THE GEOLOGY AND MINERALIZATION OF THE PEGMA LAKE AREA IN NEW QUEBEC.

A

Thesis

Submitted to the Department of Geological Sciences of McGill University in partial fulfillment of the requirements for a degree of Master of Science

by

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Fig.1 View of Pegma Lake, looking west, Moisie River is in the foreground.

Chapter I

INTRODUCTION

General Statement:

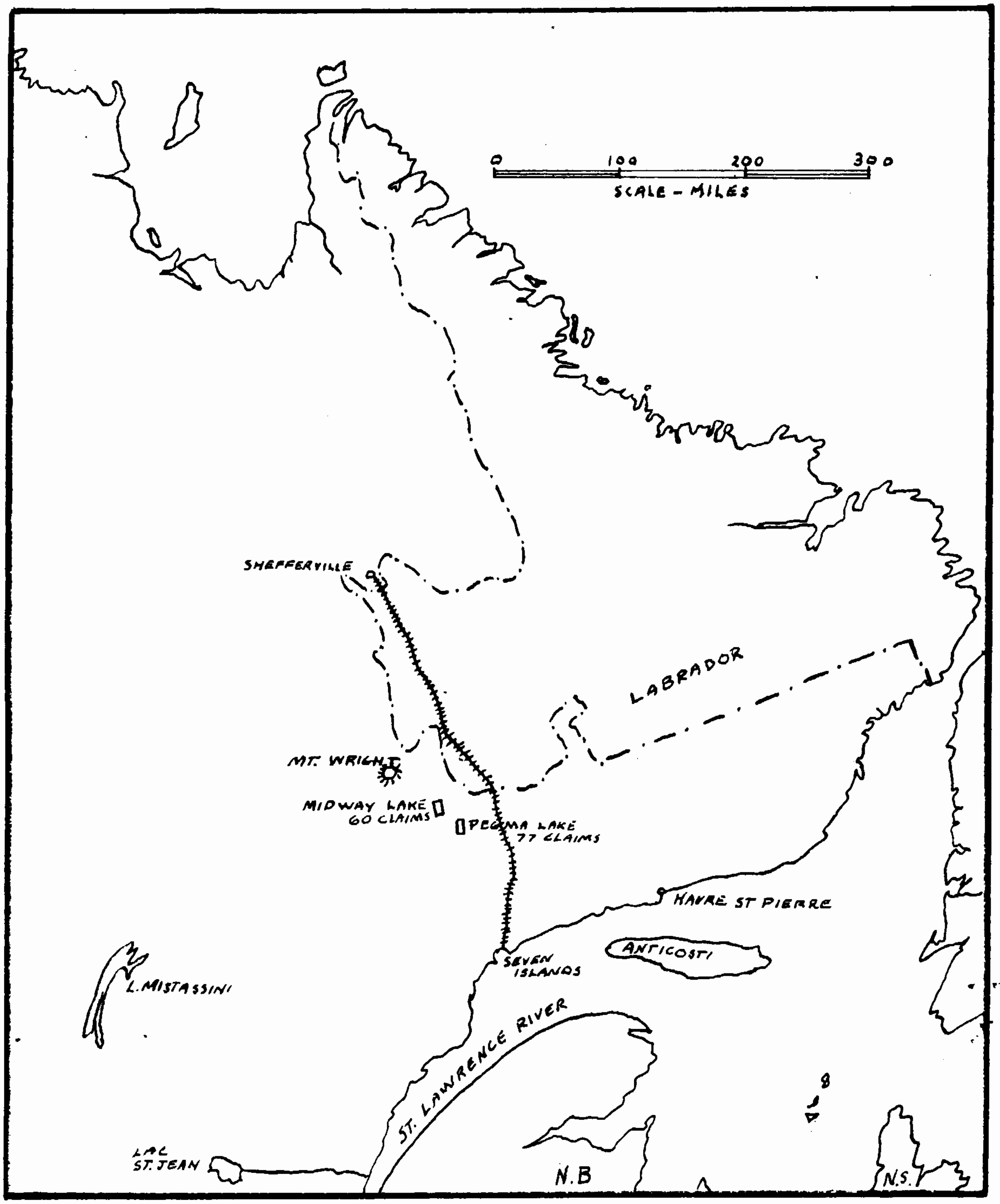
During the summer of 1955 the author was employed by Bellechasse Mining Corporation to make a geological map of a group of 77 claims and to supervise a Packsack drill programme on mineralized showings at Pegma Lake. Aeromagnetic anomalies were checked and geological mapping of these anomalies was carried out in the area surrounding Pegma Lake.

This thesis is concerned with the general geology and petrology of the rocks in the claim group. A mineralographical study is made of the metallic minerals in mineralized rocks of the area.

Location and Access:

Pegma Lake is located at latitude 52°20'N and longitude 66°45'W; 160 miles north of Seven Islands and 35 miles west of the Quebec North-shore and Labrador Railway (Map-1).

The area is accessible by float equipped plane in the summer and by ski plane in the winter.



Map-1

LOCATION MAP

Topography:

The camp is situated in the Moisie River valley at an elevation of 1500 feet. Gentle rolling hills, one half mile to the west, are at an elevation of 2000 feet (Fig.2), about one half mile to the east of the camp the hills rise to about 1800 feet and then level off to a glacial covered plain.

Drainage:

The main drainage system of the area is the Moisie River which flows south (Fig.1). Numerous rapids and falls occur in the Northern portion of this river (Fig.3). The river has been rejuvinated since glacial time, its present course is through the middle of a glacial valley.

Streeams draining the surrounding land flow east, west, and south east into the Moisie River. The lakes of the area are generally elongated in a north direction and usually do not exceed more than 20 to 30 feet in depth.

Vegetation:

Jack pine grows on the east shore of the Moisie River, where they are fairly abundant. They average about 20 feet in height and they have a diameter of 6 inches at the butt.

West of Pegma Lake, on the slopes of the hills and in the valleys there are clumps of scrub spruce and young birch. Alders and Labrador tea are abundant in all sections of the area. Cariboo moss covers most of the land.

Fig.2 Rolling hills west of Pegma Lake

Fig.3 Falls on the Moisie River

Glacial Geology:

The Moisie River flows in a glacial valley, this valley trends about north - south and is one mile wide. It is filled with glacial moraine and several small eskers. In the southeast portion of the claim group a great deal of glacial cover is found, kames, kettle holes, and moraine deposits are scattered through this section of the country. Streams have cut as much as 85 feet into this glacial debris. These streams are now misfit streams.

The arrangment of the eskers indicate the direction of glaciation was about 5 degrees west of north.

Geological Work Carried Out by Bellechasse Mining Corporation:

No previous geological work has been done in the area. The deposit was discovered by two prospectors late in the summer of 1954. Seventy seven claims were immediately staked and grab sampling was done on the largest mineralized showing. Assays from these samples proved the presence of copper and nickel in the area.

In June, 1955 the author was sent into the area to map the claim group on a scale of 500 feet to the inch. Control was established by using an 18,000 foot, north - south, chained, base line. Traverses were run at 500 feet intervals east and west from this line. Fifty feet to the inch mapping was done on all mineralized showings.

Drilling was done with a Packsack drill on the mineralized zone in the gabbro. The drill holes averaged from 75 - 100 feet in depth and 2000 feet of drilling was done in 1955.

Acknowledgments:

The author is indebted to Mr. L.T. Porter Jr., field manager of Bellechasse Mining Corporation, for permission to make use of the field information in this project. Thanks is also extended to Dr. E.H. Kranck and Mr. R. Slipp for their assistance insome of the thin section work. The helpful criticism and supervision of Dr. J.S. Stevenson proved invaluable in the study and preparation of this thesis.

Chapter 2

REGIONAL GEOLOGY

The area is underlain by metamorphosed Precambrian rocks, mainly gneisses and marble. Igneous intrusives of gabbro and granite are common in the region.

The rock types and structures found in the area agree favorably with Osborne's [1] description of the rocks of the Grenville series. Low [2] in his explorations extending northeastward from the typical Grenville area found rocks closely resembling the Grenville in composition, structure, and degree of metamorphism on all rivers traversed.

Gill, Bannerman and Tolman [3] in their reconnaissance work of Lake Wabush area, 60 miles north of Pegma Lake found the same similarity with the rocks of the Duley Lake series.

".....the resemblance to the Grenville extends to the intrusives found. Granites are potash rich types resembling those of the Grenville....."

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(1) Osborne,Fitz: The History of the Laurentian System and Grenville Series in Quebec. - Quebec Dept. Mines Publication.

(2) Low, A.P. : G.S.C. Ann. Rep. 1895 part L - P.197 (1897)

(3) Gill,J.E, Bannerman,H.M,C.Tolman: G.S.A. Vol. 48 - (1937) "Wapussakatoo Mountains, Labrador".

The Grenville Province consists roughly of a belt of rocks 200 miles wide and 1000 miles long extending from Georgian Bay to Labrador and approximately parallel to the north shore of the St.Lawrence River.

The series is made up of metamorphic units, both sedimentary and igneous in origin. These ancient sedimentary rocks with subordinate igneous intrusions rest upon and are invaded by many granites and granite gneisses.

The principal faults in the Pegma Lake region trend northeasterly, and are vertical, a subordinate set of faults strike north and northwest and generally dip east.

Northeasterly trending faults of the Grenville are considered to have been formed by thrusts from the southeast[(4)]. The Grenville province was thrust against the Superior province. Subordinate faults usually strike north and northwest, these faults are usually considered later than the northeasterly break.

The rocks of the Grenville are commonly drag folded. The rocks of the Pegma Lake area may be classified as Grenville types because of their similarity in lithology, structure, and mineral assemblages.

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(4) Tremblay, M. : "Structures in the Grenville" - MSc Thesis, McGill University (1952)

Chapter 3

LOCAL GEOLOGY

Table of Formations:

Pleistocene	Glacial material	
	Great unconformity	
Precambrian	Late	Sulfides
		Deposition of quartz
		Granite and pegmatite
		Gabbro
	Early	Marble
		Granitic gneiss
		Metamorphosed iron formation
		Pyroxene - hornblende - garnet gneiss
		Quartz - garnet - sillimanite - biotite gneiss
		Feldspar - quartz - biotite gneiss

Distribution and Occurrence of Rock Types.

1- Metamorphic Rocks:

A. Quartz - biotite - feldspar gneiss

(a) Distribution:

Bands of this rock are found; a) bordering the west side of the claim group and b) a half a mile west of the Moisie River.

(b) Megascopic Description:

The rock is medium grey in color on the weathered surface and lighter grey on the fresh surface, in places finely disseminated partly oxidized pyrite gives the weathered rocks a rusty appearence.

Medium grained feldspars, biotite, and quartz are visible in the hand specimen, in some places graphite composes up to 10 percent of this gneiss, in which case the rock appears schistose. Such graphitic rocks occur in the northwest portion of the claim group.

(c) Microscopic Description:

The minerals seen in thin section are:

Feldspar	35%
Quartz	30%
Biotite	25%
Hornblende	2%

The accessory minerals are:

Garnet, apatite and pyrite.

The quartz occurs in anhedral crystals 1 to 2 mm long (Fig.7), these grains show undulatory extinction indicating that stresses were applied after formation of the gneiss.

