1970

Petrography of Four Rock Units Exposed in the
Campbell Red Lake Mines, Ontario

Fosco V. Facca

Follow this and additional works at: http://commons.und.edu/senior-projects

Recommended Citation
http://commons.und.edu/senior-projects/57

This Thesis is brought to you for free and open access by the Theses, Dissertations, and Senior Projects at UND Scholarly Commons. It has been accepted for inclusion in Undergraduate Theses and Senior Projects by an authorized administrator of UND Scholarly Commons. For more information, please contact zeinebyousif@library.und.edu.
PETROGRAPHY OF FOUR ROCK UNITS EXPOSED IN THE CAMPBELL RED LAKE MINES, ONTARIO

by

Fosco V. Facca

A Senior Thesis submitted to the faculty of the Geology Department at the University of North Dakota in partial fulfillment of the requirements for the Degree of Bachelor of Science in Geology

REFERENCE DO NOT REMOVE FROM LIBRARY

Grand Forks, North Dakota
June, 1970
This Thesis submitted by Fosco V. Facca in partial fulfillment of the requirements for the Degree of Bachelor of Science in Geology from the University of North Dakota is hereby approved by the Faculty Advisor under whom the work has been done.

Advisor

spec. paper 3
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>0</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Location and General Operation</td>
<td>1</td>
</tr>
<tr>
<td>Gold Deposits</td>
<td>1</td>
</tr>
<tr>
<td>Purpose of Study</td>
<td>2</td>
</tr>
<tr>
<td>Samples Studied</td>
<td>3</td>
</tr>
<tr>
<td>Previous Work</td>
<td>3</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>4</td>
</tr>
<tr>
<td>FIELD STUDY</td>
<td>5</td>
</tr>
<tr>
<td>Sampling</td>
<td>5</td>
</tr>
<tr>
<td>Description of Rock Units</td>
<td>7</td>
</tr>
<tr>
<td>LABORATORY STUDY</td>
<td>9</td>
</tr>
<tr>
<td>Microscopic Analyses of Samples</td>
<td>9</td>
</tr>
<tr>
<td>X-Ray Analyses</td>
<td>11</td>
</tr>
<tr>
<td>Microscopic Analyses of Samples</td>
<td>12</td>
</tr>
<tr>
<td>INTERPRETATION</td>
<td>16</td>
</tr>
<tr>
<td>&quot;Campbell Diorite&quot;</td>
<td>17</td>
</tr>
<tr>
<td>&quot;Siliceous Rock&quot;</td>
<td>17</td>
</tr>
<tr>
<td>&quot;Altered Rock&quot; and &quot;Andesite&quot;</td>
<td>16</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>17</td>
</tr>
<tr>
<td>CONCLUSION</td>
<td>18</td>
</tr>
<tr>
<td>Future</td>
<td>19</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>21</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>22</td>
</tr>
</tbody>
</table>
ILLUSTRATIONS

Figure 1: Map showing level at which rock samples were taken-- 6
2. Quartz-carbonate veins in the "Andesite" unit------- 8
3. Illustrating sample from "Andesite" unit-------- 8
4. Thin section photo of sample #6032------------------- 13
5. Thin section photo of sample #6034------------------- 13
6. Thin section photo of sample #6036------------------- 14
7. Thin section photo of sample #6038------------------- 14
8. Thin section photo of sample #6039------------------- 15
9. Thin section photo of sample #6043------------------- 15

TABLES

1. Comparison of the different contacts between the four rock units------------------------------------------ 7
2. Megascopic description of specimens----------------------- 10
3. Minerals identified by X-Ray analyses of different rock units samples---------------------------------- 10
ABSTRACT

Campbell Red Lake Mines is a major gold producing mine located in Balmertown, Ontario on the Precambrian Shield. There are four main rock units recognized at the mine: "andesite", "altered rock", "siliceous rock", and "Campbell diorite". These units have been presumed to be igneous in origin and intruded by lamprophyre, quartz-feldspar porphyry, and grey dikes. Samples of the four rock units were taken from the mine and analyzed by macroscopic, microscopic, and x-ray diffraction techniques.

