THE GEOLOGY OF
KINSKUCH LAKE AREA, BRITISH COLUMBIA

BY

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B.Sc. (Honors) University of Alberta, 1955

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
in the Department
of
Geology and Geography

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA
April, 1957
Kinskuch Lake area covers a fifty-square mile portion of the Portland Canal district of western British Columbia. Kinskuch Lake lies near the eastern border of the Coast Mountains, approximately twelve miles north of the port of Alice Arm.

Reconnaissance mapping of the area on a scale of 1" = 1000' was done during part of the summer of 1956. Rock specimens collected in the field were examined microscopically and the results of the latter investigation form the greater part of this thesis.

The interbedded volcanic and sedimentary rocks of Kinskuch Lake area were deposited during the period of Mesozoic volcanism and sedimentation which was widespread throughout western British Columbia and southeastern Alaska. Near Kinskuch Lake, the earliest products of Mesozoic volcanism are represented by augite porphyry volcanic breccias, crystal tuffs, flows and flow breccias outcropping along the western margin of the map area. Augitic volcanics are overlain to the east by interfingering felsitic breccias and tuffs, sedimentary rocks and greenstone. East of Kinskuch Lake, the latter rocks pass gradationally into a thick overlying sequence of felsitic volcanic breccia, crystal tuffs.
and feldspar porphyry flows. The youngest rocks outcrop near the eastern margin of the map area. Here, argillites and conglomerates overlie felsitic volcanic breccia and interbedded tuff.

The Mesozoic volcanic and sedimentary rocks were folded, faulted and intruded by keratophyric and lamprophyric dykes. As a last stage in the geological sequence of events, volcanic rocks at the southeast corner of Kinskuch Lake were altered and mineralized. Highly fractured or sheared greenstone and felsitic volcanics were altered to chlorite, pyrite, epidote, sericite quartz and calcite. Minor chalcopyrite mineralization accompanied rock alteration and many small quartz-carbonate veins cut the altered rocks. Some of the latter veins carry pyrite, chalcopyrite and traces of sphalerite and galena. Albitization of some of the igneous rocks outside the altered zone accompanied the widespread carbonate alteration.
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Department of: Geology and Geography

The University of British Columbia, Vancouver 8, Canada.

Date April 24, 1957
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# MAP

Geological Map of Kinskuch Lake Area

Scale 1" - 1000'  Contour Interval 500'
THE GEOLOGY OF
KINSKUCH LAKE AREA, BRITISH COLUMBIA

CHAPTER I

INTRODUCTION

Scope of Investigation

The material used in writing this thesis was collected during part of the summer of 1956, in the course of employment with Northwestern Explorations Limited. The main object of the summer's work was the investigation of the altered and mineralized rocks near Kinskuch Lake, British Columbia. Evaluation of the mineral deposit was carried out by diamond drilling and detailed mapping at scales of 1" = 40' and 1" = 400'. Along with the detailed work in the altered-mineralized zone, reconnaissance mapping of the rocks in the area surrounding the lake was done by means of pace and compass traverses. Data obtained by traverses was plotted on a contoured base map drawn at a scale of 1" = 1000'.
The geological map of Kinskuch Lake Area, which is the result of the reconnaissance exploration described above, forms the nucleus of the present work. This thesis deals with all phases of the general geology of the map area.

Location of Map Area

Kinskuch Lake region, as defined in this thesis, is a fifty-square-mile area near the eastern side of the Coast Mountains, in the Portland Canal district of British Columbia (Figure I).

The lake is approximately twelve miles north of the port of Alice Arm. Alice Arm itself is about eighty air miles north of the city of Prince Rupert. Other well known points near Alice Arm are Anyox, twelve miles west, Stewart, forty miles northwest and Torbrib Silver mine, fifteen miles north up the Kitsault River.

Access

During the late summer months, Kinskuch Lake is conveniently reached by means of a float-equipped plane from Prince Rupert, Terrace or Alice Arm. The latter port is regularly serviced by Pacific Western Airlines from Prince Rupert.

An alternative means of reaching the area is to drive from Alice Arm up the Kitsault valley to Torbrit Mine.
FIGURE I
PORTLAND CANAL AND ADJACENT AREAS
KINSKUCH LAKE AREA - INSET
and thence to walk the remaining six miles east over a good trail to Kinskuch Lake.

Physiography

Drainage and Vegetation:

Kinskuch Lake is near the eastern border of the Coast mountains, at an elevation of 3750 feet. The lake, about one and one half miles wide east to west and some four miles long north to south, lies in a height of land between the Kitsault River valley to the west and Nass River valley to the east. The steep, narrow canyon of the Kinskuch River runs east from the north end of the lake to the Nass whereas most streams in the hills to the west of the lake drain west to the Kitsault River.

At the south east corner of the lake a glacier about 1000 feet wide continually discharges ice into the lake during the summer months. Since 1939 the ice front has retreated about 1000 feet (60 feet per year). Other extensive snowfields surrounding the lake contribute great quantities of water to it.

The hills round about the lake are practically bare of trees except for rather scrubby pine and hemlock growing at a few places. The only other vegetation is moss heather and wild flowers.
**Summer Climate:**

Spring and summer of 1956 were sunnier than normal except for periods in June and August.

In May and June the weather was dominantly clear with a few snow flurries. Ice on the lake was broken near shore by June 26th, but the main mass was still intact. In July weather was fair to sunny and the lake was essentially clear of ice on July 9th. About two weeks were fair and clear in August and two were cloudy with almost continual rain and some fog. Snow fell above the 6500 foot level on August 28th. In September, colder weather began to settle in but a two foot fall of snow on September 18th, quickly melted away at lake level. At this time snow began to accumulate continuously above 4500 feet.

**TABLE I**

**SUMMER TEMPERATURES**

<table>
<thead>
<tr>
<th>Month</th>
<th>High $^\circ$F</th>
<th>Low $^\circ$F</th>
<th>Mean $^\circ$F</th>
</tr>
</thead>
<tbody>
<tr>
<td>May</td>
<td>73</td>
<td>25</td>
<td>46</td>
</tr>
<tr>
<td>June</td>
<td>72</td>
<td>23</td>
<td>44</td>
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<tr>
<td>July</td>
<td>78</td>
<td>32</td>
<td>52</td>
</tr>
<tr>
<td>August</td>
<td>76</td>
<td>34</td>
<td>50</td>
</tr>
<tr>
<td>September</td>
<td>67</td>
<td>22</td>
<td>43</td>
</tr>
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</table>
Topography:

PLATE I

Mt. Lavender and south end of Kinskuch Lake viewed from the west

Hills immediately to the north and south, and especially west of the lake basin, are comparatively rounded and low. Just to the east of the basin, Mount Lavender at an elevation of 7660 feet towers nearly 4000 feet above lake level. Further east for some two miles, the topography continues to show rather high jagged ridges running north to south. Valleys between these ridges are filled by ice and snow and glacial tongues flow north and south from these ice masses. Beyond the eastern edge of the map area, the jagged relief gives way to the rather wide flat valley of the Nass River.

The form of these topographic features is in part
brought about by the differing lithology of the rocks to the east and west of the lake. Sedimentary rocks to the west of Kinskuch Lake are probably more easily eroded than the massive volcanic breccias and tuffs to the east. The extent of glaciation was probably another factor in the determination of the present relief as it appears that ice masses once completely covered the rocks to the north, west and south of the lake but did not erode the higher ridges to the east of it.
CHAPTER II

GEOLOGY OF ALICE ARM DISTRICT

Previous Work

Hanson (1935) described the whole of Portland Canal area from a point north of Stewart south to Alice Arm. His memoir is the only published report describing the rocks near Kinskuch Lake. Black (1951) did detailed work in the upper portion of the Kitsault valley, to the west of Kinskuch Lake.

