THE LOST HORSE INTRUSIVES
COPPER MOUNTAIN, B.C.

by

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ABSTRACT

The Lost Horse intrusives are minor plutonic bodies occurring to the north and northeast of Copper Mountain, B.C. The rocks of the intrusives were classified by megascopic examination. It was felt that microscopic examinations of the rocks might bring out relationships which were obscure megascopically. Such was the case. The nine specimens examined, which were divided megascopically into six types, were found to consist of only three distinct rock types.

The identity of the three rock types had been obscured by weathering and by different types of hydrothermal alteration. Now that the changes brought about by weathering and hydrothermal alteration are recognized, fewer rock types will appear on the detailed maps and, in addition, zones of alteration may be outlined.
FOREWARD

The specimens studied in this thesis were collected during the summer of 1949 when the writer was employed at Copper Mountain, B.C. by the Granby Consolidated Mining, Smelting, and Power Company, Limited. The laboratory work was carried out during the winter of 1949-1950 at the University of British Columbia.

Thanks are due to Mr. Keith C. Fahrni and Mr. J. Harvey Parliament for their advice during the field season and Dr. H.C. Gunning, Dr. K. DeP. Watson, and Dr. L. Dolar-Mantuani for their help in carrying out the laboratory work and in writing the manuscript. Thanks are also due to Mr. J.A. Donnen for preparing the thin sections.
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INTRODUCTION

During the summer of 1949 the writer was engaged in detailed mapping of an area north of Copper Mountain, B.C. In the area were many exposures of the Lost Horse intrusives which are minor plutonic bodies invading the Wolf Creek volcanics. The Lost Horse intrusives are thought to be genetically related to the Copper Mountain stock and therefore to the important copper mineralization of the region.

In the field the rocks of the Lost Horse intrusives were mapped by megascopic examination. It was felt that the field work during the 1950 season would be greatly aided by a microscopic examination of the major rock types. Such a microscopic examination could lead to one of two results. Either the subdivisions, which were established megascopically, could be further subdivided, or some subdivisions could be combined.

It can be seen that a relatively small amount of microscopic work would greatly increase the speed and accuracy of the field work.
II - The Copper Mountain Area (1)

A - Introduction.

The Copper Mountain area lies 120 miles east of Vancouver, B.C., and 10 miles south of Princeton, B.C.

The oldest rocks in the area consist entirely of volcanic material which Victor Dolmage tentatively correlates with the Nicola series of Triassic age. The volcanic rocks have been named the Wolf Creek formation. It is thought at the present time that the beds have a northerly strike and gentle dips to the west.

In the Copper Mountain area, two or three rather large augite diorite stocks intrude the volcanics. The largest of these intrusives is the Copper Mountain stock. To the north and north east of the Copper Mountain stock lie the Lost Horse Intrusives. These intrusives appear to be small and irregular and to be made up of several distinct rock types.

Intruding these stocks and minor plutons are many felsite, pegmatite, and andesite dykes which range in age down to late Tertiary. The north end of the area is covered by lava flows of Eocene or later age.

B - Wolf Creek Formation.

The Wolf Creek volcanics are made up of tuffs, flows, and breccias. They form the country rock throughout the area. In neighbouring areas, true sediments have been observed in the series which have aided the correlating of these rocks with Numbers in brackets refer to references.
Dawson's Nicola series of Triassic age.

Throughout the area the structure is very obscure because of the paucity of recognizable bedding. Parallel to the northeast contact of the Copper Mountain stock the volcanics have been sheared and fractured. The Copper Mountain orebodies occur in this zone.

C - Lost Horse Intrusives

The Lost Horse intrusives occur to the north and northeast of the Copper Mountain stock between it and the Voigt and Smelter Lake stocks. The Lost Horse intrusives are irregular in outline and are poorly exposed. There are two distinct types. One is a light, acid augite diorite. The other is a pinkish grey, biotite monzonite or syenite.

Near deposits of ore minerals, the intrusives are impregnated with small amounts of pyrite and chalcopyrite, and the feldspars are extensively altered to sericite. In places these rocks were mineralized by solutions which, according to Dr. Dolmage, apparently came from the Copper Mountain stock. The composition of the Lost Horse intrusives is so similar to the compositions of the Copper Mountain, Voigt, and Smelter Lake stocks that the Lost Horse intrusives may be closely related to them in time as well as in origin.

D - The Copper Mountain Stock.

The Copper Mountain stock is elliptical in plan. The major axis, extending northwest, is five miles long and the minor axis is three miles long. The Copper Mountain ore
deposits lie immediately outside the contact of the northeast side of the stock. Other deposits of ore minerals lie outside the west and south contacts of the stock.

The stock is divided into three zones. It ranges in composition from an outer zone of syenogabbro to an inner core of nearly pure feldspar pegmatite. The variation may be seen in figures 1, 2, and 3. The stock has the following three compositional peculiarities:

1. Both quartz and feldspathoids are absent.
2. Large apatite crystals are abundant.
3. Abnormal amounts of orthoclase occur with the gabbroic and dioritic phases.

The contacts of the intermediate and inner zones are abrupt and can be mapped in the field (see figure 3). Within the three zones, however, there are variations which are too gradual to permit mapping the various phases of which each is composed.

Suites of minerals from several periods of contact metasomatism have been recognized around and in the stock. The first suite occurs in the sheared zone to the northeast of the stock and does not penetrate the gabbro. Vast amounts of biotite, augite, and plagioclase and small amounts of copper-iron sulphides were deposited. The second stage, which deposited epidote, zoisite, scapolite, and andesine, contains few or no metallic minerals and is of no economic importance. These minerals cut and bleach biotitized rocks. The last stage is
### FIGURE 1

Table of Mineral Variation in the Copper Mountain Stock

(After Dr. Dolmage)

<table>
<thead>
<tr>
<th>Position</th>
<th>Percent of Minerals Present</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plagioclase</td>
</tr>
<tr>
<td>Outer Zone</td>
<td></td>
</tr>
<tr>
<td>Syenogabbro to</td>
<td>50 (Lab-And)</td>
</tr>
<tr>
<td>Syenodiorite</td>
<td>50 (Olig,And-Olig)</td>
</tr>
<tr>
<td>Intermediate Zone</td>
<td></td>
</tr>
<tr>
<td>Syenodiorite to</td>
<td>50 (Oligoclase)</td>
</tr>
<tr>
<td>Monzonite</td>
<td>55 (Ab-Olig)</td>
</tr>
<tr>
<td>Inner Zone</td>
<td>30 (Albite)</td>
</tr>
<tr>
<td>Pegmatite</td>
<td>Including Microcline</td>
</tr>
</tbody>
</table>
FIGURE X

Graph of Chemical Variation in the Copper Mountain Stock.