Fig.4 Drag folded quartz - biotite feldspar gneiss

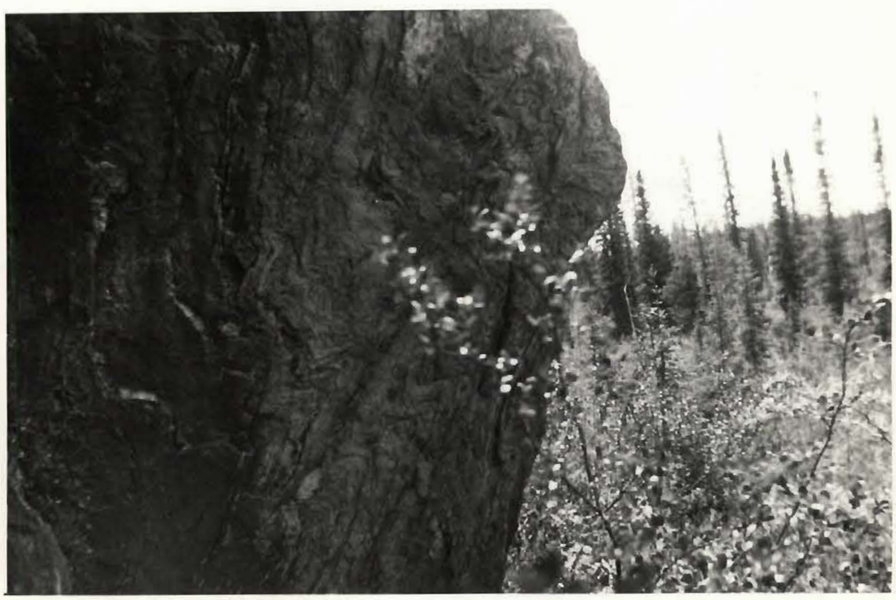

Fig.5 Close - up of drag folds

The feldspars include orthoclase (15%), and plagioclase (20%), the orthoclase is generally anhedral, has microperthitic structure, is saussuritized and some crystals show carlsbad twinning, these average $\frac{1}{2}$ mm in length. The plagioclases are calcic, (An - 55 percent), and have Albite twinning, generally the crystals are lath - like and about $\frac{1}{2}$ mm long.

Biotite occurs in tabular elongated crystals $1\frac{1}{2}$ mm long, this gives the gneiss a lepidoblastic texture. It is this orientation of mica flakes that gives the rock a gneissic structure. The biotite is brown, pleochroic, it has parallel extinction, and a small axial angle, some of the biotite has started to alter to chlorite.

In some sections pyrite in small blebs is in contact with the biotite, when this is the case specks of hornblende can be seen close to the pyrite and biotite. The metallic pyrite is visible under reflected light; in the slides studied it makes up about 2 percent of the rock sections.

The other accessories, apatite, and garnet compose from 2 to 3 percent of the rock.

Apatite is subhedral, uniaxial negative, with weak birefringence, and parallel extinction.

The garnets are fine grained, isotropic, and highly fractured, this fracturing indicates movement of the rock after formation of the garnets.

Fig.6 Ptygmatic folding and drag folding in quartz - biotite - feldspar gneiss

Fig.7 Quartz - biotite - feldspar gneiss under crossed nicols, note strained quartz (Q) and albite twinned plagioclase (P) (X36)

(d) Structures:

The rock strikes 340T and dips 45°E, it is generally contorted and drag folded (Fig.4), ptygmatic folding of pegmatitic material is common (Fig.6).

Pegmatitic material is also found in blebs or pods throughout this rock. Bands of pegmatite parallel the gneissosity of the formation and also cut the rock obliquely, the material that cuts the gneiss obliquely is probably injected. The pegmatite that parallels the structure in a lit par lit fashion may be due to recrystallization of the original material or it may be a result of injection (eg. migmatite). The discontinuous blebs of pegmatitic material are probably a result of recrystallization of the minerals in the rock.

This rock is the oldest rock type of the area; it underlies all other rocks.

B. Quartz - biotite - sillimanite - garnet gneiss

(a) Distribution:

This gneiss trends through the central portion of the claim group. In the field it is similar in appearence to the gneiss just described and has approximately the same strike and dip. It contains pegmatitic material and in places it is graphitic.

(b) Microscopic description:

Under the microscope the following minerals are seen:

Biotite 35%

Quartz 30%

Fig.8 Quartz (Q) - biotite (B)
sillimanite (S) - garnet (G)
gneiss, note blebs of quartz
in the sillimanite - plain light.

(X36)

Garnet (almandite) 15%

Sillimanite 10%

Orthoclase 10%

Quartz occurs as irregular grains between the other minerals and as nests in the sillimanite and garnet,it has undulated extinction.

Biotite is found as anhedral to subhedral lath - like crystals, these crystals parallel the gneissosity of the rocks and are often parallel to the outlines of the sillimanite crystals.

Garnet forms coarse grained (3-4 mm) anhedral and subhedral crystals whose surfaces are often pitted with small inclusions of quartz. The garnets are strongly fractured in an irregular pattern (Fig.8), and by using immersion oils and specific gravity the garnet has been identified as andradite. It comprises from 10 to 20 percent of the gneiss.

Sillimanite occurs as medium to coarse grained elongated, subhedral crystals that are from 2 to 6 mm long, they have parallel extinction and a 2 V ≈ 40 degrees. The sillimanite crystals are pocked marked by small inclusions of quartz (Fig.8), they are irregularly fractured across their elongation and they parallel the strike of the gneiss.

Feldspars are a minor constituent of this gneiss, they usually do not make up more than 10 percent of the rock. The feldspars have a large 2 V, they are blocky with low birefringence and they have been identified as orthoclase.

This gneiss is aluminium rich, as is indicated by the presence of sillimanite, and is the result of regional metamorphism of alumina rich sediments. According to Eskola's classification the rock belongs to the amphibolite metamorphic facies and has therefore probably been subjected to moderately high temperatures and pressures.

According to Yoder[5] garnets are indicative of an anhydrous environment, hence before formation of the garnets the temperatures must have been sufficiently high to drive off any excess water and thus allow for the formation of almandite.

This rock differs from the previously described gneiss in that it is deficient in feldspars and is rich in garnet and sillimanite. It is older than the gabbro and marble which it underlies.

C. Hornblende - pyroxene gneiss

(a) Distribution:

A prominent band of this rock occupies an area just west of the south end of the base line. The gneiss here forms a large hill about 300 feet high and three quarters of a mile long, the rock strikes 000T and veers to 345T in the north, the dip varies from 20°E to vertical.

Another band of this hornblende - pyroxene gneiss occurs in the southern portion of the region on the east side of the Moisie River. Here the rocks strike 340T and further north, one quarter of a mile, the band crosses the river and strikes north, the dip varies from 30°E to 60°E.

(5) Yoder, H.S. : "Bowen Volume" (1952) - Amer. Journal Science.

(b) Macroscopic Description:

On the weathered surface this rock appears dark grey, and sometimes reddish depending on the amount of garnet present, the rock is a medium grey on the fresh surface.

The visible minerals in a hand specimen of this gneiss are: pyroxene (20%) in subhedral, medium to coarse crystals; medium grained, anhedral to subhedral amphibole (25%), garnets in euhedral crystals up to a quarter of an inch in diameter (5-20%), a small amount of white fine grained quartz. Magnetite is found in two places in this band of gneiss, the two outcrops are about 200 feet long and 100 feet wide and they are situated on the west and east side of the hill that borders Hely Lake, about 10 percent of the gneiss are small granules of magnetite.

In places this rock loses its gneissic structure, it becomes massive and takes on the appearance of a gabbro, the mineral assemblages also suggests that this rock may have been a gabbro at one time.

(c) Microscopic Description:

The minerals observed in thin section and their average volume percentages are as follows:

Hornblende	20 - 40%
Feldspars	20 - 25%
Pyroxene (augite)	15%
Scapolite	10%
Garnet	10 - 20%
Biotite	< 5%

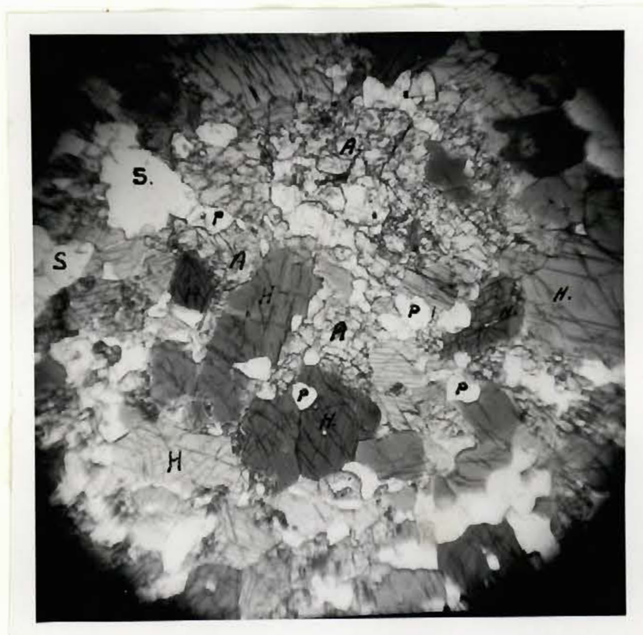

Fig.9 Hornblende(H) - pyroxene(A) gneiss under plain light, some of the augite is replaced by hornblende, scapolite(S) is replacing plagiclase (P).

(X36)

Accessories: apatite, magnetite and pyrite.

All the slides examined contain green pleochroic hornblende, it occurs in coarse grained (2mm), anhedral to subhedral crystals and good $56^{\circ} - 124^{\circ}$ cleavage can be seen in many sections of this mineral (Fig.9). Hornblende is usually the most prominent mineral in the thin sections of this rock, sometimes it becomes so plentyful that the rock sould be called an amphobolite, but on the average it makes up 25 percent of the slide.

The hornblende is usually elongated parallel to the lineation of the rock, this lineation gives the rock a gneissic appearence. The lineation is more apparent in the field than in a thin section, the thin section is usually granular in texture. Some slight alteration of hornblende to biotite is seen in several slides, biotite never exceeds 5 percent of the section.

There is a close association of hornblende and augite, in most places the augite appears to be altering to hornblende but in a few sections the reverse seems true. Both hornblende and augite exhibit a poikolitic texture, usually the augite is more pitted than the hornblende, these pits are filled with calcic plagioclase (Fig.9).

The augite occurs in short stubby crystals 1 to 3 mm long, they have a 2V = 60 degrees and they have moderate to high birefringence, the extinction angle is about 30 degrees. The average amount of augite in the thin sections is 15 percent.

The plagioclases are calcium rich (An - 60%), pericline and albite twinning is common, the plagioclase make up about 20 percent of the feldspars in the slides. Scapolite is found replacing plagioclase in several slides, the presence of scapolite indicates the introduction of chlorine and carbonate at some time. Many pegmatites cut this gneiss and it is possible that the chlorine and carbonate required to alter the plagioclase to scapolite came from these pegmatites.

Garnets occur in all the slides, they are coarse grained (3-6mm), and usually irregularly fractured. The surfaces of the garnets are pitted with blebs of plagioclase, in one section sillimanite crystals are present in the garnet and these crystals are aligned parallel to one another. Using immersion oils and specific gravity the garnet has been identified as almandite.

A study of 2 sections containing magnetite shows that the magnetite occurs in rounded, medium grained blebs, 1-2 mm in diameter. Magnetite formed at the expense of augite and hornblende, where magnetite is present fewer ferromagnesium minerals are seen. The calcium left over as a result of this reaction is found in the form of calcite, calcite makes up about 10 percent of the iron rich gneiss.

Quartz is a minor constituent in all sections except in the sections rich in magnetite, the quartz occurs as irregular, medium grained crystals and never averages more than 20 percent of the iron rich gneiss.

Pyrite in fine grained masses is found as an accessory mineral in this gneiss, it never exceeds 2 percent of the section, and it is closely associated with the ferromagnesium minerals.

Apatite is a common accessory and makes up about 5 percent of the rocks, it is found as small inclusions in plagioclase and is more abundant in the sections rich in iron.

Petrographically this hornblende - pyroxene gneiss is very similar to rocks described by Osborne[6] and Adams[7] in the Grenville series. The relative absence of quartz in these rocks was also noted by Adams as was the fact that the feldspars are calcic.

The origin of these hornblende - pyroxene gneisses is some what doubtful. They are popularly thought to be:

(1) metamorphosed volcanics of intermediate to basic composition or (6),

(2) metamorphosed diorites and gabbros or (8),

(3) metamorphosed impure sediments.