General Geology

Alice Arm district lies along the eastern margin of the northern Coast intrusions. At a point about four miles west of the port of Alice Arm, the contact between Coast intrusions and older rocks strikes northwest through the centre of the district. Tertiary basaltic lavas cap Table Mountain south of Alice Arm.

The older intrusive, volcanic and sedimentary rocks have been assigned by Hanson to the Hazelton Group. Igneous members of this group occur as three large bodies separated and surrounded by conformable sedimentary rocks. The Theophilus body, about six miles wide and the Kitsault body,
two miles across, both lie east of Kitsault River. Klayduc body, which is up to two miles wide, lies to the west of the Kitsault valley. All three bodies strike north and have been traced in this direction up to sixteen miles from their southern termination at Alice Arm.

Within the Hazelton group Hanson included argillite, quartzite, greywacke, limestone, tuffaceous sediment, breccia, tuff, augite porphyrite, felsite, amphibolite and gabbro. He found the most common sedimentary rock to be black argillite. By addition of coarser grains the latter rock was seen to grade into quartzite and greywacke. Pebbles of slate and chert were found to be common in conglomerates and the latter rocks by admixture of pyroclastic material graded into volcanic breccias. Regarding the igneous rocks, Hanson states:

There are only two main types, feldspar porphyry (felsites) and augite porphyrite, and the corresponding fragmental types. (1935) (p. 21).

By microscopic investigation, Hanson found that feldspar porphyry contained orthoclase and plagioclase ranging in composition from albite to oligoclase. Other minerals identified were biotite, apatite, sericite, calcite and chlorite. Thin-sections of augite porphyrite were seen to contain rather fresh augite phenocrysts and highly altered crystals of orthoclase and acid plagioclase. The groundmass in many specimens of augite porphyrite consisted mainly of chlorite, sericite and calcite.
CHAPTER III

GEOLOGY OF KINSKUCH LAKE AREA

Introduction

The oldest volcanic rocks near Kinskuch Lake are augite porphyry flows, flow breccias and pyroclastics outcropping along the western side of the map area. These igneous rocks are underlain by sedimentary rocks and overlain in the south portion of the map area, by felsitic fragmental volcanics. In northern localities, augite porphyry rocks are overlain by a series of alternating and interfingering felsitic breccias and tuffs, sedimentary rocks and greenstone. Intercalated volcanic and sedimentary beds grade eastward into overlying massive felsitic breccia and a thick felsitic tuff-flow sequence. The youngest rocks are a thick series of sedimentary beds overlying felsitic pyroclastics at the eastern edge of the map area.

After a period of folding and faulting, sedimentary and volcanic rocks were intruded by dykes and small stocks. Intrusive rocks include varieties identified as hornblende keratophyre, keratophyre and quartz keratophyre, quartz feldspar porphyry, augite quartz diorite and lamprophyre.

Late in the geological sequence of events, green-
stone and felsitic fragmental volcanic rocks near the south-east corner of Kinskuch Lake were altered and mineralized. The rocks of the altered zone are composed of variable amounts of pyrite, chlorite, epidote, chalcopyrite, sericite, quartz and calcite. Quartz-carbonate sulphide veins cut the altered rocks. Carbonate alteration is widespread throughout igneous and sedimentary rocks. In some igneous rocks, the formation of calcite was apparently accompanied by albitization of plagioclase.

Table of Units

Because of the variable interfingering nature of the sedimentary and volcanic rocks and later deformation of these beds, the true thickness of any sequence is largely a matter of estimation. The thicknesses listed below should be considered in this light.

The rock sequence shown is true only of portions of the map area. No attempt has been made to differentiate between successive bands of sedimentary rock and their relationships to each other are not fully understood.
### TABLE OF UNITS

<table>
<thead>
<tr>
<th>Name</th>
<th>Character</th>
<th>Thickness</th>
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<tr>
<td>Intrusive Rocks</td>
<td>Lamprophyre</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Augite Quartz Diorite</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quartz Feldspar porphyry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Keratophyre, Quartz Keratophyre</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hornblende Keratophyre</td>
<td></td>
</tr>
<tr>
<td>Argillite</td>
<td></td>
<td>Not mapped</td>
</tr>
<tr>
<td>Felsitic Breccia</td>
<td>Mainly Coarse Volcanic Breccia with some bedded tuff</td>
<td></td>
</tr>
<tr>
<td>Massive Felsitic tuff</td>
<td>Green to purple massive crystal tuff</td>
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<tr>
<td>Feldspar porphyry flow</td>
<td></td>
<td>6000 feet</td>
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<td>Thin-bedded felsitic tuff</td>
<td>Reddish crystal tuff</td>
<td></td>
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<tr>
<td>Coarse-bedded felsitic tuff</td>
<td>Green to purple crystal tuff</td>
<td></td>
</tr>
<tr>
<td>Felsitic Breccia</td>
<td>Green to red coarse volcanic breccia</td>
<td>4000 feet</td>
</tr>
<tr>
<td>Sedimentary rock</td>
<td>Argillite, impure limestone, conglomerate</td>
<td>5000 feet</td>
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<tr>
<td>Albitized Andesite (Greenstone)</td>
<td>Massive green crystal tuff and some flows</td>
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<tr>
<td>Felsitic Breccia</td>
<td>Coarse volcanic breccia with some interbedded tuff</td>
<td>5000 feet</td>
</tr>
<tr>
<td>Sedimentary rock</td>
<td>Argillite, Conglomerate and Calcareous Augitic tuff</td>
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<tr>
<td>Felsitic Breccia</td>
<td>Coarse volcanic breccia and interbedded tuff</td>
<td></td>
</tr>
<tr>
<td>Augite Porphyry rocks</td>
<td>Flows, Volcanic breccia and crystal tuff, flow breccia</td>
<td>2000 feet</td>
</tr>
<tr>
<td>Argillite</td>
<td></td>
<td>not mapped</td>
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</table>
Sedimentary Rocks

The major part of the sedimentary rocks is of thin-bedded argillite with subordinate argillaceous tuff, calcareous augitic tuff, cherty or calcareous conglomerate and fine-grained, impure, white limestone.

Distribution:

The sedimentary rocks at the western edge of the map area are apparently the oldest rocks in the vicinity of Kinskuch Lake. Other sedimentary rocks which are probably younger than those to the west, overlie augite porphyry volcanics and locally interfinger with felsitic pyroclastics and greenstone to the west, north and east of the lake. At the eastern edge of the map area, a thick series of sedimentary rocks, which are continuous with those forming the Nass valley, overlie felsitic breccia and tuffs.

Petrography:

Argillite: In a typical handspecimen of argillite, fine-grained black bands alternate sharply with bands of relatively coarse grey grains. These layers are up to one-half inch thick and cross bedded. Unfortunately, the latter feature is not well developed and top determinations are difficult where grain gradation is not notable.

Microscopically, it is seen that grains forming one
of the coarser portions of an argillite measure about .1 mm. across and are not well rounded. Quartz grains make up 15%, carbonate, some of which is secondary, makes up about 35% and the remainder of the rock is plagioclase of intermediate composition and potash feldspar.

Calcareous Augitic Tuff: Thin beds of calcareous augitic tuff occur in argillite sequences and are therefore included here as a sedimentary rock. This tuff is much coarser-grained than argillites and has a well defined stratification, easily seen owing to an alternation of softer and more resistant bands about one-half inch thick.

In thin-section, the average grain size is seen to be about .5 mm. Resistant bands are composed of about 60% feldspar and felsitic rock fragments and 40% fresh augite. Softer bands are formed by 60% calcite, 20% augite and 10% feldspar.

Volcanic Rocks

Augite Porphyry

Augite porphyry rocks are the flows, pyroclastic breccias, crystal tuffs and flow breccias which in hand specimen show dark green crystals or crystal fragments of fresh augite, as a prominent constituent. The most abundant representatives of these augitic rocks are flows and flow breccias. The thickness and extent of individual flows are unknown since no contacts were seen. Locally, the extrusives
give way to stratified pyroclastics but work was not sufficiently detailed to determine the inter-relationships between the two different types of volcanic rocks.