Field and laboratory observations suggest that the "andesite", "altered rock" and "siliceous rock" are of sedimentary rather than igneous origin and are now metasediments. The preponderance of quartz and the presence of calcite and dolomite are evidences of sedimentary origin. These fine-grained foliated rocks belong to the greenschist facies and are products of low-grade regional metamorphism. The changes in the mineralogic composition and texture within the limits of the "altered rock" and "andesite" are also evidences of sedimentary origin. Gold is found in the quartz-carbonate veins of the "andesite" which is predominately in contact with the siliceous rock. The siliceous rock may be the source of silica for the "andesite". The "Campbell diorite" however, may be of igneous origin and the source of fluids involved in alteration. The massive structure of the "Campbell diorite" and the relict pyroxene in the rock show that the rock is a metamorphosed igneous rock (saussurite rock).
INTRODUCTION
Location and General Operation

Campbell Red Lake Mines is located in Palmertown in the district of northwestern Ontario on the Canadian Shield. The Campbell mine has been in operation since 1949 and is the most extensively developed property in the Balmer Township. It has a four-compartment shaft to a depth of 3,280 feet with lateral development. On the surface, 700 tons of ore are milled per day. Roasting is required to facilitate recovery because of the large amounts of sulphide ore. The average grade of ore is about 0.45 ounces of gold per ton with a recovery of over 90 percent. Drifting along veins make the overhead shrinkage method of stoping possible. Recently, the cut-and-fill method has been adopted.

Gold Deposits

Gold is the only metal of economic importance obtained from the mine. The ore bodies are of two major types: (1) narrow, quartz-carbonate stringer veins that tend to parallel the regional schistosity; and (2) irregular zones of silification, carrying fine sulphide mineralization. The gold occurs as specks and streaks of native metal in bluish-gray to white quartz-carbonate veins. It is extremely fine-grained and most is invisible to the naked eye. In addition to gold, the veins have minerals associated with the ore which are, in order of abundance: pyrrhotite, pyrite, arsenopyrite, sphalerite and stibnite, galena, chalcopyrite, and magnesite. The last five minerals along with silver occur in minor amounts. The ore veins occupy steeply dipping, northwesterly striking, shear zones in folded and faulted Precambrian
rocks. These veins are best developed in chioritic and silica-rich rocks. Veins vary in width up to about five feet and may be over fifteen feet in length.

Purpose of Study

The purpose of this report is to present the results of a preliminary study of the petrography of four rock units exposed in Campbell Red Lake Mines. The mine identifies these rocks as "andesite", "altered rock", "siliceous rock", and "Campbell diorite". The rocks studied will be referred to by these names in quotation marks. Methods used are discussed for their value as future tools of study. It is hoped that this report will further the knowledge of the conditions in which gold occurs and aid in the exploration for new deposits at the mine.

Many surface studies and examinations of drill cores have been made in Balmer Township (Chisholm, 1951), but extensive petrographic examination of the rocks exposed in Campbell Red Lake Mines have not been made. The lack of such work probably results from the many problems encountered in the complexity of these Precambrian rocks. Since the mine operates on a small scale, the geology department is small and has little or no time for research. Therefore, the exploration of ore is dependent only on the daily examination of drill cores. To overcome this problem, samples of four rock units from the mine were studied at the University of North Dakota, Grand Forks, where proper facilities were available.
Samples Studied

Most of the study was done from sixteen samples taken from the wall of drifts being developed. Samples of "andesite", "siliceous rock", and "altered rock" were taken from the 21st level and samples of "Campbell diorite" were taken from the 6th level (figure 1). These rocks are found throughout the mine. The 21st level was selected for the following reasons: (1) the drifts in which samples were taken are mostly oriented across the width of the rock units, (2) the rocks are in contact with each other, and (3) gold-bearing veins are present in this area. Since the 21st level is the lowest level developed, this report may be useful for exploration as deeper development is expected in the near future.

