenville age metamorphism on the rocks of the Superior Province is poorly defined at the present and probably varies with the type of rocks, the mineralogy, the textures, the permeability and porosity during metamorphism, etc.

Wanless et al., (1972) summarize their findings in the following statement (p. 77):

> Anomalously high K-Ar 'ages' have been obtained for biotites from granitic rocks adjacent to the boundary between geologic provinces of the Canadian Shield. This phenomenon is particularly marked in one such area southwest of Chibougamau, Quebec, where the Dauversière stock outcrops in the Superior Province immediately north of its boundary with the Grenville Province. The stock is roughly circular in configuration having a diameter of approximately 8 miles. Rock samples selected from several localities have yielded concentrates of both biotite and muscovite, thereby providing two mineral indicators within the same rock. In some instances the muscovite K-Ar 'ages' are much lower than those of the associated biotites.
> "When the results obtained, using both the K-Ar and Rb-Sr methods, are plotted with respect to the distance of the sample sites from the Grenville Front, it is apparent that the anomalies are a function of the proximity to the front. A sample of biotite, containing the greatest quantity of excess radiogenic argon, was selected for special study. The argon was extracted at a series of gradually increasing temperatures in order to ascertain if a portion of the argon could be readily removed thereby leaving a fraction that would provide an indication of the 'true' age of crystallization of the mineral. No evidence of such a component was found; the gas being released regularly as ʼ

the temperature was increased to the fusion point of the biotite.

"The Rb-Sr whole-rock isochron technique has been applied to samples selected from the stock and from the Grenville Province immediately south of the front. The results appear to define a single isochron indicating an age of 2,610 ± 170 m.y. with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7011 ± 0.0015. This evidence is believed to indicate that the rocks on either side of the boundary were formed during the same geological period. Mineral isotopic evidence for those samples now located in the Grenville Province indicates that they were reconstituted during the Grenville orogeny. While the latter event was sufficiently intense to have modified both the $^{40}K-^{40}Ar$ and $^{87}Rb-^{87}Sr$ isotopic ratios of the constituent minerals, the whole-rock samples appear to have remained as closed systems for Rb and Sr.

"In the Superior Province, north of the front, the effects of the Grenville orogeny are strikingly illustrated where the two isotopic systems have responded differentially and anomalously to the thermal gradient although the lithologic and petrographic character of the rocks has remained unchanged."

The epigenetic vs syngenetic or at least synvolcanogenic age of the ores depends on accurate age determinations but so far we have a wide array of ages for the ores or their wall rock alterations. It is difficult for me to imagine the orebodies of the Dore Lake area emplaced over a very long span of time. Wanless et al., (1967) reports an age of 1790 m.y. for the sericite schist wallrock at the Copper Rand mine but 2706 m.y. for the actinolite next to the ore at Cedar Bay, a mere 8000 feet (2400 m.) across the lake from the Copper Rand mine.

The only positive statements we dare to make at the present regarding the geochronology of the area are the following:

a. The rocks of the Chibougamau greenstone belt are older than 2700-2800 m.y. and have been strongly affected by Kenoran metamorphism at around 2.700 m.y. (Dallmeyer, 1974). Fritz and Doig (1975) work indicates that some tonalitic gneisses in the Grenville Province are older than 3000 m.y. and could be considered as basement to the greenstone belt.

b. the ores and their wall rock alteration are probably synvolcanogenic and cannot be dated accurately with present methods.

c. Grenvillian orogeny and metamorphism has brought up the rocks on the Grenville side of the Front and has influenced the rocks on the Superior side for

distances up to 10 miles (Frith and Doig used 5 miles but it could be considerably more in the Chibougamau area proper because of the extensive faulting, shearing, and the presence of extensive hydrothermal alteration around all the orebodies of the district).

DENSITY OF ROCKS FROM THE CHIBOUGAMAU DISTRICT

A number of density measurements of the rocks of the Chibougamau district have been done either for the interpretation of gravity surveys or for tonnage and average grade calculations within the mines of the area. Table 82 gives the results of the specific gravity determinations and the number of samples used. Table 83 gives the results of density determinations done on samples from the Dore Lake Complex.

CHAPTER 9

ECONOMIC GEOLOGY AND METALLOGENESIS OF THE CHIBOUGAMAU AREA

Introduction

The Chibougamau area proper has produced to date (1975) close to
$600,000,000.00 of copper, gold, and silver. This does not include the
production of the Opemiska mines (Falconbridge Copper Limited) at Chapais, 30
miles (50 kms) west of Chibougamau; the Icon mine located 45 miles (72 kms)
north of Chibougamau within the Mistassini basin; and the Chibex mine, 40 miles
(64 kms) south of Chibougamau. All of these deposits are within the Chibougamau
mining district sensu lato. The yearly mineral production is summarized in
TAble 94.

Historical Review

The historical development of the Chibougamau area was covered in the
introductory chapter. Table 95 summarized the history of the ore deposits.

In 1911, the report of the Chibougamau Commission was published and while
they recognize the economic mineral potential of the area, they did not support
the immediate construction of a railroad.

During the twenties, prospectors making interesting discoveries in the
Noranda area were encouraged to push their efforts to other greenstone belts
and Chibougamau benefited from a number of discoveries. Consolidated Mining
and Smelting sank a 550-foot shaft at Cedar Bay during the period 1934-1937, and
Ventures sank the Opemisca shaft to 500 feet in 1936, but the low gold content,
the low copper price of the Depression years, and the lack of transportation
means forced a suspension of the operations.

In 1948, the Quebec Department of Mines under the leadership of Dr. A. O.
Dufresne, a firm believer in the mineral potential of Chibougamau, built the
all-weather 150-mile (240 kms) gravel highway between St. Félicien and
Chibougamau. The completion of the highway brought a wave of exploration and

Table 94   MINERAL PRODUCTION FROM THE ORE DEPOSITS OF THE CHIBOUGAMAU AREA
Tonnage milled

MINE	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
CAMPBELL CHIBOUGAMAU MINES LTD														
Main Mine Group	49,624	632,810	618,485	565,634	511,287	471,751	376,079	158,370	257,800	389,911	365,410	355,724	297,566	182,550
Cedar Bay				26,310	171,231	252,303	252,137	207,613	168,508	154,126	216,071	228,155	210,179	193,697
Grandroy													62,289	171,656
Henderson						11,583	168,421	338,582	346,197	326,030	355,090	360,193	410,402	455,161
Ovillia														
C.C.M. TOTAL	49,624	632,810	618,485	591,944	682,518	735,637	796,637	704,565	772,505	870,067	936,571	964,072	980,536	1,003,164
C.C.M. METAL SALES ($) Ventes de metaux ($)		13,491,529	9,049,673	6,034,894	7,759,764	9,722,583	11,389,060	10,208,202	9,925,974	10,394,526	11,546,983	13,802,959	17,305,133	17,510,626
MERRILL ISLAND MINING Corp.				77,875	149,870	157,220	156,203	152,945	157,691	143,746	117,268	85,798	115,611	
M.E. M.C. METAL SALES ($)														
PATINO (QUEBEC) LTD														
Copper Rand						424,354	353,515	359,967	329,637	344,431	353,070	300,163	263,160	294,938
Jaculet						80,261	79,460	70,154	33,874	21,622	77,393	156,372	173,450	173,221
Portage Island						45,953	171,505	201,963	210,193	181,706	151,276	137,637	162,035	276,238
Bouzan								7,622	50,783	46,255	35,554	35,205	73,574	49,978
Copper Cliff													100,000	222,000
Quebec Chibougamau									51,243	80,117	45,958	21,833	8,280	8,659
PATINO TOTAL						550,568	604,480	682,872	675,730	674,131	663,251	651,210	760,439	930,134
Patino METAL SALES ($) (vente de metaux)						6,718,677	9,565,464	10,545,251	11,341,980	11,915,366	11,788,595	12,959,389	14,371,000	15,298,000
NORBEAU MINES LTD										22,983	77,464	85,451	84,439	81,827
METAL SALES ($)														

- 313 -

Table 94 (cont'd)

MINE	1969	1970	1971	1972	1973	1974	1975	Total	METAL PRODUCED Copper (pounds)	Gold (oz)	Silver (oz)	Cu %	Au oz/t
CAMPBELL CHIBOUGAMAU MINES LTD													
Main Mine Group	182,928	333,515	410,649	341,956	314,247	600,563	181,505	7,598,264				1.68	0.025
Cedar Bay	201,305	242,272	258,057	175,952	155,253	158,732	53,129	3,325,030				1.82	0.087
Grandroy	55,477					33,001	62,524	385,047				1.23	0.02
Henderson	510,005	682,558	683,601	497,033	638,739	473,054	264,519	6,541,168				2.01	0.025
Quillim							16,588	16,588				0.08	.226
C.C.M. TOTAL	949,715	1,258,345	1,252,307	1,014,941	1,108,139	1,265,350	578,265	17,866,097	575,848,260	609,560	3,000,768		
C.C.M. METAL SALES ($) Ventes de metaux ($)	14,644,712	25,173,424	21,757,000	14,616,000	19,493,000	26,140,000	?	$269,965,618					
MERRILL ISLAND MINING Corp.								1,314,227	56,949,745	17,806	522,422	2.33	
M.E. M.C. METAL SALES ($)								$18,370,308					
PATINO (QUEBEC) LTD												(Up to 1973)	n.a.
Copper Rand	352,556	398,599	437,259	531,000	524,000	431,000	n.a.	5,697,589				2.21	n.a.
Jaculet	175,176	97,282	35,610	5,000	13,000	14,000	n.a.	1,210,980				1.93	n.a.
Portage Island	191,644	184,076	191,897	273,000	306,000	256,000	n.a.	2,841,123				1.94	n.a.
Bouzan	with Copper Rand					15,500		298,911				2.11	
Copper Cliff		152,797	327,022	211,000	130,000	131,000	n.a.	1,273,819				1.83	n.a.
Quebec Chibougamau	12,576	4,433	613				n.a.					1.26	n.a.
PATINO TOTAL	731,952	837,187	992,401	1,020,000	973,000	850,000	n.a.	11,322,422	414,585,346	368,848	1,827,630	1.90	n.a.
Patino METAL SALES ($) (vente de metaux)	22,289,000	20,768,000	20,180,000	18,672,000	22,347,280	28,730,889	n.a.	$237,490,891	(up to '73)	(up to '73)	(up to '73)		
NORBEAU MINES LTD	66,865							419,029 $7,070,205		163,541	20,270		0.329
METAL SALES ($)													
TOTAL								$532,897.022					

Table 95

CHRONOLOGICAL DEVELOPMENT OF THE ORE DEPOSITS OF THE CHIBOUGAMAU AREA

1870   Richardson of the Geological Survey of Canada reports copper mineralization from the shore of Chibougamau Lake.

1903   Peter McKenzie discovers asbestos at Asbestos Island, copper at Copper Point, Portage Island, and gold.

1906-07   John Kokko discovers the Kokko Creek showing (now mined by Campbell Chibougamau).

1906-07   Captain Machin supervises work around Machin Point (now Copper Rand Mine of Patino).

1904   J. Obalski, inspector of mines for Quebec, discovers large gold-bearing quartz vein on Portage Island.

1905   formation of Chibougamau Gold and Asbestos Mining Company.

1910-1911   examination and report of the Chibougamau Commission.

1920   discovery of Merrill Island Mining Corporation showing.

1922   discovery of a showing on shore of Merrill Island (now Campbell Chibougamau Main mine).

1928   discovery of the Obalski property showing by Chibougamau Mining Company.

1928   discovery and exploration of Cedar Bay showing (now Campbell Chibougamau Mines, Adan Bay division).

1929   Leo Springer discovers what will become the Opemiska Copper mine for Prospectors Airways.

1929   Berrigan and Larone discovered zinc showing at Berrigan Lake.

1929   S. Sharpe discovers the Sharpe gold showing on the south shore of Bourbeau Lake.

1930   Gilligan and Mahony discover the gold showing which will become the Norbeau Mine.

1934-1937   shaft sinking and development at Cedar Bay by Consolidated Mining and Smelting Cpy.

1950   discovery of Kayrand ore zone and Quebec Chibougamau ore zone.

1952   G. O. Allard discovered Siderite Hill showing (Patino).

1954   Production started at Opemiska Copper Mine.

1955 (June)   Start of the Campbell Chibougamau Mine mill.

1958 (September)   Start of the Merrill Island Mining Corporation mill.

1959 (December)   Start of the Copper Rand mill (Patino Mines).

1956-1957   discovery of the Henderson Mine ore body.

1973   discovery of Patino-Lemoine ore deposit.

the drilling of all the previous discoveries. The beginning of production for
the various mills can be found in Table 94. In May 1975, labor problems
coupled with a very low price for copper forced Campbell Chibougamau Mines to
temporarily suspend their operations. The reserves of the main companies
(Cimon, 1975) stand at the following figures:

Campbell Chibougamau (all mines) 10,927,000 averaging 1.74% Cu and
0.042 oz Au/ton

Patino (Quebec) (all mines)   6,098,000 tons

Metallogeny

The ore deposits of the Chibougamau area can be divided geologically into
five categories:

a. copper-gold deposits in the Dore Lake complex

Dore Lake group: Campbell Chobougamau Main mine
                    Merrill Island Main mine
(Fig. 127)   Kokko Creek (CCM)
                    Quebec Chibougamau (CCM)
                    Cedar Bay (CCM)
                    Siderite Hill (Patino)
                    Copper Cliff and North Siderite (Patino)
                    Copper Rand Main mine (Patino)
                    Jaculet (Patino)
                    Bateman Bay (Patino)

Henderson-Portage group:
                    Henderson I (CCM)
                    Henderson II (CCM)
                    Portage (Patino)

b. copper-gold deposits in the gabbro sills and volcanics of the Gilman
   formation   Bruneau Mine

c. copper-gold deposits in the Grandroy stock (satellitic to the Chibougamau
   pluton)   Grandroy mine (CCM)

d. gold deposits in the Bourbeau sill

                    Norbeau mine

e. copper-zinc deposit at the Waconichi-Gilman contact (stratiform
   volcanogenic)   Patino Lemoine deposit.
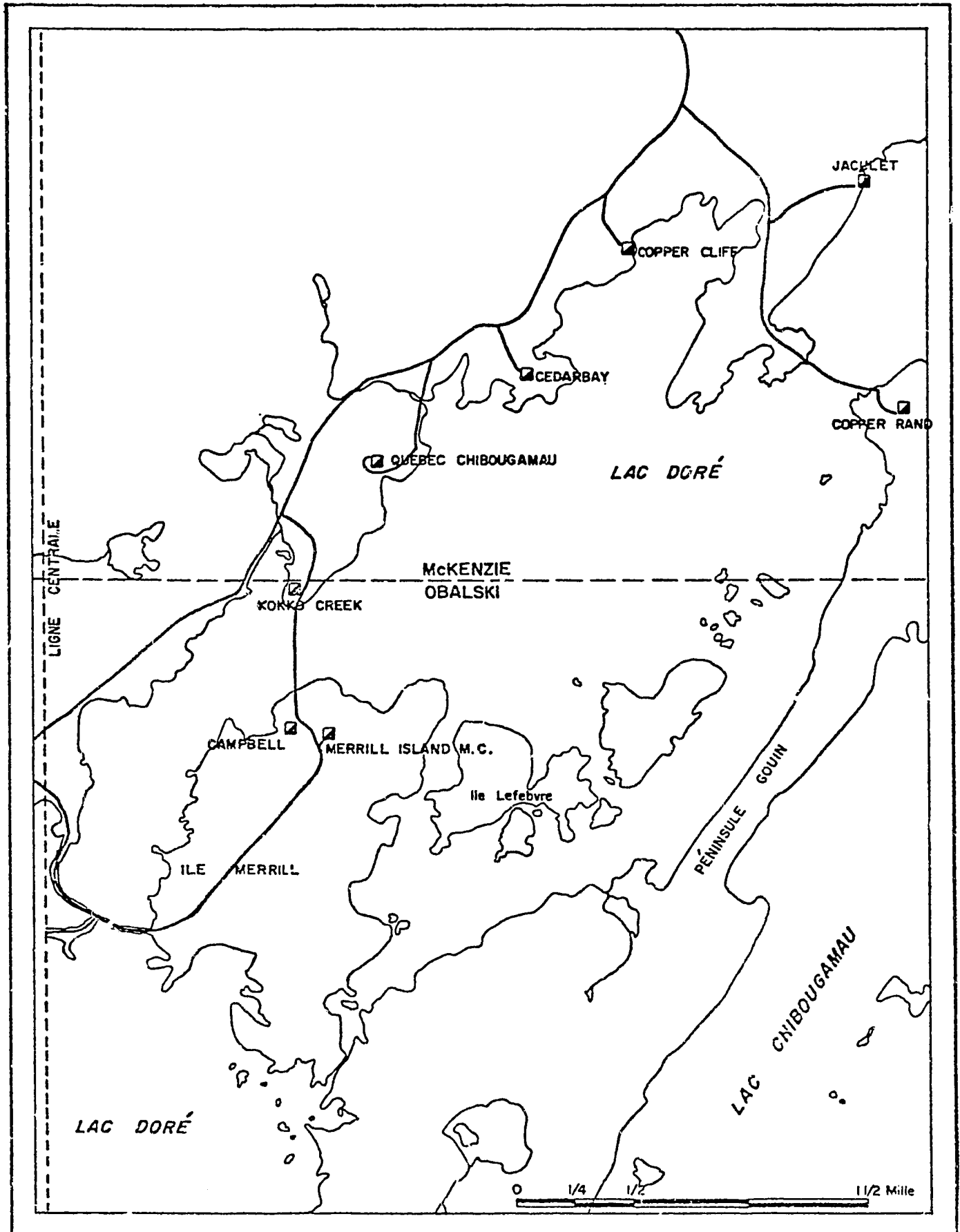
Fig. 127. Sketch map of the main deposits in the Dore Lake area.

The ore deposits of the Chibougamau district have unique characteristics. They are lenses of sulfides (chalcopyrite, pyrite, pyrrhotite, quartz, carbonate) in paragonite-sericite-chlorite (chloritoid) schist along dikes in meta-anorthosite and gabbroic meta-anorthosite of the Dore Lake Complex. This setting is unique amongst deposits of the Superior Province and has led to all sorts of speculations on the origin of the deposits.

Geologists in the fifties and sixties explained the deposits using the classical replacement hydrothermal theory and the deposits fitted the expected pattern: vicinity of a granitic pluton, along northwest-trending shears, on either side of a major fault (Fig. 129).

Vollo (1959) working on the Henderson "A" orebody, under Chibougamau Lake, thought that the ore was related to the Grenville orogeny and the metals derived from the country rocks by lateral secretion. He stated (p. 64-65):

> "The Henderson orebodies are the result of hydrothermal replacement of meta-anorthosite along the more permeable sections of the Main Shear and the "A" zone. In this process iron, magnesium, potassium, sulphur, carbon dioxide and the valuable metals have been introduced.
> "The source of the hydrothermal solutions is ope to speculation. Miller suggests that they are derived from the trondjemitic Chibougamau Lake granite (Miller, 1957). This granite, however, must be much older than the ore; it trends parallel to the east-west structures of the "Keewatin" orogeny and is cut by northeasterly fault zones related to the younger Grenville orogeny. The Henderson orebodies occur within one of these northeasterly faults and must therefore greatly postdate the granite. The writer suggests that the water and carbon dioxide components of the mineralizing solutions originated as products resulting from the high grade metamorphism of the Grenville schists and gneisses to the southeast. High grade metamorphism is essentially a dehydration process and expelled water and volatiles must migrate to regions of lower temperature and pressure. The mechanism of such movement is discussed by Ramberg (1951); it may initially be by diffusion through crystal lattices or by capillary movement along grain boundaries. Solutions may eventually concentrate along fault or breccia zones at shallower depths.
> "The Chibougamau orebodies all occur within the meta-anorthosite, suggesting a direct genetic relationship between meta-anorthosite and ore. It is possible that the iron, magnesium and valuable metals were leached from wide shear zones in the meta-anorthosite at depth by hydrothermal solutions travelling along them and redeposited at higher levels."

Duquette (1970) relates the mineralization to the Chibougamau pluton. He

stated (p. 10-11):

> "In spite of the fact that the rocks of the granitic
> assemblage do not carry important concentrations of base-metal
> sulfides, they are, nevertheless, locally mineralized (e.g.
> Grandroy deposit, Roy twp.) and appear to have played an
> important role in the formation of the deposits found in the
> greenstone assemblage.
>
> "Considering that virtually all copper ore occurring within
> the Doré Lake complex lies along or near dike material issued
> from the nearby Chibougamau Lake Pluton (tonalite-diorite) and
> considering also that the Pluton emplacement and the sulfide
> mineralization can be interpreted as being pre-folding (Kenoran)
> events, one can conclude with a fair degree of certitude that
> copper mineralization in the Doré Lake-Chibougamau Lake basin is
> genetically related to the Chibougamau pluton.
>
> "A genetic relationship could also exist between the Opémisca
> Copper Mines orebodies and the adjacent granodioritic Opémisca
> pluton. Indeed, the sulfide zones of the Ventures Sill are
> contained, in all cases, in late structures of post-Kenoran age
> which, as mentioned previously, also appears to be the age of the
> granodioritic plutons in the district. In addition, some of the
> Opémisca ore zones carry scheelite and molybdenite or syenitic
> and granodioritic material logically all derived from the nearby
> Opémisca pluton."

Allard (1970, 1971, 1972) recognized the rhyolite dome in Scott Township

and its stratigraphic equivalent in Lemoine Township on the south limb and

recommended exploration at the contact rhyolite-pillowed basalt comparing this

situation with the Matagami and Noranda ore deposits. Noranda Mines spent the

summer of 1971 prospecting in Lemoine Township but failed to find a commercial

deposit and stopped working a short distance northeast of the Patino discovery.

The Quebec Department of Natural Resources flew an airborne INPUT survey in

1972 and an interesting punctual anomaly was staked and drilled by Patino in

the summer of 1973 resulting in a small high grade orebody (Patino announced

600,000 tons of 4.5% Cu and 10.8% Zn). This discovery of a stratabound

stratiform volcanogenic orebody close to the contact between porphyritic

rhyolites and pyroclastics with metabasalts has sparked a revival of exploration

in the volcanic areas of the Chibougamau-greenstone belt, especially along

horizons rich in porphyritic sodarhyolites.

Following a trip to Romania to visit the Upper Pliocene Gutai Mountains
ore deposits (Fig. 128), Allard (1974, verbal presentation at Chibougamau
symposium) proposed a volcanogenic vein-type model for the ores of Chibougamau
(Fig. 129). The following scenario is proposed: the volcanic rocks of the Roy
Group comprise two mafic-to-felsic cycles. The end of each cycle produces
prophyritic sodarhyolites and volcanogenic exhalites (cherty-carbonate-sulfide
iron formation, and copper-zinc lenses). Mafic sills (including the thick Dore
Lake Complex) are intruded in the volcanic sequence throughout its development.
The subvolcanic Chibo gamau pluton is diapirically rising within the volcanic
pile. A system of fractures is formed within the competent units on top of the
felsic dome and in the vicinity of major faults. Dikes associated with the late
phase volcanism and the pluton are emplaced along the fractures. The end of
the second cycle is marked by minor zinc showings in the Blondeau formation,
mostly below the Bourbeau Sill. The ore solutions, traveling along fractures
and dikes, deposit their copper content in dilatation zones within the fracture-
dike swarm. A pronounced halo of alteration surrounds each copper-rich vein.
The Kenoran orogeny is accompanied of low grade greenschist metamorphism and
folding of the volcanic assemblage. The incompetent alteration halos become
the paragonite-sericite-chlorite (chloritoid) schist which encloses the orezones,
the so-called "shear zones" of the Chibougamau district. The veins of ores
consisted in pyrite, chalcopyrite, chalcedony, calcite, etc. We can surmise
that some veins were crustified, others showed cockade structures, breccia
fillings, etc. Metamorphism affected all the rocks of the area, including the
ores. A general recrystallization of the sulfides took place. A strong
foliation gives rise to the "sulfide schist ore" of Guha and Koo (1975). This
foliation is favored by the crustification in the original veins. Chalcopyrite
is preferentially mobilized and becomes veinlets and veins cutting across the
reorganized schists and cutting the country rocks.

DETAILED MAP OF VEINS – CAVNIC MINE – RUMANIA
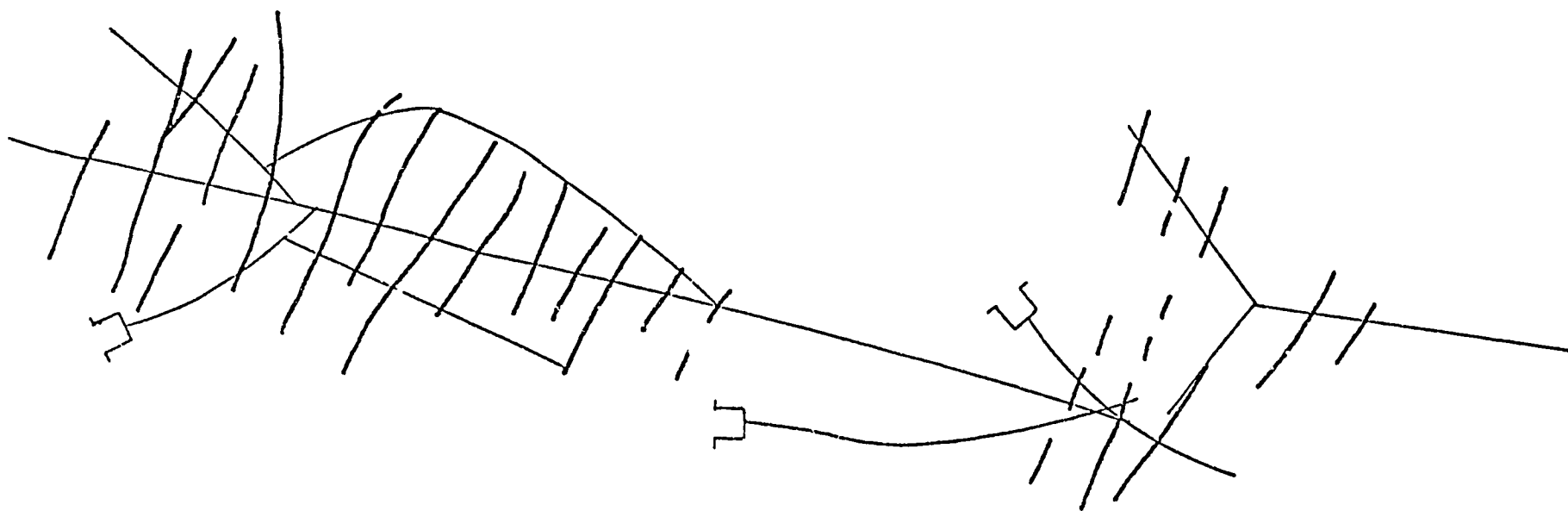
Fig. 128.   Sketch map of the veins at the Cavnic mine,   Rumania.
(from Giusca, Borcos, Lang, and Stan, 1973)

MAIN DEPOSITS – CHIBOUGAMAU
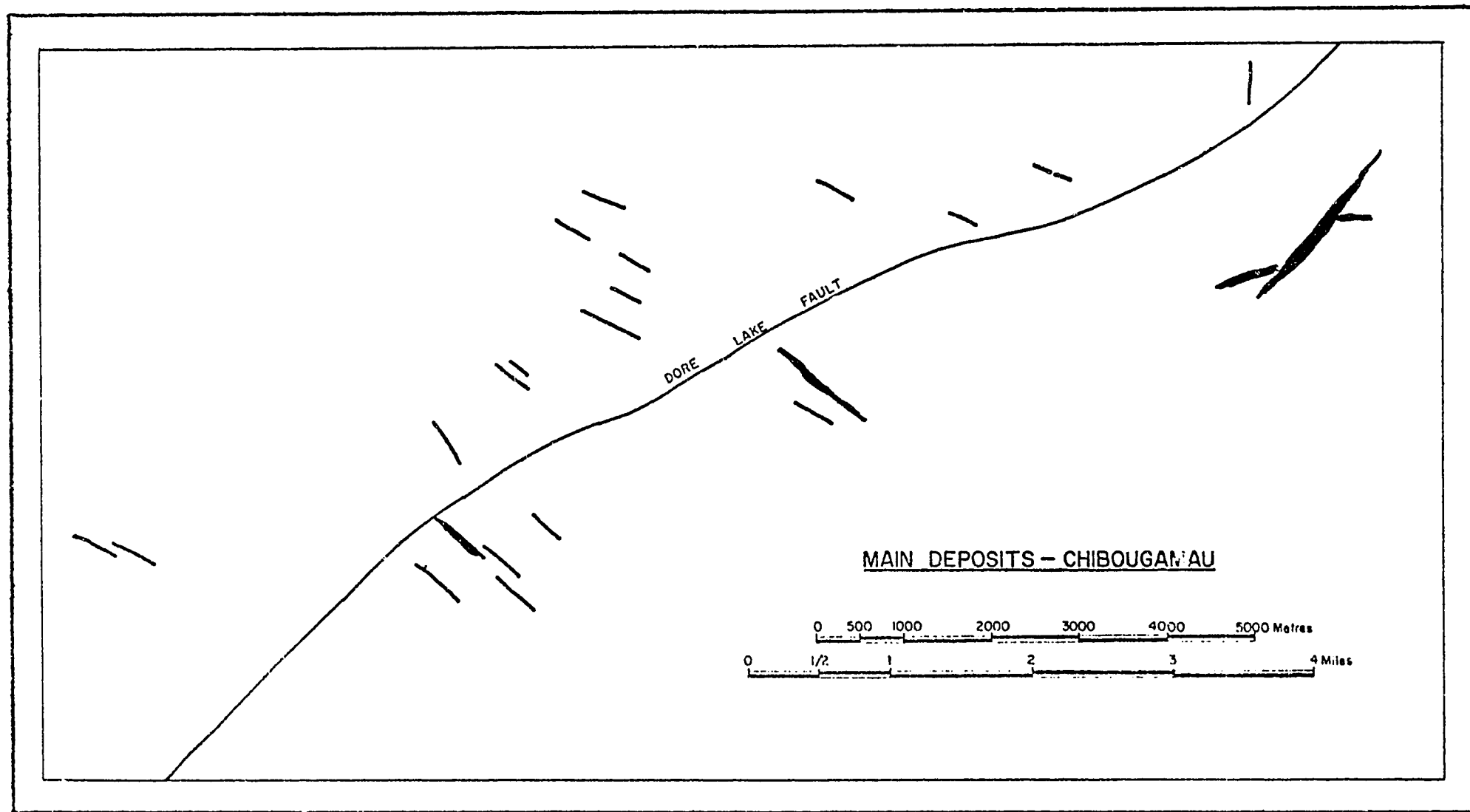
Fig. 129. Sketch map of the main ore deposits in the Chibougamau area.

The Chibougamau orebodies can thus be called volcanogenic in origin,
eipgenetic in geometry, and synvolcanic-premetamorphic in chronology.

Hydrothermal Alteration Studies

The classical hydrothermal theory of ore deposits (Lindgren, 1933; Bateman,
1950) well summarized by Ridge (1968) prescribes a hydrous fluid as the carrier
of metals and a concomitant alteration of the walls of the conduits and
receptacles. Since the alteration halo is much larger than the ore deposit
proper, it would greatly increase the target of the exploration geologist if
one could distinguish alteration associated with valuable ore deposits from
alteration along barren shears. With this in mind, numerous studies of
alteration haloes have been done throughout the world (Sales and Meyer, 1948,
1949, 1950; Schwartz, 1959; Burnham, 1962; and Lovering, 1949). The modified
volcanogenic epigenetic theory proposed here for the Chibougamau deposits does
not change the general geometric framework outlined above but only the timing
of the alteration with respect to the regional metamorphism and deformation.

The main Chibougamau deposits have been the subject of many alteration
studies, especially the dissertations and theses by Miller (1957), Jeffery
(1959), Hawkins (1960), Raychaudhuri (1959), Sutton (1959), Eckstrand (1963),
Blecha (1966), and Moritz (1975). One great advantage of such studies in the
Chibougamau district is the presence of nearly all deposits within a single
rock type, the Anorthosite Zone of the Dore Lake Complex. Unfortunately, too
many researchers have assumed that all gabbroic anorthosites of the Anorthosite
Zone are identical in composition but chemical analyses (Tables 33 to 36) of
many samples have revealed a pronounced cryptic layering throughout the complex
and the Anorthosite Zone.

Jeffery (1959) studied the Campbell Chibougamau Main mine. He had access
to underground openings from the 125- to the 1900-level. He studied 397 thin
sections and 154 polished sections. His analyses of country rock meta-anorthosite

are given in Table 33 and those of sheared and altered meta-anorthosite in
Table 35.

Jeffery recognized a halo of alteration around the Campbell orezone
grading from meta-anorthosite through a sericitic zone and into a chlorite-rich
orezone. He mentioned the possibility of paragonite but did not identify it
and referred to all white mica as sericite. He attempted to measure the
birefringence of chlorites and use Hey's (1954) data to interpret the Fe/Mg + Fe
ratio of chlorite. He established two types of chlorite (p. 149):

Type 1 (high Mg)	Type 2 (richer in Fe)
usually colourless or pale green	green
pleochroism nil to faint	pleochroism strong
length fast-negative elongation	length slow-positive elongation

he found all gradations between the two types. The optic angle passes through
zero between the two types and it becomes isotropic with nil birefringence.
Jeffery concludes (p. 150):

> "In general it can be stated that the chlorite associated
> with sulphide and its near vicinity is always the iron-rich type
> 2 which is green, pleochroic, and length slow. This type and the
> near isotropic variety which can be either length slow or length
> fast is seen throughout the length and breadth of the orezone."

In his study of 176 samples from diamond drill holes on the 550-level,
Jeffery used relative birefringence measurements of chlorite. After a long
discussion of results, he concludes:

> "From these observations the writer draws various conclusions.
> All the rocks at Campbell Chibougamau mine contain chlorite. The
> chlorite associated with massive meta-anorthosite is a magnesium-
> rich chlorite, but for the purpose of comparison it is better
> described as an iron-deficient chlorite. Chlorite within sheared
> meta-anorthosite and associated with mineralization, has a higher
> iron content, but the difference between barren schistose rock
> and mineralized schistose rock is only a matter of degree. In
> places highly schistose rock remote from ore will contain chlorite
> with optical properties which indicate an iron content equivalent
> to the chlorite associated with ore. Thus the presence of iron-
> rich chlorite in diamond drill cores cannot be used as a definite
> indication of the immediate presence of sulphide.
> "However there is a possibility that chlorite might be of
> use as an indicator with limitations. Dissemination of iron-rich

chlorite from the ore zone into the wall rock is limited; where
the wall rock is massive the change to iron-deficient chlorite is
rapid. Thus with respect to wall rocks the writer concludes that
chlorite is of little use as an ore indicator.

"Along the strike of the ore zone the iron-rich chlorite
development has been more persistent. Chlorite associated with
sulphide can be prominent along strike for approximately 300 feet
from ore. Depending upon the interpretation placed on the results
from U 575 and described above, iron-rich chlorite may persist
farther west. However as the interpretation remains doubtful the
writer assumes in these conclusions that the ore-bearing shear
persists with a N. 70° W. trend. Therefore beyond 300 feet from
ore the chlorite variation is indicative only of sheared meta-
anorthosite. The distance is applicable to the Campbell
Chibougamau ore zone and its enviornment, and it may change
considerably in other places.

"Thus the use of chlorite as an ore indicator is limited to
shear zones, and it has always to be remembered that scattered
iron-rich chlorite can be found where there is no ore. The
suggested distance of 300 feet is about one third of the strike
length of the orebody. This is a worthwhile increase in target
size.

"It was thought that chlorite close to the ore-zone might
be very deficient in iron, as part of the wall rock alteration
may have been the draining of iron from the wall rock into the
ore zone. There is no evidence of such a pattern.

"The failure of chlorite as a useful wall rock indicator of
ore is not very important. The primary requisite in the search
for ore in the Chibougamau mining camp is a full understanding of
structure. A knowledge of the distribution of shear zones is
gained from geophysical methods, and drilling on more anomalous
portions of these structures is the subsequent step in exploration.
The extension of an ore deposit along strike for 300 feet is not
a great deal and the exploration geologist would prefer that the
distance was of the order of one mile. It may be argued that an
orebody such as found at Campbell Chibougamau would give a large
enough geophysical anomaly for identification without recourse to
additional exploration aids. This is true if the orebody was on
or very close to the surface, but the writer thinks that the
chlorite pattern may be useful as a vertical guide to ore. And
mineralization at depth is the type of orebody which may not be
revealed by strong geophysical anomalies.

'In sum, the writer thinks that on the discovery of any zone
of schistose rock with a southeast trend which carries a
consistent content of iron-rich chlorite, (chlorite II), all
adjacent drilling should be carried out with a spacing not
greater than 1000 feet. This criterion applies both down the dip
as well as along the strike of the zone.

"There remains an explanation to account for the variation
of chlorite in the vicinity of Campbell Chibougamau mine.

"Chlorite in the massive meta-anorthosite has been found to
be deficient in iron compared with a general iron enrichment in
sheared and altered ground. This evidence implies that all sheared
rock in the area was subsequently soaked with iron-rich solutions
and that an iron-metasomatism has occurred. The introduction of
the iron-rich sulphide orebody was a culmination of the sequence,

which was superimposed on a particular sheared section of ground already enriched in iron compared with the meta-anorthosite. The whole pattern is substantiated by the presence of iron-rich chlorite which is pre-ore, in the paragenesis of ore and gangue minerals (see Chapter VI)."

Chloritoid was observed in only 6 thin sections in small amounts and randomly distributed throughout the mine. It is associated with mineralization and shearing in dike rocks and in altered meta-anorthosite but its spotty occurrence in the Campbell mine does not make it a good indicator of ore.

Miller (1957) studied the Cedar Bay Mine and mapped the surface and underground down to the 500-level. He found that the orezones are located at the interface between dikes and altered gabbroic anorthosite. He did not see any primary layering in the rocks at the mine. However, in a drive north of the main zone, on the 19th and 20th level, the writer saw excellent layering in the gabbroic anorthosite. Miller noted that on the weathered surface and on polished drill cores, one can recognize the original anorthositic texture in spite of intense metasomatism which replaces the original by sericite, chlorite, calcite, actinolite, and ores. No chloritoid was reported from Cedar Bay. In his study of a large number of samples, Miller adopted a classification of alteration types which he summarized in his Table 1 (page 146) reproduced here as Table 96. He studied the samples in a random order and assigned them an alteration classification number. He then contoured the map and compared it with the geological map. His main conclusions were:

1. "The main alteration zone strikes northwest-southeast as do the main sulphide veins. Near the centre of the map the alteration zones branches to the west, as do the veins."

2. "The alteration zones and the veins both coincide with the major shear zones which apparently controlled them."

3. "A quantitative aspect may also be noted. The thicker alteration zones showing ore type alteration contain the larger veins. In other words the width of the wallrock alteration zone varies directly as the width of the veins. Even along one vein, the alteration haloes seem to narrow and widen with the sulphide mineralization."

Miller did not study the chemistry of the alteration zones. He did partial analyses on 6 samples and found a sharp increase in K_2O and a decrease in Na_2O next to the orezone. His conclusions are very similar to the other workers in the mines of the Dore Lake-Chibougamau Lake area.

Vollo (1959) studied the cores of the original surface drilling program which discovered the "A" zone at the Henderson mine and the southern end of the Henderson shear or "G" zone but did not have access to underground openings. He studied in detail drill hole T-141 which was on the original section 17E at 585' S. This hole passes through both zones. Table 97 gives a summary of Vollo's findings. He divided the alteration zones in the following subdivisions:

"Main shear"	"A" zone
meta-anorthosite	meta-anorthosite
sericite-calcite 10-50' alteration	sericite-carbonate 25'
sericite-chlorite alteration	sericite-chlorite 50'
chlorite-chloritoid alteration	chlorite-sericite 50'
quartz-ankerite-sulfide zone	chlorite-actinolite 25'
chlorite-chloritoid alteration	massive sulfide (varies in thickness)
sericite-chlorite alteration	chlorite sericite 5'
sericite-calcite alteration	sericite-carbonate 5'
meta-anorthosite	meta-anorthosite

The intensity of alteration is proportional to the intensity of shearing. The zones of alteration are gradational into each other. In drill cores, the textures of the original gabbroic anorthosite can be recognized even in the most altered rocks provided the intensity of shearing is not too high. The use of a pocket knife in scratching the core will reveal a gradual softening of the rock caused by a replacement of the plagioclase by sericite or paragonite. Shearing causes a flattening of the plagioclase megacrysts giving an "augen schist" appearance to the rock. Increasing shearing intensity produces a

(Figs. 131 to 133)

Fig. 130. Meta-anorthosite and gabbroic meta-anorthosite (AZ) cut by intense shear on the left and by many incipient shears at t top and right central part of the photograph. Note the good preservation of the cumulus-intercumulus texture in the unaltered (but metamorphosed) block of gabbroic anorthosite. Underground at Jaculet mine.
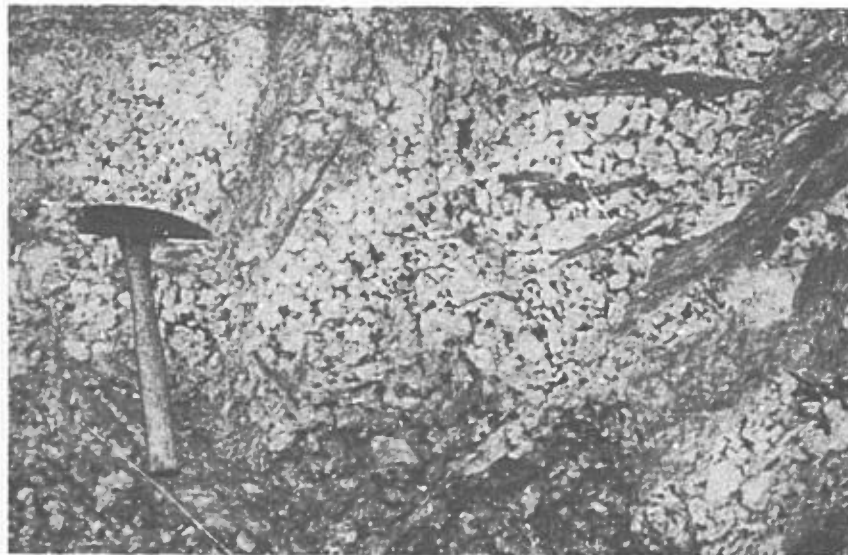
Fig. 131. Gabbroic meta-anorthosite cut by irregular minor shears in the vicinity of a major shear. The blocks between the shears show little hydrothermal alteration and good preservation of the cumulus-intercumulus relationship. The intensification of the shearing process leads to a complete loss of the traces of the original rock and to the production of a "paper schist". Underground at Jaculet mine.
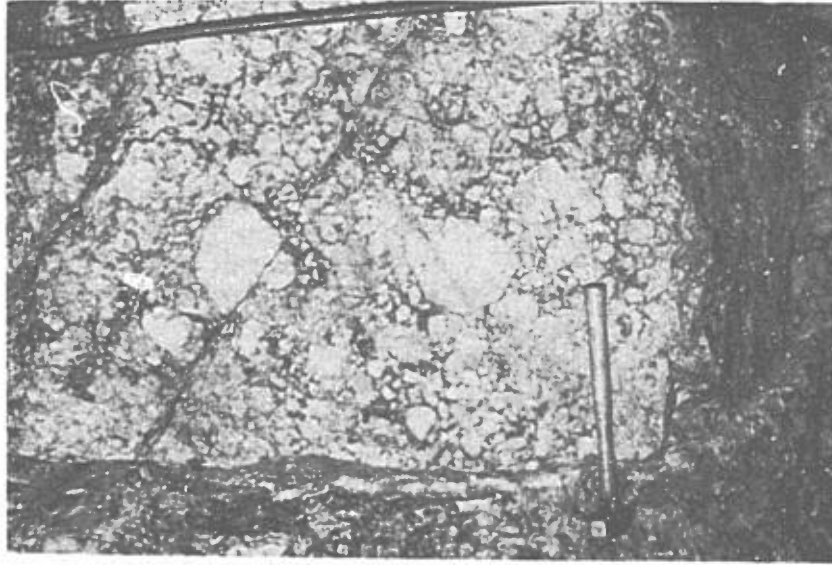
Fig. 132. Gabbroic meta-anorthosite (AZ) cut by shear zone at the left and at the top. A small fault cuts across the block of relatively unaltered gabbroic meta-anorthosite. Note the low degree of alteration away from the shears and the perfect preservation of the cumulus-intercumulus texture. The boundaries of the shears are very sharp and marked by an inch or two of "augen schist" where the plagioclase cumulus crystals are flattened and still recognizable. Underground at Jaculet mine
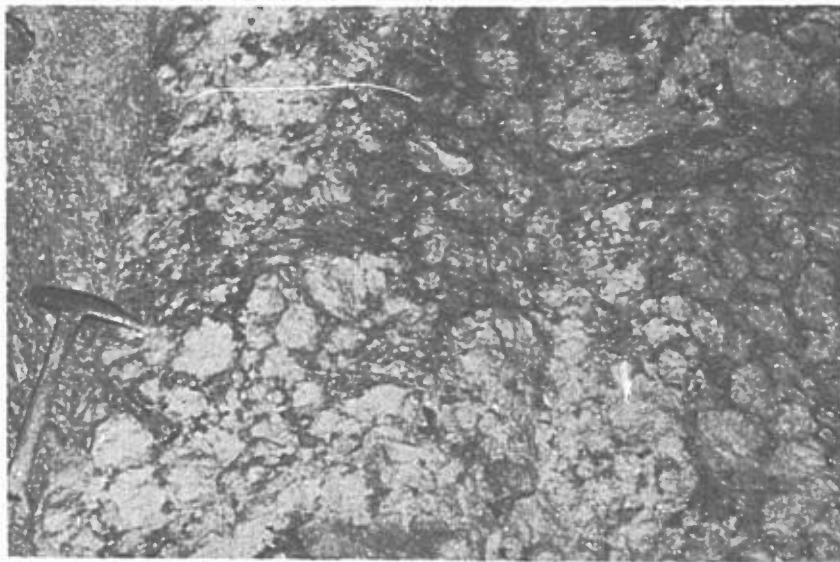
Fig. 133. Gabbroic meta-anorth-osite cut by major shear zone at the left and an incipient minor shear across the top of the photo. Note the more intense hydrothermal alteration which makes the cumulus-intercumulus relationship much more hazy than in fig. 132 above. Underground at Jaculet mine.

