PETROLOGY AND MOLYBDENITE MINERALIZATION
OF
THE LUCKY SHIP IGNEOUS COMPLEX

803177   BY David A. Silversides

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THE LUCKY SHIP IGNEOUS COMPLEX

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by

David A. Silversides

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ABSTRACT

The Lucky Ship Property is located in west-central British Columbia. Molybdenite mineralization occurs in a stockwork of quartz veinlets spatially associated with an igneous complex intruding Jurassic sediments assigned to the Hazelton Group.

Five distinct rock types make up the complex: pink quartz porphyry, grey biotite-quartz-feldspar porphyry, dark green aphanitic dykes, white quartz-feldspar porphyry, and alaskite. On the basis of chemical analyses, these correspond to very potash-rich granite, quartz monzonite, lamprophyre, and alkali granite.

The white quartz-feldspar porphyry and the alaskite, both alkali granites, have a common composition of albitic plagioclase, $Ab_{98-92} An_{2-8}$. It is concluded they are related. The albite has optical properties implying crystallization under plutonic conditions.

Potash metasomatism, indicated mineralogically by sericite and potash feldspar as a replacement of the albite, and chemically by a marked increase in K_2O, has been extensive in the white quartz-feldspar porphyry and the alaskite.

Inconclusive evidence suggests that white quartz-feldspar porphyry is younger than grey biotite-quartz-feldspar porphyry.

Molybdenite mineralization is associated with the crystallization history of the white-quartz-feldspar porphyry. This is indicated by the presence of mineralized fragments included in this rock, which itself is cut by a second period of mineralization.

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CHAPTER I

INTRODUCTION

Statement of Problem

The Lucky Ship Property is a molybdenite prospect in a complex of fine-grained, igneous porphyries. The writer's objectives in this study are:

(i) To describe the porphyry types as to their known and implied distribution, petrography, alteration, chemical variation, and petrogenesis.

(ii) To give an account of the molybdenite mineralization with regard to its distribution and possible origin in the complex.

Location and Access

The Lucky Ship Property is situated between Morice Lake and the Nanika River in west-central British Columbia (fig. 1). The small village of Houston, approximately 50 miles northeast of the property, is the nearest supply center. Access is easily obtained via the Morice Lake Forestry Development Road from Houston up to mile 49 on the east side of the Nanika River, thence via a connecting road, six miles in length, to the property's camp site.
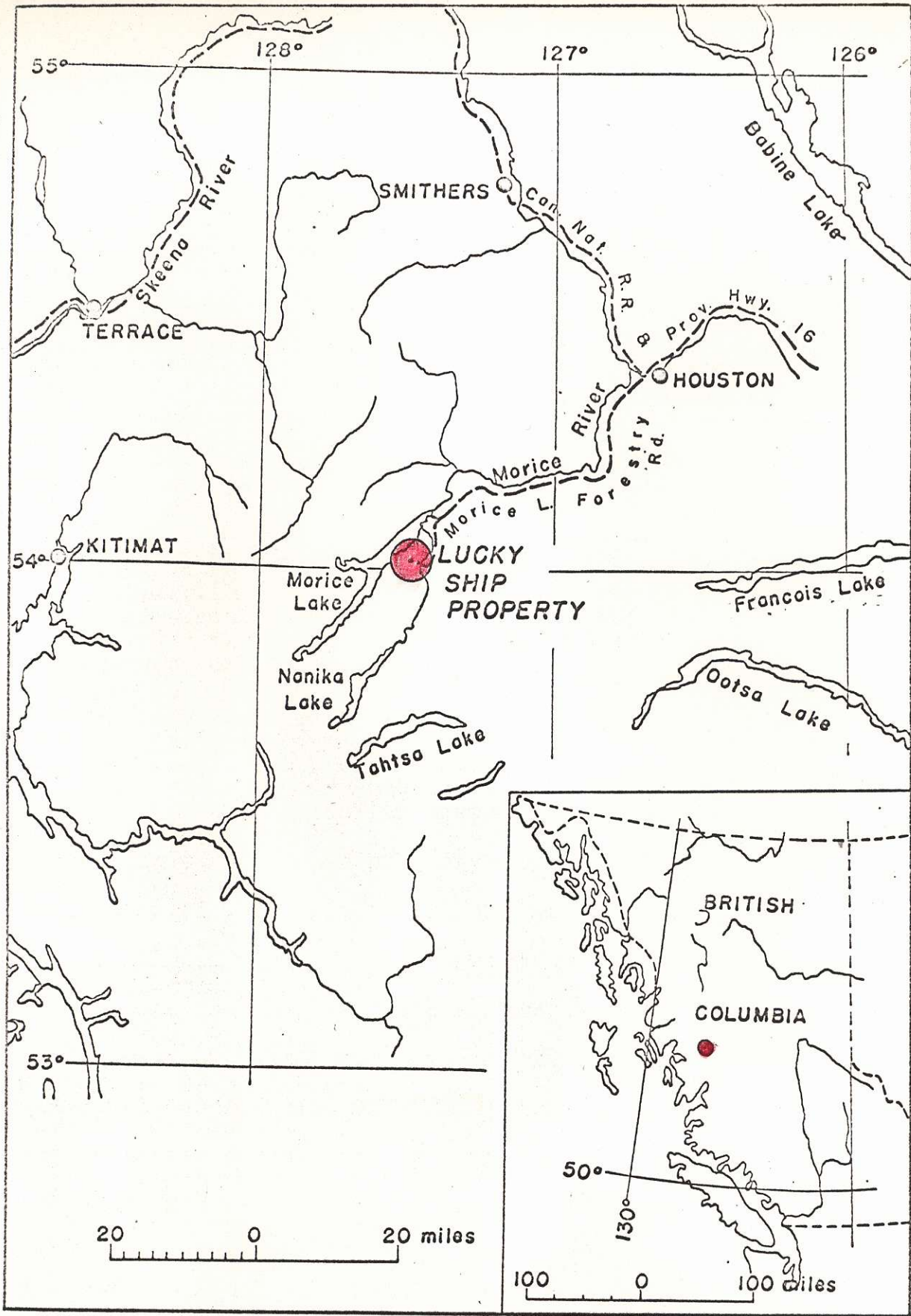
Fig. 1 - Location of the Lucky Ship Property

