THE GEOLOGY OF THE ST. PIERRE PROSPECT

FORT CHIMO DISTRICT, QUEBEC

by

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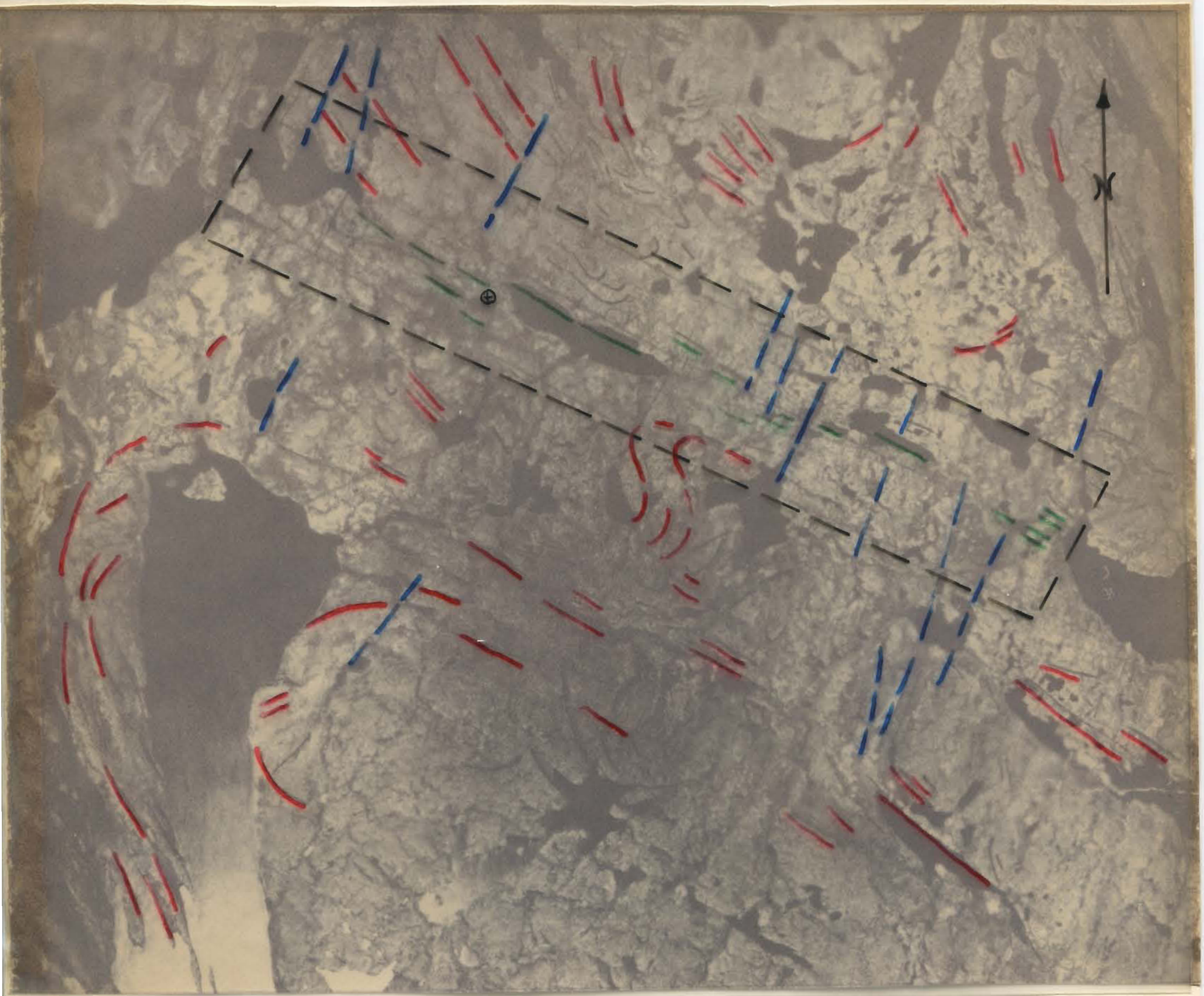
(Figures marked (c.l.) are camera lucida drawings of thin sections or polished sections).

Frontispiece

The Structural Setting of the St. Pierre Prospect.



Vertical aerial photograph - one inch to one half mile

- outline of map area
- linears of folds
- schist zone linears
- cross fractures

INTRODUCTION

General Statement

The recent development of rich iron ore deposits in the heart of the Labrador-Ungava peninsula, with the subsequent construction of a 350 mi. railway connecting the deposits to the St. Lawrence River, has opened the door to the exploration of a vast region rich in indications of iron and base metal mineralization. Systematic exploration of this hitherto inaccessible territory has revealed that potentially economic concentrations of iron, copper and nickel lie within the "Labrador Trough", a belt of ancient, more or less deformed sediments, which stretches at least five hundred miles from Menihek Lake in the south, northwestward to Payne Bay. (See fig.1)

At the time of writing, most, if not all, of the well-exposed iron ore deposits have been discovered, and prospecting activity in this field is declining.

On the other hand, the search for copper-nickel sulphide deposits is at its peak, with prospecting confined to the part of the "Trough" which lies to the southwest of Ungava Bay.

During the intensive prospecting of this area, a few deposits have been found which differ markedly from the typical occurrences of copper-nickel sulphides which sparked the original search. The discovery of each variant deposit gives rise to hopes that a new metal province has been located. For this reason, each new occurrence is subjected to detailed geologic study. One such variant deposit is the St. Pierre Prospect, the subject of this thesis. The description which follows is believed by the writer to be the first detailed report on a highgrade lead-zinc-copper-precious metals sulphide deposit in the Ungava region. Although present information indicates that the deposit is not of economic size, the material presented in this paper may be significant in the search for, and development of, possible similar deposits elsewhere in the area.

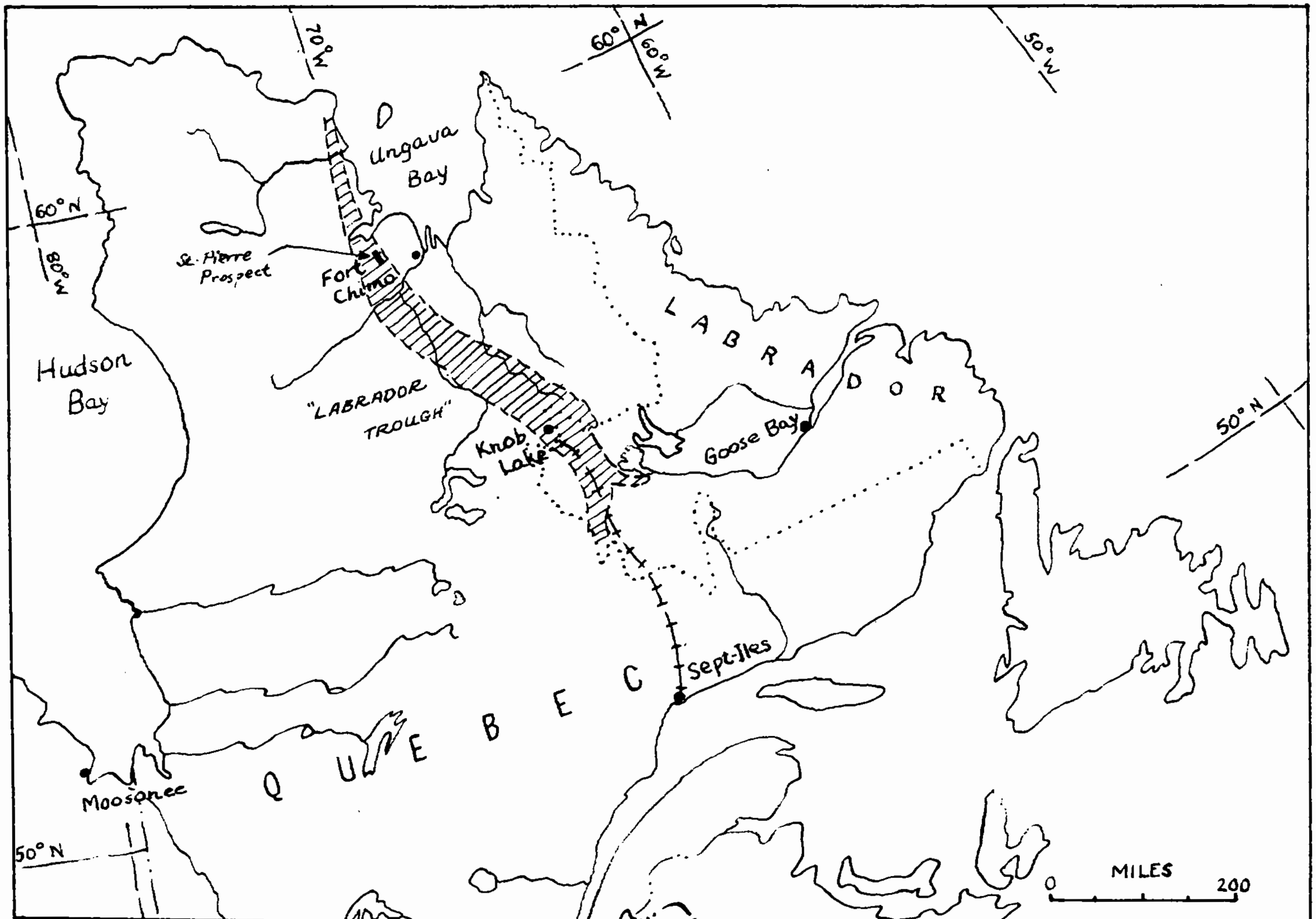
The St. Pierre Prospect comprises twenty-five mining claims which constitute a portion of the holdings of Holannah Mines Ltd. in northeastern Ungava. A small body of massive sulphides exposed at surface was found to contain significant amounts of copper, lead, zinc, gold and silver. On the basis of this, an exploration program, consisting of geologic mapping, sampling, geophysical surveys and diamond drilling, was carried out during the summer of 1955. The writer conducted the geologic mapping and sampling.

This thesis presents the result of the field study and laboratory investigations carried out at McGill University.

Location and Access

The 25 mining claims of the St. Pierre Prospect were staked along a centre line which has the azimuth of 120°. Twelve claims lie to the northeast and thirteen to the southwest of the line, giving a crudely rectangular area

Fig. 1 - The Location of the Thesis Area.



approximately three miles by one mile in size.

The southeast end of the centreline of staking is approximately forty-six miles west-northwest of the town of Fort Chimo on the estuary of the Koksoak River, near the south end of Ungava Bay. (See fig.1)

In winter and summer, the only practical means of access to the area is by the use of ski- or float-equipped aircraft, which can land on Goose, Ptarmigan or St. Pierre lakes, wind permitting. The area is inaccessible during the periods of "freeze-up" (mid-October to mid-November), and "break-up" (mid-May to mid-June), when unfavourable ice conditions prohibit the landing of aircraft.

A landing strip near Fort Chimo provides a base for the delivery of heavy equipment.

Vessels of less than 3,000 tons burden can dock at Fort Chimo during the navigation season (mid-July to mid-October).

The construction of any road or railway from the vicinity of the St. Pierre Prospect to tide water would be an expensive project, as the route would of necessity cut across the trend of the geologic structures, which govern the regional topography. Numerous rock ridges and lake-filled valleys would have to be crossed during any such construction.

History of Discovery and Development

During the 1953 field season, Holannah Mines Ltd. began a large-scale program of mineral exploration in the northern portion of the Labrador Trough. Prospecting was concentrated in a region some sixty miles west of Fort Chimo, where numerous rusty outcrops had attracted the attention of company geologists. By the middle of the 1954 season, most of the promising ground had been staked, and prospectors began to move farther afield. On one such investigation, the prospectors, St. Pierre and Alexandre, discovered a small rusty patch on the side of a rock hump overlooking the northwest end of the lake later named after St. Pierre. Close examination revealed the presence of a small body of massive base metal sulphides. On the strength of this, 5 claims were staked to cover the showing and any possible extensions along the strike.

In the following winter, after assays had revealed the presence of interesting values of gold and silver as well as of base metals, an additional twenty mining claims were staked, extending the original holdings both along and across strike.

During June and July, 1955, the writer and his assistant mapped geologically the St. Pierre claim group at one inch to one thousand feet. An effort was made to examine each outcrop in the area, and to this end, closely spaced traverses were run both along and across the regional structural trend. Outcrops were located in the field on a one inch-to-one thousand feet vertical aerial photograph. From this, they were later transferred to a base map traced from the same photograph. As the amount of outcrop is approximately thirty percent, a great deal of structural and stratigraphic information was obtained from the mapping.

The sulphide showing at the northwest end of St.Pierre Lake was mapped at one inch to one hundred feet. Outcrops were located by tying-in to an accurately established base-line. Unfortunately, the portion of the area in which the showing lies has relatively little outcrop, and a certain amount of error must be expected in structural interpretations made by interpolation between widespread rock exposures.

At the time of the geologic mapping, a survey of the magnetic and electromagnetic properties of the area was in progress. The results of this work have been made available to the writer, and have been used in the interpretation of rock structures in parts of the area in which the thick overburden allows little exposure of bedrock.

Late in August, 1955, a drilling program was started. Twenty boreholes, averaging one hundred and twenty-five feet, were drilled. The writer examined the cores of the first seventeen drillholes.

Representative samples of normal and altered rocks of the area, as well as a suite of specimens of sulphide-bearing rock, were taken. From this collection, twenty-five thin sections and twenty polished sections were studied.

In accordance with the policy of Holannah Mines Limited, the results of metals assays and the dimensions of bodies of economic minerals cannot be included in this paper.

Previous Geologic Work

As far as the writer knows, nothing had been recorded concerning the geology of this part of Quebec prior to the preparation of this thesis.

During the summers of 1953 and 1954, geologic parties of the Quebec Department of Mines mapped three areas centred some ten miles south of the St. Pierre Prospect (2; 3; 4).

Note: Numbers in brackets following sentences refer to papers and texts listed in the bibliography at the end of this thesis.

In 1955, Pierre de Montigny, a student at Laval University, wrote a baccalaureate thesis based on a study of ore minerals of the Soucy Lake Showing. This showing is eight miles west of the St. Pierre Prospect.(32)

Acknowledgements

It is a pleasure to acknowledge the cooperation of members of the staff of Holannah Mines Ltd. Dr. R.D.Macdonald, Chief Geologist of the company, kindly gave permission to use the data on which this thesis is based. R.M.Slipp gave helpful advice on many occasions, both in the field and during the subsequent research work. Dr. H. A. Shillibeer was in charge of the geophysical surveys conducted on the prospect, and J. Grant supervised the diamond drilling.

A. R. McDonald of Mount Allison University, was a capable and enthusiastic assistant during the field work.

The writer also wishes to thank the members of the staff of the Department of Geological Sciences, McGill University, for their kind help and advice. In particular, the constructive criticisms of Dr. J. E. Gill, director of this thesis, were of great value.

SURFACE FEATURES AND CLIMATE

Topography

A low, rolling topography predominates in the area, and relief is of the order of fifty feet. The situation changes in the northwest corner of the claim group, where a series of ridges, underlain by resistant gabbro sills, rises one hundred and fifty feet above local lake level. The southern and eastern sections of the area are part of a broad, shallow valley which slopes upward gently towards the southwest, and eventually culminates in a complex ridge of gabbroic and ultramafic sills which lies approximately one mile outside the southwestern boundary of the claim group. The floor of the valley is corrugated by occasional low ridges marking narrow gabbro sills, and by low linear mounds of undifferentiated morainal material.

On the whole, the topography of the map area is a faithful reflection of the underlying geological structures, slightly modified by glacial deposits. The location of each rock type can be determined by the shape and relief of its characteristic topographic expression. Gabbros and ultramafic sills produce persistent ridges whose height varies directly as the thickness of the individual sill and inversely as the distance between the sills and their degree of development of jointing. These ridges are transversely segmented by low zones caused by close cross jointing. The fissile ferruginous slates and grey schists can be traced by a series of topographic lows, in which the majority of the area's lakes are found. Quartzites and indurated metasediments have an intermediate effect, and are marked by level, well-drained terrain.

Readings taken, using an aircraft altimeter, show that the approximate elevation of the surface of St. Pierre Lake is 500' above sea level.

Most of the twenty-five small lakes of the claim group are shallow and are fed by intermittant streams. From the air, it can be seen that Ptarmigan, St. Pierre and Goose Lakes, which are aligned along the centreline of the area, are the only lakes in which the depth of water exceeds ten to twenty feet. In particular, St. Pierre Lake is seen to have a linear deep along its northeastern margin. The significance of these observations in the interpretation of the underlying rock structures will be discussed in later pages.

There are no navigable streams in the area. The southern and southwestern portions of the area drain to the northwest, and the northeastern corner drains northward.

Climate

The St. Pierre area has a typical sub-arctic climate. The prevailing winds are from the north. Precipitation is less than 20" annually (1, p.594). The mean temperature from "breakup", in late June, to "freeze-up", in mid-October, is approximately 45° Fahrenheit.

Timber Resources

Although the St. Pierre area lies north of the regional tree line, a few protected valleys exist which may be considered as northerly projecting fingers of the coniferous forest zone. One such valley north of Ptarmigan Lake contains a stand of tamarack (Larix americana) and black spruce (Picea nigra). These trees are of sufficient size to supply camping and staking needs for a short period.

The less sheltered part of the area has rare clumps of stunted tamarack and spruce, which rise two to four feet above the ground vegetation of mosses and lichens.

REGIONAL GEOLOGY

Introduction

The St. Pierre Prospect lies in the northeastern part of the geologic unit known as the "Labrador Trough". The rocks of the prospect can be understood best in the light of their relationships to the surrounding formations. For this reason, the regional stratigraphy and structural geology will be discussed in some detail in the following pages.

The Labrador Trough is a relatively narrow band of Late Precambrian rocks which extends from the headwaters of the Moisie River in southern Ungava, to the mouth of the Payne River on the west side of Ungava Bay. The width of the "Trough" ranges from a few miles to sixty miles (5,p.529). Workers in the area class the rocks as Proterozoic, and agree that the Trough formations occupy an ancient basin of sedimentation underlain by a complex of Archaean granite and gneiss (5, p.529; 1, p.2; 15, p.4,5). Actually there is, at present, no reliable basis for correlation of these rocks with formations classed as Proterozoic or Archaean in other areas.

Stratigraphy

The stratigraphic succession of the Labrador Trough is remarkably uniform despite the great length of the basin and its variation in width.

To the west of the "Trough" lies the Basal or Ashuanipi Complex, a series of biotite, hornblende, garnet and granite gneisses, amphibolites and intrusive granites. This basement is overlain unconformably by a number of sedimentary beds, comprising mainly quartzite, dolomite, iron formation, chert and slate, or their metamorphosed equivalents.

Sheets of basic volcanic rocks occur locally intercalated with the sediments. Eastward across the Trough, the proportion of igneous to sedimentary rocks increases, and gabbroic to ultrabasic sills are common in the east central part of the basin. Along the eastern side, sills and flows predominate. They are separated by narrow bands of slate, tuff, conglomerate and quartzite.

From west to east, the gabbros fall into three categories:

(a) Augite-labradorite gabbros, with scattered orthopyroxenes.
(b) Hornblende-andesine gabbros.
(c) Serpentinized basic gabbros.

The sills are remarkably concordant, and many can be traced for miles, remaining concordant with the sediments, even through complex folds.

An individual sill may show textural variations suggestive of an origin by multiple injection (9). The same features have also been attributed to differentiation in place, or to differential metasomatism (18).

The association of these basic to ultrabasic sills with pillowed basaltic flow rocks, and their alignment with respect to the orogenic features of the Trough, suggest that these rocks are an ophiolitic series, i.e., submarine basic extrusives and corresponding intrusives, characteristic of the earliest stages of orogenic activity (8).

The eastern margin of the Trough has been insufficiently studied to permit definite statements as to its stratigraphic relation to the surrounding granite-gneiss complex. It has been suggested that the metamorphosed rocks of the eastern part of the Trough grade through facies of increasing metamorphism, into the gneisses of the east (19). An alternate possibility is that the granites and gneisses may have been brought into juxtaposition with the Trough sediments through the medium of thrust faults of great displacement, and thus, these two series of rocks may have no close age relationship.

Structural Geology

The sedimentary beds of the western part of the Labrador Trough dip gently to the east, and are only slightly disturbed by folding and faulting. Eastward, however, the degree of contortion increases steadily until, in the central part of the Trough, tight overturned folds, and thrust faults, are the characteristic structural features. The axial planes of the folds dip to the east, as do the thrust fault planes. The folds commonly plunge at less than twenty degrees, but locally, plunges may reach fifty degrees (15, p.16).

Auger (5, p.531) and Harrison (15, p.16) suggest that the folds were formed at the same time as the thrust faults, and that both types of structure are the result of a stress front coming from the east and northeast.

Cross faults are common, and are usually of small displacement. The main components of movement were horizontal, and dips are steep and to the northwest or southeast. Both right hand and left hand displacements are produced (15, p.16).

Normal faults striking parallel to the major thrust faults of the region are present. These are thought to be gravity faults, caused by a release of pressure at the end of the period of thrust faulting (5, p.531 and 15, p.16).

Regional Metamorphism

The degree of regional metamorphism varies greatly from place to place within the Labrador Trough. The relatively undisturbed sediments of the central western margin of the Trough have a relatively fresh aspect, with local development of minerals of the greenschist facies.

To north, south and east, the grade of metamorphism increases. Harrison (15, p.17) describes the rocks one hundred miles south of Knob Lake as being products of a high grade of metamorphism. Auger mentions the appearance of such minerals as actinolite, cummingtonite, tremolite, garnet and specularite in the Trough formations north of the Larch River (5, p.531).

A zone of mica schists and hornblende schists separates the normal Trough sediments from the gneiss-granite complex to the east. Workers both north and south of the Koksoak

River have expressed the opinion that these schists have been derived from the Trough sediments by the processes of dynamo-thermal metamorphism (19, and 12, p.2).

Effects of hydrothermal metasomatism are seen in the vicinity of the gabbroic sills of the east central and eastern parts of the Trough. The degree of wallrock alteration along the contacts of such sills is usually slight, but in several cases, a moderate degree of silicification and replacement by sulphides is apparent both in the sills and in the sediments immediately adjacent to them.

History of the Labrador Trough

The stratigraphy and structures of the rocks constituting the Labrador Trough are evidence of a history that may be explained by the following hypothetical sequence of events:

(i) Depression by down-bowing of a shallow elongate basin in the Archaean rocks of northeastern Ungava. (The possibility that the eastern side of the Trough was depressed by rifting has also been suggested - 7).

(ii) Deposition of the basal members of a sedimentary series.

(ii) Further deposition of sediments, accompanied by intermittant igneous activity, and interrupted by periods of emergence and erosion due to orogenic disturbances.

(iv) Stress from the northeast, producing folding and thrust faulting.

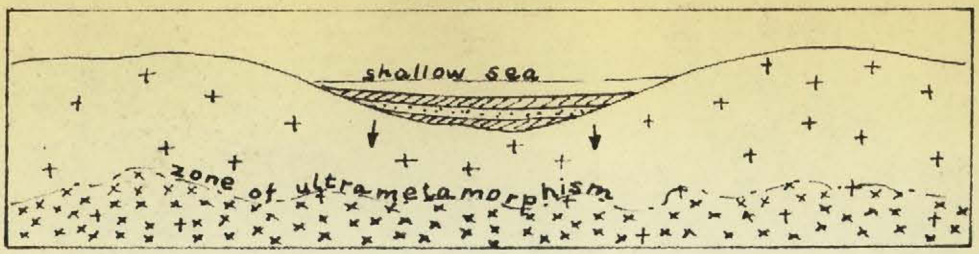
(v) Release of stress, normal faulting.

(vi) Uplift and erosion. Later deformation, producing cross faults.

This history is presented graphically in a series of diagrams. (See fig. 2) The sections are after those of Auger (5, p.530), with several significant modifications based on the conclusions reached by the writer as a result of three seasons of field work in widely separated parts of the Trough.

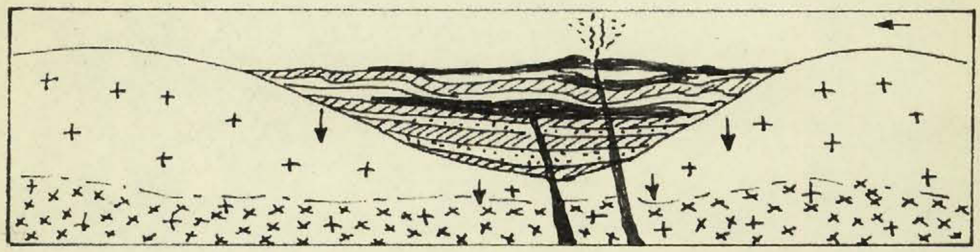
Fig. 2 - The Geologic History of the Labrador Trough, Shown in a Series of Hypothetical Transverse Sections.

1.



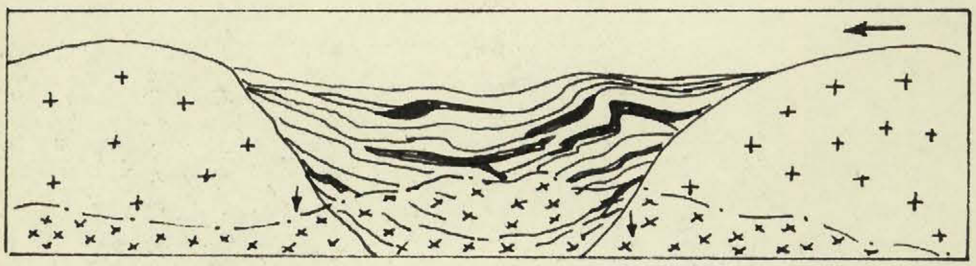
Deposition and subsidence.