Table 96

CLASSIFICATION OF ALTERATION MINERALS AT THE CEDAR BAY MINE (FROM TABLE 1 - P.147 - MILLER, 1957)

CLASSIFICATION DES MINERAUX D'ALTERATION A LA MINE CEDAR BAY (TIRE DU TABLEAU 1 - P.147 - MILLER, 1957)

Zone	CHLORITE	EPIDOTE	APATITE	CARBONATE	ZOISITE	SERICITE	FELDSPAR	ORE MINERALS	ACTINOLITE
1 ore	Chlorite II Large crystals Rosettes, semi-rosettes Elongated crystals abundant-medium to good pleochroism rarely isotropic commonly occurring in veinlet	If present Well-shaped crystals clear usually in veins or as veinlets	Large to medium prismatic crystals - corroded and healed by quartz, carbonate, etc.	If present usually euhedral to subhedral crystals	If present is Fe-rich variety or altered to epidote	Usually present as good crystals (muscovite) relatively large	Little or none	Present in substantial quantities	Fresh acicular crystals or may be completely altered to quartz and chlorite
2 near ore	Same as Zone 1 except sparingly present or absent ore minerals.						Same as Zone 1 except sparingly present or absent ore minerals		
3 Transitions	Chlorite II possibly some Chlorite I rare as veinlets Semi-rosettes to poor crystals poor to medium pleochroism rare to abundant maybe isotropic	poor to good crystals present in veinlets or disseminated may be clear may surround zoisite	medium to small crystals Hexagonal sections common	may be present as subhedral crystals and as veinlets	May be present probably as Fe-rich variety	Present as medium to good crystals, medium sized crystals except in dyke where may be small to large	Sodic feldspar be present usually highly altered	Probably absent	Probably absent
4 no ore	Chlorite I possibly little Chlorite II - medium to good crystals-including rosettes-poor to medium pleochroism-nearly isotropic, few chlorite veinlets	poor crystals dirty appearing crystals may by small to large	very small crystals or none	present as crystals, but mostly as nondescript blebs	May be present but probably variety low in Fe.	If present, mostly as very fine crystals	Sodic feldspar may be present altered	Absent	Probably absent
5 no ore	Chlorite I (no type II) Poor crystals most common, nearly isotropic, few or no chlorite veinlets	rarely present dirty and definitely alteration of adjacent feldspar probably as medium to small grains.	very small crystals or none	same as Zone 4	Same as Zone 4	Same as Zone 4	Sodic feldspar present as good, well formed crystals. usually clear	Absent	Probably absent

328

Table 97

SUMMARY OF ALTERATION STUDIES IN HOLE T-141 - HENDERSON MINE - (FROM VOLLO, 1959 - TABLE 1 AND 2, P. 47 & 49)

RESUME DES ETUDES D'ALTERATION DANS LE TROU DE SONDAGE T-141 - MINE HENDERSON - (TIRE DE VOLLO, 1959, TABLEAU 1 ET 2, pp. 47 et 49)

Footage Profondeur	% Fe	% K	Optic sign Signe optique	Ny	Fe/(Fe Mg)	Al	Remarks - Observations
100	2.3	0.6	Pos.	1.62	0.41	1.4	Unaltered meta-anorthosite
125	3.6						" " " "
150	5.6	1.2	Neg.	1.63	0.55	1.1	Narrow altered zone in meta-anorthosite
175	3.7						Unaltered meta-anorthosite
200	4.2		"	1.63	0.55	1.1	" " " "
225	3.7						" " " "
250			"	1.624	0.67	0.5	Lightly altered meta-anorthosite
255	9.3	2.7					Sericite carbonate zone
275	7.8						" " "
300	6.2	1.3	"	1.639	0.65	1.2	Chlorite sericite zone
325	12.5						" " "
350	10.3	1.2	"	1.640	0.67	0.5	MAIN { Chlorite sericite zone
375	19.2						" " "
390	8.9	2.0					Chlorite chloritoid zone
400			"	1.642	0.70	1.2	" " "
405	7.3						SHEAR " " "
440	14.5	1.7					" " "
450	11.9		"	1.639	0.67	1.2	Chlorite sericite zone
475	5.5	0.8	Pos.	1.637	0.63	1.3	Sericite carbonate zone
500	6.4						Lightly sericitized meta-anorthosite
525	5.5	0.65	"	1.618	0.45	1.5	" " " "
550	6.7						" " " " "
575	7.9	0.55	"	1.640	0.65	1.4	" " " " "
600	15.6	1.8					Chlorite sericite zone
625	22.0	1.3	Neg.	1.643	0.73	0.9	"A" { Chlorite sericite zone
650	12.4	2.1	"	1.641	0.70	0.9	" " "
676			Pos.	1.625	0.53	1.3	Actinolitic alteration
690			Neg.	1.640	0.73	0.6	ORE ZONE Chlorite zone
700			"	1.635	0.65	1.0	Ore zone
711			- -	1.630	0.55	1.2	Chlorite zone
715	13.7	0.4					Chlorite zone
720			Pos.	1.633	0.55	1.3	Chlorite sericite zone
725	7.7	1.4					Sericite zone
750	4.6	0.1	"	1.615	0.30	1.6	Unaltered meta-anorthosite
790	3.7						" " "
825	5.0	0.2	"	1.612	0.25	1.7	" " "
875	4.1						" " "
925	4.8	0.3					" " "

- 329 -

"paper schist" consisting of elongated lenses of sericite, chlorite, quartz, and carbonate and strings of tiny orange-colored leucoxene grains which pseudo-morph original ilmenite grains. Calcite veinlets at a high angle to schistosity are very common especially in the outer zones. Chlorite is an intercumulus mineral in the meta-anorthosite and varies in composition with stratigraphic height in the complex. It increases in quantity forming irregular veins in the sericitized plagioclase gradually replacing the sericitized plagioclase. The optical and chemical changes in the chlorite are shown in Table 97. In general, Vollo found an increase in Fe and a decrease in the Al-content of chlorite as one approaches the core of the orezones. Vollo does not mention paragonite but Moritz (1975) has positively established that much of the white mica called sericite in the Chibougamau mines is paragonite. The relationship of chlorite with actinolite and chloritoid will be discussed in another chapter. Vollo concludes that chloritoid is a stress mineral formed from iron-rich chlorite. He also derives actinolite present in part of the "A" zone from chlorite and calcite. Vollo concluded that the iron-rich chlorite haloes around orezones and the chloritoid-ankerite suite of the main shear should be considered favorable exploration targets.

Sulfide Studies

Many theses and dissertations dealing with alteration studies or mine studies have a chapter on the sulfides found in the orezones. Table 98 tabulates the gangue minerals reported and Table 99 reports the sulfides found in the Chibougamau area ore deposits.

Allard (1953) did spectrographic quantitative analyses of pyrite and pyrrhotite (Tables 100 and 101) from surface samples and from a few drill cores. Raychaudhuri (1960) did an extensive study (1716 samples) of the sulfides in the Chibougamau mines. His results and those of Nichol (1958) are presented in Tables 102, 103, and 104. All these studies show the great variability in

the content of trace elements in the major sulfides. All authors agree on the high content of cobalt and nickel in pyrite and pyrrhotite.

Table 105 gives analyses of magnetite concentrates from samples of sulfide ores rich in magnetite. When compared to the Dore Lake Complex magnetites (see section on iron-titanium-vanadium deposits), those from the sulfide ore deposits are remarkably low in TiO_2 and V_2O_5.

We do not have at present good mill analyses of the quantitative distribution of the various sulfides in each deposit. The early work on the Campbell-Merrill orezone indicated that the ore contained 50% pyrrhotite, 30% chalcopyrite, 10% pyrite, and traces of sphalerite. The ores at Quebec Chibougamau, Portage Island, Copper Rand, and Jaculet mines contain little pyrrhotite.

Description of Individual Deposits

Campbell Chibougamau Mines Ltd. (C.C.M.)

Main mine

The Main mine of C.C.M. (No. 1-Plate 1) was discovered in 1920 on the shore of Merrill Island in Dore Lake. It was known as the Blake showing. It became the property of Chibougamau Prospectors Ltd. who sold the property in 1934 to Consolidated Chibougamau Goldfield Ltd., a subsidiary of Consolidated Mining and Smelting of Canada Ltd. Drilling was done on the Blake showing (13 holes) but the main efforts of the company were concentrated on the Cedar Bay property. Exploration efforts were suspended in 1936. The completion of the St. Félicien-Chibougamau highway in 1949 brought a fresh wave of exploration to the Chibougamau area. Campbell Chibougamau Mines Ltd. was formed and acquired the property of Consolidated Chibougamau Goldfields and drilled 41,183 feet in 1950 and 1951. C.C.M. obtained a lease from Merrill Island Mining Corporation (M.I.M.C.) on all the land under the island and started underground work in November 1951. The 1700-ton per day mill started production in June

Table 98

GANGUE MINERALS REPORTED IN THESIS FROM CHIBOUGAMAU DEPOSITS

MINERAUX STERILES DANS LES GISEMENTS DE CHIBOUGAMAU TEL QUE RAPPORTES DANS LES THESES

Mineral	Campbell Main Mine Jeffery 1959	Campbell Cedar Bay Miller 1957	Campbell Henderson "A" Vollo 1959	"B"	Patino Copper Rand Sutton 1959	Eckstrand 1963
Quartz	x	x	x	x	x	x
Calcite	x	x	x		x	x
Ankerite	x			x	x	x
Siderite				x	x	x
Chlorite	x	x	x	x	x	x
Sericite	x	x		x	x	x
Paragonite					x	x
Chloritoid				x	x	x
Actinolite	x	x	x			
Epidote family	x					x
Albite	x					x
Apatite		x	x			
Biotite			tr			
Allanite			tr			
Sphene			tr			
Tourmaline				x		

TABLE 99

SULFIDES REPORTED IN THESIS FROM CHIBOUGAMAU DEPOSITS

SULFURES DANS LES GISEMENTS DE CHIBOUGAMAU TELS QUE RAPPORTES PAR LES THESES

Mineral	Campbell Main Mine Jeffery 1959	Raychaudhuri 1959	Campbell Cedar Bay Miller 1957	Campbell Henderson "A" Vollo 1959	"B"	Patino Copper Rand Sutton 1959	Eckstrand 1963	Quebec Chib. Raychaudhuri	Portage Raychaudhuri	Jaculet Raychaudhuri
Pyrite	xx(10%)	(10%)	x	xx	xxxx	x	xxx			
Pyrrhotite	xxxx(65%)	(50%)	x	xxx	x	x	x	minor	minor	minor
Chalcopyrite	xxx(25%)	(30%)	x	xxxx	x	xxx	xxxx			
Sphalerite	x	tr	x	x		x	xx			
Galena	tr					tr				
Gold	tr									
Cubanite	tr									
Valleriite	tr									
Tetradymite	tr									
Pentlandite	uncertain			x						
Cobaltite		x		x	x					
Magnetite	tr		x		xxx					
Siegenite				x						
Willyamite				x						
Arsenopyrite			x	x						

x = microchemical tests

Table 100 SPECTOGRAPHIC ANALYSES OF PYRITE
(from Allard, 1953, p. 115-117)

Group 2 Copper deposits (cobaltiferous pyrite present)

Sample	Location	Per centage		Intensity ratios of elements present									
		Co	Ni	Zn/Fe	Ag/Fe	Ti/Fe	Pb/Fe	As/Fe	Mn/Fe	Mg/Fe	Au/Fe	Sn/Fe	Mo/Fe
A-1	Merrill	0.035	.0114	3.20	3.22	-	.39	-	tr	2.83	-	-	tr
				3.62	3.75	-	.29	-	tr	2.92	-	-	tr
				5.25	7.20	-	.47	-	tr	3.16	-	-	tr
A-2	Merrill	.154	.0736	13.40	9.60	-	.80	.46	tr	s	-	-	-
				.93	6.50	-	.59	.46	tr	s	-	-	-
				-	18.70	-	.40	-	tr	s	-	-	-
A-15	Merrill	.285	.126	s	3.82	-	.24	-	.53	1.74	-	-	-
				s		-	.38	-	.39	1.23	-	-	-
				s		-	.46	-	.38	1.40	-	-	-
A-3	Campbell	.990	.0345	3.65	10.40	-	tr	-	-	s	-	-	-
				3.80	11.50	-	tr	-	-	s	-	-	-
				3.07	6.30	-	tr	-	-	s	2.64	-	-
A-5	Bear Bay	.00723	.0057	2.18	.78	4.05	-	-	.47	s	-	-	-
				1.47	.19	1.74	-	-	.74	s	-	-	?
				1.35	.80	3.82	-	-	.57	s	-	-	-
A-6	Bear Bay	.173	.0091	5.10	4.80	3.70	-	-	.42	s	-	-	—
				10.00	-	7.25	-	-	.75	s	-	-	-
				6.80	1.83	3.75	-	-	.60	s	-	-	-
A-7	Bear Bay	.920	.0165	.89	2.98	.35	-	-	1.03	s	-	tr	tr
				3.58	9.50	1.27	-	-	.36	s	-	tr	tr
				2.10	7.80	.69	-	-	.44	s	-	tr	tr
A-9	Eastman (Obalski option)	.142	.0580	2.50	2.67	tr	tr	-	.24	s	-	-	tr
				.80	3.50	tr	tr	-	.24	s	-	-	tr
				.95	2.10	tr	tr	-	.29	s	-	-	tr

Group 3 Copper deposits (cobaltiferous pyrite absent)

Sample	Location	Co	Ni	Zn/Fe	Ag/Fe	Ti/Fe	Pb/Fe	As/Fe	Mn/Fe	Mg/Fe	Au/Fe	Sn/Fe	Mo/Fe
A-4	Grandines	.015	.0234	.74	2.67	.24	-	-	.11	2.05	-	-	2.17
				2.03	4.00	.21	-	-	.12	1.98	-	-	3.80
				2.80	7.50	-	-	-	-	2.05	-	-	3.70
A-14	Opemiska Copper	.0254	.031	6.80	8.40	-	.23	.17	.40	s	-	-	-
				s	26.20	-	.54	-	-	2.34	-	-	-
				2.20	3.76	-	-	.20	.42	s	1.56	-	-

Group 4 Zinc deposit

Sample	Location	Co	Ni	Zn/Fe	Ag/Fe	Ti/Fe	Pb/Fe	As/Fe	Mn/Fe	Mg/Fe	Au/Fe	Sn/Fe	Mo/Fe
A-10	Tache Lake	.0273	.0374	5.80	4.65	28.20	.51	-	.48	s	-	-	-
				2.62	2.53	12.20	.60	-	.64	s	-	-	-
				10.00	1.52	13.70	.65	-	.57	s	-	-	-

Group 5 Gold deposits (arsenopyrite absent)

Sample	Location	Co	Ni	Zn/Fe	Ag/Fe	Ti/Fe	Pb/Fe	As/Fe	Mn/Fe	Mg/Fe	Au/Fe	Sn/Fe	Mo/Fe
A-12	Obalski	.0010	.00548	1.54	10.80	-	-	-	-	s82	-	-	-
				-	6.45	-	-	-	-	.64	-	-	-
				-	8.25	-	-	-	-	.54	-	-	-
A-13	Obalski	.062	.01	17.30	10.80	-	.30	-	-	.63	-	-	-
				10.50	30.40	-	.12	-	-	.20	-	-	-
				.80	4.90	-	.13	-	-	.36	-	-	-
A-8	Royran Central Group	.015	.0192	6.45	5.55	-	-	1.15	-	.26	tr	-	-
				2.88	4.40	-	-	.88	-	.21	tr	-	-
				6.95	12.20	-	-	1.43	-	.16	tr	-	-
A-11	Chibougamau Explorers	.077	.00496	1.78	4.50	-	-	tr	s	-	-	-	-
				2.24	3.86	-	-	-	tr	s	-	-	-
				1.04	3.22	-	-	-	.19	s	-	-	-

Spectroanalyst: Miss Nina Sine, Queen's University   SYMBOLS: tr: trace
s : strong
- : non detected

Table 101 - SPECTOGRAPHIC ANALYSES OF PYRRHOTITE
(from Allard, 1953, p. 118-120)

Group 2   Copper deposits (cobaltiferous pyrite present)

Sample	Location	Co	Ni	Zn/Fe	Ag/Fe	Ti/Fe	Pb/Fo	As/Fe	Mn/Fe	Mg/Fe	An/Fe	Sn/Fe	Mo/Fe
A-56	Merrill	.0705	.0182	s	2.92	-	.40		-	2.20		2.72	-
				1.60	.98	-	.32		-	1.43		-	-
				6.80	4.20	-	.13		-	1.18		-	-
A-67	Merrill	.0111	.019	4.00	3.00	tr	tr		—	1.37		-	-
				5.90	2.00	tr	tr		-	1.46		-	-
				3.20	1.59	tr	tr		-	1.20		-	-
A-64	Campbell	.133	.071	s	1.87	tr	.47		1.14	s		-	.48
				5.10	5.80	tr	.44		.53	s		-	tr
				2.48	1.50	tr	.17		.58	s		-	.37
A-65	Campbell	.133	.0139	9.40	3.33	-q	.13		-	s		-	-
				21.29	2.95	-	.26		-	s		●	-
				9.60	3.20	-	110		-	s		-	-
A-60	Bear Bay	.0718	.0428	.76	.40	2.94	-		-	-		-	-
				3.21	.43	2.78	-		-	-		-	-
				.87	.60	2.35	-		-	-		-	-
A-61	Bear Bay	.060	.0383	1.77	1.42	1.10	.27		.32	-		-	-
				1.92	-	1.43	.20		117	-		-	-
				1.00	1.60	1.15	-		.20	-		-	-
A-68	Eastman	.150	.0905	1.09	1.14	s	-		.29	s		—	-
				.369	.29	s	-		.47	s		-	.54
				.71	.70	s	-		.32	s		-	.57
A-66	Kokko Creek	.1730	.0483	9.29	-	-	-		-	-		-	-
				s	-	-	124		-	-		-	-
				19.30	-	-	-		-	-		-	-
A-69	Kokko Creek	.165	1272	tr	1.20	-	tr		tr	s		-	-
				1.95	1.35	-	tr		.22	s		-	-
				s	-	-	tr		tr	s		-	-
A-70	Copper Point	.187	.260	5.51	8.45	5.45	-		tr	s		-	-
				s	6.30	4.65	2.75		tr	s		2.75	-
				26.80	20.60	5.20	-		tr	s		-	-

Group 3   Copper deposits (cobaltiferous pyrite absent)

Sample	Location	Co	Ni	Zn/Fe	Ag/Fe	Ti/Fe	Pb/Fo	As/Fe	Mn/Fe	Mg/Fe	An/Fe	Sn/Fe	Mo/Fe
A-73	Openiska	.104	.072	s	s	tr	tr		1.24	s		tr	1.99
				vs	30.00	tr	tr		.64	s		-	-
				s	s	tr	tr		.96	s		2.20	2.05
A-74	Area	.100	.0125	s	s	1.98	tr		.63	vs		-	tr
				s	s	1.59	tr		.73	vs		-	tr
				s	s	2.18	tr		.90	vs		-	tr

Group 4   Zinc deposit

Sample	Location	Co	Ni	Zn/Fe	Ag/Fe	Ti/Fe	Pb/Fo	As/Fe	Mn/Fe	Mg/Fe	An/Fe	Sn/Fe	Mo/Fe
A-63	Tache Lake	.0213	.18	6.80	3.60	2.17	.21		.44	-		-	-
				5.80	3.96	4.05	.35		.36	-		-	-
				5.55	3.22	1.78	-		.32	-		-	-

Group 6   Gold deposit (arsenopyrite absent)

Sample	Location	Co	Ni	Zn/Fe	Ag/Fe	Ti/Fe	Pb/Fo	As/Fe	Mn/Fe	Mg/Fe	An/Fe	Sn/Fe	Mo/Fe
A-71	Obalski	.061	.0052	s	6.80	3.52	.45		.65	s		m	tr
				2.82	2.06	2.32	-		.66	s		m	tr
				9.80	2.38	3.80	.23		.69	s		-	tr
A-75	Chibougamau Explorers	n.d	.0315	s	5.70	tr	.45		.84	s		-	-
				s	11.80	tr	.85		.89	s		-	-
				s	4.90	tr	.44		.50	s		-	-

Spectroanalyst: Miss Nina Sine, Queen's University.

SYMBOLS: s : strong
tr: trace
- : not detected

Table 102

TRACE ELEMENT CONTENT OF CHIBOUGAMAU SULPHIDES - (FROM NICHOL, 1958, QUOTED AS TABLE 3 IN RAYCHAUDHURI, 1959)

TENEUR EN ELEMENTS TRACES DES SULFURES DE CHIBOUGAMAU - (TIRE DE NICHOL, 1958, TABLEAU 3 DE RAYCHAUDHURI, 1959)

	PYRITE (4)			PYRRHOTITE (20)			CHALCOPYRITE (9)		
Element	No. of Determinations	Range %	Mean %	No. of Determinations	Range %	Mean %	No. of Determinations	Range %	Mean %
Co	4	.031-.86	.3	20	.051-.19	.11	9	.0084-.145	.049
Ni	4	.0029-.019	.011	20	.012-.082	.032	9	.0036-.024	.012
Co:Ni	4	1.6-87.7	27.3	20	.78-9.2	3.43	9	.90-22.6	4.1
Ag	4	.00017-.0082	.0039	20	.00015-.0052	.00091	9	.0058-.0172	.012
Cr	2	.0011-.0012	.0012	1	.0015	.0015	5	.0009-.001	.001
Pb	2	.0018-.0021	.002	3	.0022-.074	.033	6	.0064-.098	.01
Sn	0	n.d.		1	.0023	.0023	2	.0013-.0019	.0016
Ti	4	.0165-.049	.03	17	.0057-.0098	.008	9	.0045-.012	.0089
Sc	1	.0051		20	Detection-.0083 limit	.0039	9	.0019-.0085	.0047

Table 103

MEAN CONCENTRATIONS OF TRACE ELEMENTS IN PYRRHOTITE (PO.) FROM CHIBOUGAMAU DEPOSITS - (FROM TABLE 10,
RAYCHAUDHURI, 1959)

CONCENTRATIONS MOYENNES DES ELEMENTS TRACES DANS LA PYRRHOTINE (PO.) DES GISEMENTS DE CHIBOUGAMAU -
(TIRE DU TABLEAU10), RAYCHAUDHURI, 1959)

Location	Number of Specimen	Ni %	Co %	Ag %	Mn %	Pb %	Ti %	V %	Bi (Int.)
Campbell Chibougamau-Merrill Island	84	.0997	.1008	.00111	.0038	.062	.0065	.0017	.153
Que. Chib. Goldfields	2	.0314	.1206	.01171	.006	nd	.0068	.0021	.15
Copper Rand Chib.	3	.642	.241	.00056	.0076	nd	.0061	.0024	nd
Cedar Bay	2	.0598	.0475	.0028	.0046	nd	.0066	.0018	nd
Chib. Kayrand	2	.0835	.1458	.00137	.0007	.0062	.0059	.0016	.09
Kokko Creek	5	.0692	.1498	.01019	.0009	nd	.005	.0012	.2238
Bateman Bay	2	.1554	.1518	.00208	.0128	.0292	.0127	.0027	nd
Henderson Ore Zone	10	.9966	.1229	.00082	.0072	nd	.0109	.0021	nd
Portage Island	3	.0547	.0436	.00026	.0523	.0017	.0271	.0059	nd
The District Average	113	.1774	.1132	.00169	.0061	.0485	.0075	.0018	.1675

nd means non-detection

(Spectrochemical analysis)

Table 104

AN CONCENTRATIONS OF TRACE ELEMENTS IN PYRRHOTITE (PO.), CHALCOPYRITE (CP.) AND PYRITE (PY.) FROM
CHIBOUGAMAU DEPOSITS - (FROM TABLE 8, RAYCHAUDHURI, 1959)

NCENTRATIONS MOYENNES DES ELEMENTS TRACES DANS LA PYRRHOTINE (FO.), CHALCOPYRITE (CP.) ET PYRITE (PY.)
DES GISEMENTS DE CHIBOUGAMAU - (TIRE DU TABLEAU 8, RAYCHAUDHURI, 1959)

Location	No. of sample	Ni%	Co %	Cu %	Zn %	As %	Mn %
Campbell Chibougamau -Merrill Island	Po (81)	.1134		.4587	.0322		
	Cp (54)	.0095			.2893		.0037
	Py (33)	.0095	.8914	.6033	.0438	.0115	
Quebec Chibougamau Goldfields	Po (1)	.0525		.7	.057		
	Cp (8)	.0044			.3594		.0105
	Py (2)	.033	.187	.705	.477	.0311	
Copper Rand	Po (2)			.03	.02		
	Cp (11)	.0176			.0873		.0052
	Py (1)	.1327	.086	.9	nd	.1465	
Cedar Bay	Po (0)						
	Cy (5)	.0013			.0623		.0026
	Fy (5)	.0562	.1393	.0707	nd	.0236	
Chibougamau Jaculet	Po (0)						
	Cp (7)	.0294			nd		.0138
	Fy (3)	.0732	.3323	1.3306	nd	.0251	
Average (Dore Lake)	Po (84)	.1126		.4505	.0323		
	Cp (86)	.011			.2755		.0053
	Py (44)	.0231	.7271	.6037	.0631	.096	

nd refers to non-detection
(Xray fluorescence analysis)

TABLE 105

ANALYSES OF MAGNETITE ASSOCIATED WITH COPPER ORES - CHIBOUGAMAU

ANALYSES DE MAGNETITE PROVENANT DE GISEMENTS DE CUIVRE - CHIBOUGAMAU

Deposit Gisement	Sample no. Echantillon no.	Fe total %	Magnetic Concentrate (-200 mesh) Concentré Magnétique " "				
			Wt % en poids	Fe %	TiO_2 %	V_2O_5 %	P_2O_5 %
Grandroy	71-197	52.8	63.0	70.26	0.04	0.02	0.01
Grandroy	72-167	36.7	32.66	71.8	n.d.	n.d.	0.03
Copper Cliff	72-186	44.8	51.8	72.6	n.d.	n.d.	0.29
Talbot-Queylus	71-198	39.6	45.2	70.09	0.01	0.01	0.01
Talbot-Queylus	JC-25-69	13.	83.0	69.9	0.01	0.02	<0.01

Analyses done in Laboratories of the Quebec D.N.R.

Analyses faites dans les Laboratoires du M.R.N. à Québec

1955. Since then, C.C.M. has developed and mined many orebodies in the district. In 1971, C.C.M. acquired the property of M.I.M.C (No. 19, Plate 1) and mined by open pit the low grade material left as a surface pillar and along the walls of the main orezone previously mined by underground methods.

The Campbell-Merrill orezones are parts of a major shear zone system trending N 70 W and dipping steeply to the south (Fig. 134). The overall width of the shear zone complex is about 900 feet (300 m.). The host rock is the anorthosite of the Dore Lake Complex. A swarm of dikes intruded the shear zone. The ore lenses are best developed in the vicinity of dikes. Many subparallel dikes and orezones can be found within the area. The anorthosite has often been called a breccia since it consists of angular plagioclase in a matrix of chlorite. It is not a breccia but a normal cumulus rock with the plagioclase forming the cumulus phase and the chlorite replacing an original intercumulus pyroxene. Malouf and Hinse (1957, p. 448) described the mineralization as follows:

"The main orebody at the Merrill Island property has a length of 800 feet and an average width of 36 feet. It is a sulphide replacement of the gold-copper type. The sulphide content is of the order of 50 per cent, of which 33 is pyrrhotite, 10 chalcopyrite, 5 pyrite, and 2 sphalerite, with a cobalt content of 2 pounds to the ton.
"Gold in the free state accompanies the sulphides. It is extremely fine, and is rarely seen. It seems to be localized in the west part of the ore zone, where the dykes are best developed. There are no known megascopic characteristics by which the gold-rich ore can be identified.
"The chalcopyrite may be either coarse or fine. The pyrrhotite is only slightly magnetic, and generally non-nickeliferous. The sphalerite is iron-rich, and varies in colour from black to reddish brown; it also varies greatly in amount, being most abundant in the central part of the orebody."
"Gangue minerals are quartz in irregular patches, chlorite, sericite, talc, and a series of pink to grey carbonates. Actinolite in rude rosettes is quite common, particularly where the pyrrhotite content is high. Siderite is found in places, mainly in the upper workings."
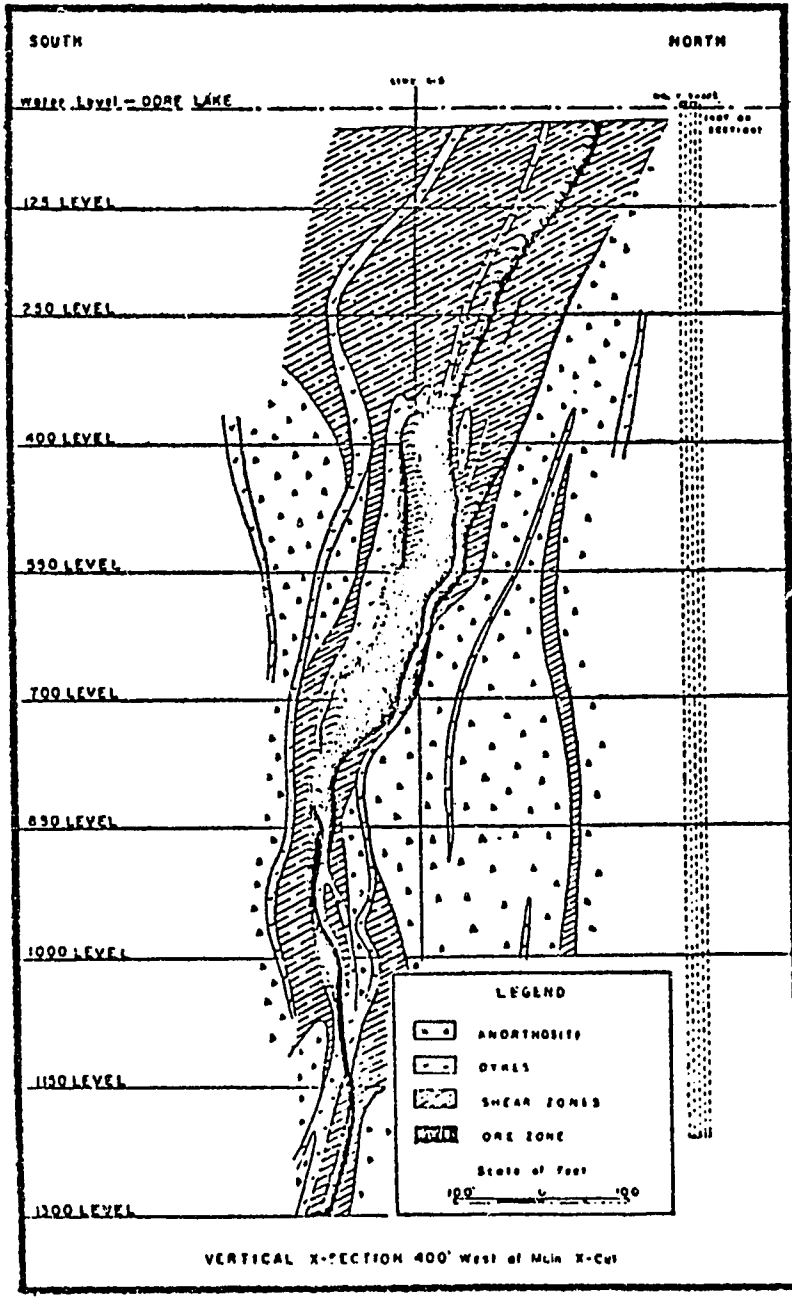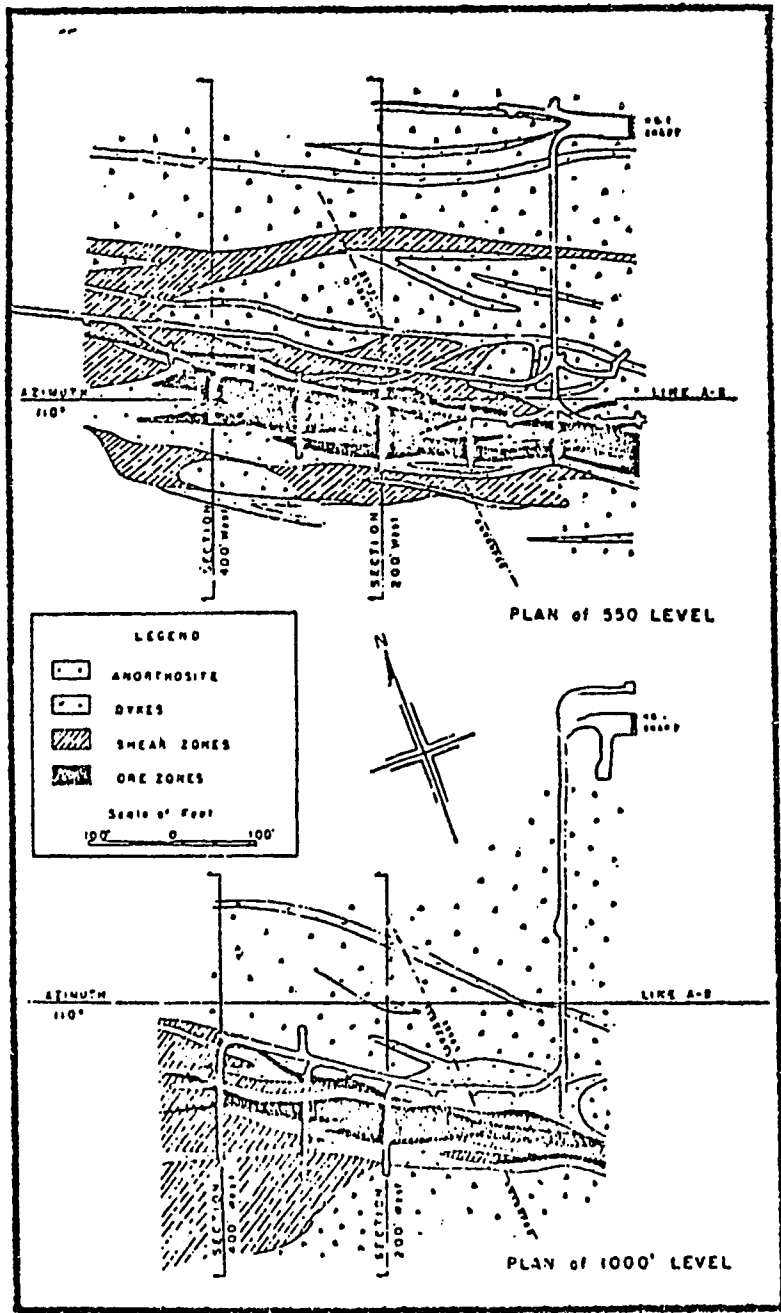
Fig. 134 (Left) Plan of the 550-level and 1000-level at Campbell Chibougamau Main mine.

(Right) Vertical cross section 400' west of main crosscut at Campbell Chibougamau Main mine.

Kokko Creek mine

The Kokko Creek property (No. 2, Plate 1) belonged to Merrill Island Mining Corporation who leased it to C.C.M. for 99 years in 1953. The original Kokko Creek discovery is probably the oldest in Chibougamau dating back to John Kokko in 1906-07. Trenching and stripping was done by Northern Investment and Mining Co. Campbell first opened a drift under Dore Lake at the 400-level to join the shaft at the Main mine with the Kokko Creek deposit. Mining was done from underground and later by open pit. Another drift at the 800-level was driven from the Main mine. We do not have the total production data since the company reports the ore milled from Kokko Creek with the Main mine division.

The early aspect of the deposit was well described by Mawdsley and Norman (1935) and will not be repeated here. The deposit is one of the simplest of the Dore Lake area. It is located in gabbroic meta-anorthosite of the Dore Lake Complex. The mineralized zone occurs in northwest-trending shear along a quartz feldspar porphyry dike. The dip is steep. The mineralized zone is 2000 feet (600 m.) long and reaches widths of 40 feet (12 m.). The sulfide minerals are chalcopyrite, pyrrhotite, pyrite, and very minor sphalerite. Chloritization, silicification, and carbonatization are the most common types of alteration.

Cedar Bay mine

The Cedar Bay mine showings (No. 4, Plate 1) were discovered on the shore of Dore Lake at the entrance to Cedar Bay in 1928. Consolidated Chibougamau Goldfields did extensive work in the period 1934-1936: a 552-foot shaft, 5000 feet of drifts and crosscuts and 34,000 feet of diamond drilling. Work was suspended in 1936 because of the low grade of gold, the low price of copper, and the lack of transportation facilities.

Campbell bought the property in the early fifties and started production in 1958. The shaft was deepened to the present 2450-level and 3,325,030 tons of ore have been mined so far, averaging 1.82% Cu and 0.087 oz. Au per ton.

The orebodies at Cedar Bay are in the gabbroic anorthosite of the Dore Lake Complex. The meta-anorthosite is sheared and altered. The Dore Lake fault cuts the southeastern corner of the property. The main shear zone strikes N 70 W and includes a swarm of dikes. Miller (1957, p. iii) describes the orebody as a set of

> "east-west veins in which pyrite predominates over chalcopyrite and which contain gold with some sphalerite and arsenopyrite.... and a northwest type which is parallel to the Cedar Bay shear and which contains chalcopyrite in excess of pyrite with minor gold and arsenopyrite, and rarely pyrrhotite."

The veins occurring in the northwest-trending shears are lenticular and the thickest parts occur along the junction with the east-west veins. The width and length of the veins is quite variable. Since Miller's work was limited to the top 500 feet, much more knowledge has been acquired but it is in company files and was not available to us at the time of writing. Exploration on the 19th and 20th level discovered a major orezone about 1500 feet (450 m.) north of the shaft, close to the boundary with Copper Cliff (Patino) and roughly parallel with the main zone.

Koene (1964) presented a detailed structural description of the Cedar Bay mine based on his field work at the mine. His petrographic description of the host rocks is essentially the same as in other mines and will not be repeated here.

Koene divided the mine into three distinct areas (Fig. 134A and 134C):

Western part

Central part

Eastern part (west of the Dore Lake shear).

He recognized four directions of shearing and faulting: S 70E; N 5 E; S 35 E; and N 55 E.

Koene described the structure and mineralization in the following terms:

> "Ore is commonly associated with the first three directions; the fourth represents the northeast trend of major cross faults, which are

only locally ore-bearing. Other directions of mineralization exist, but these have yielded rather insignificant tonnages of ore.

The Western Part is bounded on the northwest by a shear zone called the North shear. This shear strikes approximately N 70°W and dips south at 60 degrees. The dip steepens near the surface. All predominant directions of mineralization, alteration zones and associated dykes in the Western Part are close to east-west.

Another shear or fault zone in the Western Part is called the Shaft fault. (It passes through the old shaft sunk by previous operators.) This structure also has an east-west strike, but has a much flatter southerly dip, and, for this reason, joins the North shear at the elevation of the 375 level.

The South shear forms the boundary between the Western and the Central Part. It is approximately parallel to the direction of major regional faulting (N 55° E) and dips northwest at 35 degrees.

The Central Part lies between the South shear and the South cross fault. The latter, which is also parallel to the trend of the major regional faulting, has a net northwest dip of 70 degrees. A broad dyke structure, called the Main South dyke, forms the south limit of the mineralized area. This dyke strikes S 35° E and is parallel to the reference line "A B". The net dip between the surface and the 950 level is northeast at 70 degrees. The general direction of mineralization is also S 35°E. However, east-west strikes are important on and below the 500-ft. level, where they are associated with several extremely good stopes.

The Eastern Part is the area between the South cross fault and the Doré Lake shear. Both structures are sympathetic in strike; the Doré Lake shear, however, has a flatter (60 degree) dip to the northwest. The Main South dyke structure is also present in the Eastern Part, and a swarm of parallel dykes has been noted to the north. Both dyke systems are associated with ore. The dip of the Main South dyke has steepened to 80 degrees to the northeast, opposing the 65-degree southwest dip of the north dyke swarm.

The area east of Doré Lake shear is virtually unknown, because of lack of exploration, and will not be discussed here.

Faults and Shears - Relative Movement

(See Figure 134C)

The North shear is a very strong structure, probably representative of repeated movement. The last cycle induced a relative movement of the hanging wall to the west and down.

The Shaft fault shows indications of the hanging wall having been moved up and to the east. This supports evidence of a reverse movement on the South shear. Although there is no visual sign of horizontal movement on the South shear, there may have been a relative movement of the hanging wall to the northeast. Drag features on the footwall, where the Main vein terminates against this shear on the 250- and 375-ft. levels, are in agreement with this right-hand movement.

"Movement on the South cross fault is indicated by displacement on the Main South dyke structure. Features on the fault itself point toward normal faulting on the 375-, 500- and 800-ft. levels, and to reverse movement on the 950-ft. level. Movement on this fault must have been multiple, but it is believed that the foot-wall block went up relative to the hanging-wall block. In strong support of normal movement is the fact that the Main South dyke structure on the upper levels in the Eastern Part looks very much like the dyke in the Central Part at depth. Drilling below the developed levels in the Central Part indicated an increase in width and alteration of the dyke at depth. In particular, the presence of black sericite* and dark pseudophenocrysts of chlorite and sericite indicate a similarity of alteration. This may offer a possible basis for comparison. The width and degree of alter-ation of the dyke structure at the 1,250-ft. level in the Central Part is similar to that noted 300 feet below the surface in the Eastern Part. The amount of vertical movement, therefore, must exceed 950 feet.

Rotational movement on the South cross fault may be considered a possibility. The amount of offset on the Main South dyke decreases from 250 feet on the 500-ft. level to almost nil on the 800-ft. level, and, on the 950-ft. level, reverse movement is indicated. Figure 6 illustrates this rotational movement. The circle is drawn on the plane of the South cross fault. The position and width of the dyke are plotted for different horizons. The tenta-tive location of the axis of rotation is also indicated. After the initial rise of the footwall, or Eastern Part, was completed, rotation took place, moving the Central Part to the south and down. There is no evidence to show that rotation also affected the Eastern Part. Rotational forces may have offered the necessary stresses to create openings for the main vein systems, especially the Flat vein.

Another important fault is the 5-24 fault. It parallels the other cross structures and dips 35 degrees southeast. Reverse faulting, with an unknown horizontal component, is indicated.

The Doré Lake shear, as well as several minor cross structures, occurs in the Eastern Part of the area. Representing the series of major regional faults, the Doré Lake shear is the most prominent shear zone in the mine. Striking N 60°E and dipping 60 degrees northwest, this shear limits the known ore occurrences in the Eastern Part. Drag features on the Main South dyke suggest right-hand move-ment, and the hanging-wall contact shows reverse faulting. Several geologists have estimated the amount of offset to be in the order of miles rather than feet (Horscroft, 1958). In the Cedar Bay area, there is no evidence offering a solution to this question.

Vein Systems

There are several veins or vein systems in the mine area. They are indicated by name or number. Most veins are rather small and fairly narrow. No attempt will be·made here to analyze each one of them.

---

*Microscopic examination reveals an abundance of minute opaque impurities in the sericite, causing its black colour.
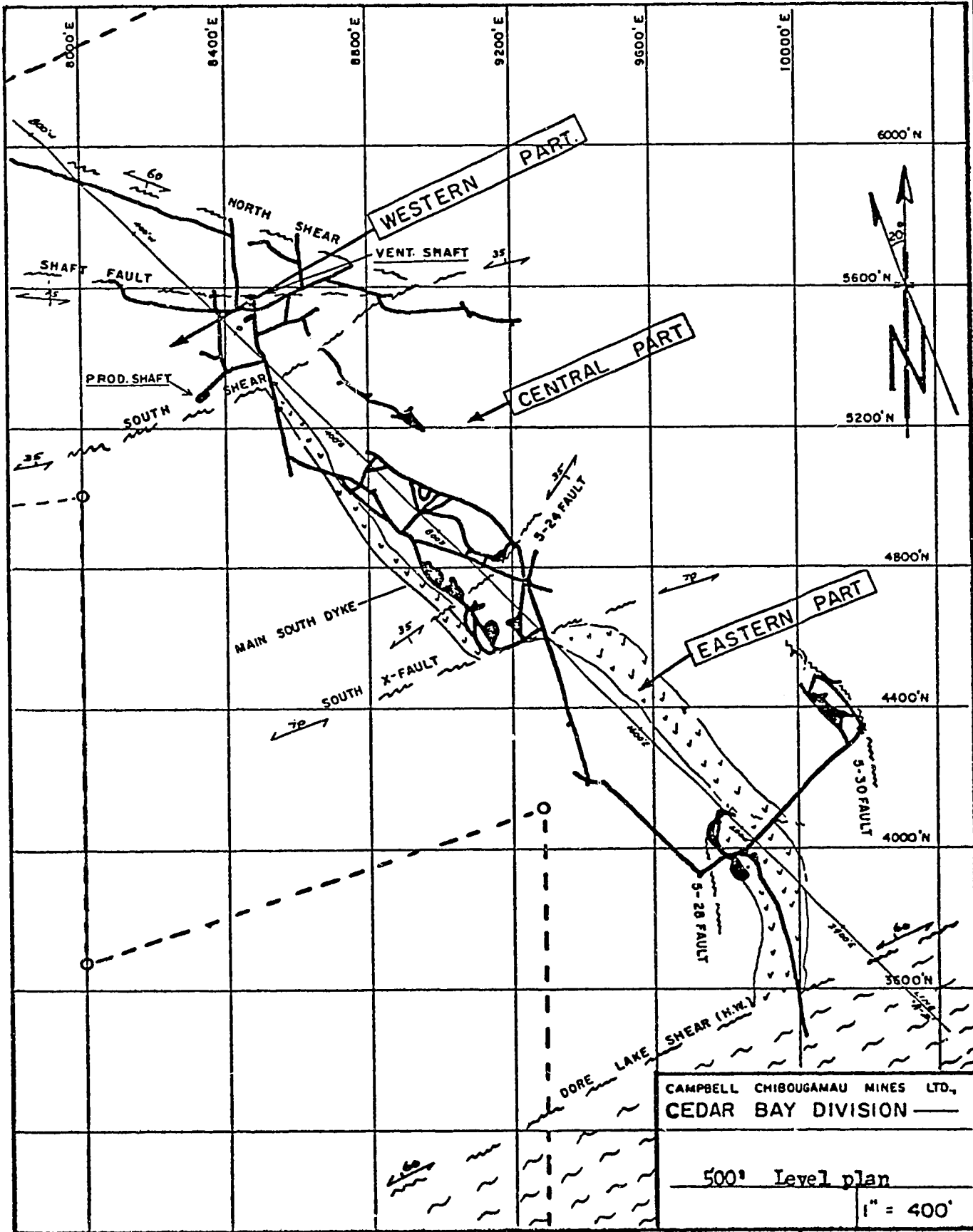
Fig. 134A.   500-level plan of the Cedar Bay mine showing the main structural units. (From Koene, 1964, fig. 4, p.1066).

TYPES OF MINERALIZATION
IN RELATION TO STRUCTURE

Fig. 134 B. Relationships between the types of mineralization and
the faults and vein systems at the Cedar Bay mine.
(from Koene, 1964, fig. 7, p. 1069)

Fig. 134C. Longitudinal section of the Cedar Bay mine along line A-B of fig. 134 B. (From Koene, 1964, fig.5, p. 1067)

Fig. 134D. Vein deformation due to cross faulting.

(From Koene, 1964, fig. 8, p.1070)

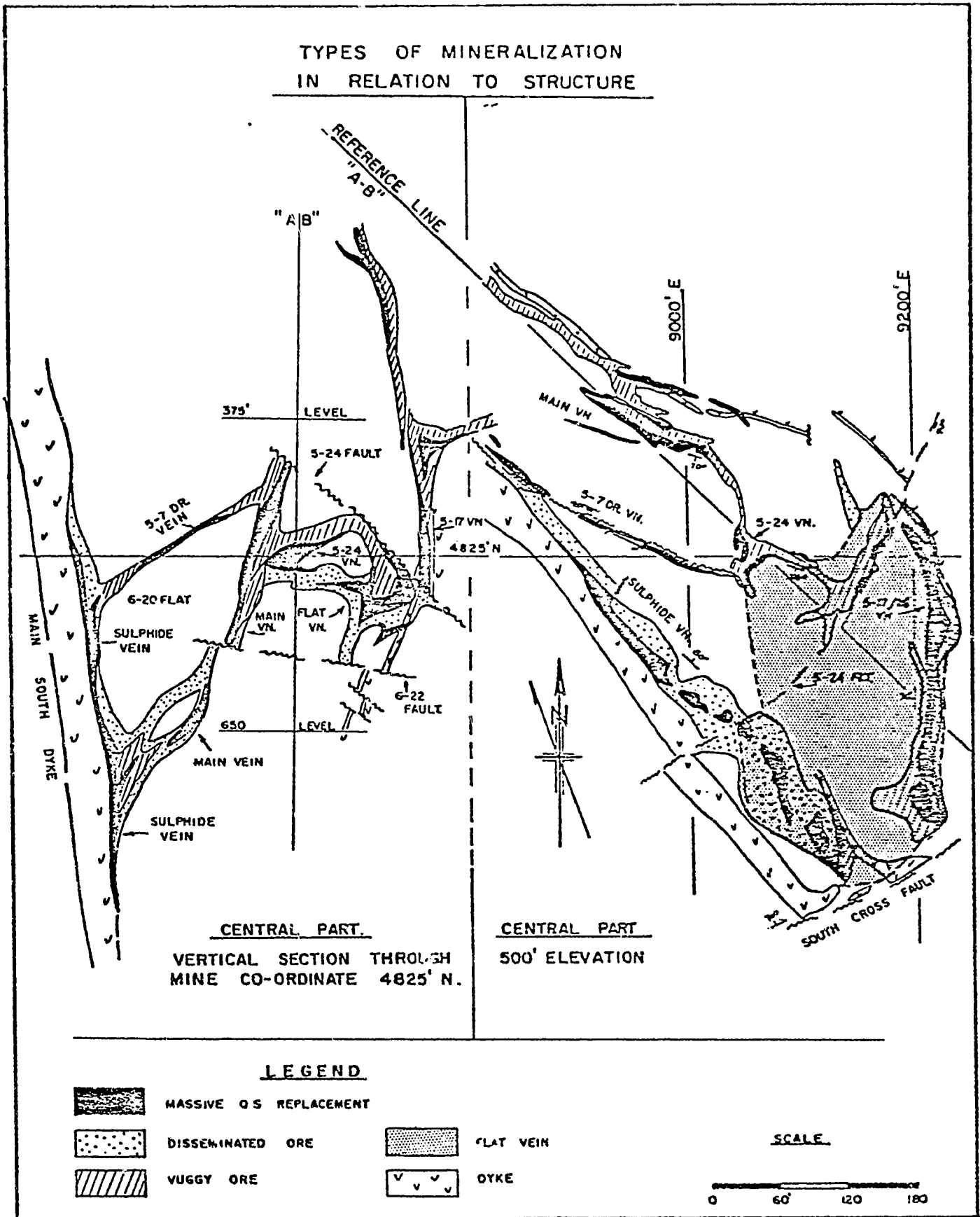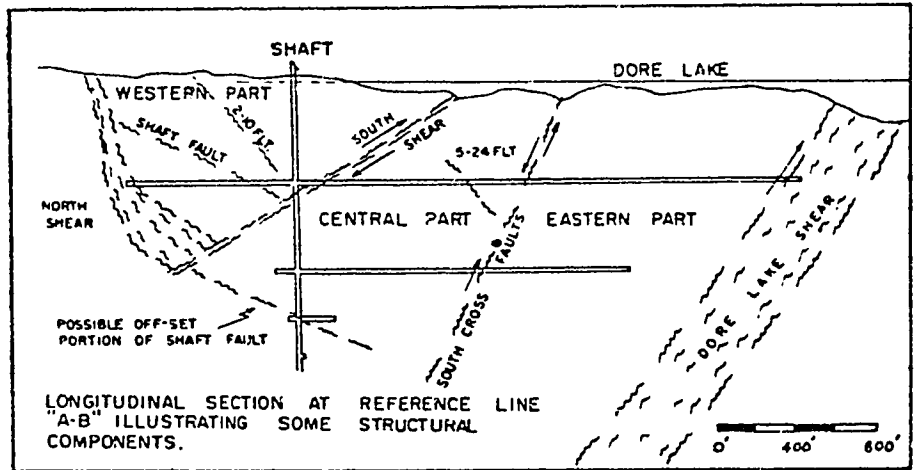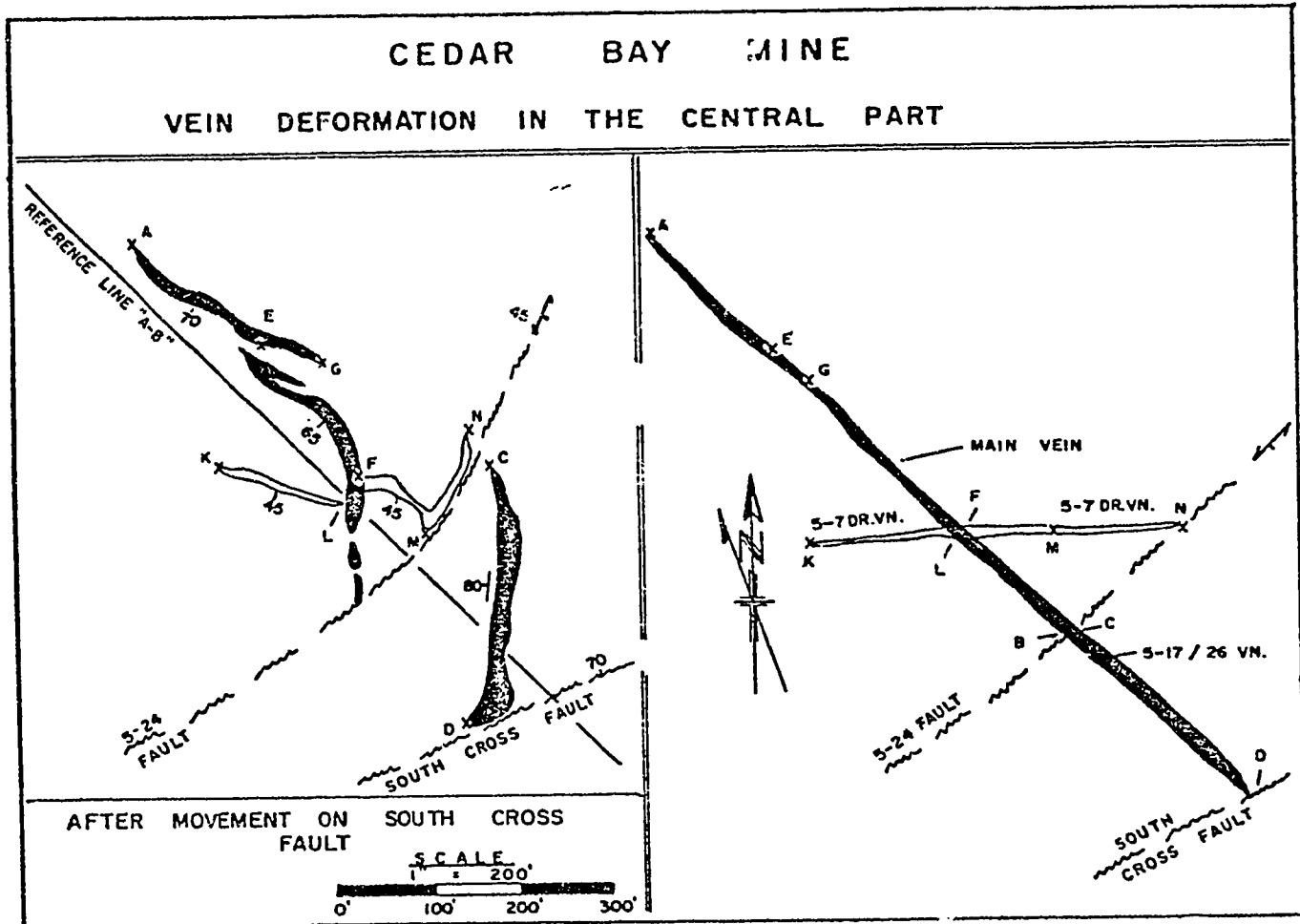However, a few very important veins will be discussed in a little more detail (Figure 134B).

