A STUDY OF METAMORPHIC STRATA NEAR FORT CHIMO, NORTHERN QUEBEC.

by

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FRONTISPIECE

Looking north with Green Lake in foreground.

INTRODUCTION

General Statement

The material used in this paper was obtained while carrying out mapping for the Quebec Department of Mines during the summer of 1957.

The map area is underlain by gneisses and Labrador "Trough" type rocks. Included here is a brief outline of the general geology of the area with special petrological emphasis on the following five major rock types:

1) Amphibolite
2) Ultra-basic amphibolite
3) Impure dolomite limestone
4) Biotite-muscovite schist
5) Nodular sillimanite-biotite-muscovite schist

The detailed investigation on these rock types was carried out in the hope of establishing distinct metamorphic contacts in the "Trough" type rocks and the gneiss-granite-migmatite complex to the east.

The method of metamorphic facies classification was based essentially on Eskola's (1921) mineral classification. In addition partial X-Ray analyses were performed on garnets and biotites, attempts were made to correlate the concentration of iron, manganese, and calcium in the garnets and the iron, manganese, and titanium content in the biotites with the metamorphic grades established by the component minerals.

These latter analyses were also carried out in an attempt to confirm the validity of sillimanite as an index mineral of metamorphic grade.

Location

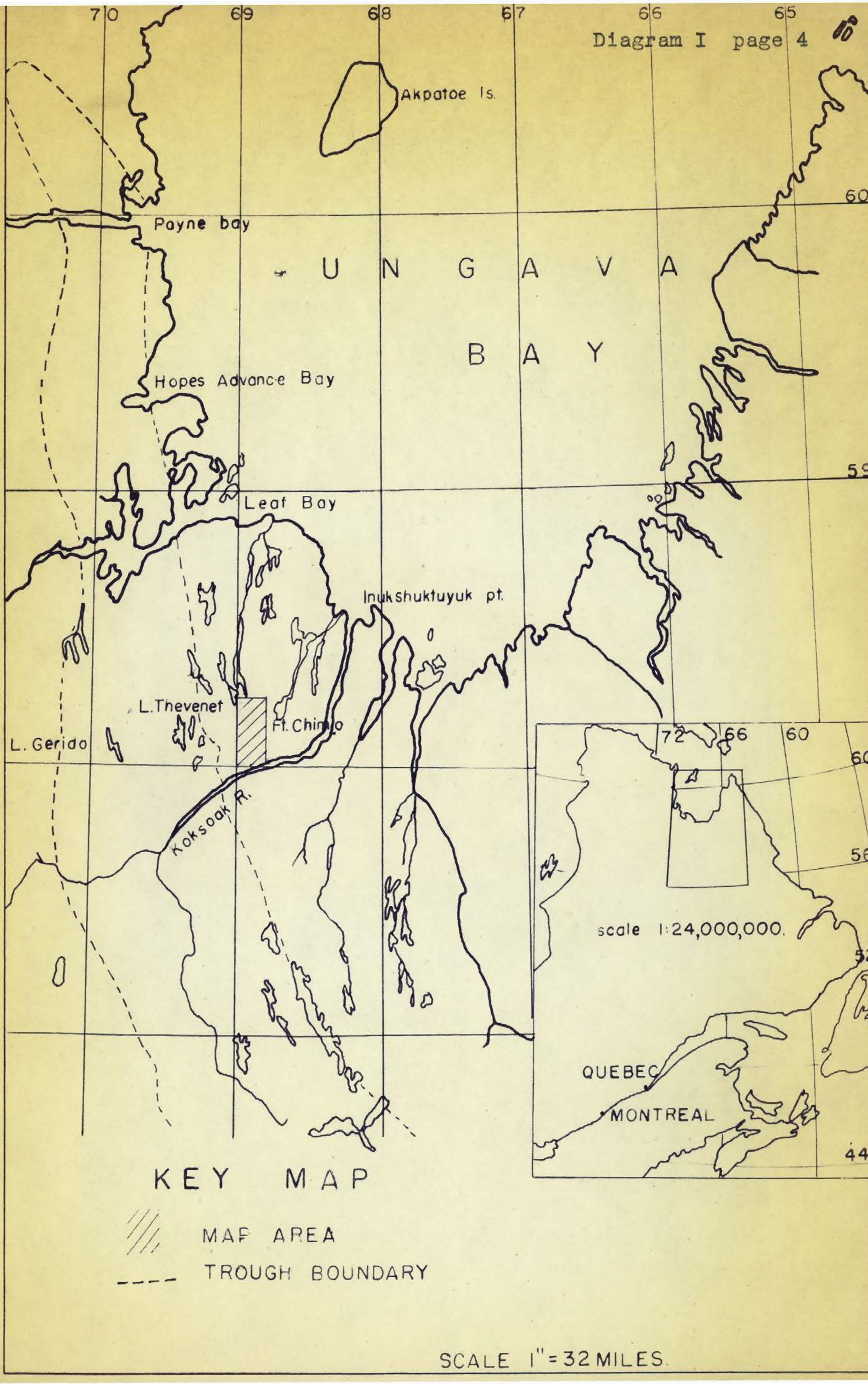
The West half of the Lake Gabriel sheet is bounded by latitudes 58°00' - 58°15' North and longitudes 68°45' - 69°00' West, enclosing an area of 160 square miles.

The Koksoak River occurs immediately to the South of the area; the South-east corner of the map quadrangle comes within 600 yards of the river, the South-west corner is situated upstream and three miles from the nearest point on the Koksoak River.

Fort Chimo, located on the Koksoak River about thirty miles upstream from Ungava Bay is in turn situated some twenty miles downstream from the nearest point on the Lake Gabriel West sheet. By direct route the distance from the centre of the map to Fort Chimo is 18 miles.

Accessibility and Communication

Fort Chimo is accessible by aircraft, or by boat during the short navigation season. Initially the map area was reached by canoeing up the partly frozen Koksoak River in the middle of June; two weeks later accessibility by light airplane equipped with floats was possible. Away from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TROUGH BOUNDARY
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the Koksoak River in the southern half of the map, paucity of large lakes and navigable rivers necessitated long portages. At this stage supplies were obtained from Fort Chimo by canoe.

In the northern half of the mapped area Lakes Fortin and Green are accessible to light aircraft so that communication is readily made with Fort Chimo 18 miles to the east.

PHYSIOGRAPHY

Topography

From the Koksoak River, whose high water level lies near the 50 foot contour, the land to the north rises quite steeply up to 750 feet; this abrupt change is expressed by conical hills which have a steep southern face.

Away from the Koksoak River the relief is less marked, resistant volcanics and gneisses afford the only variation to a gently undulating topography. They lend themselves to the formation of ridges ranging up to 350 feet above the surrounding land surface. These ridges and valleys roughly conform to the strike of the schistosity of the rocks. The low areas are underlain by the softer schists. However, there are exceptions to this; along the east bank of the Cailloux stream sillimanite and biotite schists are the underlying rock types of a ridge running parallel to the river.

Small local folds are well expressed topographically by the differential weathering of hard and soft rocks making it an easy matter to locate structure on aerial photographs.

Drainage

A highly irregular watershed passes approximately from east to west through the centre of the quadrangle. The irregularity is attributed to a deranged pattern produced by the glaciation. The southward flowing waters empty into the Koksoak River by way of the Cailloux tributary that passes through the centre and south east ninths of the sheet. To the north the land is drained by Lakes Diana and Gabriel which in turn discharge into Leaf Bay and Inukshuktuyuk Point respectively (Diagram I).

In the main belt of metamorphic strata comprising volcanics and schists, the cuesta topography produces longitudinal lakes having their long axes parallel to the strike of the valleys.

Glaciation

The main trend of gouge marks and striations is notth 165°, a second cross cutting set trending N 195°, were also locally developed making an angle of approximately 30° with the former. Its local development suggests a similar age for the two sets rather than two periods of glaciation.

Topography had a modifying influence on the ice sheet as demonstrated by local variations in direction of striae near prominent resistant beds.

The glaciation served to scour out the lake floor and polish the ridges; loose material being deposited along the valley floors.

The direction of movement of the ice appears to have been from the south-southeast as indicated by roches moutonnees and glacial trains, the large blocks of the latter feature are always found to the north-northwest of the recognizable outcrop. These observations are in agreement with those published by the Geological Survey of Canada (Wilson et al. Fig. 81, 1957).

Climate

During the summer months the day temperature rarely exceeds 70°F although a maximum temperature of 88°F was recorded during July. The 50°F isotherm of the noon temperature for the warmest month is located fifty miles to the north of the area. (Hare xvii, 1950), The mean daily temperature for January is -12°F (Hare, fig. 54, p. 81).

This area is well within the permafrost boundary line which passes some 200 miles to the south (Hare, fig. 75, p. 99).

Except for a light snowfall on the 19th August, all precipitation was in the form of rain. Most days a mist would start forming around 11 p.m. and persist until 9-10 a.m.

The mean annual precipitation at Fort Chimo is 14 inches, snowfall amounts to 50 inches (Hare, fig. 92, p. 158). The isohyets are very sinuous as precipitation is greatly influenced by the relief of the land.

FAUNA AND FLORA

FAUNA:

Birds

Although a variety of birds were seen, the quantity was not great, with the exception of White-crowned Sparrows (Zonotrichia leucophrys leucophrys) and the Ungava Willow Ptarmigan (Lagopus lagopus ungavus). These birds bred profusely; by the end of July most hatchings had taken place.

One male Hudsonina Spruce Grouse (Canachites canadensis canadensis) was identified in the forrested area along the Koksoak River.

No more than a dozen American Rough-legged Hawks (Buteo lagopus johannis) were seen throughout the summer, this scarcity is attributed to the acute shortage to almost total absence of lemmings.

The Canada Jay (Perisoreus canadensis canadensis) was a fairly frequent inhabitant of the wooded areas.

In the barren rocky areas, the Black-backed Robin (Turdus migratorius nigtideus) was a timid inhabitant.

The water birds do not appear to be very prolific breeders in this harsh climate. The common (Gravia immer immer) and Red Throated Loon (Gravia stellata) made their appearance in pairs.

Canada Geese (Branta canadensis interior) have a more gregarious nature, two flocks of ten and eight were seen.

In addition, a pair with five youngsters were seen along the Cailloux River.

A few occurrences of breeding Black Duck (Anas rubripes) were observed in the swampy areas.

One family of American Merganser (Mergus meganser americanus) comprising 10-15 birds were seen.

Spotted Sandpiper, (Actities macularia) and unidentified Gulls, were of fairly frequent occurrence along lake shores (Manning).

Mammals

Two Arctic Foxes were seen; fresh tracts of a Cariboo herd about 10-20 strong were observed, but none of these animals were seen.

Squirrels were scarce. The half dozen seen were confined to the wooded banks of the Koksoak River.

Lemmings (Dicrostonyx hudsonius) experienced a very lean year, two specimens were noticed throughout the summer, this is in complete contrast to 1955, when the camps were overrun with these rodents.

Muskrat were not infrequent inhabitants of most sizeable lakes.

Fishes

Two types of trout supplemented our diet during the summer, Brook Trout (Salvelinus fontinalis) were caught in the fast flowing streams, at lake overflows, and at the entry of tributaries into the Koksoak River. The largest specimen caught weighed three pounds and measured sixteen inches long.

Lake Trout (Cristivomer namaycush) were found in abundance in the larger lakes having an average weight of 5-6 pounds. The largest caught weighed 10 pounds and measured thirty inches. (M.J. Dunbar and H.H. Hildebrand, p. 94-96, 1951).

FLORA:

Trees

White Spruce (Picea glanca) and Black Spruce (Picea mariana) were the dominant trees along the river valleys and low-lying swamps, on the better drained slopes Tamaracks (Larix laricina) made their appearance in profusion.

Balsam Fir (Abies balsamea) was of rarer occurrence making its appearance at only a few localities.

A variety of populus was found in two or three areas, comprising very slender stems, and growing only to a height of ten feet in sheltered areas.

Moss, Lichen

Reindeer Moss (Cladonia rangiferina) and to a far lesser extent other mosses, lichen, and blueberries made up the entire vegetation in the hilly areas, and form a mat amongst the trees located around the river valleys.

As one goes northwards the trees decrease rapidly in stature and quantity; the limit of the tree line occurs fifty miles to the north.

MAPPING PROCEDURE

By means of half mile to the inch aerial photographs compiled by the Royal Canadian Air Force, traverses were systematically carried out at half mile intervals. Generally the lack of vegetation allowed one to inspect most outcrops within the half mile span covered by the two traverse lines. Where possible, the traverses were arranged to pass normal to the strike of the strata.

The photographs supplied a virtually monochromatic geological map as the outcrop was as much as 50 per cent of the total land area. This proved particularly useful in the solution of structural problems.

History and Previous Work

Dr. Mendry is believed to be the first white man whose travels in this part of Ungava have been recorded. Fort Chimo, thirty miles upstream from Ungava Bay, on the Koksoak River, was established by Mendry in 1827 as a trading post.

The first geological work in this district was carried out by A.P. Low of the Geological Survey of Canada (A.P. Low 1895, p.6.L). In 1893 from Lake Nichicum a portage route was followed to Lake Kaniapiskau, and the Koksoak River, which flows out of it, was descended to its mouth at Ungava Bay.

During the summer of 1896 a more comprehensive traverse was made across this area by Low (1896, p.1) from Richmond Gulf on the east coast of Hudson Bay to the mouth of the Koksoak River at Ungava Bay.

More recently, geological mapping has been carried out in this area by the Geological Survey of Canada, and Quebec Department of Mines. Further north, economic interest in iron has encouraged various companies to carry out prospecting and systematic mapping.

The Nickel Belt stretching from Cape Smith to Wakenham Bay aroused considerable economic interest during the summer of 1957, which prompted the Quebec Department of Mines to map the 350-mile belt (Bergeron, 1958).

REGIONAL FEATURES

Structure

The Labrador "Trough" is a belt of proterozoic rocks that is geographically continuous for 600 miles from the southwest corner of Labrador to a few miles north of Roberts Lake, where it tapers to nothing (Bergeron 1957, p.101).

The "Trough" is about 60 miles wide in the central part; across the 58° north latitude line, which bounds the southern extremity of the map area, it reaches an approximate width of 35 miles (Bergeron 1957, p. 101).

It has commonly been presupposed that the Proterozoic rocks of the "Trough" lie with great unconformity on Archean gneisses (Harrison 1952, p. 3). However, more recent field work has led Gill (de Römer 1956, p.15) to suggest that the so-called Labrador "Trough" represents a foothill zone of a truncated mountain built belt typified by the granite-migmatite-paragneiss complex to the east. The present "Trough" would correspond to the miogeosyncline and the "basement complex" to the east would represent the former eugeosyncline which was subjected to plutonic and volcanic activity, eventually reducing it to the plastic zone with granitization of the sediments taking place. The eugeosynclinal series was then folded and thrust up against the relatively stable sediments of the miogeosyncline, causing folding and overturning to the west in the present "Trough" area.

Slipp, working in the Gerido Lake area, came to conclusions which are in agreement with this speculation when he states "the layered rocks of the "Trough" and at least some of the paragneisses to the east are of one general age" (1957, p.15).

The fold axes in this area have a general south-easterly trend which is parallel to the "Trough"-complex contact (Bergeron 1955, p. 4; Sauve 1955, p.5; 1956 (a) p.6; 1956 (b) p. 6). This appears to support the idea that the movement was from the northeast.

The eastern margin of the "Trough" has been generally recognized as a fault contact along most of its length; the sediments at the contact dip eastwards under the complex (Auger 1954, p. 531).

Along the western border, the trough rocks lie unconformably on an erosion surface of the granitic basement with a gentle easterly dip, there is a stratigraphic thinning towards this margin suggestive of this being the marginal shoreline of the basin (Auger 1954, p. 531).

Geology

Eastwards the series becomes very thick by the addition of sediments and volcanics, and by the introduction of numerous intrusions.

In the Burnt Creek Area, latitude 55° north, the trough rocks underlie a belt about sixty miles wide from southwest to northeast. The southwestern thirty miles is composed mainly of sedimentary rocks referred to as the Kaniapiskau System. The northeastern thirty miles along this section line consists mainly of volcanic rocks, the Murdock and Doublet Groups. In addition there is the relatively narrow sedimentary member of the Howse Group (Harrison 1952, p.3-4).

Harrison hazards an estimate of 20,000 feet as being the total thickness of the Proterozoic succession in the Knob Lake area.

The stratigraphic succession between the Koksoak River and Leaf Bay is summarized by Bergeron (1957, p. 101) and is of more immediate concern to the map area.

TABLE I

KANIAPISKAU ?	Granite gneisses and paragneisses, Metagabbros
	INTRUSIVE CONTACT
KANIAPISKAU GROUP	Larch River sèries: sedimentary and volcanic rocks.
	ABNER dolomite
	CHIOAK formation: sandstones, conglomerates, shale.
	Disconformity
	Sokoman formation (iron formation)
	Quartzite locally overlain and/or underlain by siltstones, shale, phyllite, slate or schists.
	Unconformity
	Basal Granite-Gneiss Complex

(From Bergeron 1957, p.103)

As in the Knob Lake area, sediments predominate in the southwest part of the "Trough" and volcanics to the northeast.

Massive, white, pink, grey or brown quartzite is present almost everywhere at the contact between the rocks of the Kaniapiskau Group and the underlying granitic rocks.