Of the three suggestions, the first two seem more probable. The gneisses surrounding this rock are rich in biotite and have a continuous gneissic structure. In the hornblende - pyroxene gneiss, the gneissosity is not always constant, sometimes the rock becomes massive and then it looks like a gabbro. Relatively little biotite is present intthis gneiss,

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(6) Osborne, F. : "Petrology of the Shawinigan Falls Area". G.S.A. Bull. Vol. 47 - part "A" - pp.197 - 228 (1936)

(7) Adams, F.O.: "Geology of a portion of the Laurentian Area North of Island of Montreal". G.S.C. Ann. Rep't Vol.8 - part 5 p.92 (1895)

(8) Buddington, A.F.: "Adirondack Igneous Rocks and their Matamorphism". G.S.A. Memoire 7 - p.257 (1932)

the surrounding paragneisses contain abundant biotite. If the sediments have been regionally metamorphosed to a uniform degree it is probable that the resultant rock would have more biotite in it than is present in the hornblende - pyroxene gneiss, it is possible that there is not as mush biotite because the ferromagnesium minerals were present in an igneoous rock as hornblende and pyroxene.

The mineral assemblages suggests that the gneiss may have been a gabbro. No volcanics are found in the region but many gabbroic intrusions are seen. Hence the rock was originally a gabbro or a volcanic but no clear cut evidence is present to support either opinion oxcept that the mineral assemblages of the hornblende - pyroxene gneiss are similar to the minerals found in the gabbros of the area.

On the bases of Ramberg's[9] work this rock may be classified as belonging to the granulite metamorphic facies.

D. Granitic Gneiss

(a) Distribution:

On the east side of the Moisie River and west of Felix Lake there is a pink fine grained granitic gneiss.

(b) Macroscopic Description:

The rock is composed of fine grained feldspars and quartz with minor amounts of biotite and pyroxene.

(9) Ramberg, H. : "The origin of metamorphic and metasomatic rocks" University of Chicago Press p.156 (1952)

(c) Microscopic Description:

In this section the following minerals were observed:

Microcline	25%
Quartz	25%
Plagioclase	15%
Biotite	10%
Hornblende	10%
Garnet	5%

Accessories included:

Apatite, sphene, magnetite, ilmenite and allanite.

Microcline shows well developed polysynthetic twinning, some grains are microperthitic, the crystals are irregular and blocky and average 5 mm in diameter (Fig.11).

The plagioclases found in this rock are calcic (An - 50-70%), the crystals are lath shaped and average 1.5 mm in length. All of the plagioclases seen have albite twinning and they are moderately saussuritized but the microcline is unaltered. This surfaces of the plagioclases often enclose small crystals of subhedral apatite, hornblende with good 60 degrees cleavage, and magnetite are also formed in the plagioclase.

Biotite occurs in small leaves, they are pleochroic and have parallel extinction it is the parallelism of this meneral and other ferro-magnesium minerals that gives the rock its gneissic structure.

Garnet occurs as medium grained, (0.5 - 1.5 mm in diameter),

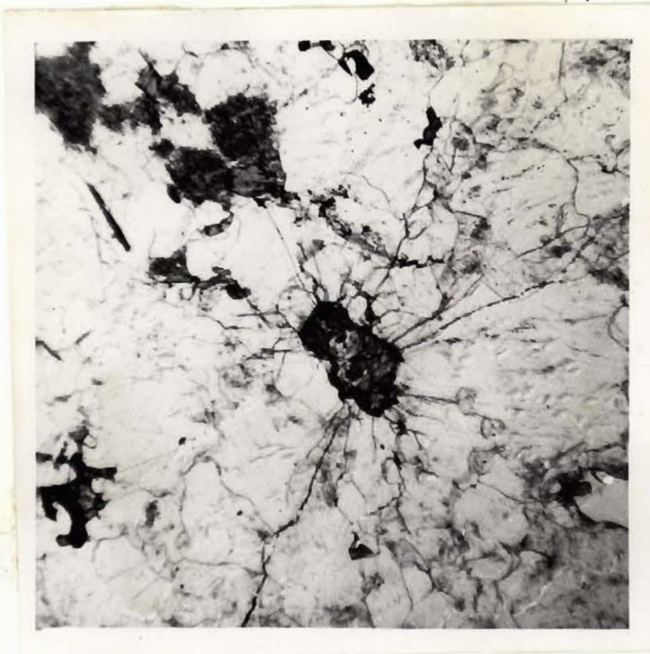


Fig.10 Allanite crystal in granitic gneiss, note how the quartz and feldspars are fractured from the metamict mineral.

(X36)

Fig.11 Same section as fig.10 but under crossed nicols, note grid twinning in microcline (M) and undulated quartz (Q), the palgioclase (P) is saussuritized.

(X36)

irregularly fractured masses - the surfaces of the garnets have a poikoilitic texture. Quartz is the common mineral in these pits.

Quartz makes up about 25 percent of the gneiss, it has an irregular outline and undulatory extinction and also occurs as small inclusions in other minerals.

One very interesting accessory mineral is allanite. It has a reddish brown color, high relief, and strong birefringence. It is irregularly fractured and makes up about 3 percent of the gneiss. Allanite is a metamict mineral; as a result of breakdown of the space lattice and radioactive emanations the minerals surrounding allanite have become fractured, these fractures cut the other minerals in a radiating pattern (Fig.10). The allanite grains are about .25 mm in diameter.

Enough titanium is present in the rock to form minor amounts of ilmenite and sphene. Ilmenite is closely associated with magnetite and most of the crystals are small, none of them are larger than .25 mm.

The minerals of this granitic gneiss are equigranular and it is difficult to see the gneissic lineation of the mafic minerals in thin sections but in the field this gneissosity is obvious.

It is difficult to decide whether this rock is an orthogneiss or a paragneiss. The surrounding paragneisses seems to indicate that the rock is of sedimentary origin, if this is the case then the original sediment has undergone a large amount of granitization.

(d) <u>Structure</u>:

The formation strikes 340T and dips 40 to 50°E. In several places to the east beyond the thesis area the gneiss has a dip of 40°W, this change in dip suggests a syncline with an axis trending northwest.

The northern portion of the Moisie River that drains Lake Felix cuts across the strike of these gneisses as does one of its tributeries 3000 feet to the south. The streams have cut deeply into the rocks and they have produced cliff faces on both sides of their courses (Figs. 22, 23). In these cliff faces a good crossectional view of the structure can be seen, the gneiss is folded in a corrugated manner. The folds on the north plunge north and those on the south plunge south. (Fig.22).

E. Metamorphosed Iron Formation

(a) Distribution:

This rock is located 500 feet east of the main base and forms a ridge which is about 400 feet higher than Pegma Lake.

A smaller band of this metamorphic iron formation is found in the northern sector of the claim group, it is located 700 feet west of station 6000 N, the band trends northward out of the claim group. The only other occurrence of this pyroxene - quartz rock is over an intrusion of gabbro. This small lens is an erosional remnant of the main band of iron formation.

(b) Macroscopic Description:

The rock is composed of medium to coarse grained pyroxenes, interbanded with white, milky quartz, the bands strike 350T and dip 40°east (Fig.12).

In places the metamorphosed iron formation contains up to 80 percent quartz and looks like a quartzite, in other localities the formation has 60 to 80 percent pyroxene, when this is the case the rock looks like a pyroxenite. Generally the pyroxene forms bands varying in width from one quarter of an inch to four feet, the quartz bands have similar proportions.

The only other mineral observed in this rock is graphite, flakes of this mineral are often disseminated through the pyroxene, rarely does graphite exceed 10 percent of the rock.

In this particular area no hematite or magnetite is found in this formation, but 20 miles northwest, at Midway Lake, the same rock contains up to 60 percent magnetite and specular hematite. In the Pegma Lake area insufficient iron was present at the time of lithification of the sediments to give magnetite and hematite and as a result pyroxene formed.

(c) Microscopic Description:

The rock has a granoblastic texture, it is medium grained and equigranular. In the slides the following minerals are seen:

Quartz	50 - 60%
Aegirinaugite	40 - 60%
Graphite	5 - 10%

In the slides studied quartz is usually the predominant mineral but in some cases pyroxene is found in greater abundance than quartz, the quartz grains average .5 - 2mm in length and they are elongated parallel to the pyroxene. In the field this lineation is expressed by alternating bands of pyroxene and quartz of varying widths. The quartz

Fig.12 Outcrop of metamorphosed iron formation dipping 40°E.

Fig.13 Metamorphosed iron formation under plain light, note band of aegirinaugite(A) at the top of the photo, quartz (Q) is interbanded with the pyroxene, the long black needle like crystals are graphite.

(X36)

has been strained, some of it is fractured across the direction of elongation and all grains show uneven extinction, this rock therefore has been subject to cataclastic forces.

The pyroxene is identified as aegerinaugite, the refractive indices were determined using immersion oils, they are:

Ny	-	1.740
N'x	-	1.72
Nz	-	1.745

The extinction angle is 60°; z∧c and 2V were determined using the 4 - axis universal stage and a stereographic projection net. The axial angle is 80° and the sign is positive, the mineral has green to brownish - green pleochroism.

The pyroxene occurs in medium to coarse grained crystals, they vary in size from .5 mm to 2.5 mm, some of the crystals are polysynthetically twinned and basal sections showing 90° cleavage are common. A definite lineation of the crystals is obvious in the thin section (Fig.13).

Parallel to the pyroxene are small blade - like crystals of graphite, these blades never exceed 10% of the rock and they are found associated with the aegerinaugite (Fig.13).

Because of the abundance of pyroxene and the absence of other minerals, except for quartz and graphite, this rock is called an iron formation. No hematite or magnetite is found in any of the sections studies, but at Midway Lake this formation is rich in iron oxides.

The formation is evidently an off shore facies of an iron formation, at the time of lithification insufficient iron was present to give the ores of iron but there was enough to produce an iron silicate. The graphite resulted from the metamorphism of the carbonaceous material in the iron silicate. The sedimentary facies of this rock is probably and impure sandstone.

(d) Structures:

Like most other rock units of the group, this series of rocks is drag folded, a major drag can be seen 600 feet east of station 1500N, here the rock changes strike from 350T to 250T and the dip alters from 50° east to 45° south; the fold seems to plunge gently to the southeast. Small intrusions of pegmatite are common in this rock; the rock is underlain by a quartz - silimanite gneiss.

The thickness of the main iron formation band is estimated at about 800 feet, the thickness of the northwest band is about 500 feet.

At several places scattered occurrences of pyrrhotite and chalcopyrite are found. These deposits form at the contact of the gneiss and iron formation, they are all small and of no economic significance; assays show only traces of copper and nickel.

F. Marble

(a) Distribution:

At station 5000N there is an outcrop of medium grained, impure crystalline limestone. The outcrops of this rock form a ridge which is

300 to 400 feet higher than Pegma Lake, the ridge trends north for about a mile.

(b) Macroscopic Description:

On the fresh surface the marble is white, but on the weathered surface a black licken usually grows.

In the field calcite and blebs of tremolite are visible in this marble. The tremolite blebs are aligned parallel to t he strikes and dips of the surrounding gneisses, about 20 percent of the marble is tremolite. Veinlets of quartz are also found in this crystalline limestone, one large vein cuts the middle of the marble, it strikes about 010T. This vein will be discussed more fully later under the heading of quartz veins.

Underlying this marble is a quartz - sillimanite gneiss.

(c) Microscopic Description:

Coarse blocky grains of anhedral calcite make up 80 percent of the slides examined, some of these fragments are 3mm long; the calcite has its characteristic high birefringence and rhombohedral cleavage, twinning on the cleavage rhombs is common (Fig.15).

Grouped in clusters between the calcite grain boundaries are phlogopite, tremolite, diopside and chondrodite, these minerals are usually finer grained thanthe calcite; tremolite and phlogopite are the most common of the four. Basal section of tremolite have a poikoilitic texture, nests of calcite are found in these pits and they probably mark the remains of calcite crystals which the tremolite has replaced.