The Sulphide Vein

The Sulphide vein occurs on the hanging wall of the South dyke structure in the Central Part. Consequently, the dip is the same as that of the dyke. It contains only scattered lenses of massive quartz-sulphide replacement. The bulk of the mineralization occurs as disseminations in an anorthosite that, in most places, is not too severely altered and may be fairly "fresh" looking.

The origin of the Sulphide vein has not been established. It seems, however, that the mineralization entered at a late stage. The main reasons for this conclusion are the following:

1. Absence of the minor late-stage faults that commonly occur in other vein systems.
2. This vein was apparently not affected by the movement on the South cross fault.

The Main Vein

The Main vein, which also occurs in the Central Part, has almost the same strike (N 75°W) as the Sulphide vein. Its dip opposes that of the Sulphide vein, thus causing both systems to join at deeper horizons (Figure 7).

The 5-17/26 Vein

The 5-17/26 vein has a north-south strike and comes close to joining the Sulphide vein where it terminates against the South cross fault. The dip is close to vertical. The writer considers this vein to be the offset extension of the Main vein.

The 5-7 Drive Vein

The 5-7 Drive vein, which has a relatively flat dip, joins the Sulphide vein to the Main vein. This vein strikes S 70°E to where it is offset along the Main vein. The offset portion is dragged along the 5-24 fault and assumes a N 55°E strike.

The Flat Vein

The Flat vein is quite unique. Nowhere, to the writer's knowledge, is there an occurrence of the same magnitude and importance in the Chibougamau camp. The vein, which occurs just below the 500-ft. level, is composed of almost horizontal *en echelon* lenses of ore. The lenses are separated by low-grade disseminated material or waste. The mining of ore and waste together results in the recovery of an average thickness of 26 feet of good-grade ore. The Flat vein intersects the Sulphide vein, the Main vein, the 5-7 Drive vein and the 5-17/26 vein, and extends 300 feet north of the South cross fault (Figure 134B).

Vein Structure as a Direct Result of Faulting

The writer suggests that slicing of the anorthosite batholith by the major northeast-trending faults caused severe compressive stresses in the hanging-wall block of the Doré Lake shear. These stresses

were released by reverse movement on the Doré Lake shear, by the creation of sympathetic cross faults and by the deformation of existing formations. This may have resulted in an actual reduction in the length of existing vein systems in certain areas.

The Main vein was offset along the 5-24 fault (Figure 134D). The displaced portion, now called the 5-17/26 vein, merged with the Flat vein to join the Sulphide vein farther to the south and west (see also Figure 134B, section and plan). The Main vein west of the 5-24 fault also experienced the compressive forces. This resulted in an actual reduction of 30 linear feet in the arc between E and F (Figure 134D). It also seems that the vein was sheared off at G, and that the area east of G moved some 50 feet to the west to E.

The difference between the present length of the 5-17/26 vein and the available room along strike of the Main vein between the 5-24 fault and the South cross fault is 90 feet. From this evidence, an actual reduction of 170 feet in length is suggested.

During this process of compression, the 5-7 Drive vein was offset along the Main vein for a distance of 30 feet. The compression also caused the arc between F and M, where a reduction of 30 feet resulted. Where this vein collapsed against the 5-24 fault (MN), it piled up along it for a distance of 110 feet, indicating a total reduction of 140 feet. This figure roughly corresponds with the total reduction suggested for the Main vein if the difference in strike is taken into consideration.

Dykes as Structural Elements

The dykes in the Cedar Bay area behave, in general, like the faults and shears in the respective parts of the area. On the basis of age, the dykes can be grouped into three categories.

1.-*Oldest dykes:* These were introduced before the period of severe alteration and tectonic unrest. They exhibit very intense alteration near shear zones, but, as a rule, cannot be traced through the shears because they have been affected by movement.

2.-*Younger dykes:* These were introduced in the existing shears, and have been subject to intense alteration. It may be almost impossible to differentiate between altered anorthosite and an altered dyke.

3.-*Youngest dykes:* These are distinguished from the older dykes because they can be traced through areas of shearing and faulting. The degree of alteration is much less. Normally, they are intensely silicified and of a porphyritic nature.

The Main South dyke belongs essentially to the second group. It is known to contain injections of late dyke material. As it forms the footwall for the Sulphide vein, its control of this vein is obvious. In the Eastern Part, where relatively deeper horizons are available for inspection, ore is deposited in this and in other dykes. No parallel can be drawn, however, as these easterly mineralized sections represent brecciated areas that may have acted as ore traps for invading fluids. Drag along the Doré Lake shear is believed to have caused this intense brecciation and fracturing.

Mineralization of the Cedar Bay Mine

Any theory dealing with ore deposition in the Cedar Bay area must account for the following facts:

1.-The mine workings expose a series of (interrelated) vein systems.
2.-Mineralization occurs within a body of altered (chloritic) anorthosite, and locally within altered or even fresh dykes.
3.-Sulphide deposition post-dates the secondary alteration.
4.-Mineral emplacement is not only temperature-dependent, but is also closely related to structural conditions.
5.-The sulphides were probably deposited in three cycles.
6.-The existing mineralized veins were reopened to allow further mineral deposition. Figure 134C illustrates the deposition of ore in the Central Part.

On the left a vertical section through mine coordinate 4825 N, looking north, corresponds with the traverse on the right-hand side, where the Central Part is shown in plan at the 500-ft. level.

The mineralization differs in the three producing divisions of the mine. The Western Part, which is important for its gold content, lacks appreciable copper. The ore has a predominant brecciated quartz-carbonate gangue, with a locally high content of fine-grained pyrite. Chalcopyrite is present only in a few local areas, and seems to occur in pockets and lenses. Less common are veins with a predominant chlorite gangue, derived from chloritic anorthosite, and a few lenses of what may be an altered basic dyke. The grade in such areas is normally rather marginal, but it is not uncommon to find excellent grades in isolated lenses. One outstandingly good copper occurrence was present in the Discovery No. 2 vein. This vein extended from surface down to the 500-ft. level, where it terminated against the South shear and the Shaft fault.

The Central Part is characterized by a mixture of massive quartz-sulphide replacements, disseminated sulphides in relatively fresh anorthosite or chloritic anorthosite, and vuggy sulphides (Figure 134B). Vuggy sulphides are estimated to make up at least 40 per cent of the ore in the Central Part. The "vugs" have contributed, in large measure, to the mine's production, because of the excellent grade encountered in this type of ore.

Vuggy ores occur predominantly in the Main vein and in the 5-17/26 Vein system, but they also occur where flat-dipping branches separate from the Sulphide Vein system. Control by faults and/or slips is obvious. Cores and rims of massive quartz-sulphide replacement occur in all systems. Halos of disseminated ore are common. In the case of the Sulphide vein, disseminations make up an important portion of the ore.

In general, it seems that the quartz-sulphide replacements were deposited first. In some instances, massive barren pyrite-carbonate mixtures were introduced. This agrees with the observations of several workers in various areas. Mineralizing fluids were probably introduced after the initial faulting along the South cross fault took place, as there is no evidence of post-mineralization movement in this area.

During or after rotation on the cross fault, a second cycle of mineralization deposited sulphides in dilated zones along the earlier-formed veins. Repeated injections, perhaps accompanied or preceded by resolution of deposited carbonates, filled the spaces created by the reopening of the veins. This second cycle of mineralization consisted chiefly of pyrite crystallizing in large euhedral to subhedral crystals. Movement took place after deposition of the second cycle, as this ore is commonly slickensided. In some instances, the pyrite cubes were dragged along vein walls, resulting in bent or curved crystals. Senses of movement, as observed on oriented specimens of ore, are in agreement with evidence elsewhere.

A third cycle of mineralization is represented by a chalcopyrite coating on the second-generation pyrite crystals. Also the spaces between the large pyrite cubes are commonly filled with a fine sugary chalcopyrite dust. This has resulted in some rich copper ore. In addition, the second-cycle pyrite often contains numerous tiny vein-lets of chalcopyrite and quartz. This may enhance the grade.

Veins that are thought to contain only first-generation pyrite are particularly common in the Western Part. There, they only make ore where sufficient gold is associated with the sulphide. Second- and third-generation ores must have formed in open fissures or similar loose structures. They exhibit little evidence of replacement, and show only a limited ability to invade gouge-filled zones in or along veins. All evidence points toward an epithermal type of deposit.

The mineralization in the Eastern Part does not bear any resemblance to that in the other mine areas. The most obvious difference is the common presence of pyrrhotite. Locally, pyrrhotite makes up 95 per cent of the sulphides, and there is practically no chalcopyrite. The host rock is commonly a brecciated and altered dyke with lenses of incompletely digested anorthosite in various stages of alteration. Ore-bearing fluids invaded the dyke structure after drag movement on the Doré Lake shear had caused the intense shattering and brecciation. Sulphides were precipitated at elevated temperatures, resulting in the less favourable sulphide ratio of the mineral assemblage.

Alteration

It has been pointed out earlier in this paper that emerald green chloritic anorthosite is the most common host rock for the Cedar Bay ore. It is a very fine-grained rock, with a massive, sugary texture, and may be impregnated with fine quartz. It forms halos around the orebodies and, in this way, presents a target in the search for ore. Alteration halos also emphasize structure and are commonly present in barren areas. In several cases, alteration supplied the proof for speculation on structure."

Henderson-Portage mines

The Henderson "A" orebody (C.C.M.) (No. 5, Plate 1) was discovered in 1956 as a result of drilling an airborne electromagnetic anomaly by Chibougamau Mining and Smelting under the waters of Chibougamau Lake. The Henderson "B" and "C" orebodies (No. 6, Plate 1) were discovered in 1957 following a re-examination of the cores of the "A" orebody. The Portage deposit (No. 16, Plate 1) is on the northeastern extension of the Henderson structure. The Henderson I shaft is 794 feet deep and the Henderson II is 2372 feet deep.

Vollo (1959) studied the cores of the initial drilling program for his M.S. thesis. He did not have access to underground openings. Guha and his coworkers and students have been studying the oxidized zone and the "B" zone for many years. Guha and Koo (1975) recently published a short note on their

findings. Guha's personal communication on the oxidized zone can be found in Chapter 1 under geomorphology.

Dompierre (1972) gives the following essential descriptive notes for the Henderson mines. The orebodies are in the AZ of the D.L.C. The ore occurs in a main N 45 E shear zone dipping ± 45° to the southeast and in subsidiary steep fractures striking roughly east-west (Figs. 135, 136, and 137).

"Two types of orebodies, characterized by different structural contexts, ore and gangue mineralogical suites, and metal contents, may be distinguished at Henderson, namely the "B" and "G" type and the "A" and "D" type.

"B" and "G" Ore Zones

The "B" and "G" Zones account for the bulk of the production to-date and the bulk of the present reserves. Excluding the secondary copper minerals in the oxidized zone treated separately below, the ore may be described as fine chalcopyrite disseminations, stringers, and blebs, associated with pyrite and pyrrhotite, occurring in the Main Shear or in close proximity to the Main Shear. In the "G" Zone pyrite is the most abundant sulphide, averaging approximately 50%. The pyrite content gradually diminishes to a minimum of 5% to the Portage boundary, as we go from the "G" to the "B" Zone and along the "B" Zone. The mineralized zone is generally wider than the ore, and the ore limits are determined by assay cut-offs. There is no obvious relationship between the amount of sulphides and the copper content. This may be explained by the paragenesis which shows that chalcopyrite came later and filled fractures in pyrite and pyrrhotite.

The most common gangue minerals are, by order of importance, sericite, ferrian chlorite, ankerite, quartz, calcite, and minor chloritoid. The sericite alteration is pervasive; it overlaps both footwall and hangingwall of the Main Shear. The ferrian chlorite, characterized by a deep green colour, is usually closely associated with the ore. The ankerite and calcite are found either as fine irregular stringers in a matrix of sericite-chlorite or as massive quartz-calcite-ankerite veins. Fine chloritoid crystals are quite common in the Shear but can usually be determined with certainty only under the microscope, except in the "G" Zone and at the west end of the "B" Zone, where coarse chloritoid crystals may be readily identified in hand specimens. Magnetite is locally found in the Shear, but there was not enough magnetite to influence the readings obtained by a ground magnetic survey over the orebodies.

The ore generally occurs as lens-shaped irregularly disseminated mineralized zones, and in more massive sulphide bands within the disseminated zones. The strike and dip of the mineralized zones are generally parallel to the schistosity. The ore zones and the schistosity often are slightly at variance with the trend of the Shear, striking more to the north and dipping steeper than the Shear, resulting in an echelon pattern for the ore lenses both in plan and

in section. Ore lenses rake to the east at around 30° but the overall rake of the "B" and "G" mineralized zones has not been established yet.

"A" and "D" Ore Zones

The best copper grade at Henderson has been produced by stopes in the "A" and "D" Zones. Typical ore in these zones may be described as quartz-calcite veins with irregular chalcopyrite blebs, accompanied by pyrrhotite, pyrite and local sphalerite, filling subsidiary fractures outside of the Main Shear. In the stronger fractures part of the ore occurs as dissemination in the walls in lightly sheared sericite-chlorite zones of alteration.

The "A" Zone is located in the footwall of the Main Shear. It is a curvilinear fracture zone both in plan and sections; as we move west from the Main Shear the strike gradually changes in a counter clock-wise direction and the dip gets progressively flatter. The dip also gets progressively flatter at depth, giving the "A" Zone a trough shape with an axis plunging eastwards at around 30°. Below the 650 level, the mineralization continues, but the grade of the ore indicated diminishes gradually at depth along the axis of the concave fracture. The exploration of the "A" Zone has yet to be pursued below 700 feet, and beyond the trough axis along the south segment of the fracture.

The "D" Zone ore occurs in sinuous composite fractures in both the hangingwall and the footwall of the Main Shear. The ore is lenticular with a vertical rake."

Unfortunately, we have no recent data on the geology of the Portage mine.

The production figures are in Table 94. Duquette and Mathieu (1964) quote an

unpublished summary report prepared for the C.I.M.M.:

"Mineralization occurs in a zone of intense alteration, varying in horizontal width from a minimum of 75 feet to more than 700 feet in places which is bounded by a footwall and hangingwall of normal meta-anorthosite. The alteration consists of an outer light green, sericite-chlorite-carbonate zone in which all the original feldspar outlines have been destroyed and a more extreme altered core of black chlorite alteration. Contacts are generally gradational between the type of alteration and also between the fresh and altered bands. This zone has an average strike of N.45°E. and dip 45°E.
"The main structural feature of the deposit is a strong shear zone with the same average dip and strike as the band of alteration previously discussed, and varying in horizontal width from 40 to 200 feet. Generally this shear occurs in the more intense alteration where it has a core of quartz-carbonate but it does enter the outer zone of altered anorthosite in places.
"Mineralization occurs as (1) replacements in the shear zone and in quartz-carbonate zones, (2) as fault-filling in the strike faults with fragments of quartz black chlorite and altered anorthosite, (3) as disseminations and as fracture-filling in the shattered gabbro zone (east end of zone). Sulphides consist of chalcopyrite, pyrite, pyrrhotite and minor sphalerite and arseno-pyrite. Appreciable gold values occur throughout the ore body and
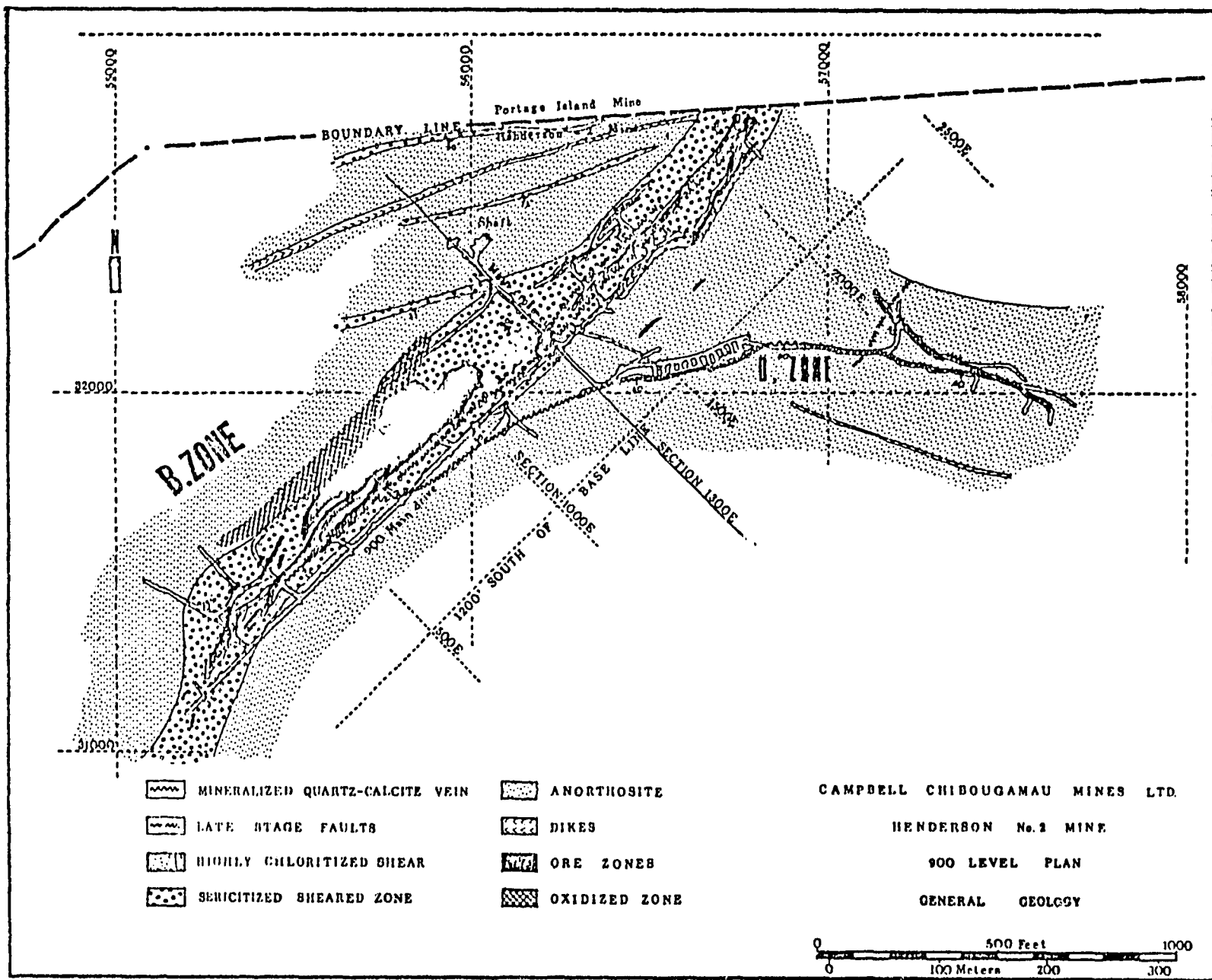
(from Dompierre, 1972)

Fig. 135. Plan of the 900-level at Henderson No. 2 mine.

HENDERSON - 2

Lac Chibougamau   A,B

---9200 E L.

:?? Level

?? Level

4?0 Level

5?5 Level   ---8700 E L.

650 Level

7?0 Level

775 Level

PLAN 900 LEVEL

900 Level

1025 Level   ---8200 E L.

1150 Level

1300 Level

1450 Level

---7700 E L.

1625 Level

Ore pass

Waste pass

1800 Level

1975 Level

---7200 E L.

	MINERALIZED QUARTZ-CALCITE VEIN		ANORTHOSITE	CAMPBELL CHIBOUGAMAU MINES LTD.
	LATE STAGE FAULTS		DIKES	HENDERSON No.2 MINE
	SERICITIZED SHEARED ZONE		ORE ZONES	1300 EAST SECTION
			OXIDIZED ZONE	GENERAL GEOLOGY

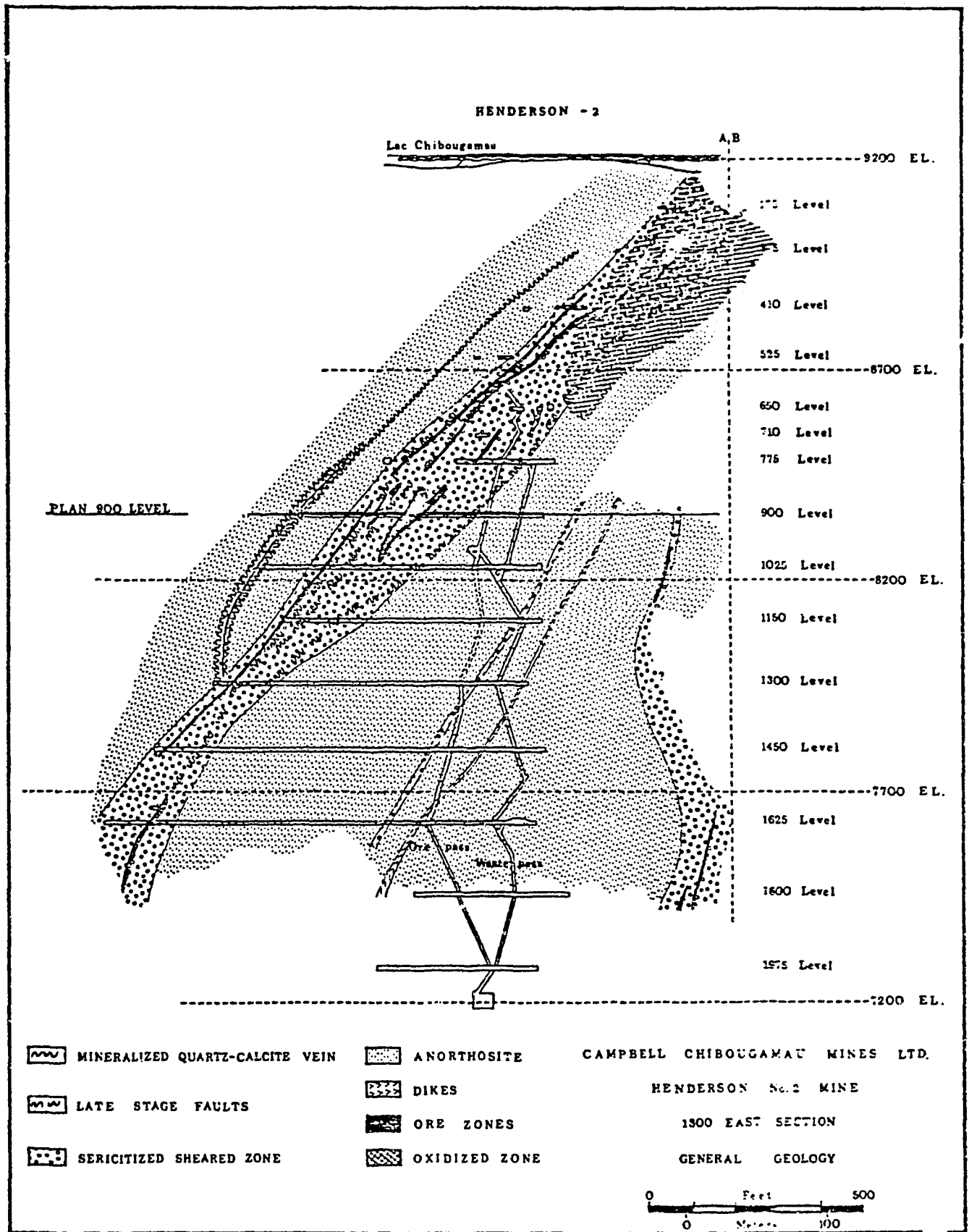0   Feet   500

0   Meters   100

Fig. 136. Cross section 1300-East at the Henderson No. 2 mine.
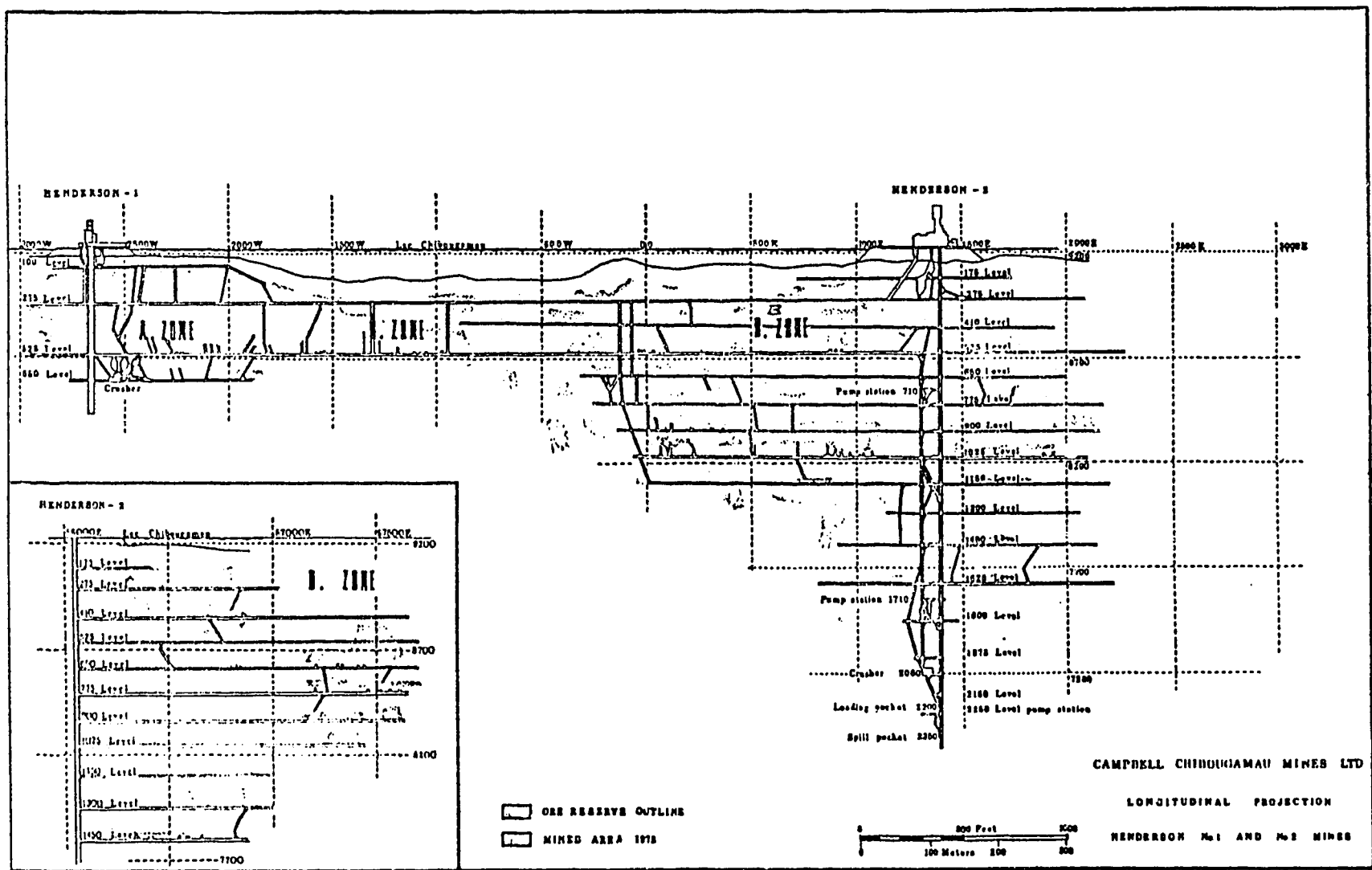
(from Dompierre, 1972)

Fig. 137. Longitudinal section at the Henderson No. 1 & No. 2 mines.
(from Dompierre, 1972)

are found in association with pyrite and gold tellurides, free
gold and with silver in a gold-silver alley."

Patino Mining Corporation mines

The corporate history of Patino Mining Corporation is nearly as complex as
the geology of its properties. The following chronological development is taken
from a number of sources and is not guaranteed for accuracy:

1906-1907 work on a showing on the shore of Dore Lake at a place called
Machin Point under the supervision of Captain H. C. Machin.

1910 Captain H. S. Machin is granted a mining concession on Block "A".

1928 additional trenching by Prospectors Airwa. Ltd.

1948 Grand Chibougamau Mines Ltd. drilled water claims on strike
with the Machin Point showing.

1950 Royrand Goldfields Ltd. acquired water claims from Grand
Chibougamau Mines Ltd.

1952 Royrand obtained title to mining concession Block "A".

1955 New Royrand Copper Mines Ltd. acquired the assets of Royrand
Goldfields Ltd.

1956 Copper Rand Chibougamau Mines Ltd. acquired the assets of Copper
Cliff Consolidated Mining Corporation and New Royrand Copper
Mines Ltd.

1956 Patino of Canada helped finance Copper Rand Chibougamau Mines Ltd.

1957-58-59 Shafts are sunk by Copper Cliff (No. 12, Plate 1) on the west
shore of Cedar Bay and on the northern tip of Merrill Island,
(No. 14, Plate 1) by Copper Rand (No. 11, Plate 1) at Machin
Point and on Gouin Peninsula (No. 4, the main mining shaft), by
Jaculet (No. 15, Plate 1) on the north shore of Dore Lake, and
by Portage (No. 16, Plate 1) on the shore of Portage Island
north of the Henderson orebodies.

1959 (December) Start of operations at the 1500-ton mill of Copper Rand.

1960   Copper Rand Chibougamau Mines Ltd. takes over the assets of

Chibougamau Jaculet and Portage Island (Quebec) Mines Ltd.

1962 (June) Patino of Canada becomes Patino Corporation Ltd.

1962 (October) Patino Corporation is recapitalized and the name is changed

to Patino Mining Corporation.

1971   reorganization of the corporation and the assets of Patino

Mining Corporation are transferred to Patino N. V. with head

office in the Netherlands.

The production of Patino mines is detailed in Table 94. The mill can

handle 2400 tons per day.

Copper Rand Main mine

Patel (1972) describes the Copper Rand Main mine as it was known at the

time in the following terms:

"Mine Geology

The ore deposits of the Copper Rand mine lie within a shear
zone dipping steeply southward and trending N 70°W. The shear
zone is 1200-1400 feet wide and over 5000 feet long. The shear
zone rocks were originally a part of the anorthosite transition
zone and gabbro sequence (upper part of the anorthosite zone).
The alteration consists of a development of sericite, zoisite,
carbonate, chlorite, chloritoid and the complete breakdown or
masking of the original rock texture. The most dominant alter-
ation is the sericite-carbonate facies. Iron increased towards
the ore.
"Fe-rich chlorite is intimately associated with the ore
zones. Chloritoid is concentrated in the hanging wall of the ore
lenses. The shear zone is truncated to the west by the Dore Lake
fault which is located along the axis of Dore Lake (see Figs. 138
and 139).

"Shear Zone

The northwesterly trending Copper Rand shear zone is the
dominant structural feature of the mine area. It contains two
major sets of faults trending northwest and northeast. Two minor
sets strike north-south and east-west. A number of northwesterly
major shear zones are a combination of faults and shearing, and
seem to have a movement of up to 4,000 feet.
A set of these faults may be responsible for the formation of
three ore zones within the main shear zone, namely Main Eaton Bay
zone, South Eaton Bay zone, and Hanging Wall zone. Northwesterly

faults dip south, northeasterly faults dip moderately to steeply
to the northwest. The north-south fault set dips west and the
east-west set dips south.

"Mineralization

It is more or less accepted by the majority of the geologists
working in this camp that the ore bodies of the Chibougamau camp
are of hydrothermal origin. The hydrothermal solutions are
believed to originate from the granite plug under Chibougamau
Lake. The associated minerals observed are apatite, peninite,
allanite, magnetite, molybdenite, and uraninite (one observation
only).

"All the major ore bodies in the Dore Lake camp are situated
in close proximity to the Dore Lake fault. The relation of this
fault to the mineralization is not very clearly understood.

"Mineralization is known to occur along the entire length of
the shear zone, with the important mineralized lenses concentrated
towards the footwall and hanging wall where dikes have been
emplaced.

"Sulphide minerals found in order of abundance are chalco-
pyrite, pyrite, pyrrhotite, sphalerite, and minor galena.
Magnetite occurs in the Eaton Bay area and in the Machin Zone.
In the Machin Zone the sulphide occurs as blebs, pockets and
lenses distributed in siderite with chlorite, quartz, calcite,
and chloritoid. The Eaton Bay Zone - the most economical -
consists of massive sulphides up to 25' wide with occasionally 1
foot magnetite vein. Minor siderite is present. The South Eaton
Bay Zone is the longest ore zone opened, over 1400 feet long and
at one place reaching a width of up to 60 feet. This zone shows
a variety of secondary minerals resulting from pre-pleistocene
lateritic type of alteration. e.g. chalcocite, native copper,
cuperite, tennorite, malachite and azurite.

"The Hanging Wall zone is in the hanging wall of a basic
dike with a dip of 55-60°. Chalcopyrite is the dominant mineral
in the Footwall while pyrrhotite is dominant in the Hanging Wall
lens. Sphalerite is also noted.

"The dikes are a major feature of the Copper Rand shear zone.

"The dikes occur along the footwall and hanging wall of the
shear zone. The main concentration of dikes is in the footwall
of the shear zone. They range from a few inches to over 60 feet
in width and were continuous over long distances prior to the
movements on the faults.

"They are sinuous and branching with dips roughly paralleling
the dip of the shear zone.

"The distinct types of dikes found are, basic dike, quartz
porphyry and quartz feldspar porphyry dike.

"Basic Dike

Named for its dark green to black colour, rather than on its
composition. This dike is the most abundant and commonly is
dense, massive, and fine-grained. It may be weakly sheared.
Chilled contacts are commonly visible, and in the majority of
cases are lighter coloured due to a relatively larger amount of
carbonate.

"The relatively fresh basic dike is composed of chlorite,
calcite, sericite, and quartz, with magnetite, ilmenite and
leucoxene and minor apatite as accessory minerals.

"Where the dike is highly sideritized with varying amount of sericite, calcite, chloritoid, and quartz, or highly carbonatized to a light grey to brownish grey rock, the dike is called an intermediate dike. This dike has gradational contacts with basic dikes.

"Quartz Porphyry Dike

This type of dike mostly occurs on the south side of the ore zone. It is yellowish to buff coloured with about 10% spherical to oval-shaped quartz eyes. Quartz eyes vary in size from "fine-grained" to one quarter inch in diameter. Calcite and sericite with quartz form the matrix. It also contains fine grained chloritoid and subordinate chlorite banded with sericite. Minor leucoxene occurs throughout.

"Quartz Feldspar Porphyry Dike

This type of dike is olive green to grey in colour and fine to medium grained with minute to one quarter inch-oval phenocrysts. The phenocrysts are in shades of green and brown or grey to white. This type of dike is relatively unsheared or weakly sheared. The phenocrysts are composed of a very fine to medium-grained mosaic of carbonate and chlorite with minor calcite.

"The matrix is similarly composed of granular calcite and chlorite with disseminated finely banded leucoxene forming flow textures around the phenocrysts. Feldspar prophyry dikes are younger than the ore and other dikes. The ore was emplaced before the quartz porphyry and the quartz feldspar dikes and possibly after or with basic dikes. Basic dikes in places are highly chloritized and show contacts mineralized."

Copper Cliff mine

The Copper Cliff mine of Patino (No. 12, Plate 1) formerly belonged to Copper Cliff Consolidated Mining Corp. who did extensive diamond drilling in 1955 and 1956 under the waters of Cedar Bay and discovered an ore shoot of sufficient economic importance to warrant sinking a 5-compartment shaft. An old showing on the shore on strike with the main lens had been discovered in 1930 by Consolidated Mining and Smelting Co. of Canada (Mawdsley and Norman, 1935, p. 83). Copper Cliff was taken over in 1956 by Copper Rand. Mining took place at various times until 1975 when the mine was closed. Production is found in Table 94.

The property is underlain by metagabbroic anorthosite of the D.L.C. cut by a northwest-trending shear zone intruded by a swarm of altered greenstone dikes, grey feldspar porphyry dikes, and fine grained quartz diorite dikes. The shears consist in paragonite, sericite, siderite, and chloritoid. The ore forms
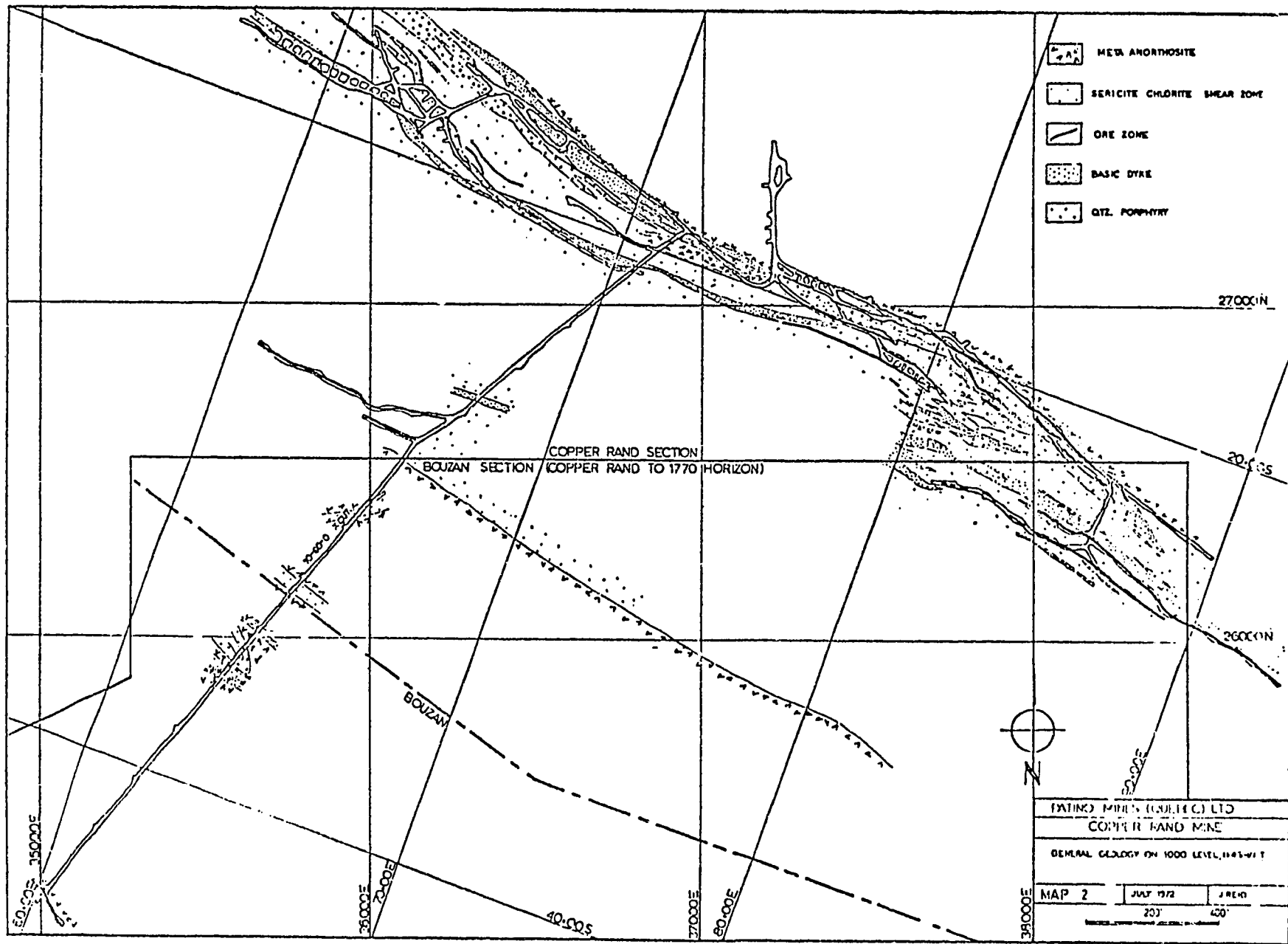
Fig. 138. Sketch map of the geology on the 1000-level at the Copper Rand Main mine.

Fig. 139. Cross section 6600 East at the Copper Rand Main mine.
(from Patel, 1972)

lenses within the shears at the contacts with dikes. Locally, chalcopyrite has replaced altered dike rocks but in general the best sulfide mineralization is found adjacent to the dikes.

Patino drove a drift to the "North Siderite Zone" and mined out a lens of ore which had been called Quebec Smelting Siderite Zone in the early days of the camp. This zone is in the gabbro of the D.L.C., very close to the upper contact with the Lac Sauvage Iron Formation. The zone has a northwesterly direction and the mineralization is similar to that of Copper Cliff but is much richer in siderite and chloritoid reflecting a host rock much richer in Fe.

Jaculet mine

The property known as the Jaculet mine of Patino Mining formerly belonged to Jaculet Mines Ltd., reorganized in 1955 to New Jaculet Mines Ltd. and to Chibougamau Jaculet Mines Ltd. in 1956. Surface drilling under Dore Lake aimed at northwest trending shears in the gabbroic anorthosite of the D.L.C. discovered good grade mineralization in 1956. A shaft was sunk to 650 feet. Production started in 1960. The shaft was deepened from 725 to 1340 feet in 1964. Copper Rand acquired control of the company and both were absorbed into Patino Mining in 1960.

The Jaculet mine is located in the upper part of the D.L.C., close to the contact with the Lac Sauvage Iron Formation. Orebody No. 1 is in a shear zone in anorthosite, under the waters of Dore Lake, striking N 70 W and dipping nearly vertical. The orebody consists of chalcopyrite and minor pyrite in an altered sheared gabbroic anorthosite. Orebody No. 2 has a strike length of 2200 feet and is located within the Lac Sauvage Iron Formation. It is made up of siderite, pyrite, sericite, chloritoid, and erratic lenses rich in chalco-pyrite. It strikes N 80 E and dips 75° south.

A long drift at the 900-level joins the Jaculet shaft with the Bateman Bay shaft.

Bateman Bay mine

The property of Bateman Bay Mining Co. (No. 17) lies under the waters of Dore Lake at the eastern limit of McKenzie Township. The area is underlain by a band of volcanics of the Gilman Formation running along the north side of Gouin Peninsula and separated by a fault from anorthosite of the D.L.C. The southern portion of the property is in Commencement Bay of Chibougamau Lake and is underlain by the upper part of the D.L.C. where it is in contact with the narrow band of volcanics (Plate 1). The rocks are anorthositic metagabbro and serpentinized metaperidotite and metapyroxenite.

The orezones are in northwest-trending shear zones in anorthosite on the Dore Lake side of the property. Bateman Bay Mining Co. did extensive drilling from the ice from 1956 to 1957 and found a series of en echelon mineralized zones. The company reported (Northern Miner Canadian Mines Handbook) 129,000 feet of diamond drilling indicating 565,000 tons averaging 1.8% Cu, 0.115 oz Au and 0.47 oz Ag per ton in the "A" zone and 183,200 tons averaging 1.65% Cu, 0.048 oz Au, and 0.187 oz Ag per ton in the "C" zone. In 1957, a shaft was sunk to 280 feet and it was deepened to 526 feet in 1959. In 1964, a joint hole was drilled by Patino on the property boundary. In 1967, a 9-year lease was given to Patino Mining who opened a connecting drift on the 900-level between the Jaculet shaft and the Bateman shaft. The property is now dormant.

Patino-Lemoine copper-zinc deposit

Lemoine Mines Ltd. was incorporated in 1973 to develop a copper-zinc orebody discovered in Lemoine Township by Patino Mines Ltd. The deposit was found following an INPUT airborne survey done by the Q.D.N.R. in the summer of 1972. Drilling has indicated over 600,000 tons averaging 4.5% Cu and 10.8% Zn, 0.138 oz Au, and 2.70 oz Ag per ton. The lens as outlined by diamond drilling is 700 feet (210 m.) long and about 10 feet (3 m.) thick and in a series of porphyritic rhyolites and felsic pyroclastics at the top of the Waconichi

Formation. The deposit is the first volcanogenic stratiform and stratabound deposit in the Chibougamau area. A shaft has been completed to a depth of 1020 feet (306 m.). Milling operations started in the Fall of 1975.

The metavolcanics strike about N 60 E and dip steeply southeastward, forming a band one to two miles (1.6-3.2 kms) wide across the eastern part of Lemoine Township (Oliveira, 1973) and continuing in Rinfret Township as far as the Grenville Front. The Dore Lake Complex has intruded the volcanics. Irregular lenses of Upper Border Zone and Sodagranophyre Zone form the upper part of the D.L.C.

The felsic volcanics constitute a sequence about 3000 feet thick (900 m.). The orebody lies within the uppermost 450 feet (135 m.) of the sequence. Donahue is studying the deposit for his M.S. thesis and more detailed petrology and geochemistry will be available shortly.

Donahue divides the felsic volcanics in the following units:

a. Felsic crystal tuffs. Large blue quartz grains are in a matrix of fine-grained quartz, mica, chlorite, and albite.

b. Fine-grained felsic crystal tuffs, similar to those above but much finer grained, and with a smaller proportion of crystal clasts.

c. Porphyritic sodarhyolite flows containing bluish quartz phenocrysts with characteristic resorption features and plagioclase phenocrysts in a fine-grained matrix derived from devitrification of volcanic glass. The rhyolite is the most important rock type of the area.

d. Metagabbro sills and dikes.