South of Leaf Bay, the Sokoman Iron Formation rests on the quartzite, but north of the Bay micaceous schists immediately overlie the quartzite.

Volcanics are restricted to the eastern part of this section of the "Trough" being composed mainly of pillowed and massive meta-basalt, but include minor rhyolites (Fahrig 1955, p. 6).

Metamorphism

Generally the metamorphic grade of the "Trough" rocks is low, however, going northwards from Larch River to Payne Bay the metamorphism increases along strike, similarly, a traverse eastwards would reveal a higher metamorphic grade on approaching the folded and faulted east contact of the "Trough".

The northward change in metamorphic grade appears to be directly related to the width of the "Trough". Wherever the "Trough" is wide, the band of iron formation of the western boundary is relatively free of high metamorphism. As the "Trough" narrows to the north, the metamorphism becomes progressively higher (Auger 1954, p. 532). This can probably be attributed to the lessening distance of the gabbro sills from the iron formation as one goes north.

Thermal energy from intrusions and dynamic metamorphism produced this effect as these sources of energy were confined to the folded and faulted eastern contact, where the metamorphism is highest.

The low grade of metamorphism in certain strongly deformed iron formations led Slipp (1957, p. 22) to suggest that pressure and movement alone were not able to produce higher grades of metamorphism. The main factor may have been the greater depth of burial towards the east, raising the isogeotherms in that part of the "Trough".

Relation of Map Area to the Labrador "Trough"

The map area lies seven to eight miles east of the recognized contact of the Labrador "Trough" and "basement complex" (diagram I) which was mapped in the Renia Lake Area by de Römer (1956), and postulated, on the basis of unconformable structure pattern and abrupt change of metamorphism, to be a fault contact.

Through the centre of the map area, trending northwest, occurs a belt averaging three and a half miles in width, made up of volcanics, intrusives and metasediments having a lithologic similarity to "Trough" rocks. It is suggested here that these rocks do in fact represent deposition of similar age as those rocks of the Labrador "Trough". Gill's idea (de Römer 1956, p. 15) that the "Trough" represents a foothill zone of a truncated mountain built belt fits the observed geology of the area very well.

The status of the intervening pink and grey gneiss, between the "Trough" rocks and the belt of volcanics and metasediments of the map area is not fully understood. Possibly this represents a granitized portion of the former marginal area between the downfolded eugeosyncline deposit and that of the miogeosyncline; the latter is equivalent to the present Labrador "Trough". The "Trough" type rocks of the map area would in turn be the marginal rocks of the eugeosyncline that have not been depressed into the granitizing zone and hence have retained their identity as meta-strata. This hypothesis is further supported by the recurrence of narrow stringers of iron formation and quartzite bands in the grey gneiss to the east of the "Trough" type rocks. Essentially, this grey gneiss to the east would represent a granitized sediment of the same depositional sequence as the meta-sediments in the "Trough" type rocks to the west.

De Römer's conclusion was: "some of the gneisses are essentially of the same material as the "Trough" strata". (1956, p. 14).

GEOLOGY OF THE MAP AREA

General

All the consolidated rocks of the area are of Precambrian age.

The northeastern part of the area is underlain by grey gneiss with many narrow amphibolite bands interspersed throughout the entire length parallel to the gneissic banding.

In the southwest section of the map pink and grey gneisses are found with a narrow band of biotite-muscovite schist traversing it.

Lying between these two major rock types occurs a spindle shaped belt with a northwest trend, narrow in the south, widening out northwards with a maximum width of four miles near the centre. This belt is comprised of "Trough" type volcanics, intrusives and meta-sediments, Varieties of schists make up the main rock types of this sector; in order of importance they are biotite-muscovite schist with or without garnet, sillimanite-biotite-muscovite schist, and diopside biotite schist. Quartzose gneiss, impure dolomitic marble and calc-silica rock constitute the other lithological units of this belt.

Narrow amphibolite bands are a component rock of the two gneissic belts as well as in the schistose sector where a wider range of thickness is found.

Several dikes of pegmatite cut this complex.

Table II includes the formations found in the map area.

TABLE II

Pleistocene and Recent	Sand, gravel, erratic boulders, and clay.	
	Great unconformity.	
	Pegmatite	
	Amphibolite	Blotchy amphibolite, ultrabasic amphibolite, amphibolite with or without garnet.
PRECAMBRIAN	SCHIST and GNEISS	Quartz-feldspathic gneiss (grey gneiss). Quartzose-gneiss, quartzite, iron formation, biotite-diopside schist, calc-silica rock, impure dolomitic marble, nodular sillimanite biotite-muscovite schist, with or without garnet.
	Major Unconformity ? ? ? ? ?	
	GNEISS	Pink and grey gneiss.

No attempt has been made to correlate rocks of the map area with established formations due to the unfamiliar status of the "Trough" type rocks in this area.

Brief Description of the Rock Types

As the amphibolites, muscovite-biotite-schists, nodular sillimanite schists, and dolomitic marbles are being discussed in detail they shall be omitted in this brief description of the remaining major rock types.

Pink and Grey Gneiss

These pink and grey gneisses outcrop in the southwestern part of the area, occurring in alternating layers twenty to forty feet wide.

Pink Gneiss often consists of alternating pink and grey layers about 1 inch thick. The pink layers have a higher percentage of microcline and a lower percentage of biotite than the grey layers.

Grey Gneiss composed mainly of quartz, plagioclase, and minor biotite, is a medium to coarse grained rock. The gneissic banding is introduced by concentration of biotite into layers.

Accessory minerals include hornblende, apatite, zircon and sphene. Muscovite is usually present.

Boudinage structure was observed in a few localities in the gneiss, quartz was filling in the fractures that developed at right angles to the gneissic banding.

Often the gneissosity is only partly developed and the rock tends to become massive. Gradations between pink and grey gneiss are the more usual characteristic.

Quartzose Gneiss (type 8 on map).

This is the gneiss that is developed within the "Trough" type belt of the map area. It is a continuous formation from north to south, the width conforming to the boundaries of the schistose belt, having a maximum width of two miles in the area immediately to the east of Lake Fortin.

The rock is characterized by an abundance of quartz, irregular grain size, and foliation.

This gneiss is medium to coarse grained. Heterogeneity of grain size is a striking megascopic characteristic, particularly noticeable on weathered surfaces. Grains of quartz and feldspar often vary from 1/16 - 1/4 inch in diameter. This weathering texture is emphasized all the more when calcite is present locally and weathers out leaving the more resistant bands to stand out in sharp relief.

Foliation lenses of biotite are a common characteristic of this rock, these lenses range in size from 10"-2" inches, an average size being 4 inches. They exhibit sharp boundaries with the host rock; usually they are composed entirely of fine grained biotite, however, laminations are sometimes observed within these lenses in which case plagioclase and quartz are identifiable megascopically.

This texture of the quartzose gneiss is by no means uniform, this rock grades into biotite-muscovite schist with or without sillimanite or else into an impure quartzite. Northeast of Lake Fortin, this gneiss has a high percentage of calcite, diopside and actinolite.

Little doubt can be thrown on a sedimentary origin for this rock type:

1) Heterogeneity of grain size.

2) Gradational contacts with schists.

3) Wide variation of constituent minerals.

All support this theory.

Initially, this formation was probably laid down as an arenaceous sediment.

Grey Gneiss (type 5)

This is the rock that forms the so-called "basement complex".

It is a quartzose-feldspathic gneiss and has a medium to coarse grained texture. On a weathered surface the gneissosity is emphasized by differential weathering of the layers whose average width is 2 inches, the less resistant layers are composed of biotite and muscovite. The remainder of the matrix comprises quartz, plagioclase, and minor microcline. Lentils of gneiss ranging up to hundreds of feet in length occur carrying the calc-silica minerals, diopside, calcite and actinolite. These are found to the southwest of Lake Raphael.

Locally, the gneiss grades into an augen gneiss, particularly in the northeast corner of the map area. The augen average 1 inch in diameter and consist of lenticular aggregates of feldspar crystals enclosed in a grey gneiss matrix.

The occurrence in this gneiss of very persistent iron formations and a quartzite band two miles to the south of Lake Hay suggests a sedimentary origin for this quartzose-feldspathic gneiss. Added support is given by the local occurrence of lentils rich in calc-silica minerals.

Pegmatites

Towards the northeast corner of the map area there is a distinct concentration of pegmatites, although they are a fairly common feature throughout the area.

These bodies appear to be structurally controlled as in most cases they align themselves parallel or slightly transgressive to the gneissic banding of the host rock. In addition they occupy structural weaknesses in folds and fill small fault zones, an excellent example of the latter type of deposit is found near the southern extremity of the map sheet where a pegmatite of great dimension insinuates itself along one of these zones. Examples of pegmatites normal to the banding are to be found, but these are more the exception.

A striking feature of the pegmatites is the colour variations in different host rocks; those outcropping in the gneisses carrying potash feldspar are noticeably pink, whereas white distinguishes those outcropping in the schists. This colour variation corresponds to a higher potash feldspar content, if this mineral is present in the host rock the pegmatite will be pink. This dependency of the composition of the pegmatite on the host rock is suggestive of the secretionary type pegmatite (Ramberg 1952, p.92) where the pegmatites derive their material by ionic migration from the host rock.

A few narrow pegmatites ranging from 2-4 inches displayed zoning, the white margin comprises feldspar and quartz and the pink centre microcline and minor quartz.

Pleistocene

Ridges have been scoured so that they are bare, however, the valleys are often covered with a thick mantle of drift. In addition, over the southern and northeastern parts of the area a blanket of glacial sand gravel occurs.

Boulder trains are of frequent occurrence west of Lake Turcotte and not far removed from their source, they rest on a thin glacial mantle.

Structure

Schistosity, Gneissosity, Foliation and Lineations

Where observable, schistosity, lineations and gneissosity are parallel to the original bedding and serve as the outline for structural interpretation. The lineation of the Gabriel Lake Area has a southeast trend with a plunge varying between 25-30 degrees and is caused by alignment of minerals along the gneissic planes.

Folds

The main folded feature occurs in the pink and grey gneiss to the southwest; here we have a doubly plunging, canoe shaped anticline, the southeast nose is located in the map area and plunges 30 degrees to the southeast, the nose to the northeast is located on the adjoining Thevenet Lake area (East Half) and plunges in the same direction (Gelinas 1958).

Along the southern limb of the anticline the dip of the gneissosity varies greatly from 80° southwest to 34° northeast, this could possibly be accounted for by minor drag folds. The north limb has a more constant dip of 37°-65° northeast.

South of the schistose band passing through this rock type the structure cannot be interpreted with any certainty.

In the vicinity of Lake Hay two synclines and two anticlines plunge at angles ranging from 15°-25° east. Towards the east they become constricted into tight folds.

The schistose belt could possibly be interpreted as homocline, as there appears to be a duplication of dolomitic, and possibly amphibolite, strata.

Faults

Obvious faulting is not prevalent in the map area, however, bedding faults could quite conceivably be present but not recognizable in the schistose rocks. A few minor oblique faults with strike slip displacements up to 600 feet occur in a few places.

East of Green Lake an oblique fault traceable for six miles with a strike of east-southeast is readily observable. Topographically this is marked by a trough-like depression 20-30 feet wide, averaging 10-20 feet in depth. A half mile from the western extremity it bifurcates, the arms having little displacement. The maximum strike slip is 2,000 feet. A diagnosis of the direction of movement could not be established as no beds have a cross cutting relationship to one another and striations on the fault walls were not observed. Drag folding was noticed near the fault.

Contact of "Trough" type rocks and gneisses

The contact of the schistose rocks with the pink and grey gneiss to the southwest is very limited as the pleistocene gravels cover up the contact to the southeast; however, the part exposed is quite conformable to one another with a sharp contact. This contact is topographically featureless.

The contact of the schistose rocks with the grey gneiss (quartzo-feldspathic gneiss) to the northeast is also one of conformability, the dips steepen to 75-80° and dip northeast.

The contact is exceedingly sharp, in places it is possible to pin-point it.

From the north end of Lake Turcotte southwards this contact is marked by a westward facing escarpment locally rising to 150 feet above the adjacent schistose rocks to the west. North of this point this contact is not expressed topographically by any undulation but is in complete continuity with the adjacent rocks.

Whether or not this should be interpreted as a bedding fault cannot be ascertained in this map area, as neither a structural unconformity or metamorphic discontinuity is suggestive of such a postulation.

PETROLOGY

Methods Used

Refractive indices

For all refractive index determinations a flat microscope stage was used. Specimens were finely ground and the relevant cleavage flakes selected for observation. In the case of dolomite, biotite, hornblende, tremolite and diopside, sodium light was used.

With the determinations on plagioclases Tsuboi's single variation method was used (1934, p. 325). Here Nx is determined on 001 cleavage flakes with the aid of a monochrometer.

A liquid is chosen near the refractive index of the fast ray of the plagioclase flake, the velocity index of the mineral is then matched with the immersing liquid at a certain wave length of light. The remaining requirement for the composition determination is to establish the dispersion (N_f - N_c) for the liquid. This was done on a Spencer Refractometer. The final step is to relate the observations to Tsubois' curve (loc.cit.).

The method used proved fast and checked well with other plagioclase curves relating refractive index and composition (Tsuboi 1923, p. 108). Only three different oils were needed to span the various compositional differences of the plagioclases.

In the case of garnet, accuracy was needed to the third decimal place as an attempt was made to correlate certain elements in the garnet with its refractive index. This accuracy was obtained by the Minimum Deviation Method. Here a single circle Goniometer (Berlin-Staglitz) was used to establish the dispersion curve for the liquid at various wave lengths of light.

Using a hollow prism with the required liquid filling the centre, D (angle of deviation) and P (prism angle) were measured and the index 'n' was calculated from the following formula:

$$n = \frac{\sin \frac{1}{2} (D + P)}{\sin \frac{1}{2} P}$$

Once the dispersion curve of the liquid had been established, the garnet specimens were matched with the same liquid at a certain wave length of light, and the refractive index read directly off the graph.

Modal Analyses

The modal analyses were carried out using a Bauch and Lomb rock section projector. This instrument has a set of nicols, hence with the projected image it is possible to identify the minerals.

The image was projected on to graph paper, a section line chosen, and the squares of intersection totaled up.

A minimum run of 2 cm. was carried out. In the case of schistose rocks section lines were selected at rightangles to the linear alignment of minerals.

AMPHIBOLITES

Definition. As used here, an amphibolite signifies a metamorphic rock of granulose texture consisting essentially of amphibole and plagioclase, and often containing quartz, epidote, or garnet (Holmes).

Field Relationships

The broadest zone passes through the centre of the map area with a northwesterly strike which, locally, is gently flexured. In all cases contacts with surrounding biotite-muscovite schists is conformable.

The maximum continuous width attained by the amphibolite is 1,200 yards, however, the main zone of alternating schists and amphibolite stretches over two miles. This belt gives rise to cuesta type topography with the more resistant amphibolites standing out as ridges rising 400-500 feet above the surrounding lowlands. The valleys are usually underlain by easily weathering acid schists.

In addition, amphibolites make their appearance as narrow stringers and dikelets; they are particularly prevalent in the gneisses to the west and east of the "Trough" type rocks. The contact of amphibolites with the gneisses is conformable to the banding in the host rock with a few minor exceptions.

Generally these narrow amphibolite bodies reach a maximum length of 2.5 miles and a width of 250 yards. However, numerous small lenticular bodies are of frequent occurrence. Usually they are less resistant to weathering than the surrounding gneisses and so lend relief to the topography by becoming gently depressed zones.

Megascopic Description

Generally a threefold classification can be applied to the amphibolites:

a) Massive

b) Sheared

c) Narrow intrusives

a) Massive amphibolite

This is a fairly massive type, with the intense shearing present in type (b) of less frequent occurrence. However, a cleavage is nevertheless present, but does not dominate the megascopic appearance. This rock is characterized by a perfect internal layering; alternating layers of thin light and dark bands, half an inch thick, result from a variation in the percentage of hornblende.

The rock weathers a blackish green. On a fresh surface it is dark green and fine grained, with a faint trace of preferred orientation indicated by the hornblende needles.

In the matrix light minerals are absent to rare; plagioclase and a grain or two of quartz are present locally. Occasional quartz stringers sometimes traverse the rock parallel to the cleavage.

b) Sheared amphibolite

Shearing as well as slight mineral heterogeneity distinguishes it from the massive type. The shearing has produced a marked fissility reducing the weathered rock to thinly cleaved "plates". (plate II A and B) This "platyness" is attributed to cleavage, as the rock is relatively homogeneous and where heterogeneity exists there is not a preferred parting plane. The hornblende needles show a rough orientation of their long axes parallel to the cleavage but no preferred lineation on these surfaces. This type of cleavage would correspond to fracture cleavage as defined by Nevin (1953, p. 151) which is caused by shearing.

Plagioclase and quartz is a more frequent component than in the massive type, making up to 45 per cent of the rock.

In only one locality (F.A.8) was garnet found outside of the narrow intrusive type amphibolite. Here the host rock was of the sheared type. The garnets were confined to certain layers only; these layers are up to ½ inch thick and are identified by a zone of prismatic crystals of hornblende up to ¼ inch long. The groundmass of the rest

A.

Sheared type of amphibolite in southern part of map area, west of Cailloux River.

B.