At one place in the main zone of augitic rocks, a sill-like body of augite porphyry outcrops. This body may be an intrusive equivalent of augite porphyry volcanics.

Distribution:

The occurrence of augite porphyry rocks is mainly restricted to a zone near the western edge of the map area. Here, augitic volcanics outcrop between underlying argillite and overlying felsitic breccias or sedimentary rocks. Some thin augitic flows are interbedded with felsitic breccias, west of the south end of Kinskuch Lake. Two other isolated patches of augite porphyry volcanics outcrop west of the north end of the lake and appear to overlie felsitic breccia and sedimentary rocks, at this point.

Petrography:

Augite Porphyry Flows: In a handspecimen of augite porphyry flow rock, augite crystals generally measure from one-sixteenth to one-half inch across. The matrix surrounding augite is fine-grained and green, weathering dull green or white. In most specimens the matrix encloses white amygdules of calcite and other minerals.

In thin-sections of flows, microlites of plagi-
clase, fine flakes of chlorite and much brown cryptocrystalline material, possibly originally glassy, form a pilotaxitic to felted groundmass surrounding phenocrysts of plagioclase and pyroxene. In some specimens, pyrrhotite and hematite are also present as groundmass constituents. Round amygdules and connecting veinlets filled with chlorite, sodic feldspar calcite and quartz are dispersed through the flow matrix. (Plate II). Feldspar phenocrysts are highly altered with the development of sericite and calcite. In other flows the plagioclase is relatively fresh. Twinning of these feldspars is sharp and extinction angles of up to 12° X C and negative relief indicate a composition near An_{10}. The zoned pyroxene is an aegirine-augite, pale green in color and somewhat pleochroic. The optic sign is positive and 2V is about 60°. Extinction angles X'A'C range up to about 40°. The refractive index nB determined with oils, is between 1.683 and 1.692.

Augite forms 30% of the rock, plagioclase, in matrix and phenocrysts 50% and chlorite, etc. 20%.
PLATE II

.5 mm.

Photomicrograph of amygdule of sodic feldspar

A partial analysis of a typical specimen of an amygdaloidal augite porphyry flow, and a list of the calculated normative minerals and their percentages is given below. In calculation of all norms it was assumed that the weight percentage of Fe$_2$O$_3$ determined in the chemical analysis was divisible into FeO and Fe$_2$O$_3$ in a ratio of 3 : 1

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Weight Percentage</th>
<th>Normative Minerals and percentage</th>
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<tbody>
<tr>
<td>SiO$_2$</td>
<td>51.20</td>
<td>orthoclase 7.0</td>
</tr>
<tr>
<td>Al$_2$O$_3$+TiO$_2$</td>
<td>16.60</td>
<td>albite 27.5</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
<td>2.62</td>
<td>anorthite 26.5</td>
</tr>
<tr>
<td>FeO</td>
<td>7.75</td>
<td>diopside 25.5</td>
</tr>
<tr>
<td>MgO</td>
<td>6.40</td>
<td>hypersthene 2.0</td>
</tr>
<tr>
<td>CaO</td>
<td>10.80</td>
<td>olivine 9.5</td>
</tr>
<tr>
<td>Na$_2$O</td>
<td>3.30</td>
<td>magnetite 3.5</td>
</tr>
<tr>
<td>K$_2$O</td>
<td>1.18</td>
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</tr>
<tr>
<td></td>
<td>99.85</td>
<td></td>
</tr>
<tr>
<td></td>
<td>101.5</td>
<td></td>
</tr>
</tbody>
</table>
Although staining indicated the presence of a fair proportion of potash in augite porphyry rocks, the percentage of normative orthoclase is very low. Most of the substance which stained must be present in the cryptocrystalline material of the flow matrix. The normative percentages of plagioclase and pyroxene agree with the amounts of these minerals which were noted in thin-sections. The normative composition of plagioclase is An₄₉, assuming all the CaO calculated as normative anorthite is contained in plagioclase in the rock.

Augite Porphyry Flow Breccia: Megascopically, the flow portion of augite porphyry flow breccia is entirely similar to the augitic flows, just described. White fragments of crystalline augitic rock are surrounded by the flow matrix. These fragments are quite rounded and measure from one inch up to about six inches across.

Under the microscope it is seen that the flow portion of these flow breccias has a felted groundmass formed of microclites of plagioclase, fine flakes of chlorite and much brown cryptocrystalline material. This groundmass is crowded with innumerable, round blebs which are possibly sodic feldspar. (Plate IV). A few amygdules of sodic feldspar and chlorite are present in the matrix. Zoned augite and a few sericitized plagioclase crystals comprise the phenocrysts in the flow portion of this rock.
PLATE III
Augite porphyry flow breccia

PLATE IV
Photomicrograph, in ordinary light of matrix of flow breccia
Along the contacts with rock fragments are veinlets and connecting amydules of chlorite, quartz and plagioclase.

The breccia fragments are porphyritic having phenocrysts of indeterminable sericitized plagioclase and zoned augite enclosed in a groundmass of fine chloritic particles and dark cryptocrystalline substance. Vesicles contain chlorite, sodic feldspar and some epidote.

Augite Porphyry Pyroclastics: Interbedded augite porphyry volcanic breccias and crystal tuffs are green on fresh surfaces and white or brown, where weathered. The matrix of the volcanic breccias is similar to the interbedded tuffs. Crystalline augitic rock fragments in these breccias measure up to a foot across.
In thin-sections of tuff it is seen that augite occurs as crystals, more or less broken, about .6 mm. wide and 1.2 mm. long. Augite composes 40% of the rock and the remaining 60% is a mixture of highly altered plagioclase fragments, fine flakes of chlorite and particles of altered cryptocrystalline material.

Altered Augite Porphyry Flows: In at least two places where augitic flows and felsitic tuffs and breccias are in contact, the contact is marked over a width of about 15 feet by alteration that is restricted to the porphyry flows. In the altered rock, augite is replaced by a greyish mixture of carbonate and chlorite and zoning of these crystals is made apparent.

In thin-section it is seen that feldspars are replaced by sericite and carbonate and the groundmass by chlorite.

Felsitic Rocks:

The term "felsitic rocks" is applied, following Hanson's usage, to all the tuffs, volcanic breccias and flows which in hand specimen appear to contain few or no mafic minerals. In some felsitic rocks a good deal of feldspar is visible. Colors range from red and purple to green. Green varieties weather white or brown and weathered breccias and tuffs are difficult to distinguish from one another as weathering obscures their texture.
Sequences of interbedded breccias and thin bedded tuffs make up most of the felsitic group. Other felsitic rock types are, greenish to purple coarse-bedded or massive tuff, thin-bedded tuff and feldspar porphyry flow.

Distribution: Felsitic volcanic breccias with some thin interbedded tuffs are the most abundant rocks of the map area. West, north and immediately east of Kinskuch Lake, these pyroclastics are interlayered with sedimentary beds and greenstone. East and south of the lake, Mount Lavender and its surrounding slopes are formed almost solely of felsitic breccia and tuff. Massive breccias stretch east from Kinskuch Lake for some two miles, gradually passing into a thick sequence of overlying volcanic rocks, including coarse bedded or massive tuff, fine bedded tuff, and feldspar porphyry flow. Near the eastern edge of the map area, felsitic volcanic breccias underlie sedimentary rocks.