2.



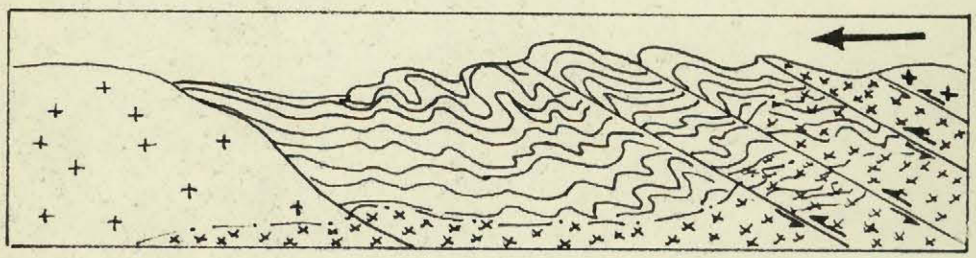
Subsidence, compression and vulcanism.

3.



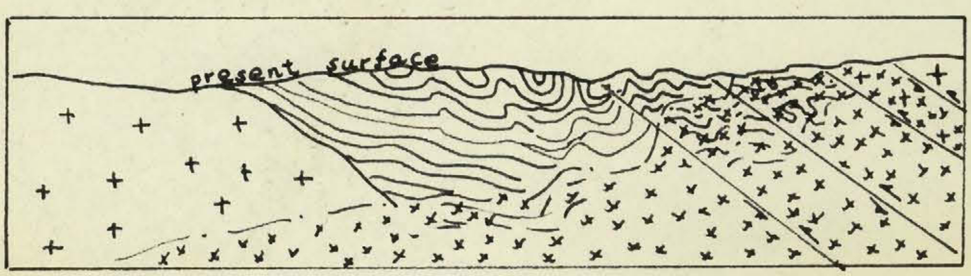
Subsidence, with increasing compression.

4.



Thrusting from the east.

5.



Erosion to present surface.

LOCAL GEOLOGY

General Statement

The St. Pierre Claim Group is underlain by a series of metasediments which have been intruded by basic to intermediate metagabbro sills. The resulting complex has been intricately folded and faulted. The metasediments are for the most part grey slates, with interbedded quartzites, iron-carbonate slates, and green, magnetite-bearing slates. These bedded rocks are the metamorphosed equivalents of a conformably deposited series of clastic and chemically precipitated sediments.

The area has been glaciated, and is at present partially covered by ground moraine and fluvioglacial deposits.

Table of Formations

Recent and Pleistocene	Tundra soils Frost-heaved rubble Fluvioglacial deposits Glacial boulder clay
Great Unconformity	
Late Precambrian (?)	Metagabbro sills
	Igneous Contact
	Grey Slate Complex: Iron-carbonate Slate Quartzite Green, Magnetite-bearing Slate Grey-Green Slates, Phyllites and Metatuffs (?)

Description of Rock Types

Metasediments

Grey-green Slates, Tuffs and Phyllites. Ten separate bands of interbedded slates and tuffs are found in the map area. These bands are separated by gabbro sills, or by sedimentary sub-facies of different compositions formed during temporary changes in the conditions of deposition.

The designation of some of the beds as "tuffs", or "metatuffs", is an arbitrary one, as no direct evidence of volcanic activity was seen in the area. Fine-grained, laminated, green chloritic beds are considered to be andesitic to basaltic metatuffs because of their anomalously mafic composition in an environment of quartz-sericite metasediments. Prospectors report the presence of pillowed basic volcanic rocks some three miles north of the map area.

The slates, tuffs and phyllites are for the most part light grey weathering, with local variations towards blue or green.

Most of the sections examined show well marked bedding. This is expressed in color changes which show to best advantage on the weathered surface. Bedding thickness varies from finely laminar to six inches. No bedding is seen in the phyllitic grey metasediments which outcrop along the centre-line of staking.

Small-scale crossbedding and scour-and-fill structures are common in the finely bedded tuffs and slates. Penecontemporaneous and post-lithification crenulations and minor dragfolds are abundant. Slaty cleavage is present throughout, and is particularly evident in the more thickly bedded members.

The grey slate is fine-grained and of even texture, except where regional or local alteration has caused the development of porphyroblastic minerals. Near igneous contacts, narrow zones of slate have been silicified, and have developed spots of biotite and chlorite. The tuffaceous members have the same alteration texture and minerals, in addition to which they have buff-specked weathered surfaces due to incipient carbonatization.

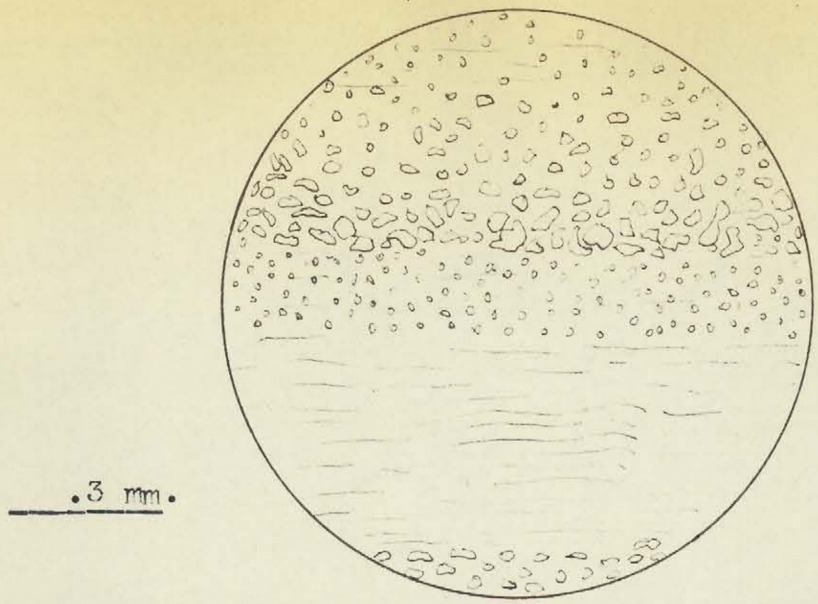
Under high powers of magnification, it is seen that the grey slate consists of a felty mass of subangular quartz grains and flakes of sericite. Chlorite accompanies these minerals in varying amounts, and biotite is a common accessory. When a rock contains more chlorite than sericite, its color is green. The reverse of this condition results in a grey rock. The latter case is the predominant one in the map area.

The phyllitic members show much sericite, uniformly oriented along cleavage planes parallel to the bedding of nearby slates.

A specimen of green slate from the vicinity of a gabbroic sill shows alternating micro-beds of quartz grains and pale green chlorite. The chlorite has anomalous "Berlin blue" birefringence, and is assumed to be penninite (fig.3.)

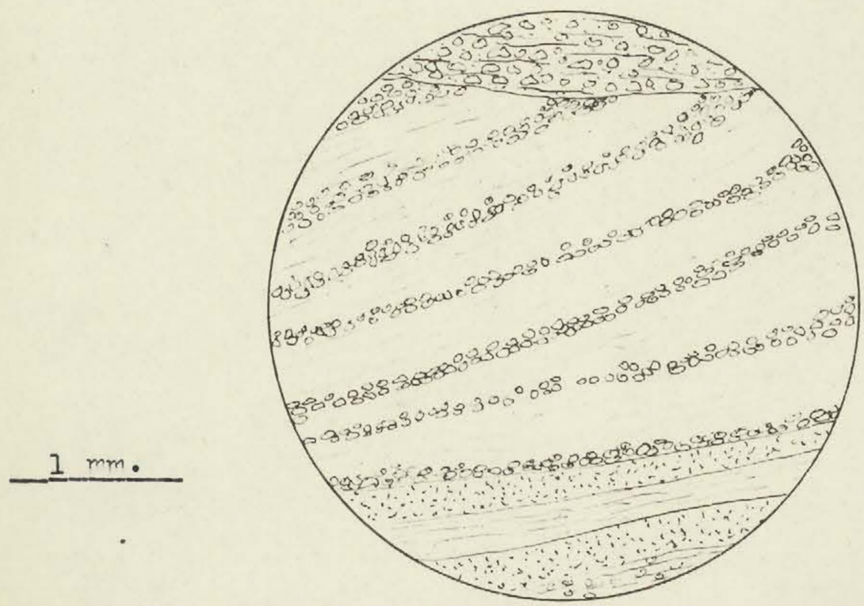
Microscopic cross-bedding and poorly developed grain gradation were seen in thin sections of grey slate (see figs. 3, 4).

Figure 4



Typical grey slate, showing micro-graded bedding. The rock is composed of subangular quartz grains in a matrix of fine-grained sericite and chlorite.

Figure 3



Cross laminated chloritized grey slate. The 'c' layers are fine-grained argillaceous material altered to pennine chlorite. The coarser beds are made up of quartz and sericite.

Two hundred feet south of the southeast end of St. Pierre Lake, two lenses of dolomite pebble conglomerate fill channels near the top of a grey slate band. In cross sections these lenses have maximum thicknesses of four and six feet respectively. Their exact long dimensions could not be ascertained due to lack of outcrop, but probably are approximately fifty feet. Seventy percent of the conglomerate is made up of well-rounded, buff-weathering dolomite pebbles, which range in diameter from one quarter of an inch to four inches. The pebbles are held in a fine siliceous grit, in which both grey and opalescent blue quartz grains can be seen.

Iron-Carbonate Slate. Two bands of ferruginous slate outcrop in the southeastern part of the map area. The bands are separated by a gabbro sill. The upper band is terminated to the southeast by another sill, and the lower band passes gradationally northward into grey slate. The true thicknesses of the upper and lower bands are forty feet and 250', respectively.

Outcrops of this rock type are inevitably low-lying, and are usually weathered to a rough, pitted surface. The color of the weathered surface may be dark grey, brown, black or rust red. The grey and black beds are characteristically fissile (see fig. 5). The brown and rust-red beds have well-marked bedding, which ranges in thickness from one inch to four inches. Bedding cleavage is pronounced, and poorly developed schistosity is found in several beds.

On the fresh surface, the iron-carbonate slates are brown or black. The grain is generally fine and the texture uniform. In a few beds, blebs of magnetite or pyrrhotite can be distinguished megascopically. Linear series of ellipsoidal quartzite fragments are conspicuous in certain outcrops of narrow beds near the centre of the thicker rusty slate band. These may be the results of "boudinage" segmentation of thin beds of quartzitic material formerly interbedded with less competent slate.

The magnetite content of the iron-carbonate slates varies from 3% to 20%, and consists of steely black anhedral aggregates up to one tenth of an inch in diameter, intermixed with powdery, dull black cryptocrystalline concentrations. Magnetite is concentrated in the upper part of the thicker slate band, and in all the members of the thinner band.

Pyrrhotite forms 2% to 10% of many of the rusty-weathering beds. It occurs as fine disseminated grains and powdery aggregates which seem to have preferentially replaced certain thin beds. A few of these thin beds have been completely replaced over small areas. In three places, narrow discordant veinlets of coarser pyrrhotite were seen.

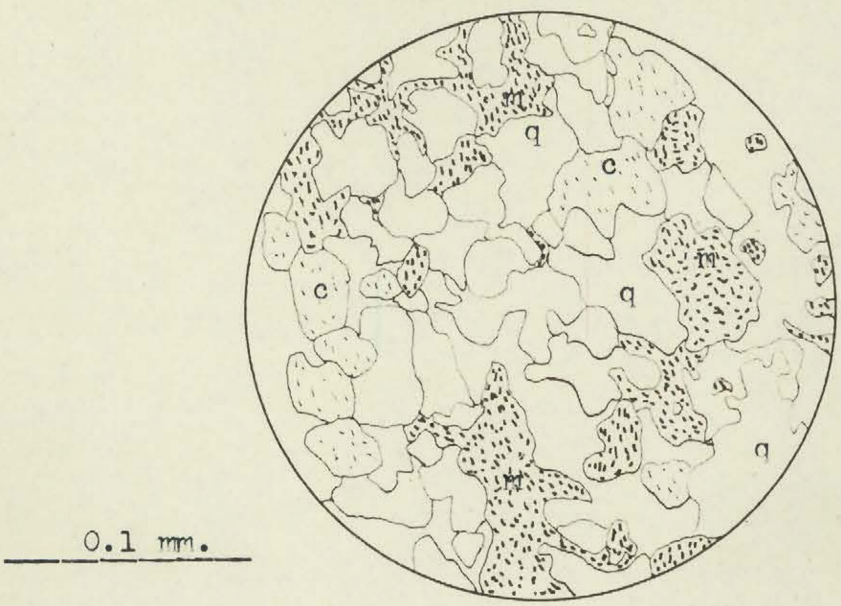
The examination of typical iron-carbonate slate in thin section shows the presence of the following minerals and textures (see fig.6):

(a) Quartz. Subangular, anhedral fragments make up thirty percent of the rock.

Figure 5

Fissile black ferruginous slate east of Slate Lake. The fissility is due to bedding cleavage.

Figure 6



Iron-carbonate slate. Type 'c' grains are calcite, type 'q', quartz and type 'm' fine-grained powdery aggregates of magnetite and a cryptocrystalline mineral.

(b) Calcite. Clusters of sub-rounded grains are more concentrated in some microbeds than in others - thirty percent.

(c) Magnetite. Cryptocrystalline powdery aggregates and prominent subhedral masses, the latter replaced in part by quartz and biotite, make up 30% of the rock.

(d) Siderite (?) Sub-rounded fragments which change relief with rotation, have brown-stained margins (may be stained calcite) - 2-3%.

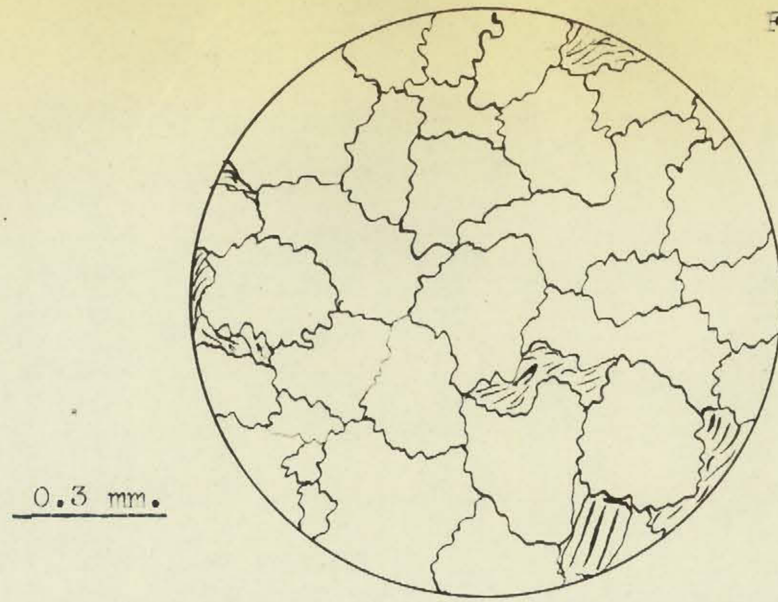
(e) Sericite. Scattered flakes are crudely oriented parallel to cleavage planes - 2-3%.

(f) Biotite. Irregularly oriented flakes form 1-2% of the rock.

The relatively large calcite content is not evident in the hand specimen, being detectable only by the vigorous effervescence which results when the rock is treated with dilute hydrochloric acid.

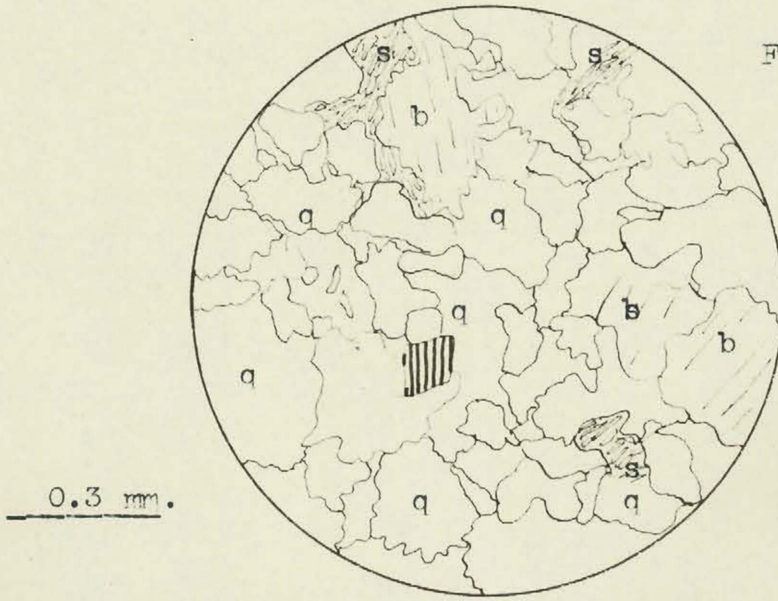
Quartzite. North of the iron-carbonate slates, and parallel to them, is a 275' thickness of dominantly quartzitic rocks. This unit is made up of alternating thicknesses of white-weathering quartzite and grey siliceous slate. The slaty members are similar to the grey slates previously described, except that their quartz content is higher, resulting in greater hardness. The quartzite is thick-bedded and resistant to weathering, outcropping as series of protruding but well-rounded humps.

Figure 7



Quartzite, showing minutely interlocked grains of recrystallized quartz. Flakes of sericite are seen between the quartz grains, and a subhedral lath of labradorite occurs in the lower right hand quadrant.

Figure 8



An impure facies of the quartzite has biotite('b'), sericite('s') and a lath of twinned plagioclase in addition to recrystallized quartz('q').

On the fresh surface, the quartzite appears grey, fine-grained and of uniform texture. It is a compact, brittle rock, which shatters with a rough, subconchoidal fracture. The brittleness of the quartzite has caused it to be highly fractured in an irregular pattern. The fractures have been healed by barren milky quartz in a complex system of veins and masses characteristic of the rock.

Under the microscope, it is seen that the quartzite consists of 85% of anhedral quartz grains, tightly interlocked along minutely contorted grain boundaries. (see fig.7, 8). Two thirds of the quartz grains have tiny, bubble-like inclusions in their central portions. Extinction is wavy in many of the grains. One grain contains a prism of apatite.

Five percent of the quartzite is made up of flakes of pale-brown, moderately pleochroic biotite. The biotite grains are irregular in outline, and fill spaces between quartz grains. No inclusions were seen in the biotite. Scattered grains of well-twinned plagioclase were seen. Several measurements of the extinction angles of albite twins determine that this feldspar is in the labradorite range of composition.

One to two percent of anhedral pyrite fills cavities within the quartzite. The remainder of the rock is composed of sericite flakes, which show no preferred orientation.

<u>Green, Magnetite-bearing Slate</u>. A band of green, magnetite-bearing slate outcrops in the south central part of the area just south of the centreline of staking. This 375' thickness can be traced both to the northwest and to the southeast

almost to the borders of the map area, at which points it disappears beneath glacial drift. Smaller thicknesses of the same rock are found within grey slates to the foot-wall of the sulphide deposit at the northwest end of St. Pierre Lake, and in a band of grey slate 400' north of Dragfold Pond.

The green, magnetite slate weathers to a pale, grey-green surface, which is studded with tiny protruding crystals of magnetite. Outcrops of this rock type are characteristically obscured by a débris of frost-heaved cleavage slabs (see fig. 9). Where cleavage is not well-developed, bedding can be seen at intervals of from one tenth of an inch to two inches.

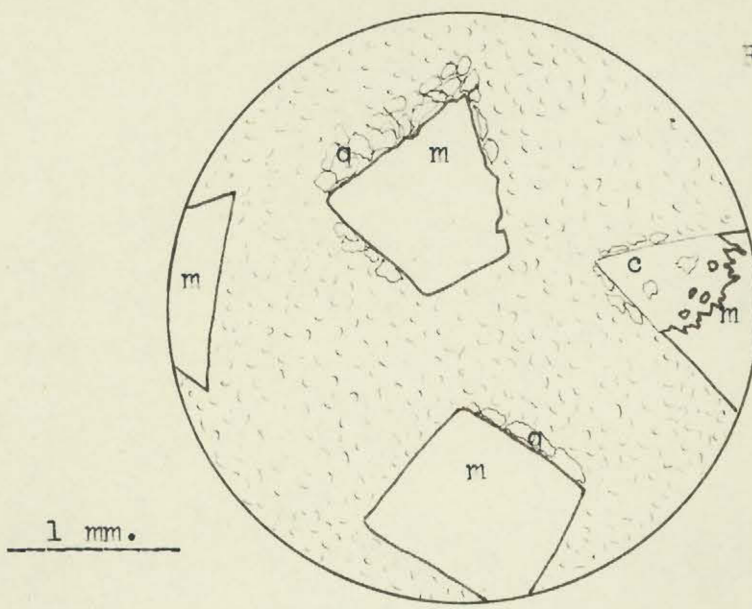
On the fresh surface, the slate appears dark green to pale grass-green. A fine-grained matrix of uniform texture holds from 3% to 15% of tiny porphyroblastic octahedra of magnetite. The octahedra rarely reach lengths of one tenth of an inch, the average being one fortieth to one twentieth of an inch long. The octahedra show no preferred orientation.

Under the microscope, it is seen that the magnetite porphyroblasts are in part replaced pseudomorphically by quartz and chlorite. The thin section examined was taken from a bed with a somewhat higher than average magnetite content. In it, the magnetite forms fifteen percent of the rock. The fine-grained, almost cryptocrystalline remainder of the slate consists of 40% of subangular quartz grains, 30% of flakes of pale-green chlorite, and 15% of variously oriented sericite flakes (see fig. 10).

Figure 9

Frost-heaved cleavage slabs of green, magnetite-bearing slate. This is the characteristic outcrop habit of the rock type.

Figure 10



Euhedral porphyroblasts of magnetite('m') in typical green, magnetite-bearing slate. Chlorite('c') is replacing one magnetite grain pseudomorphically. The magnetite grains have "collars" of quartz('q'). The matrix of the rock is very fine-grained quartz, sericite and chlorite.

Gabbro Sills

Parts of sixteen separate sills of highly altered gabbro outcrop on the St. Pierre Claim Group. The thicknesses of the sills range from four feet to 750'. Two thirds of the sills are one hundred to 300' thick. These intrusive sheets are remarkably concordant with the metasediments of the area, and only two minor cases of cross-cutting were seen, both involving the truncation of minor fold structures in the grey slates. The sills do not maintain constant thickness, and a few of the smaller ones terminate within the area mapped.

The sills are massive and resistant to weathering. They form the cores of all rock ridges in the map area. In outcrop, the gabbro presents a rounded, hummocky appearance. Two sets of joints at right angles combine to give a blocky effect.

The gabbro weathers to a creamy brown to dark, grey-brown surface, and is commonly pitted, due to the weathering-out of secondary calcite.

On the fresh surface, the typical altered gabbro of the area is a grey-green, medium-grained, even-textured rock with a dull lustre. The rock near the sill margins is finer in grain, dark grey, and slightly ophitic.

Chlorite, greenish plagioclase, dark green amphibole, epidote, sphene and biotite constitute the greater part of all the sill rock in the area. Quartz, calcite, pyrrhotite, pyrite and magnetite are common accessory minerals. These minerals are present in varying proportions, indicating the presence of several sub-facies, both syngenetic and metamorphic.

The most common facies of the gabbro is grey-green and medium- to coarse-grained. A mafic content of seventy percent is made up of chlorite, dark green amphibole and biotite. The remainder of the rock is greenish-white plagioclase. Disseminated pyrrhotite is a ubiquitous accessory. The marginal parts of several of the sills have been sheared to a dark green chlorite schist over narrow widths. On the whole, this rock has a dull lustre and "altered" appearance.

Under high magnification, it is seen that the "typical gabbro" is made up of:

(a) Penninite. Aggregates of pale green chlorite seem to have replaced amphiboles - 30% (see fig.11).

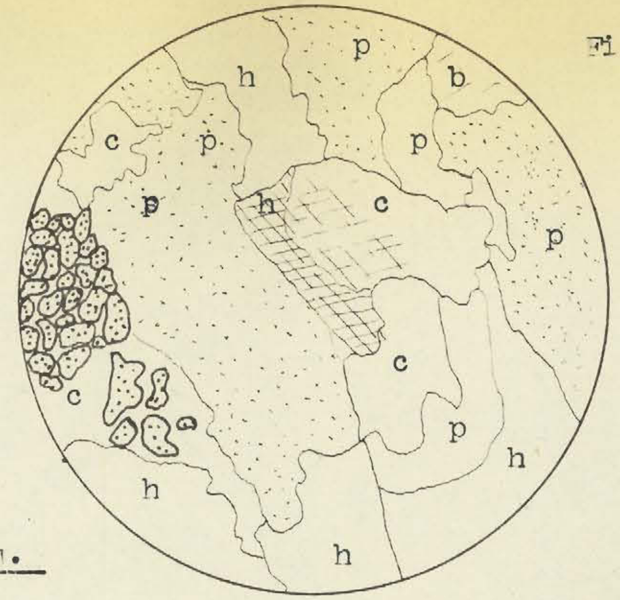
(b) Actinolitic hornblende. Pale to dark green, moderately pleochroic amphibole in ragged chunky laths, makes up 30% of the rock.

(c) Labradorite. Most laths are obscured by saussuritic alteration. A few relatively unaltered laths have twinning according to the albite law. The extinction angles of the albite twinning lamellae average 31° - 20%.

(d) Epidote. Groups of small, euhedral grains make up 5% of the gabbro.

