METAMORPHISM
At The
ANDREW YELLOWKNIFE PROPERTY
NORTHWEST TERRITORIES

A Thesis

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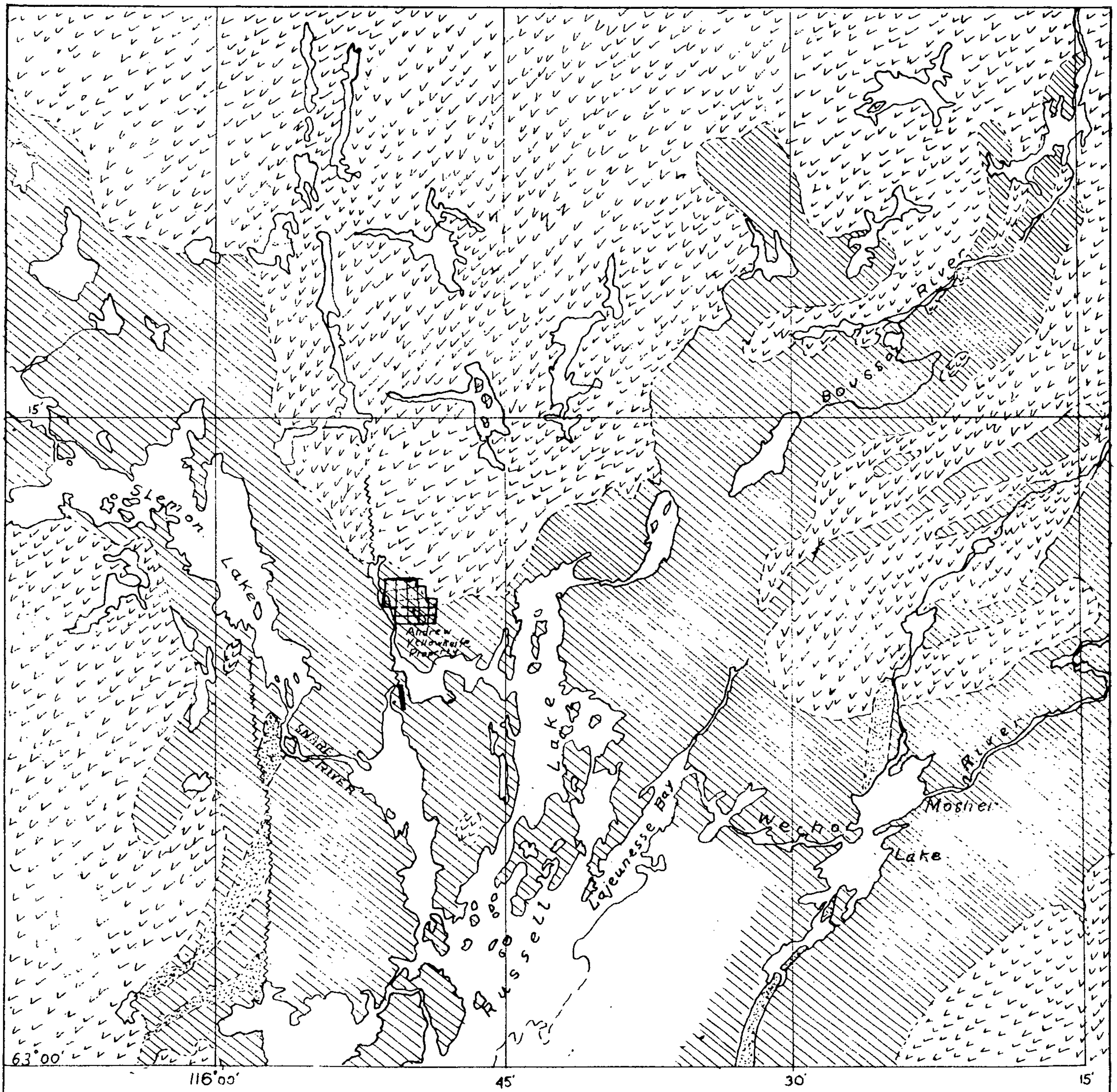
ABSTRACT

A study of Precambrian sedimentary rocks belonging to Division three of the Yellowknife group has been made. Samples for this study were obtained from an area 2 miles north of the northeast arm of Russel Lake near the granite contact. The rocks are greywacke, arkose and phyllite that have suffered low grade regional metamorphism. Shear zones that parallel the strike of the sediments have provided channelways for mineralizing solutions so that these zones now constitute mineral deposits important for their gold content. The shear zones contain, in addition to quartz and sulphides, an intergrowth of grunerite and hornblende ~~much~~ similar to that found in the iron-bearing district of Lake Superior. This amphibole intergrowth is particularly well developed in an assemblage of thinly banded sediments containing a narrow (about 4") iron formation.

Although Almandite garnet is found to a small extent in the shear zones, it is the characteristic wall rock alteration of these zones.

An attempt has been made to show that the elongated "quartz pebbles", which occur in the shear zones, are of hydrothermal origin.



MAP SHOWING LOCATION
Of The
ANDREW ' PROPERTY

Granite	Archean	YELLOWKNIFE GROUP	
Volcanics			
Sediments			
Fault			

Scale 1 inch = 4 Miles

Traced from G.S.C. Map 690A - Snare River

CONTENTS

Page

ILLUSTRATIONS

PREFACE

During the greater part of the 1947 summer season, the writer was in charge of the Andrew Yellowknife Mines Limited. Although the property did not prove to be economic, certain features of it posed an interesting problem and provided good material for the subject of a thesis. For example, the origin of the quartz pebbles and their relation to the gold was a moot point that could be settled only in the laboratory.

A suite of over sixty specimens was collected. Thin and polished sections of these together with field observations provided the information on which the conclusions of this thesis are based.

As the work progressed it became evident that the area from which the specimens were obtained provided an interesting and absorbing study of regional metamorphism and hydrothermal alteration of Precambrian sediments.

The work, therefore, resolved itself into these various problems:

1. A description of the Precambrian sediments of the Yellowknife group in the area in question with special emphasis on the metamorphism they have undergone.

2. A study of a thin band of iron formation.

3. A study of hydrothermal alteration in the mineralized shear zones and of the paragenesis.

4. A detailed description of the "quartz pebbles" in these shear zones and an attempt to provide a satisfactory explanation for this unusual geological phenomenon.

ACKNOWLEDGMENTS

The writer is much indebted to George Radisics, engineer in charge of the Andrew Yellowknife Mines Ltd., who not only placed at the disposal of the writer all the available information on the property but also gave much encouragement in carrying on this study.

It is a pleasure to acknowledge the aid received from various members of the Geology Department and in particular from Dr. Gunning under whose supervision and guidance this work was carried out.

Thanks are also due to Dr. C. S. Lord of the Geological Survey of Canada for some of his photographs which are included in the thesis.

INTRODUCTION

Location:

The property is located north of the northwest arm of Russel Lake and just east of Andrew Lake in the Yellowknife Mining Division, Northwest Territories, at latitude 65° 11' and longitude 115° 30'. It is approximately 75 airmiles northwest of Yellowknife. (See Plate 1)

Accessibility:

The property can be reached by barges with average draught of from 2½ to 3 feet by way of the northwest arm of Great Slave Lake, thence through Russel Lake.

Andrew Lake is sufficiently large and deep to make the claims readily accessible by air, using the usual Norseman types of planes or smaller aircraft.

Claims:

The property consists of twenty patented Mining Claims bearing designations L45 to L64 inclusive and disposed as shown on the accompanying map. Total acreage is about 1,000 acres.

History:

The claims were staked in the summer of 1945 by Andy Bugow for Frederick Yellowknife Mines Ltd. and were later acquired by Bryhern Exploration for cash and a number of shares in the newly incorporated Andrew Yellowknife Mines Ltd.

Exploration work amounting to 7,800 feet of diamond drilling and 900 cubic yards of rock trenching was carried on during the summers of 1946/47.

Fig. 1 — Showing Relief . View looking northwest south of Cabin Lake.

Topography:

The area is one of low relief but in detail the surface is quite rugged. Rock outcrops form sharp prominent knobs rising 20 to 50 feet above the intervening muskegs. The lower depressions are occupied by lakes. (Fig. 1 and 2)

Fig. 2 - Andrew Camp. Note low relief.

Pleistocene and Recent Geology:

Glaciation and post-glacial action have played an important part in giving the country its present appearance.

The average strike of seven measured ice striae was S. 55°W. The strike of the sediments is approximately at right angles to the ice movement and these two factors have determined to a large extent the shape of the outcrops. They tend to be elongated in the direction of ice movement or parallel to the strike of the sediments.

Boulders are common but found only on rock outcrops. The intervening areas between the outcrops consist of clays and silts. These were examined closely where the overburden had to be stripped to expose part of a mineralized zone at the southern end of claim L55. Here the deposit consisted of poorly sorted, rudely banded sands, silts and clays. The samples obtained from this locality were washed free of silt and clay which made up about 65% of the volume. The remaining 35% consisted of a medium to fine sand averaging 1/100" in size. The largest fragment measured was 1/5" in diameter.

The fragments consisted of about 50% quartz, 40% feldspar and 10% of hornblende, mica flakes, olivine, magnetite, ilmenite and 3 or 4 pyrite grains.

The grains were well rounded to angular, smaller grains being better rounded. Coarse feldspar grains displayed cleavage faces.

It appears, therefore, that a post-glacial lake occupied this area in which these sandy silts and clays rapidly accumulated. Rock outcrops were apparently swept bare of drift material by wave action leaving only the large boulders.

BEDROCK GEOLOGY

General Statement

The claims are underlain chiefly by Archean rocks of Division three of the Yellowknife group[1] and consist of greywackes, arkoses and some phyllites. They trend in general N 55° W and dip steeply to the southwest. An extensive granite area lies just east of the property and the contact between the granite and sediments passes through the north-east part of the property, the granite forming a nose protruding into the sediments at this point. The granite contact dips about 45° to the southwest under the sediments.

Pegmatite dykes and pegmatitic quartz veins (Fig. 3) are fairly

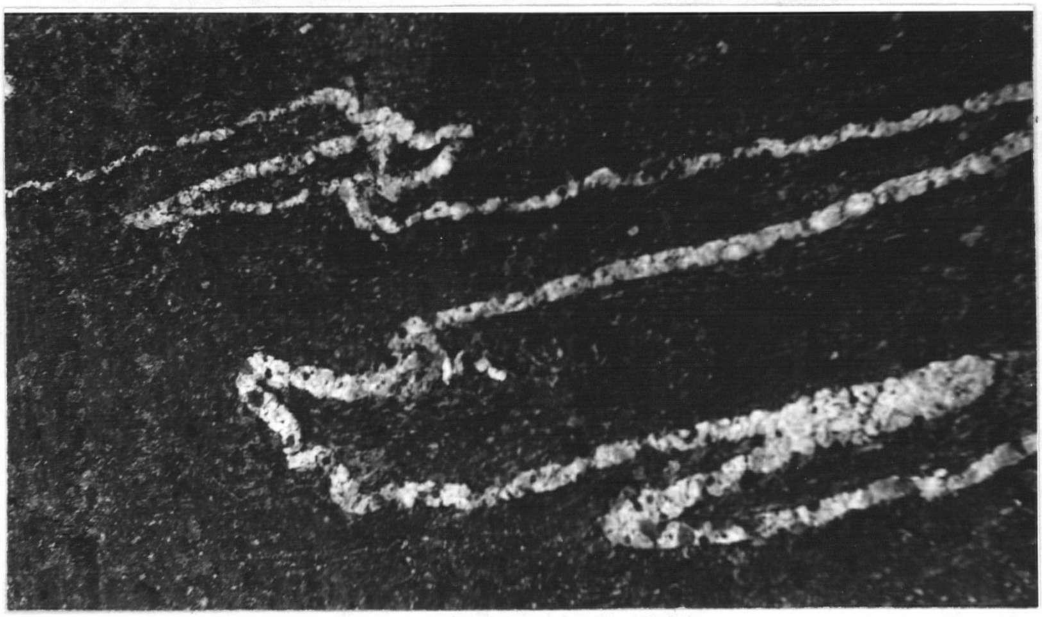


Fig. 3 - Pegmatitic Quartz Veins

numerous particularly in the northern section near the granite contact. On claim L47 a diabase dyke cuts a pegmatite dyke. Two acid dykes occur, one on claim L61 and the other on claim L58. Both cut through mineralized shear zones.

[1]Lord, C.S. "Snare River and Ingray Lake Map-Areas Northwest Territories" Geol. Surv. Canada, Mem. 235 PP. 9 and 14.

The Granite

A nose of granite forms part of the rocks underlying the property in the northeast corner. This granite is medium grained, with small patches of coarse pegmatitic phases. Two prominent sets of joints striking N-S and S 60° W and dipping steeply, give it a blocky appearance. The latter set is sometimes occupied by pegmatitic quartz veins; small pegmatites and pegmatitic quartz veins were noted to occupy the former set.

The plutonic mass dips about 45° under the sediments and platy flow structure was observed close to the contact. Here the tabular feldspar crystals and the muscovite plates tend to be oriented with the largest face parallel to the contact.