1. From border of the stock
2.5 = from pegmatite core
2.3 = from intermediate position

Number of Chemical Analysis

Graph of Oxidation Variation

Oxidation: 0

Metal Oxides:
Figure 3 - Graph of Modal Compositions vs Position in Copper Mtn Stock

(Information from Roswell Analyses by Victor Dolmage)

- Outer Zone
- Intermediate Zone
- Central Core

Samples Plotted in Positions Shown on Map
responsible for most of the ore deposition. Orthoclase, albite, green biotite, and iron and copper iron sulfides form veinlets in the biotitized rocks. This stage of metasomatism has effected a wide zone within the intrusive as well as altered the surrounding volcanics.

E - Voigt and Smelter Lake Stocks.

The Voigt and Smelter Lake stocks occur to the north and northeast of the Copper Mountain stock respectively. The area between the two stocks is covered by Tertiary lavas of no great thickness beneath which the stocks probably join.

Unlike the Copper Mountain stock, the Voigt and Smelter Lake stocks are nearly uniform in composition. They consist of dark grey, medium grained augite diorite or syenodiorite composed essentially of plagioclase, augite, and hornblende with small amounts of orthoclase and biotite. Accessories are apatite and magnetite. The plagioclase ranges from andesine to labradorite.

The mineralization in and around these stocks differs from the Copper Mountain mineralization in that the opaque minerals are hematite, magnetite, and pyrite rather than bornite.

III - Description of Methods.

A standard petrographic microscope was used for all descriptions. In some slides the orthoclase was very difficult to distinguish from the plagioclase. The use of oils of known
refractive index was attempted but the feldspars are so altered that grains immersed in the oil were not transparent. As a result, the potassium feldspar was recognized by etching the slides with hydrofluoric acid and then staining them with sodium cobaltinitrite (2). The staining of slides also facilitates Rosiwal analyses (3).

The following is a brief summary of the procedure used in staining slides.

1. The minerals are identified qualitatively.
2. The cover glass is removed and the balsam is cleaned off with gasoline.
3. The under side of the glass slide is covered with celluloid dissolved in acetone. The celluloid protects the glass from the HF fumes.
4. The slide is set in a lead tray and the tray is placed in a lead fuming box for 40 to 50 seconds. HF in the bottom of the box is heated to 65°C by placing the box six inches above a one half inch bunsen flame.
5. After being removed from the fuming box, the section is covered with concentrated sodium cobaltinitrite solution for 30 to 40 seconds. The stain is very gently washed off the slide with water.
6. The section is dried for 24 hours and then a cover glass is cemented on top of the stained rock section with a cold solution of balsam in xylol. The balsam becomes hard in about a week.

The staining treatment colors potassium feldspar
yellow, roughens and darkens plagioclase, and does not affect quartz at all.

The concentrated sodium cobaltinitrite solution is prepared by adding 15 millilitres of glacial acetic acid and 25 millilitres of water to 12.5 grams of Co(NO₃)₂·6H₂O and 20 grams of sodium nitrite. The lead box is made of sheet lead one-sixteenth of an inch thick. (Figure 4).

The modal compositions of the slides were obtained by means of Rosiwal analyses. Slide S₁₋₅ was tested twice and the percentages of the main minerals were found to be as follows:

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Before Staining</th>
<th>After Staining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augite</td>
<td>19.2%</td>
<td>18.7%</td>
</tr>
<tr>
<td>Labradorite</td>
<td>51.0%</td>
<td>50.8%</td>
</tr>
<tr>
<td>Orthoclase</td>
<td>18.5%</td>
<td>21.2%</td>
</tr>
</tbody>
</table>

In addition to the increase in amount of orthoclase counted after staining, this comparison shows that the Rosiwal analyses can be repeated with fair accuracy. Consequently, in the appendix, the amounts of the minerals present in each slide have been given to the nearest percent.

Although a Rosiwal analysis can give the modal composition of a slide accurately, a slide is not a perfect sample of a rock specimen and a specimen is not a perfect sample of a body of rock. Consequently, the author does not wish to emphasize the exact modal compositions of the specimens. Only general comparisons and conclusions are justified.
FIGURE 4 - FUMING BOX

Fuming Box (Lid not shown)

Tray Support

Tray

Thin Section.
IV Results of the Detailed Descriptions.

A - Definitions.

The various rocks of the Copper Mountain area have been given code symbols. The volcanics are designated by V plus a subscript, the dykes by D plus a subscript, and the various plutonic intrusives by S plus a subscript. The Lost Horse intrusives are all S rocks. The numerical subscripts do not signify anything geologically; each time a new rock is encountered the next unused subscript is assigned to it. The letter after the subscript indicates the number of the specimen. For example, \( S_3 \) signifies that the rock is the second specimen of the rock type \( S_3 \).

The rock types investigated in this thesis and their definitions are as follows:

1. \( S_1 \) - Massive coarse grained grey green feldspathic with augite and biotite.
2. \( S_3 \) - Light greenish to green medium grained to coarse grained feldspathic rock with some pale green augite. It is like \( S_5 \) but has a definite greenish color.
3. \( S_5 \) - Light greenish to white monzonite of medium to coarse grained granitic texture and massive character. It contains mostly feldspar and practically no mafics.
4. \( S_6 \) - Greyish green to pinkish syenite with a fair amount of mafics, but less than 15%. The texture is medium to coarse grained granitic.
(5) \( S_9 \) - Very light acid augite diorite.

(6) \( S_{10} \) - Biotite monzonite. Pinkish grey with orthoclase, plagioclase, and numerous small flakes of biotite.

(7) \( S_{11} \) - Feintly pink to pinkish medium grey, coarse grained monzonite with about 10% augite and 1 or 2% biotite.

**B - Comparison of the investigated Specimens.**

The composition of all the specimens are listed in figures 5 and 6. It may be seen that four distinct types of rock are represented. \( S_3 \) - Specimens \( S_{3-A'}, S_{3-B'}, S_{3-C}, S_{5-B'} \) and \( S_{6-A} \) are similar to each other. The composition of the feldspar is very close to the andesine-labradorite boundary. These rocks fit into the group \( S_3 \). Specimen \( S_{5-B} \) was classified in the field as \( S_5 \) rather than \( S_3 \) because of the light color of the augite. In the hand specimen, \( S_{6-A} \) apparently contains a great deal of orthoclase but microscopically it is seen to be typical, \( S_3 \). The pink color in the feldspar is caused by iron stain. It may be concluded that possibly the rock type \( S_6 \) does not exist.

\( S_5 \) - Specimens \( S_{5-A}, S_{9-A}, S_{10-A} \) also are similar to each other. The rocks all fit into the group \( S_5 \). Specimen \( S_{9-A} \) appeared different megascopically because of extensive alteration to epidote. \( S_{10-A} \) looked in the hand specimen as if it contained a considerable amount of orthoclase and some biotite. The former was iron stain and the latter was possibly chlorite.
**FIGURE 5**

Table of the Modal Composition of the Lost Horse Intrusives.