Previous Work

The Ontario Department of Mines has made a geological investigation of Balmer Township in which Campbell Red Lake Mines is located (Chisholm, 1951). Property maps and drill core with drilling information were used to tie in the geological information of the area. In Campbell grounds, (Chisholm, 1951) indicates that the formations are composed of a massive series of Keewatin volcanics that are intruded by infrequent narrow felsic and mafic dikes of later ages and by large masses of diorite. The lavas consist of thick flows of intermediate andesite and dacite. The texture of the volcanics is fine-grained for the most part. It is difficult to distinguish from medium-to-coarse-grained basic rock that has been locally called "Campbell diorite". Because of widespread ore-zone alteration, no attempt has yet been made to correlate the individual flows in the volcanic series. The intrusives consist of 2 types:
(1) Narrow quartz-feidspar porphyry dikes from 5-10 feet wide which have been altered to sericite schist.

(2) A medium-to-coarse grained basic rock that is difficult to distinguish from coarse-grained andesite. There is some doubt as to how much of it may be classed as an intrusive.

Two types of post-ore intrusives occur in narrow dikes. The prominent type is dark gray to black in color and when narrow, is fine-grained in texture. The thicker dikes are coarse towards the center and may show segregation of pink feldspars and presence of syenite. Stringers of coarsely crystalline calcite containing cubes of pyrite cut the dike. This represents the latest stage of mineralization in the mine. The other type of post-ore dike is a grey rock that cuts the ore in places. It has a very fine-grained, light grey ground mass that may contain ferromagnesian minerals and resembles the "Campbell diorite".

ACKNOWLEDGMENTS

I am greatly indebted to the management of Campbell Red Lake Mines for making available to me much of the material used for the report. May I also express my gratitude to Mr. C. Lalonde, chief geologist of Campbell mine and to his experienced assistant, Mr. W. Sanderson for their suggestions and assistance in preparation of this paper.

The research reported herein was carried out at the University of North Dakota under the immediate supervision of Dr. Frank Karner, Professor of Geology. I wish to express my appreciation to Dr. Karner for his valuable suggestions and assistance and for his critical
reading of this manuscript: to Dr. E. A. Noble, Chairman of the Geology Department, for showing interest in my project: to Mr. N. N. Kohanowski, Associate Professor of Geology for assistance in identification of rock minerals and to Mr. John Delimata, for his fruitful discussions.

FIELD STUDY
Sampling

Samples of approximately 2 inches in diameter representing "andesite", "altered rock", and "siliceous rock" were taken from the 21st level drifts. A 6th level drift was selected for samples of "Campbell diorite" because this type is best represented in the upper levels. Locations of the samples taken are shown in figure 1. The sixteen specimens were numbered in sequence 6029-6044 away from the shaft. "Andesite", "siliceous rock", "altered rock" and "Campbell diorite" are represented by 6029-31, 6035, 6039, 6040, and 6032-34, and 6036-6038 and 6041-6044 respectively. The samples were removed at eye level from the north wall of the drifts. Special care was taken in selecting specimens near contact for study of the interrelationships of the rock units. The rest of the samples were taken at centers of the rock units to see if any changes occur between centers and contact areas.

Figure 1. Geologic map prepared from diamond drilling logs of the 21st and 6th levels showing the location of the rock specimens under study.
Description of Rock Units

Because of the prominent contacts, the rock units show apparent bedding planes that strike slightly northwest and dip south at about 50-60 degrees. Changes in strike and dip occur rapidly to the north of the area under study. All of these rocks appear to have gone through a metamorphic process of alteration. A greenstone metamorphic facies may be applied to most of these rock units. Contacts between these rock units vary (table 1).

TABLE 1

Variation in contacts between rock units in the 21st and the 6th level in the Campbell Red Lake Mine.