In thin section the following minerals were noted: quartz 25%, albite 30%, orthoclase 20%, microcline 10%, muscovite 13%, and fluorite 2%. The rock has typical granitic texture. The albite and orthoclase are in part intergrown (is myrmekitic). Muscovite forms irregular ragged interstitial flakes. It is tinged green and is pleochroic. Twinning on 110 plane is common. In hand specimen the muscovite parts readily along the twinning plane. It has a honey-yellow color suggesting the presence of iron. However, under the microscope it has a 2V of 40° and the mean index was found to be between 1.588 and 1.578. These optical properties indicate that it approaches the composition of pure muscovite.

The fluorite occurs as rounded grains usually in the albite. It is tinged purple and has deep purple spots. Under high power these spots seem to be due to inclusions. It is possible that they are due to the presence of minute amounts of radioactive elements.

Pegmatites

As might be expected from the proximity of a large granite body, pegmatite dykes are numerous in the area. They vary in size from a few inches to several feet across and some can be traced for lengths of as much as 500 feet. They strike in all directions but the trend of the majority follows three directions, namely N 40° E, N-S and parallel to the bedding. The first two directions conform with the strike of the two most prominent sets of joints. They cut, and are cut, by irregular pegmatitic quartz veins. In many instances the dykes are offset by slips parallel to the bedding and by the mineralized shear zones. Offsets vary from 2 to 3 inches by minor slips to 25 feet by shear zones.

Almost all are composed entirely of coarse grained orthoclase, quartz, and minor amounts of albite and muscovite. However, one large dyke on claim L60 that strikes N 75° W contains considerable lepidolite. Its color is violet and it is quite coarse grained with good twinning on 110 along which parting is easily affected. 2V varies from 20 to 40 degrees. The mineral gives an excellent flame test for lithium.

Along with lepidolite, but sparsely distributed, are coarse crystals of a green mineral with a greasy lustre. It has all the optical and physical properties of serpentine. It is clearly a pseudomorph after some other mineral which may possibly have been hornblende.

The large pegmatites in the northern end of the property are worthy of special attention since they exhibit distinct banding throughout the whole width of the dyke. Alternating bands of feldspar, quartz, and a fine grained granite phase parallel the strike of the dykes. The layers of quartz and feldspar are between 1/4 to 1/2 inch thick and sometimes grade into each other.

The granite phase forms bands usually an inch to two inches across. The band next to it may be either a feldspar layer or a quartz layer but the crystals usually show preferred orientation with long dimension of the crystals perpendicular to the strike of the bands. The muscovite of the granite band has a linear arrangement that parallels the strike of the dykes.

Because of the width of the dykes and the regularity of banding it is inconceivable that this layering is a result of fracture filling. A more logical explanation seems to be rhythmic precipitation. Rapid crystallization at the borders of the dyke would give a granite band while the liquid immediately adjacent to this band would be enriched in fluids and feldspar and quartz constituents. These would then crystallize leisurely forming relatively narrow coarse grained bands of feldspar and quartz. The pegmatitic liquid, however, being in constant motion would carry away the attenuated fluids and a new granite band would crystallize from the new pegmatitic liquid. Repeated surges of the magmatic material would thus result in the formation of these alternate bands.

The Diabase

A diabase dyke about 12 feet wide and exposed for a length of 50 feet cuts a pegmatite in the northwest corner of claim L47. Megascopically it is fine-grained and appears chloritized and is slightly mineralized by pyrite.

In thin section it is clearly evident that the rock has undergone considerable alteration. It consisted originally of an open network of labradorite laths in a pyroxene matrix giving a sub-ophitic texture. Much of the labradorite has been partly altered to sericite which has a smaller optic angle than ordinary muscovite. The pyroxenes consist of augite and pigeonite. Optic angles vary from 20 to 50 degrees. The pyroxenes have been largely altered however to chlorite and uralite. Apparently there was a considerable amount of diffusion since rims of uralite are seen around a pyroxene crystal sandwiched between two altered crystals of labradorite. The sodium released from the alteration of the feldspar probably contributed to the formation of uralite. Irregular patches of chlorite occur both in the pyroxene and feldspar and between grain boundaries, while a considerable amount of carbonate has formed in the labradorite.

A few small grains of pyrite and magnetite are sparsely distributed while semi-opaque brownish cloudy masses of altered ilmenite are present.

The Porphyry

Two such dykes were observed, one on claim L61 and the other on L54. They are about 2 to 4 feet wide and can be traced only for short distances. Both cross shear zones and so are definitely younger than the shearing. The one on claim L61 contains inclusions of the mineralized zone and its injection has resulted in contortion and drag folding of the beds in the immediate vicinity. The dyke rock weathers a light grey but a fresh piece is greenish-grey and appears to be uniformly fine-grained. Microscopically, however, it consists of about 50% feldspar phenocrysts set in a fine-grained matrix of quartz, feldspar and muscovite. The phenocrysts average 3/100" in diameter and are composed of albite. The grains of the groundmass average 1/200" in diameter.

The feldspars have a cloudy appearance and are sericitized. The muscovite forms laths in the phenocrysts and tends to occur as irregular veinlets in the fine-grained groundmass. Some of it has been chloritized. The quartz shows wavy extinction and has sutured boundaries. A few grains of pyrite partly altered to haematite are also present as well as grains of leucoxene.

The rock was apparently fractured before it had completely solidified and the fractures are filled with deuteric muscovite.

The Sedimentary Rocks

Before going on to a consideration of the metamorphism of the sediments, it is necessary to describe them in some detail.

In the field these rocks form an interbedded succession of greywacke, arkose and phyllite, the former two predominating over the phyllite. The arkose weathers a light grey and has a rough sandy texture with angular to rounded grains of quartz and feldspar. They are clastic grains varying in size from 1/80" diameter in coarse arkoses, which are poorly sorted, to the lower limits of fine sand, i.e. 1/250"[1]. The greywacke is quite similar but weathers a darker grey or buff and contains more fine grained interstitial material.

Most of the rocks appear quite normal and seem to have suffered little or no metamorphism. They exhibit no schistosity or even tendencies towards any lineation. However, a few beds containing considerable chlorite and micas have a distinct schistosity. These weather a dark grey or dirty green color.

Beds range in thickness from a fraction of an inch to about 8 inches. Rarely do individual beds exceed this thickness except for a schistose bed that forms part of the wall rock along the southwest side of No. 2 Zone. This bed is about 12 feet across.

In thin section it was noted that the proportion of quartz is fairly consistent in all the rocks and varies between 45 and 55 per cent. The amount of feldspar, however, varies a good deal. The coarse grained sediments contain as much as 40% feldspar but this percentage decreases proportionately with decrease in grain size such that the fine-grained greywackes contain only about 5% feldspar. About 95% of the feldspar is albite, the rest being orthoclase. The interstitial clay material (now

1 Tyrrell, G.W. The Principles of Petrology P. 190

altered largely to chlorite and micas) also increases in percentage with decrease in grain size. Hence to summarize, a coarse arkose is composed of about 45% quartz, 40% feldspar and 15% fine flaky material now in the form of chlorite and micas, while a greywacke is made up of about ~~5.5%~~ 55% quartz, 5% feldspar and 40% micas. The composition of the rocks varies between these two extremes.

Not included in the above compositions are minor amounts of accessory minerals. They are rarely in excess of 1 or 2 percent. They are composed of small hexagonal grains of apatite, a few grains of zircon, and minor amounts of magnetite. But the chief accessory is a black opaque mineral, white in reflected light and semi-opaque brownish under high power. It is apparently ilmenite now altered to leucoxene.

Phyllite beds occur almost entirely on claim L61. They are dense, black thin-bedded rocks with good cleavage in places across the bedding. They are interbedded with thin quartzitic bands and arkose and greywacke. They are well sorted and the quartzitic bands grade into the dense black bands. (Fig. 4)

Fig. 4 - Phyllite Beds

METAMORPHISM OF THE SEDIMENTS

General Statement

Considering the proximity of a large intrusive mass and the age of these sediments they are remarkably fresh looking. Except for a few schistose bands they present no structures that characterize dynamically metamorphosed rocks. Nevertheless, the shear zones and drag folding in some beds (Fig. 5) indicates that the rocks have been subjected to strong

Fig. 5 - Z-shaped Drag Fold

shearing stresses. The microscopic study substantiates this fact. The deformation of quartz grains, their sutured boundaries and the consequent development of strain shadows is testimony of the enormous pressures once applied to these rocks. The textural and mineralogical changes in the rocks have, therefore, been due chiefly to dynamic metamorphism with little rise in temperature. The overall mineralogical composition indicates low grade metamorphism.

In a few instances, however, there has been addition of volatile components resulting in the development of tourmaline, but these metasomatic changes are confined to certain argillaceous beds. Metasomatism has played an important role in the assemblages of thin beds that contain the iron formation, but this case will be treated separately.

PRODUCTS OF METAMORPHISM

Before dealing with the actual chemical changes undergone by the original constituents of the sediments, let us first examine the minerals, now present in the rocks, individually.

Quartz:

As mentioned before this mineral is the most abundant constituent. It consists of clastic grains varying in size from 1/80" diameter to 1/250". It is difficult to determine the original shape of the grains since nearly all have suffered various degrees of metamorphism. They were presumably well-rounded to sub-angular. They now tend towards dimensional orientation, the long diameter parallel to, or making an acute angle with, bedding. They usually exhibit strain shadows and undulatory extinction and invariably produce a biaxial figure with a 2V of 10 to 20 degrees. Strain shadows show a tendency to be parallel to the bedding but often they are almost at 90° to the bedding even in crystals that are elongated along the strike. The inference is that the direction of strain shadows depends on the orientation of the grain and not on the direction of pressure. Considerable recrystallization has occured at grain boundaries where the brunt of the pressure was sustained and they now have sutured boundaries. In rare instances complete recrystallization has occured forming small pods or xenoblasts of quartz. Trains of minute fluid-pores are developed in parallel planes which are parallel to the strain shadows. An exceptionally broad band of one of these trains was observed in a quartz pod. (Fig. 6)

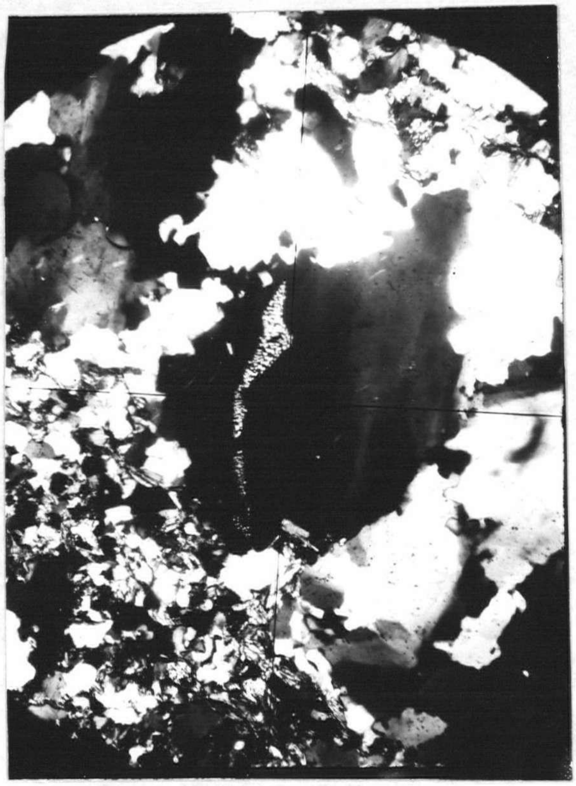


Fig. 6 - Fluid-pores in a Quartz Pod. Crossed Nicols X70

Feldspar:

The stress effects exhibited by quartz are little apparent in the feldspar. They show only occasional weak undulating extinction but secondary albite twinning was observed in one thin section. The twinning lamellae are very fine and sometimes end abruptly at a crack which has relieved the stress.

Under medium power the grains usually appear quite clear like the quartz, but under high power and condenser removed they have a cloudy appearance and contain small sericitic inclusions. A few large grains have long thin oriented laths of sericite and in the coarser arkose most of the albite has been converted to a fine scaly mass of sericite.

Biotite, Muscovite, Chlorite:

These three minerals are so closely associated that they are difficult to treat separately. They occur in varying amounts and proportions in all the sediments and result from the alteration of the fine sedimentary material between the quartz and feldspar grains.

All three are stress minerals and they show a marked tendency towards orientation, the largest face being parallel to the strike of the beds. They vary in size from numerous little flakes, that often serve to indicate the clastic nature of the rock, where metamorphism has not progressed far, to fewer larger flakes where metamorphism is more advanced.