This sequence of felsic rocks is overlain by the Gilman Formation mafic volcanic assemblage consisting of chlorite-rich tuffs, metabasalts, and pillowed metabasalts. They are poorly exposed and known only from a limited number of exposures (Oliveira, 1973) and from the cores of a few drill holes.

The orezone lies on a dome-shaped body of rhyolite at the contact with felsic crystal tuffs. In some places, the orebody lies on fresh meta-rhyolite and in

others on intensely chloritized lapilli f rich in disseminated sulfides and
allanite. The hangingwall contact of the orebody is sharply defined. Banding
is poorly developed in the orebody. Discontinuous thin lenses of pyrite
interlayered with sphalerite have been reported locally. Rounded to angular
ore-in-ore clasts, colloform pyrite, and skeletal sulfide intergrowths have
been reported by Donahue.

The wall rocks and the orezones have been affected by two periods of
metamorphism, the Kenoran metamorphism (greenschist facies) and the Grenville
metamorphism (biotite grade). Three deformation episodes have been noted,
the older two associated with Kenoran metamorphism and the other with Grenville
metamorphism. More data will be available soon when Donahue completes his
study of the deposit and surrounding rocks.

Chib Kayrand mine

The Kayrand orezone (No. 20, Plate 1) was discovered by geophysical surveys
in 1950. Kayrand Ltd. became Kayrand Mining and Development Co. Ltd. in 1944
and Chib-Kayrand Copper Mines Ltd. in 1955. Over 80,000 feet of drilling was
done in the period 1950-1960 and 125,000 tons averaging better than 2% Cu were
outlined. The property was optioned by Merrill Island Mining Corp. who drove
a production drift from the 625- and 950-level. After Campbell acquired the
Merrill Island ground, a drift was driven from the Campbell Main mine shaft
at the 1025-level.

Graham (1956, p. 29) describes the occurrence. A few quotes give the
essential geology. The property is underlain by anorthosite of the D.L.C. and
tonalitic rocks of the C.P. A dike of gabbro crosses the shear zone in the
anorthosite and terminates 1500 feet to the southeast. The gabbro has a general
st-ike of N 35 W and dips ± 50° northeast. The true thickness varies from 30
to 90 feet (9 to 27 m.). Graham stated:

"The copper-bearing zone.....lies along a shear in anorthosite
breccia. It has been traced southeast from the north boundary

for a length of 1600 feet.....A grey fine-grained quartz diorite
dike intrudes the shear zone.....The copper-bearing shear zone,
the gabbro, and the fine-grained quartz diorite dike have been
cut into two nearly equal segments by a fault striking N 70 E.....
The sulfides mineralization occurs in and adjacent to the dike,
and extends a short distance laterally beyond the shear zone
into the Anorthosite breccia.....In the surface exposure the
sulfides are on the hangingwall side of the fine-grained dike.
An envelope of alteration of the type previousl: described as being
a favorable indicator of sulfide mineralization surrounds the
sulfide zone. It is variable in width, and is locally absent.
The alteration extends laterally beyond the sulfides and has a
maximum width of 50 feet, as determined from a few type sections.
The sulfide mineralization consists of chalcopyrite, pyrrhotite,
pyrite, and a little sphalerite. Small amounts of gold and
silver are associated with the sulfides."

Quebec Chibougamau mine

The Quebec Chibougamau property (No. 3, Plate 1) lies on the north shore

of Dore Lake between the Kokko Creek and Cedar Bay mines. The property is

underlain by meta-anorthosite in the southern part changing northward to

gabbroic anorthosite and rocks of the Layered Zone. A number of northwest-

trending shear zones and mineralized lenses have been discovered on the

property. Drilling was done in 1950-51 and 1955. A shaft was sunk in 1956 and

in 1962, Patino Mining agreed to mine and mill ore from the Quebec Chibougamau

mine. From 1963 to 1967, Patino milled 199,151 tons averaging 1.7% Cu. In

1970, Campbell Chibougamau Mines acquired the property and put in a decline

under the surface pillar of the main zone. Campbell also mined by open cut

the surface pillar of the "H" zone.

Duquette and Mathieu (1964) described the property in the following terms

(p. 92):

"Three mineralized zones are known - the main or A zone, the
B, and the H zones. All three are zones of schistose and silicified
anorthosite within the main anorthosite mass. "A" zone.... is a
shear zone of schistose anorthosite measuring up to 100 feet in
width, striking N.70°W. to N.75°W. and dipping 60° southwest. The
anorthosite of the shear zone is silicified and chloritized and
intruded by fine-to medium-grained grey dikes measuring up to 10
feet in width. Diamond drilling of this zone has outlined a
mineralized shoot 350 feet long and up to 50 feet in width. The
mineralization is associated specially with dike sections within

the schistose anorthosite. It consists of pyrite, chalcopyrite, and a little pyrrhotite and sphalerite in a quartz chlorite gangue. This mineralized shoot in the A zone is estimated to contain, between surface and the 750-foot level, 811,000 tons of mineral having an average tenor of 0.107 ounce of gold per ton, 0.85 ounce of silver per ton, and 1.17 per cent copper.

"It is to be noted that in May 1962, Copper Rand (now Patino Mining) reached an agreement whereby it will mine and mill ore on the property of Que. Chib. Goldfields. Mining started early in 1963 using a 3 compartment shaft to a depth of 847 feet with levels established at 200, 350, 650 and 800 feet.

"In 1963, 51,243 tons of ore were extracted, grading 2.01% Cu. and 0.083 ounce of gold per ton."

Obalski mine

The property known as the Obalski mine (No. 8, Plate 1) is located in Obalski Township, 4000 feet (1200 m.) east of the Chibougamau-St. Félicien highway and 50 feet (150 m.) south of the old road to the Campbell mine. The property goes back to the Chibougamau Mining Company who worked in the area in 1928 and 1929 and its successor the Obalski Mining Corporation which was reorganized into Obalski Ltd. in 1955 and into United Obalski Mining Co. in 1961.

In 1946, a shaft was sunk to 277 feet on the D vein with 1179 feet of lateral development on two levels. Drilling was done in the period 1953-55 and 1955-56. Ninety thousand feet of drilling indicated 236,000 tons in four zones including 207,000 tons of 2.4% Cu and 30,000 tons of 3.5% Cu. In 1963, the property was leased to Merrill Island Mining Corporation. Mining was started in 1965 at a rate of 500 tons per day and operations ceased in 1966. In 1972, Campbell opened a decline 940 feet under the G vein and mined some of the ore close to surface.

The Obalski property straddles the contact between the volcanics and the Dore Lake Complex. The UBZ, SZ, LZ, and AZ, are all well represented around the property. The copper-gold mineralization is in quartz veins injected along shears trending west-northwest. The shears are much narrower and have much less alteration in the dense fine-grained chlorite-rich granophyre and UBZ rocks than in the anorthosite of the other mines in the Dore Lake area.

An extensive detailed description is given by Mawdsley and Norman (1935, p. 70-74). Graham (1956, p. 34) describes in detail the D, A, and C veins. The following is a brief quote from Mawdsley and Norman:

> "Greenstone dykes cut all the above rock types and the quartz and sulphide mineralization present is later than them all.
> "Shattering is not uncommon in the rock masses on these claims, but wide shear zones are not in evidence. Narrow, persistent shears are present and have played a prominent part in the localization of carbonate, quartz, and sulphide-bearing mineralization. In the main showings the shearing follows three general directions, namely: north 83 degrees east, south 65 to 70 degrees east, and south 40 degrees east, the shearing in this direction being probably the youngest. Some of the directions of shearing parallel the strikes of narrow greenstone dykes, and all the shearing has been influenced in whole or in part by contacts between dissimilar rock masses or between different phases of the same type of rock. The sheared and mineralized zones are generally sinuous and in places branch. Shearings along two directions exist in places along a single zone."

Graham also stated (p. 34):

"D vein

> The D vein strikes approximately east and dips 75° south to vertical. It has been traced for 1,200 feet and is 6 inches to 1 foot wide. It lies along a shear in fine-grained gabbro. The shear joins the fault described above 400 feet west of the vein.
> "The D vein consists of milky quartz well mineralized with chalcopyrite and pyrite. In polished section some pyrrhotite and a little sphalerite were found associated with the chalcopyrite. Locally there are vugs in the vein. As the shear zone becomes weaker at the east and west ends of the exposed parts of the vein, the vein becomes narrower and more lens-like. This vein has been explored to a depth of 600 feet by diamond drilling.
> "According to company assay plans, the part of the D vein exposed at the surface is 528 feet long and contains 1.09 ounces of gold per ton over a width of 15.9 inches or 0.50 ounce over a width of 8.4 inches. A part of this is a high-grade shoot which has an average tenor of 1.78 ounces per ton over a length of 110 feet and a width of 20 inches. Eleven diamond drill holes, drilled over a length of 1200 feet to intersect the vein at depths ranging from 110 to 608 feet, showed gold tenors up to 0.04 ounces per ton for core lengths of 0.6 to 3.2 feet."

(p. 35):

"A vein

> The A vein lies about 300 feet southeast of the D vein along a discontinuous shear zone which has been traced for a length of 1,600 feet.
> "Other discontinuous quartz veins are found along this zone for a further 800 feet to the southeast; their gold tenor is low.

A vein strikes N.70°W. and dips close to vertical down to the 200-foot horizon. Below this it dips 70° southwest. Diamond drilling has established the continuity of the vein to a vertical depth of 360 feet. The southeast part of the vein lies in quartz gabbro and quartz diorite. According to assay plans of the trenching, the gold tenor is lower in this part of the vein.

"The A vein consists of milky quartz which in places contains vugs. The largest vug noted is 3 feet by 3 feet by 2 feet. It is lined with quartz crystals which are cut by fractures filled with massive chalcopyrite. The vein has a maximum width of 7 feet, but is ordinarily between 1 and 3 feet wide. Narrow stringers from this vein branch off into the wall rock. The vein is mineralized with pyrite and chalcopyrite as lenses and stringers up to 3 inches wide. According to company assay plans, the average tenor of this vein at the surface is 0.28 ounce of gold per ton and 2.76 per cent copper for a length of 256 feet and a width of 50 inches. This vein was explored by 9 diamond drill holes over a length of 600 feet. Intersections at vertical depths of 82 to 360 feet were encouraging, the best three being 22.4 feet at 0.09 ounce of gold per ton and 2.00 per cent copper, 17.9 feet at 0.07 ounce of gold per ton and 3.17 per cent copper and 6.8 feet at 0.226 ounce of gold per ton and 6.16 per cent copper. Further drilling on this vein was carried out in 1951 by Campbell Chibougamau Mines Ltd. No important mineralization was reported.

"C Vein

The C vein lies along a moderate shear about 5 feet wide which strikes N.65°W. and dips 60° southwest to vertical. West of the vein the shear curves towards the west and merges with the shear containing the A vein. The C vein has been traced for a length of 885 feet on the surface and explored to a depth of 340 feet by diamond drilling. It has a maximum width of 3 feet.

"The C vein consists of well fractured milky quartz. It is somewhat lens-like; also small veinlets of quartz branch into the country rock. Pyrite occurs abundantly along fractures in the quartz. Only a little chalcopyrite occurs in this vein."

(p. 36)

"The C vein has been trenched and sampled for a length of 540 feet. Four high-grade shoots are reported to have the following gold content at the surface:

No. 1 shoot (at east end) - 0.78 ounce of gold per ton for a length of 75 feet and a width of 40.1 inches.

No. 2 shoot (55 feet west of No. 1) - 0.49 ounce of gold per ton for a length of 40 feet and a width of 18.7 inches.

No. 3 shoot (205 feet west of No. 2) - 0.78 ounce of gold per ton for a length of 45 feet and a width of 12.3 inches.

No. 4 shoot (70 feet west of No. 3) - 0.51 ounce of gold per ton for a length of 25 feet and a width of 21.2 inches.

The above tenors are for the vein only. The wall rock is mineralized but the gold content is low. No. 3 and No. 4 shoots are separated by drift and there is a possibility that they are two parts of a single continuous shoot."

"The vein has been explored to a depth of 340 feet by 4 diamond drill holes spaced over a length of 600 feet. The best intersection reported is 1.80 ounces of gold per ton for a core length of 4.0 feet.

"The company reports 150,000 tons with an average tenor of 0.404 ounce of gold per ton and 1.18 per cent copper for the A, C and D veins. Several other veins occur on the property, but their gold tenor is reported to be low.

"A vein 1 to 3 feet wide, striking a few degrees west of north, was discovered on the east edge of a hill 6,000 feet west of the north-south centre line and 2,900 feet south of the north boundary of the township. It is mineralized with pyrite and chalcopyrite. A sample taken by the writer was found to contain 0.017 ounce of gold per ton and 1.04 per cent copper.

"In the fine-grained gabbro 2,300 feet south and 400 feet west of the Obalski shaft a sulphide zone of the replacement type has been explored by trenching. Its site is indicated by an anomaly on the electrical survey that was carried out on the property. The sulphides consist of chalcopyrite, pyrrhotite, and pyrite as veinlets up to 1.4 inch wide and as disseminations in the gabbro. Quartz veinlets are also present in this zone and magnetite is common in the gabbro. A sample taken from this zone by the writer contained 0.002 ounce of gold per ton, 1.84 per cent copper and a trace of nickel."

(p. 37)

"A narrow, sparsely mineralized quartz vein outcrops on the southwest shore of Cachée bay. It strikes N.35°W. and dips 80° northeast. A sample taken by the writer assayed 0.028 ounce of gold per ton."

Norbeau mine

The Norbeau mine (No. 22, Plate 1) gold vein was discovered in 1930 by Gilligan and Mahoney on the south shore of Bourbeau Lake. Noranda (hence the named Norbeau from Noranda-Bourbeau) optioned the property in 1933 and formed Norbeau Minets Ltd. Fifteen thousand feet of drilling was done and a grey quartz vein with minor sulfides (pyrrhotite, pyrite, arsenopyrite, chalcopyrite) and free gold was proved to a depth of 500 feet over a strike length of 800 feet. The vein strikes N 30 E and dips 50-55° southeast, averaging 4.5 feet in width carrying an average value of 0.35 ounce of gold per ton.

Norbeau Mines Ltd. became Norbeau Mines (Quebec) Ltd. in 1939. Work on the property resumed in 1959. Geophysical work was completed followed by 27,154

feet of drilling, 1,018 feet of underground drifting and 1,938 feet of under-
ground drilling. The indicated tonnage was 359,520 tons of ore averaging 0.4C9
ounce of gold per ton.

In 1964, a shaft was sunk to 850 feet and deepened in 1965 to 1,573 feet
in order to open 10 working levels. The mill started in September 1964 at a
rate of 200 tons per day and increased to 250 tons per day in 1965. The
company produced 419,020 tons of ore with a value of $7,070,205 (including
subsidies from the EGMAA). The company was taken over in 1970 by Lake Shore
Mines Ltd.

The deposit lies within the upper part of the Bourbeau Sill which consists
of a quartz-bearing chlorite and amphibole rich differentiate lying above the
leucogabbro. The sill has been described in detail in previous papers.

Bruneau mine

The Bruneau mine (No. 23, Plate 1) was found by Snowdon Mining and
Exploration Ltd. who optioned the property in 1960 to Bruneau Mines Lt. The
latter did drilling on geophysical anomalies and optioned the property in 1962
to Rosario Exploration, a wholly-owned subsidiary of New York Honduras Rosario
Mining Co. (now Rosario Resources Corporation). Rosario did additional
drilling and opened two adits, No. 1 about 200 feet above the bottom of the
hill and No. 2 about 200 feet below the No. 1 adit. Drifting and crosscutting
was done and some ore was mined starting in February 1966. The ore was
shipped to the Merrill Island Mining Corp. mill. In 1967, when the Merrill
mill was reserved for treatment of the ICON mine ore, arrangements were made to
truck the ore from Bruneau to the Copper Rand mill. We do not have information
on the exact quantities and grades produced, but it appears that less than
100,000 tons were mined averaging around 1.75% Cu per ton. In March 1970, the
company was reorganized into Bruneau Mining Corporation. Additional drilling

was done from 1970 to 1972. An option on the property was held by Muscocho

Explorations who, in turn, optioned it to Texas Gulf in 1975.

The Bruneau property is underlain by volcanic rocks of the Gilman Formation

(upper part). It consists of pillowed metabasalts interbedded with minor

pyroclastics and intruded by gabbro sills. The rocks have an east-west trend

and are steeply dipping. A number of quartz feldspar porphyry dikes cut the

whole assemblage in a north-south direction. Their concentration (see Smith

and Allard's maps, 1960) indicate the possibility of a volcanic subcenter in

the vicinity of the property. The mineralization is limited to fractures in

the competent gabbro sills and in a band of felsic pyroclastics bordered by

gabbro sills. Mineralization consists of chalcopyrite, pyrite, pyrrhotite,

minor magnetite. Quartz, calcite, epidote, and axinite are abundant gangue

minerals. Detailed work in progress should add much information on the

geology of this property, the only known orezone in the volcanics around

Dore Lake.

Tache Lake Mines Ltd. (now Canadian Merrill Ltd.) deposit at Berrigan Lake

This orezone (No. 21, Plate 1) was discovered by D. Berrigan and F. Larone

in 1929 about one mile northeast of Antoinette Lake. It was optioned to

Consolidated Mining and Smelting Co. who did trenching, stripping, and some

diamond drilling. From 1950 to 1960, more than 95 drill holes were drilled for

a total of 66,000 feet. In 1968, an additional 2,145 feet were drilled. In

1969, an adit was driven from the north side of a steep hill by Canadian

Merrill Ltd. who had optioned the property. Reserves reported by company

officials are 381,285 tons averaging 7.49% Zn, 0.181 ounce Au, and 0.82 ounce

of Ag per ton.

The property lies very close to the axis of the Chibougamau syncline. It

is underlain by volcaniclastics of the Blondeau formation and ultramafic of

the Roberge and Ventures Sill. Smith (1960) gives the following account:

(p. 37)

"Two sulphide zones have been located just north of Berrigan lake. One is 400 feet to 650 feet north of the centre of the north shore, and will be called the north zone. The other outcrops on the north shore near the east end of the lake, and will be called the Berrigan zone.

"The north zone is a zone of shattering in otherwise massive serpentinized pyroxenite. The shattering resulted in some places in the formation of a three-dimensional reticulate pattern of joints, and in other places in irregular brecciation of the rock. The shattering was evidently followed by the deposition of dark grey, fine-grained vein quartz and some rusty-weathering carbonate in the fractures, each constituent replacing the wall rock to some extent. Ore minerals ar· concentrated in veins and masses in the vein quartz and silici_ied wall rock, in some places constituting the matrix of a breccia of the siliceous rock; in other places massive sulphides have completely replaced the host rock. Country rock in the ore zone is black and textureless, apparently chloritized and carbonatized; at the main surface exposure of the north zone such alteration extends only a few feet into the wall rock. At the main exposure the sulphide minerals observed are, in order of abundance, pyrrhotite, sphalerite, galena, chalcopyrite, pyrite and arsenopyrite. In other exposures galena is rare, and the relative abundance of the other minerals is variable. In the main exposure the zone is 20 feet wide.

(p. 38)

"The Berrigan zone outcrops along the north shore of Berrigan lake for a distance of 140 feet near the east end of the lake and extends inland in an east-northeasterly direction for a total exposed length of ˈ,30̇ feet. Two parallel zones, north and south of the main zone, have been found near the eastern extremity. It has not yet been fully established whether or not the main zone extends to the west under Berrigan lake. In one diamond drill hole beneath Berrigan lake 200 feet we̤t of the lake shore exposures of the main zone only scattered sulphides were found, but shearing is found along the north shore west of these exposures, and there is some pyrrhotite and sphalerite in a rusty shear 350 feet west of them.

"The wall rocks of the Berr_gan zone are mostly serpentinized dunite and sheared serpentine, with less serpentinized pyroxenite. Within the zone the rocks are altered to carbonate-rich, rusty-weathering schists and breccias, so that it is difficult to determine their original nature; it seems likely that they were ultrabasic rocks. At the main exposure of the zone brecciation of the host rock is made apparent by differential weathering of the fragments and matrix of the breccia. Rocks of other parts of the zone are schistose, and brecciation is not apparent. Within the ore zone, parts of the carbonatized rock are replaced by dark grey, very fine-grained to cherty vein quartz, which in turn acts as host for the ore minerals. The quartz generally occurs in irregular layers separated by layers of carbonatized rock. The

quartz layers have been fractured, and the ore minerals occur
both in the fractures and as replacements of the quartz. In some
places layers of massive sulphides have apparently entirely
replaced the siliceous host rock. Ore minerals are commonly
scarce in the carbonatized rock between siliceous layers.
Pyrrhotite and sphalerite are by far the most abundant sulphide
minerals in surface exposures of the zone. A small amount of
chalcopyrite was seen in some specimens. Galena is rare or
absent. The company reports one assay of 0.50 per cent nickel,
and at least one other assay of a sample containing a significant
amount of that metal. The richest and widest part of the
Berrigan zone is the part nearest the lake. Carbonatized and
brecciated rocks there are 200 feet wide, and 40 to 100 feet of
that width is sulphide-bearing."

Gwillim Lake gold mine

The Gwillim Lake gold zone (No. 10, Plate 1) was discovered in 1934 on the

shore of Gwillim Lake close to the western boundary of McKenzie Township. It

was explored by McIntyre Mining Corporation, Gwillim Lake Gold Mines Signal

Oil, Dauphin Iron Mines, Yorbeau Mines Inc. and finally the present-day

operator, Campbell Chibougamau Mines Ltd. Over 60,000 feet of diamond drilling

have been done. In 1971, a tonnage of 156,000 tons of 0.25 ounce of gold per

ton was outlined in the main zone. In 1974, Campbell started a spiraling

decline in order to develop and mine the upper part of the deposit.

No published accounts of the underground findings are available to us at

the time of writing. The best description of the property is that of Mawdsley

and Norman (1935, p. 61):

"The main showing at this point is disclosed in three trenches
30 to 50 feet long, and consists of a sheared zone in massive,
fine-grained greenstone. Fine-grained quartz to quartz feldspar
porphyry dykes that weather white similar to anorthosite occur
near the showing. The rocks in the most western trench only were
visible when visited in September, 1935. The chloritic schists,
which form part of the shear zone in this trench, contain only a
few small quartz veins 1 foot or less wide, irregular carbonate
stringers, and one vein-like mass of carbonate 3 feet wide.
"Pyrite, chalcopyrite, and a little sphalerite are present
in the quartz and occur to some extent disseminated in the
chlorite schists. The length of the shear zone proved by
trenching is at least 175 feet: its width ranges from 20 to 11
feet. The gold values are not uniform across these widths and
are reported to range upwards to 0.5 ounce to the ton."

Roberge Lake asbestos deposit

The Roberge Lake asbestos deposit (No. 24, Plate 1) is located under Roberge Lake in McCorkill Township. In 1904, Peter McKenzie discovered asbestos on Asbestos Island in the northern extension of Chibougamau Lake, about 7 miles west of the Roberge Lake deposit. From 1955 to 1959, drilling for sulfides in the Blondeau volcaniclastics at the contact with the Roberge Sill revealed considerable asbestos in the serpentinized peridotite of the sill. Tests were done at the Q.D.N.R. pilot mill which showed the commercial interest of the asbestos. In 1960, Flanagan McAdam Co. staked the Roberge Lake property. Drilling was done intermittently from 1961 to 1966 indicating 165,061,000 tons of ore averaging 4% of asbestos fibers mineable by open pits. A 200-foot shaft was sunk in 1966-67 and crosscuts driven under the lake to obtain a bulk sample. The latter was taken to the pilot mill in Quebec and indicated 5.5% of fibers per ton, a marked improvement from the drill samples. The deposit, owned by McAdam Mining was optioned to Riocanex (Rio Algom Mines) in 1970. A spiraling decline was driven under the lake in the orebody to obtain additional material for pilot mill tests. Feasibility studies are in progress.

The deposit is in the Roberge Sill metadunite and metaperidotite. Crysotile veinlets constitute the bulk of the ore. Magnetite, brucite, picrolite, brugnatellite and a few other accessory minerals have been encountered. Slip fibers is dominant. Cross fibers are rare when compared with some of the Thetford deposits. The deposit is cut by numerous left-hand north-northeast faults associated with the Grenville Front and the Mistassini Fault which are located six miles and three miles respectively east of the deposit.

Iron-titanium-vanadium deposits

The magnetite-rich rocks of the D.L.C. were described in Chapter 3. They can be divided geographically and chemically in the following zones (Fig. 140):

South limb
- Rinfret and Lemoine Township Zone -- Jalore & Q.D.N.R. drilling
- IGC traverse in Lemoine Township -- series of surface samples

North limb
- Cache Lake area -- Grand Chibougamau and Chibougamau Mining and Smelting
- Portage Island
  - north zone
  - south zone
- Sorcerer Mountain zone
- Magnetite Bay zone

Rinfret-Lemoine Township zone

Much chemical and metallurgical work has been done by exploration companies, the Q.D.N.R., and by research laboratories in order to evaluate the potential of the magnetitites as an ore of vanadium and/or titanium and iron.

Table 106 shows IRSID's complete chemical analyses of five bulk samples ($\pm$ 4 tons each) of magnetitites from large blasted trenches in the P_1 member of Rinfret Township. Sample 5 has a higher TiO_2 content and a lower V_2O_5 content indicating a higher stratigraphic position for the same reason that sample 1 is fairly low within the P_1 member. The CAO, Al_2O_3, and MgO is due to epidote and chlorite. Table 107 presents analyses on mill fractions from 4 of the samples used by IRSID for Table 106 and shows the distribution of elements between the magnetic concentrate, the ilmenite concentrate, the middlings and the t ailings.

From this table, one can easily see that the vanadium is $\pm$ 5 times more abundant in the magnetite concentrate than in the ilmenite concentrate due to the replacement of Fe^{3+} in magnetite by V^{3+}. On the other hand, the sulfides are not magnetic and tend to follow the ilmenite concentrate.

Table 108 presents similar data from a large sample done in the laboratories of the Q.D.N.R. The results are quite comparable to those of IRSID.

Table 109 summarizes all the data from the Rinfret-Lemoine Township drilling. The weighted average at the bottom of the table is a representative average (4,503 feet) of the P_1 member since most of the drilling was done in this member. Note that the grinding for all these samples was -200 mesh. As seen in Tables 110 and 111, the degree of grinding does change the composition of the magnetite concentrate but less than in the case of the Sorcerer Mountain zone as seen in Tables 126 and 127. Table 111 clearly shows the effect of -325 mesh grinding vs -200 mesh grinding for the Rinfret-Lemoine Township zone. Analysis X is a composite of 9 samples representing a length of 2017.9 feet of core. The finer grinding increases the Fe-content of the magnetic concentrate by 3.4%, reduces the TiO_2 content by 2.1%, and increases the V_2O_5 tenor by 0.10 per cent. These changes are accompanied by decreases in SiO_2, Al_2O_3, MgO, and CaO.

Table 112 compares the Fe-TiO_2-V_2O_5 content of the magnetite concentrate vs the non-magnetic concentrate on the same samples from hole No. 7 of the Q.D.N.R. in Rinfret Township. The hole is drilled northward from the P_2 member across the A_1 and most of the P_1 members. Hole 17 continues the section across the remainder of the P_1 member. On Table 112 one can readily see the increase in vanadium downwards towards the base of P_1. However, the V_2O_5 content of the non-magnetic fraction (ilmenite-rich) remains remarkably constant while the TiO_2 content decreases gradually downwards within a small rise at the base in spite of the fact that for the same samples the TiO_2 content of the magnetic concentrate is very low. This behavior is certainly due to the grain size of the magnetite-ilmenite intergrowths as discussed briefly by Caty and illustrated in Figures 141 to 148. A detailed mineralographic study will be necessary to fully explain the variables shown in Table 112. Surprisingly, the V_2O_5 is the component with the most constant behavior.

The detailed analyses (punctual or from continuous cores) from many drill holes are presented in Tables 113 to 118 and Figures 149 to 162.
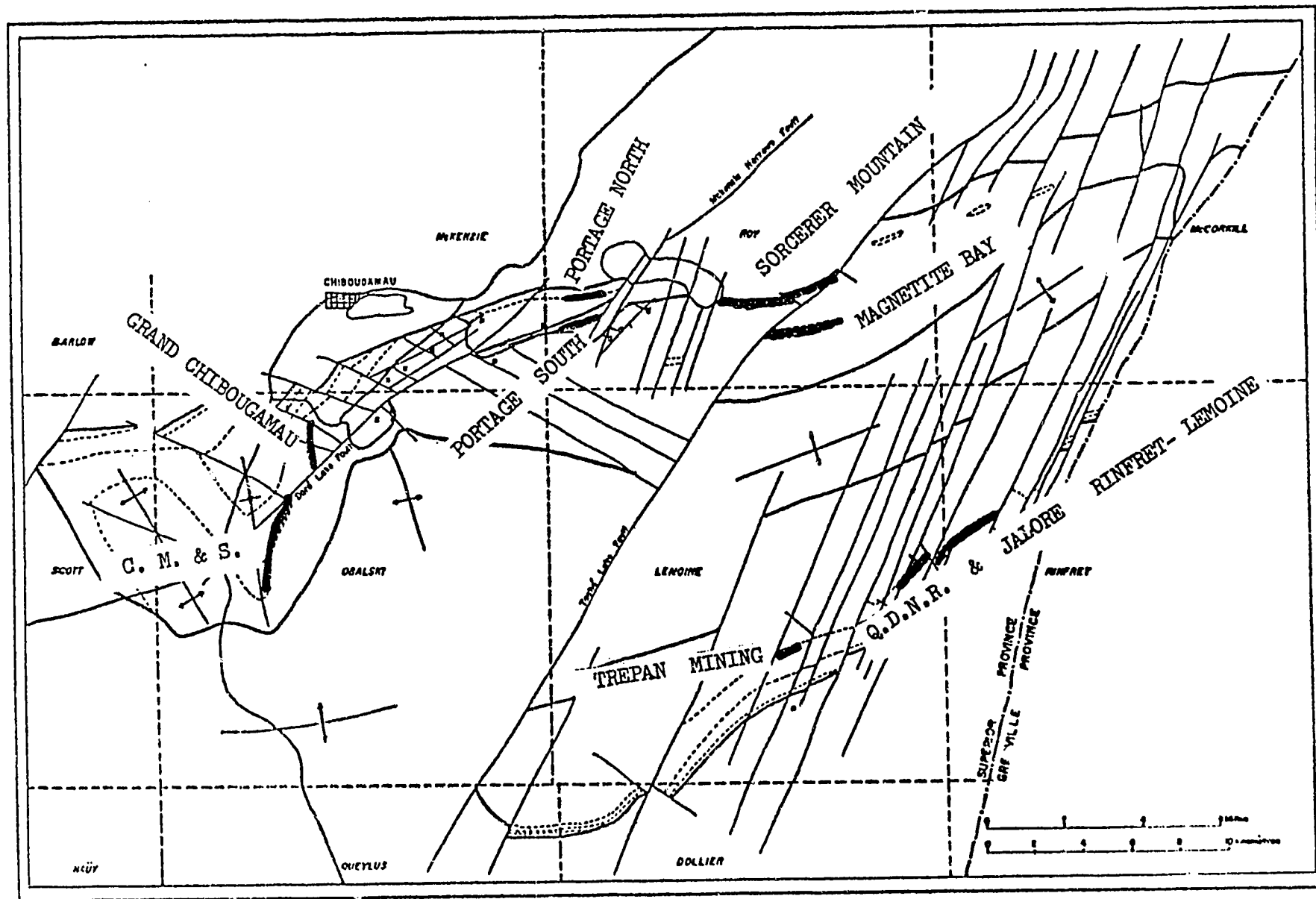
Fig. 140. Location of the magnetite-rich zones which have been
drilled in the Chibougamau area and for which data is
presented in the chapter on ore deposits, section Fe-Ti-V.

TABLE 106

Chemical Analyses of 5 bulk samples of magnetitites from Rinfret twp. (IRSID)
Analyses chimiques de 5 échantillons de magnétitites du canton Rinfret (IRSID)

	I(line 0)	II(line 22E)	III(line 43E)	IV(line 29E)	V(line 11E)
S_1O_2	17.4	17.6	12.6	13.8	12.2
TiO_2	9.9	10.6	12.7	12.0	13.9
Al_2O_3	10.5	10.4	8.9	9.3	8.6
Fe Total	37.7	36.7	41.1	40.5	40.4
Fe^{++}	17.7	18.1	20.6	20.1	20.8
Mn	0.19	0.20	0.313	0.189	0.241
MgO	3.0	3.5	2.6	2.7	2.9
CaO	4.4	3.8	2.7	3.1	2.65
Na_2O	0.63	0.68	0.42	0.52	0.44
K_2O	0.12	0.11	0.04	0.05	0.04
H_2O	2.94	3.12	2.73	2.74	3.15
CO_2	0.15	0.18	0.31	0.14	0.15
S	0.08	0.17	0.19	0.17	0.26
P	0.033	0.029	0.011	0.016	0.016
V_2O_5	0.75	0.70	0.71	0.71	0.52
* Pb	0.018	0.014	0.020	0.021	0.021
* Zn	0.030	0.032	0.048	0.032	0.038
* Cu	0.010	0.005	0.005	0.005	0.007
* Cr	0.054	0.049	0.043	0.037	0.024
Forrer Index	30.2	29.6	34.1	35.1	30.35

* semiquantitative analyses
  Forrer index = ratio of magnetization of sample compared to a standard sample
  (single crystal of pure magnetite from Sweden)
  Indice Forrer = rapport des aimantations à saturation de l'échantillon à un
  étalon (monocristal de magnétite pure suédoise)
  Adapted from Gerbe et al - 1970 (Table 15 + 16)
  Adapté de Gerbe et al - 1970 - (Tableau 15 et 16)

TABLE 107

Chemical analyses of mill fractions on 4 bulk samples of magnetitite (P_1) from Rinfret twp. IRSID

Analyses chimiques des produits de traitement de 4 échantillons du canton Rinfret IRSID

Wt. %	Feed alimentation		Magnetic concentrate Concentré magnétique		Ilmenite concentrate Concentré d'ilménite		Middlings Fins à retraiter		Tailings. Stériles	
	max	min	max	min	max	min	max	min	max	min
SiO_2	17.6	12.6	2.35	1.9	4.3	2.7	29.7	24.3	35.1	31.0
TiO_2	12.7	9.9	12.4	9.5	43.5	39.8	9.5	6.6	4.0	2.9
Al_2O_3	10.5	8.9	2.55	1.9	3.2	2.0	18.1	17.2	20.8	18.6
Fe Total	41.1	38.7	61.4	58.8	35.2	34.2	23.2	20.9	18.5	16.1
Fe^{++}	20.6	17.7	25.7	24.2	24.2	17.8	18.5	15.2	13.9	11.3
Mn	0.313	0.189	0.272	0.158	0.900	0.585	0.303	0.187	0.20	0.12
MgO	3.5	2.6	0.9	0.7	0.75	0.5	6.4	5.25	5.2	4.65
CaO	4.4	2.7	0.3	0.2	1.6	0.8	6.5	5.25	10.0	8.2
Na_2O	0.68	0.42	0.14	0.08	0.15	0.09	1.05	0.68	1.39	1.12
K_2O	0.12	0.04	0.02	0.01	0.02	0.01	0.11	0.06	0.17	0.09
H_2O	3.12	2.74	1.15	0.99	0.98	0.71	5.71	5.38	4.96	4.18
Cu_2	0.31	0.14	0.07	0.03	0.05	0.02	0.58	0.27	0.47	0.15
S	0.19	0.08	0.03	0.03	1.01	0.51	0.28	0.13	0.17	0.06
P	0.033	0.011	0.015	0.01	0.02	0.019	0.032	0.022	0.03	0.019
V_2O_5	0.75	0.70	1.39	1.16	0.32	0.285	0.27	0.20	0.21	0.16
Pb	0.021	0.014	0.012	0.007	0.013	0.009	0.052	0.031	0.031	0.015
Zn	0.048	0.030	0.041	0.02	0.023	0.015	0.070	0.036	0.039	0.027
Cu	0.010	0.005	0.002	0.001	0.010	0.004	0.012	0.011	0.009	0.005
Cr	0.054	0.037	0.081	0.047	0.014	0.011	0.023	0.016	0.015	0.013
Torrer Index	35.1	29.6	71.5	64.6	4.45	3.1	1.6	1.2	1.85	1.1
Recovery % Fe	100.0	100.0	74.5	66.0	7.6	6.6	16.9	12.5	10.0	6.4
% TiO_2	100.0	100.0	51.7	39.5	34.4	26.2	20.3	18.1	6.8	4.0
% V	100.0	100.0	86.9	78.3	3377	3.2	11.2	6.2	7.0	3.6

adapted from Gerbe et al - 1970 - Tableau 19
adapté de Gerbe et al - 1970 - Tableau 19
(Samples are no. I-II-III and IV of table 106
Echantillon no. I, II III, et IV du tableau.

TABLE 108

DISTRIBUTION OF ELEMENTS IN CONCENTRATION TESTS ON A BULK SAMPLE FROM RINFRET TOWNSHIP

DISTRIBUTION DES ELEMENTS DANS DES ESSAIS PRELIMINAIRES DE CONCENTRATION SUR ECHANTILLON BRUT DE TIR - RINFRET

(Results in table 1 and 2, p.14 & 15 - report by Kish, Cloutier and Olivier, 1971)

(Résultats dans table 1 et 2, p.14 & 15 - d'un rapport de Kish, Cloutier et Olivier, 1971)

Products Produits	Distribution %	Fe Total %	Distribution %	TiO_2 %	Distribution %	V_2O_5 %	Distribution %	SiO_2 %	CaO %	MgO %
Heads Alimentation	100	44.2	100	14.35	100	0.65	100	Na	Na	Na
Magnetite Concentrate	52.58	59.7	72.02	11.00	40.28	1.08	87.69	2.35	2.35	2.35
Ilmenite Concentrate	9.55	35.3	7.62	45.9	30.52	0.17	3.08	3.38	0.81	0.61
Mixtes	5.28	24.9	2.99	19.5	7.18	0.15	1.54	21.07	5.40	6.65
Rejects	32.59	22.8	18.37	8.87	22.02	0.14	7.69	24.92	6.23	3.01

Tests done by Gérard Castonguay in 1967

Essais faits par Gérard Castonguay en 1967

- 374 -

TABLE 109

SUMMARY OF CHEMICAL ANALYSES ON CORES FROM RINFRET - LEMOINE (Q.D.N.R. & JALORE)

SOMMAIRE DES ANALYSES CHIMIQUES SUR CAROTTES DES TROUS DANS RINFRET - LEMOINE (M.R.N. & JALORE)

Hole no. No. du trou	Length Longueur	Fe %	TiO_2 %	V_2O_5 %	Magnetic Concentrate (-200 mesh) Concentré Magnétique			
					Wt % % en poids	Fe %	TiO_2 %	V_2O_5 %
Jalore - 1	190'	29.4		0.46	29.32	62.87	10.70	1.09
2	128'	30.27		0.47	26.80	65.44	7.87	1.20
3	551'	32.7	6.7	0.51	30.16	64.19	7.9	1.22
4	141'	36.85		0.57	36.17	66.24	7.11	1.22
5	132'	32.57		0.46	31.05	65.43	9.56	1.05
6	143'	30.72		0.48	30.32	64.42	9.29	1.13
QDNR - 7	508'	33.28		0.52	34.57	60.50	8.23	1.13
8	200'	31.2		0.50	33.53	60.44	9.33	1.09
9	244'	33.3		0.50	33.67	62.30	8.19	1.09
10	205'	24.30		0.45	25.6	61.68	8.87	1.19
11	186'	37.3	10.7	0.68	39.5	61.6	11.0	1.34
12	273'	37.2	10.5	0.66	39.58	63.6	10.7	1.33
13	269'	36.8	10.9	0.67	42.10	61.0	12.4	1.28
14	264'	39.4	11.9	0.70	48.71	56.3	13.2	1.23
15	194'	37.7	11.5	0.65	43.07	59.14	12.7	1.22
16	229'	37.9	11.7	0.67	41.23	59.88	12.3	1.25
17	145'	37.7	10.5	0.75	44.03	57.08	11.8	1.38
18	296'	37.0	10.6	0.69	40.96	61.4	9.9	1.42
19	205'	32.4	10.1	0.51	28.31	61.8	9.8	1.28
Weighted average reported by Avramtchev Moyenne pondérée donnée par Avramtchev.		35.15	10.26	0.629	40.91	60.71	10.74	1.25

TABLE 110

Vanadium recovery vs. Grinding intensity on magnetitite from Rinfret twp. - QDNR
Récupération du vanadium vs. finesse de broyage sur magnétitites du canton Rinfret

Grinding-Broyage		Wt. %	Fe Total		TiO$_2$		V$_2$O$_5$	
100% passing / 100% passant	% - 200 mesh / % - 200 mailles	% enpoids	% Fe	% Distr.	% TiO$_2$	% Distr.	% V$_2$O$_5$	% Distr.
Magnetic concentrate (Sala separator) / Concentré magnétique (séparateur sala)								
35 mesh	32.1%	49.6	57.4	75.6	13.7	61.0	1.15	84.3
48 mesh	38.6	47.6	58.3	74.1	13.3	58.2	1.18	83.6
65 mesh	50.4	45.3	60.0	72.5	13.0	53.4	1.17	82.9
100 mesh	62.2	43.5	60.8	70.6	12.8	52.3	1.25	81.4
150 mesh	71.5	44.4	60.8	71.2	12.6	50.2	1.26	82.8
200 mesh	100.0	41.9	60.9	68.3	12.1	47.1	1.27	81.3
Non-magnetic fraction (sala separator)								
35 mesh	32.1	50.4	18.2	24.4	8.6	39.0	0.21	15.7
48 mesh	38.6	52.4	18.5	25.9	8.7	41.8	0.21	16.4
65 mesh	50.4	54.7	18.9	27.5	9.4	48.6	0.20	17.1
100 mesh	62.2	56.5	19.5	29.4	9.0	47.7	0.22	18.6
150 mesh	71.5	55.6	19.7	28.8	10.0	49.8	0.21	17.2
200 mesh	100.0	58.1	20.4	31.7	9.8	52.9	0.21	18.7
Non magnetic Sala fraction (séparateur Jones) / (Jones magnetic separator) / Fraction non magnétique (50.4% - 200 mesh sample)								
6 amperes		28.0	28.9	43.2	27.9	77.4	0.29	41.4
10 amperes		42.5	27.2	62.1	21.2	89.9	0.29	58.6
15 amperes		48.1	26.0	69.0	19.4	93.1	0.27	64.9
Non magnetic Sala fraction (Wilfley table) / Fraction non magnétique Sala (table Wilfley) / (24% - 200 mesh)								
Magnetic concentrate		48.7	55.9	74.0	13.5	60.2	1.07	83.8
Ilmenite concentrate		3.0	36.5	3.0	46.6	13.0	0.23	1.1
Middlings		29.6	16.7	13.4	6.5	17.6	0.19	9.1
Rejects		18.7	19.0	9.6	5.4	9.2	0.20	6.0

Feed (alimentation) - 37.6% Fe, 10.9% TiO$_2$ 0.66% V$_2$O$_5$
Adapted from Delisle and Cloutier, 1973
Adapté de Delisle et Cloutier - 1973

Table 111   200-mesh vs 325 mesh grinding Influence on chemistry of concentrates
— Magnetites from drill cores in Rinfret township QDNR

	I :(178.7°)			II (268.5°)			III (252.6°)			IV (263.8°)		
	Comp.	Conc 1	Conc 2	Comp.	Conc 1	Conc 2	Comp.	Conc 1	Conc 2	Comp.	Conc 1	Conc 2
Weight % -	100.0	40.82	36.87	100.0	40.44	37.20	100.0	44.11	39.99	100.0	49.26	44.43
Fe Total	37.0	61.5	64.3	37.0	61.0	63.4	37.2	58.7	62.3	39.0	57.0	60.8
TiO_2	11.0	11.0	8.54	10.7	10.8	9.29	11.1	12.4	10.7	12.0	13.5	12.4
V_2O_5	0.70	1.29	1.41	0.73	1.29	1.41	0.71	1.33	1.38	0.73	1.27	1.38
SiO_2		1.50	0.38		1.75	0.38		1.75	1.00		2.13	0.88
Al_2O_3		0.99	0.40		1.13	0.38		1.89	1.06		2.31	1.18
MgO		0.37	0.15		0.39	0.14		0.53	0.26		0.65	0.25
CaO		0.24	0.09		0.24	0.09		0.26	0.12		0.36	0.16
P_2O_5		0.01	<0.01		<0.01	<0.01		<0.01	<0.01		<0.01	<0.01
S		0.03	-0.006		0.03	0.009		0.06	0.04		0.16	0.13
Cr_2O_3		0.12	0.15		0.13	0.15		0.11	0.12		0.09	0.10

	V (194.5°)			VI (219.4°)			VII (144.7°)		
	Comp.	Conc 1	Conc 2	Comp.	Conc 1	Conc 2	Comp.	Conc 1	Conc 2
Weight % -	100.0	45.36	40.76	100.0	44.36	39.60	100.0	44.35	40.27
Fe Total	37.7	58.5	62.3	38.9	59.0	63.2	37.4	60.1	62.8
TiO_2	11.4	12.6	11.2	12.3	12.4	10.2	10.6	12.3	10.7
V_2O_5	0.70	1.29	1.44	0.71	1.30	1.43	0.77	1.42	1.51
SiO_2		2.13	0.63		2.00	1.13		1.63	0.63
Al_2O_3		2.05	0.87		1.72	0.83		1.65	0.66
MgO		0.59	0.21		0.54	0.24		0.54	0.19
CaO		0.35	0.13		0.33	0.14		0.44	0.10
P_2O_5		<0.01	0.01		<0.01	0.01		<0.01	0.01
S		0.13	0.09		0.08	0.05		0.03	0.006
Cr_2O_3		0.08	0.09		0.09	0.10		0.11	0.13

	VIII (290.7°)			IX (205.0°)			X (2017.9°)		
	Comp.	Conc 1	Conc 2	Comp.	Conc 1	Conc 2	Comp.	Conc 1	Conc 2
Weight % -	100.0	44.66	41.14	100.0	29.03	26.05	100.0	42.48	38.12
Fe Total	36.5	61.0	63.6	32.8	61.8	65.6	37.3	60.1	63.5
TiO_2	10.7	9.8	8.0	10.2	9.7	6.68	11.1	11.9	9.8
V_2O_5	0.71	1.48	1.56	0.56	1.32	1.45	0.72	1.38	1.48
SiO_2		1.63	0.88		1.38	0.50		1.75	0.50
Al_2O_3		1.70	0.99		1.04	0.43		1.72	0.76
MgO		0.43	0.26		0.34	0.16		0.50	0.21
CaO		0.27	0.15		0.22	0.10		0.31	0.13
P_2O_5		0.01	0.01		0.01	0.01		0.01	0.01
S		0.08	0.05		0.05	0.05		0.11	0.12
Cr_2O_3		0.11	0.13		0.09	0.10		0.12	0.12

Composite = 274 samples from 9 drill holes divided in 9 samples
— No. 10 is a composite of the 9 composites
Data adapted from M. Richard - 1975
Concentrate I is 61% -200 mesh (Davis tube, 15 grams, 10 minutes, 2 amperes)

TABLE 112

COMPARISON BETWEEN THE MAGNETIC FRACTION AND THE NON MAGNETIC FRACTION FROM THE SAME SAMPLES IN HOLE
Q.D.N.R. 7 - RINFRET

COMPARAISON ENTRE LA FRACTION MAGNETIQUE ET LA FRACTION NON-MAGNETIQUE DES MÊMES ECHANTILLONS DANS LE
TROU DE SONDAGE M.R.N. 7 - RINFRET

Footage Pieds de carotte	Fe total %	Magnetic Concentrate Concentré Magnétique				Non Magnetic Concentrate Concentré Non-Magnétique		
		Wt % % en poids	Fe %	TiO_2 %	V_2O_5 %	Fe %	TiO_2 %	V_2O_5 %
247 - 257	44.97	48.9	60.32	7.50	0.86	28.50	23.82	0.19
257 - 267	46.31	53.7	58.9	8.78	0.94	27.95	25.24	0.19
267 - 277	43.28	49.9	59.8	7.98	0.98	25.40	21.17	0.17
350 - 360	41.62	49.4	58.08	11.19	1.08	24.55	13.51	0.17
360 - 370	39.22	40.2	59.29	10.08	1.20	25.25	12.40	0.18
370 - 380	37.06	33.1	60.03	11.41	1.23	25.00	11.23	0.26
496 - 506.4	36.26	35.5	62.6	4.54	1.28	20.55	11.91	0.20
507.5- 518	40.78	38.6	67.9	1.97	1.52	23.90	15.67	0.17
526 - 529	45.05	46.9	66.2	2.54	1.40	27.20	19.68	0.19
Weighted average Moyenne pondérée	41.32	43.8	61.05	7.74	1.14	24.00	16.97	0.19