Sheared type of amphibolite east of Green Lake.

of the rock is composed of fine hornblende needles, barely discernible to the naked eye. The selective distribution of garnet suggests that it is not necessarily in equilibrium with the host rock.

c) Narrow Intrusive Amphibolite

Unlike the amphibolites of the former two types, these, when occurring in the gneisses and sillimanite schist, are characterized by garnet porphyroblasts. North of Lake Fortin these porphyroblasts reach a diameter of two inches. The great concentration of garnets gives the rock a "knotty" appearance on a weathered surface. More generally, the porphyroblasts are 1/8 inch in diameter, making up about 5-10 per cent of the rock. The bulk composition is similar to the former amphibolites, except for the occurrence of garnets.

Origin of Amphibolites

The origin of the rock poses a problem as to whether it is of intrusive or extrusive nature. The possibility of the rock being a metasediment can be reasonably ruled out, as the bulk composition and homogeneity of grain size is suggestive of an igneous rock.

On strike of the main amphibolite belt in the adjoining map area highly stretched pillow lavas were observed (plate IIIA).

The excessive deformity that they have undergone did not allow top determination to be made with any degree of certainty.

Another feature observed but of obscure origin were homogeneous unsheared lenses of amphibolite, set in a sheared amphibolite (plate IIIB). This form was seen only in a few localities immediately northeast of Green Lake, being confined to a narrow zone. This "boudinage" could arise in a number of ways. Chilled layers at the top or bottom of a lava flow or a post deformation dike could offer more resistance than the surrounding rocks and so differentially deform to give rise to this stretched "boudinage" set in the sheared amphibolite.

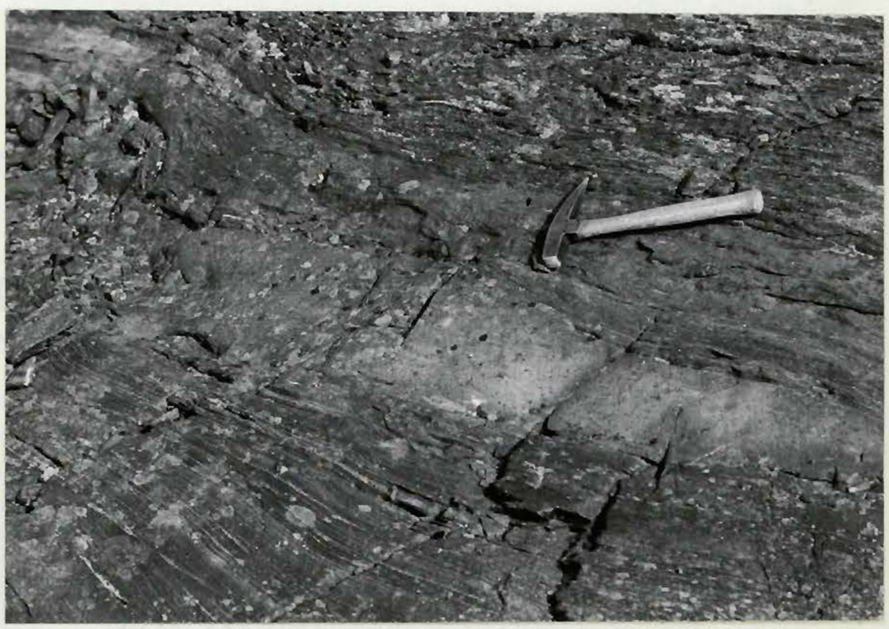
That intrusion took place, cannot be doubted, as is recorded by the smaller, coarser grained bodies.

The contacts of the amphibolites of the main zone with the surrounding schists, where noted, were always conformable to the schistosity of the surrounding acid rocks.

It is concluded that the origin is predominantly volcanic with minor intrusions.

A.

Stretched pillow lavas west of map area.



B.

Stretched "boudinage" of amphibolite set in rock of similar composition.

Petrology

Petrologically the three subdivisions can be incorporated together as essentially the mineralogy is constant. Subdivision was made more on a megascopic and field observation.

Hornblende makes up the greatest percentage of the rock, with quartz and plagioclase filling interstices, veinlets, and small foliation lenses (Plate IVA).

Pennine Clinochlore and dolomite are frequently found in small amounts, biotite and epidote are of rarer occurrence, garnet appears only in the narrow intrusive type amphibolite where it is found in profusion.

Zircon, sphene, apatite, magnetite and pyrite make up the accessory minerals.

TABLE III.

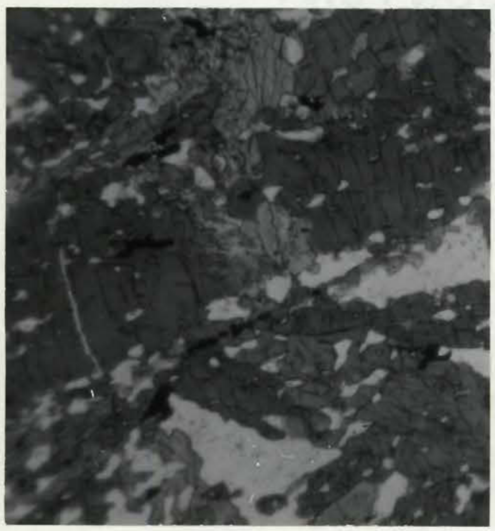
MODAL ANALYSES OF AMPHIBOLITE SUITE

SPECIMEN	HORNBLENDE	QUARTZ	PLAGIOCLASE	CHLORITE	BIOTITE	ACCESSORIES
F.A.4	67.8	32.2				
F.A.8	95.0	1.6	1.9			1.5
F.A.9	60.6	35.0	4.4			
F.A.10	76.8	23.2				
F.A.11	54.6	27.5			17.9	
F.A.12	48.1	45.4	5.2			1.3
F.A.13	93.3	6.7				
F.A.13(a)	90.4	2.1	7.4			
F.A.14	95.5	4.3	0.2			

AMPHIBOLITE

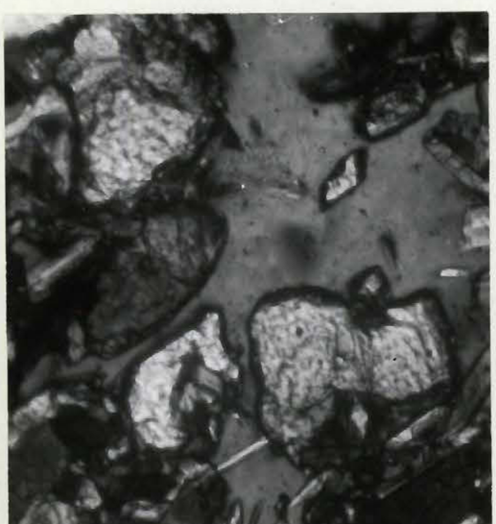
A. Hornblende crystals with plagioclase and quartz making up the matrix.
Crossed nicols x 50

A



B. Hornblende showing poecilo-blastic habit, inclusions made up of quartz.
Crossed nicols x 50

B



C. Epidote associated with plagioclase and quartz.
Crossed nicols x 225

C

Hornblende

Texture ranges from decussate to schistose. Hornblende crystals usually are prismatic and vary in grain size; this is often the criterion for distinguishing banding.

Characteristically, this hornblende is poeciloblastic, the inclusions are usually concentrated towards the centre; in order of importance they are quartz, which occurs as small round blebs, dolomite, epidote, and zircon. The latter mineral often gives rise to pleochroic haloes within the hornblende (Plate IVB).

Rock slide F.A.14 revealed two modes of occurrence of the hornblende. Primarily there is a faint parallelism of hornblende flakes, and within this structure occur aggregates of hornblende needles with heterogeneous orientation forming "eyes". These augen are surrounded by a rim of fine grained quartz. In addition, the crystals within the "eyes" are more prismatic, the eyes have an almond shape with the long axis parallel to the schistosity.

Felted clinochlore is often in close association with the hornblende, suggesting a breakdown of the latter mineral to give rise to the chlorite member. Clinochlore also occurs within the boundary of the hornblende crystal, but is more often found along the margin of the crystal.

The refractive indices as determined on 010 cleavage flakes of the hornblende for the Nx ray are:

TABLE IV

F.A.4	1.646	F.A.9	1.655	F.A.12	1.655
F.A.6	1.643	F.A.10	1.661	F.A.13	1.661
F.A.8	1.662	F.A.11	1.656	F.A.13(a)	1.649
				F.A.14	1.654

Twice the optic angle (2v) ranged from 78° to 86° (optically-) with an average 2v = 83° which corresponds to Winchell's classification of common hornblende (Winchell 1951, p. 431).

Plagioclase

The maximum mineralogical concentration of plagioclase in the amphibolite suite is 7.5 per cent. However, it is present in all the specimens, sometimes only a trace occurring.

Commonest form is that of small grains filling the interstices between the hornblende crystals, often the plagioclase is intermixed with quartz. Occasionally, this mineral occupies narrow veinlets in the amphibolite, which are composed of quartz and plagioclase aggregates.

More usually, the grains of plagioclase are untwinned, or weakly so, however, it is not uncommon to find albite twinning and untwinned plagioclase in the same slide. Inclusions of sericite, when present, form a cloudy mixture concentrated towards the centre of the grain.

The composition of the plagioclases in this suite of rocks varies from An_{25}-An_{44} as can be seen from table V.

TABLE V

F.A.6	F.A.7	F.A.9	F.A.10	F.A.11	F.A.12	F.A.13A	F.A.14
An42	An35	An34	An43	An44	An33	An25	An36

(based on Tsuboi's curves, 1934, p.325)

Quartz

This mineral occurs in all amphibolite specimens ranging from 45.4 to 1.6 per cent (see Table III). Its form is usually granulose and equigranular, occupying interstitial spaces and veinlets that infrequently traverse the rock. Often rounded blebs of quartz make up the poeciloblastic inclusions in the hornblende.

Quartz grains are free from inclusions; sometimes strain shadows are apparent.

Dolomite

Finely disseminated grains and porphyroblasts of dolomite are found, the former occurrence is the more common. Usually dolomite is found in areas interstitial to the hornblende, but also occurs as inclusions in the latter mineral.

Chlorites

Clinochlore is commonest member of the chlorite group, pennine was identified in rock slide F.A.10.

Clinochlore occurs as platy crystals and felted aggregates which are often bent; maximum angle of bending was 46^{o}.

Usually a zone of chlorite traverses the rock parallel to the schistosity, flakes bend around any obstruction in this plane, however, isolated occurrences of this mineral are not uncommon.

Pleochroism of clinochlore is quite marked

Nx pale green

Nz colourless

$2v = 0^{o}$

Polysynthetic twinning is occasionally developed on the 010 face.

The intimate association of the hornblende and the chlorites suggests a breaking down of the hornblende. This relationship is seen as replacement taking place on extension of a hornblende crystal and often grading imperceptibly into it. Needle-like relics of hornblende enclosed in a clinochlore matrix are a common feature. This replacement process can also be seen taking place within the boundage of a hornblende porphyroblast.

One appearance of pennine is found. The anomalous "berlin" blue birefringence distinguishes it from clinochlore. The same replacement texture as the other chlorite member held towards hornblende exists here.

<u>Epidote</u>

Epidote occurs as fine grains scattered sparingly through the rock suite. Usual association is with plagioclase. However, it also makes its appearance as inclusions in the hornblende (Plate IVC).

<u>Biotite</u>

The occurrence of biotite is limited. A few flakes occur associated with clinochlore.

In rock section G.75 which belongs to the narrow intrusive amphibolite type, the biotite is present throughout the rock as small flakes. Characteristic feature is alternating brown and green streaks in the biotite, both zones exhibiting strong pleochrois.

<u>Augite</u>

Only in one location was this mineral found being associated with the hornblendes.

$$\text{average } 2v = 61^{\circ} \text{ (optically +)}.$$

<u>Garnet</u>

As mentioned, only one occurrence of this mineral was found in the massive and sheared type amphibolite.

refractive index 1.785

The narrow intrusive type amphibolite acted as a host for large development of garnet porphyroblasts. In rock slide G.75 these porphyroblasts reached a size of 1/8" diameter and made up 15 per cent of the rock.

Refractive indices:

F.G.2	1.787
F.G.9	1.803

Poeciloblastic texture is exhibited by these garnets, the included minerals being made up of quartz, hornblende, pyrite fragments, and occasional small biotite flakes. The surrounding hornblende crystals have a disorientated long axis due to garnets' crystalloblastic strength in pushing these minerals aside.

Apatite

This is a major accessory mineral. Water clear barrel-shaped crystals are common.

Zircon

Zircon is a frequent inclusion in hornblende, giving rise to faint pleochroic haloes.

Sphene

Sphene, less frequent than zircon, makes up part of inclusions in hornblende.

Magnetite and pyrite

These two minerals have regular distribution throughout the rocks of this suite, pyrite forming from the iron oxide.

ULTRABASIC AMPHIBOLITES

Field and Megascopic Description

This group of amphibolites is closely associated with thick layers of amphibolite northwest of Lake Fortin and south of Lake Murray; smaller bodies also occur. The ultrabasic amphibolites have a sharp contact with the amphibolite. West of Lake Fortin an ultrabasic amphibolite lens is found within the biotite schist, the contact being parallel to the schistosity.

This amphibolite is massive, coarse grained, having a semi-fibrous matrix. On a weathered surface the rock is a bleached white; when sulphides are present, the surface locally takes on a reddish-brown hue. Freshly broken, the rock is dark green.

The outcrop forms a shattered mozaic of blocks two to three feet in diameter (Plate VA). Perpendicular to the lensoid shape of these bodies fractures have developed, which have been filled by carbonates (Plate VB). These make up lenses and bands two to three feet wide.

Veinlets of amphibolite were often present, also at right angles to the trend of the lentils of ultrabasic amphibolite. Here fibers of an average length of ½ inch have developed perpendicular to the walls of the vein. Amphibole fibers six to twelve inches long were also recorded, but were of the slip variety.

A.

Ultrabasic amphibolite showing shattered mozaic with pitted surface where dolomite has weathered out. Outcrop occurs half mile west of Lake Fortin.

B.

Ultrabasic amphibolite with carbonate vein. Location as above.

Petrology

TABLE VI

MODAL ANALYSES OF ULTRABASIC AMPHIBOLITE.

Specimen No.	F.A.1	F.A.3
Tremolite	28.8	19.0
Dolomite	31.9	9.2
Clinochlore	24.8	57.3
Prochlorite	4.2	7.8
Magnetite	2.8	-
Olivine	7.5	6.7

Tremolite

Characteristically tremolite occurs as radiating fibrous needles which traverse the surrounding minerals indiscriminately, but are truncated by olivine (Plate VI A & B). Heterogeneity of fibre size is typical throughout the rock suite.

Nx was determined on 010 cleavage flakes

Nx = 1.621 (average)

2v = 82 (optically)

this corresponds to a composition of

85% Tremolite ($H_2Ca_2Mg_5Si_8O_{24}$)

15% Ferrotremolite ($H_2Ca_2Fe_5Si_8O_{24}$)

ULTRABASIC AMPHIBOLITE

A.

A. Felted aggregates of tremolite traversing dolomite matrix. Crossed nicols x 50

B.

B. Tremolite crystals traversing across dolomite grains. Olivine occurs in southeast corner. Crossed nicols x 50

Prochlorite

This mineral is intimately associated with the tremolite, confining its distribution to areas between the needles and occasional cross-cutting veinlets. In addition, scaly aggregates of prochlorite occur as infilling between the fractures in olivine crystals.

The mineral is yellow-green, pleochroismis absent to weak, and length fast.

Clinochlore

Clinochlore occurs in colourless aggregates of fibro-lamellar structure. Islands of dolomite in this chlorite are common, tremolite has the habit of transversing these clinochlore zones.

Dolomite

Usual occurrence is a regular scattering throughout the rock of heterogeneous grain sizes. Tremolite needles cut through the dolomite crystals.

The extrapolated refractive indices for N_O and N_E as obtained from N_E' determinations on 1011 cleavage flakes in slide F.A.1 was

$$N_O = 1.683$$

$$N_E = 1.504$$

which corresponds to a composition of:

95% $CaMgC_2O_6$

5% $CaFeC_2O_6$

(Winchell 1951, p. 116.)

<u>Olivine</u>

Two rock sections show this highly fractured colourless mineral (Plate VIB). The fractures are filled with the chlorites and magnetite grains

$$2v = 80 \quad (\text{optically} +)$$

This corresponds approximately to

50% Mg_2SiO_4 (Forsterite)

50% Fe_2SiO_4 (Fayalite)

IMPURE DOLOMITIC MARBLE

Field and Megascopic Description

This rock group occurs as two parallel bands making their first appearance east of Green Lake; south of this point their location is unknown as pleistocene alluvial occurs on strike. North of this location the two parallel northwest striking bands persist as far as Lake Fortin. Here the eastern member disappears north of the lake.

On a weathered surface the dolomite is light grey to buff, freshly broken it is pearly white, fine grained and crystalline.

This formation is characterized by narrow, highly weathered resistant parallel bands averaging 2-3 inches in width. These bodies are made up of diopside, tremolite and quartz, persisting as regular parallel sinuous bands (Plate VIIA). More rarely a few veins of diopside cut these composite bands (Plate VIIB).