In the early stages of metamorphism the fine interstitial material has, by the process of local solution and diffusion, collected into irregular patches and recrystallized as chlorite and muscovite. These two minerals have crystallized side by side sometimes with considerable increase in grain size without mutual reaction between them. The iron oxides have also collected as small irregular grains or patches disseminated throughout the chlorite and biotite. The chlorite-muscovite patches are lenticular shaped with the long axis parallel to bedding and the individual crystals in these patches are well oriented in the same direction. Sometimes these patches come to an abrupt stop against a large quartz grain. In other cases, in fine-grained sediments, the chlorite and muscovite are intimately intergrown and have been thrown into minute folds whose axes are perpendicular to the strike of the bedding. (Fig. 7)

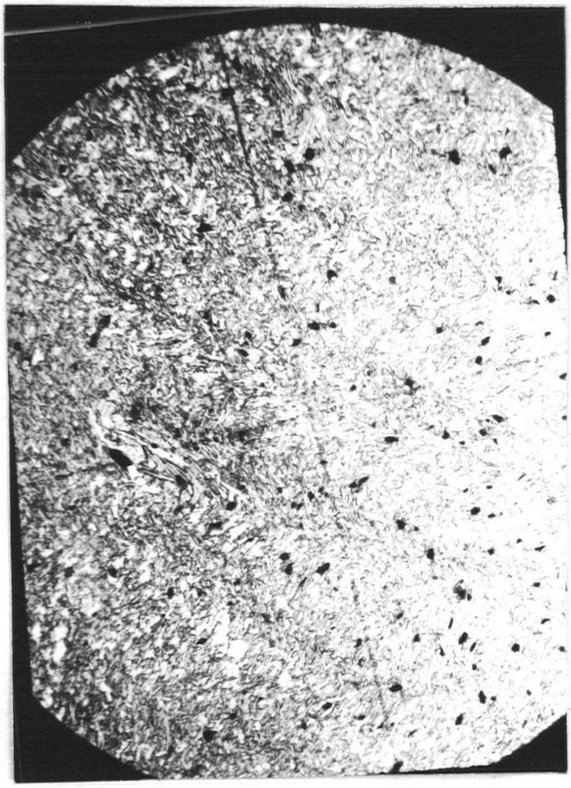


Fig. 7 - Intergrown chlorite and muscovite thrown into minute folds X70

These folds stop abruptly against a gritty band. The chlorite is light green, slightly pleochroic and biaxial negative with a 2V varying between 0 and 20 degrees. Its index is slightly higher than muscovite. It appears to be a relatively iron rich magnesium-free chlorite similar to daphnite.

In the more advanced stages of metamorphism the iron oxide, chlorite and muscovite have reacted to form biotite. This mineral is deep brown, strongly pleochroic and idioblastic towards all the other minerals. Although it tends towards orientation, the flakes are often arranged obliquely to the schistosity. The ore minerals have disappeared but the biotite grains have small round strongly pleochroic black patches that indicate local greater iron content probably due to lack of complete absorption of the iron-oxide grains. The chlorite too is usually absent but clear, well crystallized muscovite is intergrown with the biotite. This indicates lack of enough magnesia in the chlorite to convert all the muscovite to biotite.

Accessory Minerals:

Of the accessory minerals, apatite has suffered no change and still occurs as small hexagonal grains. The few zircon grains have of course undergone no change either. The ore minerals on the other hand have undergone considerable transformation. It has already been noted how they have reacted with other minerals to form biotite. It seems that these ore minerals were titaniferous or that rutile was originally present. Magnetite has reacted with the latter to form ilmenite which is now altered to a semi-opaque brownish mass of leucoxene. Some of these masses contain remnants of a network of rutile laths. This does not, of course, preclude the fact that ilmenite was originally present in the sediments.

Small amounts of tourmaline grains occur scattered throughout the rocks. They are small and exhibit poeciloblastic structure. In view of a special occurrence of this mineral which will be mentioned later, it is believed that the boron has been introduced and was not an original constituent of the sediments.

SPECIAL FEATURES IN THE METAMORPHISM OF THE SEDIMENTS

Sediments near the Granite Contact:

For a distance of about 50' from the intrusive mass, the mineral composition has been largely determined by the addition and subtraction of certain components brought about by fluids emanating from the igneous mass.

The sedimentary rock has a well developed schistosity and is coarser grained than most other sediments on the property. It has been entirely recrystallized and quartz grains attain diameters of 3/100". Trains of fluid inclusions crossing several crystals are numerous. Large oriented plates of muscovite lend the rock its schistose structure and apatite now occurs as large irregular grains. The muscovite is partly altered to chlorite and the irregular leucoxene grains are still present. (Fig. 8) Except for a few small remnants albite has been almost entirely

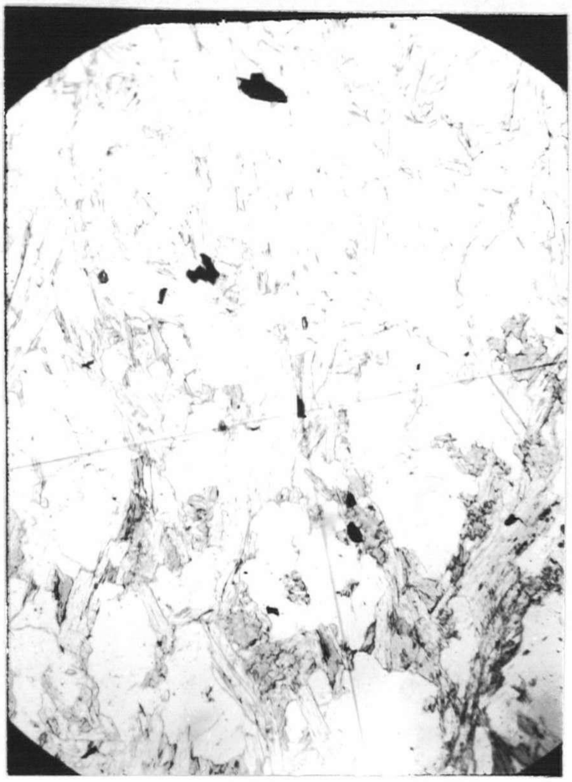


Fig. 8 - Sediments near granite contact. White-quartz; Light grey-muscovite; Dark grey-chlorite X70

removed. Obviously diffusion and recrystallization have been greatly aided by fluids emanating from the granite. Considerable potash to form muscovite has been added and soda and lime have been removed. In all probability, a little phosphate has also been added and with some calcium derived from the feldspar has reconstituted the original apatite grains into larger ones.

Spotted Sediments:

While drilling on the property, it was noticed that many polished surfaces of the drill cores had a spotted appearance as though porphyroblasts of a dark green mineral were present. The same was noticed on the surface of cut specimens. In thin section these are irregular light green areas with quartz, biotite and sometimes tourmaline inclusions, thus resembling a great deal xenoblasts having poeciloblastic structure. (Fig. 9)

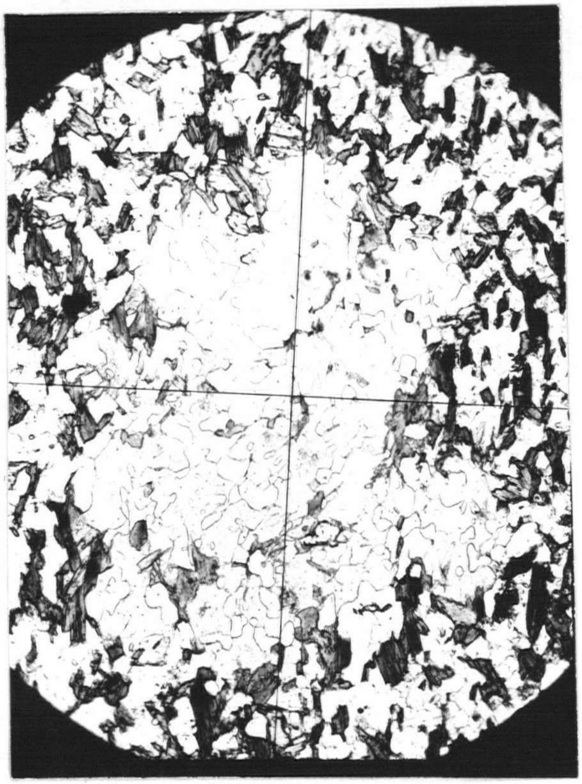


Fig. 9 - Spotted Sediment X 70

Under crossed nicols, however, they present a very fine mottled appearance. The interference colors are low, first order orange being the highest observed but due to the cryptocrystalline nature of the grains the birefringence is much stronger than is indicated. The index is intermediate between quartz and biotite. Patches of these small grains within the areas have a common orientation and seem to be in the process of forming large crystals. They appear to be composed of a very fine-grained scaly mass of sericite.

This occurence is analogous to the spotted slates and bears the same significance, that is they testify to low grade metamorphism. By comparing thin sections 4 and 58, it can be shown that these spots are at different stages of recrystallization. They vary from an indistinct cryptocrystalline mass to a minutely crystalline mosaic and finally to a fine scaly aggregate of muscovite plates. The spots have a tendency to be arranged along bands that contain a large percentage of micas and chlorite and are often surrounded by an aureole of intergrown muscovite and biotite. The occurrence of these spots is the result of local solution at isolated points in the rock where a considerable amount of solvent was present and where there may possibly have been a larger percentage of fine interstitial material. Some diffusion of material to the isolated points probably took place increasing the size of the spots. However, the physical conditions obtained were not favorable for the complete recrystallization of the amorphous substance in the spots. The temperature in particular was not raised sufficiently to effect the process of re-crystallization. It is true that biotite, which results from a higher grade of metamorphism has formed in the spotted sediments, but metamorphism goes on at a tardy rate and the rock is reconstituted gradually and piecemeal successively at different points in the rock. Solution, chemical reaction and consequent formation of new minerals did not take place as separate stages throughout the whole rock so that biotite was forming while solution was still going on. The spots express a late stage in the process of metamorphism when the agents of metamorphism were no longer capable of recrystallizing the substance segregated into the isolated areas.

Tourmalinization:

Metasomatic effects again manifest themselves in the tourmalinization of the argillaceous rocks. The presence of this mineral in abundance was noted in a fine-grained altered greywacke and in the phyllite. (Fig. 10)

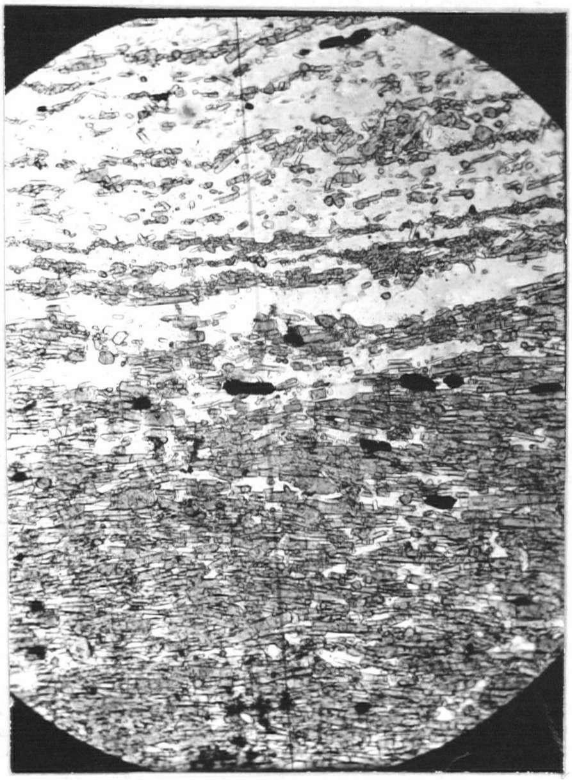


Fig. 10 - Quartz-tourmaline rock. Opaque mineral is leucoxene X 70

It is medium green in color with strong pleochroism. No lies between 1.6420 and 1.6521 while Ne is between 1.6218 and 1.6318. It is and iron rich tourmaline belonging to the dravite-schorlite series. It is to be expected that such a mineral will be associated with sediments of higher alumina content and hence it displays a gradual increase from the coarser quartzitic bottom of the beds to the finer argillaceous tops where it now constitutes about 90% of the rock.

Tourmalinization first began in the fine argillaceous material and then the biotite was attacked converting it into tourmaline. The little prisms of tourmaline have such a perfect orientation that they look like corded wood. They are often crowded along thin particular bands reflecting the original bedding of the rock. The coarser quartzitic bands contain considerable muscovite, some of it in the fine sericitic form.

Leucoxene grains are numerous and a few pyrite grains partly altered to haematite were noted.

There is little doubt that there has been considerable accession of boron. However, all the other constituents necessary for the formation of tourmaline were already present and probably nothing else was added. The potash present entered into the formation of muscovite while possibly some soda was removed.

<u>Retrograde Metamorphism:</u>

A certain amount of retrograde metamorphism has taken place. In several cases the biotite has been partially altered to chlorite. However, one case is worthy of special attention. Thin section No. 3 is a section of a fine-grained schistose sediment with irregular lenticular-shaped areas of chlorite. The chlorite is biaxial (-) with 2V from 0 to 20 degrees. These areas are replete with small dark needles arranged in radiating clusters. (Fig. 11 and 12) The needles under high power are brown ~~semi-~~ semi-opaque to transparent and have parallel extinction. Their index is high but the strongest birefringence observed was .030. The needles, however, are so thin that their maximum birefringence is probably much higher than that. The properties of this mineral, therefore, conform with those of rutile. Some chlorite grains show fairly high birefringence and perfect basal cleavages, and small muscovite plates are fairly plentiful.

This seems to be a case of retrograde metamorphism in which biotite was altered back to chlorite with the consequent formation of

Fig. 11 - Chlorite lenticles with rutile needles. X 70

Fig. 12 - No. 11 highly magnified to show rutile needles. X 280

rutile needles and muscovite. Such a transformation involves the addition of water. Whether this water is of meteoric origin or not is unknown. It has already been shown how fluid emanations have played an important role in the reconstitution of some sediments and water could easily have been derived from the same source as these fluids.