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Specimen</th>
<th>% Aug.</th>
<th>% Plag</th>
<th>Compo Plag</th>
<th>% Ortho</th>
<th>% Biotite</th>
<th>% Magnetite</th>
<th>% Hematite</th>
<th>% Apatite</th>
<th>% Sphene</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>S1-A</td>
<td>19</td>
<td>51</td>
<td>An55</td>
<td>21</td>
<td>4½</td>
<td>4½</td>
<td>--</td>
<td>&lt; 1/2</td>
<td>--</td>
</tr>
<tr>
<td>S3</td>
<td>S3-A</td>
<td>27</td>
<td>73</td>
<td>An40-45</td>
<td>--</td>
<td>--</td>
<td>&lt;½</td>
<td>&lt; 1/2</td>
<td>1/2</td>
<td>&lt; 1/2</td>
</tr>
<tr>
<td>S3</td>
<td>S3-B</td>
<td>21</td>
<td>76</td>
<td>An47-52</td>
<td>--</td>
<td>--</td>
<td>&lt;½</td>
<td>--</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>S3</td>
<td>S3-C</td>
<td>31</td>
<td>67</td>
<td>An55-60</td>
<td>--</td>
<td>--</td>
<td>&lt;½</td>
<td>--</td>
<td>1</td>
<td>1/2</td>
</tr>
<tr>
<td>S5</td>
<td>S5-A</td>
<td>19</td>
<td>76</td>
<td>An5-10</td>
<td>--</td>
<td>--</td>
<td>1/2</td>
<td>2 1/2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td>S5-B</td>
<td>17</td>
<td>82</td>
<td>An45</td>
<td>--</td>
<td>--</td>
<td>1/2</td>
<td>1/2</td>
<td>1/4</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>S5-A</td>
<td>15</td>
<td>82</td>
<td>An50</td>
<td>--</td>
<td>--</td>
<td>1 1/2</td>
<td>1 1/2</td>
<td>1/4</td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td>S5-B</td>
<td>16</td>
<td>77</td>
<td>An10</td>
<td>--</td>
<td>--</td>
<td>2 1/2</td>
<td>--</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>S11</td>
<td>S11-A</td>
<td>15</td>
<td>26</td>
<td>An50</td>
<td>48</td>
<td>4½</td>
<td>4½</td>
<td>--</td>
<td>1 1/2</td>
<td>--</td>
</tr>
</tbody>
</table>

*1% Quartz*
FIGURE 6
Table of Range in Compositions of Augite-Diorite and Augite Syenite

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Specimens</th>
<th>Percent Augite</th>
<th>Percent Plagio</th>
<th>Comp. Plagio</th>
<th>Percent Magnetite</th>
<th>Percent Hematite</th>
<th>Percent Apatite</th>
<th>Percent Sphene</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₅: Augite syenite</td>
<td>S₅-A, S₉-A, S₁₀-A</td>
<td>5-19</td>
<td>76-92</td>
<td>An₅ - An₁₀</td>
<td>0-2½</td>
<td>0</td>
<td>&lt;½</td>
<td>2 - 3</td>
</tr>
</tbody>
</table>
$S_1$ - Specimen $S_{1-A}$ was collected near the outer margin of the Copper Mountain stock and is typical syenogabbro.

$S_{11}$ - Specimen $S_{11-A}$ is an augite monzonite. However, as may be seen in table III, the rock is similar to $S_{1-A}$. The main difference is that there is twice as much orthoclase in $S_{11-A}$ as in $S_{1-A}$. In addition there is slightly over one percent quartz in $S_{11-A}$. No generalities can be made on two specimens collected over a mile apart but the author wishes to point out the similarity as being very interesting.

V Alteration.

It may be concluded from the previous section that the Lost Horse intrusives are made up of two main kinds of rock, augite diorite and augite syenite. Megascopically it appeared that there were other rock types present. The reasons for this is the variation in the color of the augite and the presence of different types of alteration.

The reasons for the variation in the color of the augite is obscure but the different types of alteration were apparent microscopically (Figure 7).

In $S_{3-A}$, $S_{3-B}$, and $S_{3-C}$, or better, in typical $S_3$, there is moderate alteration to clay mineral, sericite, a little carbonate, and a little epidote. Specimen $S_{5-B}$, which is $S_5$, was mistaken for $S_5$ because of the light color of the augite. $S_{6-A}$ differs greatly in appearance from typical $S_3$ because the feldspars are stained with red iron oxide.
Specimen $S_{5-A}$ is typical $S_5$. The main alteration products are clay mineral and sericite. Specimen $S_{9-A}$ originally had the same composition as $S_{5-A}$, but the main secondary minerals are epidote and clinozoisite rather than clay mineral. Specimen $S_{10-A}$ has dark green augite and epidotized rather than kaolinized feldspar.
**FIGURE 7**

Table of Alteration and Replacement in the Ten Investigated Specimens.

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Specimen</th>
<th>Alteration and Replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁</td>
<td>S₁-A</td>
<td>Augite - Unaltered</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plag. - Partly altered to fine grained sercite.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orthoclase - Cloudy.</td>
</tr>
<tr>
<td>S₃</td>
<td>S₃-A</td>
<td>Augite - Partly altered to clay mineral and a little clinozoisite Partly replaced by carbonate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plag. - Partly to epidote and sercite</td>
</tr>
<tr>
<td>S₃-B</td>
<td>S₃-B</td>
<td>Augite - About 10% altered to chlorite(?) and/or serpentine (?)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plag. - Partly altered to clay mineral, sercite, and some clinozoisite. Some pyrite is present.</td>
</tr>
<tr>
<td>S₃</td>
<td>S₃-C</td>
<td>Augite - About 5%-10% altered to clay mineral, carbonate, and sercite.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plag. - Extensively altered to clay mineral, carbonate, and sercite.</td>
</tr>
<tr>
<td>S₅-B</td>
<td>S₅-B</td>
<td>Augite - Relatively unaltered, some clay mineral.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plag. - Moderate amounts of clay mineral, sercite, clinozoisite, and chlorite.</td>
</tr>
<tr>
<td>S₆-A</td>
<td>S₆-A</td>
<td>Augite - More than 50% replaced by chlorite and carbonate - not clay mineral.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plag. - Extensively altered to sercite, clinozoisite, epidote, and a little clay mineral. It is also stained red. Some pyrite is present.</td>
</tr>
<tr>
<td>S₅-A</td>
<td>S₅-A</td>
<td>Augite - Partly to clay mineral, carbonate, and clinozoisite.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plag. - Extensively to clay mineral. Some sercite, clinozoisite, and epidote. Some chalcopyrite is present.</td>
</tr>
<tr>
<td>S₅</td>
<td>S₉-A</td>
<td>Augite - Heavily replaced by the groundmass, carbonate, and a little clay mineral.</td>
</tr>
<tr>
<td>-----</td>
<td>-------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Flag. - Extensively to sericite, epidote, clinozoisite, and chlorite. Some pyrite is present.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S₁₀-A</th>
<th>Augite - Relatively unaltered, a little clinozoisite and chlorite.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Partly altered to clinozoisite, sericite, epidote, and clay mineral.</td>
</tr>
<tr>
<td></td>
<td>There is a little iron stain.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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**Note:** The fine grained material called "Clay Mineral" is undoubtedly partly very fine grained sericite.