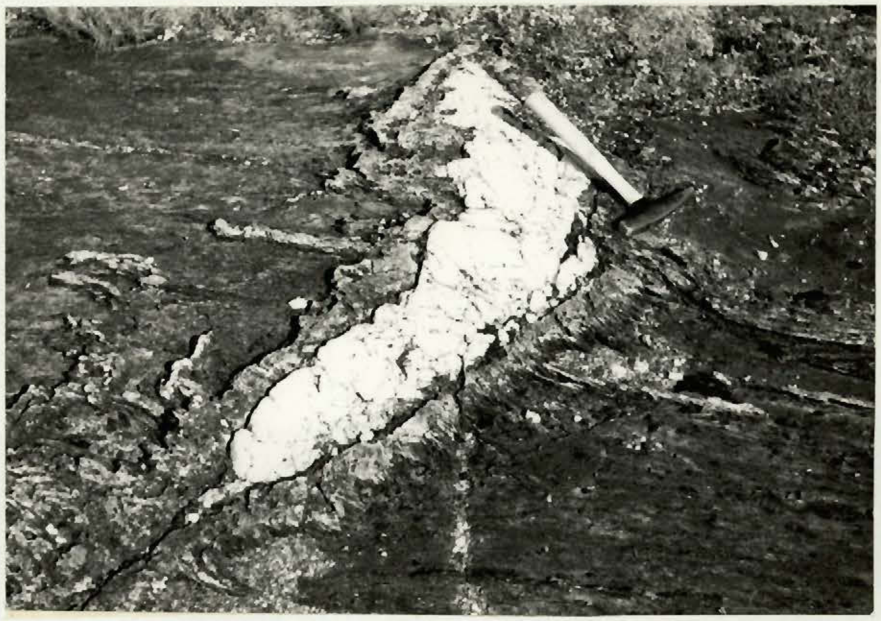
These calc-silica bands probably represent former quartzitic layers. Often in the centre of these resistant bands quartz is present as stringers, blebs, or as a series of disconnected lenses. That the diopside and tremolite are a result of reaction between the quartz and the dolomite cannot be doubted, as quartz is never in contact with the dolomite but is always surrounded by a reaction rim of these minerals. This is usually seen only on a small scale,

A.

Sinuous resistant bands of diopside and tremolite passing through impure dolomitic limestone one mile east of Green Lake.

B.

Resistant cross-cutting calc-silica bands occurring in impure dolomitic limestone; Lake Murray.



A.

Quartz lens in dolomite displaying a reaction rim of diopside and tremolite; half mile south of Lake Fortin.

B.

Diopside with border of tremolite, set in impure dolomitic limestone; one mile east of Green Lake.

however, a lens of quartz three feet long was located, displaying this reaction rim (Plate VIIIA).

In most cases reaction appears to have been complete between the quartz and dolomite as lenses and bands of diopside surrounded by tremolite occur, which are devoid of quartz (Plate VIIIB).

The diopside has a very characteristic appearance, 001 parting has been well developed. This has given rise to platy "books" each "leaf" being about 1/16 inch thick. These pale green crystals often are up to six inches long.

Tremolite has the long prismatic fibrous form with a white to pale green silky lustre. More commonly the fibers are only $\frac{1}{4}$ - $\frac{1}{2}$ inch long and occur scattered throughout the dolomite.

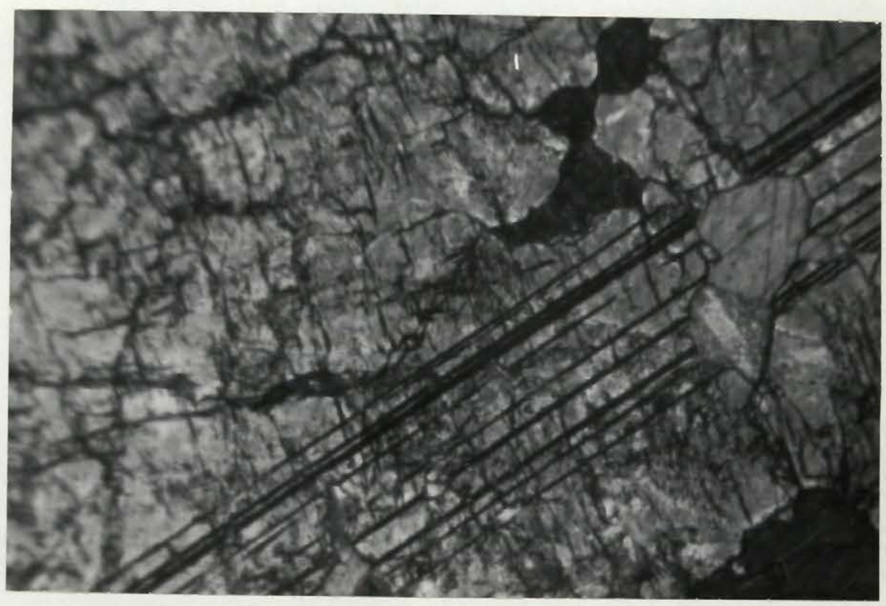
Southeast of Lake Fortin a change into a clastic facies is exhibited in the dolomite, hornblende and pink feldspar make their appearance with an abundance of quartz. The latter mineral makes up contorted lenses ranging from 6 inches to 1 foot in length (Plate IXA).

Petrology

Dolomite is the only carbonate mineral present. The calc-silica minerals are represented by diopside and tremolite. The other major silicas occurring are phlogopite, muscovite, sericite, quartz and plagioclase.

A.

Contorted lenses of quartzitic material occurring in very impure dolomitic limestone; southeast corner of Lake Fortin.



B.

Diopside porphyroblast showing 001 parting being truncated by dolomite inclusion.

Hornblende, clinochlore and locally microcline make up the minor silicates.

Sphene and zircon constitute the accessory minerals.

Dolomite

When this mineral makes up the matrix, the grains are remarkably equigranular and have sharp crystal boundaries to one another giving rise to a decussate structure. Here tremolite passes through the dolomite, sometimes showing parallel orientation.

Most diopside and tremolite crystals have inclusions of dolomite, In the case of the former the dolomite often insinuates itself along cleavage directions in the tremolite or else occurs as angular inclusions.

The relation of dolomite inclusions in diopside is very interesting. Where 001 parting has been strongly developed in the diopside, and a dolomite inclusion lies in the path of these twinning planes, the latter are truncated by the dolomite (Plate IXB).

When dolomite is present in minor quantity only, as in the calc-silica bands, the porphyroblasts tend to become large and euhedral.

N_o and N_e as extrapolated from $N_{e'}$ determinations on 1011 cleavage flakes ranged from

N_o 1.683 - 1.690

N_e 1.509 - 1.504

which corresponds to the following compositions:

100% $CaMgC_2O_6$

and

93% $CaMgC_2O_6$

7% $CaFeC_2O_6$

(Winchell 1951, p. 115).

Diopside

The most striking feature of the diopside is the strong 001 parting which has been developed. On a weathered surface this gives rise to a bladed appearance, and microscopically to well defined parallel "grooves", sometimes showing a displacement.

Generally the diopside crystals are large and euhedral, however, jagged remnants engulfed in tremolite and dolomite are also found.

Inclusions in the euhedral form are tremolite, phlogopite, and dolomite. The 001 parting directions serve as channelways for insinuating material, hence dolomite and fine grained sericitic material occur as veinlets in the diopside.

In rock section F.D.14, diopside makes its appearance in an arenaceous facies of the impure dolomitic marble, occurring as small grains intimately associated with hornblende and confining its distribution to narrow bands.

Diopside is colourless and shows high relief.

Average Nx as determined on 001 lammellar twinning planes:

$Nx = 1.672$

$2V = 60^{o}$ (optically +)

This corresponds to a composition of:

90% diopside $CaMgSi_2O_6$

10% hedenbergite $CaFeSi_2O_6$

The diopside in rock slide F.D.1 showed the following variation:

$Nx = 1.674$

$2V = 52^{o}$ (optically +)

This is probably accounted for by a higher magnesia content.

(Winchell 1951, p. 413)

Tremolite

It occurs either as large euhedral crystals or as a felted mass of needles.

Prismatic crystals are frequently found in the dolomite transversing it in all directions, sometimes a parallel orientation is to be noted.

In association with diopside, in the calc-silica bands, these minerals tend to confine themselves to separate areas, often the tremolite is found interstitially and as inclusions in the diopside. However, in predominantly tremolite areas discontinuous orientated diopside inclusions are engulfed in the euhedral tremolite. Dolomite also occurs as inclusions usually by insinuating itself along cleavage directions in the tremolite.

The mineral is colourless to neutral, sometimes showing pale green pleochroism.

Nx was determined on 010 cleavage flakes giving the following values.

TABLE VII

Nx DETERMINATIONS OF TREMOLITE

F.D.1	F.D.2	F.D.3	F.D.5	F.D.6	F.D.7	F.D.9	F.D.10
1.625	1.626	1.614	1.617	1.613	1.618	1.625	1.623

F.D.11	F.D.16	F.D.17
1.611	1.621	1.619

Average 2V = 82 (optically -)

These results fall into the following category:

85% Tremolite $H_2Ca_2Mg_5Si_8O_{24}$

15% Ferrotremolite $H_2Ca_2Fe_5Si_8O_{24}$

(Winchell 1951, p. 433).

Plagioclase

This mineral is found in zones of more clastic habit. Bands of equigranular quartz and plagioclase are found in association with calc-silica minerals.

Usually the grains are clear and untwinned, however, twinned and zoned plagioclase occurs not infrequently, all three can be found in the same slide.

Limited distribution of porphyroblastic plagioclase does occur, more frequently fine grained quartz and plagioclase aggregates fill interstices between the calc-silica minerals and hornblende.

TABLE VIII

PLAGIOCLASE COMPOSITIONS

F.D.2	F.D.3	F.D.9	F.D. 12	F.D. 15
An_{24}	An_{35}	An_{32}	An_{28}	An_{26}

(based on Tsuboi's curves, 1934, p. 325)

Microcline

This mineral is of very limited occurrence in this rock suite. In rock slide F.A.8 microcline occurs as rounded grains in a fine matrix of muscovite and phlogopite. The feldspar has a concentration of inclusions towards the centre. The edges of the microcline are very irregular. In addition, quartz is graphically intergrown. Polysynthetic twinning is present.

Quartz

Occasional fine grained aggregates of quartz and plagioclase make up the interstitial material between the calc-silica minerals. The usual occurrence of quartz is as inclusions in diopside and tremolite.

With the exception of a single grain of quartz in rock slide F.A.6 it is never found in direct contact with the dolomite. In the field there was always a reaction rim of tremolite and diopside surrounding the quartz (Plate VIIIA).

Phlogopite

This mineral makes its appearance in the more clastic zone of the impure dolomitic marble. In rock slide D.D.8 phlogopite and muscovite make up a fibrous aggregate.

Sometimes this mineral occurs as inclusions in tremolite. Its close association with clinochlore in rock section F.D.2 suggests a breakdown of the phlogopite.

This mineral is pleochroic.

Nx colourless

Nz pale brown

extinction parallel

$2V = 5^{\circ}$

$Nz = 1.592$

Muscovite

The greatest concentration of this mineral occurs in fibrous association with phlogopite.

Its fine grained associate, sericite, is found in narrow veinlets traversing diopside, and as a cloudy mixture in the centre of microcline crystals.

Hornblende

Hornblende occurs in clastic facies zone; in rock slide F.D.9 decussate structure is shown by hornblende.

In rock slide F.D.14 there is a close relationship between diopside and hornblende, the latter mineral appears to be forming at the expense of the diopside, usually the grading of the one mineral into the other is difficult to discern.

Hornblende is bluish green with moderate pleochroism.

$$2V = 84^{o} \text{ (optically -)}$$

Sphene and Zircon

These two minerals make up the accessory constituents of the rock. Zircon, when an inclusion in hornblende, gives rise to faint pleochroic haloes.

In rock slide F.D.10 euhedral sphene with acute rhombic cross section is found. More commonly it makes up inclusions in most of the minerals.

BIOTITE-MUSCOVITE SCHIST

This series is found predominantly in the western half of the "Trough" type belt of rocks.

Southwest of Lake Fortin this belt of northwesterly trending biotite-muscovite schists reaches its maximum width of 1½ miles continuing into the adjoining map sheet to the west. In the eastern part of this biotite-muscovite schist zone the percentage of amphibolites increases.

It is thought that the biotite-muscovite schists occurring on the south side of the pleistocene covering and on strike of the main belt, are of the same formation.

This biotite-muscovite schist has a dark grey weathered surface and a lighter shade of grey on a fresh surface.

They are highly schistose rocks. The general ground mass of the rock consists of a very fine grained equigranular and generally homogeneous mixture of quartz, biotite, muscovite and plagioclase.

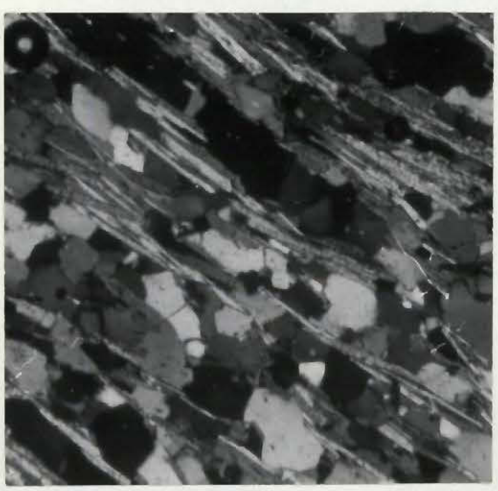
The rock comprises alternating layers rich and poor in biotite. The schistosity is characterized by lenses, stringers and blebs of quartz, sometimes including feldspar (Plate XA). These bodies average 10 inches in length and are elongated parallel to the schistosity.

The schistosity as outlined by the micas is usually regular and continuous, locally, it is wavy and small, tight

A.

Quartz lenses and stringers in a biotite-muscovite schist; northwest of Green Lake.

B.



Typical texture of biotite-muscovite schist showing parallel orientation of mica flakes in a matrix of quartz and minor plagioclase grains.
Crossed nicols x 50

C.

Garnet porphyroblast in southeast corner set in matrix of quartz, plagioclase, muscovite and biotite.
Crossed nicols x 50

contortions are found which are often well defined by the quartz stringers. These contortions are often small enough to be recorded in hand specimens, usually biotite outlines the schistosity.

A narrow band of biotite-muscovite schist containing garnets is found to the north and south of Lake Fortin, and one mile north of Green Lake. The garnets are finely disseminated locally through this rock.

Petrology

TABLE IX

MODAL ANALYSES OF BIOTITE-MUSCOVITE SCHIST

Specimen No.	Quartz	Biotite	Muscovite	Plagioclase	Garnet
F.B.1	64.6	13.2	21.1	1.1	-
F.B.2	69.8	28.3	1.9	-	-
F.B.9	66.8	30.2	-	1.6	1.4

Quartz

Quartz that makes up the matrix is characterized by zones of different grain size, but each zone has an equigranular texture which is parallel to the schistosity. In addition coarse grained quartz stringers are found, which also parallel the schistosity. In most cases quartz exhibits strain shadows under crossed nicols and is free from inclusions.

Interspersed in the quartz bands occur minor plagioclase grains of equal dimension.

Biotite

This is one of the micas which is responsible for the schistosity in the rock. Its usual occurrence is in the form of prismatic flakes either in bands or individually traversing the rock (Plate XB).

Zircon inclusions are present in all the specimens of this suite giving rise to marked pleochroic haloes in the biotite.

Biotite is always associated with muscovite, except when garnet is present.

TABLE X

Nz VALUES TAKEN FROM 001 BIOTITE FLAKES .

F.B.1	F.B.2	F.B.3	F.B.4	F.B.5	F.B.6	F.B.7	F.B.8
1.643	1.643	1.650	1.653	1.649	1.646	1.643	1.644

F.B.9	F.B.10
1.645	1.649

$$2V = 0^{\circ}$$

Muscovite

Biotite predominates over muscovite with one exception. These two micas usually occur in close association with one another, muscovite is conspicuous by its absence when garnet is found in the rock.

Muscovite takes on a prismatic form.

Plagioclase

Of very limited distribution, plagioclase is found interspersed with the quartz grains of the matrix as well as in the lenses and stringers of quartz.

Generally untwinned or weakly so, both forms are to be seen in the same slide. Grains have sharp boundaries with surrounding minerals.

TABLE XI

COMPOSITION OF PLAGIOCLASE

F.B.1	F.B.2	F.B.3	F.B.4	F.B.5	F.B.6	F.B.7	F.B.8
An_{35}	An_{40}	An_{28}	An_{36}	An_{35}	An_{36}	An_{19}	An_{39}

F.B.9	F.B.10
An_{36}	An_{32}

Range An_{19} - An_{40} (based on Tsuboi's curves, 1934, p.325)

Garnet

Porphyroblasts of garnet range up to 1/16 inch. In all occurrences this isotropic mineral has forced aside the surrounding mica due to the crystalloblastic strength of the garnet (Plate XC).

Quartz makes up the inclusions and is in some cases elongated perpendicular to the schistosity of the rock. In rock section F.B.9 four garnet porphyroblasts lie on the same schistosity plane with only one other garnet occurring in the same rock section. This schistosity plane also lies on the boundary of two distinct zones of different grain size, suggesting a dependency of garnet formation on the chemical composition of the host rock.

Refractive Indices of Garnet

F.G. 14	F.G. 15
1.784	1.789

Zircon

This mineral is found mostly as fine grained inclusions in biotite, giving rise to marked pleochroic haloes.

Tourmaline

Euhedral, strongly pleochroic green schorlite occurs in a few of the rocks of this suite.

Apatite

Usually, apatite is present as water-clear, barrel-shaped crystals.