SUMMARY

In a general way the metamorphism of these sediments corresponds to the biotite zone and is a result chiefly of dynamic metamorphism. ~~The metamorphic minerals produced are stress-minerals.~~ The spotted sediments indicate arrested metamorphism and testify to the low grade of metamorphism. It has been difficult to completely divorce metamorphism from metasomatism. The latter could probably be defined in terms of the first as metamorphism plus the addition and subtraction of some constituents. In many cases it is impossible to tell whether water, which plays such an important role in metamorphism, was already present in the rock or was derived from a foreign source.

The fine detrital interstitial material was apparently high in iron and potash but too deficient in magnesia to convert all the chlorite and muscovite to biotite.

THE IRON FORMATION

Occurrence

An interesting feature of the rocks in this area is the présence of a thin band of iron formation. It occurs in an assemblage of thin bedded sediments on the west side of the property just west of the No. 1 Zone. Where best exposed on an outcrop just north of the trail running east from the camp on claim L53, the sediments consist of thin beds ranging in thickness from 1/8" to about 3 inches and average 1/2". The assemblage is about 35 feet across and the upper part grades into coarser greywacke and arkose. The beds have a very fine sandy texture and weather shades of green and light brown to dark reddish-brown. They are considerably drag folded and pegmatitic quartz lenses parallel or cut across the bedding. The lower part of the assemblage contains considerable quartz pebbles and below these occurs a 45 band of an iron formation.

The formation consists of haematite-rich bands with a little magnetite and pyrite. The haematite is usually concentrated into two or three layers about 1/4" thick and one inch apart. Sometimes, however, it is uniformly distributed over a width of 2 or 3 inches, but generally with some concentration along very thin bands.

The formation can be traced southward along the strike and on one outcrop on claim L57 the haematite occurs as specularite admixed with quartz and limonite. The quartz is medium grained and colored rose and has well developed crystal faces. It is due to solution and reprecipitation in situ. The limonite of course is a result of hydration of the haematite.

Microscopic Study

In thin section the thinly-bedded sediments consist of amphiboles and quartz with minor amounts of iron oxide and pyrite. The proportion of quartz and amphibole varies and either one or the other predominates giving the rock a rough banded appearance. Some bands are made up entirely of amphibole.

The quartz is clear but under crossed nicols it shows strain shadows and, commonly, sutured boundaries.

The amphibole includes two minerals. One is colorless non-pleochroic, biaxial (-) with a 2V of 80° and extinction angles up to 16° with a birefringence as high as .045. It is probably grunerite. The other is bluish green, strongly pleochroic, biaxial (-) with a 2V 70° ~~and~~ and extinction angles up to 20°. The birefringence is moderate (.025). The mineral is hornblende with a high ferro-ferric ratio. The two amphiboles are intimately associated and quite often intergrown but the hornblende is more abundant. They occur as blades or laths oriented in various directions presenting a decussate structure but with a tendency to parallel the bedding of the rock. Sometimes a blade of amphibole consists in part of grunerite and in part of hornblende. The cleavage runs from one to the other, showing that both are part of the same crystal but these show a slight difference in extinction. Occasionally they occur in radiating clusters. The grunerite may form the nucleus of the cluster, surrounded by the hornblende as though it were an added growth and in other instances the opposite occurs. Grunerite is commonly twinned and in rare cases the twinning lamellae consist of alternate grunerite and hornblende lamellae.

Haematite occurs as flakes scattered throughout the rock. They usually have a blood-red color in reflected light but sometimes they remain quite dark. They are small with frayed borders and parted along the cleavage. Quite often they are intergrown with the grunerite as though the two had formed together.

A crushed sample of the rock reveals that it contains quite a few magnetic grains. This magnetite is at times difficult to discern in thin section and may be confused with haematite that does not show the red color in reflected light. It seems to occur scattered along certain bands, and to have been pyritized.

A thin section was made of the rock containing two haematite bands. The mineral assemblage between the bands is much the same as already described, except that quartz grains and haematite flakes are more abundant and the minerals are better oriented parallel to the bedding. There is a rather abrupt change as the haematite bands are approached. The proportion of haematite flakes rapidly increases and the quartz almost entirely disappears. (Fig. 13 and 14) The green hornblende too becomes

Fig. 13 - Grading into haematite band. X 25

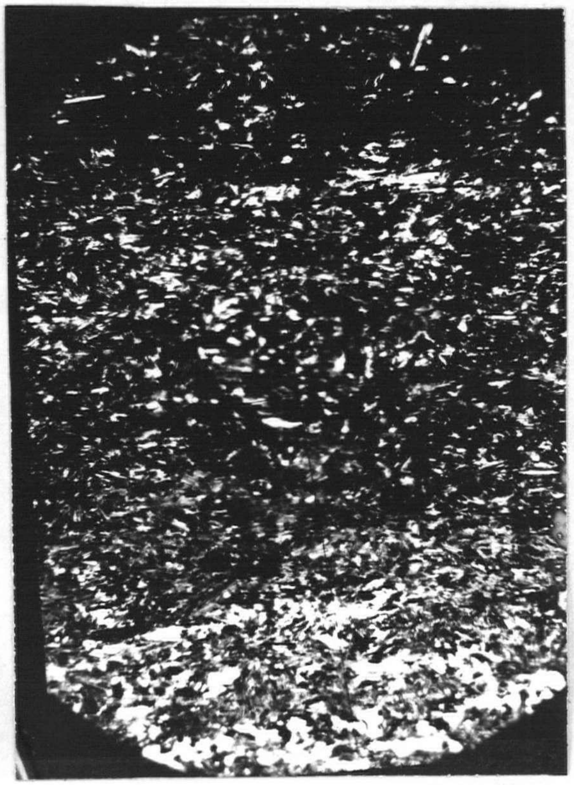


Fig. 14 - Haematite band. X 25

rare and grunerite is the chief constituent. Haematite is seen replacing the grunerite along the cleavages. The haematite bands are made up of closely fitting flakes of haematite usually parted along the cleavage. The grunerite has disappeared and in its place are thin laths of a colorless mineral with low birefringence. It has fine twinning lamellae and fine haematite flakes are often intergrown with it. The extinction is undulating and it is difficult to measure the extinction angle but it appears to be small. It is biaxial with 2V very large, but the sign is not known. Much of it contains a fine aggregation of a greenish-grey mineral moderately pleochroic and with weak birefringence. A small amount of quartz is still present and fine needles of the colorless mineral project into the quartz grains. A few grains of a carbonate were also noted. Magnetite occurs as small octahedrons in the haematite or in the colorless laths. It also occurs as lenticular areas along with pyrite. These two minerals are closely associated but magnetite may occur as isolated grains while pyrite never does.

Origin

It is difficult to trace the history of these haematite bands since little is known about the composition of the original sediments. There is nothing to indicate that they were originally ferruginous, but in all likelihood they were high in alumina and contained fair amounts of magnesia. Consequently the formation of the amphiboles, particularly grunerite, and of haematite cannot be attributed solely to processes of metamorphism. These two minerals, grunerite and hornblende, constitute a large proportion of the country rock in the mineralized shear zones where they are clearly the result of hydrothermal alteration. Their presence in the iron formation is apparently due to this same cause.

Haematite forms under oxidizing conditions and since haematite is so often intergrown with the amphiboles, it seems that they too formed under oxidizing conditions. However, we have noted the presence of pyrite with magnetite so that reducing conditions must at one time have prevailed.

It seems, therefore, that hydrothermal solutions travelling through these beds were highly ferriferous. They reacted with the sediments to form hornblende and grunerite. The amount of hornblende developed depended on the amount of aluminum originally present in the rock. Silica was abundant so that as the aluminum became tied up in the hornblende molecule the excess iron reacted with the silica to form grunerite. Aluminum was apparently deficient in certain bands so that only grunerite formed and this grunerite was later converted to haematite by the continued action of the solutions. Haematite in the iron bands often occurs as pseudomorphs after grunerite. It is not certain what by-products were formed as a result of this last reaction. Some of the colorless twinned mineral in the haematite bands has parallel extinction, while some of it has not. It is possible that both anthophyllite and cummingtonite are present while the small amount of greenish mineral may be actinolite. Grunerite has the following formula: $H_2Fe_7Si_8O_{24}$ with variable amounts of magnesium, while cummingtonite is $H_2(FeMg)_7Si_8O_{24}$. Consequently by the extraction of iron from grunerite and the removal of silica, several grunerite molecules could be reconstituted as cummingtonite. The proportion of amphibole would of course be greatly reduced and that is actually the case in the haematite bands. The presence of a carbonate suggests that the iron may have been introduced as the bicarbonate. The nature of the solutions must have changed, however, and become reducing. It is well known that haematite can be easily reduced to magnetite. Sulpheretted solutions were later introduced, reducing some of the haematite to magnetite and at the same time producing pyrite. The pyrite, as was noted, is always associated with the magnetite.

THE SHEAR ZONES

Description

The mineral deposits on the property occur in a series of sub-parallel rusty shear zones. Shearing of the sediments is parallel to the strike and seems to have occured wherever there was an assemblage of especially thin-bedded sediments. The intensity of shearing and magnitude of displacement varies a good deal in different zones, but it is interesting to note that the more intense shearing and best mineralization occurs in the zone closest to the granite contact.

Although the quartz pebbles will be dealt with separately, something should be mentioned about them now. These are elliptical shaped structures composed of light bluish, sugary-looking quartz. They resemble a good deal flattened quartzite pebbles with the long axis of the ellipse parallel to the strike. Sometimes they are rod-like down the dip. They tend to occur at definite horizons in the shear zones but are not confined to any single horizon.

Seven of these shear zones were explored either by rock trenching or diamond drilling or both.

No. 1 Zone:

The original discovery on the property was made on the southern end of this zone. It dips almost vertical in the southern part but flattens progressing northwest to a dip of 65°SW. It varies between 20 and 50 feet in width and is much fractured and mineralized, but the horizontal displacement between opposite walls of the zone is small. It disappears under extensive swamp areas to the north and south. Few quartz pebbles are present in this zone and the gold values obtained were negligible.

No. 2 Zone:

This zone, the most promising of all, averages about 10 feet wide and can be followed on strike for a distance of 3,500 feet. The southern end disappears under a swamp but it was intersected in diamond drill holes drilled in the swamp between No. 2 and No. 6 Zones. The northern part ends rather abruptly. The succeeding outcrop to the northwest is badly cut up by pegmatite dykes and the zone is absent. It may lie under the overburden between the two succeeding outcrops, but the zone could not be picked up on rock exposures farther to the northwest. The central portion of the zone on claim L51 is badly cut up and consists of disconnected lenses. A number of pegmatite dykes striking in a northeasterly direction cut across the rocks intervening between the lenses.

The zone runs along the top of a ridge that is much boulder strewn in the northwest part. Dips are steep to the northeast in the southern portion but change to vertical at the northern end. Locally the zone is bent and twisted, but on the whole it maintains a fairly consistent strike of N 50°W.

The amount of displacement seems to vary from place to place. A dyke in the southern portion was offset 15 feet while the displacement of a similar dyke in the northern part was only 5 feet. This may be due to the fact that stress effects were absorbed more by the compression of the sediments in some parts of the zone than in other parts, or it may be due to slightly different ages of the dykes injected during the interval of time in which shearing took place. The boundaries of the zone on the west are generally fairly sharp while the east boundary tends to grade into the country rock.

No. 3 Zone:

This zone outcrops for only a short distance on claim L54 just west of zone No. 4. Mineralization is weaker than in the other zones and gold values were insignificant.

No. 4 Zone:

A very narrow (averages about 2 feet wide) but persistent zone designated as zone No. 4 parallels No. 2 zone west of it. It offsets several pegmatite dykes ~~covering~~ causing horizontal displacements of 20 to 25 feet. The boundaries of the zone are often limited by coarse pegmatitic quartz. Mineralization is not strong and quartz pebbles are absent. Dips are fairly uniform to the southwest about 85°.

No. 5 Zone:

This zone outcrops at the base of a prominent knoll in the northern section of the property on claim L46. It extends into the adjoining claims to the north but is lost in the swamp to the south. Diamond drilling revealed that another zone parallels it under the swamp on the east.

The zone contains abundant quartz pebbles and is well mineralized. The sulphides (chiefly pyrite) are coarser grained than seen elsewhere on the property, but gold values are not outstanding. The zone averages about 7 feet wide and dips vertical.

No. 6 Zone:

Although this zone is not on strike with No. 2 Zone but is offset to the east, it is probably its extension. It is much similar in character to the No. 2 Zone though somewhat weaker. It could be offset by a fault but no sign of faulting was observed on outcrops northeast or southwest of the swamp intervening between Nos. 2 and 6 Zones. The apparent displacement is probably due to a bend in the strike of the sediments under the marsh area. The width of the zone is reduced, mineralization is less pronounced and gold values are low.

No. 7 Zone:

This zone is a weak narrow structure occuring on claim L63. Since the strike of the sediments changes to a north-south direction in the southern section of the property, it may well be the extension of the No. 1 Zone in this direction. It is only about 3 feet wide and mineralization is weak.