Petrography:

Felsitic Volcanic Breccia:

Most rock fragments in felsitic breccias measure two inches to three inches across and are quite angular. These fragments are mainly of a highly feldspathic igneous rock. Some felsitic breccias are green, but other types, especially those east of Kinskuch Lake have a fine-grained red matrix surrounding felsitic rock fragments.
In a thin-section of a red felsitic breccia, the only identifiable original mineral is plagioclase. Crystal fragments of plagioclase, are unzoned and only slightly sericitized. Composition of this feldspar ranges from An₀ to An₅ but some crystals have positive relief and their composition is about An₃₀. Plagioclase fragments are surrounded by a dense reddish indeterminable matrix. Scattered through this red matrix are grains of opaque iron-oxide. Numerous veinlets containing calcite, sodic feldspar and probably some quartz cut through feldspars and matrix. Some of the sodic feldspar in the veins is twinned and blade-like (Plate VII). In other veinlets feldspar forms a fine-grained mass of interlocking crystals. Along parts of some of the veinlets, fresh vein feldspar is in optical continuity with sericitized plagioclase crystals bordering the veinlet.
PLATE VII
5 m.m.
Photomicrograph of a veinlet of calcite and sodic feldspar

PLATE VIII
5 m.m.
Photomicrograph of veinlet of calcite and fresh sodic feldspar bordering sericitized plagioclase
A partial chemical analysis of the red felsitic breccia just described, is shown below. The calculated normative minerals are also listed.

TABLE III

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Weight Percentage</th>
<th>Normative Minerals and percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>61.0</td>
<td>Quartz 7.0</td>
</tr>
<tr>
<td>Al₂O₃+TiO₂</td>
<td>17.9</td>
<td>Orthoclase 2.0</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1.5</td>
<td>Albite 51.5</td>
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<tr>
<td>FeO</td>
<td>4.8</td>
<td>Anorthite 20.0</td>
</tr>
<tr>
<td>MgO</td>
<td>1.5</td>
<td>Diopside 11.5</td>
</tr>
<tr>
<td>CaO</td>
<td>6.8</td>
<td>Hypersthene 6.0</td>
</tr>
<tr>
<td>Na₂O</td>
<td>6.1</td>
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<td>K₂O</td>
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</tr>
<tr>
<td></td>
<td>99.95</td>
<td>100.0</td>
</tr>
</tbody>
</table>

All the minerals calculated in the norm, except feldspar and magnetite, must be represented in the rock in the indeterminable reddish groundmass and veinlets of calcite.

In addition to the common type of felsitic breccia, described above, there is one type which is rich in hornblende. In most specimens of the latter type, sedimentary rock fragments, mainly argillite and siltstone, form about 20% of the breccia. Fragments of crystalline igneous rocks constitute another 30% of specimens. Most fragments in
hornblende rich felsitic breccias measure about one inch across. These breccias are grey on a fresh surface, and white, where weathered.

PLATE IX
Hornblende rich felsitic breccia

In a thin-section of hornblende rich breccia it is seen that breccia fragments are of calcareous siltstone and various types of indeterminable crystalline igneous rocks. The latter fragments are composed mainly of sericitized plagioclase and some hornblende and potash feldspar. The crystal tuff matrix surrounding fragments composes about 50% of the specimen. Crystals of green pleochroic hornblende, now almost completely altered to chlorite and biotite, form about 30% and subhedral plagioclase another 50%, of the
matrix. This plagioclase (Ang) is quite fresh except for certain zones which are altered to chlorite. The balance of the matrix consists of fine flakes of chlorite and small brown particles of cryptocrystalline material.

Coarse-bedded Felsitic Tuff: - Handspecimens of coarse-bedded tuff are green or purple and most are very fine-grained or contain a few small fragments of rock. Individual beds, in outcrops, are about 20 feet thick. Stratification of beds of alternating color is apparent from a distance.

PLATE X
Coarse-bedded felsitic tuff

In a thin-section it is seen that some of this massive tuff has fragments measuring as much as 3 m.m. across. Rock fragments are composed of augite and highly altered
indeterminable plagioclase phenocrysts in a flow matrix. Crystal fragments forming the groundmass about the latter rock inclusions are augite, altered plagioclase and some biotite. The crystal tuff groundmass forms 80% of the specimen.

Although some specimens of coarse-bedded felsitic tuff may contain notable amounts of augite, the latter mineral is not visible in hand specimens. For purposes of field work, the classification of this type of rock as felsitic is probably the most useful one.

**Thin-bedded Felsitic Tuff:** Thin-bedded felsitic tuffs are composed of white crystal or rock fragments ranging in size from microscopic up to one-quarter of an inch across. The fine-grained matrix surrounding white fragments is red in color. In all of these tuffs, bedding is well defined by bands a fraction of an inch to fractions of a foot thick.

PLATE XI

Red, thin-bedded tuff
In a thin-section of a fine-grained specimen of red tuff it is seen that most of the angular crystal grains measure .3 to .6 mm. across. These grains are mainly un-twinned plagioclase, highly altered by carbonate and sericite. Staining shows that no potash feldspar is present. Minute reddish particles and large opaque grains of iron-oxide surround crystal fragments.

Purple to Green Felsitic Tuff: - Purple and green felsitic tuffs are massive but here and there they contain randomly distributed rock fragments.

In a specimen studied in thin-section, the largest crystal fragments measure .2 mm. across. Optically positive grains of sodic plagioclase compose the major part of the rock and these feldspars are highly altered to mixtures of carbonate and sericite.

Grains of fresh potash feldspar are a minor constituent of this tuff. Thin veinlets of calcite and sericite transgress the rock.

Another particularly fresh specimen of massive crystal tuff is seen in thin-section to be composed mainly of euhedral plagioclase crystals. These crystals, forming about 75% of the rock, have a rough flow-like alignment and their extinction angles, optically positive sign and negative relief indicate a composition of An5. The matrix interstitial to these crystals is composed of small ragged grains of plagi-
clase and some chlorite, epidote, pyrite and carbonate. Quartz, epidote and carbonate vein the rock.

A partial chemical analysis of this fresh tuff and the calculated norm is as follows:

**TABLE IV**

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Weight Percentage</th>
<th>Normative Minerals and percentages</th>
</tr>
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<tbody>
<tr>
<td>SiO₂</td>
<td>55.0</td>
<td>orthoclase 1.0</td>
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<tr>
<td>Al₂O₃+TiO₂</td>
<td>20.3</td>
<td>albite 52.5</td>
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<tr>
<td>Fe₂O₃</td>
<td>2.4</td>
<td>anorthite 26.5</td>
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<td>FeO</td>
<td>7.2</td>
<td>hypersthene 6.5</td>
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<tr>
<td>MgO</td>
<td>3.4</td>
<td>olivine 9.5</td>
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<td>CaO</td>
<td>5.4</td>
<td>magnetite 3.5</td>
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The amount of plagioclase indicated in the norm agrees well with the percentage of feldspar noted in thin-section. Assuming all the CaO is contained in plagioclase the composition of feldspar is An₃₃. In thin-section it was seen that notable amounts of calcite and epidote are present and the composition of the feldspar is in fact An₈.

Feldspar Porphyry Flows: - Type Number One: The first type of feldspar porphyry flow is greyish-purple with
euhedral white feldspar phenocrysts and subhedral greenish-black mafic. Staining with HF etch and sodium cobaltinitrite indicates that there is very little potash feldspar in the rock.

Under the microscope, the rock is seen to be highly altered. Phenocrysts are sericitized plagioclase. Composition of the latter could not be determined because of alteration, but extinction angles indicate it may be close to An₃₀ or An₀. A few large pseudomorphs of chlorite and carbonate after hornblende are present. The groundmass is a mixture of anhedral grains of chlorite, carbonate, sericitized feldspar and apatite. Less than 5% quartz is present in this matrix.

Type Number Two: A second variety of feldspar porphyry, probably also a flow, outcrops only in the northeast corner of the map area and its relationship to other rocks is largely unknown. This rock has a fine-grained greenish matrix enclosing large phenocrysts of white potash feldspar and smaller phenocrysts of plagioclase and mafic minerals. Potash feldspar phenocrysts have a flow-like orientation.