Every specimen examined has been sericitized to some extent. Possibly variations in intensity of sericitization could be recognized if a great deal of microscopic work were done but sericitization can not be seen in the hand specimen.

In some of the rocks, for example S₅-A, the most apparent secondary mineral is clay mineral. In other rocks, for example S₉-A, the dominant secondary mineral is epidote. In specimen S₆-A, the feldspar is stained pink with iron oxide. These types of alteration and replacement can be recognized in the hand specimens. Consequently, with the knowledge that different secondary minerals may be recognized in various rock types, it should be possible to map zones of alteration and replacement.
According to Victor Dolmage, epidote and zoisite were deposited in the second stage of contact metasomatism and also simultaneously with the ores in the volcanics and in the pegmatite dykes. Possibly the epidote and clinozoisite (zoisite ?) of the Lost Horse intrusives had the same origin. The hematite which stained the feldspars of S_{6-A} probably originated in the Voigt or Smelter Lake stocks which deposited hematite during their periods of mineralization.

Inside the eastern contact of the Copper Mountain stock, the late felsite dykes caused the growth of poikiloblastic biotite in syenogabbro. These dykes also occur to the north of the stock among the Lost Horse intrusives. Consequently, consideration should also be given to the possibility that the dykes have effected part of the alteration of the Lost Horse intrusives.
CONCLUSIONS

It has been established by microscopic examination that the number of distinct rock types of the Lost Horse intrusives is less than was originally thought. In addition it was observed that different types of alteration were dominant in different outcrops and that the types of alteration could be recognized in the hand specimens.

Simple laboratory tests will prove the presence or absence of orthoclase. The etching with hydrofluoric acid and covering with sodium cobaltinitrite may be carried out on fairly smooth rock chips and then the feldspars examined with a hand lens to determine whether they have been stained. The augite diorite and the augite syenite can probably be distinguished, when the rock color is not definitely green or definitely white, by immersing very finely crushed feldspar in an oil with refractive index of $n = 1.54$.

With the knowledge of the distinct rock types and of the types of alteration and with the use of the simple laboratory methods outlined above, the mapping of the Lost Horse intrusives will be simple and accurate. Furthermore, zones of different types of alteration will probably be established.
REFERENCES

(1) Dolmage, V. (1934) Geology and Ore Deposits of Copper Mountain, British Columbia: Geol. Survey, Canada, Memoir 171.


Specimen S1-A (2500 N, 13,600 E)

I Megascopic Description.

The rock is medium to fine grained holocrystalline with a medium dark, greenish grey color and a faint pink tinge. The texture is granitic. The composition is 30% dark green augite, 60% greenish grey to pinkish grey feldspar, 5% fine grained biotite, and some very fine, black, metallic mineral.

On weathered surfaces, the augite is lighter green and the feldspar is pinkish white. On each side of fractures, the rock has been bleached for one sixteenth of an inch. The augite is lighter green and the feldspar is white.

II Microscopic Description

(a) Minerals

1 - Augite - Pale green, stubby, eight-sided crystals;
   opt +, 2V = 55°, no pleochroism, length slow, maximum extinction angle is 45°, maximum birefringence is .024 - .027, n = 1.67
   - 19% of the rock
   - Size ranges from 1/2 mm - 2 mm.
   - Subhedral to euhedral; some crystals are broken and rounded.
   - The augite is unaltered.

2 - Labradorite - Colorless, relief low, n greater than balsam, shows polysynthetic twinning, maximum extinction angle in sections perpendicular to (010)
is 30°. The Pc is An_{55}
- 51% of the rock
- The grain is seriate, ranging up to one mm. The average size is .5 mm.
- The crystals are mostly euhedral with the length two to three times the width.
- The crystals are zoned. The outer rim is always unaltered, whereas the interior may or may not be partly altered to fine grained sericite.

3 - Orthoclase - Slightly pink, n less than balsam, some simple twinning, stains yellow with sodium cobaltinitrite.
- 21% of the rock
- The average size is 5 mm.
- Subhedral to anhedral, slightly elongate.
- The crystals are cloudy but the alteration is not as intense as in the interior of the Pc crystals.

4 - Biotite - Pleochroic from light yellow to medium dark reddish brown. The absorption is maximum when the cleavage is parallel to the polarizer.
- 4½% of the rock
- The grain ranges from .1 to .8 mm.
- Subhedral to anhedral.
- Unaltered.

5 - Magnetite - Opaque, black, white pebbly surface under reflected light.
- 41\% of the rock
- The grain ranges from microcrystalline up to .5 mm.

6 - Apatite - Colorless, n = 1.63, interference colors are first order blue grey. End sections are hexagonal and the crystals are length fast.
- Accessory.
- The crystals are very small.
- Euhedral hexagonal prisms terminated with dipyramids.

(b) Mutual Relations.

The texture is poikilitic with the orthoclase as the oikocrysts and the other minerals as chadacrysts. In some places the orthoclase cuts into the augite and plagioclase. Some labradorite is enclosed in augite and some augite is enclosed in labradorite. Biotite cuts augite and labradorite. Magnetite occurs throughout. It occurs in and cuts all the other minerals but some grains are very irregular and fill between augite and plagioclase crystals.

(c) Composition

i - Augite - 19\%
ii - Labradorite - 51\%
iii - Orthoclase - 21\%
iv - Biotite - 43\%
v - Magnetite - 43\%
vi - Apatite - Accessory
(d) The texture is Poikilitic. From the composition, the term Monzonitic may be used.

(e) The rock is a Syenogabbro.

Specimen S3-A (10,200N, 8700E)

I Megascopic Description

The rock is medium grained holocrystalline with a greyish green color. The texture is granitic. The composition is 25% medium green augite and 75% light grey feldspar. There is a thin coating of brown hydrous iron oxide along fractures.

II Microscopic Description

(a) Minerals

1 - Augite - Pale green, stubby, eight sided crystals; no pleochroism, maximum extinction angle is 45°, n = 1.67

- 27% of the rock

- The grain size is seriate, ranging down from 1 mm.

- Subhedral to euhedral, now mostly rounded and corroded.

- The greater part of the original augite crystals still retain their interference colors but are partly altered to clay mineral and a little clinoczoisite and are partly replaced by carbonate and feldspar matrix.
2 - Andesine - Colorless, low relief, n greater than balsam, exhibits coarse polysynthetic twinning, optically positive. From sections perpendicular to z, the composition is An$_{40-45}$

- 73% of the rock.

- There are two different modes:
  (1) Euhedral crystals 1 - 3 mm in size
  (2) Anhedral crystals .05 mm in size

which form a matrix. The former comprise 30% of the section, the latter comprise 43%.

- The groundmass is less altered than the Andesine phenocrysts but the edges of the anhedral grains are sericitized (?). The contacts of the groundmass with the augite were stained slightly yellow by sodium cobaltinitrite, indicating the formation of sericite or narrow rims of potassium feldspar caused by reaction. In addition, most of the epidote in the slide has altered from andesine.