In addition to the above described principal mineralized zones, several rusty narrow short irregular zones occur in various localities within the boundaries of the property. They are always parallel to the bedding but movement along them has been small. One of these, however, is a wide fairly continuous zone with abundant quartz pebbles. (Fig. 15)

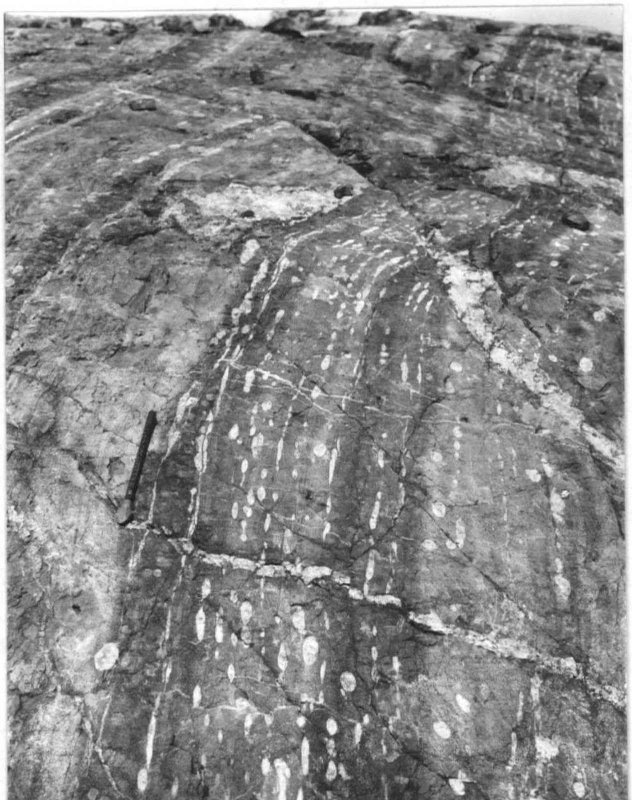


Fig. 15 - Shear Zone with quartz pebbles

It occurs on the outcrops that lie on the claim line dividing claims L52 and L53. It outcrops again in the northwest corner of claim L61 where it has been intruded by an acid dyke.

METASOMATISM OF THE SHEAR ZONES

General Statement

In dealing with this problem most of the information has been derived from the No. 2 Shear Zone. It is the best mineralized and has all the combined features exhibited by the other zones developed to a greater degree.

Megascopic Description

The Mineralized Zone:

As already noted, No. 2 Zone averages about 10 feet wide. Locally it pinches out to widths of 3 or 4 feet but in general it maintains a fairly uniform width. It can easily be followed on the surface by its dark brown rusty appearance resulting from the oxidation of the pyrite in the zone.

An open cut 340' long at the southern end of the zone afforded an excellent opportunity to study the unweathered rock. The rock has a dense massive appearance. It is dark green, medium to fine-grained and sometimes studded with coarse, deep-red garnets. The sulphides consist of pyrite with a little arsenopyrite, chalcopyrite, sphalerite and pyrrhotite and make up between 2 and 8 percent of the rock. The pyrite forms fine laminae indicating bedding replacement but it also occurs as streaks, blebs and sometimes veinlets running in various directions. The arsenopyrite is rare but occasional small splashes or irregular blebs of this mineral were noted. Chalcopyrite occurs in the same manner while sphalerite and pyrrhotite were noted as small, sparsely disseminated grains. Quartz stringers parallel the original bedding but irregular streaks, blebs and often well formed quartz pebbles are quite common. The quartz has a light bluish or smoky appearance and a granular sugary texture.

A good deal of the rock, however, is closely fractured and broken up permitting the oxidation of the sulphides to depth. The distribution of the sulphides is the same as described above except that some fracture faces will have a thin film of pyrite coating them. The rock breaks up in such a manner that the sulphide film is all on one face of the fracture. The fractures in some parts of the open cut form a network, one set of fractures being parallel to the strike of the zone, the other running in a N-S direction. Quartz-pyrite veinlets often fill these fractures and usually the pyrite is limited to one side of the veinlet although at times it occupies the centre or may entirely fill the fracture. A few of these quartz veinlets were observed to coalesce with the quartz pebbles but did not seem to cut them.

Parts of the zone are composed of a dense highly siliceous rock with very little amounts of sulphides. Here the quartz pebbles increase in size and number and are rarely pyrite-rimmed.

The Wall Rock:

The wall rock of the zone has suffered considerable alteration extending 2 to 6 feet on both sides of the shear zone. The altered country rock is medium to coarse-grained, with a dark green chloritic appearance and liberally studded with garnets. This last mineral forms the chief constituent. In a few places biotite flakes are conspicuous.

The zone of alteration is usually wider and more intense on the hanging wall side of the shear zone. Quartz veins occasionally form a band along the footwall or hanging wall side of the zone and also a stock-work of veins in the zone. These veins always strike parallel to the zone or in a N-S direction. They are about 6 inches wide and composed of coarse white quartz. Some contain inclusions of the mineralized zone and are, therefore, later than the sulphides.

Microscopic Examination

Mineralized Zone:

The minerals of the shear zone consist essentially of quartz, blue-green hornblende, grunerite and the sulphides. In places garnets, with biotite and chlorite are present in the mineralized zone. The two amphiboles are intergrown in the same manner as previously described, but here they are generally arranged in radiating clusters and the grunerite invariably occupies the central part of the cluster. Sometimes a few grains of pyrite form the nucleus. (Fig. 16) Small quartz inclusions

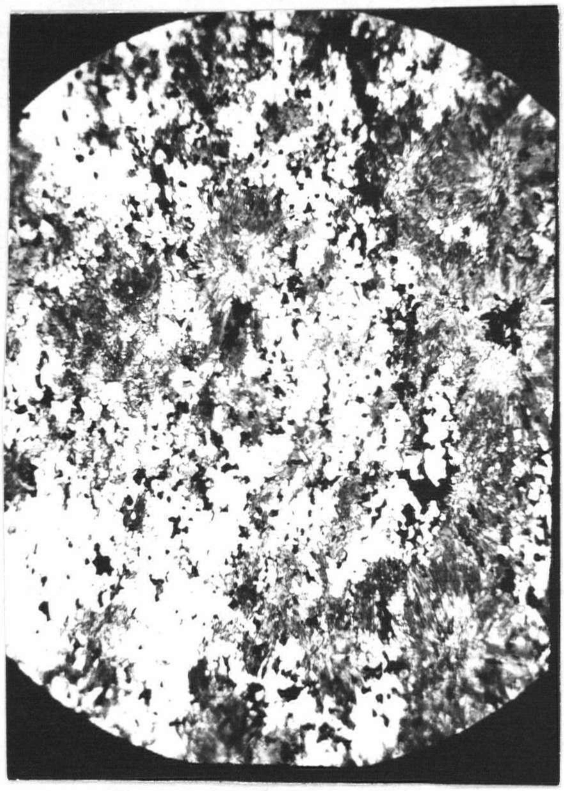


Fig. 16 - Amphibole clusters with quartz and sulphides X 25

give the clusters a sieve structure. The length of the amphibole plates vary in such a manner as to give the clusters a rough elliptical shape and these tend to be arranged along certain lines giving the rock a rude banded appearance.

About 50 percent of the rock is made up of quartz. It occurs as polygonal grains but it has been strained and tends towards dimensional orientation - long diameter parallel to the bedding. It contains abundant dust inclusions many of which under high power have a red color. They are probably magnetite and haematite particles. They form a crude polygonal pattern indicating the original shape of the quartz grains. Sometimes the present grain boundaries corresponds with the linear arrangement of the inclusions.

The sulphides are rather uniformly distributed throughout the rock but are more abundant in, and have a distinct relationship to, the quartz. They occur as if they were "molded" around the quartz grains, rarely show traces of crystal faces and, therefore, reflect the dimensional orientation of the quartz grains.

A very small amount of carbonate is closely associated with the sulphides though at times it is found with the amphiboles. A few grains of hornblende are also partly chloritized.

The grunerite is not always present and some thin sections contain only the blue-green hornblende. Where grunerite is absent the hornblende shows no tendency towards radial structures and the laths show a strong inclination towards orientation parallel to bedding. The quartz is quite clear and has few dust inclusions but the distribution of the pyrite is the same as that already described.

The mineral relationship is somewhat different where the rock is criss-crossed by quartz veinlets. The amphiboles are absent but their pre-existence is quite apparent. The radial clusters are present but are now composed of a chlorite. Under crossed nicols the radial arrangement of the original mineral can be clearly seen and the alteration has obviously been volume for volume. The quartz veinlets are more numerous than is apparent in the hand specimen. The quartz of these veinlets is quite clear in contrast with the quartz in the rest of the rock which is full of dust inclusions. Where the veinlets are closely spaced the intervening quartz is very fine-grained and so full of dust inclusions as to give it a dark grey appearance. As a matter of fact, the quantity of dust inclusions is a rough index of the degree of alteration. In most cases, however, the veinlets cannot be distinguished under crossed nicols except by the line of inclusions bordering it. Quartz grains form both part of a veinlet and part of the original rock. The quartz of the veinlets is also strained. It appears, therefore, that considerable recrystallization followed the introduction of this late quartz.

Where the veinlets are wide they contain appreciable sulphides which consist of pyrite and sphalerite. A carbonate and phlogopite are also present. The quartz is in the form of prismatic and hexagonal grains oriented with the long dimension perpendicular to the wall of the vein so that the crystals have obviously grown inwards from the vein wall. (Fig. 17) It usually occupies one side of the veinlet and the sulphides the other side, but sometimes the latter are in the centre of the veinlet and have therefore crystallized last. The pyrite is more abundant than the sphalerite but they are intimately associated. The two will run along as short veinlets with the intervening distance occupied by the carbonate. The phlogopite is closely intergrown with the pyrite. It is colorless to light brown, slightly pleochroic and uniaxial negative.

The quartz veinlets sometimes contain a fair amount of chlorite and hardly any sulphides are present in the country rock outside of the quartz veinlets in the thin sections studied.

Where the quartz pebbles occur the surrounding rock is composed of the grunerite-hornblende intergrowth, and quartz. It is not intended to

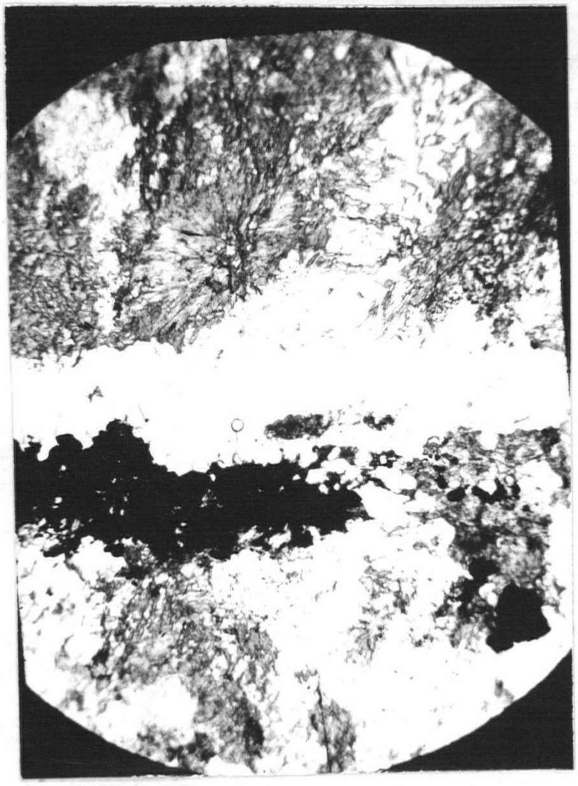


Fig. 17 - Quartz-Pyrite veinlet.
Note shape of quartz
grains in veinlet X 25

describe the "pebbles" here in detail but they cannot be entirely ignored in discussing the shear zones. The quartz in the pebbles is relatively coarse-grained but is strained and grains are elongated parallel to the long axes of the pebble. The quartz is clear but contains streaks of the amphibole and a small amount of pyrite grains molded around the quartz grains (Fig. 18 and 19). Occasionally the pebble has been fractured at the edges and pyrite introduced in the fracture (Fig. 20) but most of the pyrite forms a rim around the pebble (Fig. 21). A fair amount of sphalerite with a carbonate and occasionally phlogopite, are associated with the pyrite.