<table>
<thead>
<tr>
<th>&quot;Andesite&quot;</th>
<th>&quot;Siliceous Rock&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Andesite&quot;</td>
<td>Very well defined contact. The two rocks do not grade into each other.</td>
</tr>
<tr>
<td>&quot;Altered Rock&quot;</td>
<td>Gradation distinguished by hardness of rock. &quot;Andesite&quot; contains more silica than the &quot;altered rock&quot;.</td>
</tr>
<tr>
<td>&quot;Campbell Diorite&quot;</td>
<td>Gradation distinguished by the change in grain size. Rocks very similar but the &quot;Campbell Diorite&quot; is coarser grained than &quot;andesite&quot;.</td>
</tr>
<tr>
<td></td>
<td>Gradational and containing bands of sulfide mineralization parallel to contact</td>
</tr>
</tbody>
</table>

The "andesite" is a fairly hard, fine-grained rock. Its color varies from a dark blue to a blue-green. It is amygdaloidal in places. The numerous fractures are filled with quartz-carbonate which may contain gold (figure 2).
Figure 2. "Andesite" rock unit illustrating the numerous quartz-carbonate veinlets which are disseminated in part by pyrite.

Figure 3. Rock sample #6029 "Andesite" taken from rock unit of Fig. 2. The SW corner of rock shows signs of foliation and because of its hardness, it has concoidal fracturing.
The "siliceous rock" is fine grained with a white to gray color similar to a quartzite. It may be arkosic quartzite of the Timiskaming sediments series. Near its contact to the altered rock a green variety of this rock is seen due to minor chloride or serpentine. It appears massive, but is actually weakly foliated when examined carefully.

The "altered rock" is a talc-chloritic-carbonate rock, notably softer than the "andesite" and rarely carries any sulfides except at contacts. Biotite is present and imposes a brown color in places. Numerous veins of calcite and a fewer number of quartz-carbonate vein cut the rock. It is massive in parts but much of it is intensely sheared.

The "Campbell diorite" is a coarser grain and a more massive phase of the "andesite". Its color is dark green with black flecks of ferromagnesian minerals. Mineralization is uncommon but it may contain veinlets of calcite or quartz.

LABORATORY STUDY

Macroscopic Description

All of these rocks look alike because of the similar amounts of chloritization, carbonization and silicification (Table 2). However, the "andesite" is a harder rock than the "altered rock" because it contains more quartz. The "siliceous rock" contains the most quartz of all the rocks but no chlorite. The "Campbell diorite" is the coarser grained rock of all the rocks studied. The mineralogy of the "andesite", "siliceous rock" and the "altered rock", suggest that they are of
TABLE 2

General description of the 16 rock specimens taken from the individual descriptions in the appendix

<table>
<thead>
<tr>
<th></th>
<th>&quot;Andesite&quot;</th>
<th>&quot;Siliceous Rock&quot;</th>
<th>&quot;Altered Rock&quot;</th>
<th>&quot;Campbell Diorite&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture</td>
<td>Fine-grained</td>
<td>Fine-grained</td>
<td>Fine-grained</td>
<td>Medium-grained</td>
</tr>
<tr>
<td>Structure</td>
<td>Soliated</td>
<td>Foliated</td>
<td>Schistosity</td>
<td>Massive</td>
</tr>
<tr>
<td>Mineralogy</td>
<td>Chlorite</td>
<td>Quartz</td>
<td>Chlorite</td>
<td>Chlorite</td>
</tr>
<tr>
<td></td>
<td>Quartz</td>
<td>Dolomite</td>
<td>Quartz</td>
<td>Quartz</td>
</tr>
<tr>
<td></td>
<td>Carbonates</td>
<td>Pyrite</td>
<td>Carbonates</td>
<td>Carbonates</td>
</tr>
<tr>
<td></td>
<td>Garnet</td>
<td></td>
<td>Calcite</td>
<td>Pyrite</td>
</tr>
<tr>
<td></td>
<td>Pyrite</td>
<td></td>
<td>Pyrite</td>
<td>Pyrrhotite</td>
</tr>
<tr>
<td></td>
<td>Tourmaline</td>
<td></td>
<td></td>
<td>Ferrous Oxides</td>
</tr>
<tr>
<td></td>
<td>Ferrous Oxides</td>
<td></td>
<td></td>
<td>Ferrous Oxides</td>
</tr>
<tr>
<td>Color</td>
<td>Dark blue-green</td>
<td>White-grey</td>
<td>Dark green</td>
<td>Dark green</td>
</tr>
<tr>
<td>Hardness</td>
<td>Very hard</td>
<td>Very hard</td>
<td>Soft</td>
<td>Fairly hard</td>
</tr>
</tbody>
</table>