NODULAR SILLIMANITE-BIOTITE-MUSCOVITE SCHIST

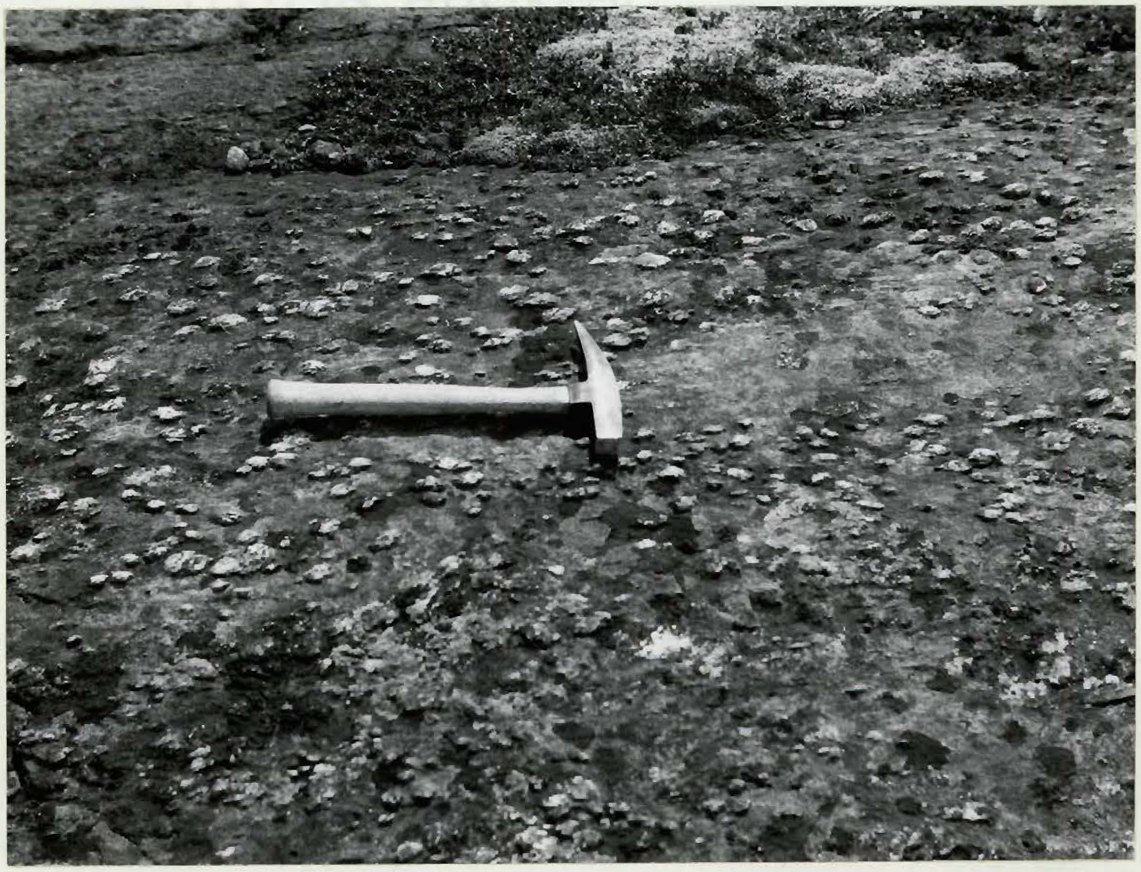
Field and Megascopic Description

These schists occur in several places in the eastern part of the belt of "Trough" type rocks.

In the southern part of the area they outcrop east of the Cailloux River. Northeast of Green Lake occur two bands of nodular sillimanite schist straddling the eastern ridge of impure dolomitic marble.

On a weathered surface the nodular sillimanite-biotite-muscovite schist has a dark grey to rusty appearance which penetrates the rock for a few inches. Freshly exposed, the colour is a grey-white.

Surface texture is rough and irregular with sillimanite standing out in relief as weather resistant nodules (Plate XIA). The nodules are oblate, averaging ½ inch but occur up to 2 inches in diameter with the long axis tending to align itself parallel to the schistosity. These nodules are made up of an intergrowth of quartz, biotite, and sillimanite, the aggregate is fibrous and pearly. In some locations garnets occur in the centre of these nodules. This is particularly noticeable on a weathered surface, where the garnet is less weather resistant than the sillimanite nodules, resulting in depressions in the latter, which outline the euhedral crystal boundaries of the garnet.



A.

Sillimanite nodules standing out in relief on a weathered surface of a sillimanite-muscovite-biotite schist.

These garnets attain an average size of 1/8 inch. Biotite often forms a wrapping around these sillimanite nodules.

A biotite-muscovite schist with a trace of sillimanite also occupies definite zones. In the vicinity of Lake Hay, three miles east of Lake Fortin and south of Turcotte Lake these occurrences are to be found. Here the essential difference is that the nodules have far smaller and more erratic distribution, the remaining part of the rock texture is the same.

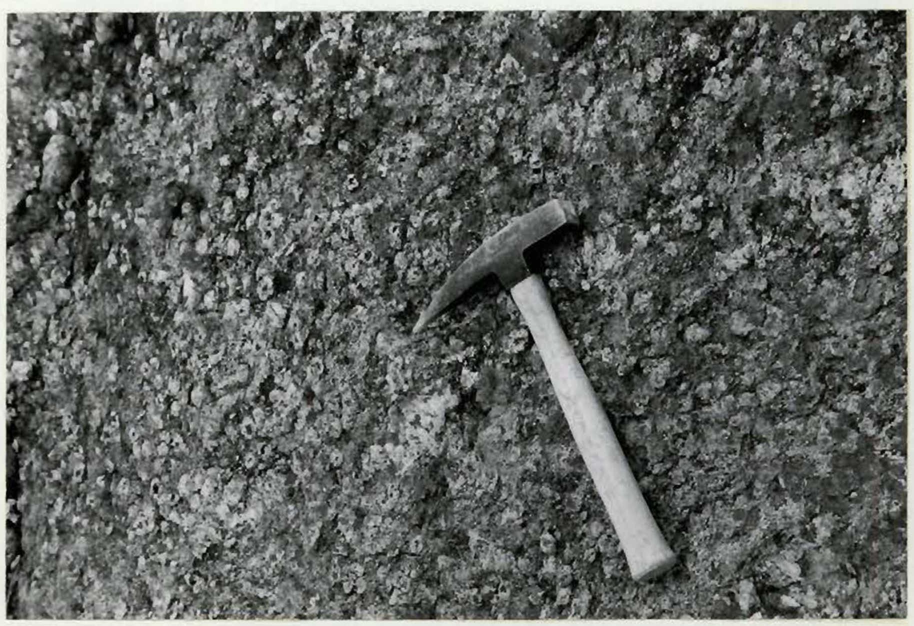
The matrix of the rock is medium to coarse grained, and is characterized by thin lenses and irregular patches rich in biotite. The quartz tends to be equigranular with the micas lending a heterogeneity to the matrix of the rock.

Lenses, stringers, and blebs of quartz are often seen paralleling the schistosity which, locally, can be highly contorted.

Stringers of sillimanite nodules develop along what must have formerly been bedding which parallels the schistosity (Plate XIIA).

A.

Stringers of sillimanite nodules in a sillimanite-biotite-muscovite schist.



B.

Nodular sillimanite with garnet occurring in the depressed centres of the nodules. One mile east of Green Lake.

Petrology

TABLE XII

MODAL ANALYSES OF NODULAR SILLIMANITE-BIOTITE-MUSCOVITE SCHIST

Specimen No.	xF.S.3	F.S.6	F.S.8	F.S.9	F.S.10	F.S.11	F.S.12
Quartz	68.7	48.7	45.0	45.7	51.5	56.9	32.3
Biotite	14.8	23.5	18.0	23.1	25.9	22.6	26.6
Muscovite	8.8	19.5	22.4	23.5	4.6	13.0	12.0
Plagioclase	3.5	5.3	6.2	2.9	2.0	5.1	20.39
Sillimanite	2.7	2.9	8.4	4.7	15.4	2.4	5.0
Garnet	1.1	-	-	-	-	-	.84
Accessory	-	-	-	-	.67	-	2.85

Quartz

This mineral is the major constituent of the rock, usually medium grained, and has equigranular texture. Veinlets of a coarser grained quartz are to be found traversing the rock parallel to the schistosity. Quartz is also found as inclusions in garnet.

Except for occasional sillimanite fibres, quartz is free from inclusions; these fibres project into the quartz with random orientation.

Strained quartz, as exhibited by irregular extinction, is found frequently.

Biotite and Sillimanite

Biotite tends towards prismatic flakes which, together with muscovite, outline the schistosity of the rock. Locally these flakes are bent through as much as 30°; this is most noticeable when the biotite is in association with garnet.

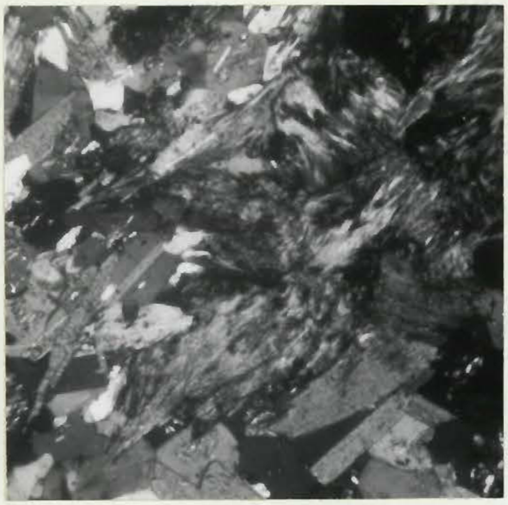
The intimate relationship of biotite and sillimanite is very striking (Plate XIIIA and B). The commonest textural form is an interdigitating habit of sillimanite fibres and biotite, usually with decolourization of the latter. This intergrowth is often so gradational that the transition boundary of the one mineral into the other is difficult to distinguish. In 95% of its occurrence sillimanite grades into biotite. However, randomly orientated needles of fibrolite also project into the surrounding minerals.

Felted fibrous aggregates of fibrolite and biotite tend to form turbulent clusters. Here, biotite is often preserved as irregular ragged inclusions in the predominantly sillimanite mass.

In the case of nodular sillimanite-garnet association, the latter mineral becomes surrounded by the fibrolite biotite aggregate (Plate XIIB).

Pleochroic haloes in the biotite result from inclusions of zircon.

SILLIMANITE SCHIST



A.

Felted sillimanite forming at expense of biotite.
Crossed nicols x 50

B.

Biotite and sillimanite aggregates with needles of latter projecting into quartz and plagioclase.
Crossed nicols x 50

C.

Garnet, sillimanite, and biotite intimately associated.
Plain light x 50

D.

Garnet porphyroblast with inclusions of fibrolite.
Plain light x 50

Pleochroism Range:

Nx	pale brown
Ny	dark brown
Nz	dark brown

TABLE XIII

Nz TAKEN ON BASAL PLATES (001)FOR BIOTITE

F.S.1	F.S.3	F.S.4	F.S.5	F.S.6	F.S.8	F.S.9	F.S.10	F.S.11	F.S.12
1.639	1.634	1.635	1.637	1.648	1.644	1.645	1.643	1.643	1.645

Muscovite

Generally ancillary to biotite, together with the latter muscovite is responsible for schistosity in the rock.

The muscovite tends to form prismatic flakes that generally have a truncating effect on the cleavage directions of the biotite. The flakes of muscovite are noticeable for their freshness and lack of inclusions. Only in one occurrence were a few fibrolite needles seen projecting into the muscovite.

Recrystallization appears to have taken place as bent flakes extinguish in sections independently of one another.

Plagioclase

This comprises heterogeneous grain sizes in the same rock, usually twinned and untwinned plagioclase occur side by side.

Cloudy sericitic inclusions are found in some of the plagioclase grains concentrated towards the centre. Projecting fibrolite needles are not an uncommon feature (Plate XIIIB).

TABLE XIV

COMPOSITION OF PLAGIOCLASE AS DETERMINED ON 001 CLEAVAGE FLAKES

F.S.1	F.S.2	F.S.3	F.S.5	F.S.6	F.S.7	F.S.8	F.S.9	F.S.10	F.S.11	F.S.12
An_{32}	An_{30}	An_{34}	An_{35}	An_{34}	An_{34}	An_{28}	An_{36}	An_{29}	An_{33}	An_{37}

(based on Tsuboi's curves 1934, p.325)

Garnet

These porphyroblasts are surrounded by fibrolite-biotite matrix (Plate XIIIC and D).

Inclusions make up from 2-5 per cent of the garnet and comprise mostly quartz. In one locality the latter mineral is graphically intergrown. Biotite and magnetite make up the remaining inclusions.

TABLE XV

REFRACTIVE INDEX OF GARNETS

F.G.1	F.G.3	F.G.4	F.G.5	F.G.6	F.G.7	F.G.8	F.G.10	F.G.13
1.799	1.786	1.799	1.790	1.788	1.800	1.789	1.786	1.790

This corresponds to a composition of approximately:

80% Almandite $Fe_3Al_2Si_3O_{12}$

20% Pyrope $Mg_3Al_2Si_3O_{12}$

Pennine

One occurrence of pennine, forming from the breakdown of biotite, was observed in specimen F.S.12.

Magnetite

This is commonly found throughout the rock suite, and is usually concentrated along boundaries and cleavage directions of biotite.

Tourmaline

Strongly pleochroic, olive green schorlite, forming long prismatic euhedral crystals. This is the predominant accessory mineral of the rock suite, showing affinity for biotite where it occurs as inclusions or in close association.

Zircon

Small grains of zircon, when included in biotite, give rise to strong pleochroic haloes.

Apatite

Water-clear apatite has minor distribution.

THE PETROLOGY AND STATUS OF SILLIMANITE

The use of sillimanite as an index mineral of metamorphic grade has been doubted (Saunders 1954, p. 144) due to the close relationship of this mineral, in many instances, to agents of granitization.

Before proceeding to classify the rocks of the area into their respective metamorphic facies, an attempt will be made to summarise the occurrences and modes of formation of sillimanite and correlate these observations with those observed in the map area.

Magmatic Origin

Adams and Barlow (1910, p. 138) in their study of the Haliburton and Bancroft areas, Ontario, describe an occurrence of nodular sillimanite in a granitic rock, and attribute the origin of the nodules to schlieren, which, richer in silica and alumina than the rest of the magma, were eventually mobilized and separated out as immiscible globules giving rise to the present spherulitic arrangement.

A similar opinion was held at an earlier date by Backstrom (1893, p. 778) to account for a nodular granitic occurrence at Kortfors, in Sweden.

Gelinas (1956, p. 82) described an occurrence of nodular aplite dikes in the Fort Chimo region, eighteen miles to the east of the area mapped by the author, and arrived at the conclusion that they are the result of liquid immiscibility. Here, a second liquid phase of a magma, rich in silica, alumina, and mineralizing agents which insinuated itself into the overlying rocks, is thought to have been the responsible agent. The alumina fraction of this liquid phase then separated out as immiscible globules. The host rock for the mozaic of cross-cutting nodular aplite dikes is para- and orthogneiss. Based on the mineral assemblage, they belong to the epidote amphibolite metamorphic facies.

This apparent incompatibility of metamorphism between host rock and dikes is difficult to explain other than by resorting to the magmatic theory.

Metasomatic Origin

The occurrence of sillimanite nodules or faserkiesel in pegmatites and aplites has sometimes been attributed to late magmatic metasomatism.

Janet Watson's study of the Moine Series in Central Sutherland (1948, p. 149) revealed that sillimanite was not only abundant in the country rock, but also in pegmatites and aplites. This led her to the opinion that the sillimanite was formed as a result of metasomatic activity at a late stage in the history of the Strath Halladale injection complex.

The association of sillimanite with magmatic intrusions has been recorded in a number of localities. Moore (1949, p. 1642) finds sillimanite occurring in the Kinsman quartz-monzonite, New Hampshire, with concentration where inclusions of schist are numerous.

Sillimanite in the Wissahickon schist, Pennsylvania, has been studied by Wyckoff (1952, p. 48) who found that this mineral was invariably associated with pegmatites and igneous intrusion. However Weiss (1949, p. 1703), studying this area, claimed that it did not appear possible to relate the occurrence of sillimanite to the intrusive granodiorites.

Smith (1945, p. 303) while working on an occurrence of sillimanite in South Carolina, noted an association of this mineral with granite intrusions. However, he made no claim to the latter as being an agent of metasomatic addition, but rather attributed the synthesis of sillimanite solely to heat and aqueous solutions supplied by the granite.

Heinrich and Bever (1957, p. 46 and 49) describing sillimanite deposits in Colorado, noticed that in Park County, this mineral becomes more abundant in the schists towards the margin of intrusive bodies. In Fremont County sillimanite is found along the fringe and in the marginal zones of pegmatites.

Osborne, working in the Shawinigan Falls District, Quebec, (1936, p. 209) records pegmatites being intimately associated with aggregates of sillimanite. Not being able to relate these pegmatites to a plutonic rock, he accords their origin either to metamorphism or injection.

Sillimanite in migmatites has been described from the Kenya Basement System by Saunders (1955 loc. cit.). Here he attributes the formation of faserkiesel to the granitization of sillimanite schists; these nodules are not present in the schist.

The unusual occurrence of a kyanite-andalusite-sillimanite schist in the Pritchard formation, Idaho, (Hietanen 1956, pp. 3-4) is described as being in close association with metasomatic anorthosite bodies. It is suggested that part of the alumina in the schist may have been introduced during the metasomatism of the anorthosites.