Reported in Kish 1971 - Appendix C-4 and page B-13 & 14

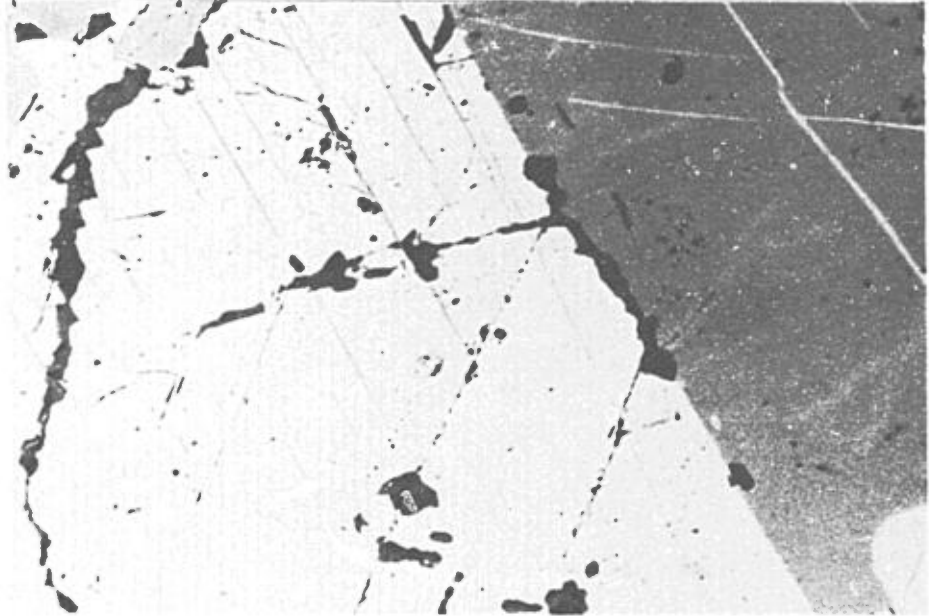Rapporté dans Kish 1971 - Appendice C-4 et pages B-3 & 14

Fig. 141. Photomicrograph of polished section in reflected light. Very narrow ilmenite lamellae in the (111) planes of magnetite. From Caty (1970), plate 5 B, p.92. Width of the field is 1.1 mm.
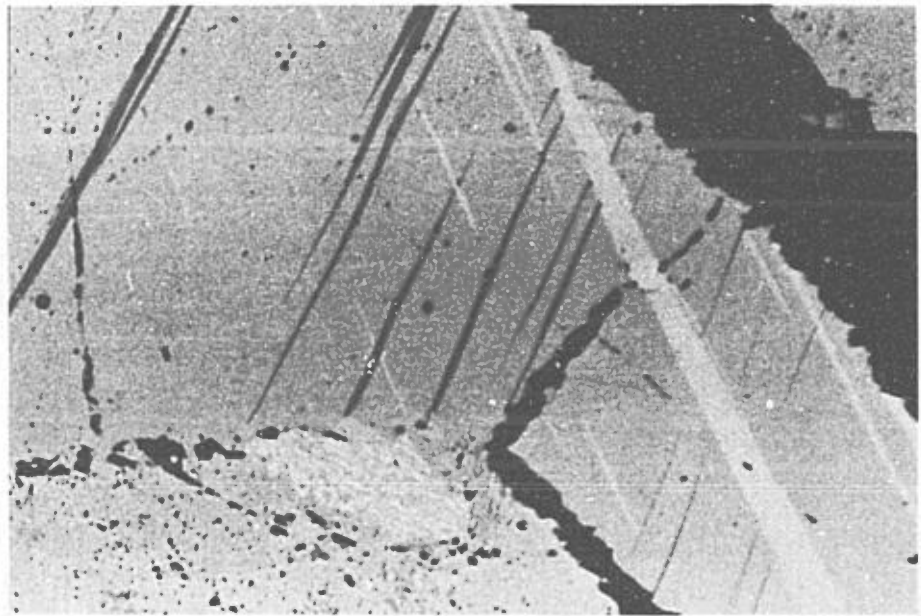

Fig. 142. Photomicrograph of polished section in reflected light. Broader ilmenite lamellae in the (111) direction of titaniferous magnetite. Note at the bottom the vermicular intergrowth of ilmenite and magnetite. From Caty (1970), plate 6A, p. 93. Width of the field is 1.1 mm.
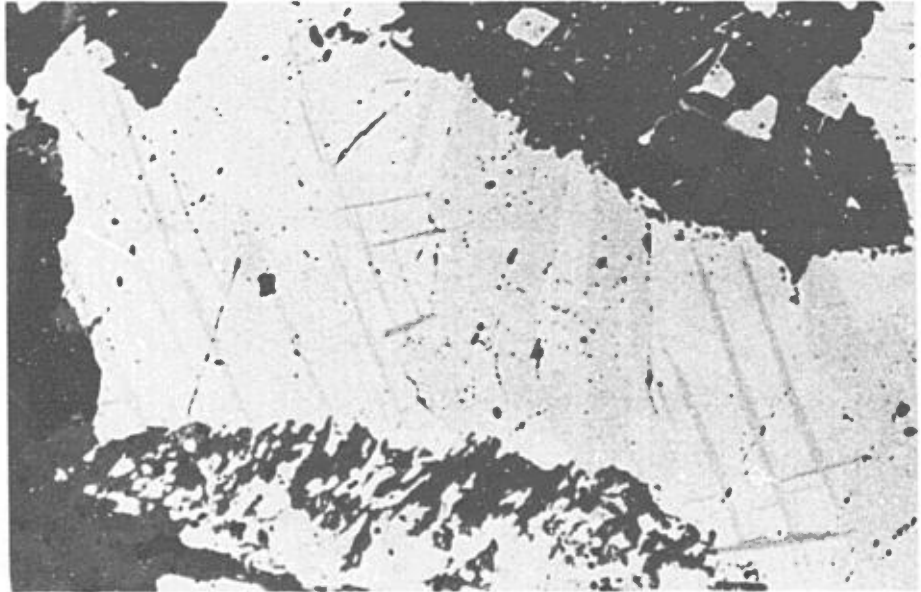
Fig. 143. Photomicrograph of polished section in reflected light.
Hematite lamellae in ilmenite grains. From Caty (1970), plate 9A,
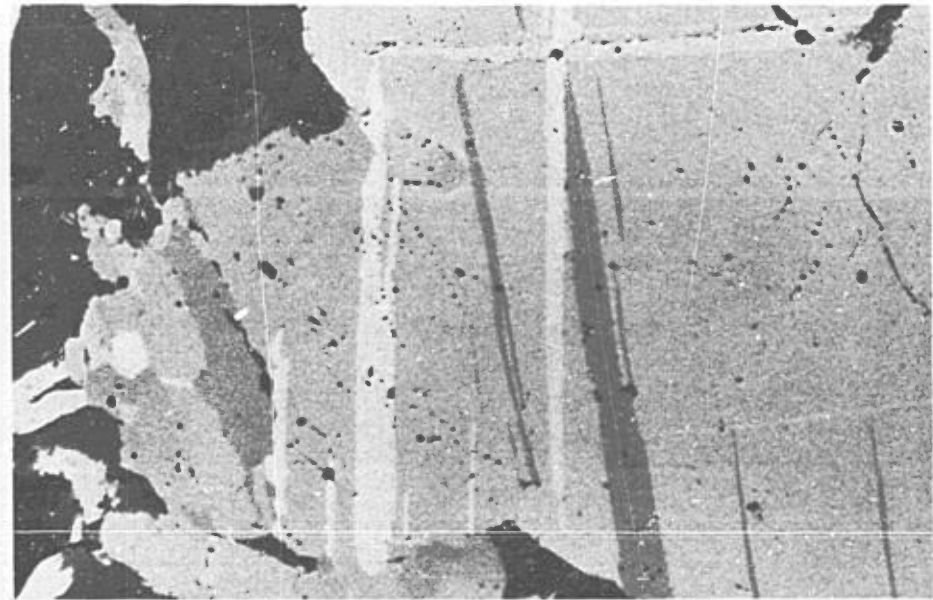p. 96. Width of field: 1.1 mm ,

Fig. 144. Photomicrograph of polished section in reflected light.
Coarse hematite lamellae in ilmenite grains. From Caty (1970),
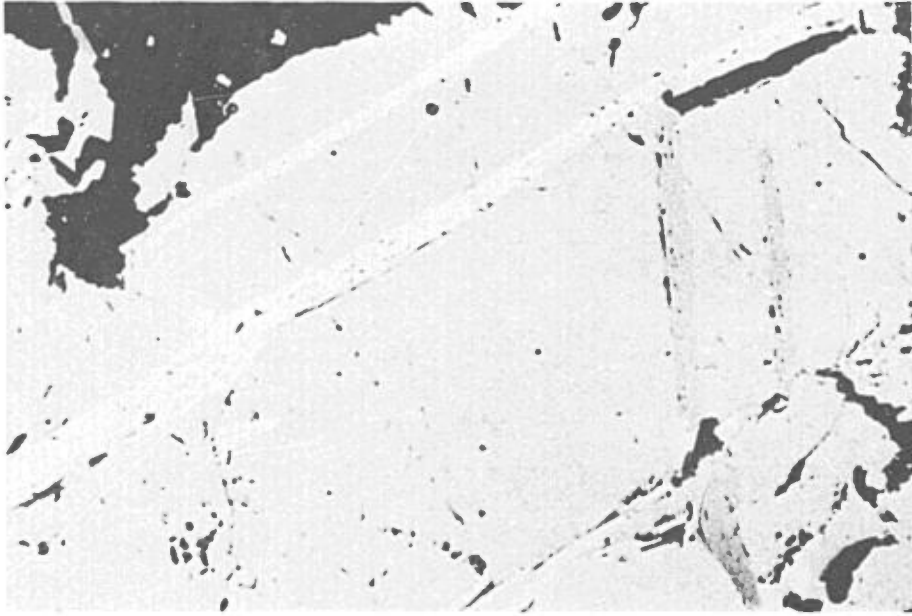plate 9B, p. 96. Width of field is 1.1 mm.

Fig. 145. Photomicrograph of polished section in reflected light. Very coarse ilmenite lamellae in the (111) planes of magnetite. From Caty (1970), plate 6B, p. 93. Width of field is 1.1 mm.

Fig. 146. Photomicrograph of polished section in reflected light. Micrographic intergrowths of ilmenite (dark grey) and titaniferous magnetite (pale grey matrix). From Caty (1970), plate 7A, p.94. Width of field is 0.6 mm.

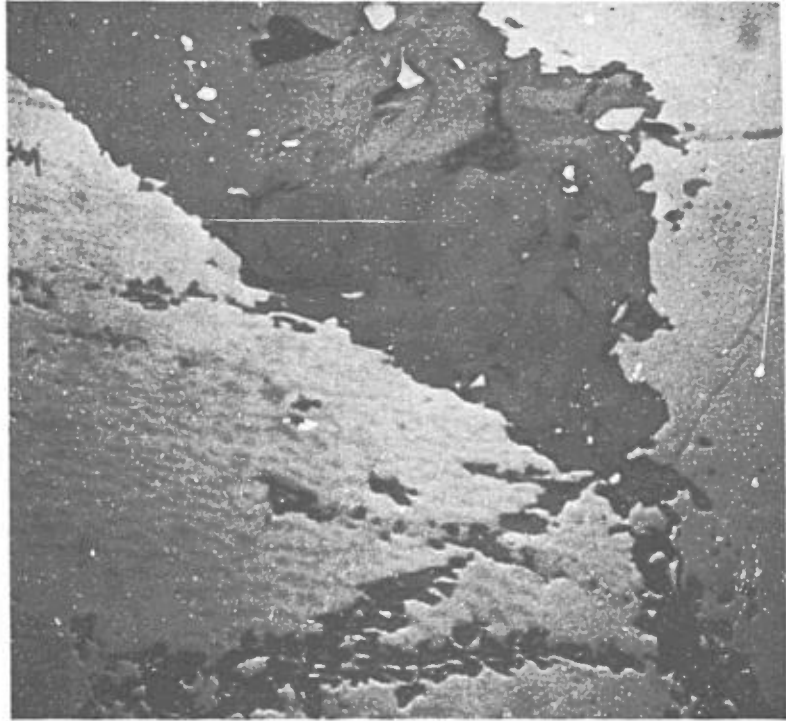Fig. 147. Photomicrograph of polished section in reflected light. Micrographic intergrowth of titaniferous magnetite(pale grey) and ilmenite (dark grey). From Caty (1970), plate 7 B, p. 94. Width of field of view is 0.6 mm.
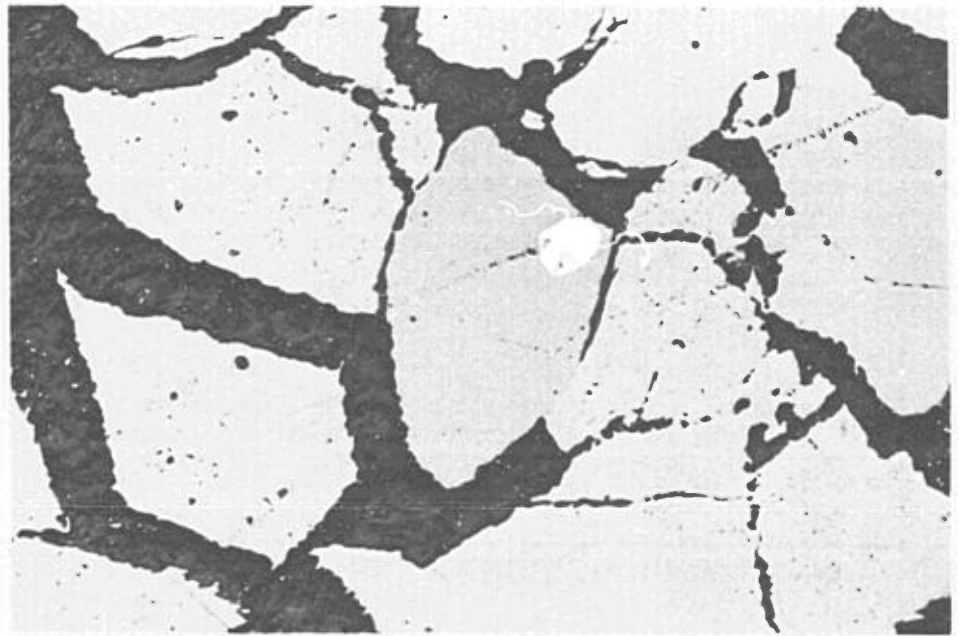

Fig. 148. Photomicrograph of polished section in reflected light. Individual grains of ilmenite and of titaniferous magnetite. From Caty (1970), plate 8A, p. 95. Width of field is 1.1 mm.

TABLE 113

CHEMICAL ANALYSES (SPOT SAMPLES) D.D. HOLE #1 - JALORE - KINFRET

ANALYSES CHIMIQUES (ECHANTILLONS PONCTUELS) TROU #1 - JALORE - KINFRET

Footage Pieds carotte	Fe total %	Magnetic concentrate (200 mesh) Concentré magnétique			
		Wt % % en poids	Fe %	TiO_2 %	V_2O_5 %
53	44.4	38.8	63.9	9.0	0.91
71	47.9	56.7	62.7	10.9	0.75
94	32.7	22.8	61.6	11.5	0.94
98	51.7	68.3	60.3	13.4	0.77
103	48.3	59.9	59.9	12.7	0.87
133	51.9	68.9	61.3	12.6	0.87
139	53.8	73.1	61.8	12.3	0.89
149a	36.6	37.0	61.7	9.8	1.00
149b	37.4	37.7	62.7	9.2	1.09
171	30.5	16.9	68.2	3.0	1.83
177	45.2	49.6	63.7	8.0	1.05
212	44.8	54.1	60.9	11.5	1.01
222	47.5	62.0	61.1	10.7	0.96
228	13.3	2.5	x	6.9	1.41
236	49.0	64.8	62.7	11.6	1.05
258	50.9	70.5	62.2	11.2	1.03
262	54.0	76.2	61.8	11.4	1.05
278	33.9	35.9	63.5	8.6	1.14
296	50.4	67.8	63.1	9.6	1.10
300	51.7	69.1	63.1	9.0	1.19
301	17.4	6.9	x	4.3	0.66
316	22.7	12.7	59.9	2.6	0.59
328	34.3	34.9	63.6	8.0	1.14
337	54.0	72.9	63.4	9.2	1.10
344	31.7	32.0	64.8	7.8	1.21
350	50.2	68.3	62.4	10.1	1.10
351	53.0	73.8	62.3	10.2	1.09
354	18.9	12.7	63.2	8.6	1.16
376	44.9	53.0	63.9	7.4	1.14
405	17.5	6.5	x	4.4	1.32
408	34.4	33.8	64.8	6.7	1.26
422	42.1	47.1	63.9	8.0	1.21
429	43.2	46.6	64.4	6.9	1.26
441	42.3	43.1	66.8	4.7	1.44
443	45.4	52.5	64.4	7.2	1.32
456	19.4	11.1	69.2	1.0	1.42
459	23.0	15.8	68.7	0.8	1.39
Mathematical average Moyenne mathématique	39.7	44.8	63.3	8.4	1.10

TABLE 114

CHEMICAL ANALYSES (SPOT SAMPLES) D.D. HOLE #2 - JALORE - RINFRET

ANALYSES CHIMIQUES (ÉCHANTILLONS PONCTUELS) TROU #2 - JALORE - RINFRET

Footage Pieds carotte	Fe total %	Magnetic concentrate (-200 mesh) Concentré magnétique				
		Wt % % en poids	Fe %	TiO_2 %	V_2O_5 %	SiO_2 %
18	24.6	0.1	échantillon insuffisant			
38	37.7	27.2	67.35	3.96	0.87	0.46
91	36.9	34.5	59.10	13.34	0.62	2.08
103	42.1	51.3	60.29	14.0	0.66	1.44
136	44.1	41.1	63.81	10.0	1.05	0.70
154	42.4	43.1	58.7	12.5	0.96	2.48
167	42.7	40.0	61.56	12.4	1.16	0.95
216	39.6	39.6	59.78	14.9	0.91	1.10
227	40.6	38.4	61.25	11.7	1.01	1.28
264	47.1	42.2	66.84	3.2	1.19	1.49
289	50.3	61.2	63.46	9.7	1.05	1.03
299	43.6	45.7	60.72	11.0	1.03	1.90
395	41.9	38.4	64.09	5.3	1.41	2.03
434	44.6	50.3	64.31	8.63	1.34	1.10
560	43.7	49.5	63.38	5.44	1.35	2.36
621	42.3	41.7	67.31	3.12	1.53	1.15
Mathematical average Moyenne mathématique	41.5	40.3	62.80	9.28	1.08	1.44

Analyses done in the Q.D.N.R. Laboratories in 1967

Analyses faites aux Laboratoires du M.R.N. en 1967

Samples collected by Jean-Louis Caty

Echantillons de Jean-Louis Caty

TABLE 115

CHEMICAL ANALYSES OF MAGNETITE-POOR FRACTION OF THE LAYERED ZONE
(HOLE JALORE 3 - RINFRET)
ANALYSES CHIMIQUES DE LA PARTIE PAUVRE EN MAGNETITE DANS LA ZONE LITEE
(TROU JALORE 3 - RINFRET)

Footage Profondeur	Length of sample Longueur	V_2O_5 %	TiO_2 %	Wt % magnetic fraction % en poids de la fraction magnétique
6- 27	21'	0.09	1.9	0.5
34- 54	20'	0.09	1.6	0.8
78- 95.5	17.5'	0.12	1.6	0.4
151-168.5	17.5'	0.17	2.9	0.5
258-263	5'	0.34	3.4	1.9
402.2-436	33.8'	0.27	1.8	0.4
498-499	1'	0.15	1.8	1.3
520-528	8'	0.16	1.9	1.3
532-534	2'	0.13	1.7	0.4
537-544	7'	0.25	2.2	3.2
545-546.5	1.5'	0.17	1.9	1.3
583.5-599	15.5'	0.15	1.3	0.2
Mathematical average Moyenne mathématique		0.17	1.67	0.63

Reported in Kish (1971) as annexe C-5

Rapporté dans Kish (1971) en appendice C-5

Work done in laboratory of the Q.D.N.R. - 1971

Analyses faites au laboratoire du M.R.N. - 1971

TABLE 116

CHEMICAL ANALYSES OF SELECTED SAMPLES FROM D.D. JALORE 3 - RINFRET - DONE BY I.R.S.I.D. IN 1970

ANALYSES CHIMIQUES D'ECHANTILLONS CHOISIS DANS LE TROU JALORE 3 - RINFRET - FAITES PAR I.R.S.I.D. EN 1970

Footage Profondeur	Length Longueur	Fe	Fe^{++}	SiO$_2$	CaO	Al$_2$O$_3$	TiO$_2$	MgO	V	Mn	S	P	Magnetite
64 - 88	24'	25.7	15.2	28.6	6.6	13.5	8.4	3.3	0.16	0.29	0.34	0.04	13.2
204 - 224	24'	42.9	25.0	10.2	3.2	7.5	15.5	2.1	0.38	0.25	0.35	0.03	31.5
305 - 325	20'	.39.5	24.0	13.9	4.2	9.3	12.2	2.4	0.41	0.24	0.26	0.03	26.4
436 - 452	16'	32.5	16.8	23.1	5.2	12.6	7.4	4.9	0.32	0.19	0.18	0.03	27.7
547 - 567	20'	29.3	13.9	23.8	6.9	15.9	6.9	2.2	0.34	0.14	0.10	0.04	22.5
640 - 653	13'	15.8	9.2	35.1	9.8	21.6	3.2	2.2	0.16	0.09	0.12	0.04	7.4
Weighted average Moyenne pondérée		33.0	18.0	21.5	5.7	12.7	9.5	2.8	0.30	0.21	0.24	0.03	22.1

FROM DATA ON TABLE 1 IN ASTIER ET AL, 1970

A PARTIR DE DONNEES DANS LE TABLEAU 1 DANS ASTIER ET AL 1970

Table 116. a

CHEMICAL ANALYSES OF P_1 MEMBER (LZ) - RINFRET TOWNSHIP - HOLE NO. 12 Q.D.N.R.

Analyses chimiques du membre P_1 (ZL) - Canton Rinfret - Trou No. 12 Q.D.N.R.

Interval	length (feet)	Fe	TiO_2	V_2O_5	Analysis of the magnetic concentrate % wt.	Fe	TiO_2	V_2O_5	Chemical analysis of the composite of all the samples analysed on the left.	
20.2 - 25.2	5.0	39.3	14.1	0.51	40.20	60.0	13.5	0.99		
25.2 - 33.0	7.8	46.4	16.3	0.65	54.47	61.6	13.3	1.02		
33.0 - 37.6	4.6	24.0	7.2	0.29	14.07	61.2	9.7	1.09	SiO_2	15.30
48.4 - 53.7	5.3	45.6	16.3	0.70	56.53	59.6	14.6	1.06	TiO_2	11.70
75.6 - 85.6	10	47.4	16.6	0.79	60.80	60.2	14.5	1.14	Al_2O_3	9.89
85.6 - 95.6	10	44.9	14.9	0.71	54.07	59.7	14.5	1.17	Fe_2O_3	24.30
95.6 - 103	7.4	41.4	13.7	0.69	45.77	60.2	13.2	1.21	FeO	28.05
103 - 113	10	38.1	11.4	0.61	40.20	60.3	12.8	1.18	MgO	2.32
113 - 123	10	41.1	13.0	0.79	47.13	60.4	13.0	1.18	CaO	2.83
123 - 133	10	39.1	12.0	0.67	44.73	60.1	12.5	1.21	Na_2O	0.56
133 - 143	10	39.0	11.7	0.66	41.13	61.9	12.1	1.29	K_2O	0.08
143 - 153	10	38.5	11.0	0.68	42.47	61.1	11.7	1.27	H_2O	2.84
153 - 163.2	10.2	39.6	11.3	0.74	45.73	61.6	12.3	1.27	CO_2	0.73
166 - 174.5	8.5	40.7	11.5	0.75	44.93	64.1	9.2	1.40	P_2O_5	0.01
174.5 - 184	9.5	40.7	11.4	0.79	47.33	61.2	11.5	1.34	V_2O_5	0.79
191.3 - 201.3	10.0	41.0	11.3	0.76	48.27	62.5	10.9	1.36	Cr_2O_3	0.08
201.3 - 211	9.7	41.8	11.4	0.87	52.60	61.9	11.6	1.37	NiO	0.02
231.3 - 241.3	10	43.5	11.4	0.85	49.0	62.8	8.6	1.47	As	0.01
241.3 - 251.3	10	39.4	10.1	0.75	40.73	63.7	7.4	1.53	S	0.15
251.3 - 255.5	4.2	38.4	9.7	0.74	37.93	65.3	5.6	1.65	Total	99.66
255.5 - 264.3	8.8	40.8	10.5	0.79	45.27	62.2	8.6	1.47		
271.8 - 276.0	4.2	43.6	10.7	0.86	41.13	68.0	1.9	1.78	(data from Richard, 1975)	
280.0 - 284.2	4.2	31.8	7.5	0.59	24.07	66.4	2.3	1.71		
290.0 - 300.1	10.1	41.0	10.0	0.82	38.27	67.6	2.8	1.75		
305.7 - 312	6.3	35.6	8.6	0.67	31.47	66.7	2.7	1.73		
318.9 - 328.6	9.7	44.8	11.2	0.90	55.33	61.9	10.2	1.45		
weighted average	215.5	40.78	11.87	0.73	45.36	62.1	10.5	1.34		

Avramtchev's weighted average for complete set of analyses

273.5		37.2	10.5	0.66	39.58	63.16	10.7	1.33		

(Date from Avramtchev, 1975)

TABLE 117

WEIGHTED AVERAGES OF CHEMICAL ANALYSES FROM D.D. HOLES - TREPAN MINING - LEMOINE

MOYENNES PONDEREES D'ANALYSES CHIMIQUES DES TROUS DE SONDAGE DE TREPAN MINING - LEMOINE

Hole no. No. du trou	Length Longueur	Fe total %	TiO_2 %
1	308'	31.1	9.1
2	256'	32.4	9.7
3	239.5'	29.4	10.7
4	130'	29.9	9.5
Weighted average Moyenne pondérée	933.5'	30.8	9.7

Holes drilled in 1960 under the direction of C. T. Bischoff

Les trous furent forés en 1960 sous la direction de C. T. Bischoff

It is not known where the analyses were done

On ne connait pas le laboratoire responsable des analyses
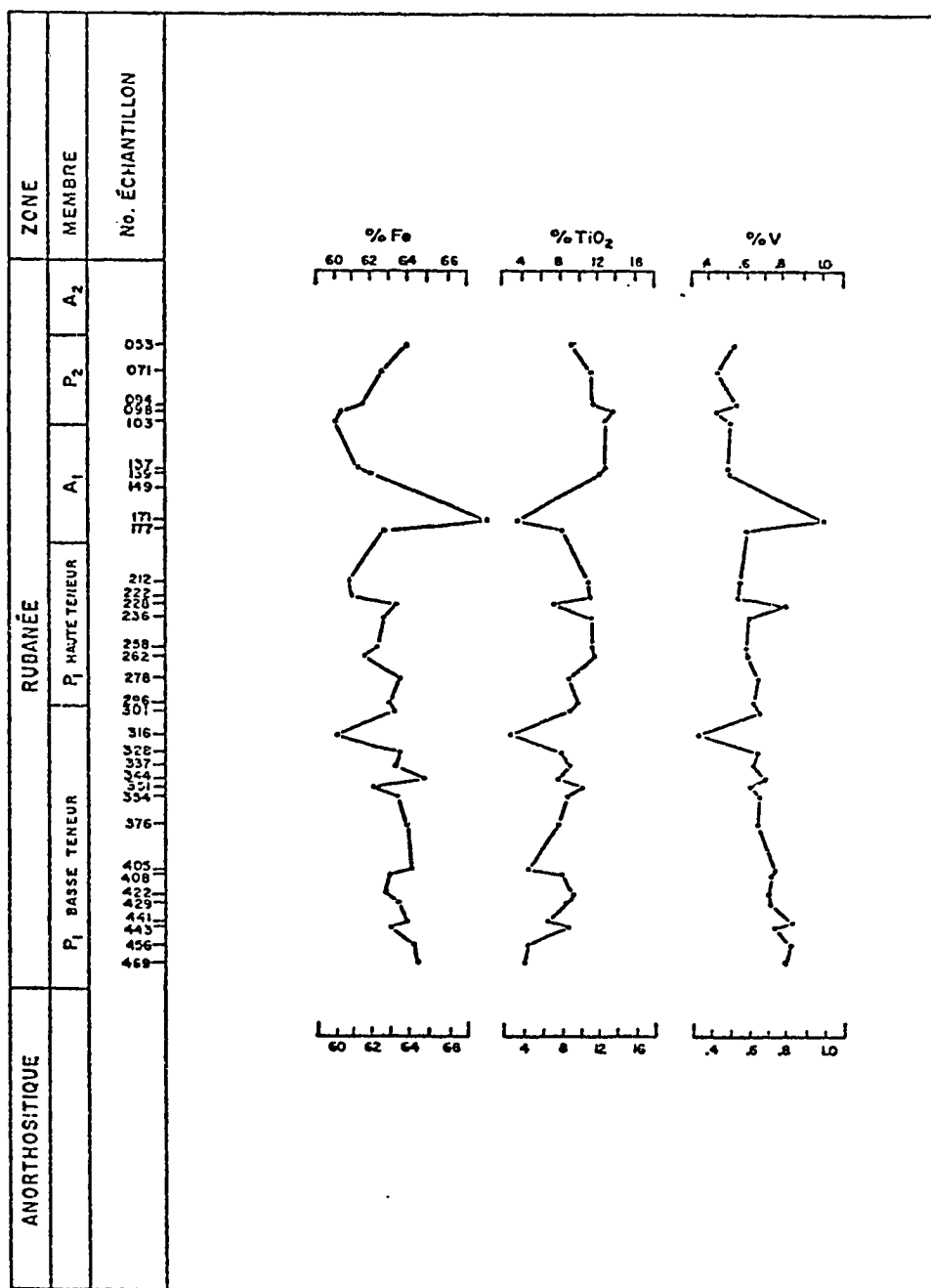
Fig.149 Fe - TiO$_2$ - V assays from magnetic concentrates, Hole No 1,
Jalore, Rinfret Township (footage of punctual samples indicated
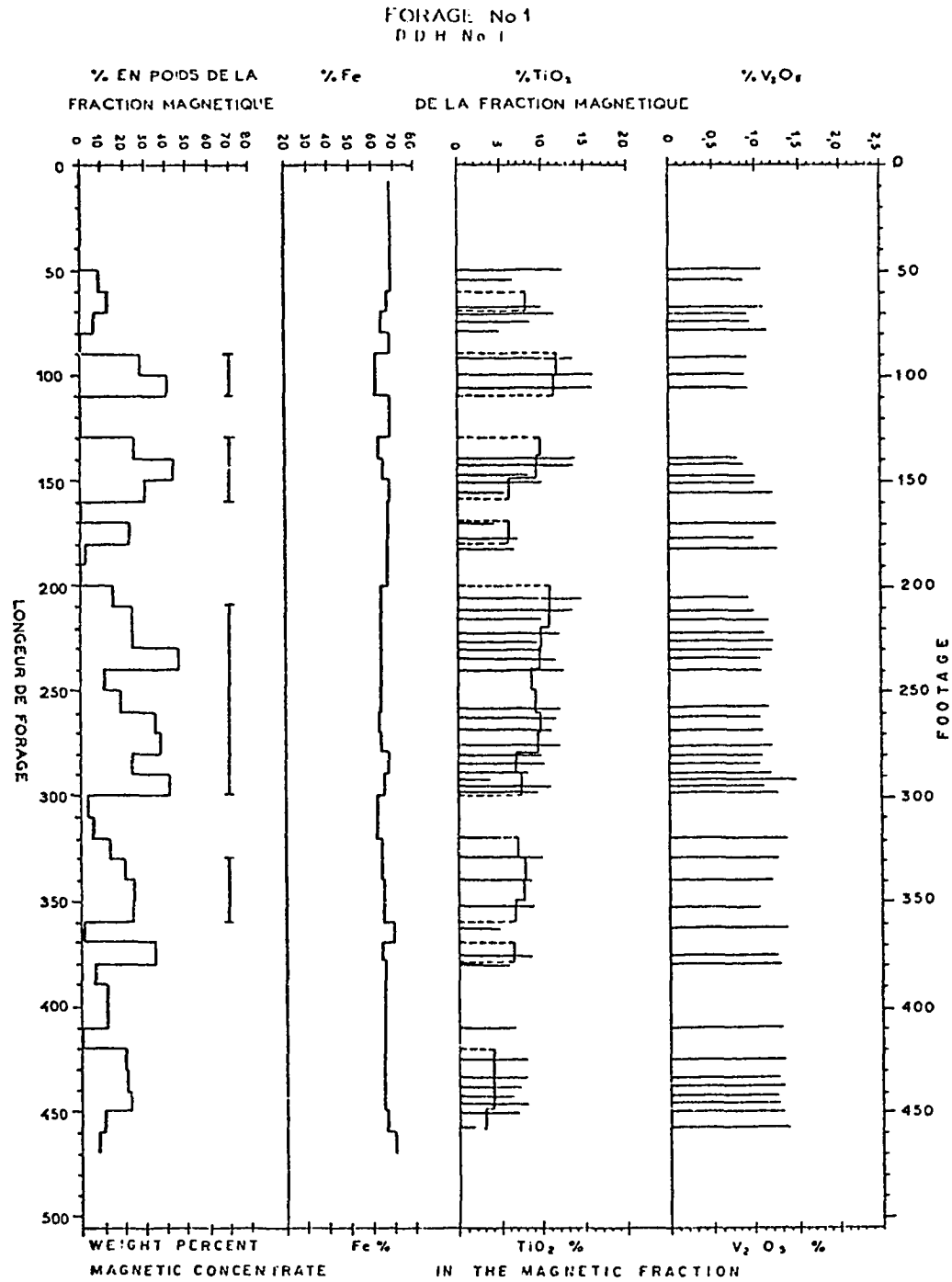under No. echantillon). From Caty (1970), fig.11, p.117.

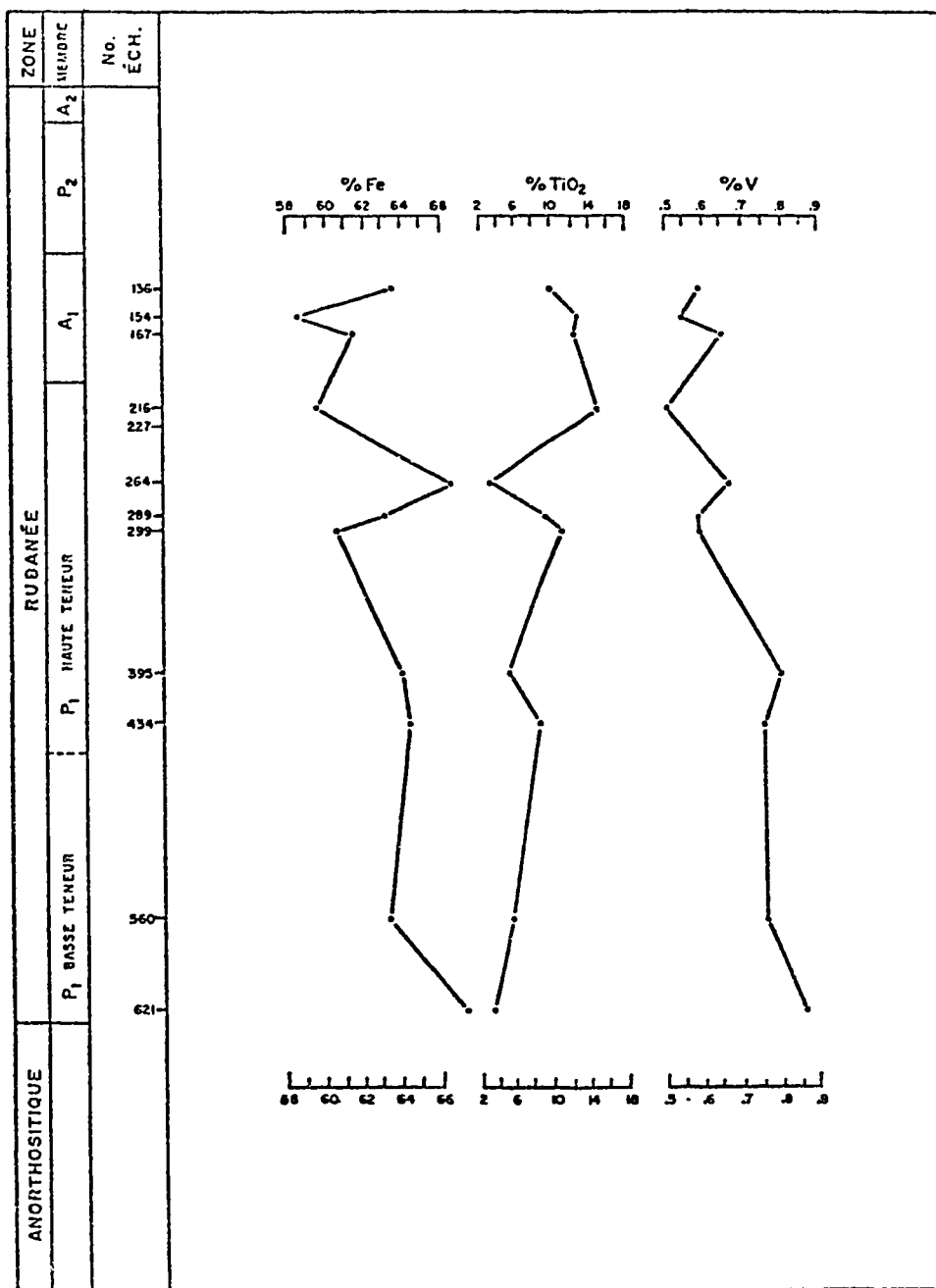Fig. 150. Graphic plots of assays from drill hole No.1, Jalore, Rinfret Township. (From Kish, 1971, g fig. 7-1)

- 390 -

Fig.151 Fe - TiO$_2$ - V assays from magnetic concentrates, Hole No 2,
Jalore, Rinfret Township (footage of punctual samples indicated
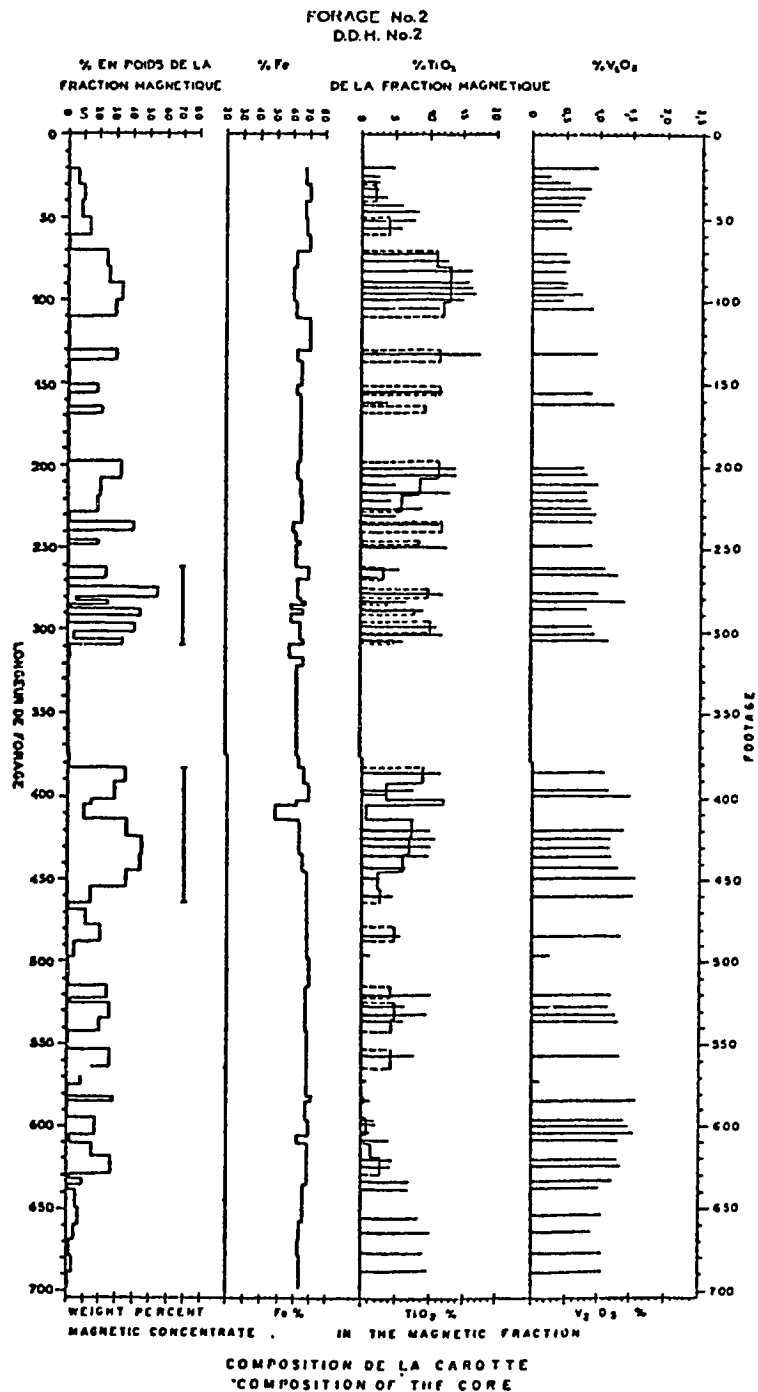under No. ech.). From Caty (1970), fig. 12, p. 118.

Fig. 152. Graphic plot of assays from drill hole No. 2,
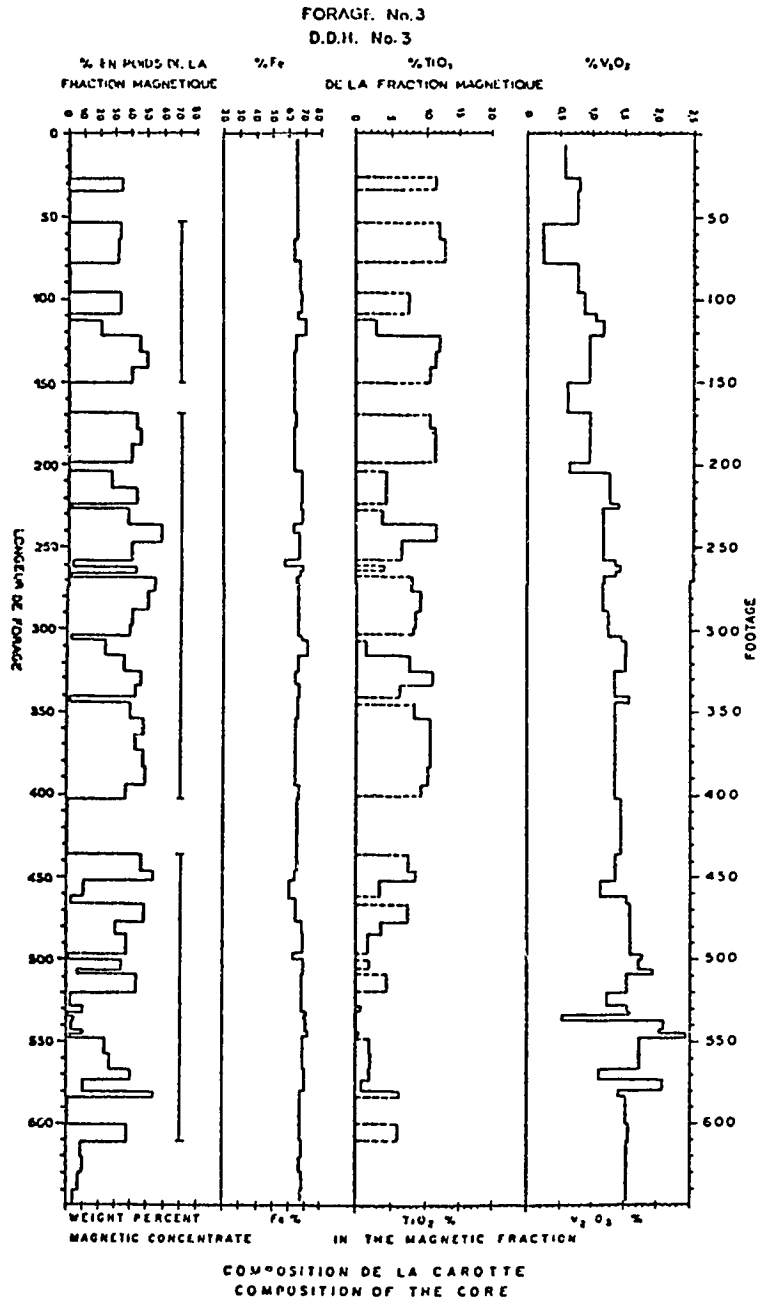Jalore, Rinfret Township (from Kish,1971,fig.7-2).

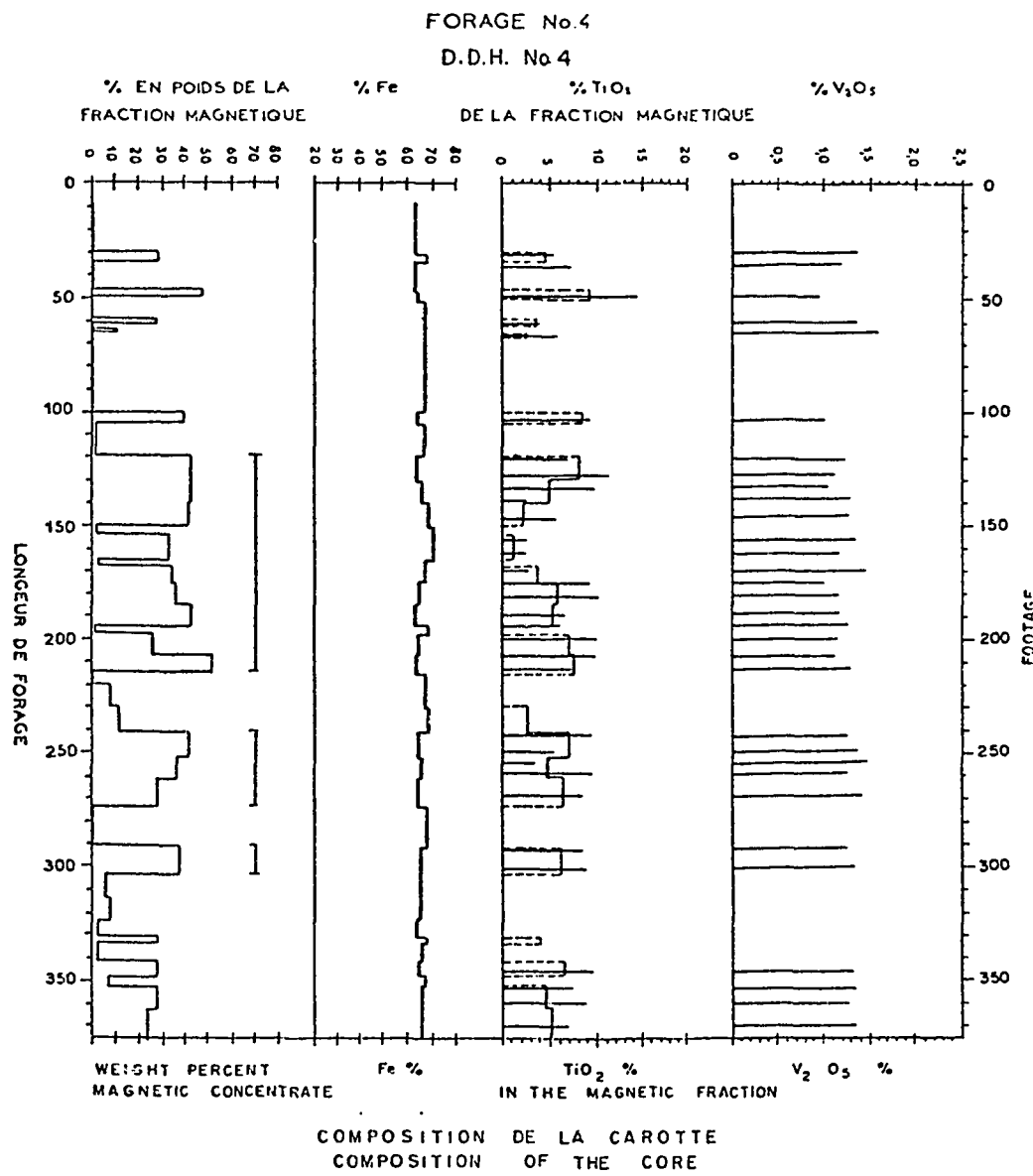Fig. 153. Graphic plot of assays from hole No. 3, Jalore, Rinfret Township (from Kish, 1971, fig.7-3).