Chondrodite is a high birefringent mineral showing polysynthetic twinning. It has an irregular fracture pattern like olivine but it is only slightly pleochroic, this mineral also encloses blebs of calcite.

This rock was originally a limestone, it has been altered by temperature and pressure to its present recrystallized state.

2- Quartz Veins:

(a) Distribution:

The largest deposition of quartz occurs in the marble, the vein strikes about 10° east of north and it is vertical. The vein can be traced for about one half of a mile northward; at its widest the vein is 250 feet, in the north it narrows to 25 feet, the south portion forms the nose of the marble ridge.

(b) Macroscopic Description:

Some of the quartz is white and milky but much of it has a brown stain as a result of leaching of the sulfides in it.

Sphalerite, pyrrhotite and chalcopyrite occur as isolated blebs in the quartz, these sulfides are found in fractures of the quartz and as disseminations. The largest of these pods is at the nose of the hill, the occurrence is about 15 feet in diameter. There are insufficient sulfides in this quartz vein to make it economically significant.

The quartz was evidently deposited in a fracture in the marble, much of the marble has become silicified as a result of this deposition. Many small shoots of quartz are found irregularly distributed throughout the marble.

Small quartz veins are also found in the granitic gneiss, they do not exceed 2 feet in width. They usually conform to the strike and dip of the gneiss. In places vugs in these veins contain well formed

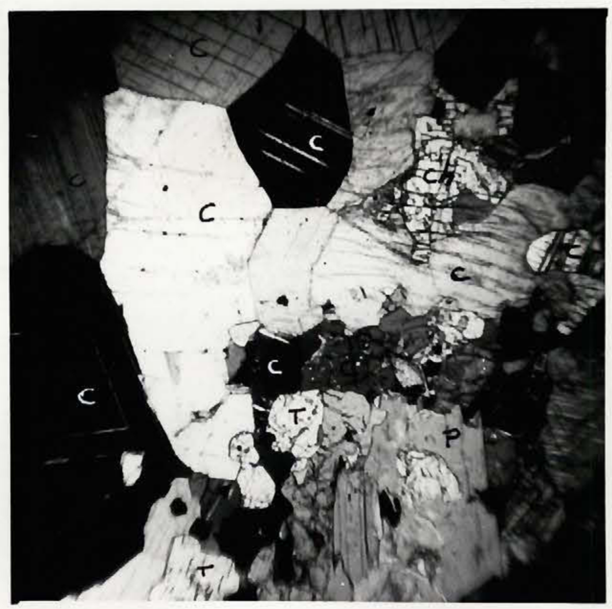


Fig.14 Marble under crossed nicols, note rhombohedral cleavage of calcite (C), Irregularly fractured chondrodite(Ch), and leaf of phlogopite (P) surrounded by tremolite (T).

(X36)

crystals of milky quartz, these crystals have the form of hexagonal pyramids. No sulfides are found in these veins.

3- Igneous Intrusives

A. Pegmatites:

All rocks of the area are intruded by pegmatites, these intrusions vary in width from a few inches to 10 feet. The minerals in these intrusives are coarse - grained feldspars, quartz, some biotite and occasionally, pyroxene. Small amounts of sulfides are also found in these pegmatites; pyrite is the common sulfide mineral but it never exceeds 5 percent of the rock.

The strikes of the pegmatites are usually east - west and north - south, most of the dykes are vertical.

B. Granite:

(a) Distribution:

An outcrop of granite cuts the hornblende - pyroxene gneiss 850 feet west of station 2500S, the intrusion is 3000 feet long and 400 feet wide.

(b) Macroscopic Description:

The rock is pink, medium grained, and contains 25 percent quartz, 60 percent feldspar and 15 percent biotite. The north end of the intrusive is massive and the south end has a gneissic texture.

Small, light grey, aplite dykes are commonly found cutting the gabbroic rocks and the hornblende pyroxene gneisses of the claim group.

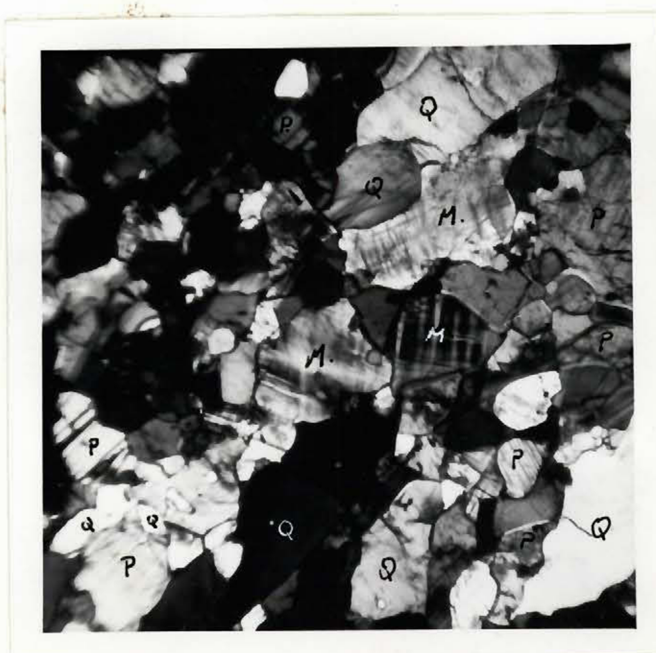


Fig.15 Granite under crossed nicols, quartz is strained (Q), note grid twinning in microcline (M), plagioclase (P) is saussuritized, note also myrmekite texture in the feldspar in lower left corner.

(X36)

Fig.16 Gabbro under crossed nicols, note hornblende (H), and plagioclase laths (P) offset by a fracture which is now filled with quartz, augite (A) encloses plagioclase.

(X36)

(c) Microscopic Description:

In thin section the rock has a medium grained, granular texture, microcline, plagioclase, and quartz are the dominant minerals (Fig.15).

Quartz is found in fairly large irregular grains varying in size from .5mm to 3mm, it has undulatory extinction, therefore it has been strained. Intergrowths of the quartz and feldspar gives the minerals a myrmekite texture; quartz makes up 25 percent of the slides.

The feldspars are subhedral to anhedral, medium grained, microperthitic orthoclase, microcline (50 percent), and plagioclase (15 percent), the feldspars are saussuritized.

Garnet occurs in irregular blebs about .5mm - 1mm in diameter, they are heavely fractured and their surface are pitted with quartz.

Leaves of brown mica make up 10 percent of the rocks.

Small apatite crystals are found in the feldspars, apatite comprises less than 2 percent of the volume of this rock. Small granules of magnetite are also found as an accessory in this granite, it occurs in small rounded grains about 0.3mm in diameter.

C. Gabbro

(a) Distribution;

Several gabbroic intrusives are found in the area. Most of them are small, the largest intrusion occurs 200 feet east of station 1000N, this gabbro forms a hill which is 450 feet higher than Pegma Lake and about 500 feet in diameter (Fig.17).

(b) Macroscopic Description:

The visible minerals in this intrusions are olivine, pyroxene (amphibole), feldspar, magnetite and calcite. Some garnets are found in the more acidic phase of the gabbro. The top of the sill has a larger percentage of feldspars than the bottom. These additional feldspars make the upper part of the intrusion more acid in content than the lower portion, this lower portion is a peridotite, the peridotite is composed of pyroxene, amphibole, olivine and sulfides.

(c) Microscopic Description:

(1) Gabbro:

The minerals in thin section have a hypidiomorphic granular texture. The minerals visible under the microscope are:

Plagioclase	40%
Hornblende	30 - 35%
Augite	20 - 25%
Garnet	5 - 10%
Pyrrhotite	2%

The augite fragments have a pitted surface in which occur plagioclase and hornblende. The augite grains are anhedral and average .5 to 1mm in diameter, they make up about 20 percent of the rock.

Hornblende occurs in anhedral to subhedral crystals and often replaces augite, the amphibole has green pleochroism and good 56° - 124° cleavage; about 30 to 35 percent of the gabbro is hornblende, the crystals average .5 to 1mm in diameter. Minor amounts of hornblende has altered to brown biotite, this alteration takes place on the outer grain boundaries of the amphibole, less than 5 percent of the slides are biotite.

Plagioclase (An - 50) is a common constituent of this gabbro, it is unaltered and has albite twinning, some zoning is also visible. The laths are blocky and their growth seems to have been interfered with by the hornblende, it is found in and around the plagioclase, forty percent of the gabbro is labradorite.

Very little quartz is visible in the thin sections. In one of the slides a small fracture cuts across the minerals, this fracture is filled with irregular fragments of wall rock that are cemented by quartz (Fig.16), quartz never exceeds 5 percent of the rock.

Garnet is found in all sections, it has high relief, it is irregularly fractured and isotropic. Using immersion oils and specific gravity the garnet is identified as almandite. Almandite tends to occur in and around the hornblende, the garnet blebs average .1mm in diameter and about 10 percent of the gabbro is garnet. The presence of almandite garnet suggests that this rock is regionally metamorphosed.

Pyrrhotite in small rounded grains (.2mm in diameter) is found in the hornblende and augite, about 2 percent of this rock is pyrrhotite.

(2) Peridotite:

The following minerals are found in the basic portion of the gabbroic intrusion.

Olivine	20 - 40%
Hornblende	20 - 25%

Fig.17 View of gabbro hill looking east, peridotite zone is outlined by dashed marks, mineralized zone "C" is in this olivine rich rock, note how this rock weathers to a crumpled mass. The outcrop is 450 feet long.

Fig.18 Gouge zone in the peridotite, the fault dips 62°W, view looking north, the movement is post mineralization.

Hypersthene	10 - 20%
Magnetite & Pyrrhotite	5 - 15%
Augite	5 - 10%
Calcite	5%

Olivine is the predominent mineral in this rock, it occurs in coarse anhedral crystals, which average 2 to 3mm in diameter. The olivine is extremely fractured, magnetite is present in these irregular fractures. The olivine in slides of samples taken near the surface is altered to antigorite (Fig.19) but most of the slides made from drill cores are relatively fresh (Fig.20). Olivine has a 2V almost equal to 90° and it is negative. The percentage of olivine in the peridotite varies from 20 to 40 percent.

Hornblende is very common in the peridotite, 20 to 25 percent of the sections are made up of this mineral. This amphibole has the characteristic green pleochroism of hornblende and many sections show good $56^{\circ} - 124^{\circ}$ cleavage (Fig.20). The grain size averages 1 to 2mm in diameter. Hornblende tends to replace augite in some sections of this rock. Some of the hornblende is a result of deuteric alteration of the pyroxene and olivine.

Calcite composes 5 percent of the peridotite, it is found close to the contacts of the pyroxenes, olivine, and hornblende. Small leaves of biotite are also found in the hornblende.

Augite and hypersthene can be seen in most sections, but the latter is more commonly found. Hypersthene exhibits good schiller structure, it has parallel extinction and pink to light green pleochroism. This orthorhombic pyroxene frequently encloses grains of olivine. The hypersthene crystals are anhedral and about 1 - 2mm in diameter. About 15 percent of the rock is hypersthene.

Augite occurs usually as small, granular anhedral crystals. They are probably a deuteric alteration product of olivine, 5 to 10 percent of the slides are augite.

The two common opaque minerals in thin sections are magnetite and pyrrhotite. Some of the magnetite is found as an alteration product of olivine, some of it occurs in round grains (.1mm in diameter) in the oli-vine and pyroxene, these grains of magnetite are probably primary. Hence it is evident that in this sill we have differentiation. When the mass was introduced, and began to crystallize the heavier minerals sank to the bottom of the sill while the light minerals remained atop, therefore we have peridotite on the bottom and gabbro above. This is a similar occuren-ce but on a smaller scale to the Karroo dolerites of South Africa.

Fig.19 Section of peridotite from a surface sample The olivine has altered to antigorite(A) the opaque material is magnetite, note twinned crystal of calcite (C) in upper right corner, hornblende (H) borders antigorite at the bottom of the section.