(e) Sericite. 2-3% of fine disseminated flakes are

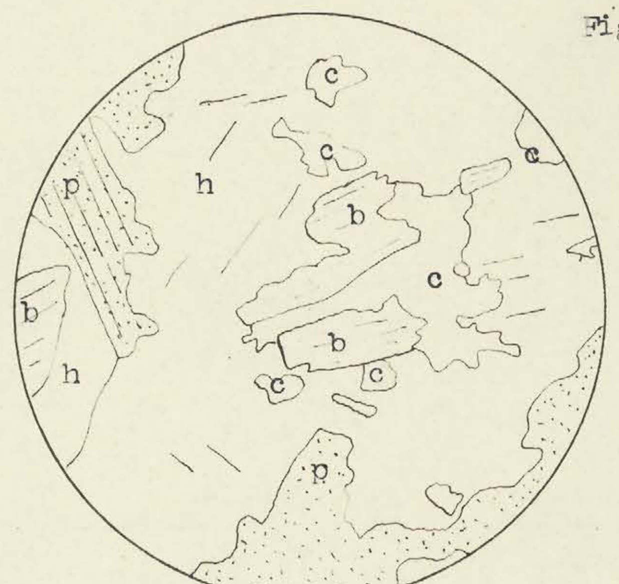
Figure 11



0.5 mm.

Typical metagabbro. The majority of the rock is made up of saussuritized plagioclase('p') and green actinolitic hornblende('h'). Chlorite('c') replaces hornblende. A clump of leucoxene-coated sphene nodules is seen near the left margin of the field. One grain of biotite occurs in the upper right quadrant('b').

Figure 12



1 mm.

Spots of biotite and chlorite replacing amphibole. The remainder of the rock is made up of saussuritized plagioclase.(Symbols as in figure above) scattered throughout the rock.

(f) Biotite. Aggregates of dark brown flakes are associated with chlorite - 2-3%.

Quartz, calcite and pyrrhotite are present throughout in minor quantities.

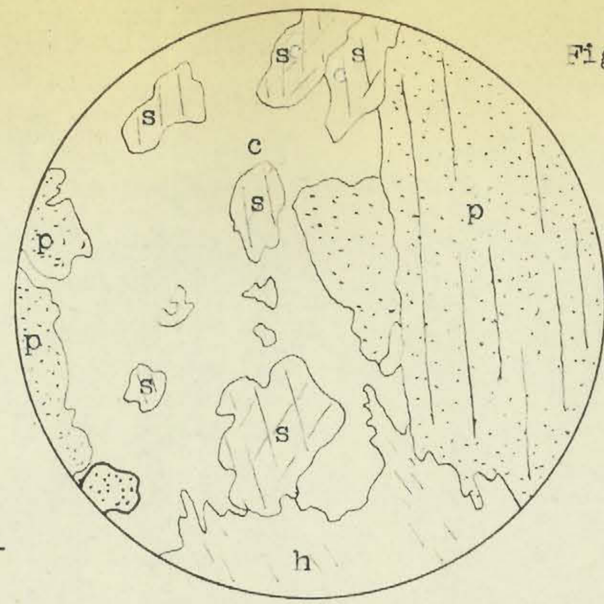
Chilled marginal sill rock contains less chlorite, and has 10% of clusters of subrounded anhedral sphene grains. The sphene is invariably coated by leucoxene.

In the sills of the southeastern part of the map area, the gabbro contains scattered clumps of biotite. These clumps form up to ten percent of the rock, and average one tenth of an inch in diameter. In thin section, these prove to be the centres of larger aggregates of pale green chlorite, in part replaced by dark brown, highly pleochroic biotite (see fig. 12).

Certain narrow sills to the west of Goose Lake have marginal facies which consist of dark green hornblende laths in matrices of fine-grained, apple-green epidote.

In the complex of sills and metasediments in the vicinity of Slate Lake, one sill has a markedly dioritic aspect (see map, app. 1). This sill is 175' thick. The weathered surface is distinctly lighter in colour than those of the nearby typical gabbro sills. On the fresh surface the rock is pale grey-green and of medium grain and subophitic texture. In thin section, the relatively greater acidity of this rock is apparent (see fig. 13). It is made up of 55% of saussuritized plagioclase feldspars, 20% of pale green hornblende,

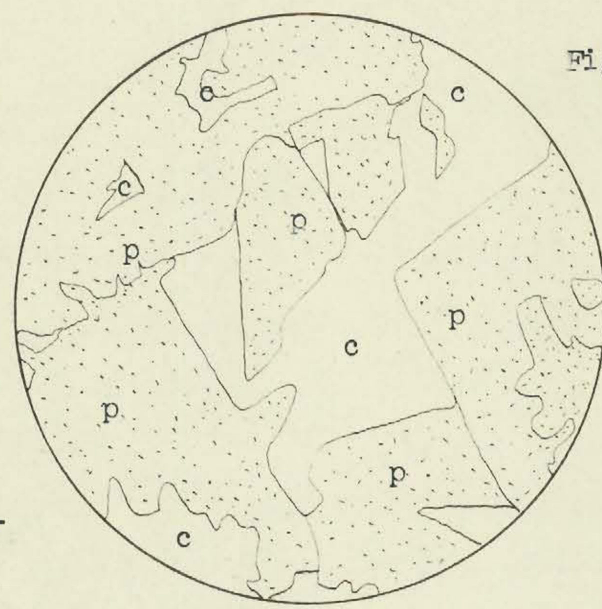
Figure 13



0.3 mm.

Dioritic gabbro. The rock consists of actinolitic hornblende('h'), saussuritic plagioclase('p') and pennine chlorite('c'). Secondary calcite('s') forms a moderate proportion of the rock.

Figure 14



1 mm.

Chloritized feldspathic gabbro. Aggregates of pale green chlorite fill the spaces between subhedral grains of chloritized and saussuritized plagioclase. (Symbols as in the above diagram.)

and 20% of apple green chlorite. Quartz and calcite are interstitial accessory minerals.

Narrow schist zones in the central part of the sill carry disseminated fine grains of pyrrhotite.

In the northwestern corner of the area, a block of gabbros and metasediments has been faulted southward into the map area. The northernmost rock unit of this block is a porphyritic feldspathic gabbro in which subhedral laths of plagioclase are held in a schistose matrix of chlorite. The plagioclase particles vary from one twentieth of an inch to one quarter of an inch in length, and form 50-60% of the rock (see fig. 14).

Seen in thin section, the rock consists of pennine chlorite, and heavily saussuritized feldspars of indeterminable composition. Euhedral grains of epidote form 10% of the rock. Ten percent of calcite and ten percent of green hornblende are present in close association.

Considering the foregoing rock mineralogy, there may be some doubt as to whether the term "gabbro" can be applied to these rocks. The usage is justified, however, from the point of view of the regional geology. The sills of the St. Pierre area are part of an assemblage of basic intrusives which outcrops along the eastern side of the Labrador Trough for a distance of at least 400 miles. Petrographic examination of rocks in areas of little metamorphism shows them to be mainly true gabbros, with dioritic, uralitic and peridotitic subfacies (6, p.64). Hence, although most of the

St. Pierre intrusives are uralitic in appearance, they should be included under the designation of "gabbro", or more properly "metagabbro", as this denotes more clearly the genetic classification of the sills. The writer's conclusions as to the processes that resulted in the differentiation of these rocks from an original gabbro magma, will be presented in a following section ("Historical Geology").

Pleistocene and Recent Deposits. The east, south and southwest parts of the area are covered by a layer of glacial boulder clay through which only the more resistant rock ridges protrude. Several low, drumlinoid ridges of the same material trend north-northeast across the central part of the area. The boulder clay mantle in the vicinity of the sulphide showing was found by drilling to be approximately fifty feet thick. This measurement, however, was taken in a low, valley floor. The average thickness of overburden in the area is estimated to be five to ten feet.

The trend of the drumlinoid features, together with observations of glacial striae, roches moutonnees, and erratics known to have originated to the west, indicates that the direction of ice movement was from south-southwest to north-northeast. This conclusion agrees with those reached by Bergeron and Sauve in areas to the south (2, p.5 and 4, p.5).

Frost-formed soil features are seen throughout the area. The overburden has been disturbed by the formation of polygonal soil patterns in which the underlying clay has been brought to the surface. The polygons average four feet in diameter, and are common on the tops of clay-covered ridges, Small but well developed mud flows are found on the flanks of many of the steeper hills. The processes which formed the polygons and mud flows have prevented the formation of a regular soil profile.

The topsoil consists of a light-brown humus of decayed vegetation, rock detritus and glacial clay. This layer is not continuous, and where present, varies in thickness from one inch to three inches. The ground surface throughout the area is littered with frost-heaved rock fragments and glacially transported erratics.

Structural Geology

General Statement

The rocks of the St. Pierre area have been affected by at least two periods of folding and three of faulting. Fold structures range in size from minute crenulations to anticline-syncline units with amplitudes of thousands of feet. The majority of the folds are oriented in approximate accordance with the general trends of folding in the Labrador Trough (see "Regional Geology", p. 13).

Faults in the area are of three types, and are expressed by schist zones and fracture zones.

Strong jointing in the igneous rocks of the area may be related to the stresses which produced folding.

Cleavage is well developed in the metasediments, and follows closely the relict bedding planes.

The following observations on the structure of the area are based on field studies, the interpretation of geophysical data, and the examination of aerial photographs.

Folds

Field observations and the examination of regional aerial photographs indicate that the St. Pierre area lies on the northeast limb of a northwest-trending syncline (see frontispiece). Within the area there are two lesser orders of similarly oriented folds which plunge 15-20° to the southeast.

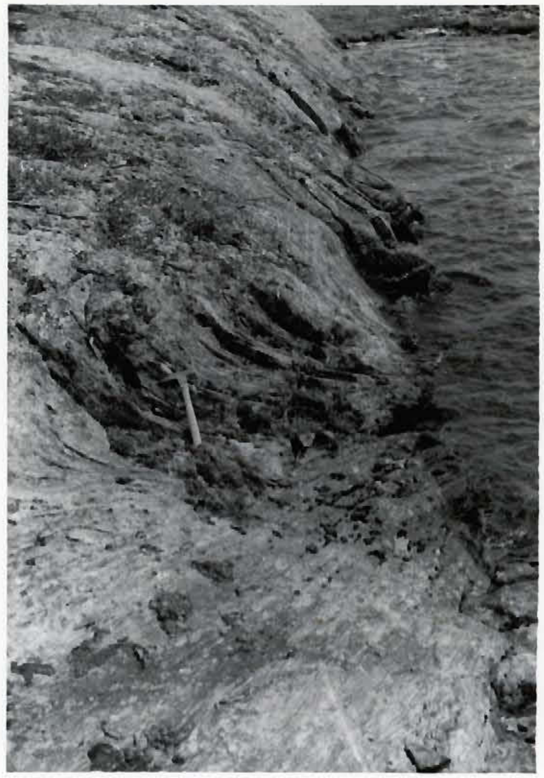
The most notable of these subsidiary folds is an S-shaped structure west of Slate Lake (see map, app.1). The northeast limb and part of the nose of a well-developed syncline lie within the map area. A band of rusty-weathering slates provides an excellent marker which can be traced through the synclinal fold into the adjoining anticlinal bend which lies outside the area. The mapped portion of the fold is an asymmetrical plunging syncline. (Terms used to describe folds are those of Billings, reference 22, pp.35-43.) The strike of the surface trace of the axial plane is approximately S40°E. Flowage towards the nose of the fold has caused a disruption of the metasedimentary beds at their points of maximum curvature, thus rendering difficult any measurement of plunge or inclination of the axial plane.

It is estimated that the axial plane dips steeply to the southwest, and that the plunge of the fold is from 20° to 40° southeast. The cleavage of the beds involved in the fold is not parallel to the axial plane of the fold, but follows the bedding with few deviations. Minor dragfolds on the limbs were found to be unreliable as indicators of local structure.

The anticlinal portion of a similar but smaller fold is exposed at the northwest end of St. Pierre Lake (see map, app. 3). This fold is separated from the previously discussed fold by an area poor in outcrop but possessing contorted structure. It is possible that the two structures may be directly connected. The smaller anticline is asymmetrical and plunges 20° southeast. The axial plane is inclined at 70° southwest. The surface trace of the axial plane strikes S30°E. The anticline is terminated to the north by a fault which trends S60°E. On the north side of the fault, the metasediments are complexly folded. The plunges of all small folds north of the fault are to the northeast.

Complex small scale folds are seen on the shores of Dragfold Pond (see fig. 15, 16). At least three S-shaped folds of amplitude 20-50' are oriented crudely parallel to the larger folds of the area. Minor parts of these folds are truncated by gabbro sills, suggesting that at least some folding preceded the intrusion of these sills.

Figure 15



Southest-plunging syncline. This minor fold is part of a complex of contorted grey slates on the north shore of Dragfold Pond.

Figure 16

Ptygmatic dragfolds south of Dragfold Pond.

Faults

Three types of faults are found in the map area. They are expressed as:

(a) narrow schist zones along metasediment bedding planes and near the margins of gabbro sills,

(b) reverse faults in complex schist zones concordant in strike but not in dip with the metasediments and sill rocks (thrust faults?),

(c) a prominent set of steeply dipping cross faults.

These fault-types are described and interpreted below.

(a) Schist zones up to two feet wide are commonly found at the contacts of metasediment beds, or near the margins of gabbro sills. Those in the metasediments are quartz-sericite schists, and those in the gabbros are dark green chlorite schists. Slippage of beds over one another during folding may have caused these schist zones.

(b) A complex schist zone containing a reverse fault outcrops along the centreline of the claim group. The schistosity strikes S60°E and dips 60°SW. to vertically. The plane of the fault dips 70°NE., as determined by bore-hole intersections at depth. The schist zone is not sharply defined laterally, and the maximum width of highly schistose rock varies from twenty to fifty feet. The zone is characteristically mineralized by small amounts of pale yellow, finely disseminated pyrite, and white quartz.

The fault has topographic expression in the form of

St. Pierre Lake, which has a noticeable linear deep along its northern shore. A linear cliff along the north shore of the same lake suggests a fault line scarp. If this is so, it may be interpreted that the movement on the fault was reverse, with a vertical component of at least one hundred feet. This sense of movement is in accord with the regional structure (5, p.531). As the fault trace is for the most part concordant with the local formations, there is little field evidence of displacement. In the vicinity of the northwest end of St. Pierre Lake, the fault zone separates a southeast-plunging anticline from northwest-plunging minor folds.

The relatively high degree of schistosity in the rocks adjacent to this fault indicates that it was formed at considerable depth (29, p. 3).

(c) A prominent set of subparallel cross faults causes both right and left hand displacements of all other structures in the area. The strikes of the surface traces of these faults vary from S 10°W to S 40°W, and the horizontal displacements are of the order of from one hundred to five hundred feet. The cross faults of the northwestern end of the claim group have low, but well defined scarps.

Evidence for the existence of these faults is found in the presence of linear topographic lows, cross-structure drainage, fracture zones, silicification and displacement of formations.

In general, even along the cross faults of relatively large displacement, schistosity is absent or minor, and fracturing is the main evidence of movement. From this fact, and the existence of the scarps previously mentioned, it is assumed that the cross faults were formed at considerably less depth than was the "thrust" fault previously discussed. The locations of these faults may have been controlled by the degree of cross jointing existing in the area previous to the time of faulting.

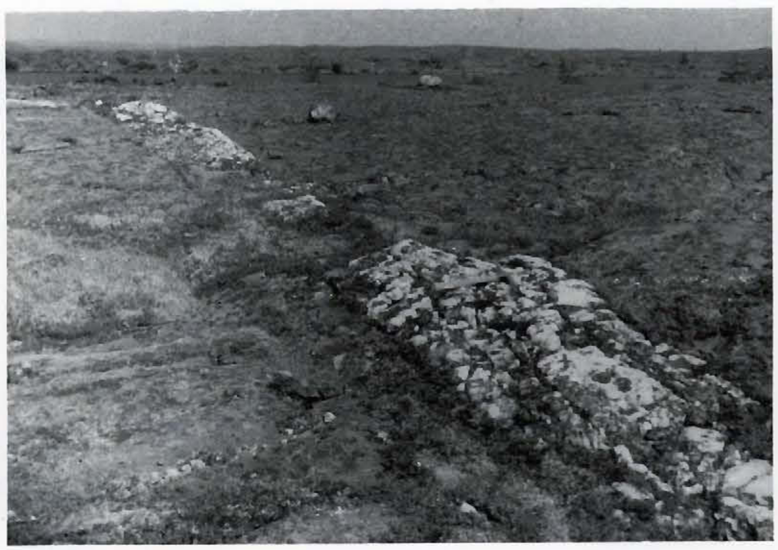
Near the northwest shore of Slate Lake, a minor cross fault was seen in outcrop. It had displaced a gabbro-slate contact ten feet to the right. The trace of the fault strikes S 40°W and the dip appears to be vertical. The relation of the gabbro to the slate indicates that the northwest block moved down at least thirty feet relative to the southeast block. The faulting was accompanied by strong silicification, weak shearing and mineralization by disseminated magnetite and pyrrhotite.

Joints

Two prominent sets of joints are found in the area. The lesser set strikes and dips in accord with the bedding of the metasediments.

The most prominent joints are best expressed in the gabbro sills. They strike due south to S 30°W, and dip from 60° west to vertically. This set of joints is considered to have been formed with the major folds of the area, by compression from the northeast.

Figure 19



Near vertical vein of barren quartz. This is one of a large number of veins which fill tensional crossfractures in gabbro sills throughout the claim group. The level horizon line in this photograph shows the plateau nature of the region.

Several of these joints have been filled by veins of barren, milky quartz (see fig. 19). Similar veins six miles north of the map area carry galena and minor chalcopyrite (7).

The quartzite band is characteristically possessed of a complex network of quartz-filled fractures.

Cleavage

The metasediments, with the exception of the quartzite, have well developed slaty cleavage. The cleavage follows closely the original bedding of the metasediments, and does not bear any relation to the axial planes of major folds in the area. This suggests that the cleavage may have been formed prior to the epoch of folding.

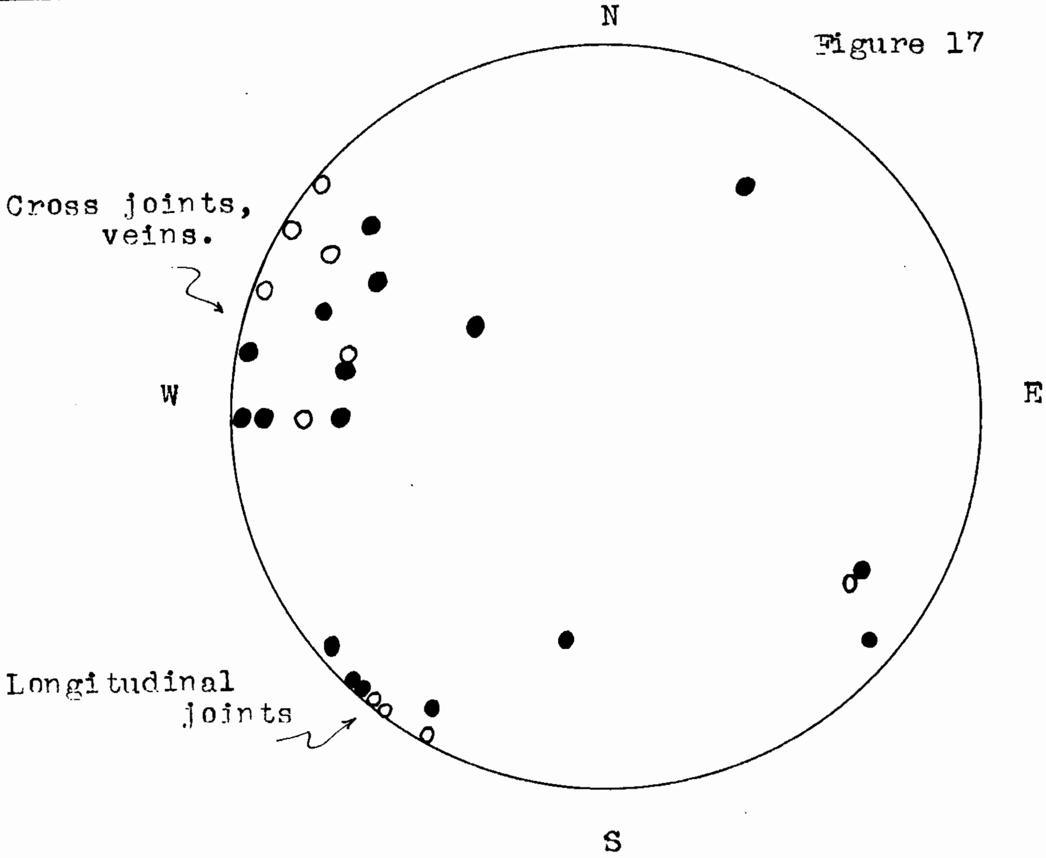
Minor Structures

Minor structures formed during, and soon after, deposition can be seen in many outcrops of laminated slates and tuffs. Crossbedding and "scour and fill" structures in the central and north-central parts of the area show that the tops of the metasediments face toward the southwest. Slumping soon after deposition caused minute contortion of the laminated sediments in the vicinity of the northwest end of St. Pierre Lake.

Structural Trends

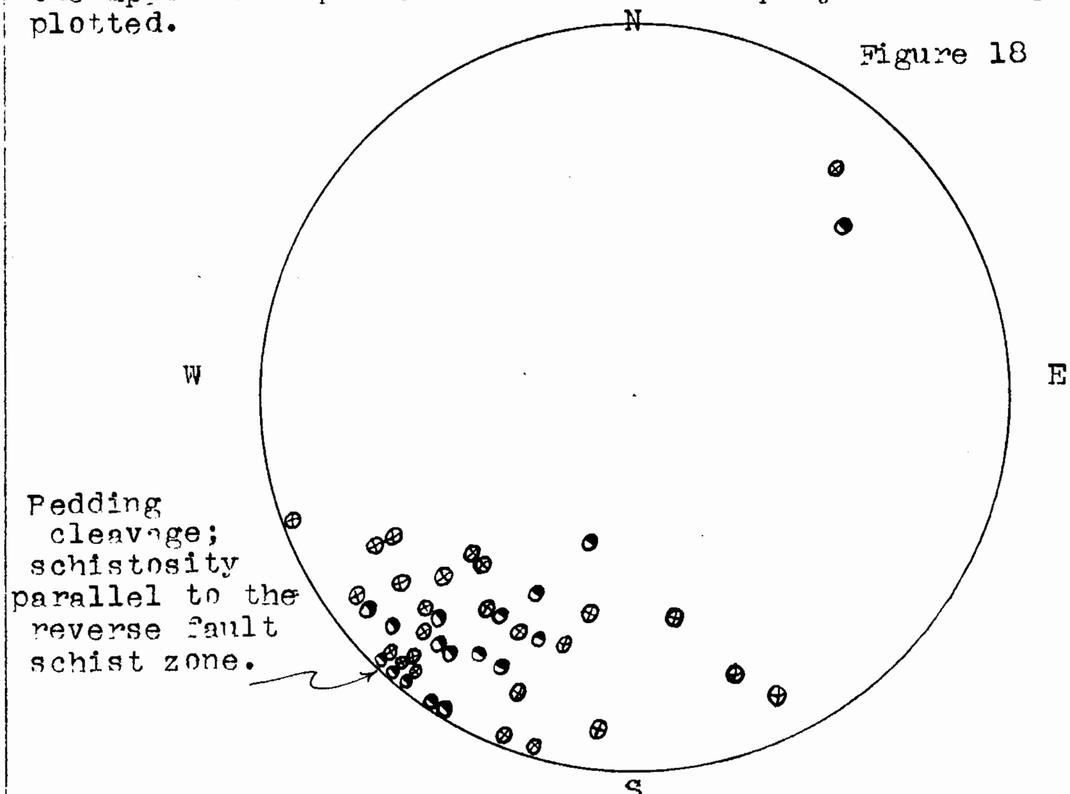
Figures 17 and 18 illustrate structural trends shown by the orientations of joints, veins, schistosity and

Figure 17



Point diagram of joints (•) and quartz veins (○).
The intersections of the poles of these structures with the upper hemisphere of an equal area projection have been plotted.

Figure 18



Point diagram of cleavage (⊕) and schistosity (◑).
The structures are plotted by the method given above.

cleavage. The predominant trend is northwest, with a steep southwest dip. Certain joints and veins are approximately at right angles to this trend.

Metamorphism

Deuteric alteration, low-grade regional dynamothermal metamorphism, and local metasomatism have been factors in the history of the rocks of the St. Pierre Area. Evidence of the presence and stage of development of each of these types of metamorphism can be seem in the structural and mineralogical changes which they have produced. These changes are discussed below under their separate categories.

Deuteric Alteration

As previously mentioned, the intrusive rocks of the area are considered to have originated from a gabbroic magma, as did other similar sills of the region. The examination of hand specimens in the field suggested that the mafic minerals of the sills were pyroxenes. Several crystals seen appeared to have the characteristic rectangular cleavage of the members of the pyroxene mineral group. On examination of thin sections, however, it was found that these mafic minerals are amphiboles. It is suggested that these amphiboles were formed by the alteration of pyroxenes during a water-rich stage late in the process of crystallization. This supposition is supported by the work of Leith, who found that in igneous rocks, the average length of hornblende crystals is two and one-half times their width, while in metamorphic rocks, the ratio of length to width is increased to four or five (27, p. 30). The lengths of the hornblende crystals of the St. Pierre sills vary from twice to three and one-half times their widths. This suggests that the amphiboles resulted from retrograde autometamorphism during crystallization rather than from any epigenetic alteration.