Where garnets occur, the rock close by is very fine-grained, dust inclusions are abundant and may have a streaky arrangement. The amphibole clusters are almost entirely grunerite and the end of the fibres project

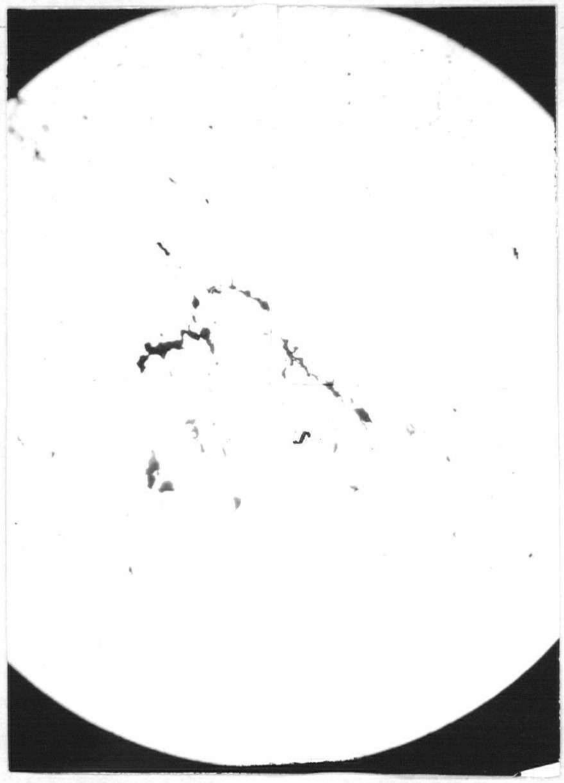


Fig. 18 - Pyrite in quartz pebble X 25

Fig. 19 - Same as 18. Crossed nicols X 25

Fig. 20 - Pyrite introduced in fracture at edge of pebble X 25

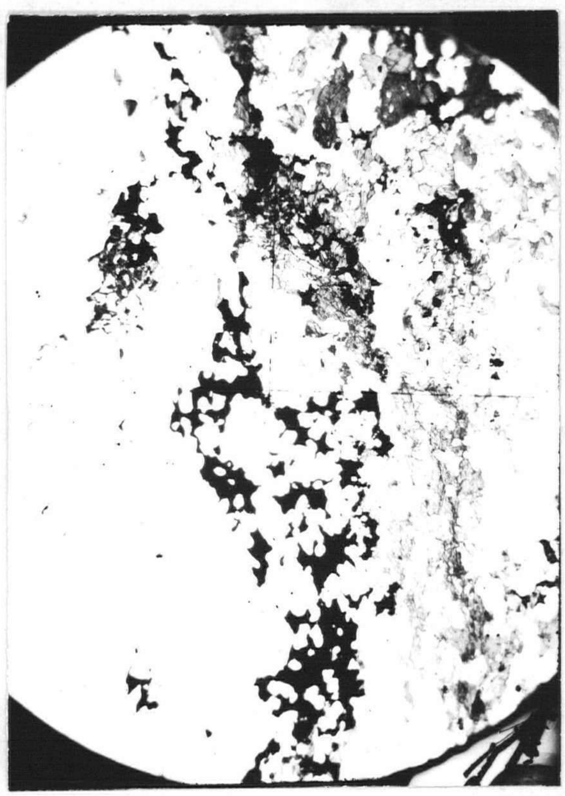


Fig. 21 - Sulphides rimming pebble quartz on the left. amphiboles on the right X 25

in the garnet crystals. Some biotite may have formed and is rimmed by magnetite inclusions. Chlorite fills fractures in the garnet. Mineral grains around some of the garnets have a streaky arrangement and have been deflected all in the same direction indicating that the garnet crystal has been rotated.

The relationship between pyrite and sphalerite has already been indicated. Where arsenopyrite occurs it is intimately associated with the pyrite and is intergrown with it. The larger arsenopyrite areas are sometimes rimmed by pyrite but the reverse also occurs. Chalcopyrite occurs as small grains adjacent to larger pyrite grains while sphalerite occurs as small blebs both in the pyrite and arsenopyrite. This relationship indicates that all the sulphides are contemporaneous. Pyrrhotite was not observed in thin section.

Wall Rock:

Typical wall rock alteration consists of garnet, biotite, chlorite, quartz and some magnetite. The garnet belongs to the pyralspite group and approaches the composition of almandite, the iron garnet. Its index is greater than 1.74 and it gave a specific gravity of 4.10. However, its true gravity will be a bit higher since it contains considerable impurities in the form of quartz and chlorite.

The garnet grains obtain diameters of 1/4" but most of them are between 1/16 and 1/8 inch across. They are highly fractured and veined by chlorite (Fig. 22) and numerous quartz inclusions give it a poeciloblastic structure. The centre of a chlorite veinlet cutting a garnet grain in two is sometimes occupied by clear quartz. The quartz inclusions show sometimes a tendency to be elongated and oriented in the same direction, while at other times they form a crude hexagonal pattern indicating successive

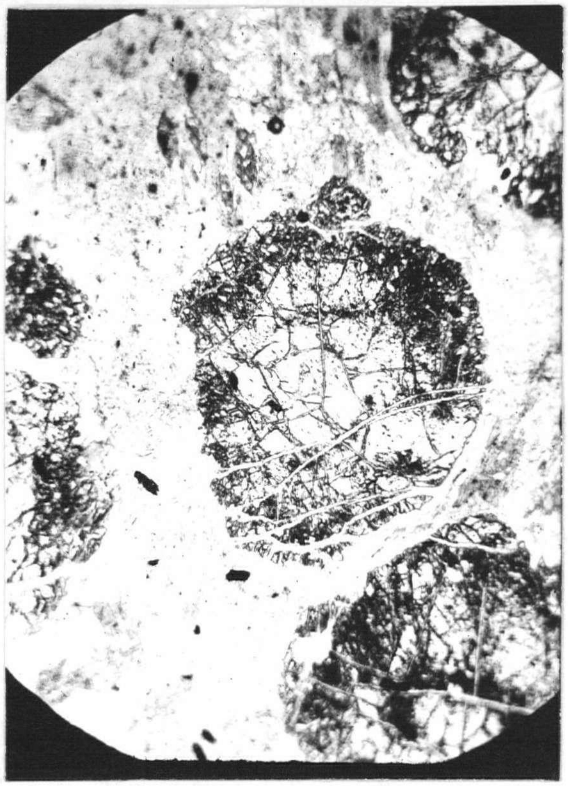


Fig. 22 - Garnets veined by chlorite. Dirty grey is biotite. X 25

stages of growth.

The biotite forms large irregular plates between the garnets. Sometimes they are curved around garnet grains and exhibit undulating extinction. It occasionally forms small embayments into the garnet and appears to have formed at the expense of this mineral. The biotite is in various stages of alteration to chlorite and contains quartz and magnetite inclusions. The latter are often arranged along the cleavage planes of biotite.

Chlorite fills the fractures in the garnet or forms a ring around it. All of this chlorite has the anomalous blue interference color of penninite.

The quartz occurs as small round inclusions in all the other minerals and gives the rock a distinct sieve structure. In part it is the result of incomplete reaction and failure to be absorbed by the garnet and biotite but a large proportion is also the result of the break down of these two minerals by chlorite.

Where alteration has progressed to an advanced stage, the rock is almost entirely penninite. Small residuals of garnet are still present but the biotite is completely lacking. Under crossed nicols the chlorite appears as a pseudomorph after biotite and often the magnetite has arranged itself around the original borders of the biotite flakes (Fig. 23)

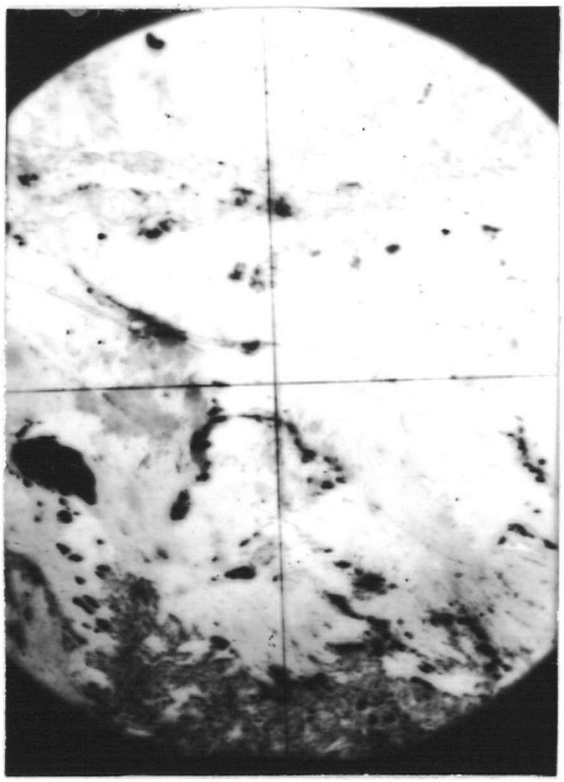


Fig. 23 - Biotite completely replaced by chlorite. X 70

but the quartz has segregated itself into large irregular patches. This last mineral is much less abundant and has largely been removed from the rock.

A thin section made from coarse-grained biotite garnet rock taken from the centre of the zone presented an interesting assemblage of minerals. The garnet has been fractured and veined by chlorite, but along some of these fractures thin laths of grunerite have formed and project into the garnet forming rosettes. Some beautifully twinned rhombic grains of grunerite have formed. Considerable biotite has developed and it contains numerous laths and twinned rhombs of grunerite.

Still another sample from a similar locality shows the introduction of sulphides along the chlorite veinlets in the garnet (Fig. 24). The

Fig. 24 - Sulphides in garnet
X 70

biotite is absent and instead the blue-green hornblende occupies the space between the garnets. Sulphides associated with a little carbonate are fairly abundant in the hornblende and tend to rim the garnet grains. In one instance a little bit of apatite has formed with the sulphides.

The Mineralizing Solutions

Means of Access:

It is quite obvious that the shear zones afforded channelways for the mineralizing solutions. The problem is rather at what stage of the shearing were the solutions introduced.

Shearing is a process that takes place by stages and extends over a long period of time; by that is meant that rupture of the rock occurs when the shearing stresses exceed the shearing strength of the rock. However, as rupture takes place, stresses are relieved and have to be built up again before rupture can again take place. The openings thus produced in the rock are infinitesimal in size and the fracturing is expressed as innumerable, closely spaced, more or less parallel surfaces of discontinuous rupture. The movement of solutions under these conditions would be slow hence it is likely that the period of mineralization lasted during the whole duration of shearing.

It is possible that much of the mineralization occured after the shearing but all the quartz in the shear zones is strained and the quartz pebbles which are of hydrothermal origin have been deformed by shearing stresses.

There are no fissure veins in the zone and sulphides are finely disseminated or replace the bedding but in some places small fractures providing an easier means of access for the solutions and these fractures now appear as quartz-sulfide veinlets.

<u>Nature of the Solutions:</u>

The ferriferous nature of the solutions is unquestionable. Of the sulphides, pyrite makes up 98%, grunerite is an iron rich amphibole and hornblende is fairly high in iron. The chief wall-rock alteration product is the iron garnet almandite. It seems, therefore, that considerable iron must have been introduced for the formation of these various minerals. The solutions were undoubtedly siliceous, but how much of the silica was derived from the magma source and how much came from the quartz already present in the sediments is difficult to ascertain.

The fluids contained also a fair amount of volatile constituents. Water acted as the chief solvent but it was aided in this role by the presence of sulfur and small amounts of carbon-dioxide. The apatite and phlogopite mentioned above, and their close association with sulphides suggests the presence of small amounts of phosphate and fluorine. Finally the solutions were hot, hot enough to heat the rock to temperatures that would permit the formation of the various silicates praticularly garnet.

All the garnet is isotropic and smoky quartz loses its color at 300°C so that crystallization occured between 300°C and 800°C - probably at about 500°C.

Chemical Processes Involved:

Temperatures were high and pressures great at the time of mineralization. The minerals in the zone were in a metastable condition as a result of the shearing stresses. These conditions greatly enhanced solution and diffusion of material with the result that the rock could be easily reconstituted into new minerals.

The overall composition of the rocks in the shear zone was probably much similar to the rest of the country rock. Probably albite was present but it has now all disappeared. Here we then had all the elements necessary for the formation of hornblende. This does not preclude the addition of soda and lime, but the fact is that the amount of hornblende formed was dependent chiefly on the presence of these constituents in the original rock, and particularly on the amount of alumina, otherwise all the amphibole would have been grunerite. What was chiefly needed was the addition of iron and a medium by which diffusion could take place. The centre of amphibole clusters are usually grunerite but it must be remembered that iron was being introduced and reacted with the silica to form grunerite while the diffusion of soda, lime and alumina to these centres was slow so that hornblende formed the outer rim. The dust inclusions in the quartz arranged in irregular patterns testify to the bulk reconstitution of the whole rock. Nevertheless, original bedding was not always wholly destroyed but became reflected by the laminated sulphides. Of course the original rock composition varied from place to place and in some cases only amphibole formed. As a consequence of these reactions the hydrothermal solutions became more alkaline and excess iron reacted with the sulfur, possibly H_2S, to form pyrite and regenerate some water. Arsenic, zinc and copper also reacted at about the same time to form chalcopyrite, sphalerite and arsenopyrite.

The wall rock alteration may be looked upon as a case intermediate between thermal and normal regional metamorphism with some metasomatism. The magmatic fluids provided the necessary constituents and raised the temperature of the rock such as to favor the formation of garnet.

An assumption must unfortunately be made and that is that the wall rock was high in alumina but low in soda and lime.

The solutions, besides producing the changes already noted in the zone permeated the surrounding rock so that with the addition of iron the physical conditions were such as to be favorable for the formation of garnet and biotite. The fact that pressure was being constantly relieved in the mineralized zone, by shearing, but not in the wall rock may have some bearing on the fact that almandite was formed in the wall rock since that mineral is generally regarded as a stress-mineral. Nevertheless, one would expect some garnets to form in the mineralized zone, and that is actually the case. Two such instances have been described.

The last stages of metasomatism are manifested by the chlorite alteration. Penninite is low in alumina and iron but high in magnesia.

It seems, therefore, that in the dying stages of metasomatism the solutions became enriched in magnesia and attacked the biotite and garnet converting them to chlorite. This final transformation rarely went to completion and for the most part the rock is little chloritized.

Summary:

Metasomatic changes resulted from hot aqeous hydrothermal solutions carrying considerable iron. The rock affected by these solutions was already undergoing regional metamorphism so that the accession of these solutions and consequent rise in temperature greatly facilitated the process of solution and diffusion, and the addition of the iron constituent resulted in the formation of a distinct mineral assemblage characterized by their high iron content.