(X36)

Fig.20 A typical section of peridotite showing relatively fresh olivine(O), fractures are filled with magnetite, note section of hornblende (H) with amphibole cleavage.

(X36)

Chapter 4

STRUCTURAL GEOLOGY

The strike of the gneisses of the Pegma Lake claim group vary from 340T to 000T, the average dip is 40 degrees east.

Drag folding is common in all rocks of the area. Most of these drags are small but one fairly large one occurs in the northwest part of the claims, about 2000 feet west of station 5000N. The disturbed area is about 2000 feet long and 4000 feet wide. This structure is best expressed in the quartz - biotite gneiss.

The rocks are contorted in a broad "S". The strikes of the gneiss change from 340T to about 270T and the dips vary from 40 degrees to vertical. Ptygmatic folding is also common in this region, these folds are very irregular in shape. The drag fold may be an expression of a fault which occurs to the northeast, this fault cuts the marble and it trends northeast,up the Moisie River to Felix Lake (Map-2).

The rocks on the south shore of this part of the Moisie plunge south, those on the north plunge north. Hence a fault is postulated to account for this change of plunge. Also the course of the main

Moisie River generally parallels the strike of the gneisses, but here the river cuts across the structure. A similar fault is presumed to occur 3000 feet south of the first break. Here a tributary of the Moisie cuts across the rock structures and the plunge of the gneisses vary from 10 degrees north on the north side to 15 degrees south on the south side.

The gneisses in this part of the claim group are closely folded. The folds are clearly seen in the cliff faces which border the river (Fig.21-22). The whole series is folded in a corrugated fashion. In places the synclines have been removed due to horizontal pressures and two anticlines occur one beside the other (Fig.23). These anticlines and synclines vary in width from 200 feet to 500 feet, their axes generally strike 340T.

Small faults, approximately at right angles to the main break, occur along the cliff faces. The relative movement on these minor faults appears to be east side up relative to the west. The faults dip from 20° - 40° E, some of the shallow dipping ones are filled with quartz.

Hence there seems to have been a certian amount of compression from the east and west which caused the rocks to be folded in the manner just described. Evidently some thrusting has accompanied folding; this accounts for some of the faults which parallel the gneiss; the thrust appears greatest from the east.

There seems to have been some upward force which caused the rocks

Fig.21 West limb of an anticline in the granitic gneiss, note that the fractures in the gneiss outline the folded structure.

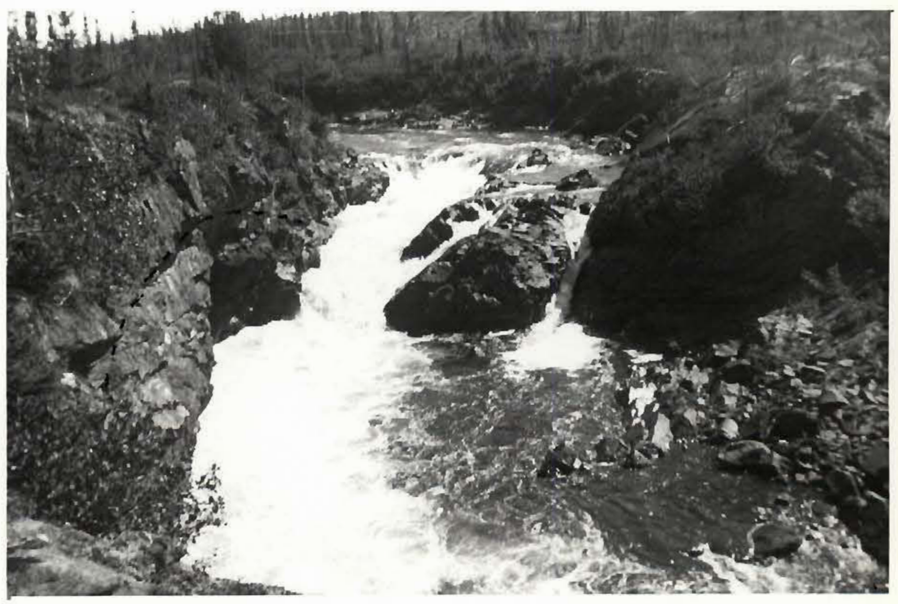
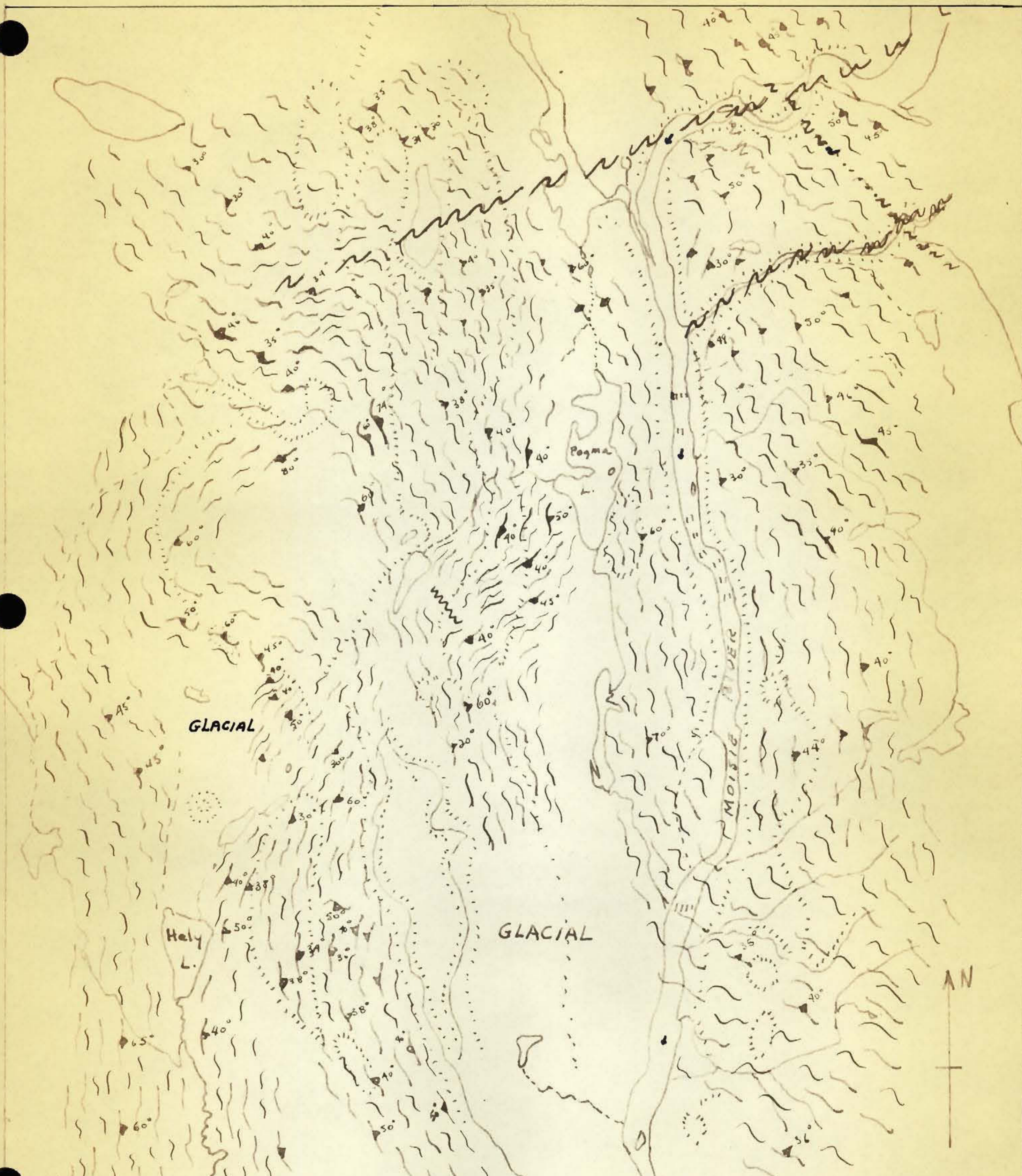


Fig.22 A view of the Moisie River, on the left cliff face is an anticline plunging north, view looking east.



STRUCTURES OF PEGMA LAKE AREA

Map. 2

to break transverse to the structure. Tension cracks resulting from this force probably accounts for the steeper faults which parallel the gneiss.

A study of the marble hill which is cut by the most northerly northeast fault, shows that the strike of the north portion of the hill is about 15 degrees west of north, the south part strikes north. This change in strike after faulting may indicate that the forces involved to produce this fault were, in part, rotational. A study of the aerophotographs shows the fault to be about 300 feet across, it is also vertical.

A smaller fault which strikes 330T and dips 62 degrees west is visible at the base of the gabbro sill, 800 feet east of station 5500N. A well pronounced gouge zone is visible in an adit which is cut 25 feet into the peridotite, this zone is three feet wide (Fig.18). Slickensides found along the fault zone indicate that the fault is normal.

This break may have resulted from a drag fold which occurs in the immediate area. The drag is best seen in the metamorphosed iron formation which adjoins the gabbro, the dragfold is about 1000 feet long and plunges to the southeast at about 20 degrees. The fault in the gabbro may be a break which formed in or near the point of maximum curvature of the drag. Another explanation may be that this fault is a result of contraction during cooling of the intruded mass, such normal faults are known to occur on the outer boundaries of igneous bodies.(10) The fault is later than the sulfide mineralization.

A small syncline occurs in the hornblende - pyroxene gneiss in the south part of the claims and just west of the base line. The axis strikes about 5 to 10 degrees east of north and plunges south.

Summary:

Pegma Lake area is cut by vertical northeasterly faults and subordinate faults which strike about 340 - 350T and dip 20 to 40 degrees east. The main faults are caused by a certain amount of vertical force plus some rotation. The other faults are a result of thrusting from the east and tension cracks.

Compression has caused the rocks in the east to be folded in a corrugated manner.

Drag folding has resulted from movement on the northeast faults.

(10) Balk, R. : "Structural Behavior of Igneous Rocks" G.S.A. Mem. 5 (1937)

Chapter 5

ECONOMIC GEOLOGY

Three zones of sulfide mineralization are found on the claim group, they are plotted on the map as zones A,B, and C (Map - 3).

Zone A:

This mineralized zone occurs on the east shore of Bar Lake, it is associated with a quartzite band in the hornblende - pyroxene gneisses. Some of the quartzite is contorted into a small syncline (Fig.24), the mineralized outcrop measures 100 feet by 20 feet.

The minerals visible in the field are chalcopyrite, and pyrite. These are finely disseminated through the quartzite and make up about 10 to 20 percent of the rock. Assays showed trace of copper and nickel.

In contact with the quartzite on the east is a pegmatite dyke which strikes 030T and dips 40°E, the dyke is about 10 feet wide. In some instances the pegmatites of the area are associated with sulfides. Throughout the claim group there are several places where the contact of the gneisses and pegmatites are mineralized, these occurrences are usually very small but they do suggest that the pegmatites are an influ-

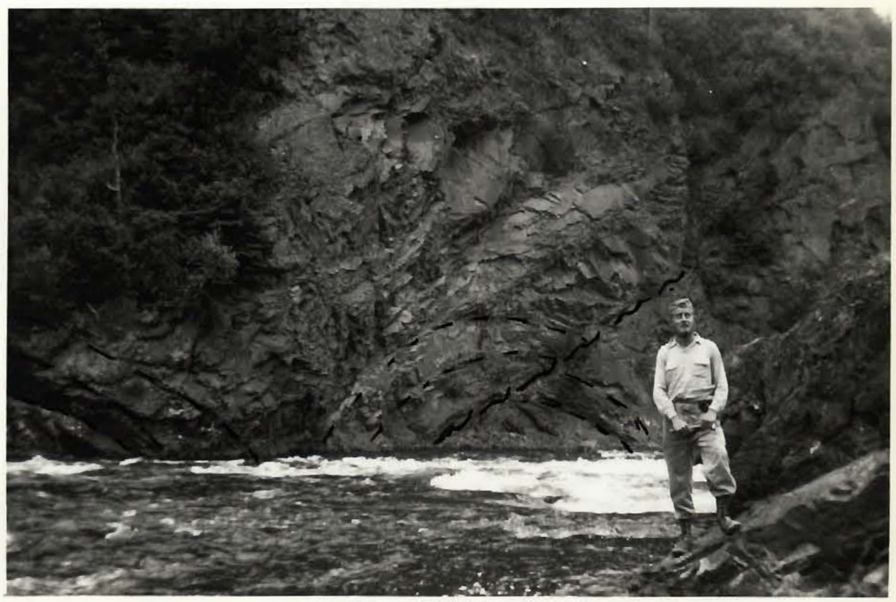


Fig.23 View of south cliff face on the Moisie River, note two anticlines close together, a fault dipping 40° E, cuts and offsets the west anticline.

encing factor in some of the sulfide deposits of the area. Probably the injecting solutions that formed the pegmatite carried sulfides which were deposited in a favorable host rock such as the gneisses, the pegmatite solution affected the gneisses in such a manner as to concentrate sulfides which were inherent in the gneisses.