In thin-section, all feldspars are quite fresh. Potash feldspar phenocrysts present smooth but somewhat irregular boundaries against the groundmass. Some of these phenocrysts contain "inclusions" of plagioclase crystals. (Plate XIII). Small phenocrysts of plagioclase with a
PLATE XII

Coarse feldspar porphyry flow

PLATE XIII

Photomicrograph of phenocryst in coarse feldspar porphyry
composition of $A_n^8$ are also present in the groundmass. The fine-grained matrix forming 50% of the rock is composed of anhedral grains of plagioclase, potash feldspar, and quartz.

In a thin-section of a second variety of this flow rock, the large phenocrysts are potash feldspar enclosing patches of plagioclase. All the plagioclase twin lamellae have the same orientation. (Plate XIV). Smaller feldspar phenocrysts are crystals of antiperthite apparently formed by potash replacing the soda of plagioclase. The matrix surrounding phenocrysts consists of anhedral grains of potash feldspar and quartz.

Secondary mafic minerals in both varieties of this flow constitute about 10% of the rock. Mafic minerals are serpentine, chlorite, biotite and magnetite. Veinlets of serpentine which are accompanied by some brecciation of groundmass and phenocrysts, cut across the rock.

Photomicrograph of patches of plagioclase in potash feldspar phenocryst
A partial chemical analysis of a specimen of coarse feldspar porphyry flow is shown below. Normative minerals and their percentages are also listed.

**TABLE V**

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Weight Percentage</th>
<th>Normative Minerals and percentages</th>
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<tr>
<td>SiO$_2$</td>
<td>63.50</td>
<td>Quartz 19.5</td>
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<tr>
<td>Al$_2$O$_3$+TiO$_2$</td>
<td>17.45</td>
<td>Corundum 6.0</td>
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<td>Fe$_2$O$_3$</td>
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<td>Orthoclase 20.0</td>
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<td>MgO</td>
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<td>Anorthite 4.5</td>
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<tr>
<td>CaO</td>
<td>0.85</td>
<td>Hypersthene 15.5</td>
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<tr>
<td>Na$_2$O</td>
<td>3.80</td>
<td>Magnetite 3.0</td>
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<tr>
<td>K$_2$O</td>
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<td></td>
<td>3.39</td>
<td>100.5</td>
</tr>
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<td></td>
<td>99.63</td>
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</tr>
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Assuming all the CaO is contained in plagioclase, the composition of feldspar is An$_{12}$. This composition is very close to the value of An$_8$, determined in thin-section. The amount of normative orthoclase points up the abundance of potash in these rocks and supports the idea, derived from the study of thin-sections, that some soda in feldspars has been replaced by potash. The amount of normative quartz is probably a true indication of the percentage of this mineral in the rock. No corundum is present in the rock and excess Al$_2$O$_3$ in the norm must be represented in other minerals. This flow has the composition of a quartz latite.
Reddish Color in Felsitic Rocks

As described in the last sections on petrography, many of the felsitic fragmental volcanics have a fine-grained reddish groundmass. Red felsitic breccias and tuffs are the predominant rocks east of Kinskuch Lake. Thousands of feet of such reddish breccia form Mount Lavender. In some specimens of the latter rocks, the white fragments themselves are rimmed just within their borders by a form of reddish alteration (Plate XV). In other places in the same rocks, rather uniform reddish bands, apparently not controlled by fractures, cut the otherwise whitish breccia. (Plate XVI). In stratigraphically lower zones of these breccias irregular veinlike masses of soft reddish material wind upward through green breccias towards red pyroclastics.

PLATE XV
Red-rimmed fragments in felsitic breccia
The reddish color of the veins and pyroclastic rocks is probably due to the presence of finely disseminated hematite. Certain features described above suggest the coloration may be a form of hydrothermal alteration but its regular distribution seems to indicate that the color is an original feature. The study of sedimentary red beds has shown that red coloration of rocks is indicative of prevalence of oxidation over reduction conditions at the site of deposition. It is therefore possible that the red colors in volcanic rocks east of Kinskuch Lake are the result of deposition in a sub-aerial environment.

Albitized Andesite-Greenstone

Greenstones are massive green rocks which in places
show flow structure (Plate XVII) and also a flow-like orientation of chlorite pseudomorphs after hornblende. But to a large extent, the rock mapped as greenstone is a fine-grained, green tuff. In the field, it is convenient to differentiate these massive green rocks from those which show a definite fragmental texture.

Distribution: Greenstone only outcrops over a relatively small area along both sides of Kinskuch Lake. Here, massive green rocks overlie felsitic breccia to the west and underlie or are intercalated with felsitic breccias and sedimentary rocks to the east of the lake.

Petrography: In hand-specimens these rocks are either massive green or crystalline. Crystalline varieties have a green matrix surrounding darker green chlorite pseudomorphs after hornblende.

Under the microscope the matrix of a greenstone flow is seen to be a felted mass of fine grains of potash feldspar plagioclase and chlorite. Subhedral phenocrysts of plagioclase have a composition of An₅ to An₈ but more calcic varieties are possibly present. Other phenocrysts are chlorite pseudomorphs after hornblende and these show parallel orientation. Apatite pyrite, carbonate and quartz are scattered throughout the rock in small amounts.
Only two recognizable fossils were found in the rocks of Kinskuch Lake area. These fossils were identified by Mr. W.R. Danner who reports as follows:

- Pelecypod - one impression of *Pseudomonotis sp.*
- Corals - remnants of a colony
- *Isastrea sp.* - resembles *I. profunda* more than it does
- *I. vancouverensis*
The rock containing the pelecypod was part of an argillite-volcanic breccia sequence near the base of sedimentary formations at the eastern edge of the map area. The coral was a fragment in a felsitic volcanic breccia and although the rock was float, it was apparently derived from similar beds nearby. The latter beds are felsitic breccias which underlie sedimentary rocks west of Kinskuch Lake.

Mr. Danner states that the two fossils which were described in the previous section, are common in the Upper Triassic of the Pacific coast and western Cordilleran area.

The lack of fossils makes it impossible to date the majority of the rocks at Kinskuch Lake with any degree of assurance. The fossils described above suggest that some beds are possibly Upper Triassic in age and Hanson indicates that sedimentary rocks east of the head of the Kitsault River are either Jurassic or Cretaceous. It is possible therefore that the rocks of Kinskuch Lake area were deposited through a large part of the Mesozoic.

Correlation

As defined by Leach, in 1910, the term Hazelton Group included all Mesozoic rocks older than the Coast intrusions. Hanson called the Mesozoic rocks of Alice Arm district Hazelton group as he believed the volcanic rocks of Portland Canal area were:
similar in age and lithological character to those of the porphyrite group of Dawson and the Hazelton group of Leach (1935, p. 4).

Mesozoic sedimentary and igneous rocks, probably largely Jurassic in age, extend south from Portland Canal area to the Skeena River and beyond. Similar successions of volcanic and sedimentary rocks, which are of Mesozoic Age have been described in southeast Alaska by Buddington and Chapin (1929) and to the north along the lower Stikine and Western Iskut River areas by Kerr and Coake (1948). Buckham and Latour (1950) working in the groundhog district east of Portland Canal area outlined Middle Jurassic to Lower Cretaceous sedimentary rocks and suggested the term Hazelton Group should be restricted to beds of this age.

Mesozoic volcanic and sedimentary rocks similar to those of Portland Canal Area are apparently widely distributed throughout southeastern Alaska and western British Columbia. In most places the age of these sedimentary igneous successions is not definitely known and their correlation locally and regionally is very difficult.

Intrusive Rocks

Dykes and sills are present in great numbers along the western side of Kinskuch Lake but elsewhere in the map area, intrusions are not abundant. Most dykes and sills are from 5 to 30 feet wide but some intrusive bodies measure as
much as 350 feet across. The latter bodies are feeders of the many smaller dykes and sills. Stock-like plutons are present in very few places. The largest of the stocks covers about one-quarter square mile.