TABLE 3

Primary minerals identified by x-ray analyses

<table>
<thead>
<tr>
<th></th>
<th>Quartz</th>
<th>Chlorite</th>
<th>Dolomite</th>
<th>Garnet</th>
<th>Calcite</th>
<th>Pyroxene</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Andesite&quot;</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>#6029</td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>#6035</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#6039</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Siliceous Rock&quot;</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#6032</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#6033</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Altered Rock&quot;</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>#6037</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>&quot;Campbell Diorite&quot;</td>
<td></td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#6042</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
sedimentary origin. However, the massiveness of the "Campbell diorite" suggests that it is of igneous origin. From the structure and texture of these rocks, it is evident that they all have undergone a process of metamorphism and are now metamorphic rocks. Descriptions are given in the appendix and summarized in Table 2.

X-Ray Analyses

The samples used to determine some of the mineralogy were prepared in the following manner under the direction of Dr. F. Karner using a Philips high-angle diffractometer.

A. Splitting and Grinding

1. About 100 grams of small fragments were taken from different parts of the specimen. Care was taken to select the fragments at random for best representation of the sample. These fragments were crushed to 1/8 inch size.

2. The sample was carefully split with a Jones-type splitter.

3. A five-gram split was ground for five minutes in a Spex 8000 mixer mill.

4. 1.2 grams were reground for another five minutes.

B. Packing of Sample in Rotating Holders

A standard Philips rotating specimen fiber holder was placed on a clean glass slide, slotted end up. The finely ground sample was dumped into the holder and spread evenly with a spatula. A smooth bottomed vial was inserted into the holder and pressed down very firmly for about seven seconds. The pressure on the vial was then released for a few seconds. While still holding the holder down, the vial was ready to
be x-rayed. The sample was run from 2° - 60°, 2θ.

X-ray analyses were made of specimens numbered 6021-31, 32, 33, 37, 39, and 42, which represented the four rock units under study. The index to A.S.T.M. Powder diffraction file was first used to identify the minerals. Standard diffraction charts of quartz, chlorite, plagioclase, hornblende, biotite and dolomite were compared with the peaks produced in order to facilitate the identification of the minerals (table 2). However, texture and structure characteristics of the specimens were studied from thin sections.

Microscopic Analyses

Description of all 16 thin sections representing the four rock units are given in the appendix. However, in the following few pages, figures 3 to 9 illustrate the texture, structure and mineralogy of the rock units. Thin sections of samples #6032, 34, 36, 38, 39, and 40 were photographed using Leitz Ortholux and Aristophot equipment under the direction of Dr. Karner. All photographs have a magnification of 47x.

The thin sections show the same rock forming minerals that were found in the megascopic and x-ray analyses. The different percentage of each mineral in each rock unit is what makes the unit distinguishable. The "siliceous rock" has the greatest amount of quartz and the "altered rock" has the greatest amount of chlorite and calcite. The "andesite" is intermediate between the two rocks mentioned above. The "Campbell diorite" is similar to the "andesite". However, the "Campbell diorite" is coarser grained than the andesite and it contains relict pyroxene which is not found in the other three rock units (figure
Figure 4. Sample #6032 of "Siliceous rock". A large cubic pyrite crystal is in contact with large quartz grains to the right. Microcrystalline grains of quartz, chert and carbonates make up the matrix.

Figure 5. Sample #6034 of "Siliceous rock". An elongated cluster of chert follows the foliation of the rock and it is bordered by lighter colored grains representing quartz and microcrystalline carbonates. The darker portion of picture is predominately chlorite developed at the "andesite" contact.
Figure 6. Sample #6036 of "Altered rock". The discordant vein containing quartz and altered chlorite shows that this rock has undergone disruption of structure because of metamorphic processes.