All these occurrences, including the Bar Lake zone, are too small to be of economic importance.

Mineralography:

A microscopic study of polished sections show the following metallic minerals and their volume percentage in the rock.

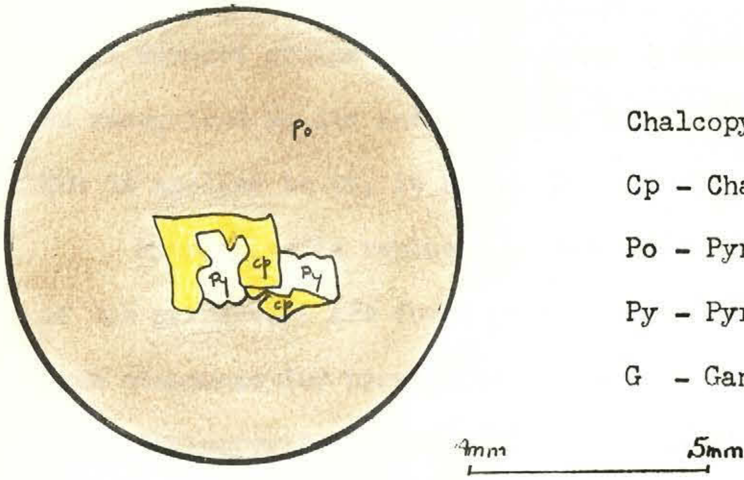
Pyrite	(FeS_2)	15%
Magnetite	(Fe_3O_4)	5%
Pyrrhotite	($Fe_{1-x}S$)	2%
Chalcopyrite	($CuFeS_2$)	<1%
Ilmenite	($FeTiO_3$)	<1%

The pyrite occurs as rounded masses about .5mm in diameter which parallel the grain boundaries of the quartz. It is a light yellow color, isotropic, high relief, and irregularly fractured. Magnetite surrounds some of the pyrite grains, this is a result of oxidation of the pyrite.

In some places blebs of ilmenite surround the magnetite. Therefore the ilmenite is later than the magnetite, some of the magnetite is earlier than the pyrite and some is post pyrite.

Fig.24 A small fold in the mineralized quartzite of zone "A"

Polished section diagrams of Zone "A"



Chalcopyrite replacing pyrite and pyrrhotite.

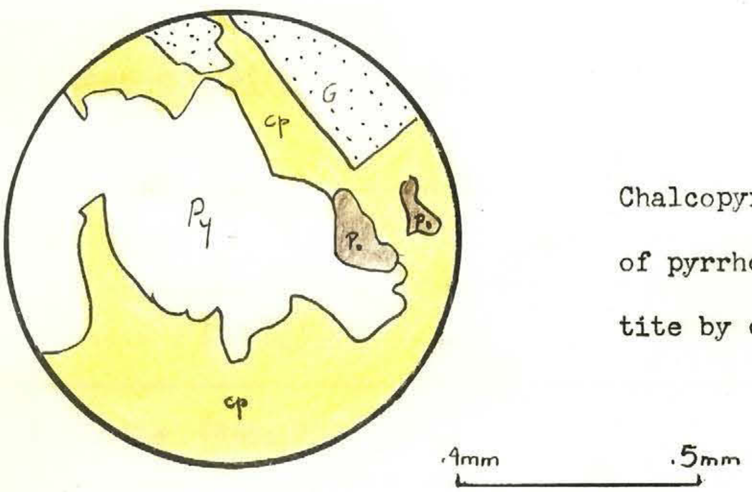
Cp - Chalcopyrite ($CuFeS_2$)

Po - Pyrrhotite ($Fe_{1-x}S$)

Py - Pyrite (FeS_2)

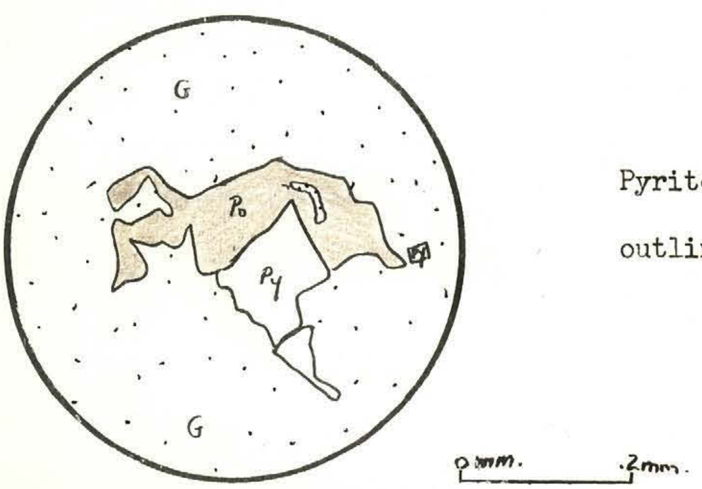
G - Gangue

Fig.26



Chalcopyrite replacing pyrite, note the island of pyrrhotite left after replacement of pyrrhotite by chalcopyrite.

Fig. 27



Pyrite replacing pyrrhotite, note the cubic outline of the pyrite - pyrrhotite contact.

Fig.28

Pyrrhotite averages 2 percent of the sections, it occurs in small rounded grains about .2 - .5mm in diameter. The pyrrhotite is recognized by its anisotropism, its pinkish brown color and when KOH is applied to it, it stains iridescent.

Pyrrhotite is replaced by the pyrite (Fig.28) and around some of the pyrrhotite are found rims of marcasite. This is a typical alteration phenomena for pyrrhotite.

Chalcopyrite is the last mineral to be introduced into this zone. It replaces both the pyrite and pyrrhotite (Fig.26). It is a characteristic butter yellow, soft, and it has a black streak. The grains of this mineral do not exceed .1mm in diameter.

Paragenetic Diagram for Zone "A"

Minerals	Early	Late
Magnetite (Fe_3O_4)	-----	---------
Ilmenite ($FeTiO_3$)	------	
Pyrrhotite ($F_{1-x}S$)	--------------	
Marcasite (FeS_2)	--?--	
Pyrite (FeS_2)		----------------
Chalcopyrite ($CuFeS_2$)		------

Zone B:

This occurrence is in the quartz vein which cuts the marble in the north part of the claim group. The sulfides are found as fracture fillings and disseminations about these fractures. The mineralized rock occurs in oval masses through the quartz vein, none of these pods are continuous, the largest one is 12 feet in diameter.

The sulfides recognizable in the field are pyrrhotite, sphalerite and chalcopyrite, they assay up to 14.7 percent zinc with traces of silver and gold.

Insufficient mineralization is present to make this find economically important.

Mineralography:

A polished section study of some mineralized rock samples show the presence of the following minerals.

Sphalerite	(ZnS)	10 - 20%
Pyrrhotite	$(Fe_{1-x}S)$	2 - 5%
Marcasite	(FeS_2)	$<1\%$
Magnetite	(Fe_3O_4)	$<1\%$
Chalcopyrite	$(CuFeS_2)$	$<.5\%$

Iron rich sphalerite is the most abundant sulfide in Zone "B". The sphalerite replaces the quartz along fractures and grain boundaries. Under the microscope this sulfide appears light grey, it is soft, and it has internal reflection.

Sphalerite replaces pyrrhotite (Fig.29), usually the zinc sulfide is coarse grained and rounded, the average grain size is 2 - 3mm in diameter.

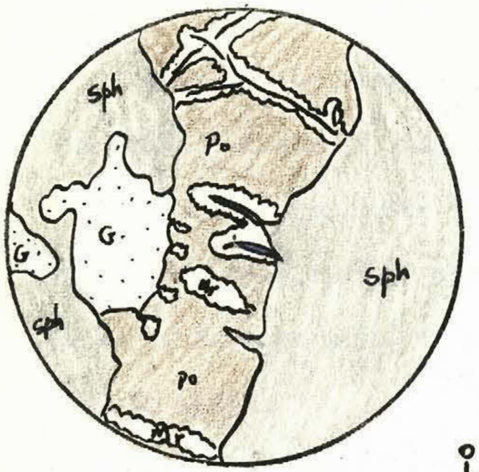
Pinkish brown anisotropic pyrrhotite is found replaced by sphalerite in grains averaging 1 - 2mm in diameter, some of the pyrrhotite is altered to marcasite. Birds-eye texture is present in places where this phenomena occurs (Fig.29). Some of the iron is oxidized and as a result small stringers of iron oxide are found in the marcasite.

Chalcopyrite is a minor mineral in this zone, it replaces marcasite and magnetite (Fig.30). The copper sulfide is in irregular grains not more than .1mm in length. On the bases of the minerals present and their association this deposit may be considered a moderate to high temperature, hydrothermal replacement type.

<u>Paragenesis:</u>

Minerals		Early	Late
Quartz	(SiO_2)	------------	
Pyrrhotite	($Fe_{1-x}S$)	? -- -- --------	
Sphalerite	(ZnS)	----------	
Marcasite	(FeS_2)		-------- - - - - -- ?
Magnetite	(Fe_3O_4)		--------
Chalcopyrite	($(FeCu)S_2$)		---------

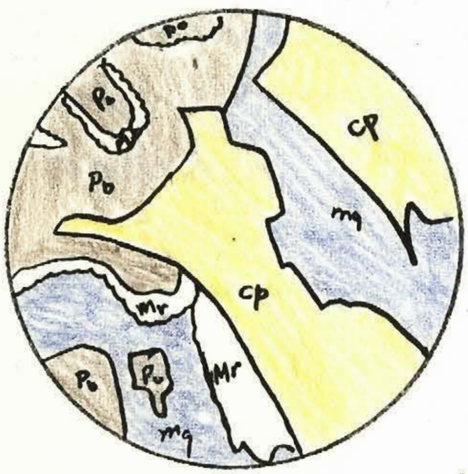
Polished section diagrams of Zone "B"



Marcasite replacing pyrrhotite (birds-eye texture). Magnetite occurs between the boundaries of the marcasite. Sphalerite has replaced pyrrhotite.

0 .5mm.

Fig.29



Chalcopyrite is replacing pyrrhotite, magnetite is replacing pyrrhotite. Chalcopyrite seems to cut the marcasite.

Po - Pyrrhotite ($Fe_{1-x}S$)

Mg - Magnetite (Fe_3O_4)

.4 .5mm.

Fig. 30

Mr - Marcasite (FeS_2)

Sph - Sphalerite (ZnS)

Zone C:

This is the largest and most promising showing of the claim group. The sulfide minerals visible in the field are pyrrhotite and chalcopyrite.

The sulfides occur in peridotite at the base of a gabbro intrusive, 2000 feet east of station 1500N. The zone strikes 340T and dips 60 to 70 degrees east, it is about 400 feet long and averages 30 to 50 feet in width.

A fault, which is post mineral, cuts the sulfide bearing rock at 360T and dips 60 degrees west, the fault is normal (Fig.18).