FORAGE No.4

D.D.H. No.4

Fig. 154. Graphic plot of assays from drill hole N^U.4
Jalore, Rinfret Township. (From Kish,1971,
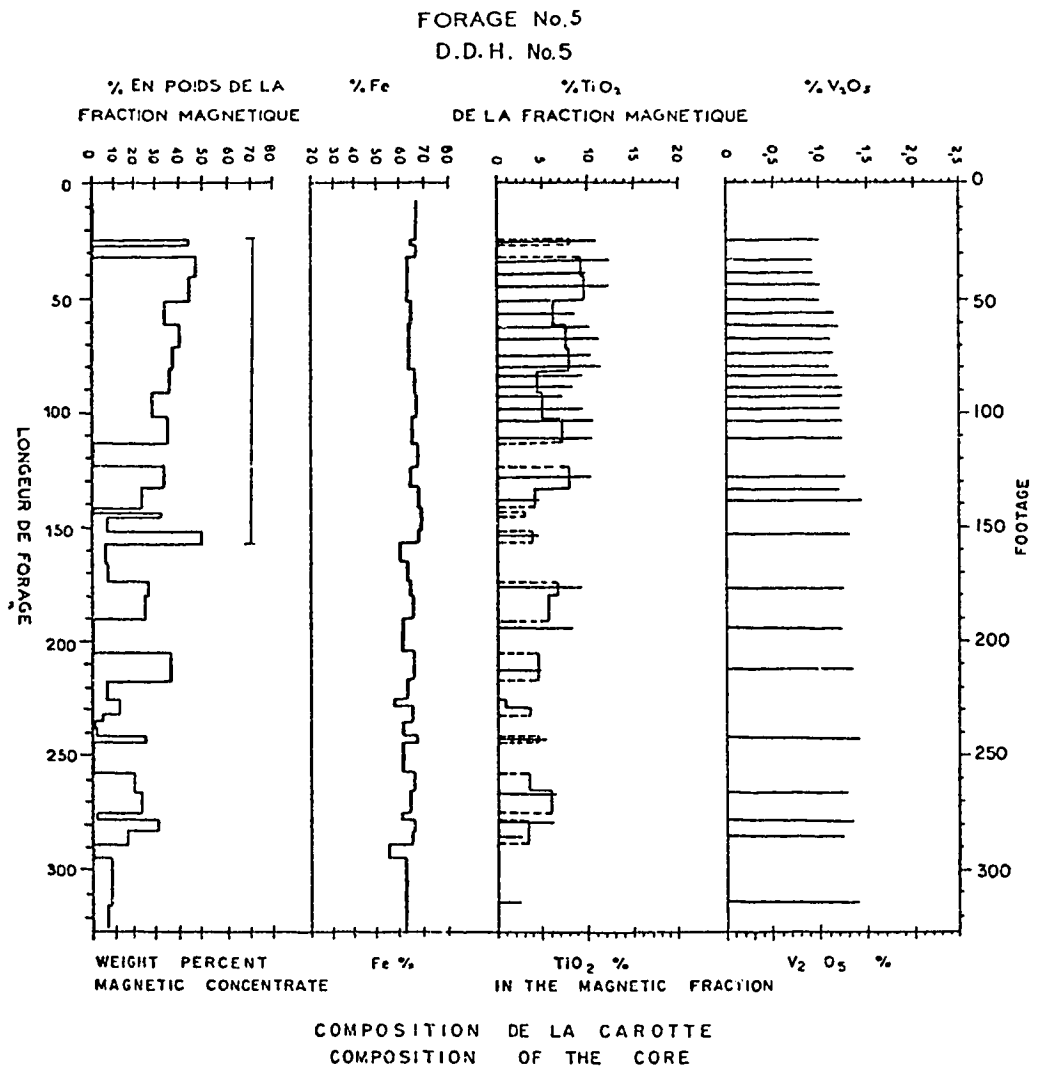fig. 7-4)

FORAGE No.5

D.D.H. No.5

Fig. 155. Graphic plot of assays from drill hole No. 5, Jalore,
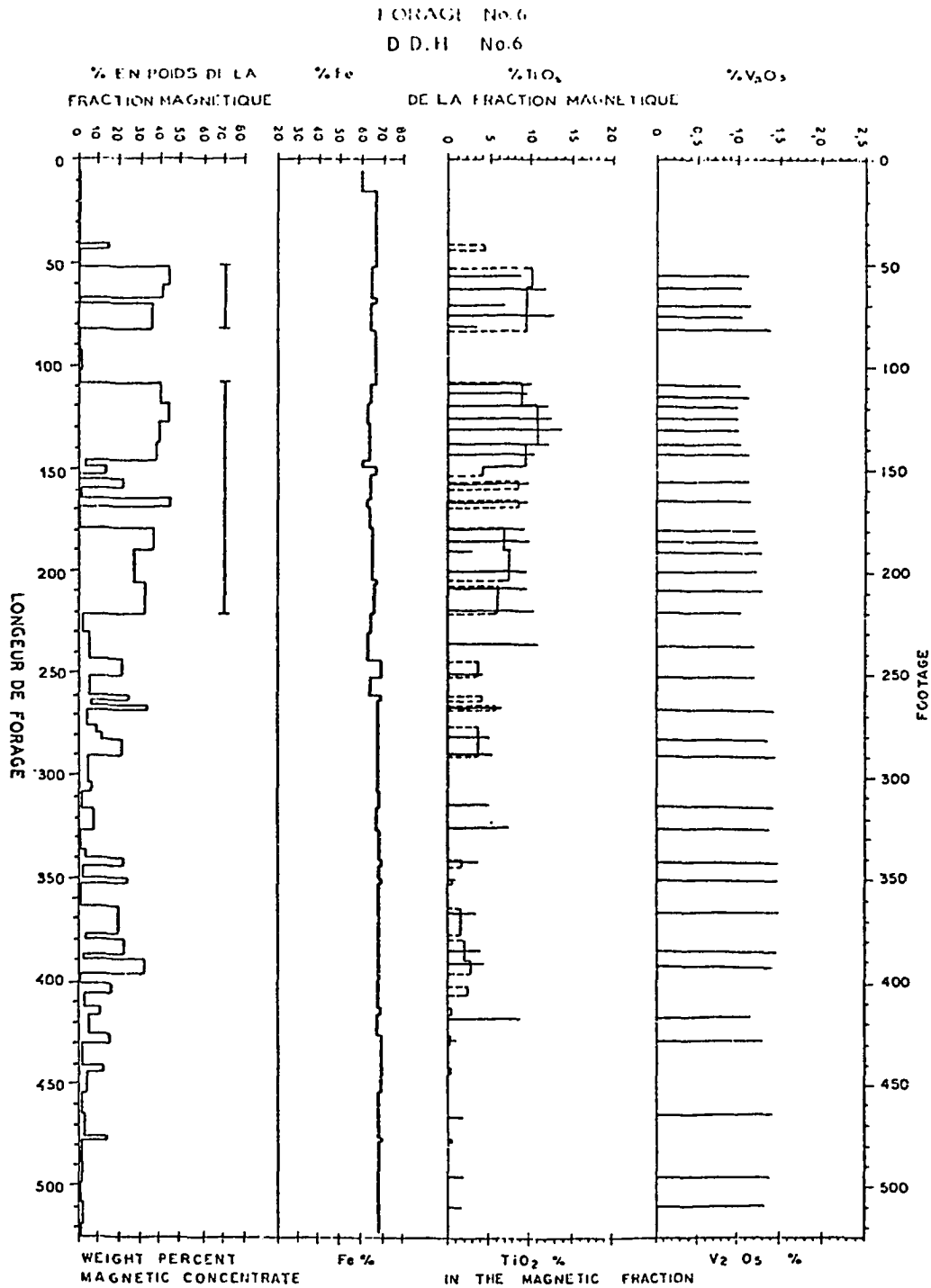Rinfret Township. (From Kish, 1971, fig. 7-5)

Fig. 156. Graphic plot of assays from drill hole No. 6, Jalore,
Rinfret Township, (From Kish,1971, fig. 7-6)

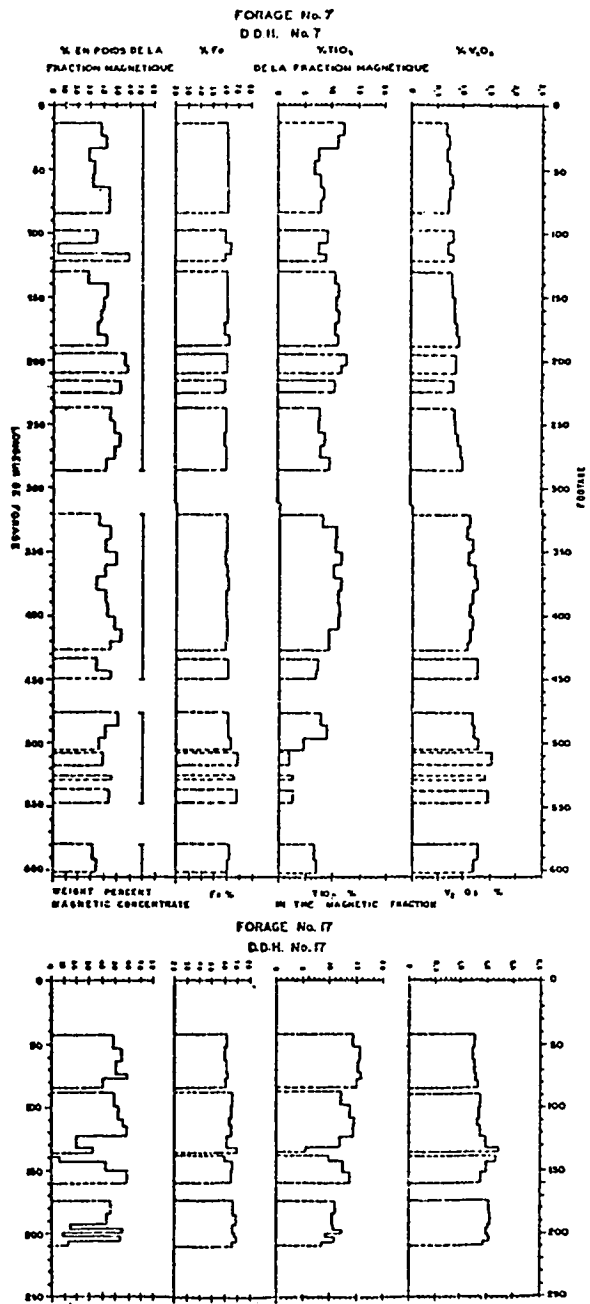Fig. 157.   Graphic plot of assays from holes 7 and 17, Q.D.N.R.,
            Rinfret Township (From Kish,1971,fig.7-7 and Avramtchev,
            1975 data)

FORAGE No.8

D.D.H. No.8

Fig. 158. Graphic plot of assays from drill hole
No. 8, Q.D.N.R. Rinfret Township.
From Kish,1971, fig. 7-8)
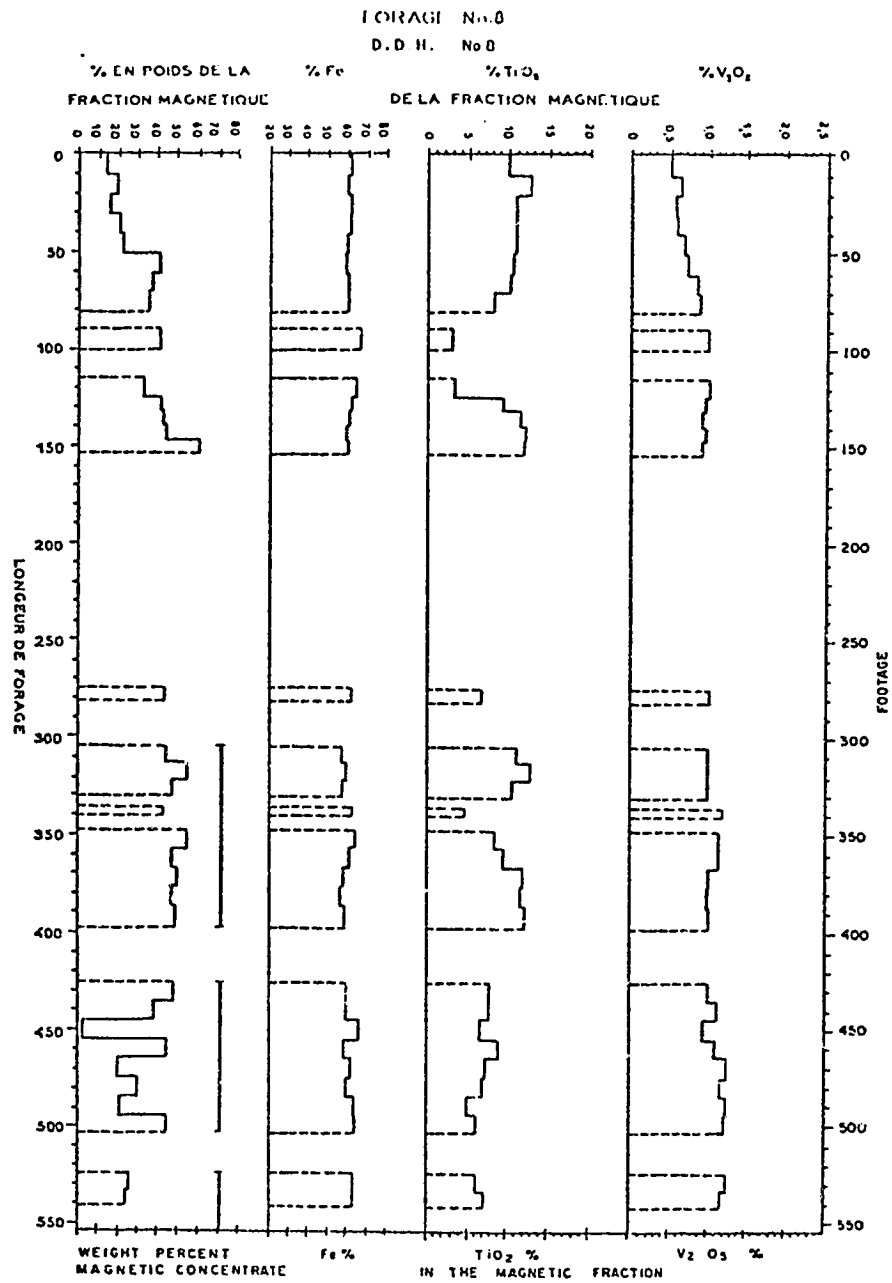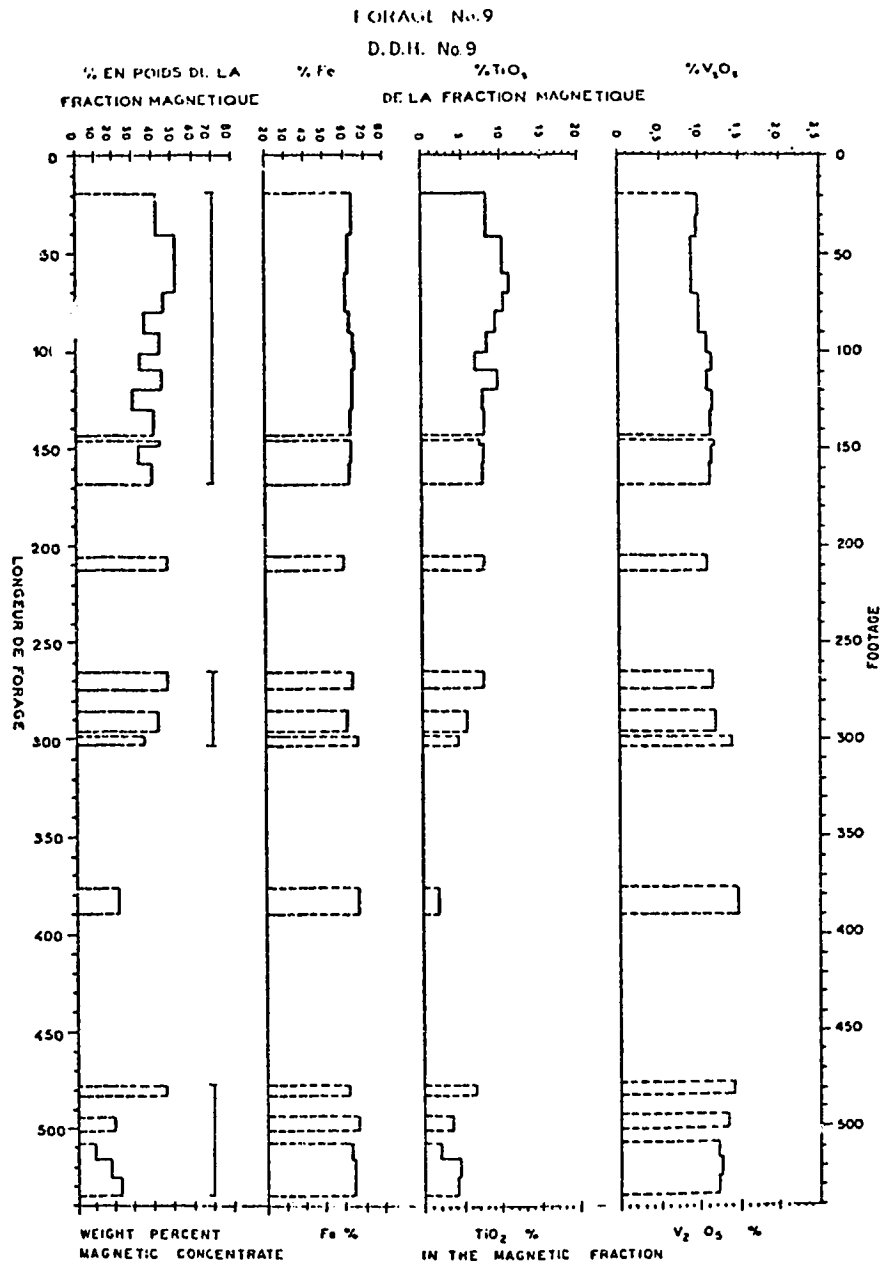
Fig. 159. Graphic plot of assays from hole No. 9, Q.D.N.R.
Lemoine Township. (From Kish, 1971, fig. 7-9)
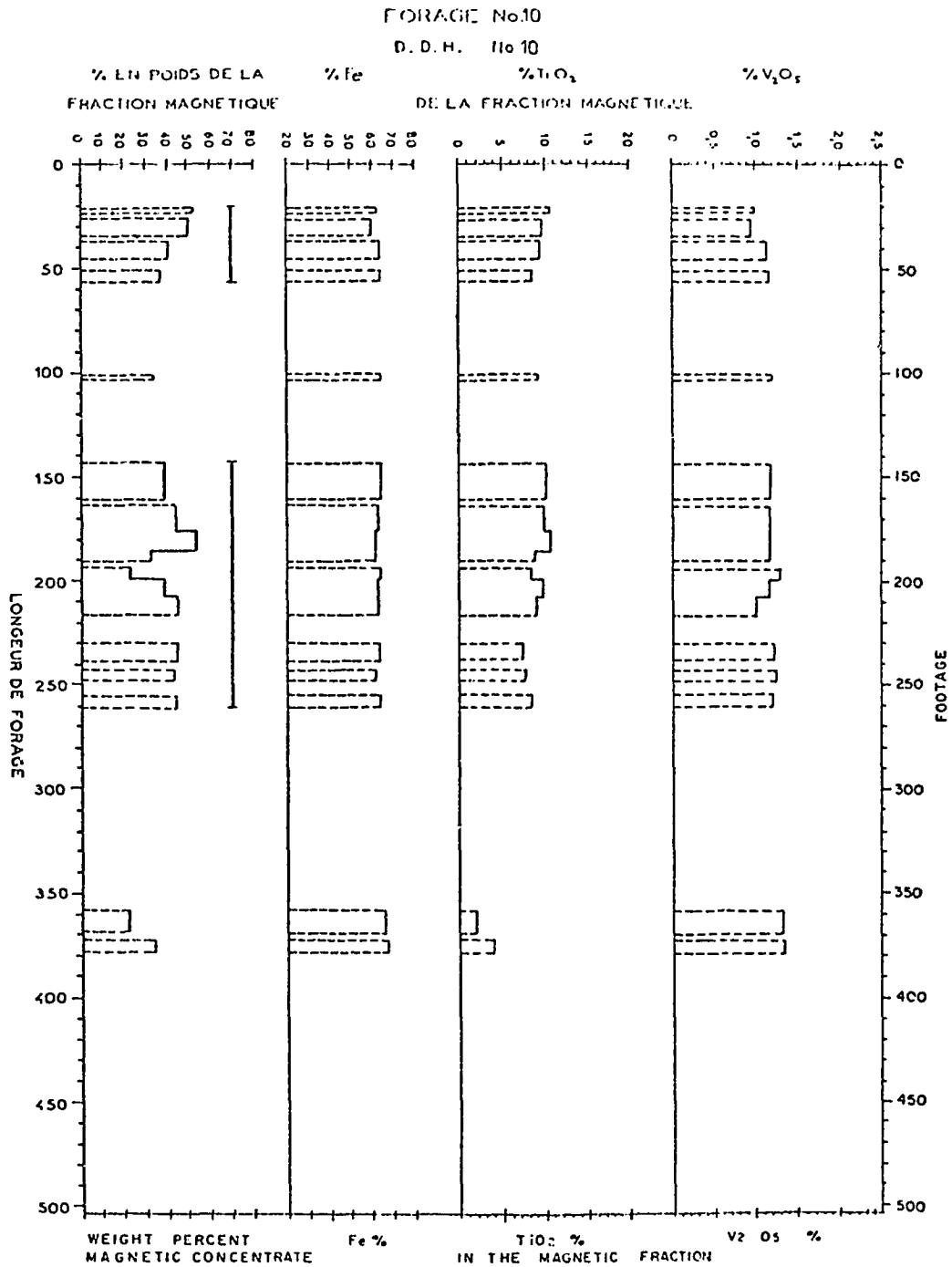
Fig. 160. Graphic plot of assays from hole No. 10, Q.D.N.R., Lemoine
Township (from Kish, 1971, fig. 7-10)

TOTAL Fe ANALYSES – TREPAN MINING – LEMOINE
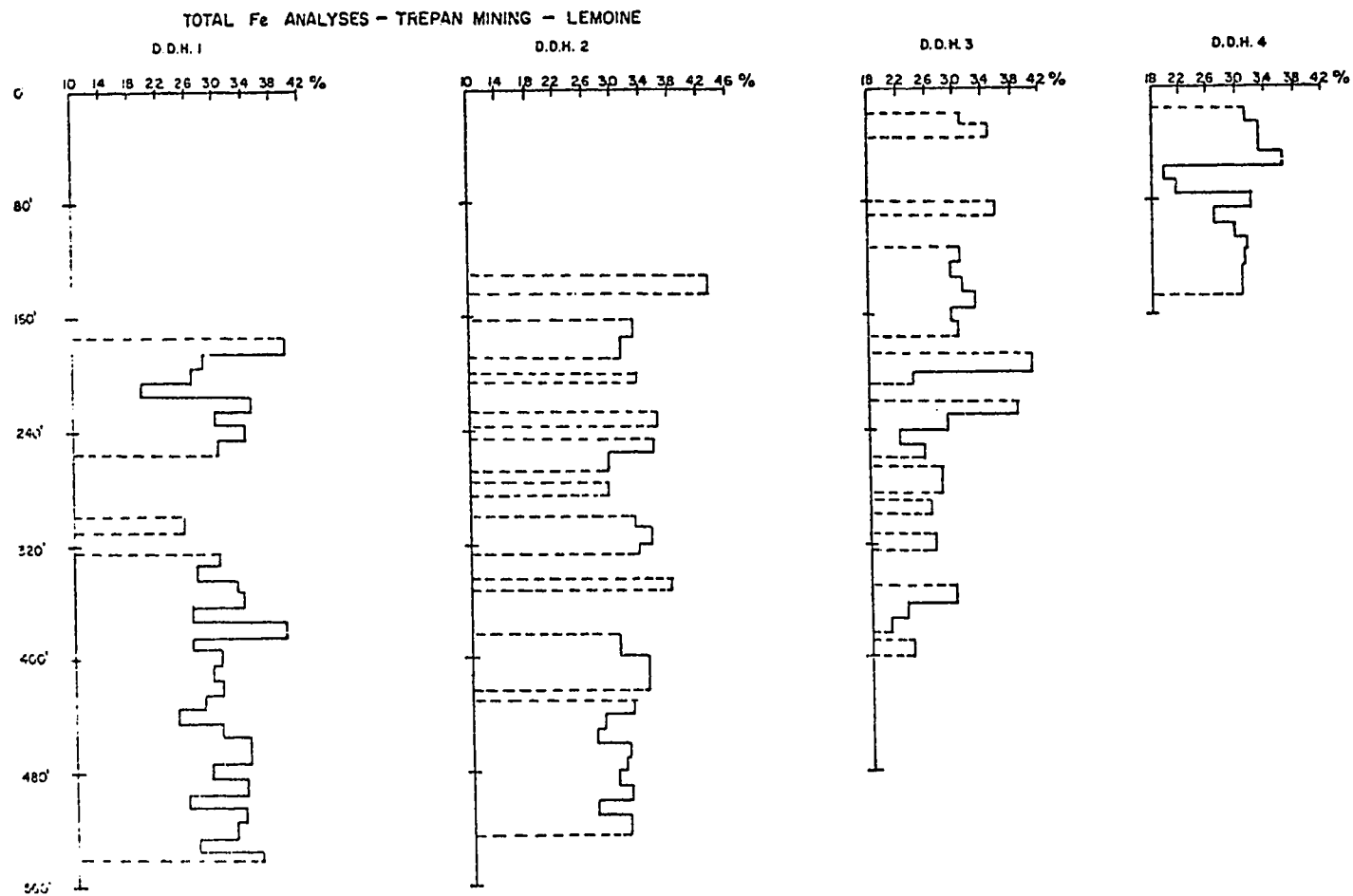
Fig. 161. Graphic plot of Fe analyses from drill holes, Trepan Mining Co., Lemoine
Township. Data in open files, Q.D.N.R.

TiO$_2$ ANALYSES − TREPAN MINING − LEMOINE

D.D.H. − 1   D.D.H. − 2   D.D.H. − 3   D.D.H. − 4

Fig. 162.   Graphic plots of TiO$_2$ analyses from drill holes, Trepan Mining Co.,
Lemoine Township.   Data in open files, Q.D.N.R.

Trepan Mining Co. drilled four holes in Lemoine Township (Fig. 140). Unfortunately, we do not know where the analyses were done and we do not have results of concentration tests. The holes were drilled down-the-dip and the lengths of cores analysed are meaningless. We note, however, a decrease in TiO_2 content with respect to the Rinfret zone.

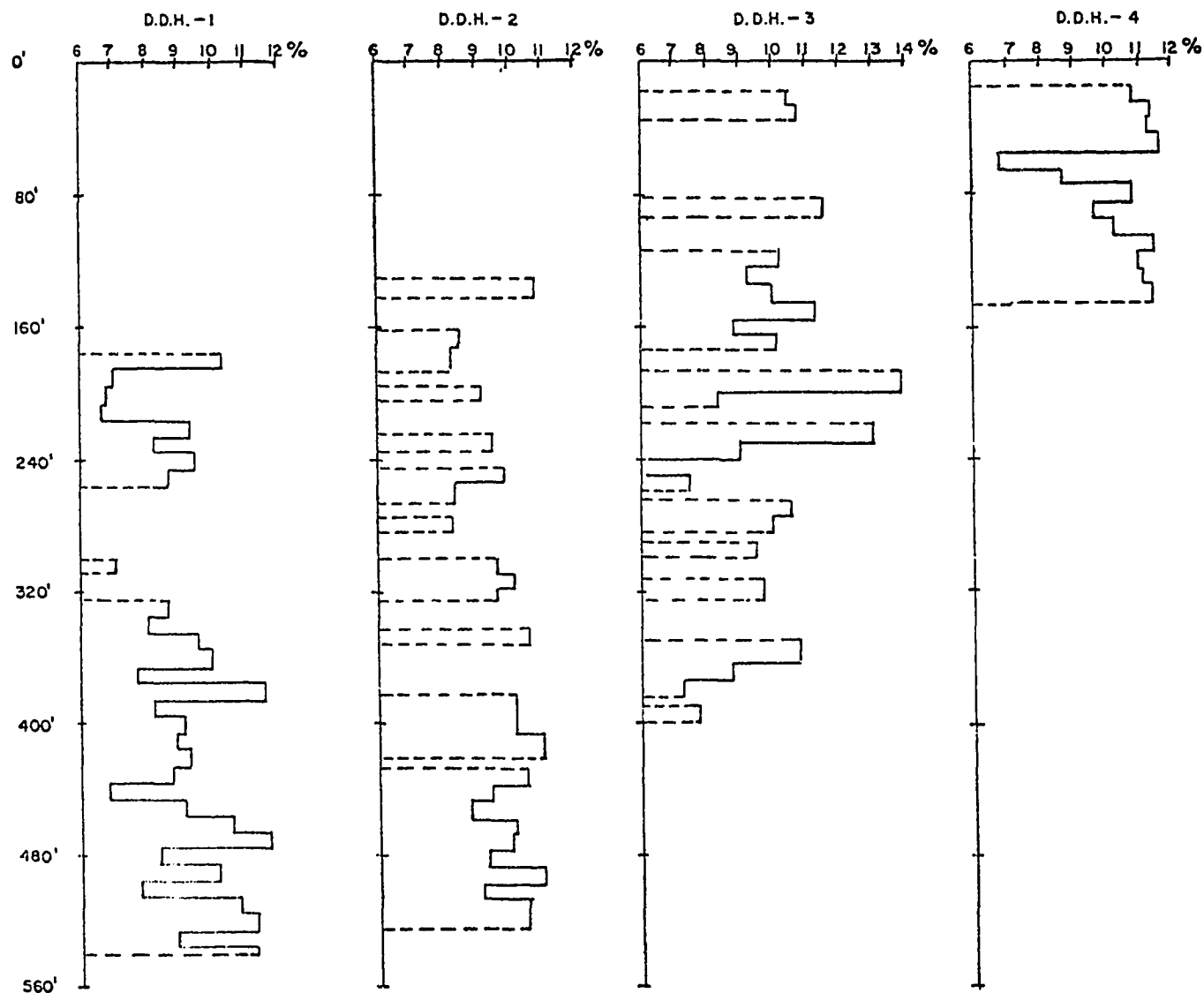Table 118 shows analyses of a series of grab samples taken along the IGC traverse in Lemoine Township, not far from Trepan drill holes (Fig. 140). Samples 110 to 112 are from the P_1 member, 113 to 122 from the P_2 member, and 123 from the very thin band of magnetite-rich metapyroxenite from the upper part of the P_3 member.

Cache Lake zone

The Layered Zone as defined on the south limb extends across the western portion of the north limb (Figs. 140, 163, and Plate 1). The LZ is thinner than on the south limb and the anorthositic members are more difficult to identify. The TiO_2 and V_2O_5 content is much lower than in the LZ of the south limb. Table 119 summarizes the data from 1143.8 feet of drilling by Grand Chibougamau. Unfortunately, we do not know the laboratory responsible for the analyses and no metallurgical testing was done on the samples. It is interesting to compare the results of Grand Chibougamau with those of C.M. & S. (Table 120): the total Fe shows the same average, 21.4%, and nearly the same TiO_2 content (3.6 vs 3.7%).

In 1968, following the discovery of vanadium on the south limb, a series of samples from hole C-8 were sent to the Q.D.N.R. laboratories for analysis and metallurgical testing. The results are in Table 121. The variations in Fe, TiO_2, and V_2O_5 do not fit a clearly predictable pattern and much more work remains to be done to clarify the geochemical situation of the north limb Layered Zone.

TABLE 118

CHEMICAL ANALYSES OF SPOT SAMPLES ALONG THE I.G.C. TRAVERSE - LEMOINE

ANALYSES CHIMIQUES D'ECHANTILLONS PONCTUELS PRIS AU LONG DU CHEMINEMENT
I.G.C. - LEMOINE

Sample no. Echantillon no.	Fe. total %	Magnetic Concentrate (200 mesh) Concentré Magnétique		
		Wt % % en poids	Fe %	TiO_2 %	V_2O_5 %
71-110	29.33	26.3	64.22	6.61	1.22
111	48.55	61.6	61.25	11.85	1.22
112	48.17	52.6	64.31	6.96	1.27
113	44.33	53.5	60.02	11.76	1.08
114	43.65	48.3	61.77	10.06	1.22
115	51.38	66.0	61.25	12.28	1.10
116	48.93	61.6	60.37	13.22	0.95
117	52.04	63.4	62.65	11.00	0.98
118	50.12	49.3	68.07	2.84	0.98
119	38.24	33.8	65.00	6.38	0.96
120	47.09	48.4	63.00	9.48	0.94
121	31.62	22.8	60.30	13.40	0.80
122	34.91	36.0	63.52	9.16	0.49
123	30.83	20.7	59.85	2.63	0.06
Mathematical average Moyenne mathématique	42.80	45.7	62.54	9.12	0.95

Analyses done in laboratories of the Quebec D.N.R. in 1972

Analyses faites dans les laboratoires du M.R.N. à Québec en 1972

Samples from Gilles Allard

Echantillons de Gilles Allard
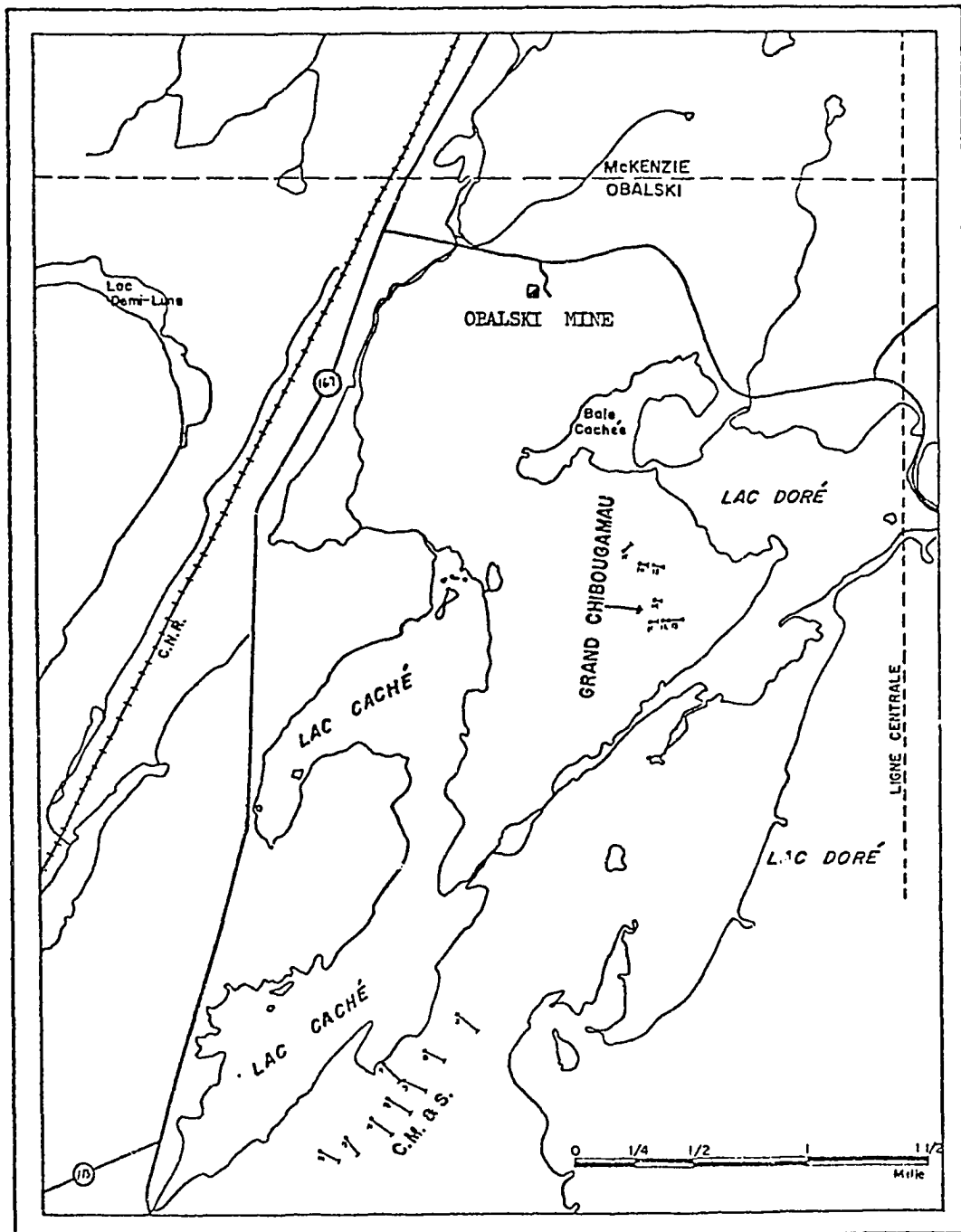
Fig.163. Sketch map showing the location of drill holes in the Layered Zone around Cache Lake, Obalski Township.

TABLE 119

WEIGHTED AVERAGES OF CHEMICAL ANALYSES FROM D.D.H. GRAND CHIBOUGAMAU – OBALSKI

MOYENNES PONDEREES D'ANALYSES CHIMIQUES DES TROUS DE SONDAGE DE GRAND
CHIBOUGAMAU – OBALSKI

Hole no. No. du trou	Length Longueur	Fe total %	TiO_2 %
11	236'	19.6	4.46
12	94'	25.1	4.6
13	263.5'	22.8	3.7
14	255'	20.0	4.0
15	86.8'	17.8	2.5
16	77'	19.6	2.3
17	131.5'	25.1	3.8
Weighted average Moyenne pondérée	1143.8'	21.4	3.7

Holes drilled in 1952

Les trous ont été forés en 1952

It is not known where the analyses were done

On ne connait pas le laboratoire responsable des analyses

TABLE 120

WEIGHTED AVERAGES OF CHEMICAL ANALYSES FROM D.D. HOLES - CHIBOUGAMAU
MINING AND SMELTING - CACHE LAKE - OBALSKI

MOYENNES PONDEREES D'ANALYSES CHIMIQUES DES TROUS DE SONDAGE DE
CHIBOUGAMAU MINING AND SMELTING - CACHE LAKE - OBALSKI

Hole no. No. du trou	Length Longueur	Fe total %	TiO$_2$ %
C- 3	326.6'	22.1	6.2
C- 8	116.2'	23.5	4.4
C- 9	180.8'	19.6	4.5
C-10	367.6	18.5	2.7
C-11	256.3	22.2	4.0
C-12	217.6	20.1	3.1
C-13	325'	17.3	2.9
C-14	305'	18.0	2.1
Weighted average (L) Moyenne pondérée (L)	2095.1'	21.4	3.6

Analyses aone in 1956 at the Campbell Chibougamau Mines Assay Office

Analyses faites aux laboratoires de la Campbell Chibougamau Mines en 1956

Samples from C. Krause and G. Allard

Echantillons de C-Krause et G. Allard

TABLE 121

CHEMICAL ANALYSES (SPOT SAMPLES) FROM HOLE C.M. & S. - C-8 CACHE LAKE - OBALSKI

ANALYSES CHIMIQUES (ECHANTILLONS PONCTUELS) DU TROU DE SONDAGE C.M. & S. C-8 CACHE LAKE - OBALSKI

Footage Pieds de carotte	Fe total %	Magnetic Concentrate (200 mesh) Concentré Magnétique			
		Wt % % en poids	Fe %	TiO_2 %	V_2O_5 %
105 -	23.8	13.3	59.5	4.7	0.50
117.5- 120.	33.2	32.0	60.6	3.8	0.40
120. - 122.5	28.8	19.8	62.6	3.5	0.50
127. - 128.5	33.9	31.1	59.6	6.15	0.48
132. - 133.	33.8	39.4	60.6	6.40	0.43
137. - 140.	33.3	32.6	60.2	6.46	0.45
140. - 145.	31.2	28.4	58.1	6.51	0.53
145. - 150.	32.0	29.2	57.9	9.5	0.59
152. - 154.	26.9	23.3	55.9	9.4	0.61
158. - 160.	27.7	19.3	57.7	9.7	0.69
160. - 165.	29.6	27.1	54.1	7.3	0.34
165. - 170.	30.2	33.3	53.6	3.8	0.21
226. - 230.	28.5	28.6	53.1	3.8	0.23
235.5- 240.	29.9	27.7	56.1	5.90	0.28
240. - 245.	30.2	27.6	57.7	6.1	0.30
248. - 250.	32.0	31.0	60.5	5.7	0.36
250. - 252.5	30.0	29.2	56.2	5.34	0.23
258. - 265.	27.3	21.1	55.7	6.52	0.45
265. - 271.	30.7	26.1	59.9	6.58	0.55
437. -	34.8	40.7	61.4	2.73	0.96
495. - 496.5	26.1	26.3	60.9	1.99	0.80
Mathematical average Moyenne mathématique	30.2	27.9	58.2	5.8	0.47

Hole drilled in 1956 by Chibougamau Mining and Smelting

Ce trou a été sondé en 1956 par Chibougamau Mining and Smelting

Samples from Gilles Allard

Echantillons de Gilles Allard

Analyses done in the laboratories of the Q.D.N.R. en 1969

Analyses faites dans les laboratoires du M.R.N. du Québec en 1969

Figures 164 to 168 summarize the assays for the various holes drilled on the western portion of the north limb.

Portage Island-Sorcerer Mountain-Magnetite Bay zones

The eastern portion of the north limb of the D.L.C., east of Jaculet shaft, is underlain by magnetite-rich rocks which are very different from those of the southern limb. The magnetite-bearing zone does not show the inch-scale layering characteristic of the south limb; the plagioclase and ferropyroxene common on the south limb are replaced by serpentinized olivine. The rock is mostly a mixture of serpentine, primary magnetite and magnetite released during the serpentinization of the olivine (Figs. 69 and 70).

On the Portage Island north zone, 2055 feet of core (Table 122) average 20.1% Fe and 1.07% TiO_2. On the Portage Island south zone, 2090 feet (Table 123) average 17.5% Fe and 1.54% TiO_2.

Campbell Chibougamau Mines has done 41,380 feet of drilling on the Sorcerer Mountain and Magnetite Bay zones (Fig. 170) indicating 270,000,000 tons averaging 27.6% Fe and 1.1% TiO_2 (C.C.M. 1975). Tables 124 to 127 and Figure 169 show the detailed assays and metallurgical tests done on samples from holes Fe-5 from Magnetite Bay and FN-68 from Sorcerer Mountain. One can see a large difference between the results presented in Tables 124 and 125, both from hole Fe-5 at Magnetite Bay. This is mostly due to the -200 mesh grinding used in 1969 and the -325 mesh grinding used in 1974.

Table 128 gives the complete chemical analyses of drill core samples from hole SC-74-3 which was drilled southward across the entire Sorcerer Mountain zone. Sample 1 is a metaferropyroxenite with 15% total Fe but no magnetite: the iron is evidently in the chlorite. Samples 2 to 7 represent the main part of the magnetite-bearing zone. Sample 9 is a gabbroic meta-anorthosite from the top of the AZ and sample 8 is transitional between the main magnetite zone and the Anorthosite Zone, producing only 6.7% magnetic concentrate by weight.

TOTAL Fe ANALYSES - (C.M. & S.) - CACHÉ LAKE - OBALSKI

Fig. 164. Graphic plots of Fe analyses from drill holes, C.M. & S., Caĝhe Lake, Obalski Township. Data in open files, Q.D.N.R.

TIO$_2$ ANALYSES (C.M.& S.) CACHÉ LAKE – OBALSKI
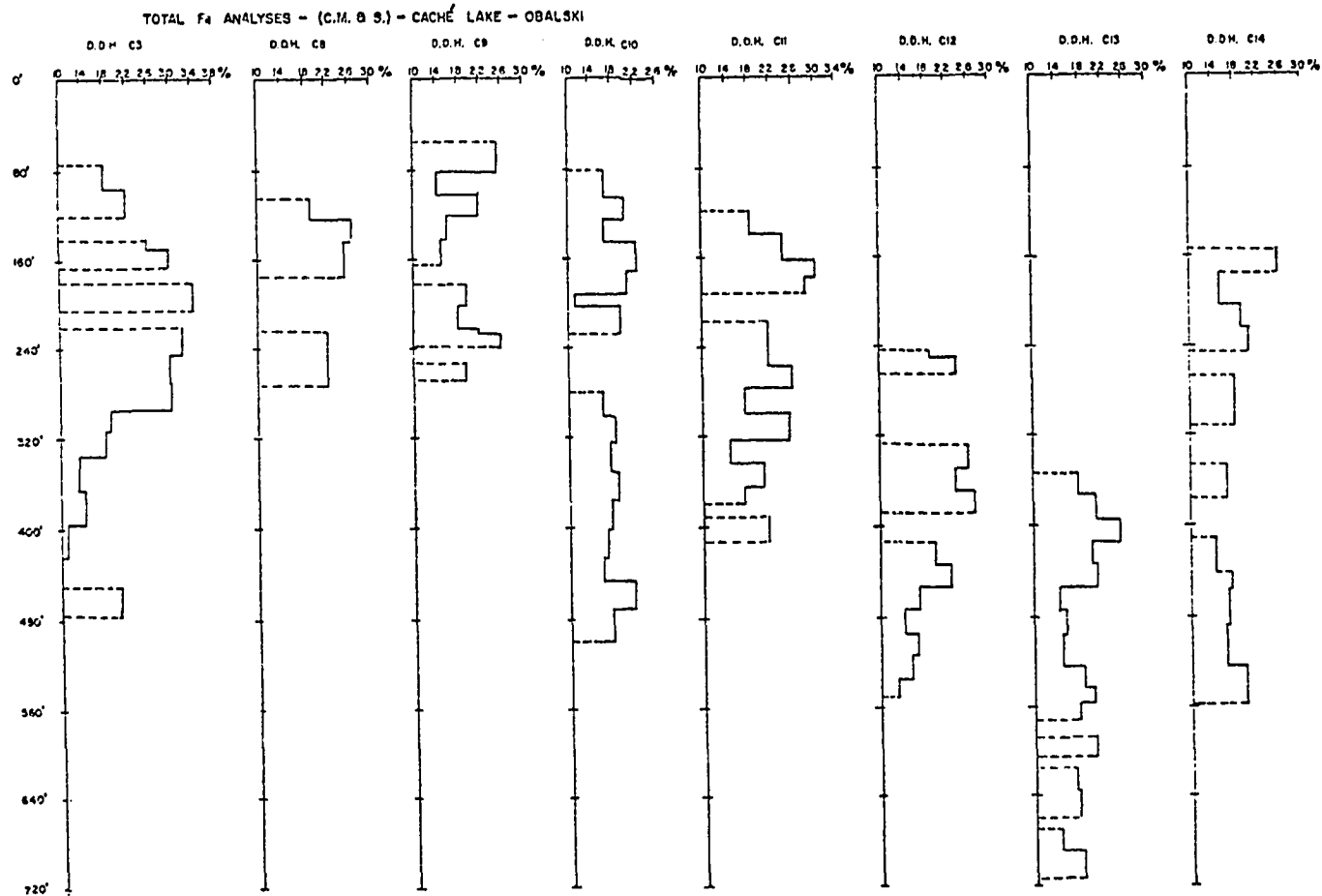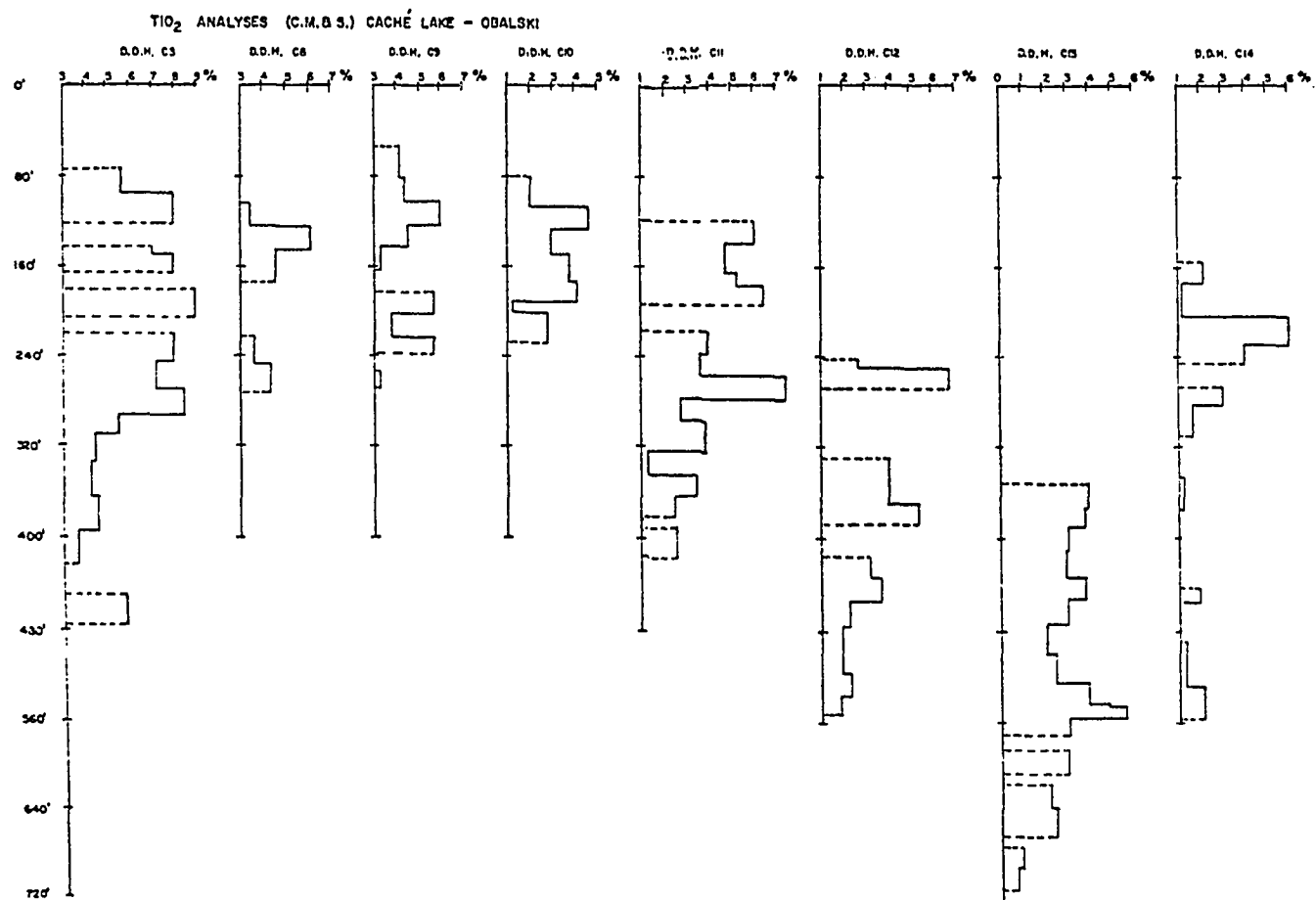
Fig. 165. Graphic plots of TiO$_2$ analyses from drill holes, C.M. & S, Cache Lake, Obalski Township, Data from open files, Q.D.N.R.
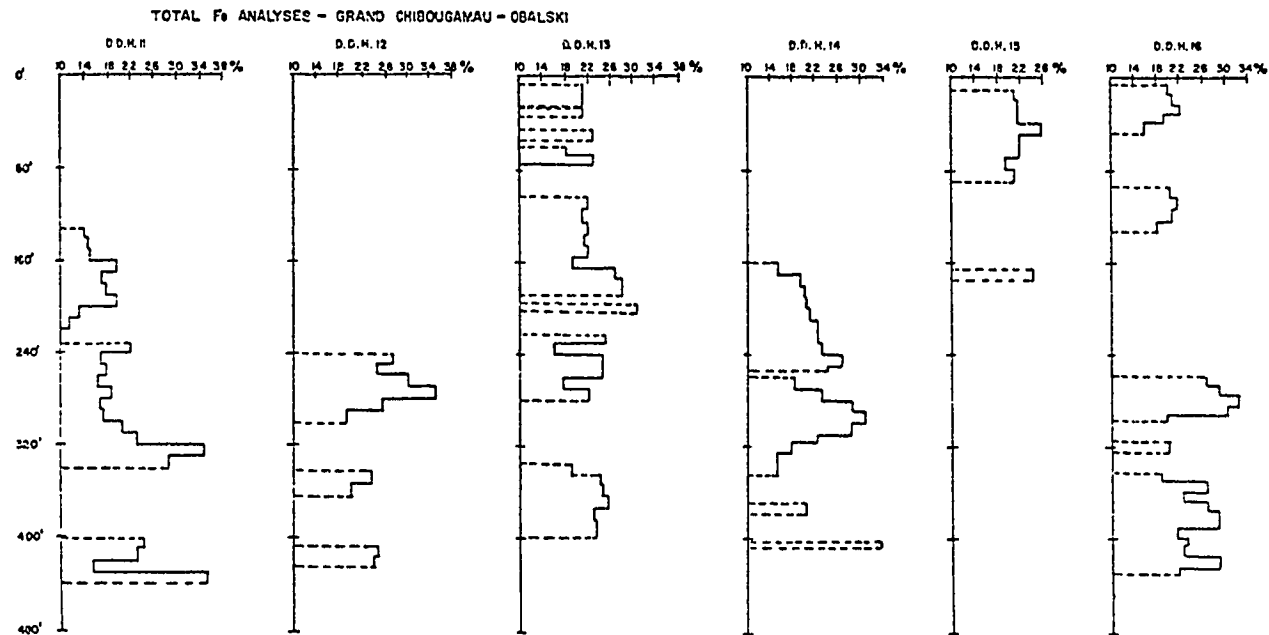
Fig. 166. Graphic plot of Fe analyses, Grand Chibougamau, Obalski Township.
From data in open files, Q.D.N.R.
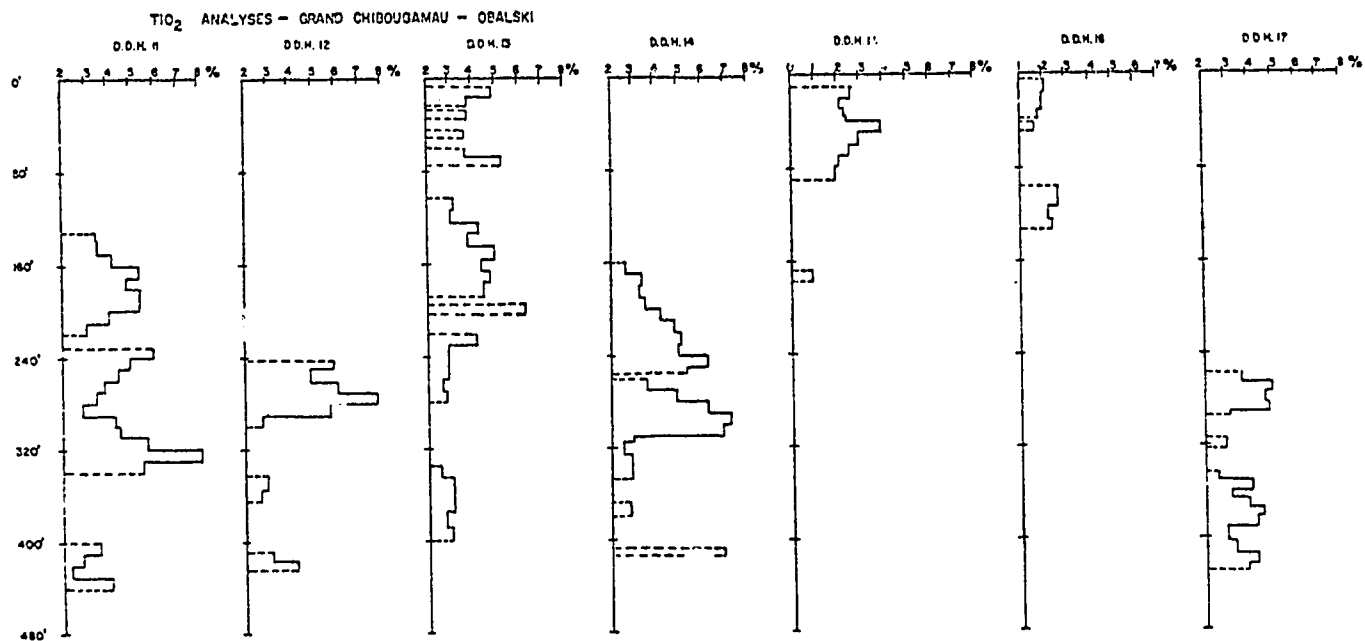
Fig. 167.   Graphic plot of TiO$_2$ analyses from drill holes, Grand Chibougamau,
Obalski Township.   From data in open files,Q.D.N.R.