Metamorphic Origin

The means by which sillimanite is thought to have formed by metamorphic processes are fairly limited.

Harker (1932, p. 58) describes sillimanite forming at the expense of biotite. Francis (1946, p. 358) gives the following reaction as a possibility for the sillimanitization of biotite:

$$\underset{\text{(Fe-biotite)}}{KFe_3Si_3AlO_{10}(OH)_2} + Al_2O_3 + SiO_2 \rightleftharpoons \underset{\text{(K-feldspar)}}{KAlSi_3O_8} + \underset{\text{(Sillimanite)}}{Al_2SiO_5} + 3FeO + H_2O$$

The synthesis of sillimanite from the inversion of andalusite, or cyanite at a later stage, is also postulated by Harker (1932, p. 227).

The assemblage sillimanite-muscovite appears before the association of sillimanite-potash feldspar. According to Chapman (1952, p. 420) the first sillimanite zone arises by the breakdown of staurolite in the presence of quartz.

3 Staurolite + 2 Quartz   Almandine + Sillimanite + 3 Water

The second reaction breaks down as follows:

$$KAl_3Si_3O_{10}(OH_2) + SiO_2 \rightleftharpoons KAlSi_3O_8 + Al_2SiO_5 + H_2O$$

Muscovite   (Orthoclase or Microcline)   Sillimanite

This reaction is quoted as one of the commonest means of sillimanite formation, and according to Ramberg (1952, p. 48) takes place at the border between amphibolite-granulite facies.

Petrography of Sillimanite Deposits

All the occurrences described occur in acid rocks.

The commonest association is with biotite, muscovite and garnet.

Tozer (1955, p. 317) draws our attention to the frequent descriptions of biotite-fibrolite associations. Smith (1945 loc.cit.); Watson (1949 loc.cit.); Harker

(1932, p. 58); Heinrich and Bever (1957, p. 45) all describe similar occurrences of fibrolite forming at the expense of biotite.

The relation sillimanite-muscovite, although more frequently quoted as the usual reaction, is described less frequently than the previous biotite-sillimanite association. Tozer (1955, p. 312) describes a second generation of fibrolite forming from the breakdown of muscovite. Moore (1949, p. 1643) describes a similar relation. More commonly the synthesis of muscovite by the replacement of sillimanite is described. Tozer (1955, p. 314), Heinrich and Bever (1957, p. 45), Saunders (1954, p. 148) have recorded this type of occurrence. Fowler-Billings (1949, p. 1262) describes pseudo-morphs of muscovite after sillimanite up to 8 centimeters long.

Two occurrences that the writer is aware of, have been attributed to the formation of sillimanite from cyanite. Weiss claimed (1949, p. 1704) pseudomorphs of sillimanite after cyanite in the Wissahickon schist; a claim which Wyckoff was unable to confirm (1952, p. 48). In Barth's study in Dutchess County, New York, he describes an occurrence where "cyanite gives place to sillimanite". (1936, p. 790).

Occurrence and Origin of Sillimanite in Nodular Schist of Map Area

The majority of sillimanite is seen forming at the expense of biotite, which, according to Francis (1956, p. 358) would be the result of alumina solution acting as a catalyst to the reaction giving rise to potash feldspar, sillimanite, and iron ore plus water. Evidence for this reaction is cited by the decolourization of biotite-sillimanite boundaries. The abundance of exsolved magnetite grains, which have an affinity for boundaries and cleavage directions in the biotite, could be a resultant of this reaction. The lack of potash-feldspar poses a problem, but the potassium could possibly have been utilized for the formation of muscovite. This latter mineral is fresh and unaltered, except for minor included sillimanite needles which have random orientation. This appears to indicate a later stage of formation for the muscovite. The very minor occurrences of the muscovite-sillimanite association could be interpreted as the muscovite forming at the expense of sillimanite, as has been described by Tozer (1955, p. 312) and others.

According to Ramberg (1952, p. 151) one could expect the reaction

$$\text{Muscovite} + \text{Quartz} \rightleftharpoons \text{K-feldspar} + \text{Sillimanite} + \text{Water}$$

to take place, or

$$\text{Biotite} + \text{Muscovite} + \text{Quartz} \rightleftharpoons \text{Orthoclase} + \text{Almandine} + \text{Water}$$

(1952, p. 57)

In either case the muscovite should enter a reaction. This gives support to the idea that the muscovite is of later origin than the sillimanite. The occurrence of abundant tourmaline is suggestive that mineralizing agents did pass through the rock and could have been responsible for the later growth of the muscovite.

In the case of the intimate association of garnet lying in the centre of sillimanite nodules, the origin of the sillimanite is probably of a slightly different nature. This could quite conceivably be brought about by the breakdown of staurolite which, according to Chapman (1952, p.420), has the following reaction

$$3 \text{ Staurolite} + 2 \text{ Quartz} \rightleftharpoons \text{Almandine} + \text{Sillimanite} + 3 \text{ Water}$$

This reaction would also account for the lack of K-feldspar in this occurrence of sillimanite.

Of the three primary modes of formation suggested, the magmatic origin is ruled out, as the rocks here in question are without doubt of sedimentary origin.

For the metasomatic viewpoint there is a stronger case. Banding of the nodular sillimanite parallel to the schistosity could mean selective replacement as well as preferred direction of insinuation of metasomatizing agents. No increase of sillimanite towards the granitic gneiss was apparent, which one would expect if the sillimanite had a metasomatic origin. Nodular sillimanite was not noticed to be in association with the numerous pegmatites that traverse the area. However, sillimanite was identified in thin section in one pegmatite occurrence. Since the pegmatites appear to be of the secretion type, as judged by the dependency of composition of the pegmatite on the host rock, it is quite feasible that the sillimanite was introduced into the pegmatite from the wall rock. Thus the idea that the pegmatites acted as solution ways for the sillimanite, is ruled out.

The theory of metamorphic origin appears to carry most weight and is expounded here as being applicable to the nodular sillimanite of the map area.

The banding (Plate XIIA) would correspond to layers in the original sediment of slightly higher alumina content than the rest of the rock, and hence would be favourable to the formation of sillimanite under the right temperature and pressure conditions.

Why the sillimanite should adopt the faserkiesel form is a little difficult to conceive. Watson (1948, p.152) advanced the following idea: "as the amount of biotite decreases and the schistosity grows less well marked, the fibrolite mats become mixed with quartz and swell up until they attain the dimensions of faserkiesel knots. The habit of the mineral is apparently controlled by the texture of the host-rock".

The problem still remains as to whether the biotite-muscovite schists to the west of the sillimanite belt are of a lower grade of metamorphism, or if the failure of formation of index minerals is due to the difference in bulk chemical composition of the rock?

A further complication, pointed out by Saunders (1954, p. 144), of the validity of sillimanite as indicating a high grade of metamorphism, is its frequent association with metasomatic agents.

In an effort to solve this question of the metamorphic grade of these two schists, partial chemical analyses were carried out on garnets and biotites from the two respective schists. Attempts were made to correlate the Mn, Fe, and Ti in biotites and the Mn, Fe and Ca in garnets with the grade of metamorphism.

STUDY OF GARNETS AND BIOTITES

It was found that in a systematic study of pyralspites (calcium-poor garnet) in pelitic metamorphic rocks of the Gosaisyo-Takanuki district a decrease in the MnO content of pyralspites took place with increasing metamorphism. Furthermore, the FeO content increases (Miyashiro 1953, p. 173). Accompanying this chemical variation, he found that the edge length of the unit cell shortens and the refractive index becomes generally higher. In addition, the associated biotite varies similarly in composition and proportion with advancing metamorphism.

It is to be noted that the absolute percentages of MnO in the same facies but different districts is not constant but rather that this variation is a relative quantity only. This has been attributed to the difference in character of metamorphism in the different districts.

Sorting of Specimens

Sorting was done on the Frantz Isodynamic separator. A slope of 15° by 15° was found most satisfactory in conjunction with a grain size of -100 to + 200 mesh.

First the garnet, hornblende and biotite were taken off as the magnetic fraction leaving a residue of quartz, feldspar, sillimanite and accessories; a current of 0.4 amps. was used.

Following this a very sensitive adjustment was needed to separate the hornblende from the garnets; the current used varied by ± 0.05 amps., depending on the iron content of the garnets. Generally the amperage was 0.3.

Following this the specimen was run through a number times varying dip and plunge of the chute. Where the specimen had an original high hornblende content, either as inclusions in the garnet or as separate crystals, a hand separation was required. With the aid of the binocular microscope the 2-5 per cent impurity was removed. In the case of the biotite, inclusions were rare, a very good separation having been perfected with the iso-dynamic separator.

Sample Preparation

For each sample 0.1 grams of -100 mesh material was mixed with one gram of sodium chloride. These materials were ground and mixed together in a Fisher automatic grinder, using an agate mortar, for forty minutes. The resulting powder was compressed in a hydraulic press at a pressure of 8,000 pounds per square inch, to form a flat pellet one inch in diameter. For convenience in handling, the pellets were glued to a narrow strip of cardboard.

Method of Analysis

Using a General Electric XRD-3 spectrometer, the concentrations of the elements required were determined by comparing the measurement of intensity of radiation of a set of prepared standards with the samples. Using logarithmic scales a straight line graph could be established by plotting the counts per second of secondary X-ray emission against the known percentage composition of the elements. The set of prepared specimens were then run and a direct percentage composition reading could be made by comparing the counts per second with those of known composition.

As air strongly absorbs the radiation in the long wavelength region of the X-ray spectrum, it was found necessary to use helium in some cases to flush the X-ray path. It has a low absorbtion for X-rays, hence increases the intensity of radiation.

Garnets

Specimens F.G.1 - F.G.13, excluding F.G.11, were obtained from within the sillimanite zone. These garnets, with two exceptions, were obtained from the pelitic sillimanite schists, in most cases the garnets sampled were taken from the centre of the nodular sillimanite. The two exceptions, F.G.9 and F.G.2, were extracted from

TABLE XVI

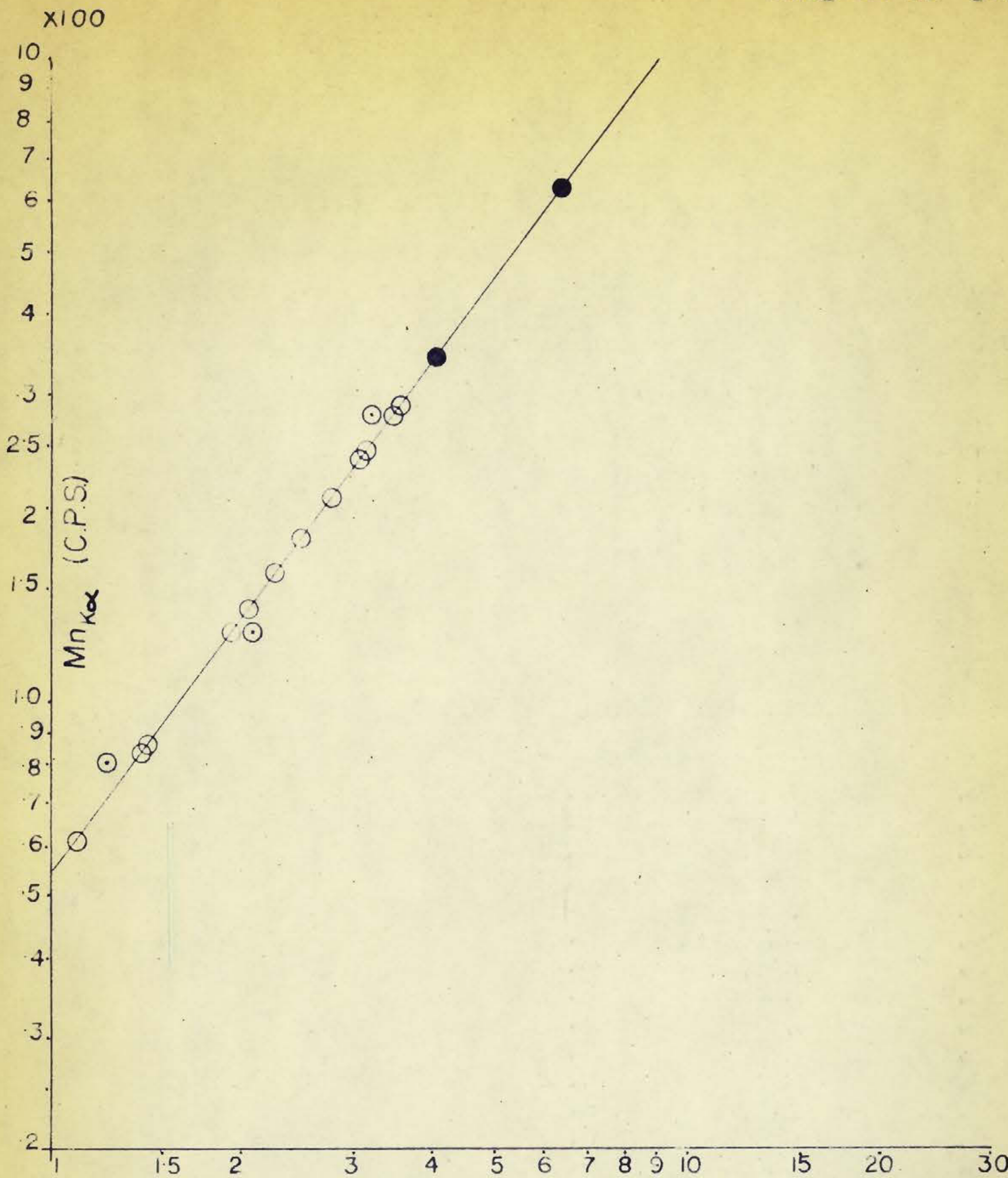
GARNETS - X-RAY FLUORESCENCE

Specimens diluted 1:10 with
NaCl in pressed mounts.
50 KV
50 MA
#4 counting tube
.005 slit
LiF crystal
Air - atmosphere for I and II
Helium " for III

Standards (percentages)

	MnO	Fe_2O_3	CaO
N.B.S.104	-	7.07	2.29
W - 1	-	11.3	11.0
B3375	-	97.93	-
G - 1	-	2.03	1.4
NH/H 9-56	3.20		
NH/H 13-56	2.09		
NH/H 26-56	1.241		

Specimen Number F.G. Series	I Mn_K 62.95°	II Fe_K 57.5°	III Ca_K 113.06°
1	160.6	2139	25.7
2	138.9	1627	49.5
3	86.3	1818	33.1
4	279.8	1675	19.0
5	181.4	1701	46.4
6	128.2	1456	38.0
7	246.4	1840	27.6
8	282.8	1603	31.8
9	238.2	1615	26.9
10	218.8	2228	57.1
11	15.5	1663	39.4
12	61.0	1871	35.3
13	83.6	1720	36.8
14	630.4	1037	79.4
15	345.6	1461	52.4
NH/H 9-56	280.6	-	-
NH/H 13-56	128.0	-	-
NH/H 25-56	81.0	-	-
N.B.S.104	-	384.1	33.42
W-1	-	551.4	150.56
B3375		4692	-
G-1		85.82	21.29



% MnO

GARNET SPECIMENS.

⊙ Analysed standards.

○ Garnets from sillimanite schist.

● Garnets from non-sillimanite schist.

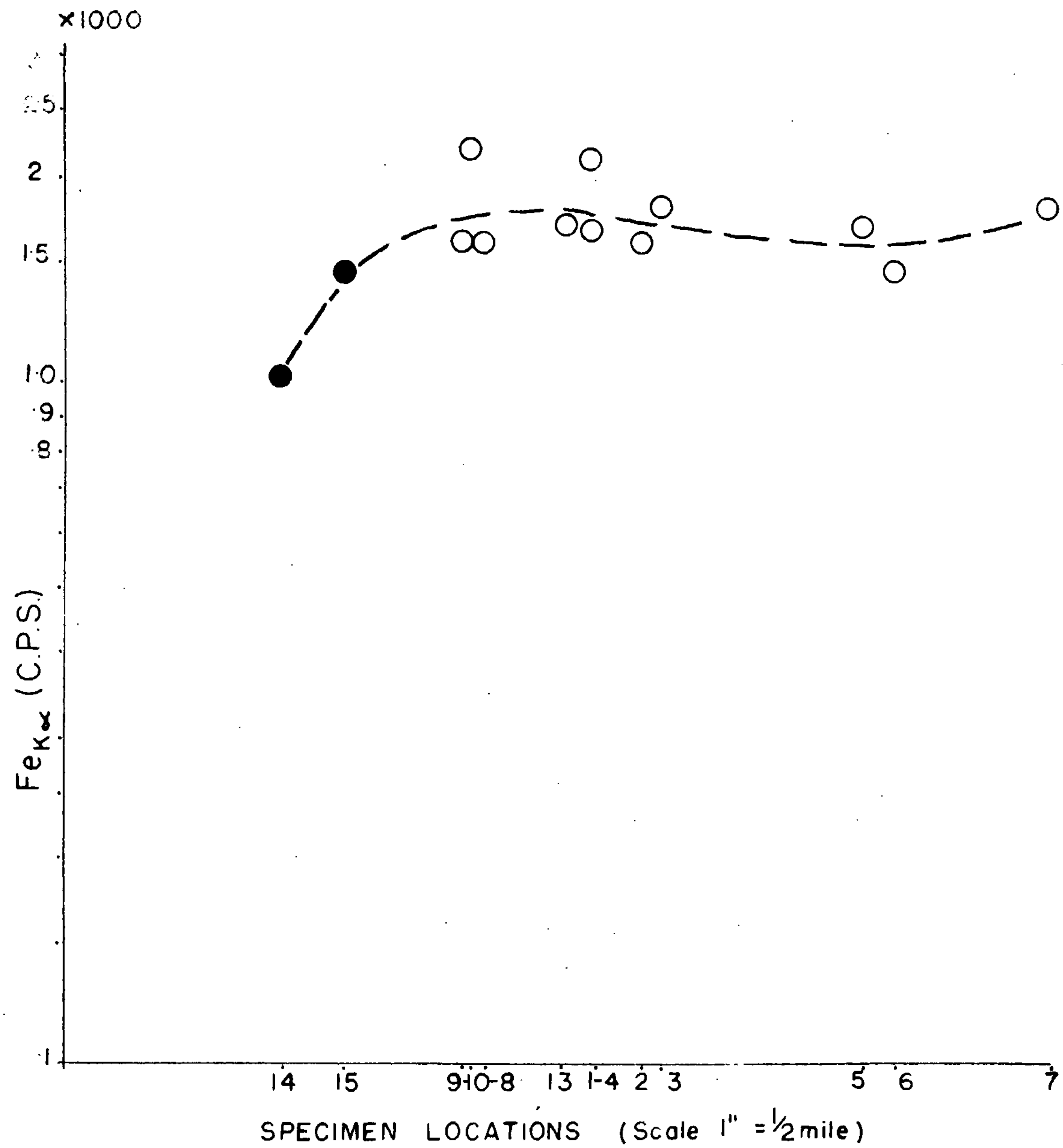
narrow amphibolite bands up to two feet in diameter. Their chemical and optical behaviour was surprisingly in accordance with the garnet sampled from the pelitic rocks of the same grade of metamorphism.