Source of Solutions:

The overall picture of metasomatism is never complete until a source for the mineralizing solutions is found. The obvious source in this case is the large granite mass lying to the northeast and which we may safely assume underlies all the sediments in this area. The pegmatite dykes are related to the granite and we have already noted how they are offset by the shear zones. It seems, therefore, that pegmatite injection, shearing of the sediments and introduction of hydrothermal solutions are closely related not only in space but in time. This is borne out by the fact that in the portion of the No. 2 Zone which consists of disconnected lenses, pegmatite dykes cut across the sediments between the disconnected parts of the zone. This indicates that pegmatites were ~~formed~~ injected over a long period of time and that the mineralizing solutions are contemporaneous with the pegmatites. It is, therefore, concluded that both the pegmatites and the hydrothermal solutions were derived from the same source, namely the granite.

Classification of the Deposits:

The mineral deposits on the property are shear zones replacement deposits. They were formed at temperatures above 300°C and under high pressures and correspond to the lower part of the mesothermal range.

THE QUARTZ PEBBLES

General Statement

Attention has already been drawn to certain quartz structures that were referred to as quartz pebbles. A detail description of these will now be given and an attempt will be made to provide a satisfactory explanation for this unusual occurrence.

Occurrence

The quartz pebbles occur in nearly all the shear zones but are more abundant in some zones than in others. They are most prominent in the No. 2 Zone while No. 1 and No. 4 Zones hardly contain any at all. They have not been noticed outside of the shear zones so that the presence of these pebbles seems to be genetically related to those assemblages of sediments that have been sheared.

Description

The first impression gained by the observer is that they are truly pebbles and thus part of a conglomerate horizon, but on closer examination they present certain features that are difficult to reconcile with this mode of origin.

Generally they are elliptical in shape with the longer dimension parallel to the strike of the beds. The long axis varies in length from 1/2" to 1 1/2" and the ratio of the long to short axis is usually about 7:5. However, they vary a good deal in shape and sometimes are lenticular shaped with pointed ends. Several of these lenticles often coalesce and form a veinlet that appears to have been pinched at regular intervals. At other times they have no distinct shape and are only quartz splashes or streaks in the rock. In some cases a group of four or five perfectly round pebbles were noted.

The elliptical ones are often rod-like down the dip and weathering has loosened them so that they can be pulled out of the rock. They then resemble fat cigars. That is not always the case, however, and the outline of the pebble down the dip may be quite irregular. Some pebbles are be pointed at one end and blunt at the other end, while others appear to have been rotated so that they are out of line with the strike but the rotational effect may be either to the right or the left.

The pebbles invariably occur in bands three to five feet wide and are strung out more or less along definite lines, but the bands do not maintain the same position throughout the zone. Sometimes it may be near the foot-wall, at other times near the hanging wall, or in the centre of the zone. In the No. 2 Zone they also occur irregularly scattered without any apparent preference for certain beds. Two small S-shaped drag-folds with their axes plunging almost vertically were also noted in the No. 2 Zone and in these two instances the quartz pebbles follow around the drag-fold so that the long axis of the pebbles remain parallel to the bedding. (Fig. 25)

Composition and Texture

All the pebbles consist of bluish-grey quartz having a sugary texture as though the quartz had been crushed and recrystallized. Nearly all contain small patches of hornblende that have a streaky arrangement in the direction of the long axis of the pebble. A few contain sparsely disseminated pyrite. On the weathered surface the hornblende and pyrite have been removed so that the pebbles have a pitted appearance.

Microscopic Examination

In thin section the stress effects on the quartz of the pebbles are quite evident. The quartz grains exhibit undulating extinction and strain shadows and have a 2V as high as 20 degrees. The grain boundaries

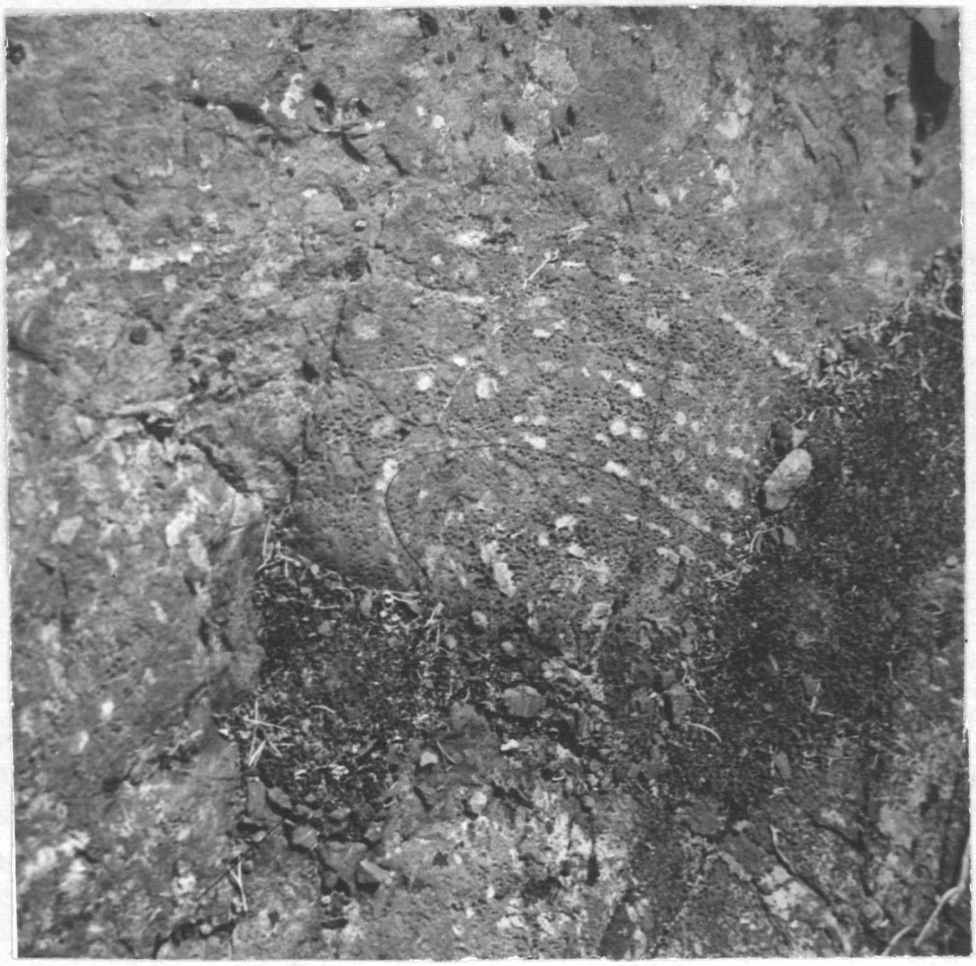


Fig. 25 - Small S-shaped drag-fold in No. 2 Zone.
Note how pebbles follow around drag-fold

are highly sutured and trains of minute fluid inclusions cutting across several grains are quite common. The quartz is much coarser-grained than that of the rest of the zone rock. The grains are much elongated in the direction of the long axis of the pebble but the average width of a grain is about 1/50". Although strain shadows have a tendency to run parallel to the longest dimension of the grain, they also trend at various angles across it.

There is no definite boundary between the quartz pebbles and the rest of the rock, the quartz seems to form a matrix in which the amphiboles and sulphides are almost entirely absent in certain elliptical areas. However, just at the borders of the pebbles the quartz becomes fine-grained and grades sharply into the amphibole rock of the zone.

The sulphides that generally rim the pebbles may be just inside the pebble in the quartz or just outside in the amphibole rock. They consist of pyrite and sphalerite; a little carbonate, and in two instances phlogopite, were noted.

The sulphides occur as irregular disconnected veinlets or as individual grains molded around the quartz grains (Fig. 21, P. 43)

More pyrite and hornblende occurs dispersed throughout the pebbles than is apparent in the hand specimen. They are present as small fine grained clusters or streaks with the pyrite molded around the quartz grains. (Fig. 18 and 19, P. 43). In places a fair amount of dust inclusions (magnetite) accompany the pyrite.

One case was noted in which a quartz veinlet containing considerable pyrite connected two pebbles.

Origin

It is quite evident that these quartz structures are not pebbles in the sense that they form part of a conglomerate formation. To begin with, if they were, why are they all composed of quartz? One would expect to find some variation in their composition, possibly granite or felsite pebbles. Their manner of occurrence in these beds violates all principles of sedimentation. The beds in general are well sorted so that the pebbles should be concentrated in the bottom of the beds, but there is no such tendency. You might expect too variations in grain sizes of the sediments that contain the pebbles from the finest greywacke to the largest pebbles, but such is not the case.

The fact too that the "conglomerate bands" in the shear zones do not maintain the same position but occupy different stratigraphic horizons along the strike of the zone is positive evidence against the theory of a sedimentary origin of the pebbles. Finally the indefinite shapes of some of the pebbles, their tendency in many instances to form veinlets, and the lack of sharp boundaries in thin section, all point to a different mode of origin. Clearly, some other solution must be sought to account for them.

The presence of sulphides, molded around the quartz grains, and of hornblende in the pebbles, and the lack of a definite boundary between the pebbles and the enclosing rock, all indicates that metasomatism has played an important part in their formation. The problem is what physical conditions prevailed at the time of their formation that would have the effect of producing pebble-like structures even though they are the result of replacement.

Enough has been said about the shape of these quartz pebbles and of the quartz grains comprising them to indicate that they express some kind of linear structure. During the process of shearing, we have mentioned how innumerable shearlike openings, infinitesimal in size are developed, but the rock, even though it were quite uniform in composition, would not yield to the shearing stresses to the same degree throughout the zone. Some of the shear-like openings would be larger than others, resembling small fissures.

These small fissures became filled by mineralizing solutions and the pressure transmitted by these solutions caused some bulging or dilation of the fissures thus enlarging the openings. At the same time replacement of the fissure walls took place. A glance at Figures 26 and 27 will show how the pebbles resemble a great deal small dilated fissure veins. Some of them are strung out like a string of sausages while others are arranged slightly en echelon.

The final shape of the pebbles, however, was determined by the shearing stresses the rocks were subjected to. These stresses caused a

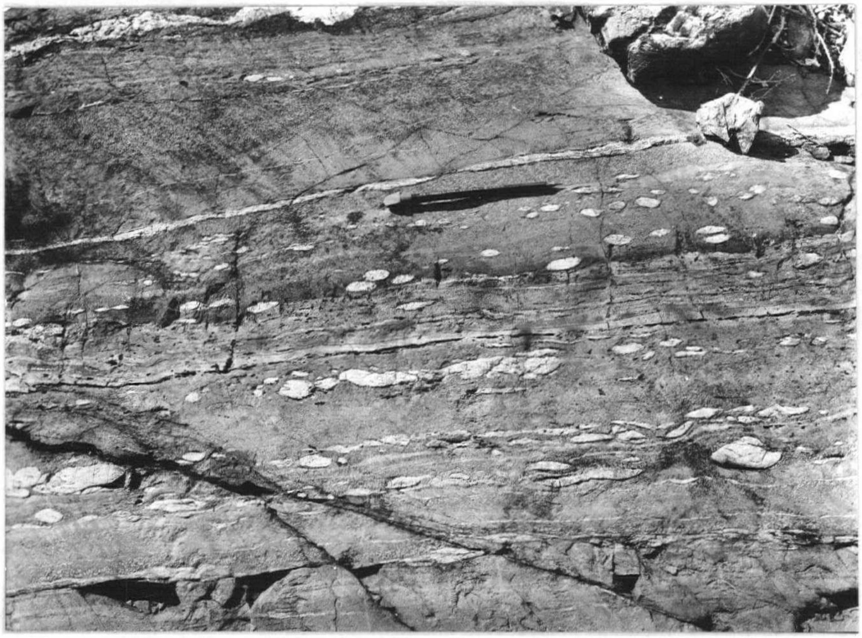


Fig. 26 - Quartz pebbles. Note how several pebbles tend to coalesce, also distortion of bedding around some of the pebbles

Fig. 27 - Quartz pebbles. Note how they tend to occur along definite bands.

stretching of the pebbles. Quite often the pebbles are striped and streaked parallel to the maximum elongation. Sometimes the pebbles were slightly rotated and this caused a deformation of the beds around the pebble. One such pebble well illustrates this in Fig. 26, P. 58.

THE OCCURRENCE OF GOLD

Assay results from diamond drill cores indicate that gold content is very erratic. For this reason bulk sampling of an open cut was undertaken. An open cut 340 feet long, averaging 10 feet wide and 2.5 feet deep was excavated at the southern end of No. 2 Zone. A detailed geological map of the open cut was made and assay results superimposed on this map. (Map 2) In a broad sense the best gold values are with the laminated sulphides and in the rusty fractured sediments high in sulphides. The highest values too seem to be where the zone is widest.

Very little visible gold occurs in these zones. It can be panned from the rusty weathered surface material and it was noted on two occasions in drill cores. In both cases the gold occurred in the bluish smoky quartz. Unfortunately, gold was not observed in any of the thin sections studied by the writer.

Since the quartz and sulphides are closely associated, it is probable that gold is closely related to both.