Figure 7. Sample #6038 of "Altered rock". A large mass of carbonate has quartz grains at top and at bottom and is in contact with a cluster of microcrystalline carbonate. Darker part of picture represents the chlorite and dissemination of ferromagnesian minerals and pyrite.
Figure 8. Sample #6039 of "Andesite". A small quartz-carbonate vein cuts across the axis of foliation. This vein zig-zags due to displacement along a micro-fracture. The dark material is predominately chlorite.

Figure 9. Sample #6043 of "Campbell diorite". This massive rock contains large quartz grains with inclusions. In the lower left corner, a grain of relict pyroxene is seen. The dark area is predominately chloritic with opaque minerals.
9). Since, there is no evidence of feldspars and their texture is fine-grained and they are foliated, the "andesite", "altered rock" and "siliceous rock" suggest that they are meta-sediments.

**INTERPRETATION**

The chief constituents of the rock types in order of abundance are: (1) "andesite" and "altered rock"; quartz, chlorite, carbonates (dolomite and/or ankerite, calcite), pyrite, arsenopyrite. (2) "siliceous rock"; quartz, chert, and/or chalcedomy, carbonates (dolomite); (3) "Campbell diorite"; quartz, chlorite, carbonate, iron oxide, relict pyroxene. The "Campbell diorite" and "siliceous rock" have less significant metallic mineralization than the others.

"Altered Rock" and "Andesite"

In the "altered rock", primarily the "andesite", the veins and lenses contain essentially quartz and carbonates with small amounts of pyrite, arsenopyrite and sometimes tourmaline (figure 2). Since these two rocks have been chloritized and well-foliated, they are a product of low-grade regional metamorphism of the greenschist facies. Carbonates are a dominant phase in the metamorphism of limestone and dolomite. There was no evidence of epidote in these rocks which is typical of propylitically altered andesite. The "altered rock" and "andesite" are both metasediments because of the carbonates originating from alteration of limestone and foliated structure.
"Siliceous Rock"

The study of the "siliceous rock" showed that it is siliceous but the quartz is associated with carbonates. The quartz found in this rock may replace the dolomite. According to Spurr (1898), silicification is common in carbonate rocks resulting in a fine-grained chalcedonic-type quartz-rock to which he applied the name jasperoid. Since little calcite is found in this rock, the calcite might have been removed and deposited further away in a zone of marginal alteration. This zone is exemplified by the "altered rock" that contains calcite which sometimes has been recrystallized to form well defined dog-tooth crystals disseminated with pyrite. The "siliceous rock" is also a metasediment because of its mineralogy and foliation.

"Campbell Diorite"

The massive, medium grained, hard, compact, greenish mineral aggregate of the "Campbell diorite" with pyroxene? is a saussurite rock. The pyroxene? in this rock and the large amounts of quartz suggest that the "Campbell diorite" was originally a quartz diorite intrusive before being metamorphosed.

DISCUSSION

The waters introduced by the intrusive "Campbell diorite" may have reacted with the originally carbonized "siliceous rock" to replace the carbonate by silica. In turn, the waters may have continued to alter adjacent rocks, thus producing extensive widths of chlorite carbonate schist and also depositing silica and sulphides. These constituents
might have mobilized together with the diffusion of minerals initially in the rock and later precipitated as carbonates, sulphides and rare minerals, primarily gold. Two or more generations of gold and quartz may have precipitated in the veins. The energy necessary to mobilize these various elements was derived from metamorphic processes and from structural deformation. During metamorphism, the structural disorders produced gases and waters which led to the liberation of silica, carbonates, iron, gold and other metallic elements which migrated and precipitated in shear zones, fractures, joints, and microfaults as quartz-carbonate veins bearing pyrite, arsenopyrite and gold.