Specimen F.G.11 was the only occurrence of garnet found in the broad belt of amphibolites. The Ca, Fe and Mn content was anomalous as compared to the values of the pelitic pyralspites. As the chemical composition - metamorphic relationship was found to exist in pelitic rocks (Miyashiro loc.cit.) the anomalous readings of this non-pelitic garnet can be discarded.

Specimens F.G.14 and F.G.15 represent the garnets taken from the biotite-muscovite schists.

A study of diagram II which is the graph of the logarithmic values of MnO percentage in garnet plotted against counts per second X-ray radiation, shows that the two specimens, F.G.14 and F.G.15 belonging to the biotite-muscovite schist have a higher MnO content than the garnets belonging to the sillimanite zone.

A similar plot using the Fe_2O_3 percentage composition of the garnets on the abscissa in place of MnO content reveals a tendency for the specimens from the sillimanite zone to have a higher concentration of Fe_2O_3 than garnets from the biotite-muscovite schist. There is an overlap of the boundaries, however, between specimens F.G.15 and F.G.6.



GARNET SPECIMENS.

○ Garnets from sillimanite schist

● Garnets from non-sillimanite schist.

A brief reappraisal of the CaO content shows that, with one exception, the concentration is lower in the garnets of the sillimanite zone (Table XVI).

TABLE XVII

COMPOSITION OF REFRACTIVE INDICES AND MnO CONTENT OF GARNETS

F.G.Series	12	13	3	6	2	1	5
% MnO	1.1	1.4	1.43	1.9	2.0	2.3	2.5
R. I.	1.798	1.790	1.786	1.788	1.787	1.799	1.790

F.G.Series	19	9	7	4	8	15	14
% MnO	2.9	3.1	3.2	3.45	3.5	4.1	6.3
R. I.	1.786	1.803	1.800	1.799	1.789	1.798	1.784

Table XVII is a plot of the refractive indices of the garnets arranged in increasing MnO content. It can be readily seen that the refractive index does not appear to change progressively with the concentration of MnO.

A plot of the counts per second of Fe radiation on the logarithmic ordinate against distances of the specimens apart plotted on the abscissa gives the curve in diagram III. The latter distances were obtained by projecting specimen locations on to a section line passing normally to the strike of the strata. It is doubtful that the downward fluctuation in the curve expresses a slight temperature change within the sillimanite zone. However, if accurate work was carried out and composition correction made for small inclusions in the garnet, it may be possible to detect sensitive changes of temperature within a single metamorphic facies.

Biotites

Biotite from the two pelitic rock types: biotite-muscovite schist and biotite-muscovite-sillimanite schist, was partially analysed for MnO, Fe_2O_3, and TiO_2 contents (Table XIX).

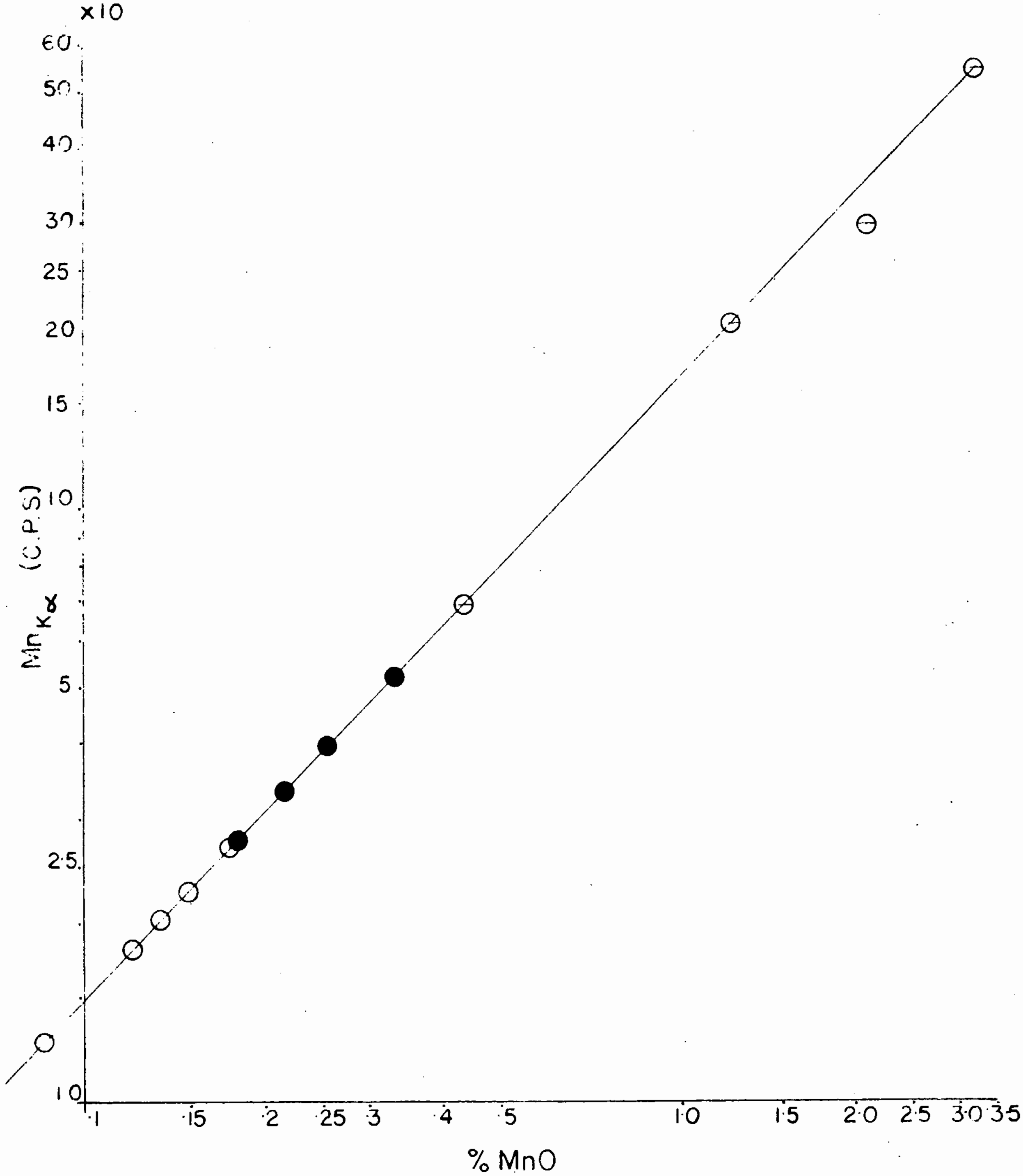
Using a double logarithmic graph scale the counts per second of secondary X-ray radiation were plotted on the ordinate scale and percentage MnO plotted on the abscissa. The graph (diagram IV) shows that the biotites sampled from the non-sillimanite zone have a higher percentage of MnO than those separated from the sillimanite-rich rocks.

With one exception, a similar plot for the Fe_2O_3 content displays the converse relationship; the biotites of the sillimanite zone having a higher concentration of Fe_2O_3 (Table XIX).

There does not appear to be any systematic relation between refractive indices of the biotites with the change in the MnO content (Table XVIII).

TABLE XVIII

(1) Sample Number	(2) Observed Nz	(3) MnO C.P.S.	(4) MnO %	(5) (total)FeO C.P.S.	(6) (total)FeO %	(7) TiO_2 C.P.S.	(8) TiO_2 %	(9) Calculated Nz	(10) error (2)-(9)
F.B.10	1.6490	52.1	0.32	5099	24.8	75.3	1.62	1.6351	-.0139
F.S.6	1.6475	18.2	0.13	5471	27.0	118.2	2.55	1.6412	-.0063
F.B.6	1.6460	27.6	0.18	4402	21.75	96.3	2.05	1.6434	-.0026
F.B.8	1.6440	33.4	0.225	4522	22.5	114.2	2.45	1.6369	-.0071
F.S.10	1.6428	20.4	0.14	5069	24.75	117.5	2.52	1.6391	-.0037
F.B.1	1.6428	39.8	0.265	4973	24.25	112.7	2.40	1.6381	-.0047
F.S.1	1.6387	26.9	0.155	5027	24.50	110.0	2.35	1.6381	-.0006
F.S.3	1.6337	22.7	0.150	5154	25.00	112.2	2.37	1.6387	+.0050



BIOTITE SPECIMENS

- ⊖ Analysed standards.
- ○ Biotite from sillimanite schist.
- ● Biotite from non-sillimanite schist.

TABLE XIX

BIOTITES - X-RAY FLUORESCENCE

Specimens diluted 1:10 with NaCl in pressed mounts
50 KV
50 MA
.010 slit
LiF crystal
Air - Helium

Standards (percentage)

	MnO	TiO_2	Fe_2O_3
NH/H 9-56	3.20		
NH/H 13-56	2.09		
NH/H 26-56	1.241		
104A	0.43		
N.B.S.98		1.43	2.05
N.B.S.69A		2.78	5.82
W-1		1.10	11.18

Specimen Numbers	Series I Fe_K 57.5	Series II Mn_K 62.95	Series III Ti_K 86.08
F.B.1	4973	39.8	112.7
F.B.6	4402	27.6	96.3
F.B.8	4522	33.4	114.2
F.B.10	5099	52.1	75.3
F.S.1	5027	26.9	110.0
F.S.2	5334	12.6	112.1
F.S.3	5154	22.7	112.2
F.S.6	5471	18.2	118.2
F.S.10	5069	20.4	117.5
N.B.S.98	388	-	68.6
N.B.S.69A	1250	-	122.0
W-1	2128	-	47.1
N.B.S.104A		69.27	
NH/H 9-56		541.57	
NH/H 13-56		296.25	
NH/H 26-56		202.17	

Some interesting results were obtained from the refractive indices - TiO_2 and total FeO content.

Hall (1941, p. 34) criticized previous workers who, he claimed, had over simplified the correlation of refractive indices of biotites with their chemical composition.

It is fairly well established that Fe", Fe"', and Ti, when substituted for Mg in increasing amounts are liable to raise the refractive index. However, the role that Mn, Zi, and Cr play is more difficult to assess. In addition, other minor elements and oxidation are liable to raise the refractive index.

As seen from Table XVIII there is little relation between the refractive index of the biotites and their iron content; a similar observation was made by Hall. Hall's plotting of refractive index against iron content (analyses obtained from published literature during the past 40 years) results in the biotites occupying two main fields. Field I are those biotites which contain iron and titania; and those containing iron, titania, and MnO in excess of 0.50 per cent in field II.

Kunitz (1929, p. 508) has shown that the refractive index of biotite increases with increasing titania content, provided that the amount of iron remains practically constant.

Using the analysis of a siderophyllite which contains practically no titania, and comparing its refractive index with a biotite containing the same amount of total FeO and a relatively high percentage of titania, he calculated the effect that 1 per cent of TiO_2 raises the refractive index.

Using this constant and adding the product of percentage TiO_2 x constant to the refractive index value obtained from the straight line relation of refractive index and total FeO content, the calculated results are compared with the observed results in Table XVIII.

It can be seen that in all cases but one, the calculated values of Nz are lower than the observed values of Nz. These are similar to Hall's observations, that in some cases the limits of error are small, and at other times the discrepancy is somewhat large.

Hall suggests that a possible solution to the noted error may lie in the Fe_2O_3, Ti_2O_3, MnO presence in the biotites. From table XVIII it can be seen that the MnO content does not appear to have any direct relation to the refractive index. However, what influence the remaining two oxides have on the refractive index cannot be ascertained as they were not determined.

From the above limited results the author finds himself in complete agreement with Hall, "it may be said that no sure information can be obtained as to the chemical composition of a biotite from its refractive index alone, since a biotite which is high in iron and low in titania may have the same refractive index as one which is low in iron and high in titania".

Summarizing the results obtained from the garnet and biotite analyses it is apparent that the MnO content, in both cases, decreases from the biotite-muscovite schist zone to the sillimanite schist zone. The FeO content varies inversely to the MnO content with one exception in both minerals.

From these results it appears that the sillimanite schists do, in fact, represent a higher grade of metamorphism than the non-sillimanite schists, so that we can consider, in this case, that the sillimanite has a legitimate use as an index mineral of metamorphic grade.

METAMORPHIC FACIES

The mineral assemblage of the biotite-muscovite schist has few criteria for establishing a rigid facies boundary. The limited occurrence of garnet within this rock type serves as a reasonably diagnostic mineral of metamorphism.

The association biotite-muscovite-almandine probably falls into the almandine zone of metamorphism occurring in the higher grade of the epidote-amphibolite facies. However, the lack of epidote could possibly indicate a slightly higher facies grade.

Tentatively this rock can be placed at the boundary of the epidote-amphibolite facies. The amphibolite rock groups, although representing a different type of mineral assemblage, should also indicate the same grade of metamorphism as the biotite-muscovite schist, as these rock types are intimately associated with one another.

Amphibolite

Epidote makes its appearance in the amphibolites but has erratic distribution. Assuming that the epidote is in equilibrium with the plagioclase, which has an average An content of 35 per cent, we can infer the following conclusions.

Ramberg's (1952, p.150) epidote-plagioclase equilibrium diagram places the boundary of the epidote amphibolite -

amphibolite facies at the equilibrium point epidote - An 30. More calcic plagioclase indicates a higher grade. This would place these amphibolite rocks in the lowest range of the amphibolite facies. The remaining chlorites and hornblendes are stable within this facies.

Ultrabasic Amphibolite

The ultramafic amphibolites should indicate the same grade of metamorphism as the two previous rock groups, as they are all intimately associated.

The mineral assemblage in this group is tremolite, chlorites, dolomite and olivine. According to Ramberg (1952, p. 147) tremolite should invert to diopside in the amphibolite facies,

Quartz + tremolite + 3 Calcite 5 Diopside + 3 CO_2 + H_2O

however, the non-existance of free silica may inhibit this reaction.

The olivine appears to be in equilibrium with the rest of the minerals in the rock. Turner (1948, p. 91) gives the association Tremolite - Forsterite - Calcite as a stable assemblage of metamorphism corresponding to the low amphibolite facies.

Impure Dolomitic Limestone

Ramberg (1952, p. 147) gives the equation

$$2\ SiO_2 + 3\ CaCO_3 + \underset{\text{(Tremolite)}}{Ca_2Mg_5Si_8O_{22}(OH)_2} \rightleftharpoons 5\ \underset{\text{(Diopside)}}{CaMgSi_2O_6} + 3\ CO_2 + H_2O$$

as the inversion point of epidote amphibolite facies amphibolite facies, which places this rock group, with its abundance of diopside, in the amphibolite facies.

The large mineral assemblage in the impure dolomitic limestone appears to be in equilibrium. The association of micas, hornblende, and dolomite is not unstable even if diopside is stable, provided that free silica does not exist in the marble (Ramberg 1952, p. 153). As we have seen, free silica does not exist, minor quartz occurrences are surrounded by reaction rims of diopside and tremolite.

The bluish-green colour of hornblende in this rock type appears to be characteristic of hornblende in the amphibolite facies as described by Miyashiro (1953b, p. 89) in his study of calcium-rich rocks in the Gosaisyo-Takanuki district.

Sillimanite-Biotite-Muscovite Schists

As pointed out by Francis (1956, p. 358) Ramberg describes the breakdown of biotite at high temperature in terms of its two end members:

$$\text{Fe-biotite} + \text{Muscovite} + 3\ \text{Quartz} \rightleftharpoons 2\ \text{K-feldspar} + \text{Almandine} + 2\ \text{Water}$$

$$\text{Phlogopite} + \text{Muscovite} + 3\ \text{Quartz} \rightleftharpoons 2\ \text{K-feldspar} + \text{Pyrope} + 2\ \text{Water}$$

and places these two reactions within the granulite facies for MnO free garnets; the first reaction occurring at a lower grade than the second.