The alteration of the plagioclase feldspars may also have taken place during the late stages of crystallization. Saussuritization has clouded the plagioclase laths to varying degrees, Both saussuritization and uralitization are cited by Harker as being typical of the late stages of crystallization (24, p. 174).

Regional Metamorphism

Low-grade dynamothermal metamorphism has affected the metasediments and gabbros of the area to varying degrees. The most noticeable changes are the results of dynamic metamorphism, which has given rise to new structures by the internal rearrangement of certain rock minerals. This has produced slaty cleavage in the metasediments and schist zones in the gabbroic sills. The cryptocrystalline micaceous interstitial materials of the sediments have been recrystallized as intimate intergrowths of chlorite and sericite. These flaky minerals are oriented parallel to the bedding planes.

In the gabbro sills, much chlorite has been developed in narrow schist zones. This mineral is oriented in the same way as are the flaky minerals of the slaty metasediments.

Thermal metamorphism acted in conjunction with dynamic alteration and continued after structure deformation had ceased. This is indicated by the lack of preferred orientation in the greater part of the metamorphic mineral assemblage. In the gabbro, the alteration was at first retrograde, as the amphiboles were altered to chlorite and the plagioclases in part to epidote and sericite. Water must have been introduced into the rocks in order to effect this change. Lime liberated from the plagioclases and amphiboles was reorganized as calcite, epidote and sphene. The latter mineral is believed to have formed in part from the alteration of ilmenite or titaniferous magnetite.

The minerals of the metasediments altered for the most part to sericite and chlorite, or merely recrystallized, without chemical change. Certain thin beds in the grey slate complex were more susceptible to alteration than were their neighbours. These beds have been converted almost conpletely to chlorite. They are assumed to have been deposits of andesitic tuff. The quartzite layer shows effects of recrystallization to a granulitic texture, without any change of composition. Impurities in the original sandstone are represented by schistose aggregates of sericite. The majority of the metasediments now consists of detrital quartz fragments in matrices of metamorphic sericite and chlorite. Chlorite-spotted slates at the northwest end of St. Pierre Lake, show metamorphism in the incipient stage (see fig. 20a).

The final stage of dynamothermal metamorphism was a progressive one. Chlorite, sericite and iron minerals combined constituents to produce biotite. This mineral is present in small amounts in all the rocks of the area, and its textural relationships indicate it to be the most recently formed rock mineral.

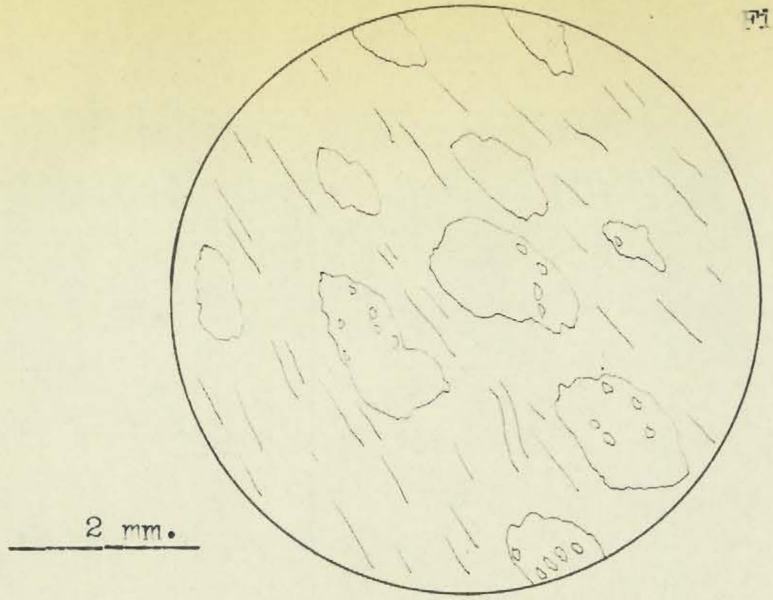
In general, it may be said that the rocks of the area have undergone low-grade dynamothermal metamorphism, which has produced both structural and mineralogical changes. The assemblage of metamorphic minerals suggests that the rocks of the area can be classified as belonging to a biotite-chlorite subfacies of the greenschist facies.

Metasomatism

The most common types of metasomatism in the map area have been silicification and pyritization. The effects of silica metasomatism are seen in the metasediments adjacent to the larger gabbro sills and along the schist zone, which passes longitudinally through the centre of the claim group. Intense silica metasomatism occurred in the vicinity of the sulphide showing at the northwest end of St. Pierre Lake. This phenomenon will be discussed in detail in a later section.

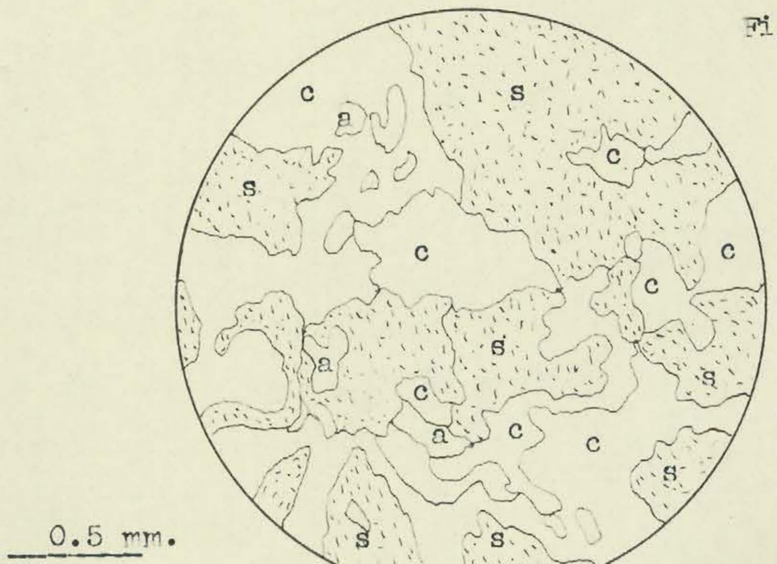
The zones of silica metasomatism adjacent to the larger gabbro sills take the form of narrow bands of indurated

Figure 20a



Spotted slate. This rock shows incipient regional metamorphism. Spots of chlorite with helecitic inclusions of quartz are held in a matrix of schistose fine-grained quartz, sericite and chlorite.

Figure 20b



Highly altered metagabbro. This rock, originally composed of plagioclase and hornblende, has been altered to saussurite('s'), chlorite('c') and calcite('a').

slate, which have been replaced by 5% to 50% of fine-grained quartz. The replaced zones rarely have widths in excess of three feet, though in one place 700' north of the sulphide showing, a 25' band of tuffaceous slate between two thick sills has been completely silicified.

Silicification along the central schist zone clearly originated from narrow irregular quartz veins.

The metasomatic pyrite of the area will be described in the later sections on "Economic Geology" and "Geology of the Mineralized Zone".

Historical Geology

Observations in the field, subsequent research work and a survey of regional geologic data suggest that the following succession of events took place in the St. Pierre area:

(1) Clastic and chemically precipitated sediments were deposited in a shallow, disturbed sea. The inter-layering of coarse clastics, fine clastics and precipitates suggests that the strand line was fluctuating. The presence of dolomite pebbles in the conglomerate lenses indicates that the provenance of the sediments may have lain to the west. Fine-grained tuff beds attest to the presence of active volcanos which may have been some distance from the basin of deposition. The sediments were depressed to great depth.

(2) Compressive forces acting in an east-west direction caused the earliest stresses of a prolonged period of mountain building. A certain amount of folding and faulting occurred during this period. The buried sediments were dynamically metamorphosed.

(3) Deformation continued, accompanied by the intrusion of a variety of differentiates of a gabbroic magma. In the zone of sediments now exposed in the area, the intrusions were for the most part concordant. Thermal metamorphism altered the sediments between the sills.

(4) After the main period of intrusion had ceased, intense deformation occurred. The complex of gabbro sills and metasediments was tightly folded and complexly faulted. The late phases of igneous activity produced the deuteric alteration of the gabbro sills.

Silicification and pyritization of the sulphide deposits occurred late in this period. Dynamothermal metamorphism continued, and erosion removed many of the superimposed strata.

(5) Relaxation of the compressive forces left a mechanically unstable complex of piled-up thrust slices and overturned folds. This situation was relieved by gravity faulting. The cross-faults of the area may have originated during this period. If so, then this was also the time of the second period of metallization, during which the sphalerite, galena and chalcopyrite of the region were deposited. An alternative suggestion is that the cross-

faults may have originated during a second pulse of compression, during which movement occurred along zones of weakness caused by tension joints produced by the first compression.

(6) Normal erosive action, aided by continental glaciation, exposed the rocks which now outcrop in the St.Pierre Claim Group.

Looking at the geology of the claim group as described in the previous sections, it is obvious that certain features are not adequately explained by the sequence of events proposed above. One discrepancy is found in the existence of the conspicuous veins of barren white quartz which cut the gabbros and metasediments of the area. Assuming that the veins are of hydrothermal origin, the question arises as to the source of the mineralizing solutions. The gabbro is a quartz-poor rock, so it must be considered that the silica-rich vein-filling solutions originated in some source not exposed within the boundaries of the map area. The alternative idea of the local mobilization of detrital quartz from the metasediments, is not a strong hypothesis, as there is no evidence that the country rocks of the veins are impoverished in quartz.

The relative ages of the folding, intrusions and mineralization, as stated in the above historical sequence, are based on so few data that they should not be considered valid on a regional basis. It is hoped that by presenting the field observations and a tentative historic interpretation, the writer has made available to future workers in the region the maximum information that can be deduced from the outcrops exposed in the limited area covered by this thesis.

Economic Geology

There are three occurrences of minerals of economic interest in the St. Pierre Claim Group. Two of these are of very minor nature and have no economic potentiality. The third is the sulphide concentration which attracted interest to the area.

Magnetite Concentrations in the Iron-carbonate Slates and the Green, Magnetite-bearing Slate.

Near the southwest edge of the claim group, thin beds in a sequence of iron-carbonate slates contain up to thirty percent by weight of magnetite. The iron-rich beds are found in the upper ten feet of the southern band of iron-carbonate slates, and in the upper fifty feet of the northern band. The magnetite is in the form of blebs 1/10 of an inch in diameter and powdery impure aggregates. The average iron content of the sixty feet in which magnetite is concentrated could not exceed ten to fifteen percent.

Pyrrhotite-Chalcopyrite Mineralization in Sheared Gabbro

Schistose gabbro in the nose of a syncline 2500' west of the southeast end of St. Pierre Lake, has been partially replaced by pyrrhotite with minor chalcopyrite. The attitude of the schistosity in the vicinity varies greatly from place to place. The presence of sulphide minerals is revealed by rusty patches on the weathered rock surface. Aggregates of fine-grained pyrrhotite form up to ten percent of the schistose gabbro over narrow widths. In all, four lenses were found. The average surface dimensions of these bodies is six feet by three feet. Magnetometer traverses were run over the mineralized zone, with readings taken at fifty foot intervals. No appreciable anomaly exists in the vicinity.

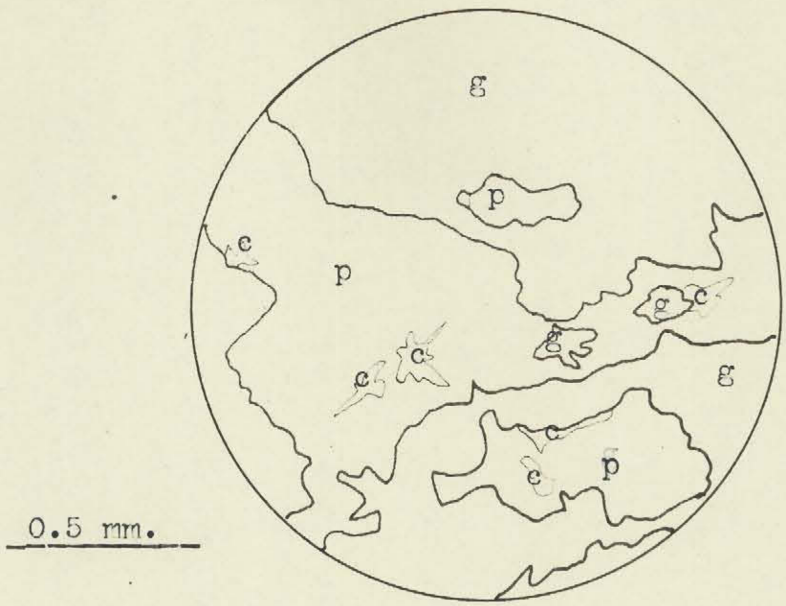
Polished sections show that the small anhedral grains of pyrrhotite contain minor amounts of later chalcopyrite. Chalcopyrite is never present in excess of 0.5% of the rock (see fig. 21).

The St. Pierre Mineralized Zone

Three hundred feet west of the northwestern extremity of St. Pierre Lake, a small body of massive sulphides is exposed on the northern side of a prominent knoll. The minerals of the deposit, in order of abundance, are pyrite, sphalerite, galena and chalcopyrite. An aureole of highly altered slate and tuff surrounds the sulphide body.

Although small, the deposit has a relatively high content of zinc, lead and copper, as well as substantial amounts of gold and silver. The nature of the sulphide body, its environment, and the percentage relationships of its

Figure 21



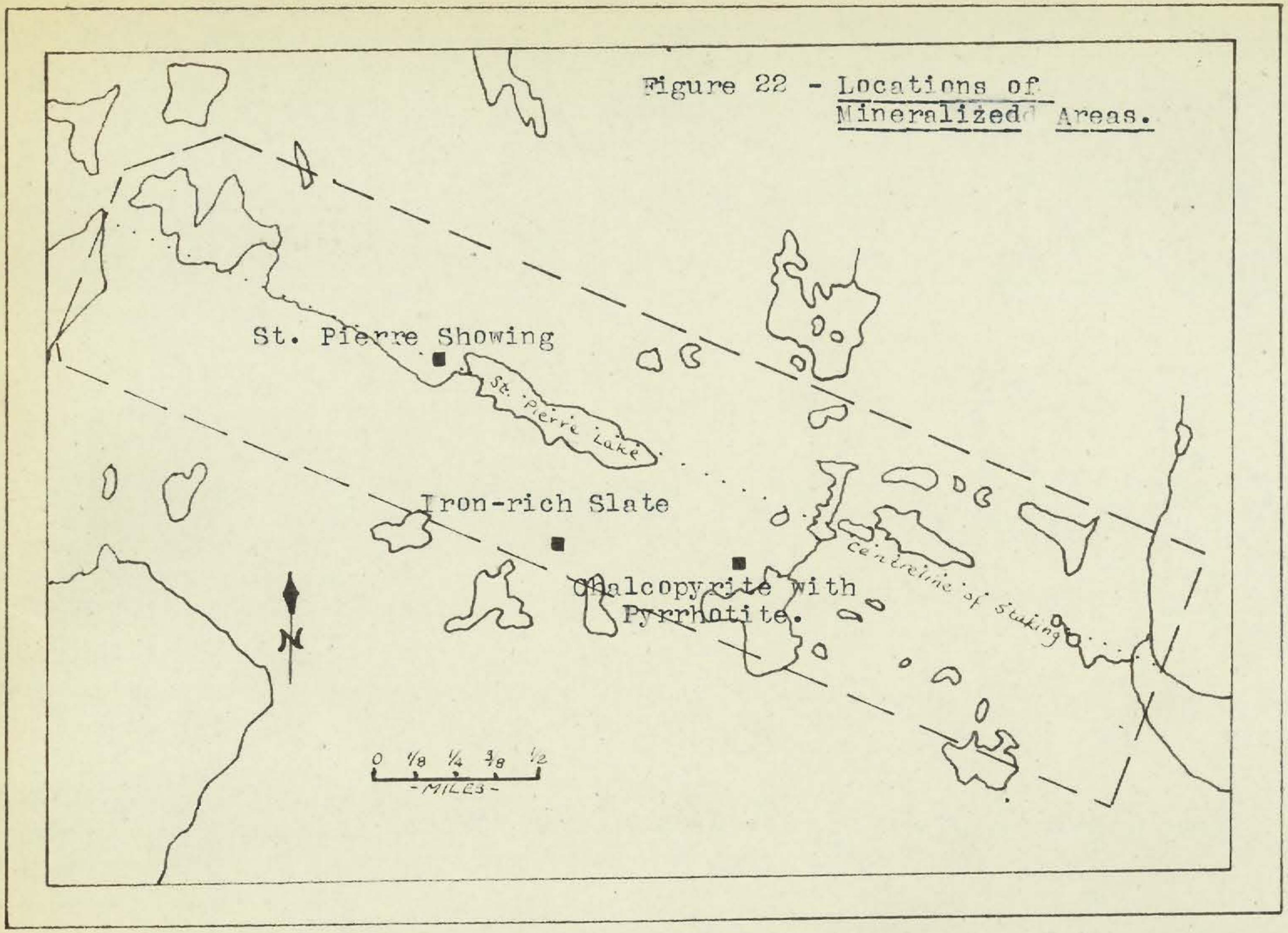
Minor chalcopyrite with pyrrhotite in sheared gabbro. Fine-grained pyrrhotite with associated chalcopyrite replaces strongly sheared gabbro in the mose of a syncline west of Slate Lake (see figure 22). The chalcopyrite appears to be later than the pyrrhotite.

Chalcopyrite - 'c'
Pyrrhotite - 'p'
Gangue - 'g'

metals are unique in the region. For these reasons, the deposit was intensively studied, and will be discussed in detail under a subsequent heading, "Geology of the Mineralized Zone".

The relative positions of the three occurrences of ore minerals are shown in figure 22.

Figure 22 - Locations of Mineralized Areas.



GEOLOGY OF THE ST. PIERRE MINERALIZED ZONE

Introduction

The showing is found on the north side of a small but prominent rock hump, which rises above swampy ground near the outlet of the stream which drains St. Pierre Lake. A discontinuous series of outcrops leads from the outlet some two hundred and fifty feet northwestward to the showing, and extends past it for fifty feet. Exposures of bedrock can be seen for one hundred feet southwest of the showing. Apart from this, no outcrops are available in the vicinity, due to a mantle of boulder clay up to fifty feet thick. The protrusion of the rock hump at the showing is due to the relative resistance to weathering of the highly silicified sediments to the hangingwall of the showing.

Geologic Environment

Metamorphosed argillaceous and tuffaceous sediments are folded into a southeast-trending minor anticline (see map, app. III). The axis of this structure strikes S 35°E and plunges 23°SE. The axial plane is inclined steeply toward the southwest. Faulted against the northeast limb of this fold is a series of complexly contorted smaller folds which plunge to the northwest at angles ranging from 2° to 10°. The fault which brings these structures into contact is in the schist zone previously described, which is exposed along the centreline of the claim group. The schistosity strikes S60°E and dips 60°SW to vertically. The reverse fault within the schist zone dips seventy degrees northeast.

On the northeast side of the anticlinal hump, a vertical to slightly overturned ten foot thickness of schistose grey slate or tuff intersects the fault zone. Along the line of intersection, the slate has been in part replaced by massive and disseminated sulphides. The deposit is surrounded by moderately to intensely altered wallrock.

In order to map the structure of the showing, an effort was made to distinguish a set of "rock types". Actually, the types described below are local variations of a single type, that is, the grey slates or tuffs. These variations may well be the result of local metamorphism, which has affected beds of slightly different compositions and permeabilities to different degrees. The variations grade into one another, and should not be considered as separate units.

Grey Slates

Pale grey-weathering, fine-grained argillites and slates. Most are grey on the fresh surface, but a few beds are greenish (chloritic), and may be tuffs. Where free from metasomatic effects, thin sections of this rock resemble those described under the heading "Grey-green Slates, Tuffs and Phyllites" (page 18).

Schistose Slates and Tuffs

Greenish, fine-bedded slates and tuffs. These beds seem to have been more susceptible to dynamic metamorphism than the surrounding beds. Rhombs and blebs of brown-weathering calcite are often seen on the surface of these rocks.

Spotty-weathering Tuffs

Pale grey-green silicified tuffs. In most places, the bedding of the original sediments has been destroyed by silicification. This rock usually weathers pale green with prominent white spots. Under the microscope, it is seen that this rock consists of fine, interlocked quartz grains and bright green, moderately pleochroic chlorite. The latter mineral occurs as isolated clumps of flakes, or as discontinuous stringers either concordant or discordant with the original bedding.

A gabbro sill, approximately two hundred feet thick, outcrops three hundred feet north of the sulphide showing. The dip of this sill indicates that it passes beneath the showing at a vertical depth of two hundred and seventy-five feet. Drilling has verified this.

A major cross-fault lies approximately 1500 feet northwest of the showing. This fault has a horizontal left hand displacement of the order of two hundred feet. At least two minor cross faults cut the mineralized zone.

Form and Orientation of the Sulphide Body

Company regulations prohibit the publication of data concerning the exact dimensions of bodies of economic minerals.

The St. Pierre sulphide zone is roughly pencil-shaped, and includes a number of disconnected lenses of mineralized metasediments. The northwestern extremity of the zone is exposed at surface. Taken as a whole, the mineralized body strikes S 70°E, dips 65°NE., and plunges 12½°SE.

The lens of sulphides exposed at surface consists of a hangingwall portion rich in massive sulphides of lead and zinc, a narrow parting of barren wallrock, and a footwall zone of massive pyrite-chalcopyrite mineralization.

Zones of disseminated pyrite and chalcopyrite are found above and below the massive portion. Lenses cut by boreholes have only the massive pyrite-chalcopyrite and disseminated pyrite types of mineralization.

Mineralogy

Introduction

Massive and disseminated sulphides are exposed in shallow trenches across the mineralized zone. A number of drill holes have intersected downward extensions of the sulphide body. Several samples were assayed, and the values thus obtained are presented in the form of ratios or variation graphs which shed some light on the distribution of certain metals within the sulphide body. Twenty polished sections were prepared from specimens representative of the various mineral assemblages. These were studied under the reflecting microscope. This study has yielded information on the texture and paragenesis of the ore minerals.

A sample of galena was sent to the geophysics department of Toronto University for age determination by the method of lead isotope ratios. Unfortunately, the result of this determination was not available in time to be included with this thesis.

In order of abundance, pyrite, sphalerite, chalcopyrite and galena constitute 95% of the ore minerals. Quartz and calcite are common gangue minerals.

Distribution of the Ore Minerals

The sulphide lens exposed at surface consists of a footwall zone of fine-grained massive pyrite and chalcopyrite, a narrow parting of barren, impervious slate, and a hangingwall zone of medium to fine-grained sphalerite, galena, chalcopyrite and pyrite. In the sections that follow, the footwall zone will be referred to as the "pyrite-chalcopyrite zone", and the hangingwall zone, as the "sphalerite-galena zone" (see fig. 23).

The lens of massive sulphides is surrounded by a zone of pyritized wall rock which, in places, has narrow veinlets of chalcopyrite.

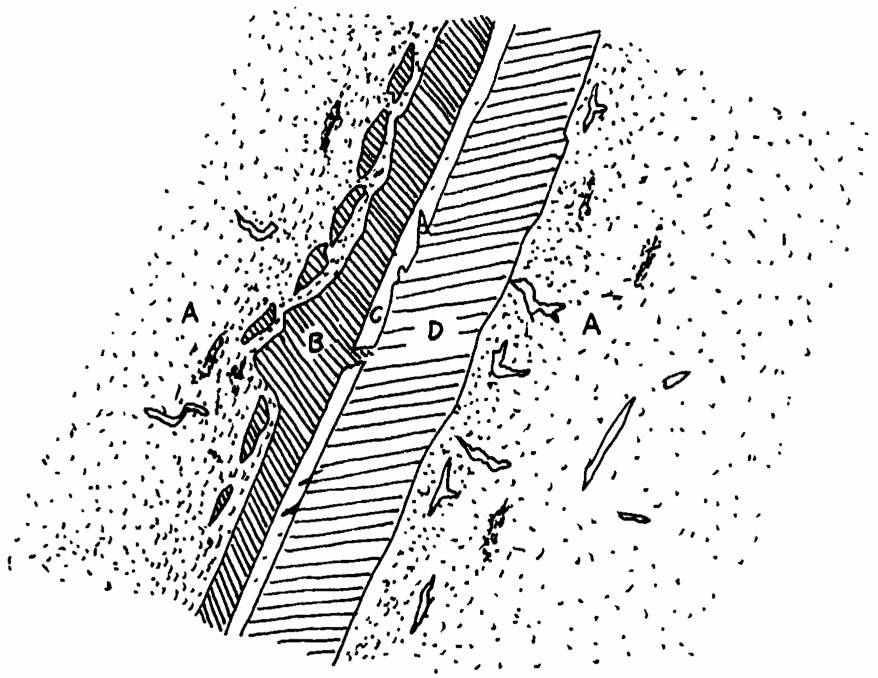
The pyrite-chalcopyrite zone consists of seventy percent of fine-grained, brecciated pyrite, which has been cemented, and in part replaced, by ten to twenty percent of chalcopyrite and five to ten percent of gangue. Minor amounts of galena and sphalerite are associated with the chalcopyrite of this zone. Assays of pyrite-chalcopyrite massive sulphides show a high gold content.

The sphalerite-galena zone contains thirty to fifty percent of sphalerite, twenty percent of galena, ten percent of chalcopyrite and ten percent of pyrite, in a gangue of quartz and calcite. The proportions of minerals in this zone do not remain constant along strike. To both the northwest and the southeast, the content of pyrite and chalcopyrite increases at the expense of the sphalerite and galena. This zone has a high silver content.