The metallic minerals are coarsely disseminated through the peridotite. Assays show approximately 1 to 1.5 percent combined copper and nickel, .3 percent cobalt and a trace to .1oz of silver per ton.

Mineralography:

Following are the minerals seen in the polished sections of the sulfide bearing peridotite.

Pyrrhotite	$(Fe_{1-x}S)$	10 - 30%
Chalcopyrite	$(CuFeS_2)$	5 - 10%
Magnetite	(Fe_3O_4)	5 - 10%
Violarite	$(NiFe)_3S_4$	5%
Pentlandite	$(FeNi)_8S_9$	3%
Ilmenite	$(FeTiO_3)$	1%
Pyrite	(FeS_2)	<1%
Cubanite	$(Cu_2Fe_4S_6)$	1%
Hematite	(Fe_2O_3)	<1%

Fig.25 A trench cut into the mineralized peridotite of zone "C", dip of the zone is 60° east.

Pyrrhotite:

Pyrrhotite is identified by its pinkish cream color, its strong anisotropism and its iridescent stain when KOH is applied.

It is the most common mineral in the sections studied, it occurs as irregular coarse grained fragments which measure up to 2mm in diameter .

Around some of its grain boundaries pyrrhotite is eaten into by pyrite (Fig.31). Magnetite is commonly found oxidizing from the pyrrhotite (Fig.38).

Pyrrhotite is the earliest deposited sulfide.

Pentlandite:

Pentlandite is lighter in color than the pyrrhotite and it is isotropic. Usually it is irregularly fractured. About 2 to 5 percent of the sections contain pentlandite, the grains are about .3mm in diameter.

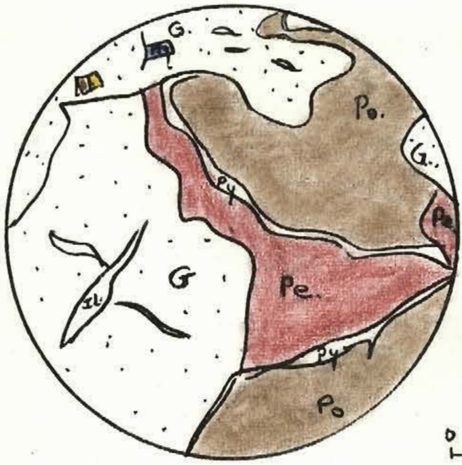
Pentlandite exsolves out of pyrrhotite giving a so called flame like texture (Fig.32). Pentlandite also rims the pyrrhotite, hence pentlandite is later than pyrrhotite.

Chalcopyrite:

Yellow chalcopyrite is fairly common in polished sections, 5 to 10 percent of the sections are chalcopyrite. It occurs in rounded grains which vary in size from .1mm to 1mm.

Chalcopyrite replaces pyrrhotite and pentlandite. When it replaces pyrrhotite, pyrite is often found in small blebs, magnetite frequently cuts chalcopyrite.

Polished sections diagrams of Zone "c"



Pentlandite replacing the grain boundary of pyrrhotite, note the rim of pyrite at the contact of pentlandite and pyrrhotite.

Po - Pyrrhotite ($Fe_{1-x}S$)

Pe - Pentlandite $(FeNi)_8S_9$

0 .2mm

Py - Pyrite (FeS_2)

V - Violarite $(NiFe)_3S_4$

Cp - Chalcopyrite $(CuFe)S_2$

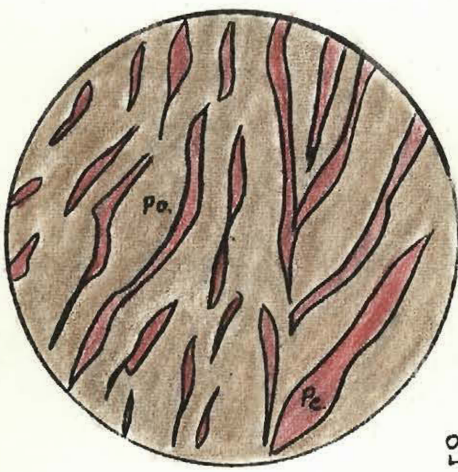
Cb - Cubanite ($Cu_2Fe_4S_6$)

Mg - Magnetite (Fe_3O_4)

Il - Ilmenite ($FeTiO_3$)

He - Hematite (Fe_2O_3)

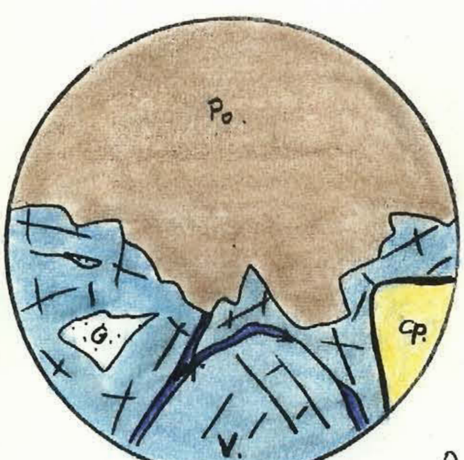
Fig.31



Feather structure formed by the exsolution of pentlandite from pyrrhotite.

0 .2mm

Fig.32



Violarite (fractured) replacing pyrrhotite, note magnetite filling some of the fractures in violarite. The boundary of the chalcopyrite seems to have been rounded from replacement by violarite.

0 .2mm

Fig. 33

In the chalcopyrite is found exsolved laths of cubanite (Fig.36-37). This exsolution phenomena indicates that the chalcopyrite present is the high temperature type. According to Schwartz[11] cubanite and chalcopyrite unmix at 450°C. The cubanite laths are easily distinguished from chalcopyrite because the laths have strong anisotropism.

Violarite:

A greyish blue isotropic mineral that effervesces and stains black when HNO_3 is applied, is identified as violarite. It is usually fractured into small, roughly square blocks and some fragments have cubic cleavage (Fig.38). Violarite replaces pyrrhotite and it in turn is replaced by chalcopyrite and cubanite (Fig.33).

It is commonly thought that violarite is an alteration product of pentlandite, but in these sections this relationship is not found. Violarite in zone "C" replaces pyrrhotite but no replacement of pentlandite by this mineral is seen. This means that the nickel preferred to enter the sulfide form as violarite, in other cases the nickel is present as pentlandite.

Short and Shannon[12] have found a similar situation at the Levack and Worthington mines near Sudbury. There the nickel ores are associated with violarite and where violarite is found no pentlandite is present. They concluded that unknown conditions allowed precipitation locally

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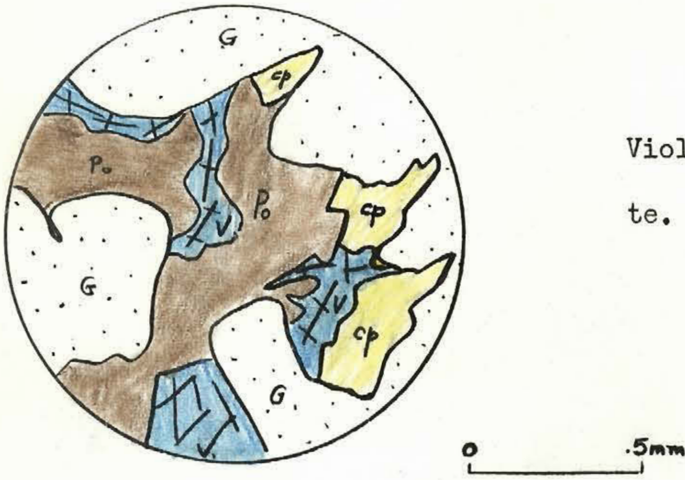
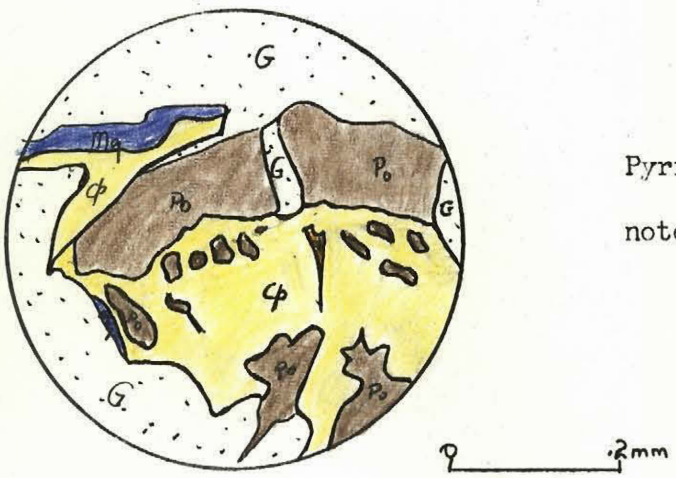
(11) Schwartz, G.M. : "Progress in the Study of Exsolution in Ore Minerals" Econ. Geol. Vol.37 pp.345-364 (1942)

(12) Short, M.N. & Shannon, E.V. : Amer. Min. Vol.15 (1930) pp.1-17 "Rare Nickel Sulfides"



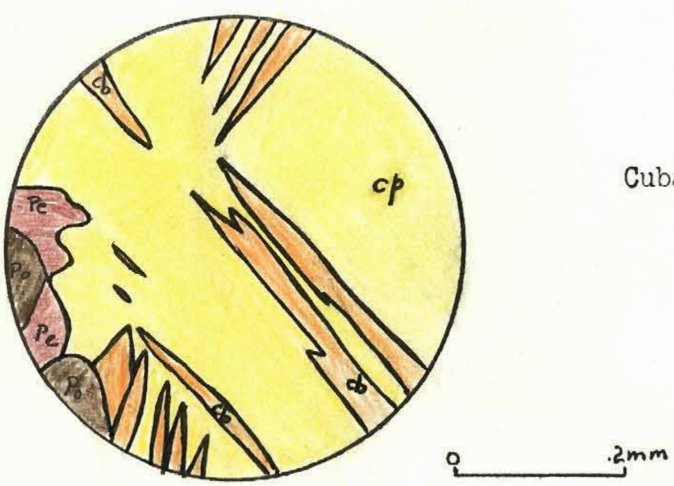
Violarite and chalcopyrite replacing pyrrhotite. Pyrrhotite is replacing the gangue.

Fig.34



Pyrrhotite being replaced by chalcopyrite, note islands of pyrrhotite in the chalcopyrite.

Fig.35



Cubanite laths exsolving from chalcopyrite.

Fig.36

of violarite rather than pentlandite, they say the violarite is hypogene. The same situation exists here. No pentlandite is seen where there is violarite. Violarite in this deposit is primary.

The three oxides present in this zone are magnetite, ilmenite and hematite. Bluish - grey magnetite is the most abundant of the three. It composes from 5 to 10 percent of the rock.

Some of the magnetite is surrounded by and enclosed in iron silicate minerals, this magnetite is considered primary. Another form of magnetite seen results from the breakdown of the iron rich minerals, especially olivine and pyrrhotite. When magnetite forms by alteration it usually occurs in stringers which cut the minerals. Olivine is cut irregularly by magnetite stringers, all sulfide minerals are intersected by magnetite.

Brownish grey ilmenite is found as inclusions in some pyrrhotite as well as in rounded masses enclosed by gangue. Ilmenite is usually found associated with magnetite, it replaces magnetite.

Hematite occurs in small, white grey anisotropic masses replacing magnetite (Fig.39). It usually makes up less than 1 percent of the section. Hematite is associated with the alteration of pyrrhotite, some of the iron formed from this alteration oxidizes as hematite instead of magnetite.

Hence these three oxides are included in the sulfides as well as in separate rounded masses, (.3mm in diameter) in the iron silicates. When the intrusion cooled some of these oxides formed at the time of crystallization, some have formed later as a result of alteration of olivine and iron sulfides.

Magnetite is usually replaced by ilmenite and hematite. Hematite is the latest formed iron oxide.

Origin of Zone "C":

This deposit is classified as magmatic in origin. Using Bateman's classification the deposit is called, a late magmatic, immiscible liquid segregation type. A similar occurence is found at Insizwa, South Africa[13].