The composition of intrusions range from acid keratophyric varieties to basic lamprophyres. The different types distinguished, namely hornblende keratophyre, keratophyre and quartz keratophyre, quartz feldspar porphyry, augite quartz diorite and lamprophyre will be discussed in the order above, which is also their order in age from oldest to youngest.

Hornblende Keratophyre

Hornblende keratophyre is the most abundant and probably the oldest type of intrusive.

West of Kinskuch Lake, hornblende keratophyre dykes and sills, fed by a 350' wide feeder, strike eastward through sedimentary rocks, felsitic breccia and greenstone. East of the lake, the dykes do not pass through massive felsitic breccia. Possibly a fault cuts the intrusives off, or they may pass beneath the breccias, not intruding them, because of the massive, competent character of the volcanic rocks.
Megascopically, hornblende keratophyre is composed of euhedral hornblende crystals in a fine-grained matrix of white weathering feldspar and mafic minerals. In most specimens the hornblende has flow-like orientation. Rock inclusions are common.

In different varieties of hornblende keratophyre, the amphibole and feldspar become very coarse or very fine-grained. All gradations of hornblende keratophyre probably exist between hornblende porphyry and feldspar porphyry. The microscopic characters of two types of hornblende keratophyre are described in the following section.

Type Number One: - Euhedral crystals of green pleochroic hornblende crowded with feldspar inclusions, form about 30% of the section. Hornblende phenocrysts, somewhat
altered to biotite and chlorite, are surrounded by smaller anhedral grains of plagioclase and fine-grained potash feldspar. The lightly sericitized and chloritized plagioclase crystals form about 50% of the rock. Only a few grains show albite twinning but others which are twinned have negative relief and extinction angles indicating a composition close to An0. Some apatite, quartz and carbonate are present in the specimen.

PLATE XIX

Photomicrograph of hornblende keratophyre

Type Number Two: - About 50% of the rock is composed of large euhedral feldspar crystals, close to albite in composition. The matrix, which forms about 30% of the specimen, consists of anhedral grains of potash feldspar, plagioclase and chlorite. Euhedral pseudomorphs of chlorite, carbonate and epidote after fine-grained horn-
blende form another 15% of the rock. Apatite is abundant.

Keratophyre, Quartz Keratophyre

Keratophyre, quartz keratophyre dykes cut hornblende keratophyre types.

In hand-specimen the groundmass is greenish grey and on staining this proves to be potash feldspar, fine grains of mafic and quartz. This matrix forms 50% of the rock. The remaining constituents of the specimen are euhedral crystals of plagioclase feldspar and anhedral mafic grains forming 35% and 15% respectively.

In thin-section, subhedral laths of plagioclase have a composition of about $\text{An}_7$ to $\text{An}_{10}$. This feldspar is partly altered to chlorite, carbonate and a white opaque mineral. The matrix is a rather close felted mesh-work of microlites of potash feldspar, needles of green, slightly pleochroic actinolite, and fine grains of chlorite, epidote and quartz. Large grains of actinolite, chlorite, quartz and carbonate and small opaque grains of magnetite are also present in the groundmass.

In a section of a similar dyke, which is more highly altered, there is up to 20% quartz present. This quartz may be secondary.
Quartz-Feldspar Porphyry

Quartz-feldspar porphyry dykes were seen at only a few places and their age with respect to other intrusives is not known. In hand specimens a fine-grained light green matrix surrounds quartz and feldspar phenocrysts. Staining shows that 20% of the rock is quartz and the remainder is plagioclase.

Under the microscope, it is seen that rounded quartz phenocrysts are ringed and embayed by zones of intermixed fine-grained quartz and feldspar. These zones grade into the matrix of fine grains of anhedral plagioclase. Subhedral phenocrysts of feldspar have a composition of An10.

Augite Quartz Diorite

A stock of augite quartz diorite intrudes rocks at the southeast corner of Kinskuch Lake. The age of this stock with respect to intrusive types already described, is not known.

The texture of this rock is medium-grained, granitic and the color is light green. Staining shows that the major components of the rock are 40% plagioclase, 20% potash feldspar and 15% quartz. The remaining constituents are anhedral grains of augite, needles of actinolite and fine grains of magnetite.
In thin-section, sericite-altered laths of zoned plagioclase form a network which encloses other minerals. Because of alteration the feldspar cannot be definitely identified. A few edges of plagioclase crystals have positive relief. Extinction angles indicate a composition as calcic as An$_{30}$. The anhedral mafic grains are colorless augite. Chlorite, epidote, biotite and magnetite are associated with the pyroxene. In some specimens the alteration of pyroxene is more pronounced and actinolite and epidote replace augite.

Quartz and potash feldspar are present as anhedral grains embaying plagioclase. In one specimen, potash feldspar forms rather euhedral crystals. In the latter rock some of the plagioclase is remarkably fresh and unzoned. Quartz-calcite veinlets cut the rock and where they transgress sericitized feldspar, the feldspar is freshened in the zone cut by the veinlet. This fresh plagioclase has negative relief with respect to quartz and is a sodic variety.
Veinlet of quartz, calcite and sodic feldspar cutting sericitized plagioclase crystal

Lamprophyre

All of the dykes mapped as lamprophyre are not truly lamprophyric as some types do not have porphyritic mafic constituents. Lamprophyre cuts all other types of intrusions. Four varieties of lamprophyre are described in the following sections.

Type Number One: - This first variety of lamprophyre occurs as a 30-foot wide dyke. The central part of this dyke is relatively coarse-grained as compared to the margins. A distinctive feature of this intrusive body is the presence of segregation veinlets rich in feldspar and long hornblende needles (Plate XXI). The latter segregation bands which are up to one-half inch wide are spaced at one foot intervals across the dyke and run parallel to its borders for many feet.
A hand-specimen of the central portion of this lamprophyre dyke is composed of equal amounts of medium-grained, anhedral brown mafic minerals and white feldspars. The microscopic characters of the coarser, finer-grained and segregation band portions, of this dyke, are discussed below.

In a specimen from the coarser-grained part of the dyke, long, narrow interlocking laths of plagioclase (An$_{30}$) form about 60% of the rock. Interstitial to the feldspars and forming 10% of the rock is a low relief mineral which is possibly analcite. Anhedral grains of augite and biotite each constitute 10% of the specimen, magnetite forms 5% and apatite and other minerals make up the remainder.

The finer-grained portion of the dyke is composed of 50% plagioclase (An$^{20}$), 35% hornblende and biotite and small amounts of augite and apatite etc.

In a specimen of a segregation band, the feldspars are short and stubby compared to those forming the other parts of the dyke. The composition of this plagioclase is An$^{25}$. Thin euhedral crystals of brown pleochroic hornblende are abundant. Some biotite, magnetite and needle-like apatite crystals are the remaining constituents of the segregation band.
Type Number Two: - In a hand-specimen of the second type of lamprophyre, a fine-grained dark brown matrix surrounds large, yellowish euhedral feldspar crystals. A thin-section shows a sub-radiating network of small plagioclase laths forming 50% of the rock. The remainder of the groundmass, forming another 40% of the specimen, is fine anhedral grains of chinopyroxene, magnetite, biotite, serpentine and carbonate. Set in this fine-grained matrix and forming the remaining 10% of the rock are large plagioclase crystals having a composition near An70.

Type Number Three: - Dykes of the third type of lamprophyre are present in somewhat greater numbers than those of the two types already described.
These third types are fine-grained, dark greyish-green and highly amygdaloidal. As seen in thin-section, the very fine-grained constituents, forming at least 80% of the rock, are radiating laths of highly altered feldspar, green mica, biotite, apatite and an opaque white alteration. Amygdules of chlorite form the remaining 20% of the rock.