3 - Magnetite - Opaque, black, shines white under reflected light.

- Occurs in very minor amounts
- Grain size is about .1 mm.
- The crystals are anhedral and bordered by hematite.

4 - Hematite - Almost opaque; it transmits light of a deep red color.

- Accessory
- Grain size is 1/4 to 1 mm.
- Originally subhedral to euhedral; now most of the grains are more or less corroded.

6 - Sphene - Pleochroic medium to dark brown, high relief, high birefringence.
- Accessory
- The average size is .05 to .1 mm.
- Occurs as subhedral to euhedral rhombs.
- Unaltered.

7 - Epidote - Pleochroic colorless to yellow; interference colors are second order reds and greens, n = 1.75
- 4% of the rock
- The crystals range in size from .2 to .6 mm.
- The epidote occurs in anhedral crystals as an alteration product of andesine and maybe of augite.

8 - Carbonate - Colorless, change of relief on rotation of the stage, high birefringence.
- Fills a veinlet .02 mm wide, and occurs as a very fine grained replacement in andesine and augite.

9 - Chlorite - Light green, low relief, very low birefringence, one cleavage.
- Occurs as a very fine, sparse alteration product of augite.

(b) Mutual Relations

The texture is porphyritic with phenocrysts of augite and andesine set in a groundmass of microcrystalline andesine.
In addition to replacing the augite, the groundmass has partly replaced the andesine phenocrystals indicating that the groundmass might be more sodic than the phenocrysts.

(c) Composition.

1 - Augite - 27%
2 - Andesine - 73%

(1) Phenocrysts - 30%
(2) Groundmass - 43%
3 - Magnetite - Accessory
4 - Hematite - Accessory
5 - Apatite - Accessory
6 - Sphene - Accessory

(d) The texture is microporphryritic. Megascopically, it appears granitic.

(e) The rock is an Augite Diorite. Microscopically, it is an Augite Diorite Porphyry.

Specimen $S_3-B$ (3750 N, 12,800 E)

I - Megascopic Description.

The rock is medium to fine grained holocrystalline with a light greyish green color. The texture is granitic. The composition is 30% medium green augite and 70% light grey feldspar.

On weathered surfaces the feldspar is slightly pink but, on the outside, there is a thin coating of light brown oxides. Fractures inside the rock are coated with dark brown
II - Microscopic Description.

(a) Minerals.

1 - Augite - Very pale green, almost colorless, stubby eight-sided crystals; optically positive, $2V = 60^\circ$, maximum extinction angle is $45^\circ$, $n = 1.67$
- $21\%$ of the rock.
- The size ranges from .1 to 1 mm.
- Anhedral to euhedral prismatic crystals.
- The augite is altered to the extent of about $10\%$ along cleavages and cross fractures and in irregular patches to a brown mineral with low relief and low birefringence. This might be bastite.

2 - Andesine - Labradorite - Colorless, low relief, $n$ greater than balsam, shows polysynthetic twinning. A section perpendicular to X shows that the composition ranges from $\text{An}_{47}$ on the rims to $\text{An}_{52}$ in the centres.
- $76\%$ of the rock.
- The grain is seriate up to 2 mm with most of the crystals 1/2 to 1 mm.
- The crystals are subhedral to almost euhedral prismatic.
- The plagioclase is altered extensively to clay mineral and sericite. Although the difference in composition of the centres and rims is only 5 to 10\%
A 

In some cases the centres are almost completely altered while the rims are unaltered. Some clinzoisite is present.

3 - Magnetite - Opaque, black, white in reflected light.
   - Occurs in very minor amounts
   - 0.05 - 0.1 mm in size.
   - The crystals are anhedral and bordered with iron stain.

4 - Pyrite - Opaque, yellow in reflected light, the crystals have square outlines.
   - Occurs in very minor amounts.
   - 0.05 - 0.1 mm in size.
   - The crystals are euhedral with square outlines and are bordered with iron stain.

5 - Apatite - Colorless, n = 1.63, low interference colors, uniaxial, optically negative.
   - 1\% of the rock
   - grain size ranges from 0.05 - 0.5 mm.
   - The crystals are subhedral to euhedral.
   - Unaltered.

6 - Sphene - Pleochroic medium to dark brown, high relief, high birefringence; 2V = 25°, optically positive.
   - 2\% of the rock
   - Grain size is 0.1 mm.
   - Anhedral to subhedral.
(b) Mutual Relations.

The rock is equigranular. The feldspar crystals have slightly irregular boundaries and apparently grew until they were in contact with each other. The augite crystals include plagioclase crystals and so may be later than the initiation of feldspar crystallization. However, the augite crystals have very irregular boundaries and completed their crystallization before the feldspar, and were then corroded by the late liquids which were richer in the albite molecule than the early plagioclase crystals.

(c) Composition.

1 - Augite - 21%
2 - Andesine-Labradorite - 76%
3 - Magnetite - Accessory
4 - Pyrite - Accessory
5 - Apatite - 1%
6 - Sphene - 2%

(d) The texture is granitic

(e) The rock is Augite Diorite.
I - Megascopic Description.

The rock is medium to fine grained holocrystalline with a light greenish grey color. The texture is granitic. The composition is 30% medium to dark green augite and 70% light grey to white feldspar.

On weathered surfaces the augite is lighter green and the feldspar is white. Fractures have films of brown, hydrous iron oxides.

II - Microscopic Description.

(a) Minerals

1 - Augite - Very pale green, stubby, eight sided crystals, optically positive, $2V = 60^\circ$, maximum extinction angle is $45^\circ$, $n = 1.67$.

- 31% of the rock.
- The grain size is seriate. It ranges down from 1 mm.
- The augite is subhedral to euhedral.
- The augite is altered to the extent of 5% to 10% to clay mineral, carbonate, and clinozoisite.

2 - Labradorite - Colorless, low relief, $n$ greater than balsam, does not stain yellow with sodium cobaltinitrite. Sections perpendicular to $Z$ show a composition of $An_{55-60}$.

- There are two modes of occurrence:

  1) Phenocrysts with an average size of 1 mm. These make up 51% of the rock.
(2) Groundmass with an average size of 0.1 mm. This makes up 16% of the rock.

- The phenocrysts are subhedral to almost euhedral. The edges are corroded by the groundmass. The groundmass is composed of anhedral plagioclase crystals which are irregularly intergrown. Since these groundmass crystals cut into the phenocrysts, they might be of different composition or they might be material which recrystallized from the edges of the phenocrysts, in the presence of the carbonate solutions which have altered the rock.

- The labradorite has been altered to clay mineral, carbonate, and sericite to such an extent that it is very difficult to recognize albite twinning. Along irregular zones, the colorless minerals have been stained yellow with sodium cobaltinitrite indicating introduction of a small amount of potassium feldspar or concentrations of very fine grained sericite.

3 - Magnetite - Black, opaque, white pebbled surface under reflected light.

- very minute amounts.

- The grain size is about 0.01 mm.