It may be considered that ore-forming solutions may have been caused by hydrothermal alterations mainly derived from a magmatic source such as the "Campbell diorite". However, the source and the origin of the metals in the ores may be assigned to deep-seated metamorphism of source beds close at hand, where lateral and vertical secretion occurred Boyle (1959). The source beds may be the originally sedimentary "andesite", "siliceous rock" and "altered rock". A clearer explanation will only be available when both the source of the ore minerals and the elements in the rocks are known.

CONCLUSIONS

The principal economic deposits occur in quartz-carbonate lenses in extensive chlorite schist zones in meta-sedimentary rocks. The deposits represent concentration of silica, sulphur, arsenic, antimony, gold, and other metallic elements.

From the structure and texture and from the carbonates present,
it is believed that the "andesite", "siliceous rock" and the "altered rock" are not of igneous origin but rather of sedimentary origin. Furthermore, there is little evidence of sericite which would indicate alteration of igneous plagioclase. These rocks may have been originally a thick series of marine sediments deposited in Precambrian time and followed by extensive folding and faulting and intruded by the dikes and the "Campbell diorite" which has altered to a saussurite rock.

Since gold is associated with quartz and dolomite and/or ankerite, it is evident that the gold would most likely occur in the "andesite". This meta-sedimentary rock has the quartz-carbonate veins favourable for the precipitation of gold. Although "andesite" and "altered rock" look very similar with the naked eye, they may be readily distinguished by their difference in hardness since "andesite" contains more silica than the "altered rock". Near the "siliceous rock", the "andesite" is more abundant than the "altered rock" (figure 1). This may explain the source of silica for the "andesite" and therefore the "siliceous rock" becomes a very important host rock.

Future

The macroscopic, x-ray and microscopic analyses have contributed to the examination of the texture, structure and mineralogy of the rock units under study. The accumulation and sorting out of the results of the above mentioned analyses have helped to clarify the rock components and their origin. However, a chemical analyses would have contributed even further information. Also, future studies of more sections of the same rock units from different levels of the mine would give a more complete understanding of the process of alteration.
The problem posed by each unit is the source of silica in the metasediments. It may be from (1) primary quartz; (2) breakdown of highly siliceous minerals such as orthoclase or albite; (3) leaching from rocks through which the solutions passed; (4) magmatic or other deep seated sources.

Further and more detailed studies of the metasediments will probably yield much more information of the origin of the minerals. Lindgren (1894) said

"that the study of changes and alteration which the rocks adjoining fissures have undergone is a subject of highest importance, for in this way a closer insight into the genetic processes of the vein may be obtained."


Macroscopic and Microscopic Description

#6020 Texture-Very fine grained to microcrystalline. 
Structure-Apparent foliation, containing small corroded garnet crystals embedded throughout the face of the rock, narrow veins containing quartz crystals, tourmaline, pyrrhotite and some oxidized iron follows the schistosity of the rock. The rock is predominately chloritic, fairly hard and dark green. In the thin section, the microcrystalline quartz grains are associated with carbonates. A micro-fracture cuts across the axis of foliation and contains fine grains of quartz with occasional larger quartz grains.

#6030 Texture-Very fine grained 
Structure-Apparent foliation containing few small lenses of corroded garnets and pyrite, smokey quartz-carbonate vein surrounded by a dark colored rock of a cherty texture. The rock is primarily chloritic, fairly hard, dark blue to lime green. In the thin section, the larger quartz crystals are detrital where they are in contact with the carbonates. A fracture follows along the axis of schistosity and is filled with large dolomite and/or ankerite crystals in a chain-like fashion.

#6031 Texture-Fine grained to microcrystalline 
Structure-Apparent foliation and the horizontal lineation is
more striking. Fractured face is very crystalline with quartz-carbonate crystals embedded in the rock. The rock is predominantly chloritic, becoming softer, dark green. The thin section shows thin veinlets of quartz contrasted by larger veinlets of dolomite and/or ankerite following in parallel to the schistosity of the rock.