FORAGE (C.M.& S.) C-8 – CACHÉ LAKE – OBALSKI

MAGNETIC CONCENTRATE – CONCENTRÉ MAGNÉTIQUE

TOTAL Fe % Fe % TIO₂ % V₂O₃ %
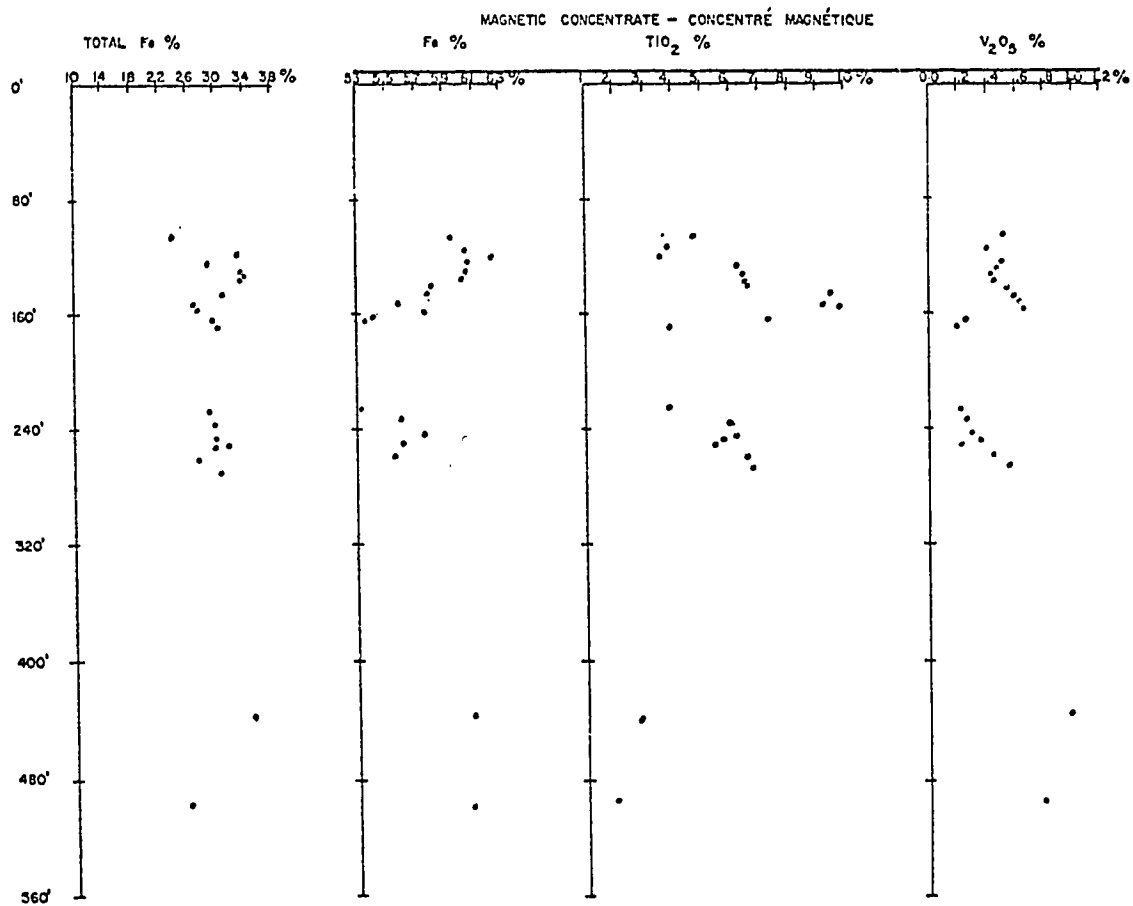
Fig. 168. Graphic plot of assays of concentrates from hole C-8, C.M. & S, Obalski Township. Samples from Allard, done in Q.D.N.R. labo.

TABLE 122

WEIGHTED AVERAGES OF ANALYSES - D.D.H. NORTH ZONE - PORTAGE - ROY

MOYENNES PONDEREES DES ANALYSES - SONDAGES DANS ZONE NORD - PORTAGE - ROY

Hole Trou de sondage	Section Section	Footage Pieds de carotte	Length Longueur	Fe %	TiO_2 %
197	5500 W	677 - 855	178'	27.00	1.21
200	5000 W	102 - 157	55'	21.3	1.39
		301 - 461	160'	24.6	1.07
201	4000 W	320 - 457	137'	22.8	1.25
202	3000 W	(130 - 545)	375'	25.3	0.90
206	3000 W	730 -1060	330'	33.7	1.13
208	2000 W	247 - 557	310'	16.1	1.71
219	6500 W	75 - 245	170'	24.7	0.63
		330 - 670	340'	25.2	0.65
Weighted averages Moyennes pondérées			2055'	20.1	1.07

TABLE 123

WEIGHTED AVERAGES OF ANALYSES - D.D.H. SOUTH ZONE - PORTAGE - ROY

MOYENNES PONDEREES DES ANALYSES - SONDAGES DANS ZONE SUD - PORTAGE - ROY

Hole Trou de sondage	Section Section	Footage Pieds de carotte	Length Longueur	Fe %	TiO_2 %
196	5000 W	288 - 371	83'	22.5	2.29
198	8000 W	(430 - 562)	112'	22.5	0.69
199	8000 W	(449 - 729)	280'	17.3	2.16
203	9000 W	(410 - 670) 450 - 630	180'	19.2	1.86
204	9000 W	(430 - 910)	495'	16.62	1.58
207	4000 W	290 - 540	250'	12.40	1.71
209	5500 W	180 - 560	380'	22.40	1.43
211	6500 W	305 - 615	310'	27.2	0.82
Weighted averages Moyennes pondérées		2090'	2090'	17.5	1.54
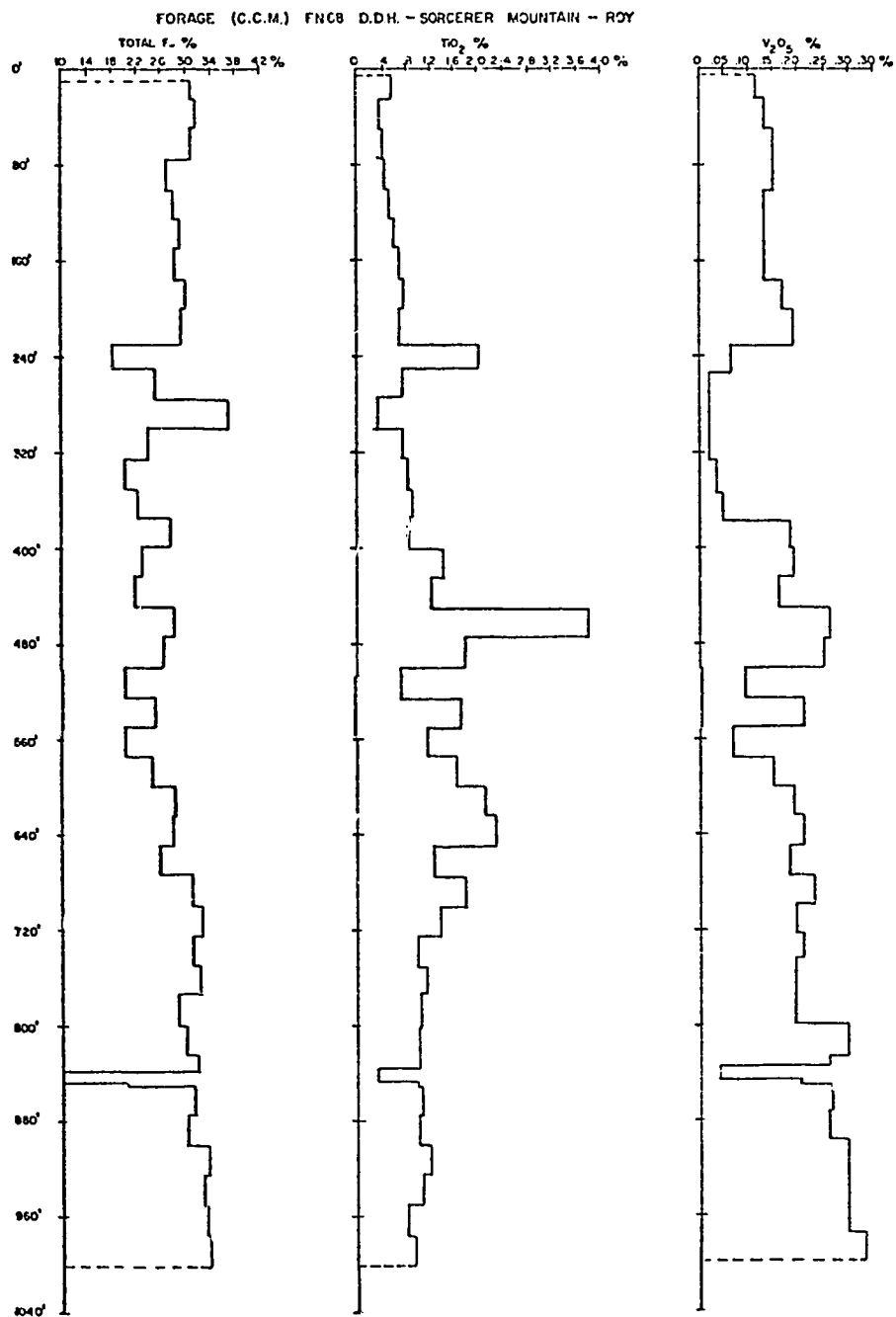
Fig. 169. Graphic plot of analyses for Fe,TiO$_2$, and V$_2$O$_5$ from hole FN-68, Sorcerer Mountain, Roy Township (data CCM)

NORTH ZONE

BAG BAY

MAGNETITE BAY

SOUTH ZONE

LAKE CHIBOUGAMAU

LEGEND

☐ Ore Zone

o Diamond Drill Holes

PLAN

SCALE: 1" = 2000 Feet

Section 42 E

Section 52 E

SECTION A - A

SCALE: 1" = 1000 Feet

NORTH ZONE

SOUTH ZONE   MAGNETITE BAY

23.6% Fe / 543.0'

24.7% Fe / 291.4'

27.8% Fe / 535.0'   Section 52 E

21.2% Fe / 451.2'

28.3% Fe / 700.0'

26.5% Fe / 143.5'

25.9% Fe / 505.5'

Section 42 E

Fig. 170. Sketch map and cross section of the Campbell Chibougamau Mines Ltd Sorcerer Mountain (north zone) and Magnetite Bay (south zone) deposits.

(from FERCHIB report)

TABLE 124

CHEMICAL ANALYSES (SPOT SAMPLES) D.D. HOLE Fi-5 - MAGNETITE BAY

ANALYSES CHIMIQUES (ECHANTILLONS PONCTUELS) TROU Fi-5 - MAGNETITE BAY

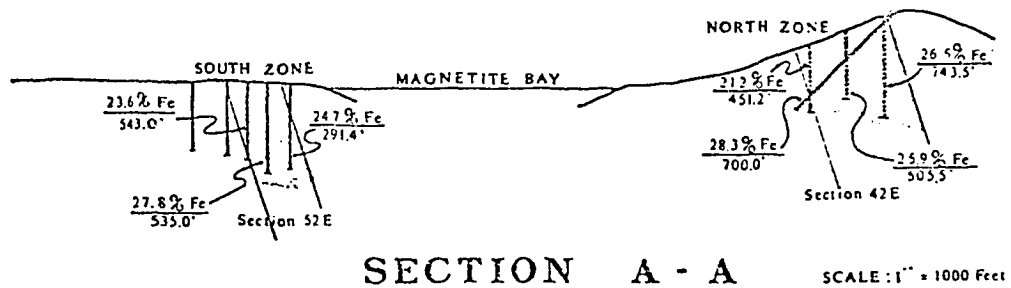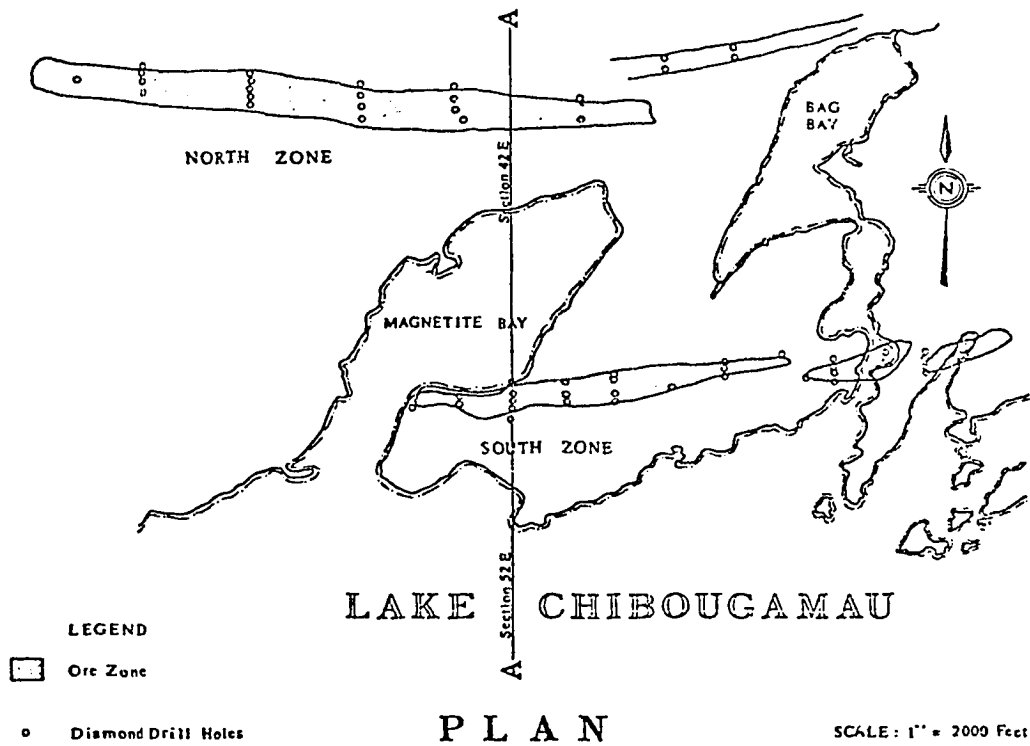| Sample no. Echantillon no.	Footage Pieds carotte	Fe total %	Magnetic concentrate (200 mesh) Concentré magnétique			
			wt % % en poids	Fe %	TiO$_2$ %	V$_2$O$_5$ %
A-68-30	245-248	8.01	0.6	Echantillon insuffisant		
A-68-31	325-332	14.85	18.2	65.1	3.29	0.04
A-68-32	332-338	5.13	4.6	57.6	8.95	0.09
A-68-33	352-355	5.76	4.8	42.3	3.07	0.11
A-68-34	365-367	4.06	0.3	Echantillon insuffisant		
A-68-35	372-375	4.68	0.8	Echantillon insuffisant		
A-68-36	390-395	7.12	9.6	41.7	2.17	0.07
A-68-37	410-414	12.13	20.8	49.5	2.27	0.11
A-68-38	415-418	19.40	31.6	52.2	0.98	0.18
A-68-39	421-424	27.71	42.1	61.9	2.33	0.55
A-68-40	500-504	10.00	11.0	59.8	4.16	0.01
A-68-41	507-510	13.66	26.1	45.8	1.64	0.11
A-68-42	510-515	28.07	45.4	57.0	1.34	0.41
A-68-43	520-525	34.89	54.5	59.5	0.96	0.53
A-68-44	532-535	26.29	46.3	52.4	0.81	0.67
A-68-45	544-547	22.95	58.0	37.0	2.14	0.01
A-68-46	550-552	13.11	40.0	29.0	2.42	0.03
A-68-47	555-557	12.28	19.4	55.7	3.41	0.10
A-68-48	562-564	9.15	14.2	49.2	5.74	0.12
A-68-49	567-569	8.00	7.2	60.0	7.42	0.09
A-68-50	580-582	7.66	9.5	64.4	0.87	0.09
A-68-51	587-589	8.57	12.0	50.2	6.00	0.16
A-68-52	600-601	23.88	34.8	63.1	0.93	1.17
A-68-53	607-608	19.25	27.1	63.5	1.58	0.35
A-68-54	617-619	14.45	18.4	61.3	2.33	0.85
A-68-55	652-653	16.41	26.6	55.3	4.75	0.64
A-68-56	660-662	12.58	18.3	54.4	3.15	0.88
A-68-57	667-669	16.62	22.3	61.5	2.73	0.92
A-68-58	670-672	13.23	19.0	57.0	2.70	0.62
A-68-59	683-685	27.03	27.6	56.1	0.62	0.37
A-68-60	686-688	21.31	33.3	58.8	1.27	0.27
A-68-61	693-695	14.54	27.1	46.3	2.39	0.19
A-68-62	695-700	16.80	26.1	58.1	1.27	0.18
A-68-63	708-712	9.85	11.6	65.6	2.76	0.04
A-68-64	717-719	6.94	3.4	65.2	3.51	0.36
A-68-65	804-806	21.10	33.1	58.7	0.50	0.37
A-68-66	810-812	7.70	6.9	61.3	2.79	0.30
A-68-67	822-824	4.81	1.2	x	x	0.62
A-68-68	836-840	18.64	31.2	53.1	1.89	0.37
A-68-69	846-848	36.91	52.4	67.5	0.68	0.60
A-68-70	867-869	32.39	53.6	53.7	0.78	0.53
A-68-71	872-874	33.08	49.2	63.8	0.93	0.75
A-68-72	931-932	11.55	19.8	46.4	1.95	0.16
A-68-73	940-942	16.67	28.9	53.8	1.93	0.21
A-68-74	945-947	9.98	14.5	51.5	2.59	0.12
A-68-75	957-959	11.48	36.4	21.5	1.63	0.04
A-68-76	968-970	11.81	17.2	57.1	2.68	0.14
A-68-77	973-975	15.61	35.7	33.6	5.93	0.09
A-68-78	982-984	19.15	29.0	59.3	0.96	0.06
A-68-79	996-998	25.48	42.7	54.9	1.74	0.05
A-68-80	1003-1005	30.57	45.3	62.2	2.01	0.59
A-68-81	1010-1012	30.29	46.3	61.6	1.70	0.30
A-68-82	1022-1024	26.37	41.4	58.7	2.18	0.16
A-68-83	1041-1043	11.19	19.9	42.6	4.83	0.04
A-68-84	1053-1055	7.27	7.9	51.8	7.21	0.04
A-68-85	1068-1070	35.06	51.8	64.5	1.32	0.19
A-68-86	1071-1073	16.03	25.0	57.5	1.30	0.23
A-68-87	1080-1082	21.08	29.5	60.5	1.35	0.30
A-68-88	1085-1087	9.30	8.4	55.6	1.39	0.02
A-68-89	342-348	6.63	13.4	50.2	5.20	0.02
Mathematical average Moyenne mathématique			12.94	15.14	58.56	2.60	0.29

TABLE 125

SUMMARY OF WEIGHTED AVERAGES (FULL SAMPLES) D.D.H. FE-5 - MAGNETITE BAY
SOMMAIRE DES ANALYSES PONDEREES (ECHANTILLONS CONTINUS) DU TROU DE SONDAGE
FE-5 - MAGNETITE BAY

Sample no. No. échantillon	Footage Pieds carotte	Length Longueur	Fe total %	TiO$_2$ %	Grind -325 mesh Broyage -325 mesh
	321 - 1097.8	776.8'	13.0	1.05	

Analyses done by Campbell Chibougamau Mines Assay office in 1965
Analyses faites par le laboratoire de Campbell Chibougamau Mines Ltd en 1965

F-5-4	321 - 500.8	179.8'	10.4	1.12	95%
F-5-1	500.8 - 716	215.2'	18.5	0.95	95%
F-5-2A	716 - 950	234'	14.3	0.76	99%
F-5-3	950 - 1085	135'	21.0	1.27	96%
Weighted average (L) Moyenne pondérée (L)		763'	15.75	0.98	

Sample no. No. échantillon	Footage Pieds carotte	Length Longueur	Magnetic Concentrate (-325 mesh) Concentré Magnétique			
			Wt % % en poids	Fe %	TiO$_2$ %	V$_2$O$_5$ %
F-5-4	321 - 500.8	179.8'	3.3	70.6	0.8	0.26
F-5-1	500.8 - 716	215.2'	18.8	69.1	1.0	0.43
F-5-2A	716 - 950	234'	3.9	69.9	0.7	0.45
F-5-3	950 - 1085	135'	23.1	68.6	1.2	0.40
Weighted Average (L) Moyenne Pondérée (L)		763'	11.4	69.61	1.2	0.39

Analyses done by Q.D.N.R. laboratories - 1974 - for Campbell Chibougamau Mines Ltd
Analyses faites aux Laboratoires du M.R.N. à Québec en 1974 - pour Campbell
Chibougamau Mines Ltd.

TABLE 126

CHEMICAL ANALYSES (SPOT SAMPLES) D.D.HOLE FN-68 - SORCERER MOUNTAIN

ANALYSES CHIMIQUES (ECHANTILLONS PONCTUELS) TROU FN-68 - MONTAGNE DU SORCIER

Footage Pieds carotte	Fe total %	TiO_2 %	V_2O_5 %
56 - 57	36.12	0.38	0.17
70 - 71	37.0	0.31	0.10
76 - 77	29.25	0.31	0.06
87 - 88	31.5	0.38	0.12
101 - 102	30.95	0.44	0.12
121 - 122	32.7	0.62	0.12
131 - 132	29.2	0.40	0.12
136 - 137	34.5	0.48	0.10
162 - 163	28.1	0.32	0.10
207 - 208	44.0	1.72	0.64
257 - 258	34.4	0.50	0.02
267 - 268	41.6	0.25	0.007
284 - 285	29.1	0.55	0.007
304 - 305	31.8	0.07	0.007
318 - 319	37.9	0.15	0.007
365 - 366	34.6	0.78	0.04
371 - 372	24.4	0.59	0.10
391 - 392	27.3	0.55	0.32
415 - 416	21.1	0.95	0.15
432 - 433	12.4	0.65	0.19
Mathematical Average Moyenne mathématique	31.40	0.52	0.12

Analyses done by the laboratory of the Q.D.N.R. in 1969

Analyses faites aux laboratoires du M.R.N. en 1969

Samples from André Dorr

Echantillons de André Dorr

TABLE 127

SUMMARY OF WEIGHTED AVERAGES ANALYSES (FULL SAMPLES) D.D.H. FN-68
SORCERER MOUNTAIN

SOMMAIRE DES ANALYSES PONDEREES (ECHANTILLONS CONTINUS) SONDAGE FN-68
MONTAGNE DU SORCIER

Footage Pieds carotte	Length Longueur	Fe total %	TiO_2 %	V_2O_5 %	Grind -325 mesh Broyage -325 mesh
7.5 - 999.0	991.5	27.94	1.08	0.17	

Analyses done in laboratories of the Q.D.N.R. for Campbell Chibougamau Mines Ltd
in 1972

Analyses faites aux laboratoires du M.R.N. à Québec pour Campbell Chibougamau
Mines Ltd. en 1972

7.5 - 150	142.5'	32.7	0.44		99%
150 - 300	150'	31.6	0.80		99%
300 - 400	100'	27.5	0.79		92%
400 - 525	125'	25.9	1.78		99%
525 - 625	100'	25.8	1.63		95%
625 - 750	125'	30.5	1.50		95.5%
750 - 900	150'	31.2	0.95		95.2%
900 - 999	99'	33.5	0.94		95%
Weighted Average (L) Moyenne Pondérée (L)		30.0	1.08		

Foota Pieds carotte	Length Longueur	Magnetic Concentrate (325 mesh) Concentré Magnétique			
		Wt % % en poids	Fe %	TiO_2 %	V_2O_5 %
7.5 - 150	142.5'	38.9	64.0	0.60	0.33
150 - 300	150'	30.0	66.8	0.60	0.30
300 - 400	100'	15.2	68.1	1.30	0.35
400 - 525	125'	25.8	66.4	2.00	0.63
525 - 625	100'	29.9	64.1	1.50	0.41
625 - 750	125'	38.4	65.3	1.10	0.49
750 - 900	150'	39.0	67.4	0.80	0.57
900 - 999	99'	44.1	67.3	0.80	0.70
Weighted Average (L) Moyenne Pondérée (L)		33.1	66.16	1.05	0.466

Analyses done in laboratories of the Q.D.N.R. for Campbell Chibougamau Mines Ltd.
in 1974

Analyses faites dans les laboratoires du M.R.N. à Québec pour Campbell Chibougamau
Mines Ltd. en 1974

Samples from Campbell Chibougamau Mines Ltd.
Echantillons de Campbell Chibougamau Mines Ltd.

TABLE 128

Chemical analyses of the Sorcerer Mountain magnetite zone – Roy township – D.D.H. SC-74-3
Analyses chimiques de la zone de magnétite de la montagne du Sorcier – canton de Roy – Trou do sondage SC-74-3

Sample No. Echantillon no.	74-3-1	74-3-2	74-3-3	74-3-4	74-3-5	74-3-6	74-3-7	74-3-8	74-3-9	Weighted Average
D.D. Hole interval Profondeur	782.2 – 791.0	791.0 – 881.7	881.7 – 980.0	980.0 – 1030.0	1030.0 – 1075.9	1075.9 – 1170.0	1170.0 – 1259.0	1259.0 – 1302.0	1302.0 – 1323.5	782.2 – 1323.5
Footage Pieds de carotte	8.8	90.7	98.3	50.0	45.9	94.1	89.0	43.0	21.5	541.3
SiO_2	34.43	22.79	25.16	28.48	31.44	23.90	29.73	36.35	41.08	27.80
TiO_2	0.36	0.82	1.18	1.30	0.79	1.45	1.09	0.99	0.98	1.09
Al_2O_3	17.33	11.37	9.57	11.61	11.42	4.36	3.09	10.09	15.80	8.66
Fe_2O_3	3.92	26.52	22.90	16.06	13.00	29.60	23.63	9.48	2.49	21.13
FeO	17.86	16.18	16.71	19.40	15.83	16.58	13.03	11.25	12.91	15.60
MnO	0.19	0.14	0.19	0.25	0.25	0.23	0.19	0.24	0.21	0.20
MgO	24.14	18.72	20.47	17.08	21.40	20.54	25.70	24.18	17.56	21.05
CaO	0.79	1.58	2.41	4.36	4.64	2.39	2.65	6.72	7.15	3.18
Na_2O	0.22	0.21	0.17	0.19	0.15	0.16	0.15	0.17	1.29	0.22
K_2O	0.16	0.51	0.08	0.08	0.06	0.08	0.05	0.05	0.14	0.15
P_2O_5	0.16	0.25	0.15	0.17	0.12	0.01	0.07	0.02	0.001	0.11
V_2O_5	0.12	0.29	0.31	0.32	0.19	0.38	0.27	0.11	0.10	0.27
Cr_2O_3	0.07	0.08	0.06	0.11	0.07	0.08	0.11	0.09	0.11	0.08
S	0.23	0.52	0.63	0.58	0.62	0.23	0.22	0.23	0.16	0.41
Total Fe %	14.84	29.20	26.80	23.84	20.00	30.75	25.00	14.60	10.68	
1974 Fe analysis % analyse Fe 1974	15.2	28.5	26.7	24.5	21.5	32.1	25.9	14.0	10.3	
Concentrate grind Concentré (broyé-. 325 mailles)	99.0%	99.0	98.0	99.0	96.0	96.0	99.0	96.0	97.0	
Concentrate weight % % poids concentré	no sample	33.2	31.4	21.9	115.1	39.2	30.1	6.7	no sample	
Concentrate Concentré %Fe	–	67.2	67.7	68.4	68.9	69.1	68.0	68.1	–	
%TiO2	–	0.97	2.24	3.36	2.96	1.32	0.94	2.65	–	
%V2O5	–	0.55	0.67	0.87	0.64	0.68	0.57	0.37	–	
%S	–	0.14	0.91	0.65	1.03	0.08	0.20	1.33	–	
%SiO2	–	2.84	2.08	1.30	1.22	2.56	2.68	2.14	–	
%MgO	–	2.16	1.56	0.50	0.72	1.81	2.26	1.00	–	
%Al2O3	–	1.01	0.85	0.80	0.76	0.40	0.40	0.52	–	

Analyses done in the laboratories of the Q.D.H.R. in 1975
Samples submitted for Fe analyses and magnetic concentrate analyses by Campbell Chib. Mines Ltd in 1974

Analyses faites aux laboratoires du M.R.N. en 1975
Echantillons soumis pour analyses de Fe et tests de concentration magnétique par Campbell Chib. Mines Ltd en 1974

The weighted average of all 9 samples is weighted only for lengths of core and not for specific gravity differences. The weighted average of samples 2 to 9 (a length of 468 feet of core) gave the following analysis which is representative of the total magnetite-bearing zone at Sorcerer Mountain

SiO_2	26.29
TiO_2	1.12
Al_2O_3	8.04
Fe_2O_3	23.38
FeO	16.08
MnO	0.20
MgO	20.87
CaO	2.72
Na_2O	0.17
K_2O	0.15
P_2O_5	0.12
V_2O_5	0.30
Cr_2O_3	0.084
S	0.44
Total Fe	26.73

1974 Fe anal.	27.2
Wt % concentrate	30.46

EXPLORATION POTENTIAL OF THE CHIBOUGAMAU AREA

The exploration of the Chibougamau area can be divided chronologically in three periods: pre-1955, 1955 to 1970, and post-1970. Before 1955, the exploration was done by prospectors and geologists looking for mineralized outcrops. Between 1955 and 1970, most of the exploration work was done by ground and airborne geophysical surveys. Up to 1970, the geologists in charge of exploration programs based their efforts on the classical hydrothermal

theory of Lindgren (1933), Bateman (1950), and others. The large number of deposits located on the shores of Dore Lake within the Anorthosite Zone of the Dore Lake Complex (Fig. 127) led many geologists in the fifties to assume that one could find deposits only in the Dore Lake Complex and only in the vicinity of the Chibougamau pluton. The discovery of the Henderson-Portage orezones under the waters of Chibougamau Lake at least four miles (6.5 kms) from the Chibougamau pluton sparked a wave of exploration in the north limb of the complex at greater distances from the pluton. In the late sixties, the volcanogenic theory of ore deposits became very popular in Canada (Gilmour, 1965; Goodwin, 1965; Dugas, 1966; Hutchinson, 1965; Sharpe, 1965; Spence, 1967; Boldy, 1968; and many others since). Duquette (1970) recognized the importance of the theory and the implications but did not identify specific targets. Allard (1970, 1971, 1972, 1973, 1974) following the mapping of a rhyolite dome in Scott Township recognized a similar lithologic horizon in Lemoine Township and recommended extensive exploration of the rhyolite-basalt contact (Waconichi-Gilman). In 1971, Oliveira mapped in detail the Lemoine Township belt of rhyolites and crystal tuffs at the contact with the Dore Lake Complex. The discovery, in 1973, of the Patino-Lemoine stratiform copper-zinc deposit on top of a well-exposed and well-visited porphyritic rhyolite dome finally convinced skeptical exploration geologists of the possibility of locating ore deposits in the Chibougamau area outside of the well-explored Dore Lake-Henderson area. Allard continued to recommend exploration at the Waconichi-Gilman contact and within the Blondeau Formation, especially at the horizon just below the Bourbeau Sill where a number of zinc showings have been located. At a symposium held in Chibougamau in 1974, Allard proposed a volcanogenic model for all the Chibougamau deposits modeled after the Upper Pliocene deposits of Rumania visited in 1973 at the International Symposium on volcanology and metallogenesis. Cimon, on the other hand, at the Chibougamau symposium of 1974 proposed that the Patino-Lemoine deposit lies within the Blondeau Formation.

O'Grady (personal communication, 1975) drilled the Patino-Lemoine deposit and later drilled a number of holes in the classical Blondeau Formation within the axial zone of the Chibougamau syncline and does not recognize any lithologic similarity between the rocks in Lemoine Township and those of the type locality for the Blondeau Formation.

The debate between Cimon and myself is more than an academic dispute on stratigraphic placement, a commonplace argument within the geological profession, since the exploration efforts of companies should be directed at two completely different units depending on which version is right.

At the present time, based on the information available to me, I would recommend exploration in the following areas (Plate 1):

a. At the Waconichi-Gilman contact (including the Lac Sauvage Iron Formation), especially in the vicinity of porphyritic rhyolite domes, for stratiform volcanogenic massive sulfide (Cu-Zn) deposits.

b. In the rocks older than the upper part of the Waconichi for feeder veins and stockwork type deposits (Cu and Au).

c. In the Blondeau Formation, close to rhyolite domes, agglomerate lenses, and cherty sulfide-bearing beds for stratiform volcanogenic massive sulfide (Cu-Zn) deposits.

d. In competent gabbro sills (including the Dore Lake Complex) of the Gilman Formation and Lower Blondeau Formation provided they are older than the mineralization described in c. Original veins located along faults, dikes, and any other dilation zones, have become the recrystallized and remobilized veins and so-called "shear zone replacement" deposits of the Dore Lake-Henderson area.

EAST — WEST LONGITUDINAL SECTION through CHIBOUGAMAU
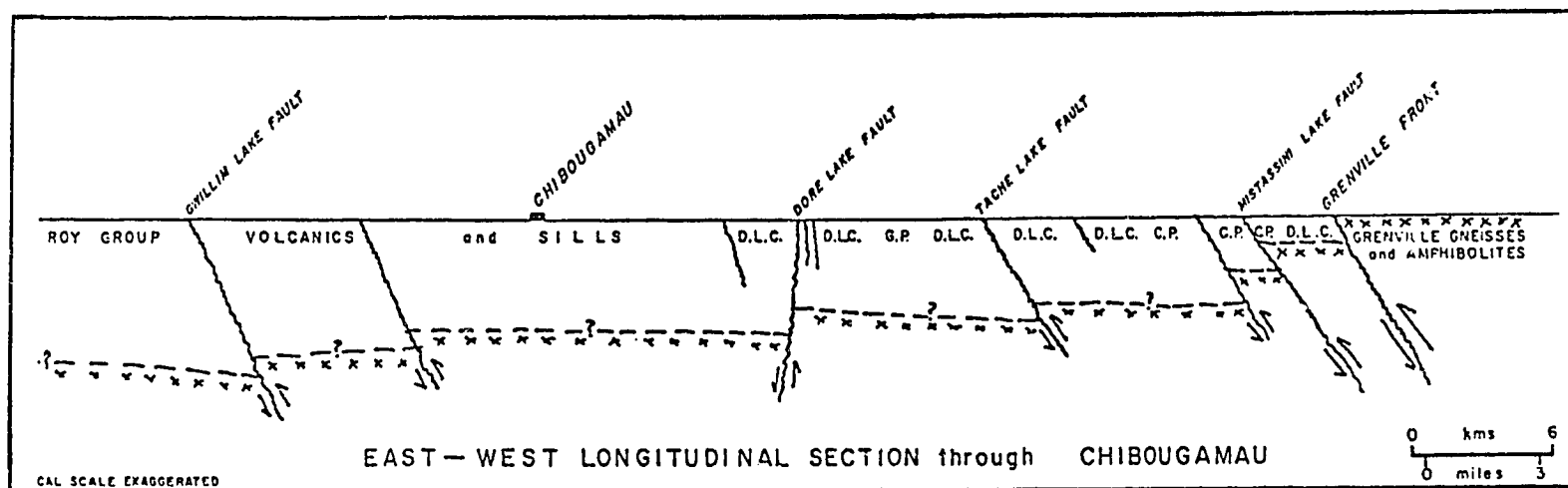
CAL SCALE EXAGGERATED

Plate 2.   Longitudinal section across the Chibougamau area drawn through the town of Chibougamau.
The evidence for the relative movement of the Dore Lake Fault and Gwillim Lake Fault
is the large block of flat-lying Chibougamau Formation on the northwest side of each
fault. The decrease in width of the Chibougamau syncline and the left-hand displacements
on the faults close to the Grenville Front indicate an upward sense of displacement
with a northeast component. The cross section covers an east-west distance of ± 40 miles
(65 kms). The vertical scale is schematic.

STRUCTURAL CROSS SECTION of the CHIBOUGAMAU AREA

Plate 3.   Structural cross section of the Chibougamau area. The line of section strikes N 04° W and
passes through the Patino-Lemoine shaft and the intersection of the road with the south shore
of Waconichi Lake (Plate 1). Map-units of plate 1 are used in the cross section.
1 = Waconichi; 2 = Gilman; 3 = Blondeau; 4 = Roberge Sill; 5 = Ventures Sill; 6 = Bourbeau
Sill; 7 to 11 = Dore Lake Complex (7 = AZ; 8 = LZ; 10 = SZ; 11 = UBZ); 14 = Chibougamau
pluton; 15 = Stella Formation; 18 = Gabbro Island dike ; CF = Chibougamau Formation.
The cross section covers a distance of 25.9 miles (41.7 kms). Vertical scale is diagrammatic.

References

Adams, F., 1893. On the typical Laurentian area of Canada; Jour. Geol., v. 1, p. 325-340.

Allard, G. O., 1953. Structure and mineralization in the Chibougamau area; M.A. thesis, Queen's University, Kingston, Ont., 126 p.

Allard, G. O., 1956. The geology of a portion of McKenzie township, Chibougamau district, Quebec; Ph.D. dissertation, Johns Hopkins University, Baltimore, 168 p.

Allard, G. O., 1960. South Half of McKenzie township, South half of Southeast quarter; Quebec Dept. of Mines, Geol. Rept. 95, p. 43-71 (maps 1292, 1293).

Allard, G. O., 1967. Northwest quarter of Rinfret township, Abitibi-east county; in Summary of results, field work in 1966; Q.D.N.R. report S-103, p. 39-20.

Allard, G. O., 1967. Geology of the northwest quarter of Rinfret township, Abitibi-east and Roberval counties; Quebec Dept. of Nat. Res., Prel. Rept. 567, 16 p. + map 1649.

Allard, G. O., 1969. Northeast quarter of Lemoine township, Abitibi-east county; in summary of results, field work in 1967; Q.D.N.R. report S-112, p. 36-27.

Allard, G. O., 1970. Northeast quarter of Scott township, Abitibi-east county; in field work in 1969; Q.D.N.R. Report S-120, p. 23-24.

Allard, G. O., 1970. Lac Dore Complex in Field work in 1970; Q.D.N.R. Report S-121, p. 90-91.

Allard, G. O., 1970b. The Dore Lake Complex, Chibougamau, Quebec--A metamorphosed Bushveld-type layered intrusion; in Symposium on the Bushveld Igneous Complex and other layered intrusions, ed. D. J. L. Visser and G. Von Gruenewaldt, Geol. Soc. of S. Africa, Spec. Publ. No. 1, p. 477-491.

Allard, G. O., 1970c. Geology of the northwest quarter of Lemoine township, Abitibi-east county; Quebec Dept. of Nat. Res. Prel. Rept. 589, 16 p. + map 1707.

Allard, G. O., 1971. Lac Dore Complex in Field work in 1971; Q.D.N.R. Report S-126, p. 94-97.

Allard, G. O., 1972. Precambrian geology and mineral deposits of the Noranda-Val d'Or and Matagami-Chibougamau greenstone belts, Quebec. Guidebook for excursion A 41-C 41 of the International Geological Congress, Montreal, 100 p.

Allard, G. O., 1973. Some speculations regarding the Lower Hidden Zone of the Dore Lake Complex and its potential mineral resources; Geol. Soc. Amer. Bull., v. 84, p. 717-724.

Allard, G. O., 1973b. Geological study-Chibougamau area; in Field work in 1972, Q.D.N.R. Report S-140, p. 107-110.

Allard, G. O., 1973c. Study of the northern contact of the Dore Lake Complex, Abitibi-east county; in Field work in 1973, Q.D.N.R. Report S-148, p. 48-49.

Allard, G. O., 1974. Unpublished conference and field trip notes prepared for the Symposium on the metallogenesis of the Chibougamau area held in Chibougamau on Aug. 3-6th, 1974.

Allard, G. O., 1975. Geology of Northeast quarter of Scott township; Quebec Dept. Nat. Res. Prel. Rept. 609 (+ map 1802) 46 p.

Allard, G. O. and Assad, R., 1968. Discovery of vanadium in Chibougamau, Quebec; Canadian Mineralogist, v. 9, pt. 4, p. 569 (abstract).

Allard, G. O. and Caty, J. L., 1969. Geology of the northeast quarter and part of the southeast quarter of Lemoine township, Abitibi-east and Roberval counties; Quebec Dept. of Nat. Res. Prel. Rept. 566, 20 p. + map 1687.

Allard, G. O. and Cimon, J., 1974. Minimal Pleistocene glaciation in the Chibougamau area, Quebec; G.A.C.-M.A.C.-program with abstracts, annual meeting 1974 (St. John's, Newfoundland).

Allard, G. O. and Henry, R., 1974. Waconichi formation, Chibougamau area (1/12,000) in Field work in 1974, Q.D.N.R. Rept. S-159 p. 22-24.

Allard, G. O. and Oliveira, J. A., 1973. Metallogenetic potential of the Chibougamau-Matagami greenstone belt, Quebec, Canada; International Symposium on volcanism and associated metallogenesis, Bucharest, 1973 (abstract).

Allard, G. O. and Simmons, W. B., 1969. Blastopoikilitic textures in gabbroic meta-anorthosite of the Dore Lake Complex, Chibougamau; Can. Mineralogist, v. 10, pt. 1, p. 126 (abstract).

Alsac, C., Lamarche, R. and Latulippe, M., 1971. Caractérisation pétrologique et géochimique des formation paléovolcaniques minéralisees d'après l'ex mple des régions de Val d'Or et Weedon-Thetford (Canada); B.R.G.M. and Q.D.N.R. publ. 71 RME 033.

Alsac, C., Bourassa, R., and Latulippe, M., 1973. Chimisme des formations paléovolcaniques de Val d'Or (Prov. de Québec, Canada) et minéralisations; B.R.G.M. and Q.D.N.R. Report 73, RME 007 AO.

Alsac, C., Bourassa, R., Lamarche, R., and Latulippe, M., 1974. Pétrographie et géochimie de quelques formations volcaniques minéralisées de l'Abitibi et des Appalaches (Québec, Canada); B.R.G.M. and Q.D.N.R. Rept. 74 RME 048 AO.

Ambrose, J. W., 1964. Exhumed paleoplains of the Precambrian Shield of North America; Amer. Jour. Sci., v. 262, p. 817-857.

Amstutz, G. C., 1968. Spilites and spilitic rocks. In Basalts, v. 2, ed. H. H. Hess and A. Poldervaart, p. 737-753, Wiley.

Anhaeusser, C. R., Mason, R., Viljoen, M. J. and Viljoen, R. P., 1969. A reappraisal of some aspects of Precambrian Shield geology; Ceol. Soc. Amer. Bull. v. 80, p. 2175-2200.