- The grains have a slight reddish tinge indicating that they might be partly altered to hematite.

4 - Apatite - Colorless, n = 1.63, low interference colors, uniaxial, optically negative.
- 1% of the rock
- The grain size ranges from .25 to .5 mm.
- The crystals are subhedral to euhedral.

5 - Sphene - Pleochroic medium to dark brown, high relief, high birefringence.
- 1/2% of the rock
- The crystals are .05 mm in size
- Subhedral to euhedral rhombs.

6 - Carbonate - Colorless, change of relief on rotation of the stage, extreme birefringence.
- The grain size ranges down from 1 mm.
- The crystals are anhedral with irregular boundaries.
- The carbonate occurs in narrow fractures with feldspar and also replacing the other minerals.

(b) Mutual Relations.

The large subhedral augite and labradorite crystals are apparently set in a fine grained groundmass of anhedral labradorite crystals. The groundmass cuts into and corrodes the larger crystals. This suggests either a late residual liquid of plagioclase composition or recrystallization of the plagioclase, perhaps by stress as indicated by wavey extinction of feldspar crystals in the groundmass.

(c) Composition.

1 - Augite - 31%
2 - Labradorite - 67%
(1) Phenocrysts - 51%
(2) Groundmass - 16%
3 - Magnetite - Accessory
4 - Apatite - 1%
5. - Sphene - 1/2%

d) The texture is microporphyritic.
Megascopically it is granitic.
(e) The rock is a Gabbro.

This rock, although it is a gabbro, is very much like S_{3-A} which was named an Augite Diorite.

Specimen S_{5-A} (13,500 N, 7000 E)

I - Megascopic Description

The rock is medium to fine grained holocrystalline with a light greenish white color. The texture is equi-granular. The composition is 20% light green augite and 80% light grey to white feldspar. Iron stain occurs around the augite. In addition, there are very minor amounts of epidote and chalcopyrite.

There is no apparent change on the weathered surface.

II - Microscopic Description

(a) Minerals.

1 - Augite - Almost colorless, tinted slightly green, stubby, eight sided crystals, maximum extinction angle is 45°. n = 1.67.
19% of the rock.
The grain size is seriate up to $1\frac{1}{2}$ mm.
The crystals are subhedral
Partly altered to clay mineral and clinozoisite.
Some carbonate is present which may be replacing augite.

2 - Albite - Colorless, low relief, n less than balsam, shows polysynthetic twinning. Sections perpendicular to Z show a composition of $A_n_{5-10}$. This was confirmed by the use of maximum extinction angles in sections normal to (010) and the use of combined albite and carlsbad twinning.

76% of the rock
There are two modes of occurrence:
(1) Phenocrysts with a size of $\frac{1}{2}$ to 1 mm. These make up 40% of the rock.
(2) Groundmass with an average size of .1 to .2 mm. This makes up 36% of the rock.

The phenocrysts are subhedral to almost euhedral. The edges are corroded by the groundmass. The groundmass crystals are anhedral and irregularly intergrown.

The feldspar has been partly altered to sericite, clinozoisite, epidote, and clay mineral. Some chlorite in the groundmass may have resulted from the replacement of feldspar.
3 - Hematite - Almost opaque but it transmits deep red light.
   - Accessory in very small amounts
   - .01 to .02 mm in size.
   - The crystals are anhedral and are scattered sparsely through the slide.

4 - Apatite - Colorless, n = 1.65, low interference colors.
   - 2½% of the rock.
   - The crystals range in size from .02 mm to .5 mm.
   - The crystals are anhedral to subhedral.

5 - Sphene - Pleochroic medium to dark brown, high relief, high birefringence.
   - 1% of the rock.
   - The crystals are 1/2 mm to 3/4 mm in size.
   - The sphene is subhedral to euhedral in elongated rhombs.

6 - Epidote and Clinozoisite - Epidote is pleochroic colorless to yellow; clinozoisite is colorless. Epidote has bright second order interference colors; clinozoisite has interference colors ranging from anomalous blue to first order yellow. Both have n = 1.7
   - Together they make up 1½% of the rock.
   - The crystals are up to .25 mm in size.
   - The epidote and clinozoisite are anhedral occurring as an alteration product of feldspar.
7. Chlorite (?) - Light green, low relief, very low birefringence.
- Occur as small, scarce crystals in the groundmass.
  They have a radiating habit.

(b) Mutual Relations.
(1) The large augite and albite crystals occur in a fine grained groundmass of feldspar.
(3) The fine grained feldspar may have been derived from the coarse.
(2) Some large feldspar crystals show fracturing and rotation of the fragments, possibly indicating a protoclastic structure.

(c) Composition.
1 - Augite - 13%
2 - Albite - 76%
(1) Phenocrysts - 40%
(2) Groundmass - 36%
3 - Hematite - Accessory
4 - Apatite - 2 1/2%
5 - Sphene - 1%

(d) The texture is either microporphyritic or primary granitic, later partly recrystallized.

(e) The rock is an Augite Syenite.
I - Megascopic Description

The rock is medium to fine grained with a light grey green color. The texture is equigranular. The composition is 20% medium green augite and 80% light grey feldspar.

On weathered surfaces, the feldspar is light grey covered with a thin coating of hydrous iron oxide. The surface is pitted where the augite has weathered out.

II - Microscopic Description.

(a) Minerals

1 - Augite - Very pale green, stubby, eight sided crystals, two cleavages at right angles, the maximum extinction angle is 45°, n = 1.67.
   - 17% of the rock
   - The crystals are up to 1 mm in size.
   - The crystals are subhedral to euhedral prismatic.
   - The augite is relatively unaltered. There has been some formation of clay mineral.

2 - Andesine - Colorless, low relief, n greater than that of balsam, shows polysynthetic twinning. Sections perpendicular to Z give a composition of An45.
   - 82% of the rock
   - There are two modes:
     (1) Subhedral crystals 1 to 4 mm in size.
(2) Anhedral crystals .02 to .1 mm in size which form a groundmass. The former make up 48% of the rock; the latter make up 34%.

- The groundmass corrodes the andesine phenocrysts. The central zones of the phenocrysts are much more highly altered than the outer zones or the groundmass. Alteration products are sericite, clay mineral, clinzoisite, and chlorite. There has been some replacement by carbonate.

3 - Hematite - Almost opaque but it transmits a little deep red light.

- Accessory, very minor amounts.
- .02 to .04 mm in size.
- The hematite occurs as very sparse anhedral crystals scattered throughout.

4 - Apatite - Colorless, n = 1.63, low interference colors.

- 1/2% of the rock
- .2 to .5 mm in size.
- The crystals are subhedral to anhedral.

5 - Sphene - Pleochroic medium to dark brown, high relief, high birefringence.

- 3/2% of the rock.
- .2 to .5 mm in size.
- The sphene is subhedral to euhedral in elongated rhombs.
6 - Chlorite - Pleochroic colorless to greenish brown, one cleavage, maximum absorption parallel to the polarizer, low birefringence with some anomalous blue. Occurs in very minor amounts near carbonate in feldspar.