All zones of mineralization intersected by drilling lack the sphalerite-galena type of massive sulphide replacement. They consist of lenses of heavily disseminated to massive pyrite and chalcopyrite, with traces of galena and sphalerite, and up to 10% pyrrhotite. Gold and silver tenors are present, but always low, in these zones.

The halo of pyritized wall rock which surrounds the massive sulphide body has an average content of five percent of pyrite and 0.5% of chalcopyrite. The latter mineral is erratically distributed. A constant low tenor of gold is characteristic of this zone.

Fig. 23 - Diagrammatic Section of the Lens of Massive Sulphides Exposed at Surface.



A - Disseminated Pyrite, Minor Quartz-calcite Veins.
B - Pyrite- chalcopyrite Zone.
C - The Parting- Barren Slate.
D - Sphalerite-galena Zone.

Ore Mineralogy

Ore minerals of primary and secondary origin were identified. Hypogene minerals are: pyrite (two ages), sphalerite, pyrrhotite, arsenopyrite, chalcopyrite (two ages), galena, and argentite (?). Small amounts of covellite, assumed to be supergene, were seen in two polished sections. Anglesite was seen to have replaced galena near the surface of the zone. A thin, leached crust at surface consists of limonite, residual after the oxidation of iron-bearing sulphides.

(1) Pyrite. Pyrite is the most common ore mineral of the St. Pierre deposit. It forms 80% of the total volume of sulphides. At least two ages of pyrite are present; the earlier of these is the more abundant. The earlier pyrite will be referred to as "pyrite I", and the later pyrite as "pyrite II".

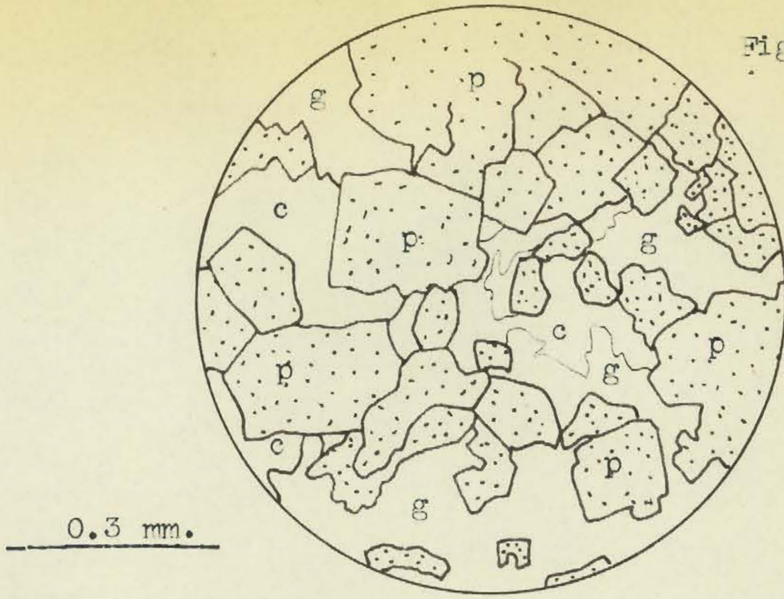
Pyrite I is very pale, brassy yellow in the hand specimen. Its habit is for the most part cubic, and the grain size is usually fine, although cubes up to one quarter inch on a side have been found. Some of the finer-grained pyrite shows in the hand specimen what appears to be crude colloform banding. Crush zones of irregular shape are common within the massive pyrite. In most places, the crush zones have been filled by later sulphides.

In polished section, the pyrite shows slight but definite anisotropism. Uytenbogaardt attributes anisotropism in pyrite to internal tensions caused by a surplus of FeS, of by the admixture of arsenic (38, p.201). Under the microscope, the color of the pyrite is almost white, having only a faint yellowish cast. Many grains of pyrite show ragged outlines due to corrosion and replacement by later minerals. In relation to the other major sulphides, pyrite I is clearly older. Fractures in pyrite grains are filled by sphalerite, chalcopyrite and galena. Pyrrhotite grains are moulded around pre-existing pyrite grains. Arsenopyrite alone has grain relationships which indicate that it may be older than the pyrite (see fig. 26b).

Pyrite II was seen in only two of the polished sections studied. This type of pyrite seems to be of limited occurrence. In the hand specimen, it can be distinguished from pyrite I by its distinctly yellower weathered surface. Under the microscope, the two pyrites are almost indistinguishable. Both are slightly anisotropic, and they can be differentiated only by their relationships to other sulphide minerals. As previously noted, pyrite I is one of the earliest sulphide minerals. Pyrite II replaces galena, which establishes it as one of the youngest sulphides of the deposit. The younger pyrite occurs as stringers or as lath-like masses which suggest the replacement of a previously existing tabular or acicular mineral (see fig.27).

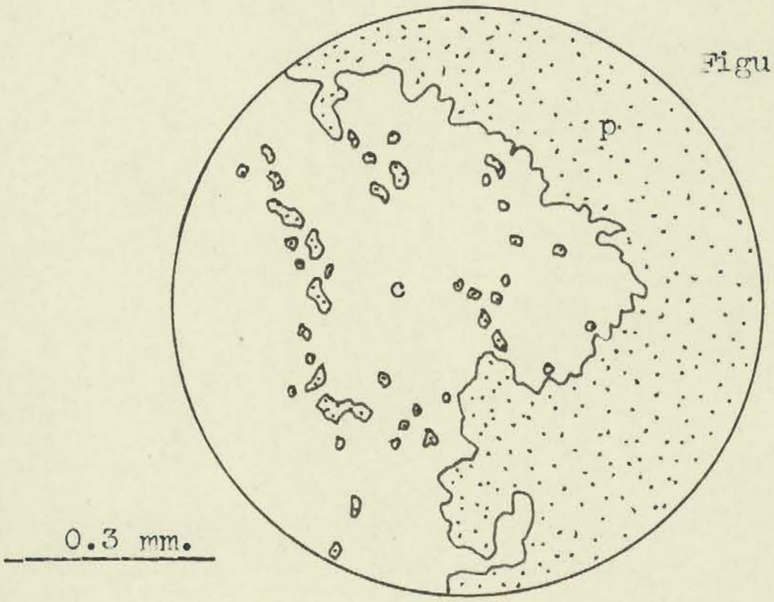
At the Soucy Claim Group of the Ungava Copper Corporation, eight miles west of the St. Pierre showing, de Montigny found three ages of pyrite (32, p.4). The earliest

Figure 24a



Massive sulphides typical of the pyrite-chalcopyrite zone. Chalcopyrite('c') and gangue('g') fill an area of brecciated pyrite('p').

Figure 24b



"Coast and Island Texture". A "sea" of chalcopyrite is replacing pyrite. Islands of partially replaced host mineral are insulated in the metasome.
(Symbols as in the above diagram.)

of these is a fine-grained variety which never shows euhedral outlines. This type is not represented in the St. Pierre Showing. The intermediate age of pyrite of the Soucy Claim Group has characteristics which indicate that it can be correlated with the pyrite I described above. The youngest pyrite of the Soucy Showing occurs only as rims around pyrrhotite grains. This cannot be correlated with the pyrite II of the St. Pierre Showing.

(2) Arsenopyrite. One polished section from the pyrite-chalcopyrite zone contains several anhedral grains of arsenopyrite. This white, slightly anisotropic mineral occurs as small euhedral grains or groups of grains scattered, with galena and chalcopyrite, in a zone of brecciated pyrite (see fig. 26a). Pyrite-arsenopyrite age relations are somewhat hard to ascertain, as very few instances are seen in which the two minerals are in contact. At one contact between the two minerals, the relationship suggests that pyrite formed later than the arsenopyrite (see fig. 26b).

(3) Pyrrhotite. Isolated corroded grains of pyrrhotite were seen in several of the polished sections. The pyrrhotite content is never more than ten percent of any one section, and is usually less than one percent. The majority of the grains are enclosed in chalcopyrite and galena. Grain boundary relationships indicate that the pyrrhotite is younger than the pyrite and arsenopyrite, but older than

all the other sulphide minerals.

(4) Sphalerite. Dark brown to black sphalerite occurs as fine-grained intergrowths with pyrite, chalcopyrite and galena in the sphalerite-galena zone of the massive sulphide lens. In other parts of the mineralized body, sphalerite is always associated closely with pyrite, which it replaces. The dark color and red-brown internal reflection of the sphalerite indicate a high iron content, and hence, a high temperature of formation (28, p.84). Examination under the reflecting microscope reveals the presence of numerous minute inclusions of chalcopyrite, which are assumed to have formed by exsolution.

The sphalerite replaces pyrite and pyrrhotite, and is cut by chalcopyrite and galena. Subrounded masses of sphalerite within pyrite cubes are assumed to be the products of incipient core replacement.

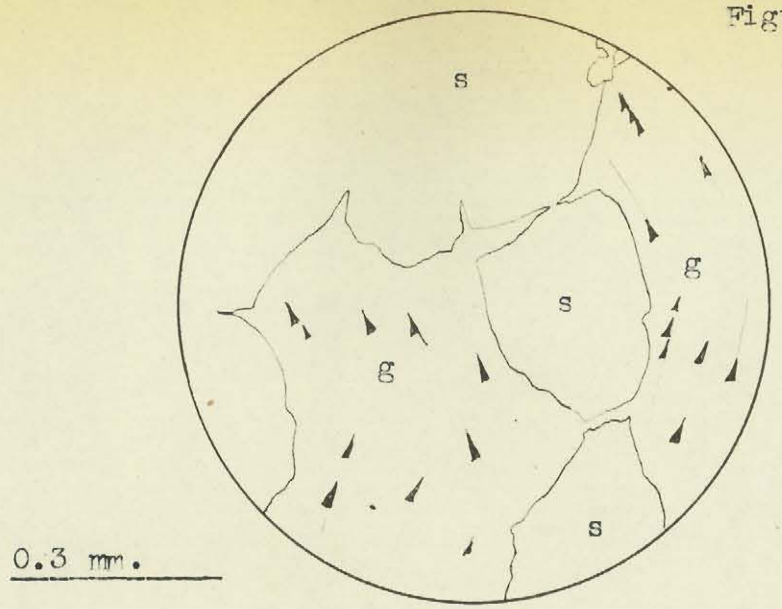
(5) Chalcopyrite. Next to pyrite, chalcopyrite is the most ubiquitous sulphide mineral in all the sections studied. Two ages of chalcopyrite occur, the younger being the inclusions in sphalerite previously described. The majority of the chalcopyrite is found in fine to medium-grained intergrowths with pyrite, galena and sphalerite in the massive sulphide body, and as veinlets in the pyritized wall rock. Minor chalcopyrite mineralization intersected by drilling is often associated with zones of strong chloritization. In the pyrite-chalcopyrite massive sulphide

zone, chalcopyrite veins and replaces brecciated pyrite I, often forming well developed "coast and island" textures (see fig. 24b). Grain boundary relations show that the chalcopyrite is older than galena and pyrite II, and younger than all other sulphides.

(6) Galena. Galena was seen in all the polished sections of the sphalerite-galena type massive sulphides, and in many of the sections of the pyrite-chalcopyrite zone. Minor amounts of galena occur with chalcopyrite in veinlets in the hangingwall margin of the massive sulphide body. Under the reflecting microscope, the galena is white to slightly greyish white, and has well developed rectangular cleavage. Lines of triangular pits follow the cleavage directions. Some of these lines are sinuous, indicating that deformative forces were in play at the time of deposition of the galena.

Assays show that the silver content of all samples submitted varies directly as the lead content. This suggests a close genetic connection between the two metals. The relationship is illustrated in figure 31a. Edwards states that at normal temperatures, galena can accomodate not more than 0.1% of silver in its structure. This is equivalent to about 0.30 ounces of silver per one percent of lead in a lead ore.(28, p.110). The silver content of certain parts of the St. Pierre massive sulphide zone is twice the maximum amount which can be held in the galena. During preliminary

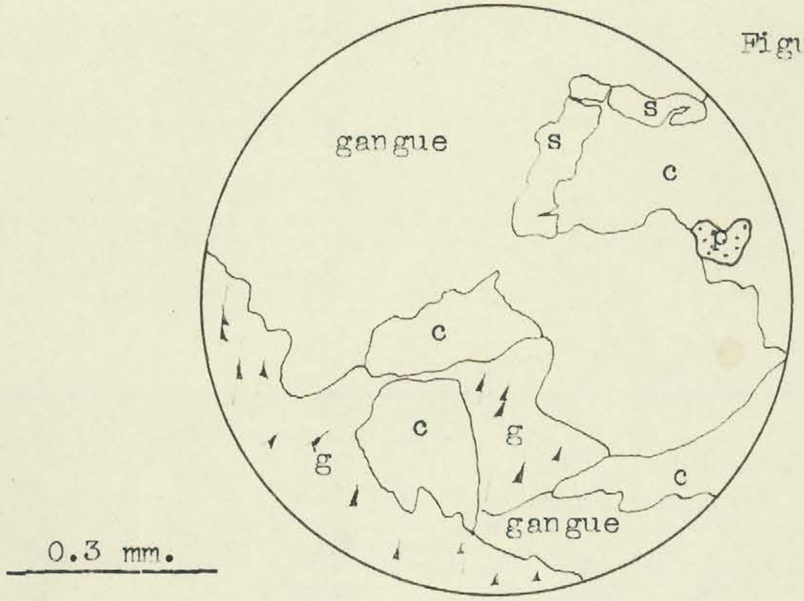
Figure 25a



Typical massive sulphides of the sphalerite-galena zone. Galena veins sphalerite, and is clearly younger.

Galena - 'g' ; Sphalerite - 's'

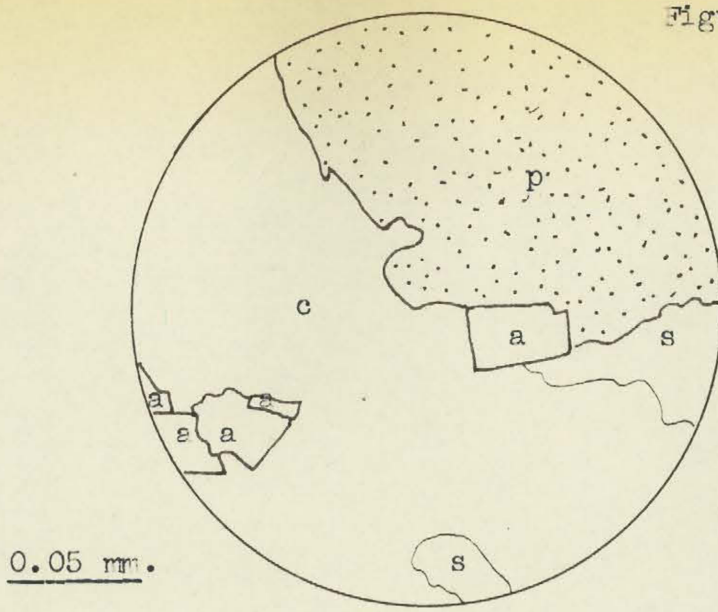
Figure 25b



Sphalerite-galena-chalcopyrite age relations. Chalcopyrite veins sphalerite and is veined by galena.

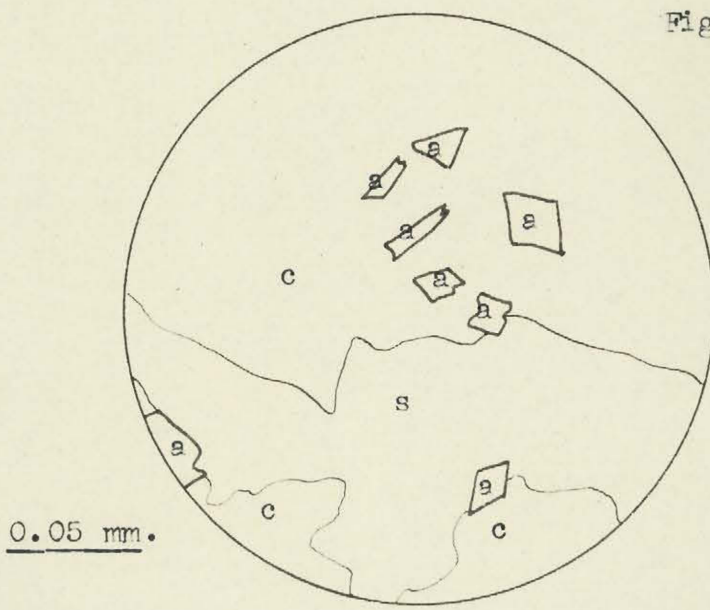
(Symbols as above, also: pyrite -'p', and chalcopyrite -'c'.)

Figure 26a



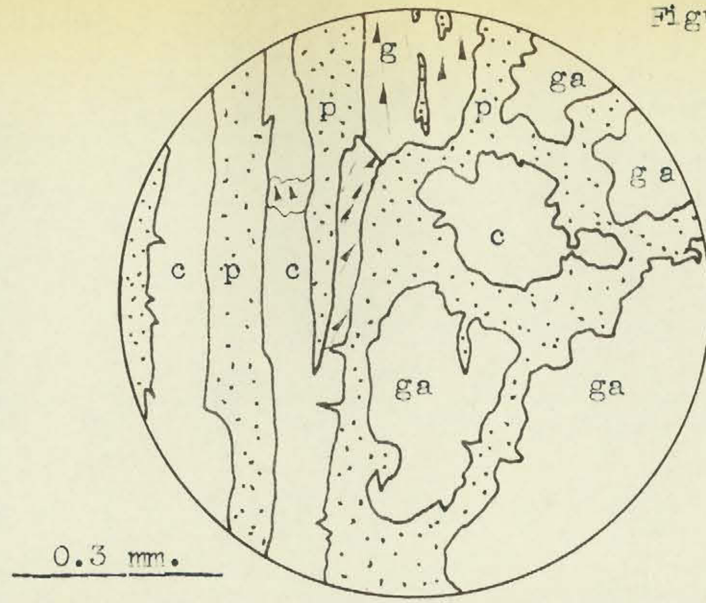
Euhedral arsenopyrite('a') in contact with pyrite ('p'), sphalerite('s') and chalcopyrite('c'). Arsenopyrite seems to be older than all these minerals, but may be contemporaneous with the pyrite.

Figure 26b



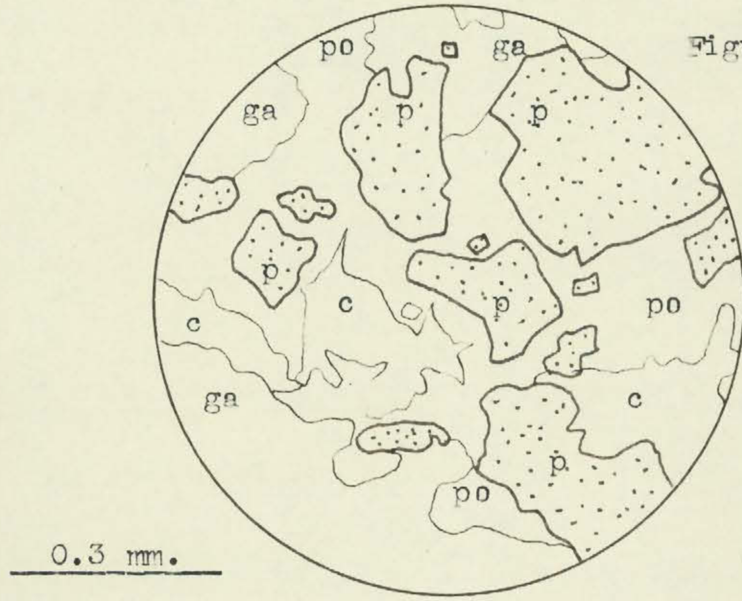
Euhedra and subhedra of arsenopyrite transgress sphalerite-chalcopyrite boundaries, suggesting that arsenopyrite is older than these minerals.
(Symbols as in the above diagram.)

Figure 27a



Pyrite II, of lath habit, seems to vein gangue('ga'), chalcopyrite('c') and galena('g').

Figure 27b



Unusually high concentration of pyrrhotite('po') with pyrite('p'), chalcopyrite('c') and gangue('ga'), in a section taken from sulphides intersected at depth. Pyrrhotite seems to be later than pyrite and earlier than chalcopyrite.

examination, no silver minerals were identified in the polished sections. However, when galena was etched for two minutes with 1;7 nitric acid, it was found to contain minute inclusions of a mineral tentatively identified as argentite (Ag_2S). These inclusions are described below.

<u>(7) Argentite (?)</u>. Polished sections of galena were blackened by prolonged etching with nitric acid. After this had been done, the sections were examined under high powers of magnification, and were found to contain numerous minute inclusions of a pale grey mineral which was only slightly stained by the acid (see fig. 28). The average diameter of the inclusions is one to three microns. They are either subround or distinctly square in section, and are arranged in lines subparallel to the cleavage of the galena, or in groups of uncontrolled orientation. Most of the groups of inclusions are in the central parts of the galena grains. The combination of the properties of slight reaction to nitric acid, isotropism, lack of internal reflection and squareness in section, serve to identify the mineral as argentite rather than as any other silver mineral of similar association. Bateman (35, p. 82), Edwards (28, p.111), and Dana (23, p.418) state that argentite commonly occurs as minute inclusions in galena. The inclusions are assumed to have formed by exsolution.

<u>(8) Covellite</u>. Two small grains of covellite were seen in specimens taken near the surface of the pyrite-

chalcopyrite portion of the massive sulphide zone. Both grains were in cracks in gangue minerals beneath the limonitic surface crust, and are assumed to represent grains of chalcopyrite replaced during the processes of supergene enrichment.

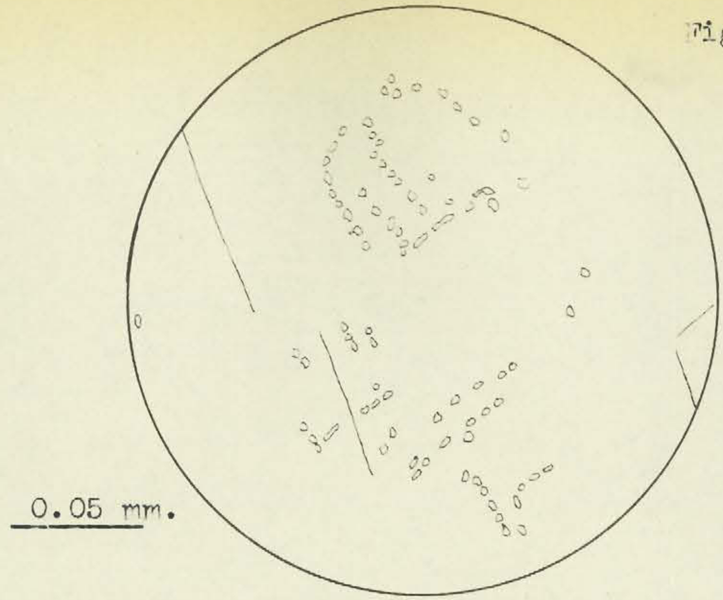
(9) Anglesite. Feathery aggregates of anglesite replace the marginal portions of galena grains near the surface of the massive sulphide body. A few veinlets extend into the central parts of galena grains, following cleavage cracks (see fig. 29).

(10) "Limonite". The term "limonite" is used in a general sense to describe the red, brown and yellow precipitates from oxidized iron minerals. Hematite (red), goethite (brown) and jarosite (yellow) are the constituents of limonite (40, p. 326). The limonite of the St. Pierre Showing occurs as an inch-thick, dark red-brown crust over the pyrite-chalcopyrite portion of the massive sulphide zone. The color of this limonite is distinctly darker than the orange shade of the limonite associated with the economically uninteresting pyrrhotite-bearing slates of the region. This distinction is a useful one in prospecting in the area.

Gangue Mineralogy

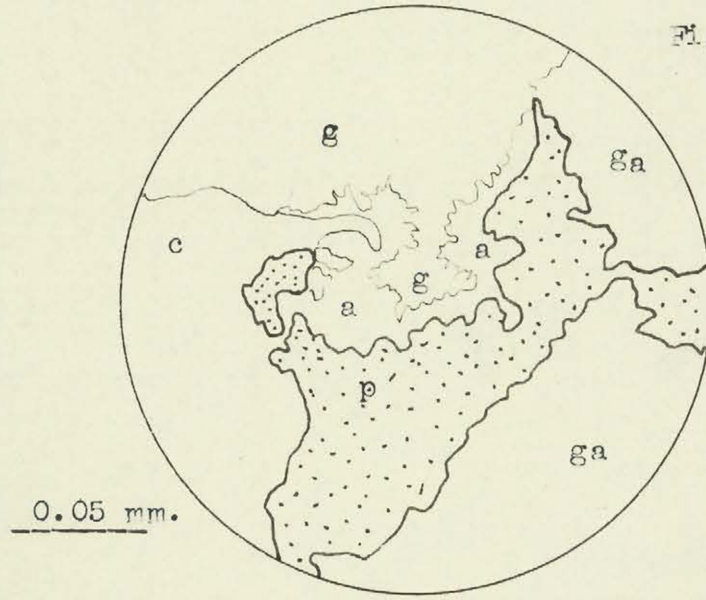
Quartz. Quartz forms approximately five percent of the massive sulphide body. Two types of quartz are found.

Figure 28



Tiny inclusions of argentite revealed by etching galena. The inclusions are oriented in a preferred pattern, possibly a crystallographic one.