Aramaki, S., 1963. Geology of Asama volcano; J. Fac. Sci. Univ. Tokyo, Sec. 2, v. 14, p. 229-443.

Archibald, G. M., 1960. Southwest quarter of Levy township; Quebec Dept. of Mines, Prel. Rept. 419, 11 p. (& map 1319).

Astier, J., Boudier, Y., Boulay, J. S., Bubenick, L., and Ivanier, L., 1970. Magnétites vanadifères et titanifères de Chibougamau; Institut de recherches de la Sidérurgie française, (IRSID) Report R C 107 in files of the Q.D.N.R.

Avramtchev, L., 1973. Géologie du quartz sud-ouest du canton de Barlow, Abitibi-east; Rapport Preliminaire Q.D.N.R. open file.

Avramtchev, L., 1975. Geology of Northeast quarter of McCorkill township, Abitibi-east and Roberval counties; Quebec Dept. Nat. Res. Prel. Rept. 611, 55 p. + map 1806 and B1201.

Avramtchev, L., 1975b. Le gisement de magnétite titanifère et vanadifère, canton de Rinfret, Abitibi-east; Q.D.N.R. report on open file.

Baker, D. and Allard, G. O., 1974. Stratigraphy and metamorphism in parts of Vimont, Lemoine, Dollier, and Rinfret townships, Chibougamau area (1/10,000); in Field work in 1974, Q.D.N.R. Report S-159, p. 24-26.

Baragar, W. R. A., 1966. Geochemistry of the Yellowknife volcanic rocks; Can. Jour. of Earth Sc., v. 3, p. 9-30.

Baragar, W. R. A., 1968. Major-element geochemistry of the Noranda volcanic belt, Quebec-Ontario; Can. Jour. Earth Sc., v. 5, p. 773-790.

Baragar, W. R. A., 1972. Some physical and chemical aspects of Precambrian volcanic belts of the Canadian Shield; Dept. of Energy, Mines and Resources, Publ. of the Earth Physics Branch, v. 42, no. 3, p. 129-140.

Baragar, W. R. A., 1975. An early Archean crust in the Canadian Shield; a review of the evidence; Geol. Soc. Amer. Abstract with programs, north-central section 1975, v. 7, no. 6, p. 717.

Barker, D. S., 1970. Composition of granophyre, myrmekite, and graphic granite; Geol. Soc. Amer. Bull. v. 81, p. 3339-3350.

Bartlett, R. W., 1969. Magma convection, temperature distribution, and differentiation; Amer. Jour. Sc., v. 267, p. 1067-1082.

Baskin, G. D., 1975. The petrology and chemistry of a portion of the north limb of the Dore Lake Complex, Chibougamau, Quebec, Canada; M.S. thesis, University of Georgia.

Baskin, G. D. and Allard, G. O., 1974. Ferrohastingsite from Chibougamau, Quebec; Canadian Mineralogist, v. 12, pt. 6, p. 428 (abstract).

Bateman, A. M., 1950. Economic Mineral deposits; Wiley & Sons, N.Y., 916 p.

Beach, H. H., 1940. Mechamego Lake and Michwacho Lake area, Abitibi Territory, Quebec; Geol. Survey of Canada, Paper 40-3 and 40-4 (maps 608A & 623A).

Blecha, M., 1966. A study of the variation in chemical composition of certain dykes at the Campbell Chibougamau mine; M.S. thesis, McGill University, Montreal.

Benoit, F. W., 1960. Preliminary report on Chomedey-Paquet area; Quebec Dept. of Mines Prel. Rept. No. 426, 7 p. (& map 1336).

Bergeron, R. and Beall, G. H., 1958. Preliminary report on Louvigny-Bochart area; Quebec Dept. of Mines, Prel. Rept. No. 365, 8 p. (and map 1220).

Boldy, J., 1968. Geological observations on the Delbridge Massive sulfide deposit; Can. Inst. Min. & Metall. Bull. v. 61, p. 1045-1054.

Borcos, M., Lang, B., Peltz, S. and Stan, N., 1972. Evolutia vulcanismului neogen in parea de vest a muntilor Gutii (Negresti-Seini-Baita); Studii de mineralogie-petrografie; ser. 1, no. 6, p. 7-35.

Bowen, N. L., 1917. The problem of the anorthosites; Jour. of Geol., v. 25, no. 3, p. 209-243.

Buddington, A. F. and Lindsley, D. H., 1964. Iron-titanium oxide minerals and synthetic equivalents; Jour. Petrology, v. 5, p. 310-357.

Cameron, E. N., 1969. Postcumulus changes in the Eastern Bushveld Complex; Amer. Mineral. v. 54, p. 754-779.

Carman, M. F., Cameron, M., Gunn, B., Cameron, K. L., and J. C. Butler, 1975. Petrology of Rattlesnake Mountain Sill, Big Bend National Park, Texas; Geol. Soc. Amer. Bull. v. 86, p. 177-193.

Carmichael, I. S. E., Turner, F. J., and Verhoogen, J., 1974. Igneous Petrology; McGraw Hill, 739 p.

Castonguary, G., 1968. Essais préliminaires sur un échantillon contenant apatite et ilménite; Quebec Dept. of Nat. Resources, Pilot mill report 526-12, 7 p.

Castonguary, G., 1975. Le gisement fer, vanadium et titane du MRN, état de la situation, avril 1975; Q.D.N.R. internal report of the Centre de Recherches Minérales.

Caty, J. L., 1970. Pétrographie et Pétrologie du flanc sud-est du complexe du Lac Doré; M.S. thesis, University of Montreal.

Chayes, F., 1965. Titania and alumina content of oceanic and circumoceanic basalt; Mineralogical Magazine, v. 34, p. 126-131.

Chayes, F. and Velde, D., 1965. On distinguishing basaltic lavas of circumoceanic and oceanic-island type by means of discriminant functions; Amer. Jour. Sc. v. 263, p. 206-222.

Chibougamau Mining Commission, 1911. Geology and mineral resources of the Chibougamau Region, Quebec; Quebec Dept. of Colonization, mines, and Fisheries, Quebec, 216 p.

Christmann, P., 1975. South half of Scott township, Abitibi-East County; Que. Dept. Nat. Res., open file Rept. DP-319.

Cimon, J., 1971. Geologie du quart nord-ouest du canton de Queylus et le quart nord-est du canton de Hauy, Abitibi-east; Rapport préliminaire en filière à Québec (QDNR).

Cimon, J., 1971. North half of Queylus township and northwest quarter of Dollier township; Quebec Dept. Nat. Res. Prel. Rept. in preparation.

Cimon, J., 1973. Possibility of an Archean porphyry copper in Quebec; Can Mining Journal, v. 94, no. 4, p. 97 (abstract).

Cimon, J., 1974. Unpublished conference and field trip notes prepared for the Symposium on the metallogenesis of the Chibougamau area held in Chibougamau on August 3-6, 1974.

Cimon, J., 1975. Exposé sommaire sur les activités minières dans la région de Chibougamau (Jan. à decembre 1974); Open file document, QDNR office, Chibougamau.

Coertze, F. J., 1970. The geology of the Western part of the Bushveld igneous complex; in Visser et al., eds., A symposium on the Bushveld igneous complex and other layered intrusions; Geol. Soc. S. Africa Spec. Publ., no. 1, p. 5-22.

Collins, J. A., Brown, A. C. and Smith, L., 1974. The Precambrian Mistassini Group, Grenville overthrusting and the Icon Copper deposit; G.A.C.-M.A.C. meeting, program and abstracts, p. 19, St. John's, Newfoundland.

Coombs, D. S., 1963. Trends and affinities of basaltic magmas and pyroxenes as illustrated on the diopside-olivine-silica diagram; Mineral. Soc. Amer. Spec. Paper 1, p. 227-250.

Cooper, J. R., 1936. Geology of the southern half of the Bay of Island igneous complex; Nfld. Dept. Nat. Res. Geol. Sec. Bull. 4, p. 1-62.

Dallmeyer, R. D., 1974. $^{40}Ar/^{39}Ar$ Incremental release ages of biotite and hornblende from Pre-Kenoran gneisses between the Matagami-Chibougamau and Frotet-Troilus greenstone belts, Quebec; Can. Jour. Earth Sc., v. 11, p. 1586-1593.

Dallmeyer, R. D., Maybin, A. H., and Durocher, M. E., 1975. Timing of Kenoran Metamorphism in the eastern Abitibi greenstone belt, Quebec: evidence from $^{40}Ar/^{39}Ar$ ages of hornblende and biotite from post-kinematic plutons; Can. Jour. Earth Sc., v. 12, p. 1864-1873.

Darwin, C., 1844. Geological observations on the Volcanic islands, visited during the voyage of H.M.S. Beagle; Smith, Elder: London, 175 p.

Deer, W. A., Howie, R. A., and Zussman, J., 1962. Rock Forming Minerals; Longmans, London, 5 volumes.

Deland, A. N., 1955. Duguesclin-Royal area; Quebec Dept. of Mines.

Deland, A. N., 1956. The boundary between the Timiskaming and Grenville subprovinces in the Surprise Lake area, Quebec; Geol. Assoc. Canada Proc. v. 8, p. 127-141.

Deland, A. N. and Grenier, P. E., 1959. Hazeur-Druillettes area; Prel. Rept. 318, 6 p. (& map 1116). Quebec Dept. of Mines Geol. Rept. 87, 71 p. (& maps 1240, 1241, 1242).

De Montigny, P. A., 1960. Geology of the southwest and part of the southeast quarter of Lemoine township, Abitibi-east; Quebec Dept. of Mines, Prel. Rept. 437, 10 p. + map 1360 (final report, 26 p. in open file).

Derry, D. R. and Folinsbee, J. C., 1957. Opemiska Copper Mine, in Structural Geology of Canadian ore deposits; Can. Inst. Min. & Metall., v. 2, p. 430-441.

Descarreux, J., 1972. Géochimie des roches volcaniques de l'Abitibi; Ph.D. dissertation, Laval University, Quebec.

Descarreaux, J., 1973. A petrochemical study of the Abitibi volcanic belt and its bearing on the occurrences of massive sulphide ores; Can. Inst. Min. Metall. Bull., v. 66, p. 61-69.

Dompierre, F., 1972. Geology of the Henderson Mine; unpublished guidebook for the visit of the Intern. Geol. Congress excursion A 41-C 41, Campbell Chibougamau Mines Ltd.

Dorr, A., 1969. Magnetite deposits in the northern part of the Dore Lake Complex, Chibougamau district, Quebec; M.S. thesis, McGill University, Montreal.

Dugas, J., 1966. The relationship of mineralization to Precambrian stratigraphy in the Rouyn-Noranda area, Quebec; Geol. Assoc. of Canada, Spec. Paper 3, p. 43-56.

Duquette, G., 1964. Geology of the Northwest quarter of Roy township, Abitibi-east county; Quebec Dept. of Nat. Res., Prel. Rept. 513, 16 p. + map 1521.

Duquette, G., 1965. Geological compilation map showing metalliferous and asbestos-bearing deposits of the Chibougamau district; Quebec Dept. of Nat. Res. Map B-850.

Duquette, G., 1967. General geology and asbestos mineralization in the Chibougamau district; Can. Min. Jour. April 1967, p. 70-77.

Duquette, G., 1968. Geology of the Northwest quarter of McKenzie township, Abitibi-east county; Quebec Dept. Nat. Res. Prel. Rept. 573, 19 p. + map 1661.

Duquette, G., 1970. Archean stratigraphy and ore relationship in the Chibougamau district. Quebec Dept. of Nat. Res., Special Paper 8, 16 p. + map 1686.

Duquette, G., 1972. The Chibougamau-Chapais greenstone belt; in Allard, G. O., ed. Precambrian geology and mineral deposits of the Noranda-Val d'Or and Matagami-Chibougamau greenstone belts, Quebec; Guidebook for IGC excursion A 41-C 41, Montreal, p. 51-70.

Duquette, G. and Mathieu, A., 1964. Annotated bibliography of metalliferous and asbestos bearing deposits of the Chibougamau district (to accompany map B-850); unpublished bibliography in the files of the QDNR in Chibougamau.

Duquette, G. and Mathieu, A., 1966. Geology of the Northeast quarter of McKenzie township, Abitibi-east county; Quebec Dept. of Nat. Res., Prel. Rept. 551, 22 p. + map 1609.

Duquette, G. and Mathieu, A., 1968. Northwest quarter of McCorkill township; Quebec Dept. of Nat. Res., Prel. Rept. in preparation.

Duquette, G. and Mathieu, A., 1970. Geology of the south half of Obalski township, Abitibi-east county; Quebec Dept. of Nat. Res., Prel. Rept. 585, 17 p. + maps 1710 and 1711.

Eckstrand, R. O., 1963. Crystal chemistry of chlorite; Ph.D. thesis, Harvard University (part 2 is titled: Chloritic alteration at the Copper Rand Mine, Chibougamau district, Northern Quebec.)

Engel, C. G. and Fisher, R. L., 1975. Granitic to ultramafic rock complexes of the Indian Ocean ridge system, western Indian Ocean; Geol. Soc. Amer. Bull. v. 86, p. 1553-1578.

Fahrig, W. F., Gaucher, E. H., and Larochelle, A., 1965. Paleomagnetise of diabase dykes of the Canadian Shield; Can. Jour. Earth Sc., v. 2, p. 278-298.

Fairbairn, H. W., Hurley, P. M., Card, K. D., and Knight, C. J., 1969. Correlation of radiometric ages of Nipissing diabase and Huronian meta-sediments with Proterozoic orogenic events in Ontario; Can. Jour. Earth Sci., v. 6, p. 489-497.

Fiske, R. S., 1963. Subaqueous pyroclastic flows in the Ohanapecosh Formation, Washington; Geol. Soc. Amer. Bull. v. 74, p. 391-406.

Fiske, R. S. and Matsuda, T., 1964. Submarine equivalents of ash flows in the Tokiwa Formation, Japan; Amer. Jour. Sci., v. 262, p. 76-106.

Fiske, R. S., 1969. Recognition and significance of pumice in marine pyro-clastic rocks; Geol. Soc. Amer. Bull. v. 80, p. 1-8.

Fleischer, R., 1971. Le gisement aurifère à tourmaline de Passagem de Mariana (Minas Gerais, Bresil) et son cadre. Influence de l'évolution structurale et du métamorphisme sur une minéralisation syngénétique familière; Thèse de doctorat, Faculté de Sciences de Paris.

Flint, R. F., 1971. Glacial and Quaternary geology; New York, John Wiley & Sons, Inc., 892 p.

Fonteilles, M., 1967. Appréciation de l'intérêt métallogenique du volcanisme de Madagascar à partir de ses caractères pétrologiques; Bureau Recherches Géologiques et Minieres, Bull. no. 1, p. 121-154.

Fonteilles, M., 1968. Contribution à l'analyse du processus de spilitisation; Bureau de Recherches Géologiques et Minières, Bull. ser 2, v. 2, no. 3, p. 1-54.

Ford, A. B., 1970. Development of the layered series and capping granophyre of the Dufek intrusion of Antarctica; in Visser et al., eds., Symposium on the Bushveld Igneous Complex and other layered intrusions; Spec. Publ. No. 1 of the Geol. Soc. of S. Africa, p. 492-510.

Ford, A., 1975. Stratigraphy and whole-rock chemical variation in the strati-form Dufek intrusion, Pensacola mountains, Antarctica; Geol. Soc. Amer. Abstracts with programs, v. 4, no. 7, Sept. 1975, annual meeting, p. 1077-1078

Ford, A. B. and Nelson, S. W., 1972. Density of the stratiform Dufek intrusion, Pensacola Mountains, Antarctica; Antarctic Jour. of the U.S., v. 7, no. 5, p. 147-149.

Frith, R. A. and Doig, R., 1975. Pre-Kenoran tonalitic gneisses in the Grenville Province; Can. Jour. Earth Sc., v. 12, p. 844-849.

Fryer, B. J., 1972. Age determinations in the Circum-Ungava geosyncline and the evolution of Precambrian Banded iron-formations; Can. Jour. Earth Sc., v. 9, p. 652-663.

Fujii, T., 1974. Crystal settling in a sill; Lithos, v. 7, p. 133-137.

Gaucher, E. H., 1959. Geology of the Southeast quarter of Roy township, Abitibi-east county; Quebec Dept. of Mines, Prel. Rept. 379, + map 1255.

Gaucher, E. H., 1960. The magnetic anomaly of the Magnetite serpentinite at the Montagne du Sorcier, Chibougamau, Prov. Quebec, Canada; Ph.D. thesis, Harvard University.

Gaucher, E. H., 1960b. Geology of the Southeast quarter of Barlow township, Abitibi-east county; Quebec Dept. of Mines, Prel. Rept. 425, 13 p. + map 1333.

Gaucher, E. H. S., 1965. Quantitative interpretation of the "Montagne du Sorcier" magnetic anomaly, Chibougamau, Quebec; Geophysics, v. 30, p. 762-782.

Gerbe, J. L., Ivanier, L., Jon, R., and Pasdej, R., 1970. Magnétite vanadifères et titanifères de Chibougamau Definition d'un schema d'enrichissement sur 20 tonnes d'échantillons; IRSID (Institut de recherces de la sidérurgie française) Report RC 150.

Gilbert, J. E., 1951. Capisisit Lake area; Quebec Dept. of Mines Geol. Rept. 48, 51 p. (& map 849).

Gilbert, J. E., 1954. Branssat-Daine area; Quebec Dept. of Mines Geol. Rept. 64, 42 p. (& map 1038).

Gilbert, J. E., 1958. Bignell area, Mistassini and Abitibi territories; Quebec Dept. of Mines, Geol. Rept. 79, 40 p. (& map 1180).

Gilbert, J. E., 1959. Rohault area; Quebec Dept. of Mines Geol. Rept. 86, 31 p. (& map 1239).

Gilbert, J. E., 1960. Distribution and general characteristics of the massive sulphide deposits of the Province of Quebec; C.I.M.M. Bull., v. 53, p. 128-135.

Gillet, L. B., 1957. Vienne area; Quebec Dept. Mines Prel. Rept. 337, 7 p. (& map 1164).

Gilmour, P., 1965. The origin of the massive sulphide mineralization in the Noranda district, Northwestern Quebec; Geol. Assoc. of Canada, Proc. v. 16, p. 63-81.

Giusca, D., Borcos, M., Land, B. and Stan, N., 1973. Neogene volcanism and metallogenesis in the Gutain Mountains; Symposium volcanism and metallogenesis, Bucharest, guidebook series No. 11.

Glickson, A. Y., 1970. Geosynclinal evolution and geochemical affinities of Early Precambrian systems; Tectonophysics, v. 9, p. 397-433.

Glickson, A. Y., 1971. Primitive Archaean element distribution patterns: chemical evidence and geotectonic significance; Earth and Planet. Sc. Letters, v. 12, p. 309-320.

Gobeil, A., 1973. Géologie de la demie sud du canton de Curvier, Abitibi-est; Rapport Prel. open file DP 201, QDNR office.

Goles, G. G. and McBirney, A. R., 1973. Heterogeneity of the Skaergaard initial magma and limits on the overall composition of the Intrusion; Trans. Am. Geophy. Union, v. 54, p. 1225.

Goodwin, A. M., 1962. Structure, stratigraphy, and origin of iron formations, Michipicoten area, Algoma district, Ontario, Canada; Geol. Soc. Amer. Bull. v. 73, p. 561-586.

Goodwin, A. M., 1964. Geochemical studies at the Helen Iron Range; Econ. Geol., v. 59, p. 684-718.

Goodwin, A. M., 1965. Mineralized volcanic complexes in the Porcupine-Kirkland Lake Noranda region, Canada; Econ. Geol., v. 60, p. 955-971.

Goodwin, A. M., 1968. Evolution of the Canadian Shield; Geol. Assoc. of Canada, Proc., v. 19, p. 1-14.

Goodwin, A. M., 1968. Archaean protocontinental growth and early crustal history of the Canadian Shield; Proc. of the 23rd International Geol. Congress, v. 1, p. 69-89, Prague.

Goodwin, A. M. and Ridler, R. H., 1970. The Abitibi orogenic belt; in symposium on basins and geosynclines of the Canadian Shield, ed. A. J. Baer, Geol. Survey of Canada Paper 70-40, p. 1-30.

Goodwin, A. M. and Shklanka, R., 1967. Archean volcano-tectonic basins: form and pattern; Can. Jour. Earth Sc., v. 4, p. 777-795.

Graham, R. B., 1951. Geology of the Cache Lake area, Northwest quarter of Obalski township; Q.D.M. Prel. Rept. No. 259.

Graham, R. B., 1956. North half of Obalski township, Abitibi-east county; Quebec Dept. of Mines, Geol. Rept. 71, 44 p + maps 1091 and 1092.

Graham, R. B., 1957. Structure of the Chibougamau area, Quebec; in C.I.M.M. Structural geology of Canadian ore deposits, v. 2, p. 423-429.

Gros, J. J., 1975. Geology of south part of Poste Bay. O'Sullivan and Gauvin townships; Quebec Dept. of Nat. Res. Prel. Rept. 610, 33 p. & map 1813.

Guha, J. and Koo, J., 1975. Role of fluid state mobilization during metamorphism of the Henderson ore bodies, Chibougamau, Quebec, Canada; Can. Jour. Earth Sc., v. 12, p. 1516-1523.

Gunderson, J. N. and Schwartz, G. M., 1962. The geology of the metamorphosed Biwabik Iron-Formation, Eastern Mesabi district, Minnesota; Minn. Geol. Survey Bull. 43, 139 p.

Gunn, B. M., 1972. Archaean tholeiitic basalt series and the significance of clinopyroxene control of fractionation; Geol. Soc. Amer. Abstracts with programs, v. 4, no. 5, March 1972, North-Central section, p. 323-324 (abs.).

Gunn, B. M., 1975. Post effusional and chemical modification of Archaean volcanic suites as inferred from modern lavas; Geol. Soc. Amer. abstracts with programs, North-Central section meeting, May 1975, v. 7, no. 6, p. 769.

Gunn, B. M., 1975. Inferences on Archaean granitic suites based on modern orogenic andesite data; Geol. Soc. Amer. abstracts with programs, v. 7, no. 6, North-Central GAC-MAC meeting, May 1975, p. 770.

Gunn, B. M. and Duquette, G., 1969. Geochemistry of the Chibougamau metavolcanics, Quebec; Canadian Mineralogist, v. 10, pt. 1, p. 135 (abstract).

Halferdahl, L. B., 1961. Chloritoid: its composition, X-ray, and optical properties, stability, and occurrence; Jour. Petrology, v. 2, p. 49-135.

Hall, A. L., 1932. The Bushveld igneous complex of the Central Transvaal; Geol. Surv. S. Africa Mem. No. 28.

Hallberg, J. A., 1972. Geochemistry of Archaean volcanic belts in the Eastern goldfields region of Western Australia; Jour. of Petrology, v. 13, p. 45-56.

Harker, A., 1950. Metamorphism (3rd edition); Methuen, London, 362 p.

Hawkins, W. M., 1960. A spectrochemical study of rocks associated with the sulphide ore deposits of the Chibougamau district, Quebec; Ph.D. dissertation, McGill University, Montreal.

Hendry, N. W., 1951. Chrysotile asbestos in Monro and Beatty townships, Ontario; Can. Inst. Min, & Metall. Trans. v. 54, p. 28-35.

Hess, H. H., 1960. Stillwater igneous complex, Montana; Geol. Soc. Amer., Memoir 80, 230 p.

Hey, M. H., 1954. A new review of the chlorites; Min. Mag., v. 30, p. 277.

Himmelberg, G. R. and Ford, A.B., 1975. Pyroxene compositional trends in the Stratiform Dufek intrusion, Antarctica; Geol. Soc. Amer. Abstracts with programs, annual meeting, 1975, v. 7, no. 7, p. 1117.

Holmes, D. W., 1959. Fancamp-Hauy area; Quebec Dept. of Mines Geol. Rept. 84, 33 p. (& map 1237).

Horscroft, F. D. M., 1958. Geology of the Southwest quarter of Roy township, Abitibi-east county; Quebec Dept. of Mines, Prel. Rept. 370, 17 p. + map 1221.

Hutchinson, R. W., 1965. Genesis of Canadian massive sulphides reconsidered by comparison to Cyprus deposits; Can. Inst. Min. & Metall., Bull., v. 58, p. 972-986.

Hutchinson, R. W., 1973. Volcanogenic sulfide deposits and their metallogenic significance; Econ. Geol., v. 68, p. 1223-1246.

Imbault, P. E., 1954. Maicasagi area; Quebec Dept. of Mines Geol. Rept. 60, 32 p. (& map 971).

Imbault, P. E., 1959. Queylus area, Abitibi-east and Roberval counties; Quebec Dept. of Mines, Geol. Rept. 83, p. 1236.

Irvine, T. N., 1965. Sedimentary structures in igneous intrusions with particular reference to the Dyke Island Ultramafic complex; in G. V. Middleton, ed., Primary sedimentary structures and their hydrodynamics interpretation, S.E.P.M. Spec. Publ. 12, p. 220-232.

Irvine, T. N., 1970. Heat transfer during solidification of layered intrusions. 1. Sheets and sills; Can. Jour. Earth Sc., v. 7, p. 1031-1061.

Irvine, T. N., 1974. Simple and multiple oxides in magmatic rock systems; Carnegie Institution, Ann. Rept. Dir. Geophysical Lab., 1973-74, p. 300-316.

Irvine, T. N., 1975. Crystallization sequences in the Muskox intrusion and other layered intrusions - II. Origin of chromitite layers and similar deposits of other magmatic ores; Geochem. et Cosmochim. Acta, v. 39, p. 991-102

Irvine, T. N., 1975. Olivine-pyroxene-plagioclase relations in the system $Mg_2SiO_4-CaAl_2Si_2O_8-KAlSi_3O_8-SiO_2$ and their bearing on the differentiation of stratiform intrusions; Carnegie Inst. of Washington Year Book 74, p. 492-500.

Irvine, T. N. and Baragar, W. R. A., 1971. A guide to the chemical classification of the common volcanic rocks; Can. Jour. Earth Sc., 8, p. 523-548.

Jackson, E. D., 1961. Primary textures and mineral associations in the ultra-mafic zone of the Stillwater Complex, Montana; U.S.G.S. Prof. Paper 358, 106 p

Jahn, B. and Murthy, R. V., 1972. Trace element abundances of the Archean volcanic rocks in the Vermilion district, northeastern Minnesota; Geol. Soc. Amer. Abstracts with programs, v. 4, no. 7, p. 553.

Jeffery, W. G., 1959. The geology of the Campbell Chibougamau mine, Quebec; Ph.D. dissertation, McGill University, Montreal.

Jolly, W. T., 1975. Relations between Archean lavas and intrusive bodies of the Abitibi greenstone belt, Ontario-Quebec; Geol. Soc. Amer. Abstracts with programs, north-central section, v. 7, no. 6, p. 793.

Jolly, W. T., 1975b. Subdivisions of the Archean lavas of the Abitibi area, Canada, from Fe-Mg-Ni-Cr relations; Earth and Planet. Sc. Letters, v. 27, p. 200-210.

Jones, J. G., 1969. Pillow lavas as depth indicators; Amer. Jour. Sc., v. 267, p. 181-195.

Jones, L. M., Walker, R. L., and Allard, G. O., 1974. The rubidium-strontium wh -rock age of major units of the Chibougamau greenstone belt, Quebec; Can. Jour. Earth Sc., v. 11, p. 1550-1561.

Kindle, E. D., 1942. Brock River map-area, Quebec; Geol. Surv. Canada, paper 42-4

Kindle, E. D. and Riley, G. C., 1958. Brock River-Abitibi and Mistassini territories; Geol. Survey of Canada, map 1060A with desc. notes.

Kirkham, R. V., 1972. Geology of copper and molybdenum deposits; Geol. Survey of Canada, Paper 72-1, pt. A, p. 82-87.

Kish, L., 1971. The Vanadium-bearing titaniferous magnetite deposit in Rinfret and Lemoine township, east of Chibougamau, Quebec; Q.D.N.R. summary report in open file.

Kish, L., Cloutier, G. H., and Olivier, C. A., 1971. Le gisement vanadifère de magnétite titanifère des cantons Rinfret et Lemoine, près de Chibougamau, comté Abitibi-Est; Q.D.N.R. Internal report.

Koene, J. D., 1964. Structure and mineralization of Campbell Chibougamau Mines, Cedar Bay Division; Can. Inst. Mining and Metall. Bull., v. 57, no. 630, p. 1063-1072.

Krogh, T. E. and Davis, G. L., 1971. Zircon U-Pb ages of Archean metavolcanic rocks in the Canadian Shield; Carnegie Institution, Ann. Rept. director Geophysical Laboratory, p. 241-242.

Kuno, H., 1954. Volcanoes and volcanic rocks; Tokyo.

Kuno, H., 1959. Origin of Cenozoic petrographic provinces of Japan and surrounding areas; Bull. Volcanol. ser. 11, v. 20, p. 37-76.

Kuno, H., 1968. Differentiation of basalt magmas in Basalts, v. 2, ed. H. H. Hess and A.Poldervaart, p. 623-688.

Laurin, A., 1955a. Preliminary report on Ducharme-Bouteroue area; Quebec Dept. of Mines Prel. Rept. No. 310, 4 p. (& map 1069).

Laurin, A., 1955b. Preliminary report on Mignault Aigremont area; Quebec Dept. of Mines Prel. Rept. No. 317, 4 p. (& map 1115).

Laurin, A., 1956. Preliminary report on Lorne-Avaugour area; Quebec Dept. of Mines Prel. Rept. No. 329, 5 p. (& map 1157).

Lavoie, J. S., 1972. Geology of Opemiska mines. Unpublished handout prepared for field trip A 41-C 41 of the International Geological Congress, 1972.

Leech, G. B., et al., 1963. Age determination and geological studies; Geol. Survey of Canada, paper 63-17.

Leeman, W. P., Goles, G. G., McBirney, A. R. and Dasch, E., 1973. Elemental and isotopic indicators of interaction between Skaergaard intrusion and host granitic gneiss, East Greenland; G.S.A. abstracts with programs, v. 5, no. 7, 1973 meeting, p. 710-711 (abstract).

Lindgren, W., 1933. Mineral deposits; McGraw Hill Book Cpy, N.Y., 930 p.

Lindsley, D. H., 1963. Equilibrium relations of coexisting pairs of Fe-Ti oxides; Carnegie Inst. Wash. Yearbook 62, p. 60-66.

Lombard, B. V., 1934. On the differentiation and relationships of the rocks of the Bushveld Igneous Complex; Trans. Geol. Soc. S. Africa, v. 37, p. 5-52.

Long, D., 1972. Chibougamau formation, Radar Hill, McKenzie township. Handout prepared for field trip A 41-C 41 of the International Geological Congress.

Long, D. G. F., 1973. The stratigraphy and sedimentology of the Chibougamau formation; M.S. thesis, the University of Western Ontario, London, Canada.

Long, D. G. F., 1974. Glacial and paraglacial genesis of conglomeratic rocks of the Chibougamau Formation (Aphebian), Chibougamau, Quebec; Can. Jour. Earth Sc., v. 11, p. 1236-1252.

Longley, W. W., 1958. Rinfret area, Abitibi-east and Roberval counties; Quebec Dept. of Mines, Geol. Rept. 81, 21 p. (& map 1210).

Lovering, T. S., 1949. Rock alteration as a guide ot ore - East Tintic district, Utah; Econ. Geol. Monograph 1, 64 p.

Lowdon, J. A., 1960 & 1961. Age determinations by the Geological Survey of Canada; Geol. Survey of Canada, Paper 6017 and 61-17.

Lyall, H. G., 1959. Brongniart-Lescure area; Quebec Dept. Mines Geol. Rept. 85, 29 p. (& map 1238).

MacIntosh, J. A., 1966. Geology of the Lantagnac-Latouche area; Q.D.N.R. Prel. Rept. No. 555, 25 p. (& map 1617).

MacNeill, R. H., 1954. Deeply weathered granite in Nova Scotia; Nova Scotia Research Foundation and Acadia University, paper 54-1.

Malouf, S. E. and Hinse, R., 1957. Campbell Chibougamau Mines in Structural geology of Canadian Ore deposits, Canadian Inst. of Mining and Metall., v. 2, p. 441-449.

Mathieu, A., 1966. Geology of the Northeast quarter of Roy Township, Abitibi-east county; Quebec Dept. of Nat. Res., Prel. Rept. 553, 20 p. (& map 1614).

Mawdsley, J. B., 1927. Lake David area, Chibougamau district, Quebec; Geol. Survey of Canada, Sum. Rept. 1927, part C, p. 1-22.

Mawdsley, J. B. and Norman, G. W. H., 1935. Chibougamau Lake Map-area, Quebec; Geol. Survey of Canada, Memoir 185, 95 p. (& map 304A).

McBirney, A. R. and Nakamura, Y., 1974. Differentiation of the Skaergaard Intrusion; Eos-Trans. Amer. Geoph. Union, v. 55, p. 459.

McBirney, A. R., 1975. Differentiation of the Skaergaard Intrusion; Nature, v. 253, p. 691-694.

McKenzie, G. S., 1934. Pusticamica Lake area; Q.D.M. Map 307.

McMillan, R. H., 1972. Petrology, geochemistry and wallrock alteration at Opemiska, a vein copper deposit crosscutting a layered Archean ultramafic-mafic sill; Ph.D. dissertation, The Uniersity of Western Ontario, London, Cana

Mereu, R. F. and Jobidon, G., 1971. A seismic investigation of the crust and moho on a line perpendicular to the Grenville Front; Can. Jour. Earth Sc., v. 8, p. 1553-1583.

Miller, R. J. M., 1957. Geology and ore deposits of the Cedar Bay mine area, Chibougamau district, Quebec; Ph.D. dissertation, Laval University, Quebec, Canada.

Molyneux, T. G., 1970. The geology of the area in the vicinity of Magnet Heights, Eastern Transvaal, with special reference to the magnetic iron ore; in Visser et al., eds. Symposium on the Bushveld igneous complex and other layered intrusions, Spec. Publ. No. 1, Geol. Soc. S. Africa, p. 228-241.

Morey, G. B., Papike, J. J., Smith, R. W., Weiblen, P. W., 1972. Observations on the contact metamorphism of the Biwabik iron-formation, East Mesabi district, Minnesota; Geol. Soc. Amer. Mem. 135, p. 225-264.

Moritz, H. W., 1975. Muscovite-paragonite relationships in altered and mineralized meta-anorthosite at Chibougamau, Quebec; M.S. thesis, University of Georgia, Athens, Ga.

Morse, S. A., 1968. Layered intrusions and anorthosite genesis: in Origin of anorthosite and related rocks, ed. Y. W. Isachsen, N.Y.S. Museum, Mem. 18, p. 175-187.

Neale, E. R. W., 1959. Dollier-Charron area, Abitibi-east and Roberval counties; Quebec Dept. of Mines Geol. Rept. 82, 46 p. (& map 1235).

Nichol, I. 1958. A trace element study of contemporaneous sulfides pyrite, pyrrhotite, and chalcopyrite; unpublished M.A. thesis, Queen's University, Kingston, Ontario.

Nockolds, S. R., 1954. Average chemical compositions of some igneous rocks; Geol. Soc. Amer. Bull., v. 65, p. 1007-1032.

Norman, G. W. H., 1936. The northeast trend of Late-Precambrian tectonic features in the Chibougamau district, Quebec; Roy. Soc. Can. Trans., 3rd ser., v. 380, sec. 4, p. 119-128.

Norman, G. W. H., 1936b. Opawica-Chibougamau map-area, Quebec; Geol. Survey of Can., Paper 36-6, 1936.

Norman, G. W. H., 1937. East half Opemisca map-area, Quebec; Geol. Survey of Canada, Paper 37-11, 1937.

Norman, G. W. H., 1937b. West half Waswanipi map-area, Quebec; Geol. Survey of Canada, Paper 37-8, 1937.

Norman, G. W. H., 1938. West half Opemisca map-area, Abitibi territory, Quebec; Geol. Survey of Canada, Paper 38-11.

Norman, G. W. H., 1940. Thrust faulting of Grenville gneisses northwestward against the Mistassini series of Mistassini Lake, Quebec; Jour. Geol., v. 48, p. 512-526.

Norman, G. W. H., 1948. Major faults, Abitibi region. In Symposium C.I.M.M. Structural geology of Canadian ore deposits, p. 822-839.

Ojakangas, R. W., 1972. Lower Precambrian volcanic-sedimentary sequence, Vermilion district, Northeastern Minnesota; Geol. Soc. Amer. abstracts with programs, v. 4, no. 7, Oct. 1972, annual meeting, p. 617.

Oliveira, J. A. L., 1973. The petrology of the Chibougamau greenstone belt volcanics; M.S. thesis, University of Georgia, Athens, Ga.

Park, C. F. and MacDiarmid, R. A., 1975. Ore deposits (3rd ed). W. H. Freeman & Co., San Francisco, 529 p.

Patel, J., 1972. History of the Corporation (Patino Mines Quebec Limited) and Copper Rand property and summary of the general geology; Unpublished guide-book for the visit of the Inter. Geol. Cong. excursion A 41-C 41, Copper Rand mine.

Pettijohn, F. J., Potter, P. E., and Siever, R., 1972. Sand and sandstone; Springer Verlag, 618 p.

Poldervaart, A. and Taubeneck, W. H., 1960. Layered intrusions; Proc. of the 21st Inter. Geol. Congress, v. 8, p. 239-246.

Poldervaart, A. and Parker, A. B., 1964. The crystallization index as a parameter of igneous differentiation in binary variation diagrams; Amer. Jour. Sc., v. 262, no. 3, p. 281-289.

✕ Pouliot, G., 1963. Geology of the Southwest quarter of McCorkill township, Abitibi-east and Roberval counties; Quebec Dept. Nat. Res., Prel. Rept. 479, 12 p. (& map 1418).

Ramsay, J. G. and Graham, R. H., 1970. Strain variation in shear belts; Can. Jour. Earth Sc., v. 7, p. 786-813.

Raychaudhuri, S. K., 1960. Trace elements in the sulphide deposits of the Chibougamau district, Quebec; Ph.D. dissertation, McGill University, Montreal, Canada.

Remick, J. H., 1956. Geology of the Anville-Drouet area; Q.D.M. Prel. Rept. no. 322, 7 p. + map 1119.

Remick, H. H., 1957. Geology of the Guercheville-Lapparent area; Q.D.M. Prel. Rept. no. 343, 11 p. + map 1169.

Remick, J. H., 1958. Geology of the Marin-Picquet area; Q.D.M. Prel. Rept. no. 361, 11 p. + map 1219.

Remick, J. H., 1959. Geology of the Margry-Prevert area; Q.D.M. Prel. Rept. no. 394, 17 p. + map 1281.

Retty, J., 1930. Township of McKenzie, Chibougamau region; Quebec Bur. Min. Annual Rept. 1929, pt. D, p. 41-73.

Richard, N., 1975. Magnétite vanadifère de Chibougamau. Séparations magnétiques au tube Davis (3 ème partie); Q.D.N.R. Centre de Recherches Minérales, rapport du projet 777.

Ridge, J. D., 1968. Ore deposits of the United States, 1933-1967; The Graton Sales volume, A.I.M.E., 2 vol., 1880 p.

Ridler, R. H., 1969. The relationship of mineralization to volcanic stratigraphy in the Kirkland Lake area, Ontario; Ph.D. thesis, University of Wisconsin, Madison, Wis.

Ridler, R. H., 1970. Relationship of mineralization to volcanic stratigraphy in the Kirkland-Larder Lakes area, Ontario; Geol. Assoc. of Canada Proc., v. 21, p. 33-42.

✕ Riley, G. C., 1956. Brock River, Abitibi and Mistassini territories, Quebec; Geol. Surv. of Canada, Map 1060A.

Ringwood, A. E., 1974. The petrological evolution of island arc systems; Jour. Geol. Soc. London, v. 130, p. 183-204.

Rondot, J., 1961. Geology of the Langelier area, Laviolette and Quebec counties; Q.D.N.R. Prel. Rept. No. 450, 13 p. + map 1387.

Routhier, P., 1963. Les gisements metalliferes; Masson & Cie, Paris, 1282 p.

Russell, R. D. and Farquhar, R. M., 1960. Lead isotopes in geology; Interscience Publishers, N. Y.

Sabourin, R. J. E., 1955. Geology of the Blaiklock area; Q.D.M. Prel. Rept. No. 323, 6 p. + map 1122.

Scholtz, D. L., 1937. The magmatic nickeliferous ore deposits of East Griqualand and Pondoland; Trans. Geol. Soc. S. Africa, v. 39, p. 81-210.

Sharpe, J. I., 1965. Field relations of Matagami sulphide masses bearing on their disposition in time and space; Can. Inst. Min. & Metall. Bull., v. 58, p. 951-964.

Shaw, G., 1939. Waconichi map-area, Quebec; Geol. Survey of Canada, Paper 39-9.

Shaw, G., 1940. Assinica Lake, Quebec; Geol. Survey of Canada, paper 1940-20.

Shaw, H. R., 1965. Comments on viscosity, crystal settling, and convection in granitic magmas. Amer. Jour. Sc., v. 263, p. 120-152.

Smith, J. R., 1953. Geology of the Southwest quarter of McKenzie Township; Q.D.M. Prel. Rept. No. 288, 19 p.

Smith, J. R. and Allard, G. O., 1960. South half of McKenzie Township; Quebec Dept. of Mines, Geol. Rept. 95, 71 p. (& maps 1292, 1293).

Spence, C. D., 1967. The Noranda area; Can. Inst. Min. & Metall. Centennial Field Excursion guidebook, p. 36-39.

Spitz, G. and Darling, R., 1975. The petrochemistry of altered volcanic rocks surrounding the Louvem copper deposit, Val d'Or, Quebec; Can. Jour. Earth Sc., 12, p. 1820-1849.

Stanciu, C., 1972. Procese de transformare hidrotermala asociate mineralizatiilor dintre Racsa si Dealul Crucii (muntii Gutii); Studii de mineralogie - petrografie; ser. 1, No. 6, Bucuresti, p. 37-63.

Stanciu, C., 1973. Procese de transformare hidrotermala in zacamintele Herja si Baia Srpie - Muntii Gutii; Mineralogie-Petrofrafie, ser. 1, No. 9, p. 73-94, Bucharest.

Stockwell, C. H., 1964. Age determinations and geological studies; Geol. Survey of Canada, paper 641-17 (part 2).

Sutton, W. S., 1959. Geology of the Copper Rand Mine, Chibougamau, Quebec; M.S. thesis, University of Michigan.

Tatsumi, T., 1970. Volcanism and Ore genesis; Univ. of Tokyo Press, 448 p.

Taylor, H. P., 1968. The oxygen isotope geochemistry of igneous rocks; Contrib. Mineral. and Petrol., v. 19, p. 1-71.

Thornton, C. P. and Tuttle, O. F., 1960. Chemistry of Igneous Rocks, 1; Differentiation index; Amer. Jour. Sc., v. 258, p. 664 -684.

Tilley, C. E., 1950. Some aspects of magmatic evolution; Geol. Soc. London Quart. J., v. 106, no. 421, p. 37-61.

Tolman, C., 1930. Obatogamau River area, Abitibi territory, Quebec; Geol. Survey of Canada, Sum. Rept. 1929, pt. C, p. 20-32.

Troop, A. J., and Darcy, G., 1973. Geology of the Icon Sullivan joint venture copper deposit, Quebec; Can. Inst. Min. Bulletin, v. 66, no. 729, p. 89-95.

Turner, F. J. and Verhoogen, J., 1951 and 1960. Igneous and metamorphic petrology; McGraw Hill, New York, 602 p.

Ueno, H. and Irving, E., 1975. Paleomagnetism of the Chibougamau greenstone belt, Quebec and the effects of Grenvillian post-orogenic uplift; paper submitted to Prec. Research.

Vallance, T. G., 1960. Concerning spilites; Proc. of the Linnean Soc. of New South Wales, v. 85, part 1, p. 8-52.

Viljoen, M. J., and Viljoen, R. P., 1969. Upper Mantle Project; Geol. Soc. S. Africa Spec. Pub. 2.

Vincent, E. A. and Phillips, R., 1954. Iron-titanium oxide minerals in layered gabbros of the Skaergaard intrusion, East Greenland; Geochim. et Cosmochim. Acta, v. 6, p. 1-26.

Visser, D. J. L. and Von Gruenewaldt, G., 1970. ed. Symposium on the Bushveld Igneous Complex and other layered intrusions; Spec. Publ. No. 1, Geol. Soc. South Africa, 763 p.

Vogt, J. H. L., 1930. The physical chemistry of the magmatic differentiation of igneous rocks; Norske Videns.-Akad. Oslo, I. Mat. Naturv. Klasse, p. 103-130.

Vollo, N. B., 1959. The geology of the Henderson copper deposit, Chibougamau region, Quebec; M.S. thesis, McGill University, Montreal, Canada.

Von Eckermann, H., 1938. The anorthosite and kenningite of the Nordingra-Rodo region: a contribution to the problem of the anorthosites; Geool. Foren. Stockholm, Forh. 60, p. 243-284.

Wadsworth, W. J., 1973. Magmatic sediments; Minerals Sci. Engng., v. 5, p. 25-35.

Wager, L. R., 1934. Geological investigations in East Greenland, part 1, General Geology from Angmagssalik to Kap Dalton; Meddel om Gronland., v. 105, p. 1-46.

Wager, L. R., 1959. Differing powers of crystal nucleation as a factor producing diversity in layered igneous intrusions; Geol. Mag., v. 96, p. 75-80.

Wager, L. R., 1968. Rhythmic and cryptic layering in Mafic and ultramafic plutons; in Basalts, v. 2, ed. H. H. Hess and A Poldervaart, p. 573-622.

Wager, L. R. and Brown, G. N., 1967. Layered Igneous Rocks; W. H. Freeman and Co., 588 p.

Wager, L. R. and Deer, W. A., 1939. Geological investigations in East Green-
    land: pt. III, The Petrology of the Skaergaard Intrusion, Kangerdlu;
    Kangerdlugssuaq, East Greenland, Medd. Gronland, v. 105, no. 4, 352 p.

Wanless, R. K. et al., 1965 to 1973. Age determinations and geological studies;
    Geol. Survey of Canada, papers 64-17 (part 1), 65-17, 67-2A, 72-23, 73-2.

Wanless, R. K., Stevens, R. D., and Loveridge, W. D., 1970. Anomalous parent-
    daughter isotopic relationships in rocks adjacent to the Grenville Front
    near Chibougamau, Quebec; Eclogae Geol. Helv., v. 63, p. 345-364.

White, W. A., 1972. Deep erosion by continental ice sheets; G.S.A. Bull., v. 83,
    p. 1037-1056.

Wiebe, R. A., 1974. Differentiation in layered diorite intrusions, Ingonish,
    Nova Scotia; Jour. Geol., v. 82, p. 731-750.

Willemse, J., 1969. The geology of the Bushveld Igneous Complex, the largest
    repository of magmatic ore deposits in the world; Econ. Geol. Symposium
    Magmatic Ore Deposits, H.D.B. Wilson ed., Monograph 4, p. 1-22.

Willemse, J., 1969b. The vanadiferous magnetic iron ore of the Bushveld igneous
    complex; Econ. Geol. Symposium on Magmatic ore deposits, H.D.B. Wilson, ed.,
    Monograph 4, p. 187-208.

Williams, D. A. and Hallberg, J. A., 1973. Archaean layered intrusions of the
    Eastern Goldfields region, Western Australia; Contrib. Mineral. and
    Petrol., v. 38, p. 45-70.

Williams, R. J., 1971. Reaction constants in the system $Fe-MgO-SiO_2-O_2$: intensive
    parameters in the Skaergaard intrusion, East Greenland; Amer. Jour. of
    Science, v. 271, p. 132-146.

Wilson, H. D. B., 1967. Volcanism and ore deposits in the Canadian Archaean;
    Geol. Assoc. Canada Proc., v. 18, p. 11-31.

Wilson, H. D. B., Andrews, P., Moxham, R. L., and Ramlal, K., 1965. Archaean
    volcanism in the Canadian Shield; Can. Jour. Earth Sc., v. 2, p. 161-175.

Wilson, J. T., Russell, R. D., and Farquhar, R. M., 1956. Economic significance
    of basement subdivisions and structures in Canada; C.M.M. Bull., v. 49,
    August 1956, p. 550-558.

Winkler, H. G. F., 1967, 1974. Petrogenesis of Metamorphic Rocks; Springer
    Verlag (2nd and 3rd editions), New York.

Wolhuter, L. E., 1960. Geology of the Southeast quarter of Levy township; Q.D.M.
    Prel. Rept. No. 434, 11 p. + map 1361.

Wolhuter, L. E., 1962. Geology of the southeast quarter of Daubree Township;
    Q.D.M. Prel. Rept. No. 474, 15 p. + map 1416.

Wolhuter, L. E., 1971. The Opemisca Pluton; Q.D.N.R. Special Paper 6, 122 p.

Young, G. M., 1970. An extensive early Proterozoic glaciation in North America?;
    Paleogeog. Paleoclim. Paleocol., v. 7, p. 85-101.

Young, G. M., 1973. Tillites and aluminous quartzites as possible time markers for Middle Precambrian (Aphebian) rocks of North America, in (ed. G. M. Young) Huronian Stratigraphy and Sedimentation; Geol. Assoc. of Canada, Spec. Paper 12, p. 97-127.