The processes involved are injection of the igneous body, followed by crystallization. During crystallization the heavier minerals tend to sink and coagulate near the bottom of the intrusive and the more acid minerals float and crystallize near the top. This process explains why the more felsic gabbro occurs above the basic peridotite. According to Vogt[14], iron-nickel-copper sulfides are soluble up to 6 or 7 percent in basic magmas and upon cooling they may in part separate out as immiscible drops, which accumulate at the bottom of the magma chamber. The sulfides remain liquid until after the silicates crystallize, then the sulfides crystallize and corrode the silicates, this gives replacement textures. The early crystallized sulfides (eg. pyrrhotite and pentlandite) are in turn replaced by the later forming sulfides (eg. chalcopyrite and cubanite).

Evidence to support a theory of magmatic segregation for this deposit is:

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(13) Du Toit, A.L. : "Geology of South Africa" 3rd ed. pp.360-370 Oliver & Boyd - Edinburgh, 1954.

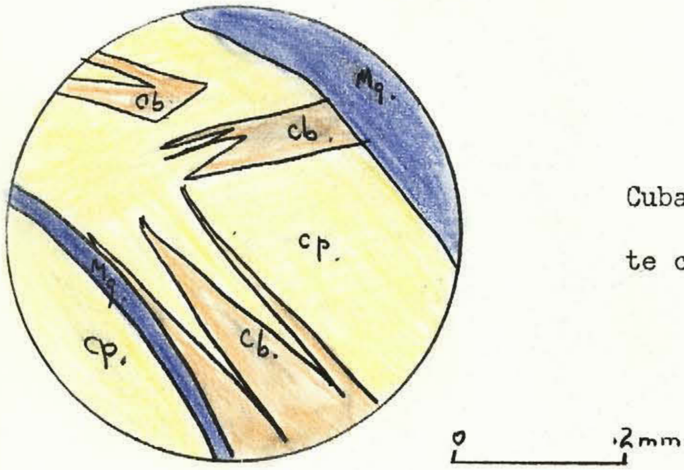
(14) Vogt, J,N.L. : "Magmas and Igneous Ore Deposits" Econ. Geol. Vol. 21 (1936)

(1) The absence of any wall rock alteration. If hydrothermal solutions were active some alteration of the wall rock would be expected, nosuch phenomena is found.

(2) The heavier minerals are concentrated in the bottom of the sill. This shows a gravitational settling out of these minerals at the time of crystallization.

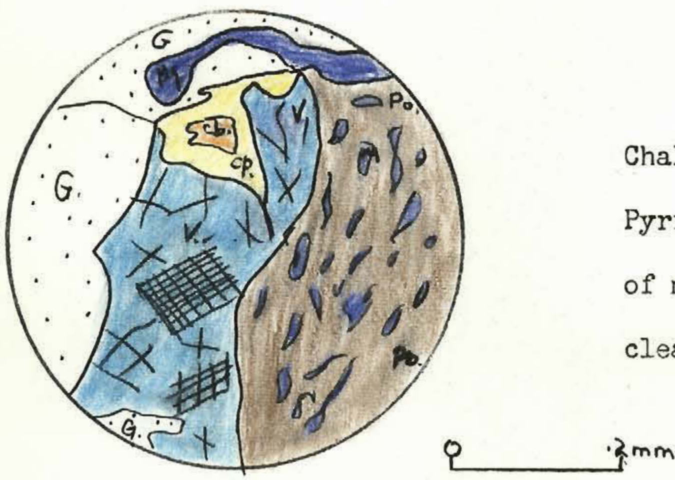
(3) The deposit is within the high temperature range of magmatic deposits. Chalcopyrite, which is the latest sulfide, shows eutectic intergrowths of cubanite, this reaction takes place at 450°C. Hence the earlier sulfides must have crystallized out at temperatures equal to or higher than 450°C.

(4) The olivines are relatively unaltered. Hydrothermal solutions would alter olivine to antigorite or serpentine. In the fresh rock samples studied the olivine is altered little. Antigorite is found in sections of rock taking near the surface. This antigorite then is a result of weathering and not due to alteration from metal bearing solutions. No such alteration is obvious in the slides of the fresh peridotite.



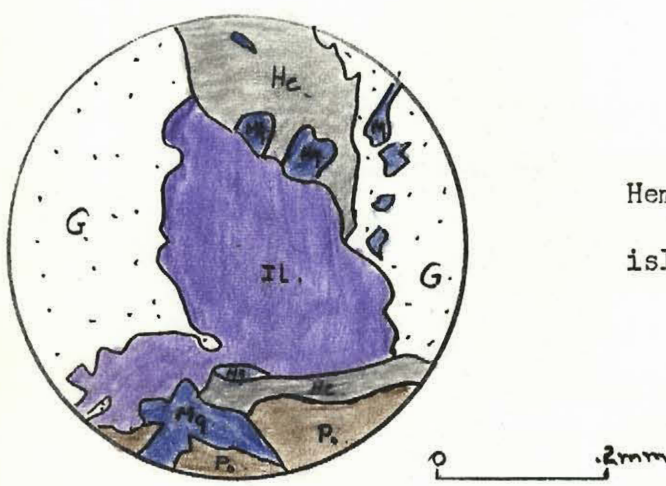
Cubanite exsolving from chalcopyrite. Magnetite cuts earlier chalcopyrite and cubanite.

Fig.37



Chalcopyrite and cubanite replacing violarite. Pyrrhotite altering to iron oxide forms blebs of magnetite in the pyrrhotite. Note cubic cleavage of violarite.

Fig.38



Hematite and Ilmenite replacing magnetite, note islands of magnetite in the hematite.

Fig.39

Paragenesis:

Minerals		Early	Late
Pyrrhotite	($Fe_{1-x}S$)	---------	
Pentlandite	($(FeNi)_8S_9$)	-- -- ----	
Pyrite	(FeS_2)	? ------	
Violarite	($(NiFe)_3S_4$)		--------
Chalcopyrite	($CuFeS_2$)		-----------
Cubanite	($Cu_2Fe_4S_6$)		---------
Magnetite	(Fe_3O_4)	------	------
Ilmenite	($FeTiO_3$)	------	------
Hematite	(Fe_2O_3)		------

Economic Significance:

The deposit in itself is too small and low grade to be economic importance at presence but the occurrence does indicate that some gabbros of the area are metallogenic.

These peridotites are easily identified because they weather to a red crumpled mass, this marker is an aid in prospecting for more of these grabbroic intrusives.

Chapter 6

SUMMARY AND CONCLUSION

Pegma Lake is 160 miles north of Seven Islands. The area is underlain by paragneisses and marble which strike about 350 T and dip $30^{\circ} - 60^{\circ}$E, gabbro, pegmatites and granite intrude these gneisses and the rocks are similar to the Grenville types.

Major northeast faults are vertical, subordinate faults strike west of north and dip east. The larger faults are a result of vertical and rotational forces, the minor faults are due to compression from the east.

Drag folds are common in all rock types. A series of closely spaced synclines and anticlines occur east of the Moisie River. Dips of the rocks east of the map area suggest the presence of a large syncline the axis of which trends about northwest. Sulfide mineralization is found in a quartz vein, in hornblende - pyroxene gneiss at Bar Lake and in a differentiated gabbro sill. The sulfides in the sill are copper - nickel bearing and they are a result of immiscible liquid segregation in a differentiated intrusive, the deposit is of late magmatic origin.

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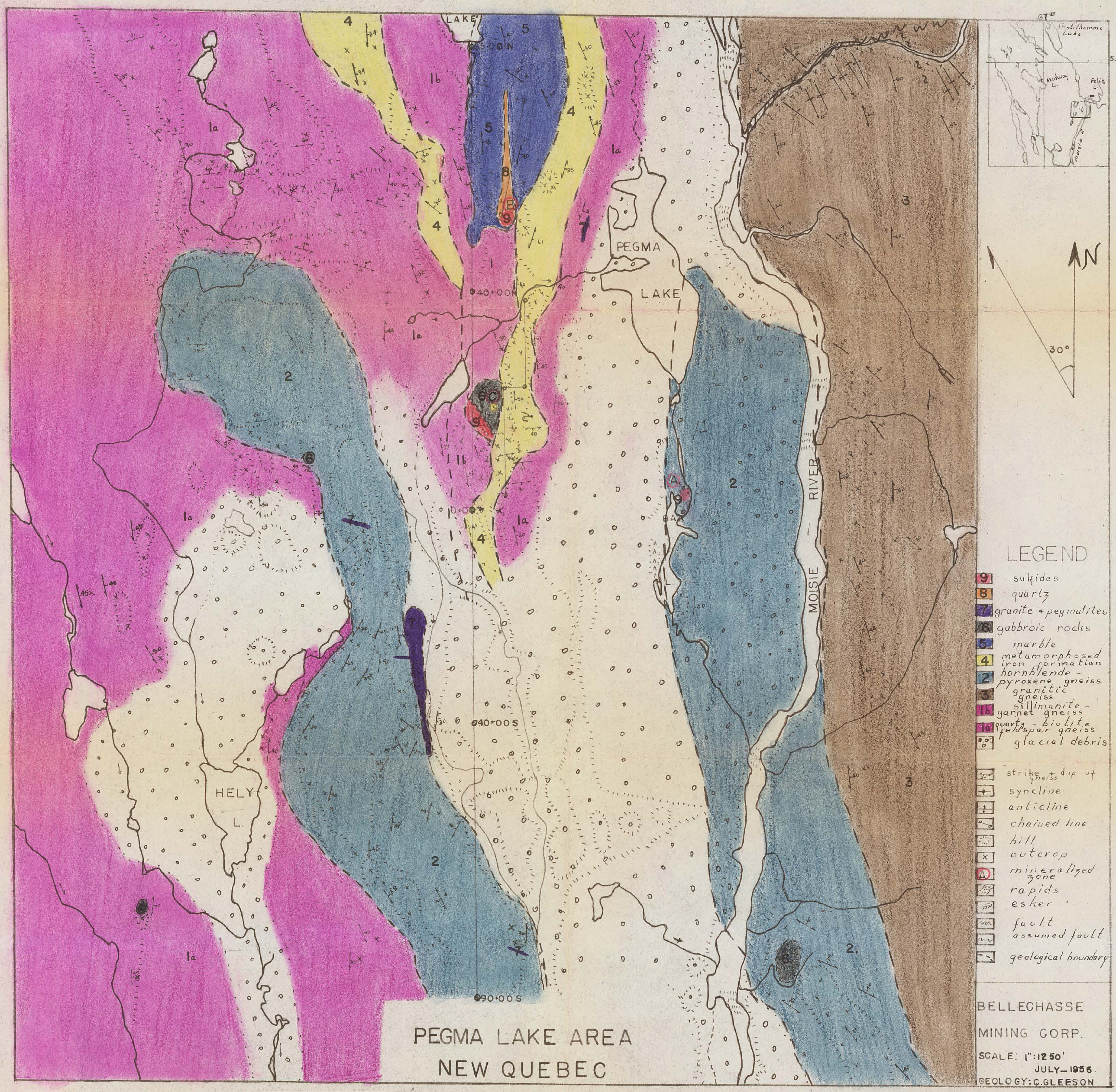
PEGMA LAKE AREA
NEW QUEBEC
BELLECHASSE
MINING CORP.
SCALE: 1" : 1250'
JULY - 1956.
GEOLOGY: C. GLEESON
LEGEND
9 sulfides
8 quartz
7 granite + pegmatites
6 gabbroic rocks
5 marble
4 metamorphosed iron formation
2 hornblende - pyroxene gneiss
3 granitic gneiss
1b sillimanite - garnet gneiss
1a quartz - biotite feldspar gneiss
glacial debris
strike + dip of gneiss
syncline
anticline
chained line
hill
outcrop
mineralized zone
rapids
esker
fault
assumed fault
geological boundary
PEGMA
LAKE
HELY
L.
MOISIE
RIVER
LAKE
40+00N
40+00S
90+00S
N
30°