(b) Mutual Relations.

The large augite and andesine crystals occur in an aphanitic groundmass of plagioclase feldspar. The groundmass has irregularly invaded the edges of the andesine phenocrysts and seems to have rounded the augite crystals to a certain extent.

(c) Composition.

1 - Augite - 17%
2 - Andesine - 82%
   (1) Phenocrysts - 48%
   (2) Groundmass - 34%
3 - Hematite - Accessory
4 - Apatite - \( \frac{1}{2} \)%
5 - Sphene - \( \frac{3}{4} \)%

(d) The texture is either microporphyritic or altered granitic.

(e) The rock is an Augite Diorite.

The rock, then, is \( S_3 \) not \( S_5 \).
Specimen S_{6-A} (12,300 N, 6,700 E)

I - Megascopic Description.

The rock is medium to fine grained holocrystalline with a light flesh pink color. The texture is granitic. The rock is 20% dark green augite, 5% magnetite, and 75% light pink feldspar. Throughout the rock there is variation in the depthness of the pink color. In addition, the feldspar on a sawn surface of the hand specimen did not stain yellow when treated with sodium cobaltinitrite. The last two facts indicate that the feldspar is plagioclase colored with finely divided hematite.

II - Microscopic Description.

(a) Minerals.

1 - Augite - Very pale green, almost colorless, stubby eight sided crystals, the maximum extinction angle is 45, n = 1.67.

- 15% of the rock
- The crystals are up to 1\(\frac{1}{2}\) mm in size
- The crystals are subhedral to euhedral in outline.
- The augite is over 50% altered and replaced by chlorite and carbonate, not clay mineral.

2 - Andesine - Labradorite - Colorless, a slight tint of pink, low relief, n greater than that of balsam, shows polysynthetic twinning. Sections perpendicular to \(Z\) give a composition of An_{50}. \(\quad\)
- 82% of the rock
- The grain is seriate from very small up to 2 mm. The average size is \( \frac{1}{2} \) to 1 mm.
- The feldspar is anhedral to subhedral.
- The crystals are altered to the extent that the albite twinning is difficult to see. Alteration products are sericite, clinozoisite, epidote, and a little clay mineral. There is also considerable replacement by carbonate.

3 - Magnetite - Black, opaque, white with a pebbled surface under reflected light.
- 12% of the rock
- Subhedral to anhedral crystals.
- The crystals are fractured along parting planes. Chlorite occurs in the fractures. The original crystals were about .2 mm across.

4 - Pyrite - Opaque, very light yellow under reflected light.
- Accessory, very minor in amount.
- The size is .1 mm.
- The crystals are anhedral.

5 - Apatite - Colorless, n = 1.63, low birefringence, hexagonal outlines.
- 12% of the rock.
- \( \frac{3}{4} \) to 1 mm in size
- The apatite crystals are subhedral to euhedral.
6 - Sphene - Pleochroic medium to dark brown, high relief, high birefringence.
- 1/3% of the rock
- .2 mm in size.
- The sphene occurs in subhedral to euhedral elongated rhombs.

7 - Clinozoisite - Colorless to neutral, interference colors are anomalous blue to first order yellow.
- 3% of the rock
- The size ranges from minute up to 3/4 mm.
- The clinozoisite occurs in anhedral crystals as an alteration product of plagioclase. The crystals occur mostly in clumps, in which a small amount of epidote also occurs.

8 - Carbonate - Colorless, change of relief on rotation of the stage, high birefringence.
- The carbonate is a replacement mineral, especially in augite, and occurs in small anhedral crystals.

(b) Mutual Relations

Previous to the alteration, the textures and crystal boundaries were those of normal igneous rocks.

(b) Composition

1 - Augite - 15%
2 - Andesine-Labradorite - 82%
3 - Magnetite - 13/4%
4 - Apatite - 11/4%
5 - Sphene - 1/4%
(c) The texture, in spite of the alteration, is granitic.

(d) The rock is an Augite Diorite.

The difference from S₃ is only in the alteration. Instead of extensive change to clay mineral, the main changes were more than ordinary amounts of carbonate in the augite and major changes of the feldspar to clinozoisite.

Specimen S₉-A (13,600 N, 9800 E)

I - Megascopic Description.

The rock is medium grained with a light greenish grey color. The texture is equigranular. The composition is 10% to 15% light green augite, 50% to 70% light grey feldspar, and the remainder epidote and other unrecognizable alteration products. Some yellow metallic is present.

The weathered surface is much like the interior of the specimen but is covered with a very thin carbonate evaporation residue.

II - Microscopic Description.

(a) Minerals.

1. Augite - Almost colorless, perhaps a slight tint of green, mostly stubby crystals, two cleavages at right angles, 2V = 60°, optically positive, n = 1.68.

- 5% of the rock

- Normally the crystals are about .5 mm in size but some of a length of 1.5 mm and a width of .2 mm.

- The augite looks as if it were once euhedral but it
now heavily corroded and replaced by the fine grained groundmass, by carbonate, and by a small amount of clay mineral.

2 - Albite - Colorless, low relief, n less than that of balsam, shows polysynthetic twinning. Sections normal to (010) indicate a composition of An\textsubscript{10}.
- 92% of the rock
- There are two modes:
  (1) Anhedral to almost euhedral crystals $\frac{3}{4}$ to 2 mm in size.
  (2) Groundmass of anhedral crystals .02 to .1 mm in size.

The index of refraction of the large crystals and the groundmass are almost exactly the same.
- The albite, especially the large crystals, has been extensively altered and replaced by sericite, clinozoisite, epidote, and carbonate. The large albite crystals have been partly altered and replaced by the groundmass.

3 - Magnetite - Black, opaque, white in reflected light.
- Accessory
- .05 to .1 mm in size
- The anhedral crystals are intergrown with the pyrite.

4 - Pyrite - Opaque, pyrite yellow in reflected light.
- Accessory
- .05 to .1 mm in size.
- Anhedral, intergrown with magnetite.
- Near the intergrown magnetite and pyrite crystals is some limonite stain and maybe some hematite.

5 - Apatite - Colorless, n = 1.63, low birefringence.
- 2% of the rock
- Ranges in size from .02 to .5 mm.
- The crystals are anhedral with irregular outlines.

6 - Sphene - Pleochroic medium to dark brown, high relief, high birefringence.
- 1% of the rock
- .1 to .2 mm in size.
- The crystals are anhedral and bordered by chlorite.

7 - Carbonate - Colorless, change of relief on rotation of the stage, extreme birefringence.
- The carbonate occurs as anhedral crystals replacing the large and small albite crystals and the augite.

(b) Mutual Relations.
The large augite and albite crystals occur in a fine grained groundmass of albite.

(c) Composition

1 - Augite - 5%
2 - Albite - 92%
   (1) Phenocrysts - 47%
   (2) Groundmass - 45%
3 - Magnetite - Accessory
4 - Pyrite - Accessory
5 - Apatite - 2%
6 - Sphene - 1%
(d) The texture is microporphyritic or altered granitic.
(e) The rock is an Augite Syenite.