#6032 Texture-Fine grained
Structure-Apparent foliation to massive. Well fractured containing a few specks of pyrite. Fine grained carbonate veinlets contain oxidized ferrous minerals. Rock is very hard, lime green to a dark green. The thin section shows lenses of mosaic-like structure of the chert grains. Dolomite and/or ankerite and quartz grains make up most of the microcrystalline matrix.

#6033 Texture-Fine grained
Structure-Apparent foliation to massive. Containing very fine dark mineralized veins with disseminated pyrite. Rock is very siliceous, very hard and crystalline, white-grey. Carbonates present on softer part of the rock. The thin section shows that the fine matrix is predominately made up of detrital quartz, chert, chalcedony and carbonates.

#6034 Texture-Fine grained
Structure-Apparent foliation, concoidal fracturing. Contact face very crystalline and chalky. Rock contains some dissemination of pyrite, very siliceous, very hard, dark grey-white. In the thin section, clusters of chert are present in the matrix of quartz and carbonates with some chlorite.
Texture—Very fine grained to medium
Structure—Apparent schistosity. Contains bluish quartz-carbonate veinlets embedded with mineralized pyrrhotite. Rock is predominantly chloritic, medium hard and dark green. The thin section shows chloritized and cherty stringers. Detrital quartz grains and microcrystalline carbonates are mixed in with the chloritic matrix.

Texture—Very fine grained to medium
Structure—Apparent foliation. Contains chert and quartz-carbonate veinlets, some pyrite, pyrrhotite and arsenopyrite. Rock is very chloritic, medium hard and dark green. The thin section shows large crystals of calcite and dolomite and buff alteration due to biotite and chlorite.

Texture—Very fine grained.
Structure—Massive to schistose. Contains a wide grey quartz-carbonate vein disseminated with very fine pyrite. Rock is primarily chloritic and very soft becoming talcish, dark green. The thin section shows the matrix is predominantly chloritic with some of the chlorite altering to talc. Quartz grains are fewer with more microcrystalline calcite and larger dolomite crystals.

Texture—Fine grained
Structure—Apparent foliation, very well mineralized with pyrite. Looks like a buff alteration. Large amounts of bluish quartz present. Mineralized zone dark brown. Rock is very altered, dark brown zone very soft. The thin section shows that the brown
zone is a biotite alteration clustered with quartz grains and microcrystalline calcite and dolomite.

#6039  **Texture:** Fine grained  
**Structure:** Banded structure with quartz veinlets rich in pyrite.  
Rock is primarily chloritic and medium hard, dark bluish green.  
The thin section shows that the quartz grains in the chloritized matrix are associated with the fine grained carbonates.

#6040  **Texture:** Fine grained to microcrystalline  
**Structure:** Similar to 6039 but rock has a fractured face of quartz-carbonate which is cemented to the rock. Rock is predominately chloritic, fairly hard but softer in places. The carbonized quartz veinlets in the thin section cuts across the axis of foliation and bends where they intersect black strands of opaque minerals. Finely divided matrix is predominately chloritic.

#6041  **Texture:** Fine to medium grained  
**Structure:** Massive smokey quartz veinlets, very fractured, contains dark specks in places. Orange coloration of quartz because of oxidization of metallic minerals. Rock is very altered, chloritic, medium hard, dark green.

#6042  **Texture:** Medium grained  
**Structure:** Layered to a massive structure containing some pyrite running parallel to structure. Quartz carbonate found throughout the faces. Joint face shows black flecks and iron stains. Rock is primarily chloritic, fairly hard and dark green.

#6043  **Texture:** Medium grained  
**Structure:** Layered to massive structure. Very similar to 6042 but
less quartz and no mineralization.

#6044  
**Texture—Medium grained**

**Structure—Layered structure is massive.** Disseminated in part with some pyrite. Contains black flecks. Rock is primarily chloritic, soft, bluish-green. Thin sections for #6041, 42, 43 and 44 and for "Campbell diorite" show this rock is massive containing large quartz grains with distinctive inclusions in a chloritized matrix. Smaller grains of quartz are clustered together mosaic-like. Pyroxene is scarce and pale green and where it is noticeable its margins and weak fractures of the grain is being altered to chlorite.