Type Number Four: - The fourth type is the most abundant type of lamprophyre.

This type is fine-grained dark green to dark grey with a few small, white, feldspar laths. It is seen under the microscope that the groundmass forming about 70% of the rock is composed of sub-parallel feldspar microlites and fine-grained magnetite. This groundmass encloses a few larger lath-shaped crystals, now wholly altered to carbonate, which were formerly feldspars. Some amygdules of chlorite and carbonate are present in the matrix.

Discussion of Albitization

Conclusions

It is difficult to estimate the extent to which the sodic feldspars, seen in many of the igneous rocks, are of primary or secondary derivation. The occurrence of sodic feldspar, calcite, quartz and other minerals in veinlets and vesicles strongly suggests that chemically complex solutions have moved through most of the rock. Evidence from thin-sections indicates that introduced soda has possibly been
exchanged for calcium in plagioclase crystals.

According to C.F. Parks, Jr., (1948 p. 320), Eskola has performed experiments in which calcic feldspar was transformed into albite in the following manner:

\[
\text{Na}_2\text{CO}_3 + \text{CaAlSi}_2\text{O}_8 + 4\text{SiO}_2 \rightarrow \text{CaCO}_3 + 2\text{NaAlSi}_3\text{O}_8
\]

Anorthite  Albite

This reaction was observed to take place over a temperature range of 264°C to 331°C.

In any veinlets containing sodic feldspar, the latter mineral is closely associated with calcite. Where rocks are cut by these veinlets, it is possible that plagioclase has been albitized in a reaction similar to that described by Eskola. A medium rich in \(\text{Na}_2\text{O}, \text{CO}_2\) and \(\text{SiO}_2\) attacked the rocks, bringing about the partial albitization of the rock feldspars and a consequent formation of calcium carbonate. Bailey and Grabham (1909) discuss the albitization of basic feldspar in some carboniferous lavas of Scotland and they put forward a similar idea regarding the relationship of sodic feldspars and calcite in albitized rocks. With regard to the association of carbonate and feldspar Bailey and Grabham state:
Epidote occurs not uncommonly in small amounts in the vesicles and groundmass of these albitized rocks, but not in the feldspars themselves. It doubtless contains part of the lime removed from the feldspars but most of this latter has probably been carried off in solution as calcium carbonate. (1909, p. 254).

Flows and intrusives rich in sodic feldspar are said to be of spilitic affinity. Such rocks are supposedly characteristic of sub-marine igneous activity associated with the deposition of geosynclinal sediments, however, Gilluly (1935) states that:

This locus in not essential for their development and many are sub aerial. (1935 p. 252).

Although the rocks near Kinskuch Lake are mainly fragmental volcanics, certain types have characteristics of rocks of spilitic association, especially with regard to a high Na₂O to low K₂O ratio in their chemical composition.

Source of Albitizing Media

There is much controversy concerning whether spilites are of primary or secondary origin. Those who say spilites have a secondary origin also question whether:

(1) the replacing soda is of hydrothermal origin, and
   (a) autolytic
   or (b) derived from outside the albitized rocks.
(2) the replacing soda is derived from sea waters.
Bailey and Grabham suggest that albitization of flows is a process of autolysis by residual solutions. Regarding the possibility of autolysis with hydrothermal solutions, Gilluly says:

This seems to require volumes of solution whose presence if entirely indigenous would be expected to be revealed by vugs combey cavities and other evidences of the volume they occupied. Also evidence generally points to reactions being younger than groundmass consolidations. (1935, p. 343).

Gilluly sums up his conclusions on the subject of spilitic rocks by saying:

The suggestion of Daly that the abundant soda of spilites has been concentrated from an underlying mass of basaltic magma, through the action of resurgent water, in conjunction with Goldschmidt's outline of trondhjemitic differentiation, satisfactorily accounts for most of the features of spilitic rocks. (1935, p. 346).

Gilluly is of the opinion that all spilitic rocks are not of primary origin, but he also states:

This does not ... exclude a magmatic origin for the peculiarities of the rocks. (1935, p. 249).

Considering Gilluly's conclusions, outlined above, it is possible to suggest that solutions rich in $\text{Na}_2\text{O}$, $\text{CO}_2$ and $\text{S}_\text{O}_2$, which were introduced into rocks near Kinskuch Lake, were related to residual segregations evolved in the crystallization of the Coast intrusions. With regard to the
latter suggestion it is interesting to note that Knopf (1912) describes certain igneous rocks of the Juneau belt which are altered to albite and other minerals. Knopf relates the metasomatic alteration to vein forming solutions of deep seated origin.

Structural Geology

The present information on the geology of the area is not sufficient to give a complete structural picture. The rather complex and variable nature of interfingering sedimentary and volcanic rocks make it difficult to correlate various sequences for any distance.

Folding

Near the southwest corner of the map area, sedimentary rocks and overlying augite porphyry volcanics are folded into a north-plunging anticline. Felsitic volcanics and argillite, overlying augitic rocks, strike north to northwest and dip eastward. Sedimentary rocks along the west side of Kinskuch Lake form another north-plunging anticlinal fold. At the north end of the lake and immediately to the east of it, small patches of folded argillite and limestone are overlain by felsitic volcanic breccia. East of Kinskuch Lake eastward-dipping felsitic breccia grades into felsitic tuffs and flows showing minor contortions and some west dips, but predominant east dips. Further east, interfingering
felsitic breccias and tuffs show many west dips and a south-plunging syncline is indicated. At the eastern contact with sedimentary rocks, fragmental volcanics dip eastward, beneath argillites and conglomerates. (see Figure II in pocket). Hanson's map shows that the volcanic rocks directly south of the latter region are folded into a south-plunging syncline and north-plunging anticline.

Faulting

Topographic indications of faults are many, in the form of low gullies, valleys, rivers and streams and offset strata. Most of the latter features are visible from aerial photographs.

Only a few faults show measurable movements and no actual fault surfaces were seen. The straight or slightly curving path of most breaks suggest that they are steep dipping. In the case of at least two faults, horizontal offsets of the order of 1000 to 2000 feet are indicated but the vertical component is unknown. Some dykes are offset along faults about 50 feet, but this displacement may not represent the total movement on the fault.

The trends of the two main types of faults are east-striking and northeast-striking. East striking faults, in general appear to be earlier than the other types, and are both right hand and left hand. Northeast-trending
faults show left hand movements and in some places in the area, cut east-trending faults.

Throughout the area, shears and fractures have trends similar to those of large breaks. Stereographic plots were made of poles of veins and shears cutting rocks of the altered zone, (Figures III and IV in Pocket). These plots show that the majority of veins strike east and dip steeply north and south. Many shears in the rocks strike northwest and dip steeply northeast and southwest and smaller numbers strike northeast, dipping northwest at moderately high angles.

Faulting offsets keratophyre and lamprophyre dykes and it is probable therefore that some or all of the faulting was late.
CHAPTER IV

ECONOMIC GEOLOGY

Introduction

A prominent crescent-shaped zone of alteration and copper mineralization borders the southeast corner of Kinskuch Lake and covers an area of approximately two-square-miles. Outcrops of altered rocks, about one mile south of the main zone near the lake, indicate that alteration and mineralization may also extend under ice and snow to this southern locality. The main zone was investigated by diamond drilling, sampling and detailed mapping in order to determine the value of its mineral content.