Figure 29



A feathery growth of anglesite('a') replaces galena ('g') in a specimen taken near the surface of the showing. Other minerals present are pyrite('p'), chalcopyrite('c') and gangue('ga').

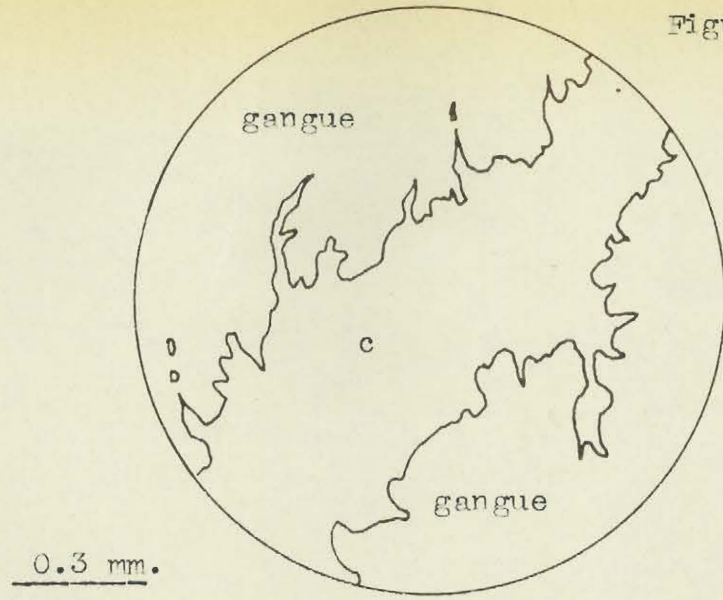
The most common variety is granular grey quartz, which is evenly disseminated through the massive sulphides. The remainder of the quartz occurs as vein matter, in association with carbonate. The veinlets are found mostly near the margins of the massive sulphide body, and are of two ages. One group of veinlets is pre-chalcopyrite, the other is post-chalcopyrite, in age (see figl 30).

Calcite. Grey translucent calcite is disseminated through the massive sulphide body in close association with the disseminated quartz described above. Creamy white calcite occurs in veinlets with quartz. Both varieties of calcite effervesce vigorously with dilute hydrochloric acid.

Small veinlets of creamy white calcite are associated with erratic low grade chalcopyrite deposits in the pyritized zone of wall rock.

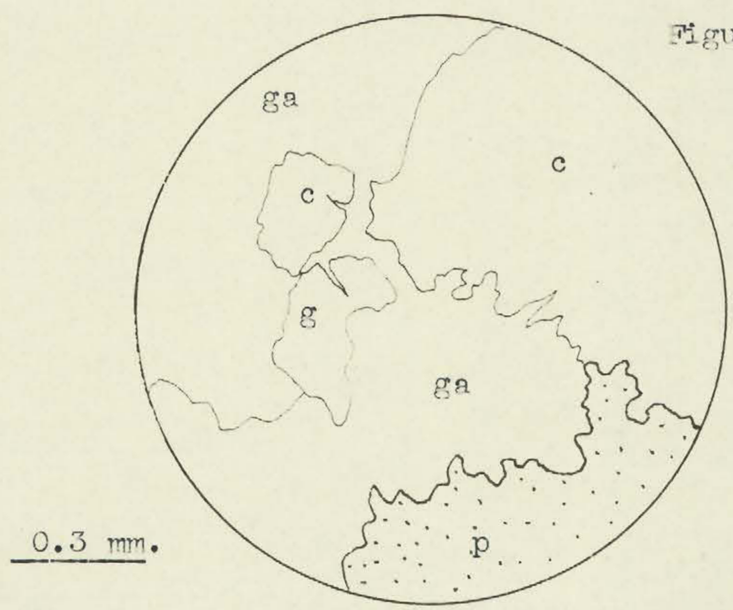
Tabular or Acicular Minerals (?). As previously noted (see "Ore Minerals - Pyrite II"), galena and pyrite II seem to have replaced previously existing minerals of tabular or acicular habit (see fig. 27). No minerals exhibiting such forms are seen in the mineralized zone at present. Dana states that calcite has been observed to have thin tabular and long prismatic habit (23, p.513). In view of the presence of carbonates at all stages of mineralization in the area, this fact provides an acceptable explanation of the phenomenon.

Figure 30a



Chalcopyrite veins quartz. This specimen was taken from the zone of altered wall rock adjacent to the massive sulphide lens.

Figure 30b



Late carbonate gangue('ga') veins chalcopyrite('c') and galena('g').

The Occurrence of Gold - An Unsolved Problem

Gold or gold-bearing minerals were not seen in the polished sections examined, though assays reveal the presence of considerable amounts of this metal. Selective sampling has shown that the gold values are highest in the pyrite-chalcopyrite portion of the massive sulphide body. The amounts of gold present, as determined by assay, are well within the bounds of the amount of gold which can be held in solid solution in pyrite (28, pp.112-113). Recent research shows that gold may also occur as crystal grains of the order of 10^{-6} centimeters diameter. These minute crystals were detected under the electron microscope (28, p. 113).

Therefore, it is reasonable to assume that the gold of the St. Pierre Prospect may occur in solid solution with the pyrite, or as microcrystals in some part of the pyrite-chalcopyrite portion of the sulphide mineralization.

Zones of massive and strongly disseminated pyrite intersected by drilling contain a constant but very low tenor of gold, despite having mineralogic assemblages megascopically identical to those of the gold-rich pyrite-chalcopyrite zone. The same holds true of small segregations of heavily disseminated pyrite in the zone of pyritized wall rock. Hawley (quoted in 41, p.1005), after a detailed spectroscopic study of pyrite from Canadian gold mines, stated that "no marked trends of gold content with temperature of formation, type of wall rock, or depth in a deposit were established; structural controls, such as proximity to a contact, seemed to have greater effect." This finding may well apply at the St. Pierre Showing, where the anticlinal fold has structurally controlled the emplacement of the sulphide minerals.

A statistical study of assay results has revealed an interesting trend, which may be of significance in understanding the mode of occurrence of the gold. The content of gold was found to be independent of the amount of zinc in all samples which contained both metals. The relationship is illustrated in figure 31b. Sphalerite, the only zinc-bearing mineral identified, was emplaced after the pyrite and before the chalcopyrite. The gold-zinc relationships suggest that the gold has no genetic connection to the sphalerite.

As all samples of high gold content were taken within three feet of the surface, the possibility of mechanical enrichment of the gold should not be disregarded. During erosion, particles of gold may have been freed from low grade gold-bearing rock. Such particles may have been washed into cracks in the rock, and thus concentrated below the present surface. However, the rocks of the area have been glaciated during Pleistocene time, and it seems unlikely that such a concentration could have accumulated in the relatively short period since glaciation.

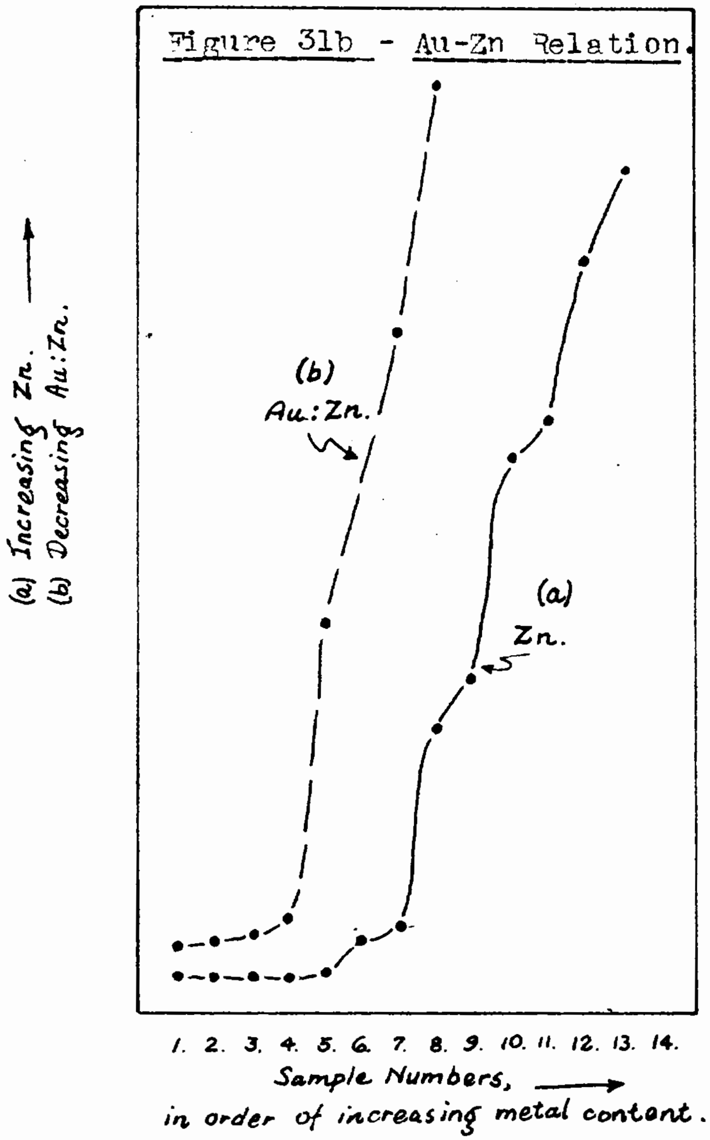


Figure 31b - Au-Zn Relation.

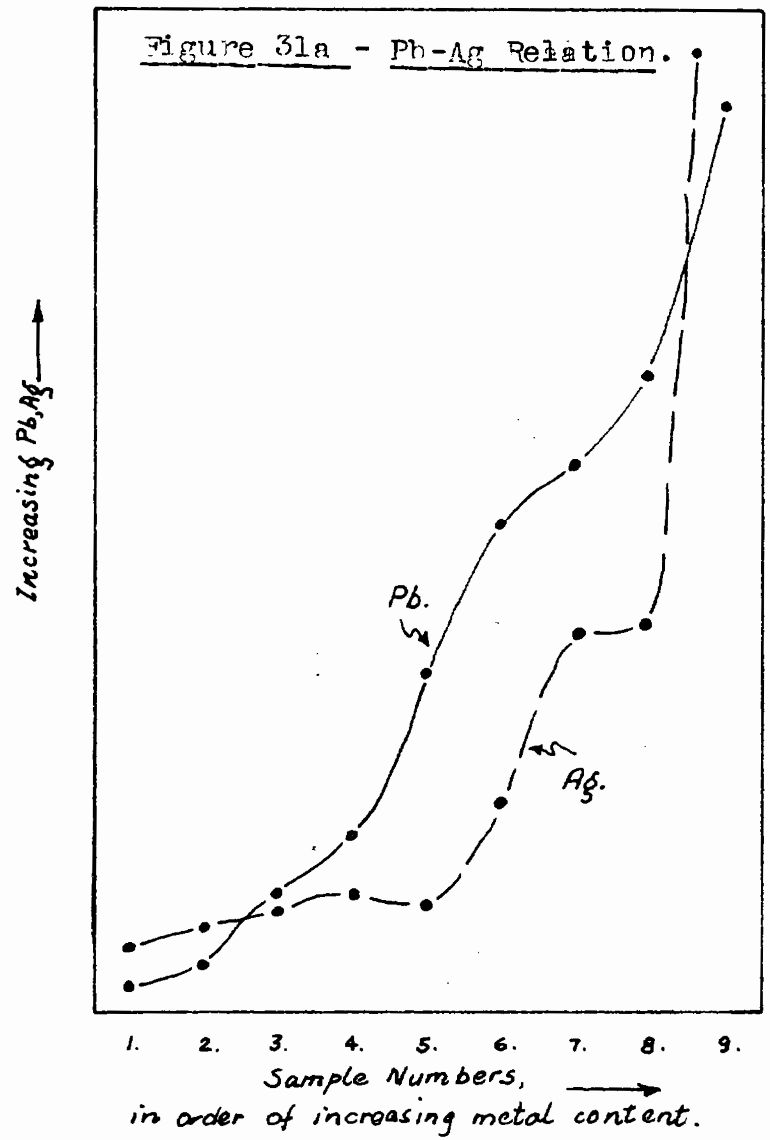


Figure 31a - Pb-Ag Relation.

In summary, the occurrence of the gold, and its erratic distribution are unsolved problems. It is possible that the gold may be in solid solution in the pyrite, or in minute crystal particles within the pyrite or the chalcopyrite. There is no genetic relationship between the gold and the sphalerite. The concentration of gold in the pyrite-chalcopyrite portion of the massive sulphide body may be due to structural control. The possibility that the gold was mechanically enriched by weathering is not likely to be vâlid because of the small amount of time available since glaciation for such a process to act.

Paragenesis

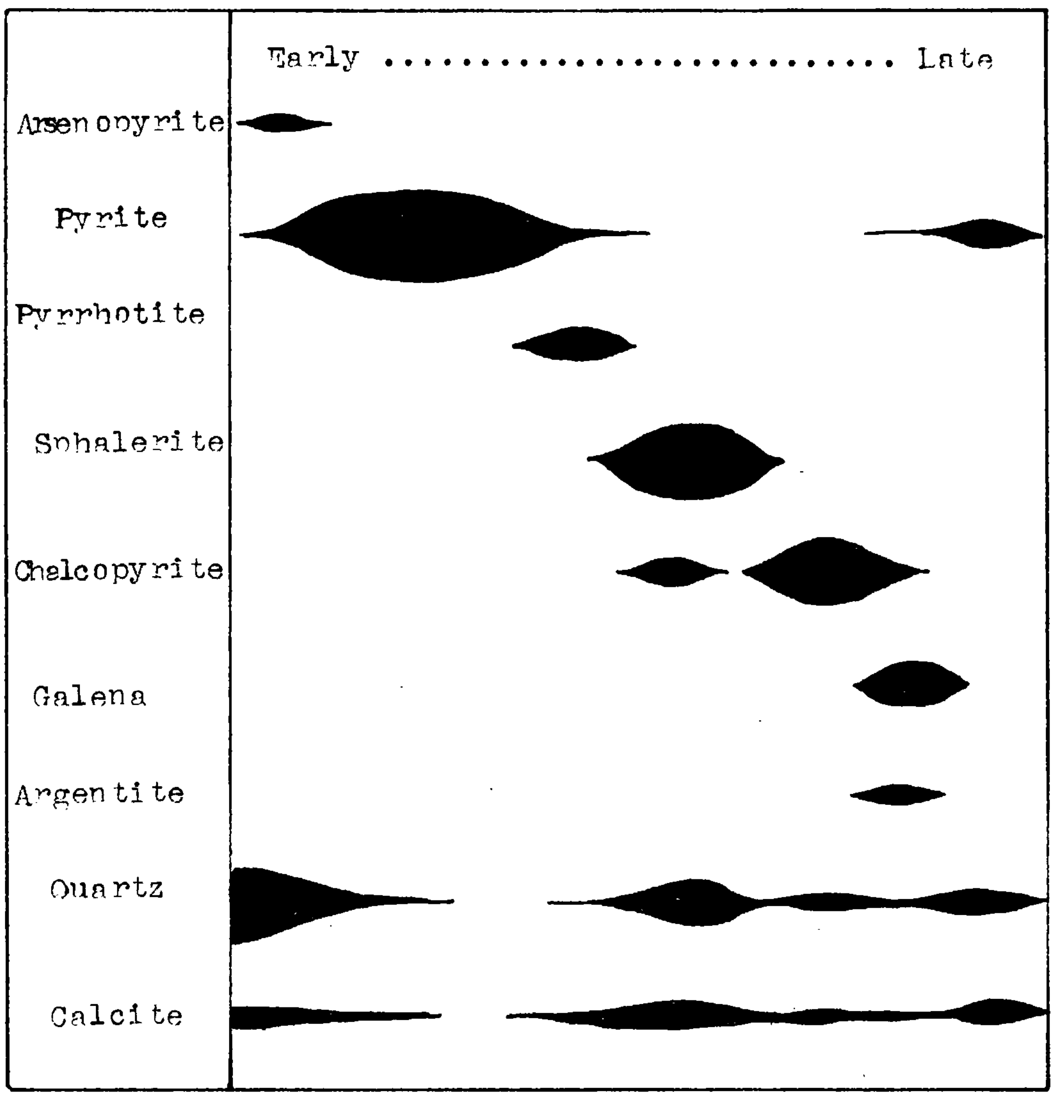
On the basis of the relationships between minerals observed in polished sections and in thefield, the following paragenetic sequence of the hypogene ore minerals is proposed:

Oldest.	1. Arsenopyrite.
	2. Pyrite I.
	3. Pyrrhotite.
	4. Sphalerite and Chalcopyrite I.
	5. Chalcopyrite II.
	6. Galena and Argentite.
Youngest.	7. Pyrite II

Evidence for placing the minerals in the above sequence is illustrated in figures 24 to 30, inclusive. Replacement criteria of dubious value were disregarded, and clearcut veining proved to be the most reliable indicator of relative age. Some doubt exists as to the pyrite I -arsenopyrite relationship. It is possible that these minerals were

Figure 32

Paragenetic Diagram, Showing the Relative Abundance of Ore and Gangue Minerals



deposited contemporaneously.

A quantitative expression of this paragenetic sequence, together with the sequence of the gangue minerals, is given in figure 32.

Wall Rock Alteration

General Statement

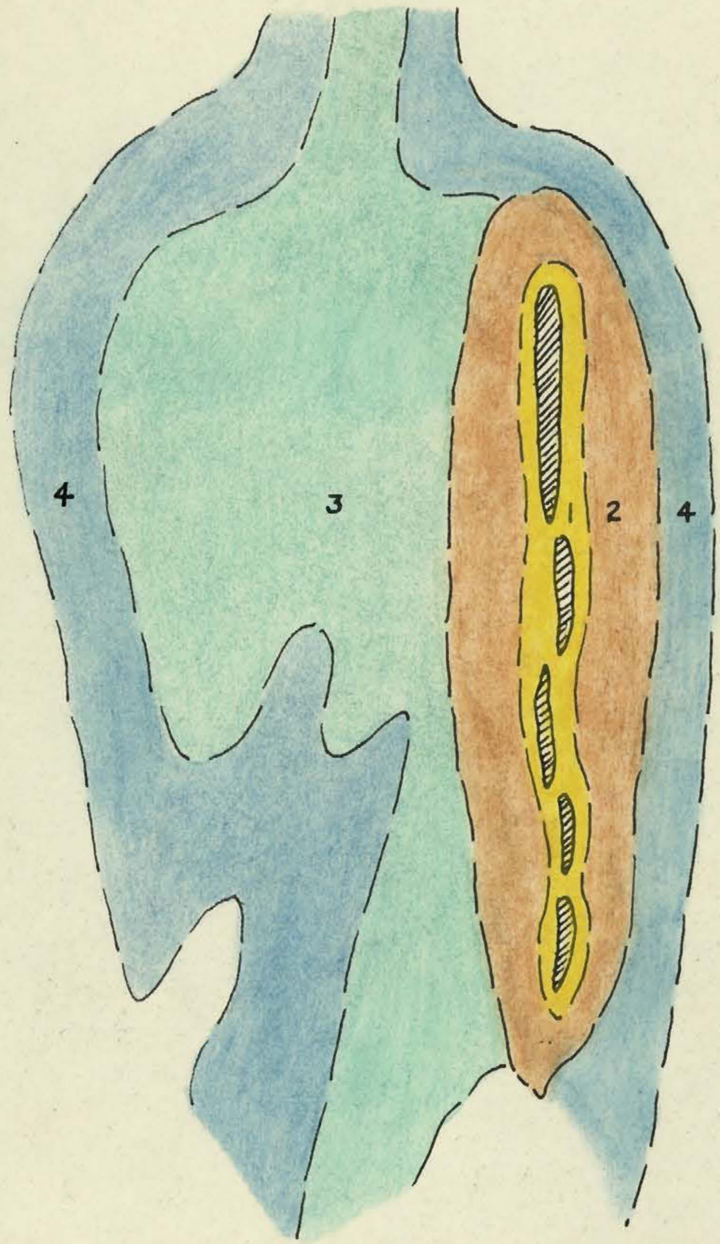
The presence of several zones of hydrothermal wall rock alteration is an outstanding characteristic of the St. Pierre mineralized zone. The sizes of these zones and their intensities of alteration are directly related to their proximity to the massive sulphide body. Each zone has a characteristic mineral assemblage. "Mixed" areas are found in gradational portions between the zones. Figure 33 is a generalized plan of the surface distribution of the various zones with respect to the massive sulphides.

Certain layers within the metasedimentary wall rocks have been preferentially altered; hence, the outlines of the zones are irregular. The zone of fracturing in the nose of the anticlinal fold added to the irregularity of the zone of intense silicification. Drilling has disclosed that the general pattern of the altered zones is continuous downward, but that the intensity of alteration decreases with depth.

The various zones are described below. The surface width of each zone is expressed as a multiple of the width of the exposure of massive sulphides. This provides an

Figure 33

The Surface Aspect of Wall Rock Alteration



1 — Zone of Silicification and Carbonatization

2 — Zone of Pyritization and Chloritization

3 — Zone of Intense Silicification

4 — Zone of Weak Carbonatization and Sericitization

(hatched) — Massive Sulphides

index to the relative values of the forms of alteration as prospecting guides. "FW" and "HW" indicate width ("w") in the footwall and hangingwall blocks of the reverse fault, respectively.

Zone I. (FW and HW - 1/5 w.). Crumpled schistose slates immediately adjacent to the sulphide body have been replaced by a narrow zone of coarse-grained quartz, calcite and pyrite, with minor sericite (see fig. 34). The average composition of the rock in the zone is:

Quartz - eyes and veinlets - 30%.
Calcite - veinlets and disseminated grains - 25%.
Pyrite - aggregates of fine cubes - 15%.
Sericite - flakes of random orientation - 5%.
Unaltered wall rock - 25%.

The relatively small width of this zone gives it little value as a prospecting aid.

Zone II. (FW and HW - 2 to 3w). Zone II is a halo of moderately chloritized, sericitized and pyritized rocks which surrounds Zone I. As both sericite and chlorite are common products of regional metamorphism in the area, it is difficult to say to what extent this alteration may be due to hydrothermal agencies. It was noted that the rocks of Zone II have a weathered surface somewhat more green than that of similar metasediments outside the vicinity of the mineralized zone. In addition, a content of five to ten percent of disseminated cubes and fine-grained aggregates of pale yellow pyrite further serves to distinguish the zone (see fig. 36a).

The chlorite content varies from five to forty percent. Drill holes intersected two narrow layers of highly chloritized rock which was associated with minor carbonate and chalcopyrite veinlets.

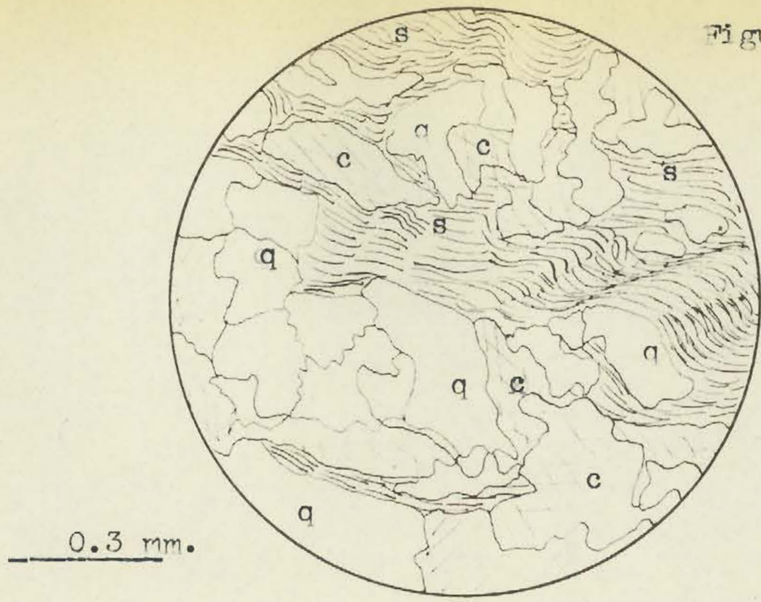
The sericite content of Zone II varies from 20% to 40%. A large part of this sericite may have been formed by dynamic metamorphism, but one thin section shows sericite of much coarser grain size than any seen elsewhere in the area.

The relative width of this zone, and the rust-mottled weathering of its oxidizing pyrite, make it a valid indicator of the proximity of the massive sulphide zone.

Zone III. (FW only. 10 to 15w). An irregular zone of intensely silicified wall rock occurs outside Zone II in the footwall block only. This restricted occurrence suggests that the hangingwall rocks were for some reason impermeable at the time of silicification. The irregular outline of the zone is due to the control of its emplacement by a previously existing irregular zone of fracture in the core of the anticlinal fold. Certain beds in the anticlinal hump seem to have been very susceptible to replacement by silica.