This rock, $S_{9-A}$, is the same as $S_{5-A}$. The alteration, however, is different. The green color is due to the presence of rather large amounts of epidote.

Specimen $S_{10-A}$ (13,800 N, 10,100 E)

I - Megascopic Description.

The rock is fine to medium grained with a light greenish grey color. The composition is 20% dark green augite, 50% light grey feldspar, and the remainder epidote and other alteration products.

The presence of megascopic epidote indicates that, although the feldspar and augite appear fresh in the hand specimen, microscopically the rock will be found to be extensively altered.

The feldspars on weathered surfaces are slightly pink and the surfaces are covered with a thin coating of hydrous iron oxides.

II - Microscopic Description.

(a) Minerals

1 - Augite - Very pale green, stubby crystals with two cleavages at right angles, the maximum extinction angle is $45^\circ$, $n = 1.67$.

- 16% of the rock.
- In general the grain size is \( \frac{1}{2} \) mm to 1 mm but a few crystals range down to a very small size.
- The crystals are subhedral. The borders are corroded and so the crystals were probably euhedral originally.
- Except for the irregular borders, the augite is relatively unaltered. There is some alteration to chlorite and clinozoisite.

2 - Albite - Oligoclase - Colorless, low relief, n a very little less than balsam, shows polysynthetic twinning.
- 77% of the rock
- There are two modes of occurrence:
  (1) Phenocrysts which are subhedral to euhedral, are 1 mm to 2 mm in size, and make up 39% of the rock.
  (2) Groundmass made up of anhedral crystals .03 mm to .1 mm in size comprising 38% of the rock.
- The albite is partly altered to clinozoisite, sericite, epidote, and clay mineral. The fine grained feldspar does not cut into the edges of the coarse grained feldspar as much as in the previously described rock. The index of refraction of the phenocrysts is a little higher than that of the groundmass.

Some areas in the groundmass were stained yellow by sodium cobaltinitrite. However, these were so irregular that it is assumed that
sericite, not orthoclase, was stained.

3 - Magnetite - Opaque, white in reflected light.
- 2 3/4% of the rock
- The grain size ranges from very small to 1/2 mm.
- The crystals are anhedral. The larger crystals have been broken into fragments.

4 - Apatite - Colorless, n = 1.63, low birefringence.
- 3% of the rock
- Up to 2 mm in size
- The apatite occurs in subhedral crystals.

5 - Sphene - Pleochroic medium to dark brown, high relief, high birefringence.
- 2% of the rock
- The grain size is .1 mm to .2 mm.
- The crystals are anhedral to subhedral.

6 - Carbonate - Colorless, changes relief on rotation of the stage, extreme birefringence.
- Occurs as anhedral crystals in veinlets. In these veinlets also occur anhedral crystals with n2-n1 = .010 & n = 1.64.

(b) Mutual Relations.

The large augite and albite crystals occur in a groundmass of fine grained albite. The groundmass appears to have been derived from the large crystals.

(c) Composition

1 - Augite - 16%
2 - Albite  
(1) Phenocrysts  - 39%  
(2) Groundmass  - 38%
3 - Magnetite  - 2½%  
4 - Apatite  - 3%  
5 - Sphene  - 2%

(d) The texture is microporphyritic or altered granitic.
(e) The rock is an Augite Syenite.

This rock has dark green augite and epidotized rather than kaolinized feldspar. Otherwise, the rock is identical to S5-A. Even the proportions of the large albite crystals, the augite crystals, and the albite groundmass are the same.

Specimen S_{11-A} (14,250 N, 9700 E)

I - Megasopic Description.

The rock is fine to medium grained holocrystalline with a medium dark pinkish green color. The texture is granitic. The composition is 20% dark green augite, 40% light pink orthoclase, 30% light green zoned plagioclase, and 5% biotite.

On weathered surfaces, the augite is lighter green and the orthoclase and plagioclase are lighter in color.

II - Microscopic Description.

(a) Minerals.

1 - Augite - Slightly pleochroic pale green to pale pinkish green, stubby, eight sided crystals,
optically positive, $2V = 60^\circ$, maximum extinction angle is $45^\circ$.
- 15% of the rock.
- The grain size ranges from .25 mm to 2.5 mm.
- The augite is subhedral to euhedral.
- The crystals are almost unaltered but are invaded along fractures to a slight extent by orthoclase.

2 - Andesine - Labradorite - Colorless, low relief, n greater than that of balsam, shows zoning and poly-synthetic twinning. Sections parallel to Z indicate that the composition grades from An$_{60}$ to An$_{10}$ (n would here be less than balsam) and that the average composition is An$_{50}$.
- 26% of the rock
- The size ranges from .5 mm to 2 mm.
- The crystals are euhedral with slightly corroded edges.
- The plagioclase is slightly altered to sericite and clay mineral, especially in definite zones.

3 - Orthoclase - Stained yellow with sodium cobaltinitrite, low relief, n less than that of balsam, exhibits microperthitic textures.
- 48% of the rock.
- The grain size ranges from .2 mm to 1 mm.
- The crystals are anhedral and fill between the augite and labradorite crystals. Their mutual boundaries are very irregular.
- The alteration products are fine grained sericite and clay mineral. The albite of the microperthite is unaltered.

4 - Quartz - Colorless, low relief, n greater than that of balsam, uniaxial, optically positive.
- 1% of the rock
- The size ranges from .1 mm to .5 mm.
- The quartz is anhedral filling between orthoclase crystals and occurring enclosed in augite crystals.
- Unaltered

5 - Biotite - Pleochroic neutral to dark reddish brown with maximum absorption when the cleavage is parallel to the polarizer. The interference figure is biaxial with a small 2V.
- 4½% of the rock.
- The size ranges down from 1 mm.
- The crystals are subhedral to very irregular anhedral.
- The biotite is relatively unaltered but on the borders with orthoclase a little chlorite has developed.

6 - Magnetite - Opaque, black, white in reflected light.
- 4½% of the rock.
- The size ranges down from .5 mm.
- The crystals are anhedral to subhedral. They occur throughout but are mainly in the orthoclase.

7 - Apatite - Colorless, n = 1.63, low birefringence.
- 1½% of the rock
- The apatite crystals are \( \frac{1}{2} \) mm to 2 mm in size.
- The crystals are anhedral to subhedral in outline.

(b) Mutual Relations.

The subhedral to euhedral augite and plagioclase crystals filled between with anhedral orthoclase crystals make up a normal granitic texture.

(c) Composition

1 - Augite - 15%
2 - Andesine-Labradorite - 26%
3 - Orthoclase - 48%
4 - Quartz - 1%
5 - Biotite - 4½%
6 - Magnetite - 4½%
7 - Apatite - 1⅓%

(d) The texture is granitic.

(e) The rock is an Augite Monzonite.

This rock is very much like \( S_1 \) except there is too much orthoclase and there is a little quartz present. Another difference is the granitic texture instead of the monzonitic texture in \( S_1 \).