Francis thinks that these reactions are placed at too high a grade, as muscovite and quartz become unstable at about the middle of the amphibolite facies.

The sillimanitization of biotite can also come about by other means

Fe-biotite + dissolved Kyanite ⇌ K-feldspar + Sillimanite + Magnetite + Water

This reaction is put forward by Francis (1956, p. 358) to account for an occurrence of sillimanite that Tozer (1955) described, which is very similar to the occurrence in the map area. Both occurrences lack K-feldspar, Tozer (loc.cit.) suggests that (K, Mg, F and (OH)) have been expelled, only Fe, as magnetite, remaining in the system. In the case of the lack of K-feldspar in the map area, the potassium is thought to have been taken up by a later formation of muscovite.

This reaction is placed by Francis (1956, p. 359) in the sillimanite-almandine subfacies at the top of the amphibolite facies.

The occurrence of the intimate relationship of sillimanite and garnet was accounted for by the reaction

3 Staurolite + 2 Quartz ⇌ Almandine + Sillimanite + 3 Water

which, according to Francis (1956, p. 359) should be grouped in the kyanite-muscovite subfacies (in a broad sense this subfacies includes the three pairs andalusite-muscovite, sillimanite-muscovite, and kyanite-muscovite, and is located in the lower part of the amphibolite facies).

This conclusion appears to be in contradiction to the facies established by the biotite-sillimanite breakdown which belongs to the sillimanite-almandine subfacies. However, if we recall that the muscovite is thought to be of later origin, and therefore not necessarily in equilibrium with the rest of the rock, the conclusion is quite compatible, both modes of formation now belonging to the sillimanite-almandine subfacies, as defined by Francis (1956).

SUMMARY AND CONCLUSIONS

The Gabriel Lake West Sheet covers an area of 160 square miles and, from the centre of the map, is situated 18 miles west of Fort Chimo, Ungava Bay, New Quebec.

The area can be divided roughly into three main geologic units with a northwest trend.

Passing through the centre of the map is a spindle shaped belt of "Trough" type rocks comprising basic metavolcanics, intrusives, and metasediments.

To the southwest of this "Trough" type belt occurs a pink and grey gneiss. A grey gneiss is found to the northeast of this belt and is thought to be a metasomatized equivalent of the "Trough" type rocks.

A detailed petrographic study was made of five major rock types occurring within the "Trough" type belt of rocks.

1) Amphibolite
2) Ultrabasic amphibolite
3) Impure dolomitic limestone
4) Biotite-muscovite schist
5) Nodular sillimanite-biotite-muscovite schist

In attempting to classify the grades of metamorphism of the five rock types it was found necessary to carry out partial chemical analyses on garnets and biotites, by means of X-ray analyses, on rock types 4 and 5 in order to understand their relation to the grade of metamorphism.

Due to the close association of sillimanite with granites and granitizing solutions, current geological literature is casting doubt on the validity of sillimanite as an index mineral of metamorphic grade. In addition, since the formation of sillimanite is dependent on the chemical composition of the host rocks, and chemical analyses were not obtained on the two rock groups, there was reason to suspect that the sillimanite schist and non-sillimanite schist belonged to different grades of metamorphism.

Total FeO and MnO contents were determined on the biotites and garnets belonging to the two respective rock types, numbers 4 and 5.

The results showed a decrease of MnO in the garnets and biotites from rock type 4 to rock type 5. The converse relation, with one exception, was exhibited by the FeO content.

The relation of Mn content decreasing with increasing metamorphism, and the Fe content increasing with increasing metamorphism, has been fairly well established. Hence, it was inferred that the biotite-muscovite schist belonged to a lower grade of metamorphism than the sillimanite-biotite-muscovite schist and that the sillimanite appears to be in this case, an index mineral of metamorphic grade.

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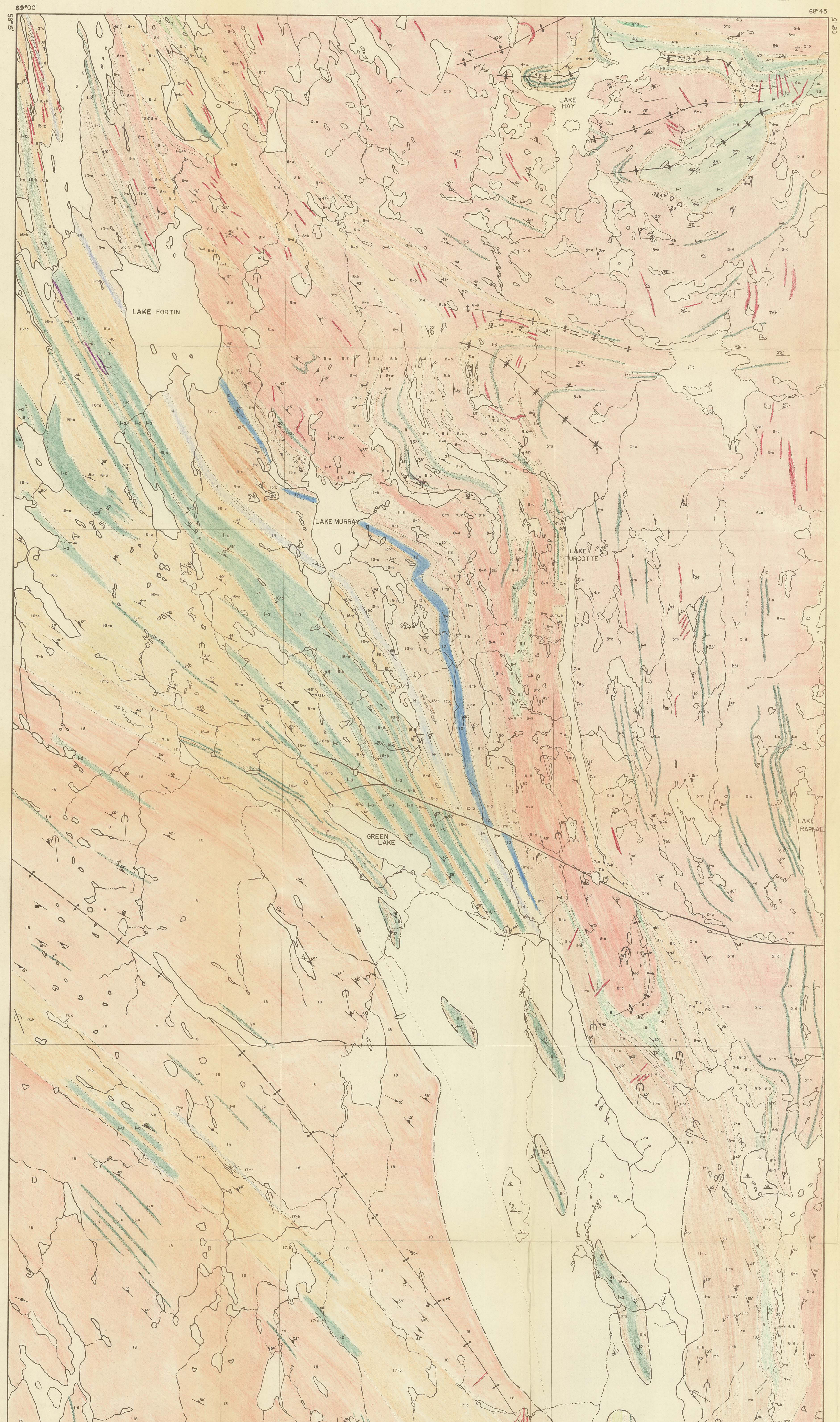


I

GABRIEL LAKE AREA

WEST PART

NEW QUEBEC

LEGEND

PLEISTOCENE

Boulders, gravel, sand, clay.

PRECAMBRIAN

Pegmatite.

1a, 1b — 1-a Amphibolite, 1-b ultramafic amphibolite.

2 — 2- Diopsidic amphibolite.

3 — 3- Blochy amphibolite, (leopard amphibolite).

4a,b,c; 4d; 4e — 4-a Biotite-muscovite schist, 4-b biotite-muscovite-garnet schist. 4-c biotite-muscovite-sillimanite schist, 4-d calc-silicate rock, 4-e iron formation.

5a,b; 5c — 5-a Gray gneiss, (plagioclase, quartz and minor biotite; locally actinolite, calcite, diopside also present), 5-b augen gneiss, 5-c iron formation.

6a,b; 6c — 6-a Biotite-muscovite schist, 6-b biotite-muscovite-sillimanite schist, 6-c lentils of calc-silicate rock. With abundant thin layers of amphibolite.

7a,b,d; 7c — 7-a Biotite-muscovite schist, 7-b biotite-muscovite-sillimanite schist, 7-c lentils of calc-silicate rock, 7-d dolomite. With few thin layers of amphibolite.

8a; 8b; 8c; 8d-e; 8f — 8-a Gray gneiss, (quartz, plagioclase with minor biotite and muscovite,) often characterized by lenses rich in biotite an irregular grain size, 8-b gray gneiss, (plagioclase, quartz and minor biotite), 8-c gray gneiss with abundant diopside, actinolite and calcite, 8-d biotite-muscovite schist, 8-e biotite-muscovite-sillimanite schist, 8-f diopside-biotite schist.

9 — 9- Diopside-biotite schist.

10 — 10- Nodular sillimanite gneiss (quartz, plagioclase with minor biotite and muscovite).

11a,b; 11c; 11e — 11-a Nodular sillimanite-biotite-muscovite schist, 11-b nodular sillimanite-biotite-muscovite schist with garnet in matrix and nodules, 11-c biotite-muscovite schist with a trace of sillimanite, 11-d calc-silicate rock, 11-e gray gneiss, (quartz, plagioclase with minor biotite and muscovite).

12 — 12- Impure dolomitic marble.

13a,b; 13c — 13-a Nodular sillimanite biotite-muscovite schist, 13-b biotite-muscovite nodular sillimanite schist with garnet in matrix and nodules, 13-c biotite-muscovite schist.

14 — 14- Impure dolomitic marble with thin layers of amphibolite.

15 — 15- Biotite-muscovite schist with thin layers of amphibolite.

16a,b — 16-a Biotite-muscovite schist, 16-b biotite-muscovite-garnet schist, 16-c biotite-muscovite schist with numerous thin layers of amphibolite.

17a,b; 17c — 17-a Nodular sillimanite-biotite-muscovite schist with thin layers of amphibolite, 17-b biotite-muscovite schist, 17-c calc-silicate rock.

18 — 18- Pink and gray gneiss, (plagioclase, quartz, microcline with minor biotite).

Note: 7-c, 8-c, 8-d, 8-e, 8-f, 11-c, 11-d, 11-e, 13-c, appear at different horizons in the formations.

SYMBOLS

(a) 25° (b) — Strike and dip of schistosity and gneissic structure: (a) inclined, (b) vertical.

(a) (b) (c) — Geological boundary: (a) located, (b) approximate, (c) assumed.

25° — Strike and plunge of lineation.

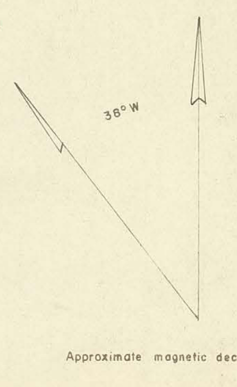
(a) (b) — Fault: (a) observed, (b) inferred.

(a) (b) — Axis of anticline: (a) known, (b) inferred.

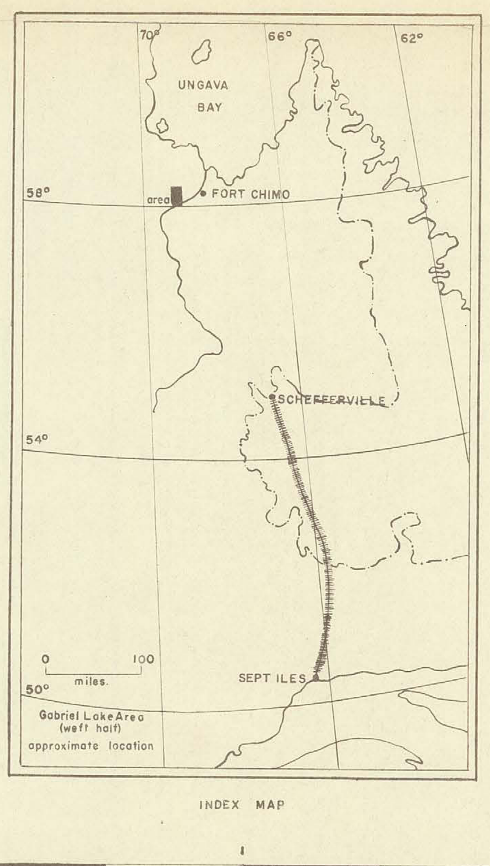
(a) — Axis of syncline: (a) known.

Glacial striae.

Drift boundary.



Approximate magnetic declination 38' West.



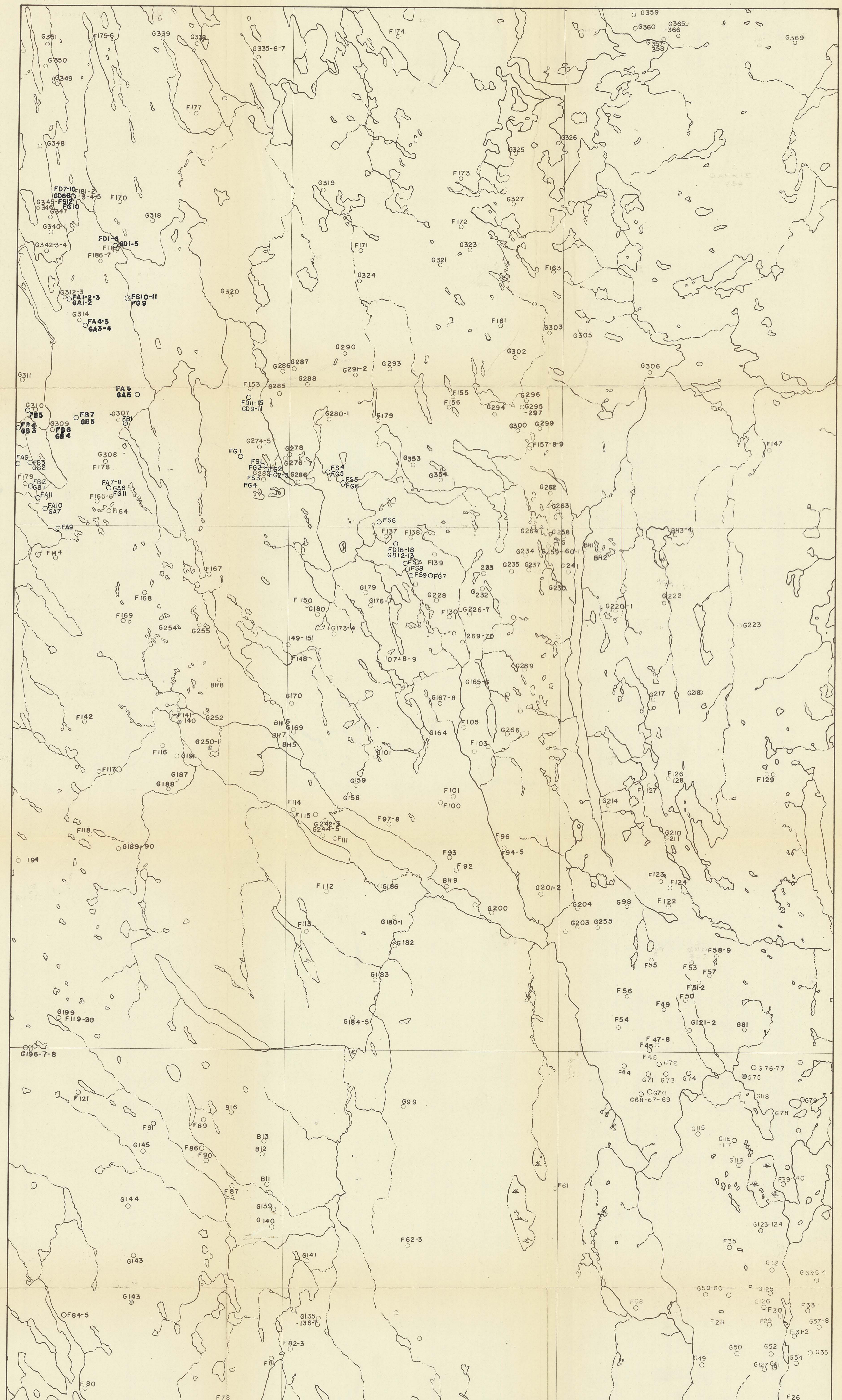
INDEX MAP

0 1 2

MILES

SCALE: 2640 feet to inch

GEOLOGY BY: L. GELINAS



LEGEND

- PEGMATITE
- AMPHIBOLITE
- DIOPSIDIC AMPHIBOLITE
- BLOCHY AMPHIBOLITE
- BIOTITE - MUSCOVITE SCHIST
- GRAY GNEISS
- DIOPSIDE - BIOTITE SCHIST
- NODULAR SILLIMANITE GNEISS
- IMPURE DOLOMITIC MARBLE
- PINK AND GRAY GNEISS

NUMBERS SHOW SPECIMEN LOCATIONS

38°W

Magnetic declination

0 1 2

SCALE 2640 feet = inch

II

GABRIEL LAKE AREA

WEST PART

NEW QUEBEC