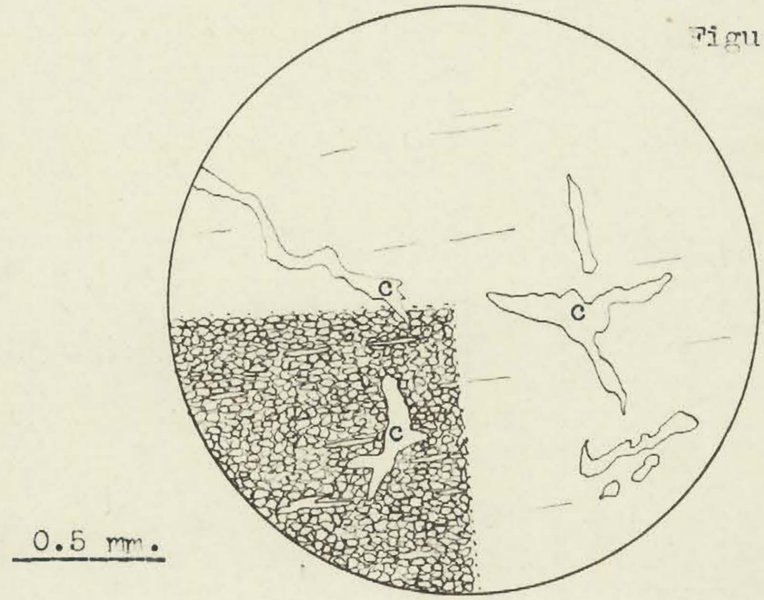
The typical rock of Zone III consists of 80% of fine-grained quartz, 10% of streaky aggregates of emerald-green chlorite, two to three percent of disseminated small grains of white calcite, and minor quantities of unaltered wall rock. The chlorite is commonly in streaks along former

Figure 34



Quartz('q') and calcite('c') replace crenulated sericite schist('s') at the footwall margin of the massive sulphide lens. This is typical of the alteration of Zone 1 (see figure 33).

Figure 35



Intensely silicified wall rock. Fine-grained quartz has replaced schistose metasediment. Detail is shown only in the lower left quadrant. Chlorite('c') occurs as irregular masses. The horizontally aligned grains are sericite flakes.

bedding or cleavage planes, but also fills discordant veinlets (see fig. 35).

The silicified rock has a pale green weathered surface flecked with white calcite grains. Fresh specimens taken at depth show a salmon pink color in the zones of most intense alteration. No silicified rock of similar color was seen at any other place in the area. The silicified rock of this zone is extremely resistant to weathering, and is the reason for the prominence of the knoll on which the showing is located. Similar knolls in areas of low-lying metasediments should be carefully investigated.

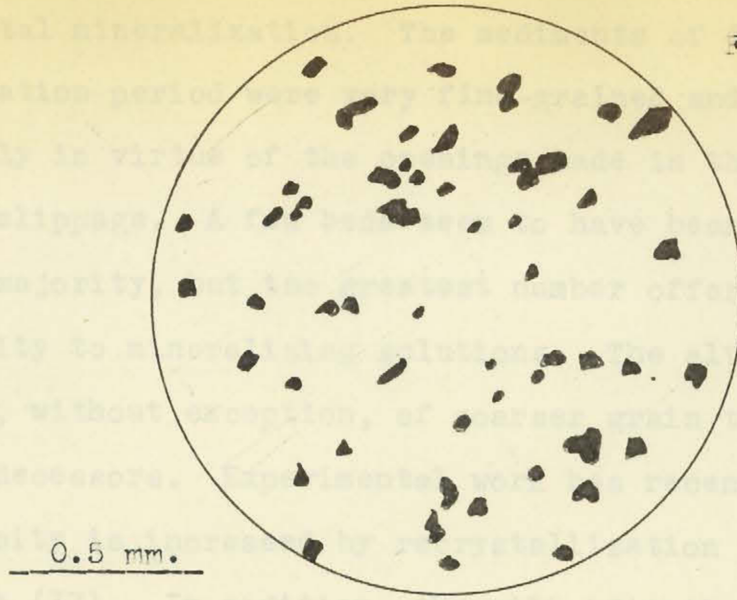
Zone IV. (FW - 4w; HW - 2w). A zone of weakly chloritized and carbonatized wall rock is the outermost expression of hydrothermal alteration at the mineralized zone. Schwartz notes that "the occurrence of a chlorite alteration well out from the ore and generally of moderate to low intensity has been emphasized repeatedly" (31, p.305). He cites Cerro de Pasco (Peru), Oruro (Bolivia) and Guanajuato (Mexico) as characteristic examples of this phenomenon.

A dark green weathered surface, flecked with blebs and rhombs of buff-weathering calcite, is typical of Zone IV (see fig. 36b).

Significance of Wall Rock Alteration

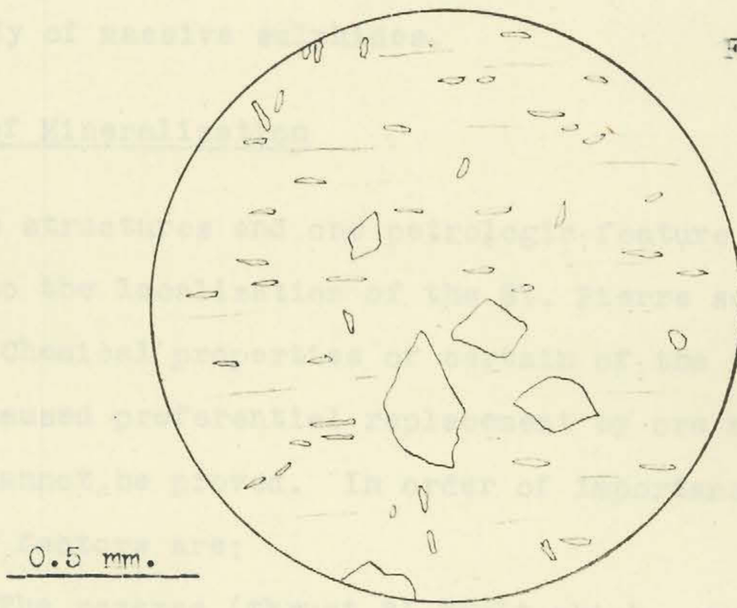
In addition to providing evidence of the presence and location of the massive sulphide body, the wall rock alteration may have had a profound influence on the localization

Figure 36a



Pyritized sericite schist nine feet from the hangingwall contact of the massive sulphide lens.

Figure 36b



Rhombic calcite grains and flakes of sericite replace fine-grained quartz-sericite schist. This alteration is typical of Zone 4 (figure 33).

of the metal mineralization. The sediments of the pre-mineralization period were very fine-grained and were permeable only in virtue of the openings made in them by fracturing and slippage. A few beds seem to have been more porous than the majority, but the greatest number offered little permeability to mineralizing solutions. The altered wall rocks are, without exception, of coarser grain than were their predecessors. Experimental work has recently shown that porosity is increased by recrystallization to coarser grain size (33). In addition, the silicification and pyritization created a block of brittle rock in incompetent schistose slates, thus producing an environment favourable to the formation of openings by fracture. Therefore, the wall rock alteration prepared the way for the emplacement of the body of massive sulphides.

Controls of Mineralization

Three structures and one petrologic feature have contributed to the localization of the St. Pierre sulphide deposit. Chemical properties of certain of the rock types may have caused preferential replacement by ore minerals, but this cannot be proved. In order of importance, the localizing factors are:

(i) The reverse (thrust ?) fault which passes through the central part of the map area. Schistosity, in part due to the fault, has also contributed to concentration of sulphides.

(ii) The anticlinal fold at the northwest end of St.

Pierre Lake.

(iii) Cross faults.

(iv) Relatively permeable beds at the intersection of the anticlinal fold and the reverse fault.

The reverse fault was formed by thrusting during the period of intense deformation of the region. At some time during or after this period, the fault zone acted as a channel-way for ascending solutions. This is evidenced by the minor quantities of quartz and pyrite found at intervals along the surface trace of the fault zone.

The reason for the concentration of sulphide minerals at the northwest end of St. Pierre Lake rather than at any other place along the fault zone, appears to be that the anticlinal fold, intersected at this place by the fault, provided a zone of fracturing available to the mineralizing solutions. Here also, certain permeable beds were downfolded into the fault plane. In short, the junction of the anticline with the fault plane is the only place in the map area where the fault plane is not concordant with the relatively imper-meable beds of the central grey slate band of metasediments.

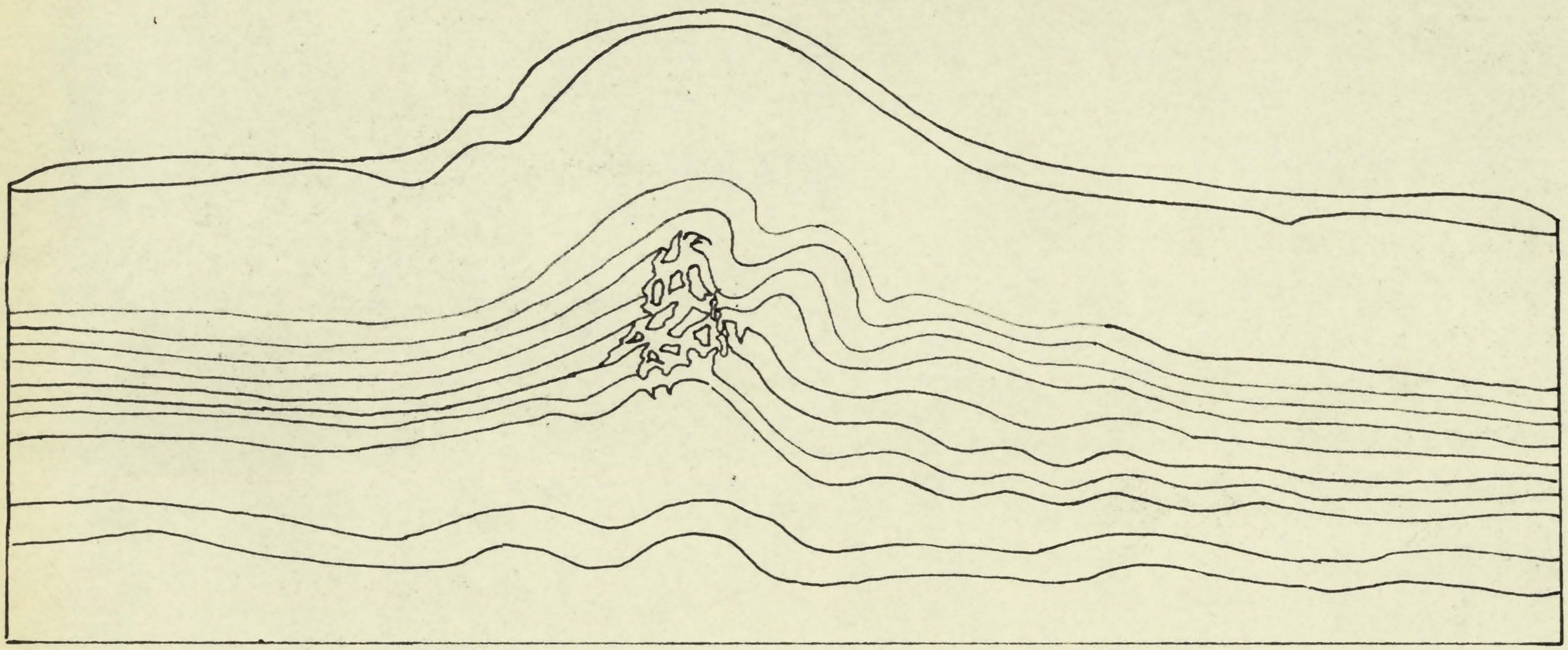
The possibility that the anticline may have provided a highly permeable zone susceptible to mineralization is strongly advocated. Both field evidence and theoretical considerations support this theory. The rock of the anticlinal hump is intensely silicified and chloritized. In all other altered sediments in the map area, secondary chlorite is present as sheet-like aggregates marking the previously existing bedding planes. On the anticlinal hump, however, the chloritic stringers are disordered, indicating that a high degree of fracturing existed at this place before chloritization.

Bailey Willis' classic experiments on compressional folds further illustrate that a tight anticline is the locale of considerable fracturing, and hence, permeability (30, pl.78; see also fig. 37).

The presence of quartz veins along the zone of the reverse fault indicates that silica-bearing solutions pervaded the fault at one or more times. Lovering (29, p. 6) states that the presence of relatively large open areas above a constricted feeding channel is a factor which favors a steep precipitation gradient. In view of the high degree of permeability in the anticlinal hump, it is therefore quite understandable that large quantities of silica were deposited in the vicinity of the showing, rather than at any other place in the area.

Following the period of silicification, large quantities of pyrite were deposited in the vicinity of the showing. The distribution of the pyrite seems to have been controlled both by schistosity and by the porosity of certain beds which had been brought into the zone of faulting by the anticlinal fold. In thin section, it is seen that unpyritized beds are either those which had been highly silicified, or dense, fine-grained layers. The average grain diameter of the latter type of barren rock is 0.01 to 0.005 mm. On the other hand, pyritized layers are always of coarser grain. The average grain diameter in heavily pyritized slate is 0.1 to

Brecciation in an anticlinal nose. Figure 37



Folding and brecciation in a series of strata of varying competence. Compression was from the right. The situation is analogous to that at the St. Pierre mineralized zone, where brecciation in an anticlinal nose gave access to mineralizing solutions.

(After Willis, Bailey; The Mechanics of Appalachian Structure; U.S. Geological Survey 13th Annual Report; 1891-2; Plate LXXVIII).

0.06 mm. Beds which have been completely replaced may well have been even coarser in grain.

At the point at which the fault zone intersects the anticlinal fold, the northwest limb does not fall away regularly from the crest of the anticline. It is indented by a dragfold of about five feet amplitude, as shown in section "A", appendix II. Minor crenulations on the northeast limb of this lesser fold are interpreted as linears giving the orientation of the axis of the fold. These linears strike S 70°E and plunge 15°SE. By drilling, it has been shown that the sulphide body strikes in the same direction as the linears, and plunges 12½°SE. This strongly suggests that the emplacement of the sulphide body was controlled by the dragfolded northeast limb of the anticline. The upward migration of the mineralizing solutions was halted by impermeable fine-grained beds and by the halo of silicified wallrock which had previously been developed.

The silicification and pyritization of the core and northeast limb of the anticline established a mass of brittle, competent rock in an environment of incompetent slates and tuffs. The deformation which produced the cross faults of the region caused the opening of fractures in and around the competent mass. This gave access to solutions bearing base metals. These solutions filled the fractures and replaced parts of the mineralized mass. It is likely that several cross fractures acted as channelways for the metal-bearing solutions. The nearest major cross fault is fifteen hundred feet northwest of the showing. Two cross faults of minor displacement are indicated at the showing, one at the northwest, the other at the southeast end of the mineralized zone. Both of these faults strike N 30°E and are vertical, with left hand displacements of the order of two feet. Drilling has shown that the pyritic body produced by the first phase of metallization is offset to both the right and the left at intervals along its length by minor faults not exposed at surface. Similar crossfaults outside the map area are known to be associated with galena and chalcopyrite occurrences (7).

In summary, the sulphide body at the St. Pierre Prospect was localized in a favourable zone formed by the conjunction of an anticlinal fold and a reverse fault. A minor fold on the northeast limb of the anticline controlled the deposition of the pyrite body. Permeability by virtue of relatively large grain size caused the selective mineralization of certain beds. Impermeable fine-grained layers and a previously developed aureole of silicified wall rock seem to have limited the upward advance of the metallizing solutions. Subsequent movements formed cross faults and opened fractures in and near the brittle quartz-pyrite mass, giving access to solutions which enriched the deposit with base metal sulphides.

Conditions of Formation of the Deposit

The mineral assemblages of the mineralized zone suggest that the St. Pierre deposit was formed under mesothermal to hypothermal conditions. Lindgren (quoted in 36, p.148) stated that high pressures, moderate depth of formation and temperatures of 200°-500°C. are the conditions necessary for the deposition of mesothermal and hypothermal deposits. No quantitative estimate of depth or pressure at the time of deposition can be made from the data studied in this thesis. There are several clues which indicate the order of temperatures which prevailed at the time of deposition. Bateman lists chalcopyrite, arsenopyrite, galena and sphalerite as being typical of "intermediate" temperatures of deposition (35, p. 158). Two features of the St. Pierre ore minerals serve to narrow the range of temperature at which the deposit could have been formed. These are the dark colour of the sphalerite and the presence of exsolution chalcopyrite in the sphalerite.

The colour of sphalerite has been found to vary from light to dark with increasing iron content (28, p. 84). Kullerud has shown that the amount of FeS which will dissolve in sphalerite can be directly related to the temperature at which the sphalerite was formed (34). The St. Pierre sphalerite is uniformly dark brown to black, and has deep red-brown internal reflection. This suggests that the FeS content of the sphalerite is from 8% to 15% (28, p. 84). Edwards notes that sphalerite with more than 10% dissolved FeS inevitably contains exsolution blebs of pyrrhotite visible under the microscope (28, p.84-85). This is not seen in the St. Pierre sphalerite. Therefore, the content of FeS in the sphalerite is limited to 8% to 10%. This suggests a temperature of formation of the range 200°C. to 500°C., depending upon pressure. If the pressure was 1000 to 5000 atmospheres, the temperature would have been approximately 400°C (34).

Experimental work on chalcopyrite solutions in sphalerite has shown that chalcopyrite exsolves from sphalerite at various temperatures. Schwartz achieved separation at 650°C., Borchert at 550°C., and Buerger at 350° to 400°C. (37, p. 361). Buerger's result approximates that obtained by the estimation of the FeS content of the sphalerite.

In summary, mineralogical and textural evidence indicates that the massive sulphide body was formed at a temperature of the order of 400°C.

Classification of the Deposit

In the terms of Bateman's system of classification of mineral deposits, the St. Pierre deposit is the product of hydrothermal replacement and cavity filling (35, p. 364). Of these two processes, replacement dominated. Evidence of cavity filling is seen in the numerous veinlets in the vicinity ofthe deposit, and in the filling of chalcopyrite which cements many brecciated zones in the pyrite-chalcopyrite portion of the massive sulphide body. Unsupported residual nuclei of wall rock are found in many places along the margins of the massive sulphide body. These are criteria of replacement, as are cubes of pyrite which transect slate laminae. In general, the early silicification and pyritization periods were times of intense replcement. Temperatures and pressures were likely high during these phases. With decreasing temperature, cavity filling became more important, and the last stages of mineralization are characterized by galena-chalcopyrite veinlets and crustified quartz and calcite.

In form, the St. Pierre Deposit is roughly pencil-shaped and is made up of a number of disconnected lenses which may have been offset by cross faulting between waves of mineralization.

The association of ore minerals found in the St. Pierre Deposit illustrates the inadequacy of the recently established chemico-mineralogic classification of Schneiderhohn (36, p.163). This classification is excellent as far as it goes, but it leaves many mineral associations unclassified. In terms of the Schneiderhohn classification, the St. Pierre Deposit must be placed in three categories:

(a) Mesothermal chalcopyrite veins and crushed zones in metamorphosed basic rocks (chloritic copper associations).

(b) Mesothermal silver-lead-zinc replacement deposits.

(c) Kata- to mesothermal pyritic stocks and impregnations.

A further classification would be necessary to explain the association of gold with the deposit. At best, this is a cumbersome definition. It can be shortened slightly by classifying the deposit as the product of a pyrite-chalcopyrite-gold mineralization followed by a lead-zinc-silver phase.

In summary, the St. Pierre Deposit is a pencil-shaped, meso- to hypothermal sulphide body, in which replacement and cavity filling have combined to deposit ore minerals of the pyrite-chalcopyrite-gold and lead-zinc-silver chemico-mineralogical associations.

Comparison to Other Deposits

General Statement

The St. Pierre Showing differs in many ways from the typical sulphide deposits of the region. A deposit at Soucy Lake has many characteristics in common with the St. Pierre Prospect, but in other ways, more closely adheres to the regional pattern of mineralization.

An interesting resemblance exists between the St. Pierre Prospect and certain silver-lead-zinc deposits of the Mount Isa District of Queensland, Australia.

In the following sections, the St. Pierre Prospect is compared and contrasted with: the "type-deposit" of the region, the Soucy Lake Showing, and the deposits of the Mount Isa District, of Australia.

The St. Pierre Prospect and the Type-deposit of the Region

The great majority of sulphide deposits along the eastern margin of the Labrador Trough are found in gabbro sills and in the sediments immediately adjacent to these sills (42; 7; 2, p. 6; 12, p. 9). Most of these deposits are associated with a blotchy, feldspathic gabbro known locally as "leopard rock". The sediments most frequently replaced by sulphides are dark brown or black slaty argillaceous formations. The sulphide deposits are concordant zones of disseminated pyrrhotite and chalcopyrite, with or without smaller bodies of massive sulphides of the same composition. In some sedimentary beds, replacement has been complete over long distances. Pyrrhotite forms over 90% of the sulphides in these deposits, and pyrite is not conspicuous except in a few places. Minor amounts of pentlandite are associated with pyrrhotite in some of the gabbro sills. Chalcopyrite is either disseminated, or in tiny veinlets which are clearly later than the pyrrhotite. Slipp suggests that at least some of the chalcopyrite was introduced along cross fractures (7).

The structural control of these deposits is not completely known. When the deposits are associated with folds, they are found on the limbs at some distance from the noses of the folds. At some deposits, shearing and jointing parallel to the sill contacts, and jointing perpendicular to them, seem to have exerted a control on the concentration of the sulphides (43, p. 11). Many of the deposits are near the lower contacts of the gabbro sills; a few are in the central portions or at the upper contacts.

The sulphides of the sediments near the gabbros are of distinctly finer grain, and contain little or no nickel. The presence of beds which have uniformly massive sulphides over great lengths suggests the possibility that the mineralization may have been caused by the mobilization of syngenetic iron and sulphur due to the heating effect of the gabbro sills. Insufficient work has been done on these deposits to support or weaken this theory.

Both the sediments and the gabbros of certain mineralized zones have low contents of zinc, lead, gold and silver, in addition to copper, and in the gabbros, nickel.

The St. Pierre Deposit has few characteristics in common with the deposits described above. It is not in the vicinity of a mineralized gabbro sill. No "leopard rock" sills were seen in the surrounding area. The host rock of the St.Pierre sulphides is a grey slate of a different appearance than the host rocks of the regional type-deposits. The ore minerals of the St. Pierre Prospect are similar to those of the other zones, but the relative proportions are uniquely different. At the St. Pierre Prospect, pyrite is the dominant mineral, and pyrrhotite forms an unimportant part of the sulphide body. High gold, silver, lead and zinc content further serves to segregate the St. Pierre Prospect. None of the regional type-deposits have the intensely silicified wall rock, associated with the St. Pierre sulphide body.

The comparison of paragenetic sequences suggests that the St. Pierre deposit and the regional type-deposits were formed by the same phases of mineralization, but that the environment at the St. Pierre Showing was favourable to the precipitation of relatively large quantities of pyrite, gold, argentiferous galena and sphalerite. The rocks of the regional type-deposits were more susceptible to mineralization during the phase of deposition of pyrrhotite. The nickel characteristically present in the mineralized gabbro is possibly a remobilized and reconcentrated constituent of the gabbro, which did not migrate far enough to form a detectable constituent of the St. Pierre sulphide body.

The St. Pierre Prospect and the Soucy Lake Showing

The Soucy Lake Showing of the Ungava Copper Corporation lies eight miles west of the St. Pierre Prospect. De Montigny studied the sulphides of this showing and those of some regional type-deposits. He concluded that the sulphides at the Soucy Lake showing were produced by the same processes which produced the regional type-deposits (32, p. 26). The Soucy Lake Showing has features which suggest that it belongs to a category intermediate between the St. Pierre Prospect and the regional type-deposit.

The main part of the Soucy Lake Showing is a lens of strongly disseminated sulphides, which occupies the axial zone of an overturned fold (32, p. 9). The lens is 1600 feet long and 66 feet wide, and contains at least two and one half million tons of ore with an average content of 1.59% of zinc, 1.12% of copper, 0.03 ounces per ton of gold, and 0.35 ounces per ton of silver. These percentages of metals are intermediate between those found at the St. Pierre Prospect and those of the regional type-deposits. The Soucy Lake sulphide body lies in black shale near a mineralized "leopard rock" sill.

De Montigny proposes a paragenesis of the Soucy Showing ore minerals which resembles closely that proposed for the St. Pierre sulphides. The correlation of the pyrites of the Soucy Showing with those of the St. Pierre Prospect has already been discussed (see "Ore Mineralogy - Pyrite"). In addition to having similar ore mineral assemblages, both deposits show textural evidences of a period of fracturing and vein formation subsequent to the deposition of the sphalerite, and prior to that of the chalcopyrite (32, pp.4, 21, 23, 24; see also, in this thesis, "Gangue Mineralogy - Quartz").

On the bases of structural, textural and mineralogic evidence, the writer supports the conclusion of de Montigny that all sulphide deposits in the sediments of the region have a genetic connection (32, p. 26). A wide range of structural controls and metal proportions is possible due to the presence of a variety of petrologic and structural environments of mineralization. The St. Pierre Prospect and the regional type-deposit are the extremes of this range. The Soucy Showing is an intermediate type. It is quite possible that the sulphide deposits within the gabbro sills will be found to be the products of the same metallogenetic epoch, with difference due to the chemical and physical properties of the original gabbro.

The St. Pierre Prospect and the Mount Isa Deposits of Australia

A striking parallelism exists between the geologic environment, structure, mineralogy and inferred history of the St. Pierre sulphide deposit, and those of the silver-lead-zinc deposits of the Mount Isa District, Queensland, Australia. The Mount Isa deposits havebeen exploited by underground mining, and intensively studied for some fifteen years. Before discussing the origin of the St. Pierre sulphide body, it is of value to review the data and interpretations accumulated during the mining of these similar deposits. The following descriptions and theories are taken from a detailed paper by Blanchard (29, pp.148-154), and from a brief account given by Bateman (35, pp.542-543).

The regional geologic setting of the Mt. Isa District is in a north-northwest-trending band of Precambrian rocks, 400 miles long and 30 to 125 miles wide. Steeply dipping beds of quartzite and shale are complexly folded and faulted. Granite intrusives are common in the region, but are not found closer than five miles from the mineralized zones.