Highly sheared rocks of the zone near the lake are impregnated with disseminated pyrite and minor chalcopyrite and are cut by quartz-carbonate veins carrying pyrite, chalcopyrite and traces of galena and sphalerite. Alteration minerals associated with mineralization are chlorite, epidote, sericite, calcite, quartz and some sodic feldspar. A stock of partially altered augite quartz diorite outcrops near the centre of the altered mineralized zone.
Mineralization

Disseminated

Disseminated chalcopyrite occurs as blebs distributed through parts of the pyritized-chloritized rocks. The fineness of chalcopyrite and pyrite and their similar appearance where tarnished make it difficult, at first glance, to distinguish between the two sulphides. Some outcrops are stained by malachite but the presence of this green stain does not prove to be a guide to copper content of the rock. In general, it can be said that the occurrence of chalcopyrite is restricted to chlorite-pyrite rocks but within such rocks, the distribution of copper mineralization is erratic and unpredictable. Outcrops containing disseminated chalcopyrite are shown on the map as chlorite-pyrite-chalcopyrite rocks. Diamond drilling and assaying of chloritized-pyritized rocks showed that the highest copper grades occur near the surface and these grades are lower at quite shallow depth. Holes drilled at lake level penetrated and passed through the best copper mineralization in about 300 vertical feet.

In polished-sections of rocks containing disseminated mineralization, blebs of pyrite and chalcopyrite are for the most part widely separated from one another. Where the two minerals are in contact, chalcopyrite fills fractures in pyrite grains or is molded onto the latter.
Vein

Numerous veins cut all varieties of altered rocks, in various parts of the altered-mineralized zone. The majority of these veins are about two feet wide but others measure up to five feet across. Some of the larger veins can be traced along strike for distances up to 1000 feet. The attitude of most veins, as shown in Figure III (in pocket) is east-striking, dipping steeply north or south. Veins are of two main types, quartz and quartz-carbonate and the majority are barren of sulphide or carry only pyrite. Some quartz-carbonate veins are locally rich, containing massive chalcopyrite and pyrite as one-foot-long lenses. At least one vein contains pyrite, chalcopyrite and also some galena and sphalerite disseminated over a length of about 20 feet.

In polished-sections of vein specimens, galena, sphalerite and chalcopyrite are seen to be younger than pyrite, and molded around the edges of the latter mineral. Galena is replaced by sphalerite and both of these are replaced by chalcopyrite. Much of the sphalerite contains minute inclusions of chalcopyrite and in some grains, blebs of chalcopyrite form a grid pattern of straight lines. The chalcopyrite that occurs as minute inclusions in sphalerite has probably been exsolved. The paragenetic sequence of vein minerals is as follows:
1. Pyrite  
2. Galena  
3. Sphalerite with exsolved chalcopyrite  
4. Chalcopyrite  

There is little evidence regarding the relationship between disseminated minerals and vein minerals. In both types of mineralization, chalcopyrite is later than pyrite. It is possible that much of the disseminated chalcopyrite and pyrite were introduced by the vein forming solutions.  

Alteration

The various types of alteration shown on the map are chlorite-pyrite-carbonate quartz, chlorite-pyrite-epidote, chlorite-pyrite-chalcopyrite and sericite-pyrite.  

Chlorite-pyrite-carbonate quartz alteration is widespread over most of the altered mineralized zone. Locally epidote or chalcopyrite is present in notable amounts in these rocks and carbonate alteration becomes very strong adjacent to quartz-calcite veins.  

Near the eastern and western fringes of the altered zone, sericite-pyrite alteration is predominant. The most striking example of sericitization is found 1000 feet above and 2000 feet east of the lake. Here, sericitic alteration takes the form of a layer, roughly conformable
with bedding, about 500 feet thick and 2000 feet long. This mass of sericitized rock gradually fingers out as thin bands of sericitization along fractures and passes into chlorite-pyrite-carbonate alteration.

Hand specimens of chloritized-pyritized rocks have a dark green matrix enclosing scattered grains of pyrite. In some specimens of altered volcanic breccia and tuffs, the fragmental texture is preserved by chloritic replacement of rock fragments. Other specimens have a crystalline texture with chlorite-carbonate pseudomorphs after hornblende crystals. In thin-section chlorite appears as ragged scattered grains between highly sericitized feldspars. Chlorite forms about 20% of these rocks, pyrite 10%. In some specimens chalcopyrite or epidote accompany chlorite and pyrite.

Heavily sericitized rocks are rusty yellow to grey and crumbly or clayey. Hand specimens consist of fine-grained sericite and granular quartz enclosing cubes and grains of pyrite. Under the microscope, this rock is seen to be composed of a fine-grained mixture formed of 50% quartz and feldspar and 40% sericite and some carbonate. A small amount of apatite is also visible and in some specimens granular or cubic pyrite composes 10% of the rock.
Genesis of Mineralization and Alteration

The fact that quartz-carbonate-sulphide veins cut the altered rocks suggests that alteration was in part earlier than mineralization but it is probable that the two processes were closely related and possibly contemporaneous.

Two factors apparently restricted localization of alteration and mineralization. The most important factor was the original rock composition. The greater part of chlorite-pyrite alteration is confined to greenstone and possibly some hornblende keratophyre dykes. The main zones of sericite-quartz-pyrite alteration are probably confined to rocks which were originally felsitic pyroclastics and at one point, well bedded felsitic fragmental volcanics pass gradationally into highly sericitized rocks. A second factor localizing alteration and mineralization was the highly shattered character of the altered rocks, which allowed entrance of the necessary solutions.

Beyond its centralized position in the altered zone, the augite quartz diorite stock shows no significant relationship to alteration and mineralization.

Certain evidence is available concerning the time of alteration and mineralization. Some lamprophyre dykes cut the altered rocks but other such dykes are veined by quartz and carbonate containing some pyrite and chalcopyrite
Some quartz-carbonate veins are offset along small north-trending faults. Alteration and mineralization was apparently late but did precede some of the latest faulting.

The type of alteration and mineralization that has been described above is similar to that present in the "copper belt" rocks of the upper Kitsault Valley west of Kinskuch Lake. Hanson, in describing the copper belt rocks states:

The rocks of the Copper Belt proper, compared with the other igneous rocks of the area are highly sheared and much altered to, or replaced by such minerals as sericite, chlorite, calcite and pyrite. The belt consists chiefly of fine-grained, fragmental volcanic rocks and of crystalline rocks that are probably mainly intrusive. In places the rocks could not be identified as certainly either massive or fragmental ... The rocks are not different in mineral composition from the other rocks of the area, but the belt is distinguished by the presence of copper deposits, by the sheared nature of the rock and by the universal presence of pyrite.

(1935 p. 39)

Conclusion

At the present time the mineral deposit at Kinskuch Lake does not seem to be of economic grade and size. Rock mineralized with disseminated chalcopyrite occurs over a fairly large area but is of very low-grade. Veins are also low-grade and of little importance. Extensions of the altered-mineralized zone may exist and these could conceivably be of economic grade.
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FIGURE II

CROSS SECTION ALONG LINE A-B OF MAP

VERTICAL AND HORIZONTAL SCALE 1" = 2000'
DATUM LINE A-B ~ 2500' ABOVE SEA LEVEL

Mt. Lavender 7600'
Kinskuch Lake 3750'

R.E.G. 1957
FIGURE III

NORTH

STEREOGRAPHIC PLOT ON UPPER HEMISPHERE OF POLES TO ISO VEINS

- 0-1%
- 1-2%
- 2-3%
- 3-4%
- 4-5%
- 5-6%

R.E.G. 1957
STEREOGRAPHIC PLOT ON
UPPER HEMISPHERE OF
POLES TO 300 SHEARS

- 0-1%
- 1-2%
- 2-3%
- 3-4%
- 4-5%
FIGURE I
PORTLAND CANAL AND ADJACENT AREAS
Kinskuch Lake Area - Inset
FIGURE II

CROSS SECTION ALONG LINE A-B OF MAP

VERTICAL AND HORIZONTAL SCALE 1" = 2000'

DATUM LINE A-B = 2500' ABOVE SEA LEVEL
Figure IV

STEREOGRAPHIC PLOT ON
UPPER HEMISPHERE OF
POLES TO 300 SHEARS

0-1%  2-3%
1-2%  3-4%
4-5%

R.E.G.1957