STRUCTURE

The rocks of the area are apparently part of the east limb of a syncline. The sediments trend in general N 55°W and dip steeply to the southwest. The strike, however, changes direction in the southern part of the property and swings to a northeast direction. The horizontal distance across the strike increases as you proceed southward. Certain argillaceous beds exposed on claim L61 are not found to the north along the strike of the beds.

Drag-folds, Z-shaped in plan, occur in the assemblages of thinly-bedded sediments. The axes of these folds plunge about 85° to the north-west; obviously they were formed by nearly horizontal movements that carried the northeast sides southeast. Two small S-shaped drag-folds in the No. 2 Zone have already been mentioned in connection with the quartz pebbles. The movement which produced the Z-shaped drag-folds is similar to that along the shear zones, since the displacement along the zones is, in all cases, right-handed.

The dip of the beds varies between 70° to the southwest and vertical, except at the southern end of No. 2 Zone where dips are 70°NE.

Two prominent sets of joints are developed. One strikes in a general N-S direction while the other strikes about N 45°E. Both dip steeply or vertical.

CONCLUSIONS

The Archean sedimentary rocks of the Yellowknife group, in the area considered in this thesis, suffered regional metamorphism. The grade of metamorphism corresponds to the Biotite-Zone. It is often difficult in a study of this kind to draw the line between metamorphism and metasomatism. It is certain, however, that the latter process has played an important and essential role in the production of tourmaline in the phyllite beds, in the development of muscovite in sediments near the granite contact, and in the formation of the haematite bands. A small amount of tourmaline is present in nearly all the sediments studied and it is probable that the whole country rock was more or less permeated by magmatic fluids derived from the nearby granite at the time of its intrusion.

Shear zones in the sediments afforded channelways for mineralizing solutions and these formed replacement mineral deposits in the zones. The wall rock alteration along the zones consists of garnet and biotite partly altered to penninite. The mineral assemblage produced by the solutions is characterized by a high iron content and attests the ferriferous nature of the hydrothermal solutions.

Quartz structures in the shear zones, referred to as quartz pebbles, are believed to be of hydrothermal origin. Their shapes are attributed to the physical conditions, existing in the rocks, at the time they were formed. Small fissures in the rock were the loci at which the "pebbles" started to form. Dilation and replacement of the fissure walls enlarged the pebbles and the shearing stresses imparted to them their final shape.

APPENDIX

Thin Sections

The following is a list of the more important thin sections studied by the writer:

T.S.	No. 3	Rutile needles in chlorite
"	" 4	Spotted sediments
"	" 7	Quartz pebble
"	" 12	Quartz-sulphide veinlets in zone rock
"	" 15	Garnetiferous wall rock
"	" 18	Typical quartz-sulphide-amphibole zone rock
"	" 20	The granite
"	" 31	The diabase
"	" 32	Sedimentary rock near granite contact
"	" 38	Garnetiferous-biotite-amphibole zone rock
"	" 39	Quartz pod with fluid inclusions
"	" 44	Wall rock altered to penninite
"	" 46	Amphibole rock near iron formation
"	" 47	Haematite bands
"	" 51	The porphyry
"	" 55	Crenulated sediments
"	" 58	Tourmalinized sediments
"	" 63	Garnetiferous wall rock
"	" 64	Quartz pebble
"	" 66	Quartz pebble
"	" 78	Quartz pebble

The following interesting rock samples are included as part of the material handed in:

Sample	
1	Banded pegmatite
2	The granite
3	Pegmatite with lepidolite
4	Haematite bands in iron formation
5	Quartz pebbles (6 specimens)
6	Garnetiferous wall rock
7	Garnetiferous wall rock with coarse biotite
8	Zone rock (sulphides and garnets) 2 specimens
9	Laminated sulphides with quartz pebble

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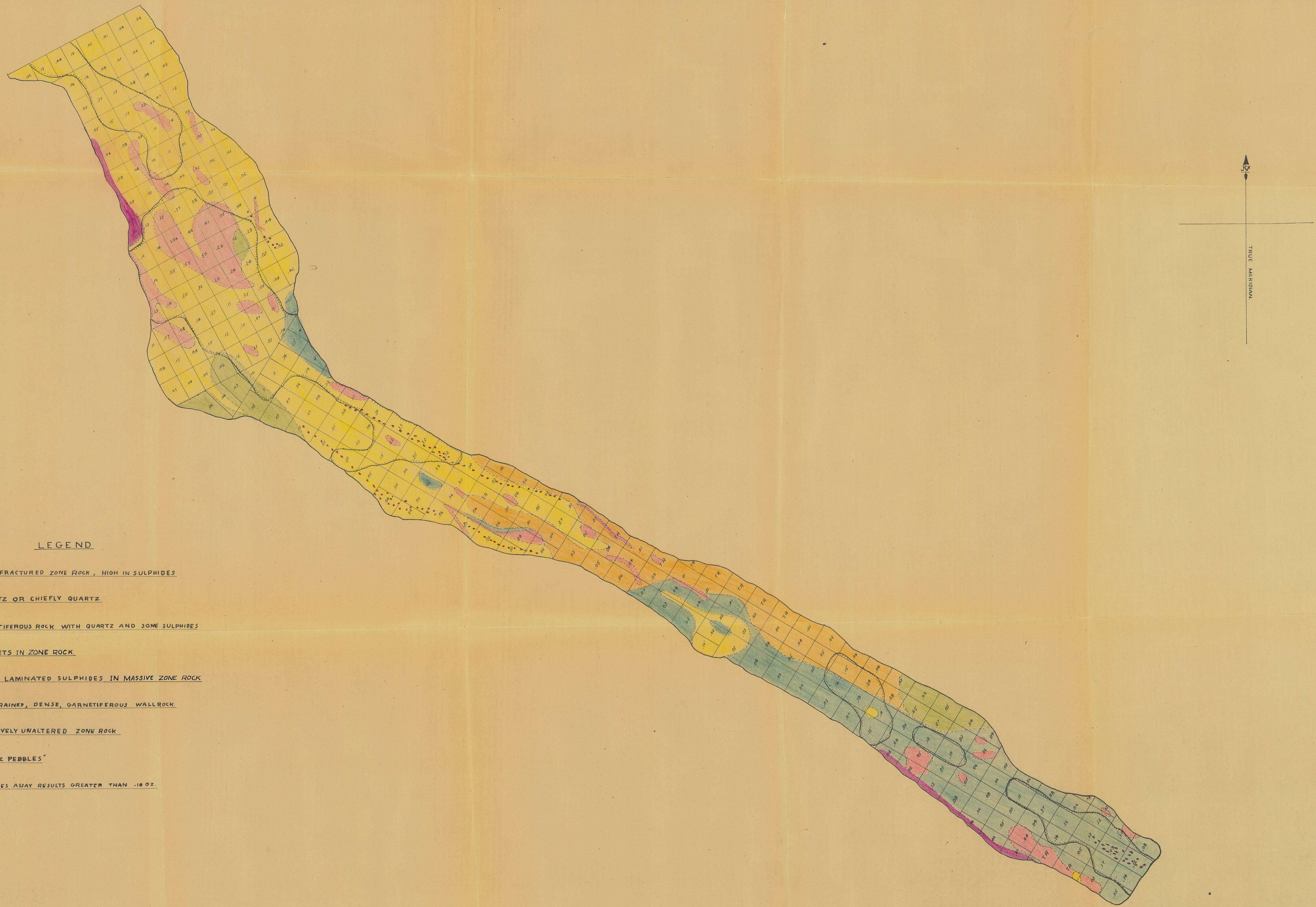
MAP 2



LEGEND

- RUSTY, FRACTURED ZONE ROCK, HIGH IN SULPHIDES
- QUARTZ OR CHIEFLY QUARTZ
- GARNETIFEROUS ROCK WITH QUARTZ AND SOME SULPHIDES
- GARNETS IN ZONE ROCK.
- FINELY LAMINATED SULPHIDES IN MASSIVE ZONE ROCK
- FINE GRAINED, DENSE, GARNETIFEROUS WALLROCK
- RELATIVELY UNALTERED ZONE ROCK
- "QUARTZ PEBBLES"
- INCLUDES ASSAY RESULTS GREATER THAN .10 OZ

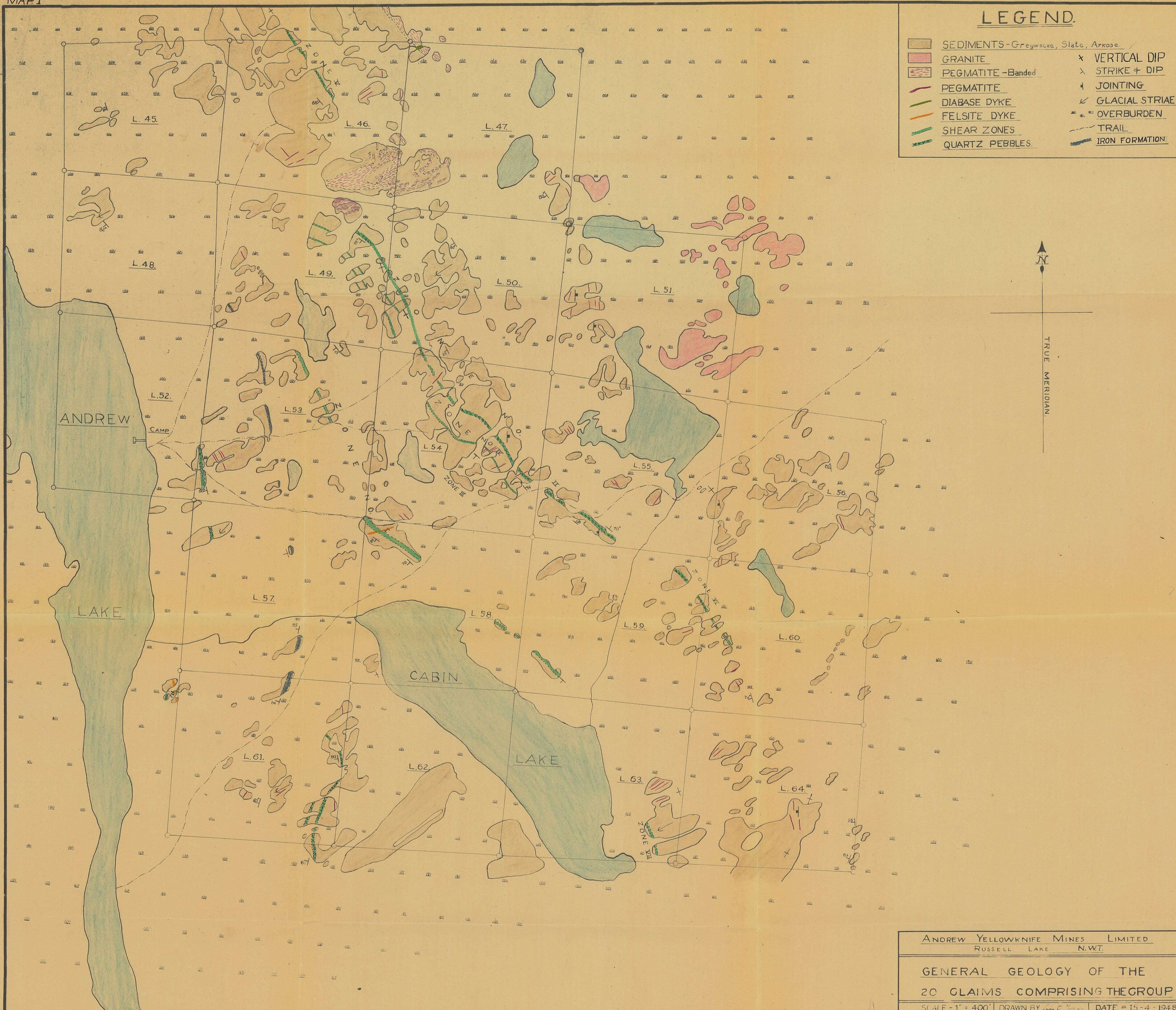
ANDREW YELLOWKNIFE MINES LIMITED.
RUSSELL LAKE ~ N.W.T.

SUBJECT ~ DETAILED GEOLOGY OF SOUTHERN SECTION OF OPEN-CUT ON THE NO II ZONE

SCALE ~ 1" = 5'	TRACED ~ Leo. O. Louie	DATE ~ 15-4-48.

NUMBERS INDICATE ASSAY RESULTS

MAP 1



LEGEND.
SEDIMENTS - Greywacke, Slate, Arkose.
GRANITE
PEGMATITE - Banded
PEGMATITE
DIABASE DYKE
FELSITE DYKE
SHEAR ZONES
QUARTZ PEBBLES.
VERTICAL DIP
STRIKE & DIP
JOINTING
GLACIAL STRIAE
OVERBURDEN
TRAIL
IRON FORMATION
N
TRUE MERIDIAN
L. 45.
L. 46.
L. 47.
L. 48.
L. 49.
L. 50.
L. 51.
L. 52.
L. 53.
L. 54.
L. 55.
L. 56.
L. 57.
L. 58.
L. 59.
L. 60.
L. 61.
L. 62.
L. 63.
L. 64.
ANDREW
LAKE
CAMP
CABIN
LAKE
ZONE III
ZONE VII
ANDREW YELLOWKNIFE MINES LIMITED
RUSSELL LAKE N.W.T.
GENERAL GEOLOGY OF THE
20 CLAIMS COMPRISING THE GROUP
SCALE - 1" = 400'
DRAWN BY
DATE = 15-4-1948.