In the vicinity of the deposits, evenly thin-bedded shales lie unconformably between thick-bedded quartzites. These shales are two miles thick, and their bedding strikes north-northwest, and dips 60^{o}SW.

The ore bodies are lenses in zones of shearing on the south limbs of both anticlines and synclines. The zones of shearing are believed to have been localized on the south limbs by thrust faulting from the southwest. Although shearing conforms closely to the bedding, the zones of shearing follow closely the dips of the axial planes of the folds, so that the ore bodies are not altogether concordant with the bedding.

The ore in the shear zones is fine-grained hypogene replacements by silver-lead-zinc sulphides, usually interbanded with, or replacing, fine-grained pyrite and pyrrhotite. Alternating bands of unreplaced shale seem to have the same chemical composition as the replaced beds. The average grade of the ore is 9.40% of zinc, 8.14% of lead, and 5.30 ounces per ton of silver. The ore minerals are galena, sphalerite, pyrite, marcasite, pyrrhotite, arsenopyrite, chalcopyrite, tetrahedrite and silver sulphides.

Wall rock alteration around the ore bodies is limited to weakly developed zones of penninite, sericite and dolomite. In close proximity to the ore bodies, are several intensely silicified masses of shale breccia. These masses are topographically impressive, but contain no ore.

The ore was emplaced as a result of three structural disturbances:

(a) Major Overthrust Movement. Folding, faulting and breccia zones were produced in the shales. The breccia zones were intensely silicified and pyritized.

(b) Crushing and Shearing Movement. This phase occurred during the late stages of the thrusting movement. Brecciation, carbonatization and pyritization of the mineralized zones took place. Late movements sheared the shales between the silicified breccia masses and the faults. Most of the fine-grained sulphides were deposited, first pyrite and pyrrhotite, then other sulphides. Small amounts of chalcopyrite were deposited in carbonate veins. Thrust faulting ceased.

(c) Cross Fracturing Movement. Cross fracturing movements caused crackling of the ore bodies. Vertical fractures at right angles to the ore bodies were produced and mineralized. These fractures were confined to zones of previous weakness. Quartz and calcite were injected into fractures which were reopened parallel to the ore bodies. Coarse galena, sphalerite and silver minerals were deposited. No faulting occurred after this phase of movement.

On the whole, the Mount Isa deposits are a large scale analogy of the St. Pierre sulphide body. Regional geology is the same in both places, and the structural controls of mineralization differ only in detail. The gabbro sills in the St. Pierre Area have no equivalents in the Mount Isa District, but their effect on structural movements may be said to approximate that of the competent quartzites near the Australian deposits. The wall rock alteration of the two deposits differs only in that the silicified breccia masses of the Mount Isa District are more divorced from the sulphide bodies than is the corresponding mass at the St. Pierre Prospect. It is in the textures and parageneses of the ore and gangue minerals that an even closer resemblance is found. Each deposit has early, fine-grained pyrite and pyrrhotite, supplemented by fine-grained base metal sulphides at Mount Isa, which were deposited during structural disturbances due to thrusting. These fine-grained minerals have been replaced by coarser galena, sphalerite and silver minerals deposited from solutions, some of which had been channeled through cross fractures. Chalcopyrite is associated with carbonate veins at both deposits. The presence of large quantities of gold in the St. Pierre sulphides is a deviation from the common pattern.

In summary, geologic conditions at the St. Pierre Prospect greatly resemble those at the sulphide deposits of the Mount Isa District, Queensland, Australia. Common geologic environment, analogous wall rock alteration, and similarities of ore mineral textures and parageneses strongly suggest that the deposits had similar histories of formation.

The Origin of the St. Pierre Sulphide Body

General Statement

The St. Pierre sulphide body was formed by a succession of phases of mineralization, each associated with a structural disturbance. The first period of mineralization occurred during the epoch of folding and thrust faulting which contorted the rocks of the area. Late spasms of movement caused reopening of fractures, and further metallization of the deposit. The final stage of mineralization was associated with cross fracturing which resulted from the relaxation of the compressive forces, or from a renewal of these forces in a later period. The stages of formation of the deposit are discussed in detail below.

Early Mineralization

During Late Precambrian time, the rocks of the Labrador Trough were complexly folded and thrust faulted by compressive forces which acted in an east-west direction. The folds of the St. Pierre area, and the reverse fault and schist zone which pass longitudinally through the centre of the claim group, were formed at this time. During late stages of the movement, silicification and pyritization occurred in the schist zone. The mineralizing solutions deposited minor amounts of quartz and pyrite at various places in the schist zone, but, as a whole, the environment was not favourable for replacement. At the northwest end of St. Pierre Lake, however, the schist zone intersects the northern limb of an anticlinal fold. Near the fault, beds in the nose of the fold had previously been brecciated during folding, and further fractured during faulting. This formed a highly permeable zone in the footwall of the reverse fault. Mineralizing solutions escaped from the confinement of the schist zone into the brecciated zone. The sudden decrease of temperature and pressure caused the precipitation of large quantities of silica, which filled fractures and replaced the deformed beds in the nose of the anticline. This produced a competent mass of quartz in an environment of easily deformed metasediments. Later movements along the reverse fault sheared the slate beds between the fault plane and the silicified mass. Solutions deposited pyrite in the sheared area.

The origin of the mineralizing solutions is not known. They may have been related to a late phase of the gabbro intrusion, but this seems unlikely, as the sulphide deposition was controlled by structural features which clearly post-date the gabbro. Dr. R. D. Macdonald notes that the St. Pierre Prospect is located only a few miles inside the eastern boundary of the Labrador Trough, and that the granitic intrusives found outside the Trough (and presumably beneath it) may have influenced the formation of the mineral deposits of thearea (42). Insufficient mapping has been done to ascertain whether any of the granites to the east are younger than the Trough sediments.

Intermediate Mineralization

The orogeny which reached its apex in the formation of the major folds and faults of the region did not cease abruptly. After the period of great deformation, intermittent pulses of movement caused minor adjustments in the rocks of the area. One or more such pulses caused brecciation of the pyrite lens of the St. Pierre area. This formed a permeable zone in which pyrrhotite was deposited. A second brecciation gave access to solutions which deposited a large quantity of sphalerite which actively replaced the pyrrhotite and pyrite. The examination of polished sections has shown that the pyrite-pyrrhotite-sphalerite mass was in turn brecciated, and veined by quartz and carbonate.

The association of pyrrhotite, pyrite and sphalerite is common in the mineralized zones of the region, although pyrite and sphalerite are usually present in only minor amounts. (7). The sphalerite is always black, indicating that it was deposited at high temperature.

Late Mineralization

The folds and thrust faults of the St. Pierre claim group are cut and displaced by a large number of cross faults. It may be that the piling-up of thrust slices and overturned folds during compression produced a complex that was not stable when the compressive forces died out. Adjustment by cross faulting may have resulted from such a situation. It is equally possible that a renewal of compression may have caused movements along previously existing weak zones due to compressional jointing. At any rate, the late period of metallization at the St. Pierre Prospect was related to cross fractures. All known occurrences of hydrothermal galena in the region are associated with quartz-carbonate veins in cross fractures (7; 2, p. 7). Slipp suggests that the chalcopyrite of the regional type-deposits was deposited in cross fractures (7). These generalities are supported by structural and textural evidence at the St. Pierre Showing. Galena and chalcopyrite, as well as occurring in the massive sulphide lens, are found in quartz-calcite veins which fill fractures at right angles to the strike of the local structures. The distribution of the ore minerals suggests that they were formed by deposition from solutions which spread into the massive sulphide zone from cross fractures. At least two minor cross fractures occur in the mineralized zone, and the configuration of the sulphide body suggests that it has been cut by at least three cross faults of minor displacement. Geologic mapping indicates that a major cross fault occurs 1500 feet northwest of the sulphide body.

In detail, the sequence of events of the late period of mineralization was as follows:

(a) Brecciation of the pyrite-pyrrhotite-sphalerite mass, with replacement and veining by chalcopyrite.

(b) Brecciation, with reopening of narrow fractures parallel to the sulphide mass near its northern margin. Deposition of argentiferous galena.

(c) Minor brecciation. Deposition of small quantities of pyrite, Formation of crustified quartz and calcite cavity fillings.

The presence of crustified veins and vugs indicates that at least the last mineralization took place at relatively low temperature.

As in the case of the earlier mineralization, the source of the metallizing solutions is not known.

SUMMARY AND CONCLUSIONS

Summary

The St. Pierre Prospect is located near the northeast margin of the Labrador Trough, forty-six miles west-northwest of Fort Chimo, New Quebec. Complexly folded and faulted Proterozoic metasediments and gabbroic sills underlie the map area.

The rock types exposed on the claim group are grey-green slates, tuffs, phyllites, and schists, iron-carbonate slate, green, magnetite-bearing slate, quartzite and uralitic metagabbro sills. Parts of sixteen separate gabbroic sills are exposed in the map area. Field observations indicate that the tops of the metasediments face toward the southwest.

The structures of these rocks conform closely to the regional structural pattern. The map area lies on the northeast limb of a northwest-trending major syncline. The general strike of the formations is northwest, and they dip 60° southwest. Within the claim group, there are two lesser orders of similarly oriented folds. These folds plunge at low angles toward the southeast. A northwest-trending, northeast dipping reverse fault and schist zone pass longitudinally through the centre of the claim group. A set of vertical cross faults displaces all other structures in the area.

Regional dynamothermal metamorphism has altered the rocks of the area to the biotite-chlorite subgrade of the greenschist facies of metamorphism. Induration due to silica metasomatism is present in the metasediments adjacent to certain of the gabbro sills.

Pleistocene continental glaciation left a mantle of boulder clay, which covers the majority of the area. The direction of the glacial movement was south-southwest to north-northeast.

Three hundred feet west of the northwestern end of St. Pierre Lake, a body of massive and disseminated sulphides is exposed on the north side of a small but prominent knoll. The major minerals of the deposit, in order of abundance, are pyrite, sphalerite, galena and chalcopyrite, The gangue minerals are quartz and calcite. The deposit is surrounded by an aureole of intensely to moderately altered wall rock. Although small, the deposit has a relatively high content of zinc, lead and copper, as well as substantial tenors of gold and silver. The nature of the sulphide body, its environment, and the percentage relationships of its metals are unique in the region.

The deposit consists of a number of disconnected lenses of massive and disseminated pyrite, with minor chalcopyrite. The largest of these lenses has been enriched by sphalerite, argentiferous galena, and gold. This lens is exposed at surface, and is the northwest extremity of the mineralized zone. Considered as a unit, the sulphide body strikes S70°E and plunges approximately twelve degrees southeast. The lenses dip seventy degrees northeast.

Textural relationships of the ore minerals show that arsenopyrite and pyrite were deposited during an early phase of mineralization. Pyrrhotite and sphalerite were introduced at a later stage. In the final phase of mineralization, chalcopyrite, galena, argentite and minor amounts of pyrite were deposited.

The sulphide body at the St. Pierre Prospect was localized in a favourable zone formed by the conjunction of an anticline and a reverse fault. A minor fold on the northeast limb of the anticline controlled the deposition of the pyrite body. Permeability by virtue of relatively large grain size caused the preferential mineralization of certain beds. Impermeable, fine-grained layers of a previously developed aureole of silicified wall rock may have limited the upward advance of the metallizing solutions. Subsequent movements formed cross faults, and opened fractures in and near the brittle quartz-pyrite mass, giving access to solutions which enriched the deposit with base metal sulphides.

Mineralogical and textural evidence indicates that the massive sulphide body was formed at 400°, under conditions of moderate to high pressure and unstable mechanical equilibrium. The deposit is classed as a meso- to hypothermal sulphide body, in which replacement and cavity filling have combined to deposit ore minerals of the pyrite-chalcopyrite-gold and sphalerite-galena-silver chemico-mineralogical associations.

The St. Pierre deposit is different in many ways from the other sulphide deposits of the region. Among its unique features are: high content of pyrite, sphalerite, galena, silver and gold; low proportion of pyrrhotite; intensely altered wall rock; control of deposition by folds; and lack of association with mineralized gabbro sills. Despite these differences, the study of mineral assemblages and parageneses, on a comparative basis, has indicated that the St. Pierre deposit was formed at the same time and by the same sequence of events as were the other deposits of the region.

Three stages of mineralization contributed to the formation of the St. Pierre deposit. An early phase of silicification and pyritization was associated with the culmination of orogenic activity in the region. Sphalerite-pyrrhotite mineralization occurred during the unsettled period following orogeny. A late phase of mineralization deposited chalcopyrite, galena and pyrite in openings caused by cross fracturing.

Unsolved Problems

Three major problems remain unsolved in the St. Pierre area. These are briefly stated below.

(a) The mode of occurrence of gold in the massive sulphide body, and the factors which control the erratic distribution of this metal, are not known. Selective sampling has shown that the richest concentrations of gold are found in the pyrite-chalcopyrite zone of massive sulphides.

The gold is not visible in polished sections, even under high powers of magnification. The amount of gold in the richest samples is well within the limit of the amount of gold which can be held in solid solution in the given amount of pyrite. Assays suggest that the gold has no genetic connection with the sphalerite or with the galena.

(b) It is not known what, if any, effect the intrusion of the gabbro sills of the area had on the emplacement of sulphide deposits. Sulphide minerals associated with gabbro sills, both in the St. Pierre area and elsewhere in the region, are always younger than the sill rocks. The sulphide deposit at the northwest end of St. Pierre Lake is localized in a schist zone and an anticline that were formed after the intrusion of the gabbro. This suggests that the sulphides were deposited after the intrusion. It is possible that some of the early sulphides at the St. Pierre showing have a genetic connection with the gabbro. Most field evidence, however, suggests that the gabbros had little or no influence on mineral deposition at the showing.

(c) The origin of the mineralizing solutions which produced the St. Pierre deposit is not known. As noted in the preceding section, it is unlikely that the intrusion of the gabbro sills had an effect on the production of the mineralized zone. No younger intrusives occur in the vicinity of the map area. A few miles to the east, outside the

Labrador Trough proper, granites intrude the gneisses of the basement complex. Insufficient work has been done in the area to establish whether any of the granites are younger than the Trough formations.

Conclusions and Suggestions

The most significant conclusions reached as a result of this study are that the St. Pierre deposit was formed by the same processes that formed the other sulphide deposits of the region, and that there is a strong possibility that similar high grade base metal deposits exist elsewhere in the region. Efforts to locate similar deposits should be concentrated in areas in which the structural conditions are analogous to those at the St. Pierre Prospect. In the terms of McKinstry, "intersecting loci" are the keys to the location of potentially mineralized zones (21, pp.210-212). In this case, the loci are northwest striking schist zones, cross faults, and brecciated zones such as the one in the nose of the anticline at the St. Pierre showing.

When examining areas in which two or three of these loci intersect, the search can be further limited to zones of metasediments which exhibit the effects of intense wall rock alteration. The mineralized zone at the St. Pierre showing outcrops on the side of a small but prominent knoll. The protrusion of this knoll above the surrounding low-lying metasediments is due to the high resistance to weathering of the intensely silicified wall rock to the footwall of the massive sulphide body.

The St. Pierre sulphide body itself is not of economic size, but its presence attests to the potentialities of the area as a mineral producing district. It is possible that further exploration will uncover similar deposits of larger proportions.

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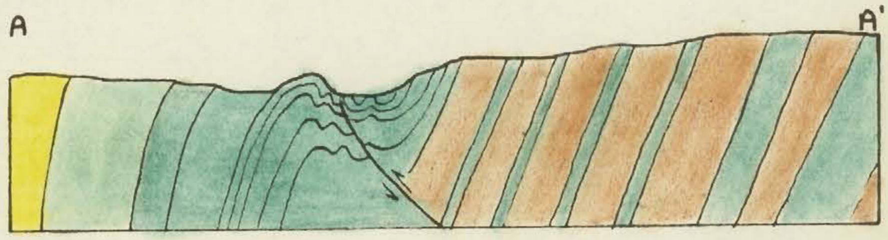
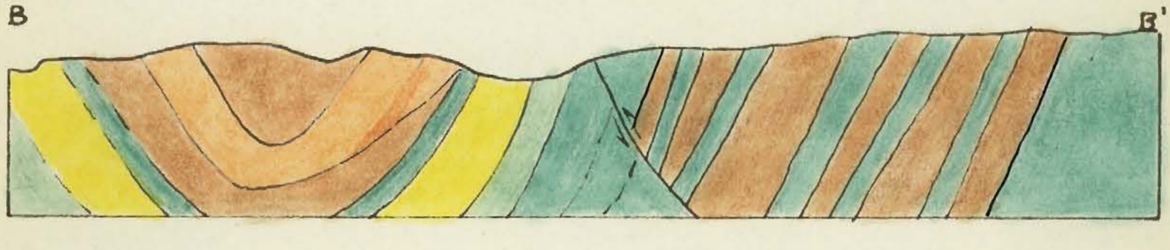
APPENDIX II

Geologic Sections Across the St. Pierre Claim Group

(For locations and legend, see Appendix I.)





APPENDIX I

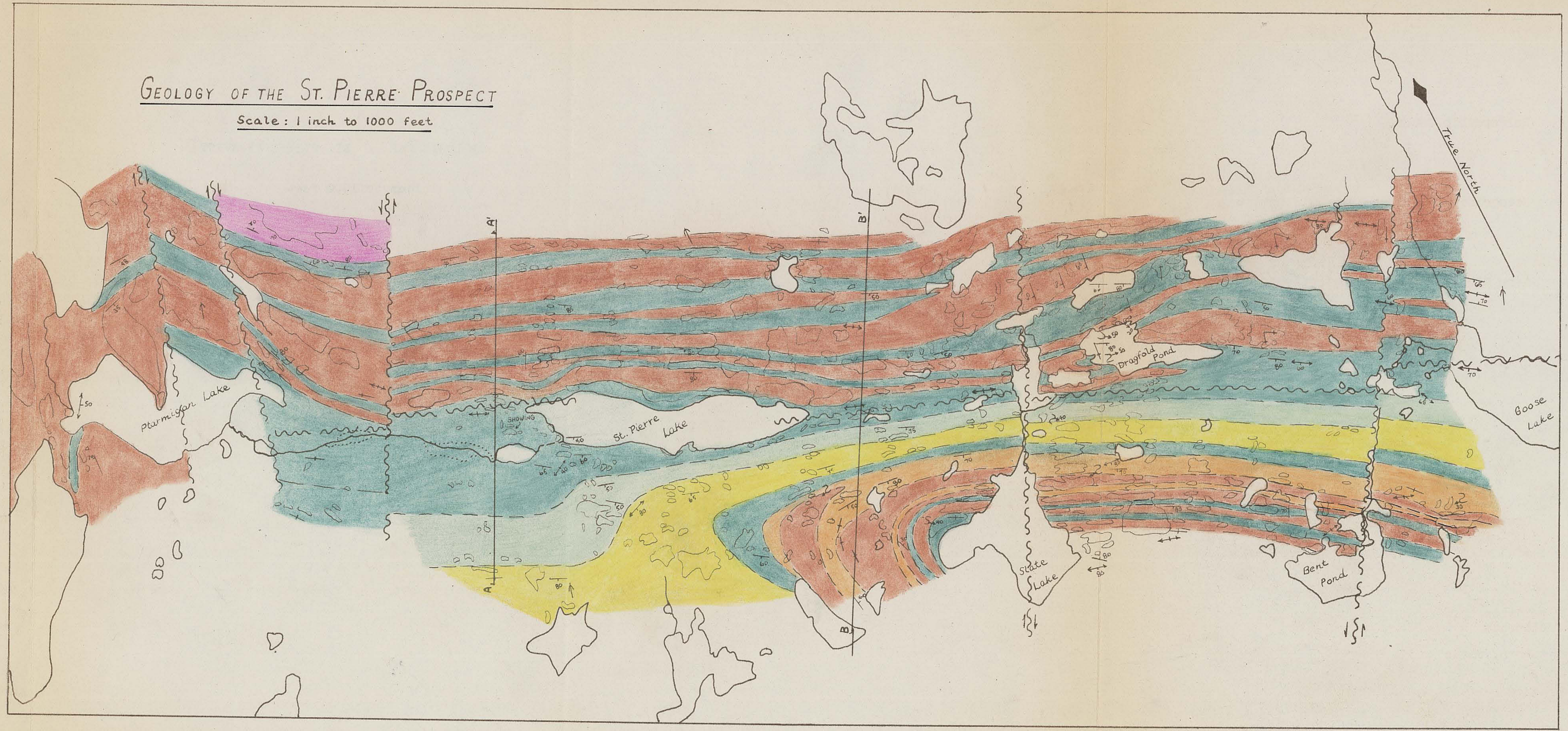
GEOLOGIC MAP / ST. PIERRE PROSPECT

1 inch to 1000 feet

LEGEND

- Feldspathic Gabbro
- Metagabbro, including Dioritic Gabbro
- Grey Slate, Phyllite, Schist, Tuff
- Green, Magnetite-bearing Slate
- Iron - carbonate Slate
- Quartzite

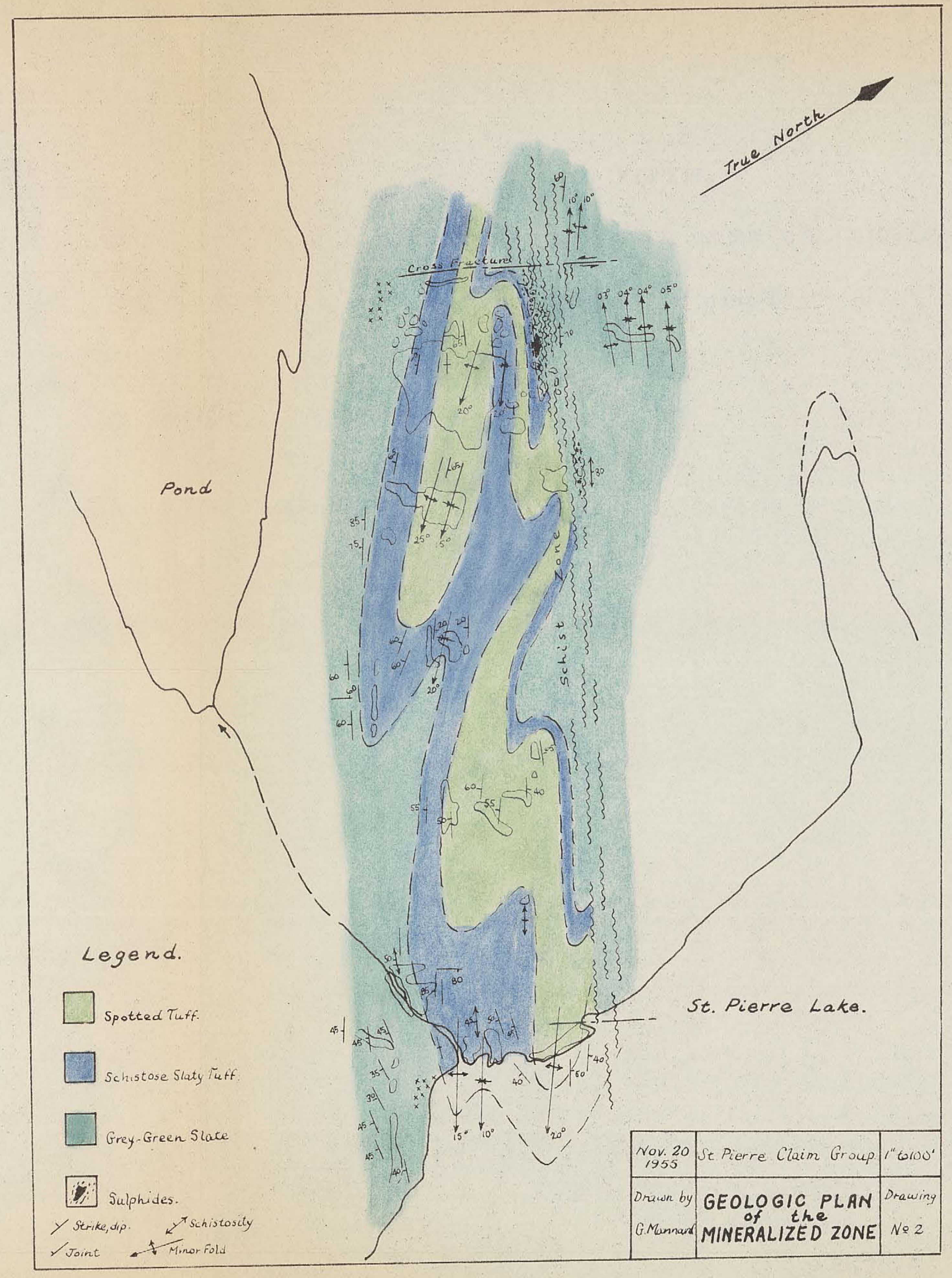
Strike, dip of bedding
Schistosity, cleavage
Joints, veins
Plunging dragfold
Outcrop
Fault
Formation boundary
Glacial grooves



APPENDIX III

GEOLOGIC MAP / THE ST. PIERRE MINERALIZED ZONE

1 inch to 100 feet


True North
Pond
Cross Fracture
Schist Zone
St. Pierre Lake.
Legend.
Spotted Tuff.
Schistose Slaty Tuff.
Grey-Green Slate
Sulphides.
Strike, dip.
Schistosity
Joint
Minor Fold
Nov. 20 1955
St. Pierre Claim Group
1" to 100'
Drawn by
G. Mannard
GEOLOGIC PLAN of the MINERALIZED ZONE
Drawing
No 2