History

The area which includes the Lucky Ship Property has been mapped in reconnaissance fashion by Armstrong (1944), but no description of the property is given in his report. To the writer's knowledge, the only mention of the property in published literature is that contained in the 1957 British Columbia Department of Mines Report:

> "Lucky Ship (54° 127° SW)
>
>   This property consists of fifteen recorded claims, owned by Matthew Sam and B. McCrae of Topley;...... It covers a zone of quartz stringers containing molybdenite that cut quartz porphyry. The Consolidated Mining and Smelting Company of Canada, Limited, optioned the property and in July, 1957 did 203 lineal feet of trenching."

Apparently the property was dropped by the above company in the fall of 1957 and returned to the vendors. In the spring of 1963, the property was optioned by Plateau Minerals Limited who conducted a geochemical soil survey and staked additional claims. Southwest Potash Corporation, in turn, optioned the property from Plateau Minerals in September 1963 and proceeded to stake additional claims, cut picket lines, and conduct mapping, geochemical soil surveys, and magnetometer surveys during September, October, and November.

During the period June-November, 1964, Southwest

Potash Corporation undertook a more ambitious development programme consisting of prospecting the entire claim group, (which now consists of approximately 109 claims), detailed mapping of the mineralized area, and diamond drilling four holes totalling 4246 lineal feet.

The writer collected most of the material for this paper during the period of June to mid-September, 1964 while employed by Southwest Potash Corporation to do the detailed mapping. Drill logs and representative core from the last three holes which were completed after the writer left the property, were obtained in December, 1964. Thin-section studies, determination of minerals by x-ray methods, and library research was conducted during the 1964-1965 winter term at the University of Manitoba.

Acknowledgments

CHAPTER II

GENERAL GEOLOGY

Regional Geologic Setting

Figure 2, compiled from the maps of Armstrong (1944), Duffel (1959), Lang (1942), and Rice (1949), depicts the regional geologic setting of the property. The following description is basically a summary of their work in this area and that of Duffel and Souther (1964), whose recent work in the Terrace Map Area immediately east of figure 2, adds considerably to the understanding of the igneous geology of the Coast Range.

The property lies east of the major batholiths of the Coast Range, within an area containing numerous small granitic plutons. The small plutons intrude Hazelton Group (Jurassic) rocks, to some extent strata of the Bowser Group (Upper Jurassic to Lower Cretaceous), and rocks of the Sustut Group (Upper Cretaceous and Paleocene).

The Hazelton Group consists of an apparently conformable succession of interbedded volcanic and sedimentary rocks which has been divided by Duffel (1957) into a lower mainly volcanic division, a middle mainly sedimentary division, and an upper dominantly volcanic division. The lower and upper divisions are characterized by a larger proportion of
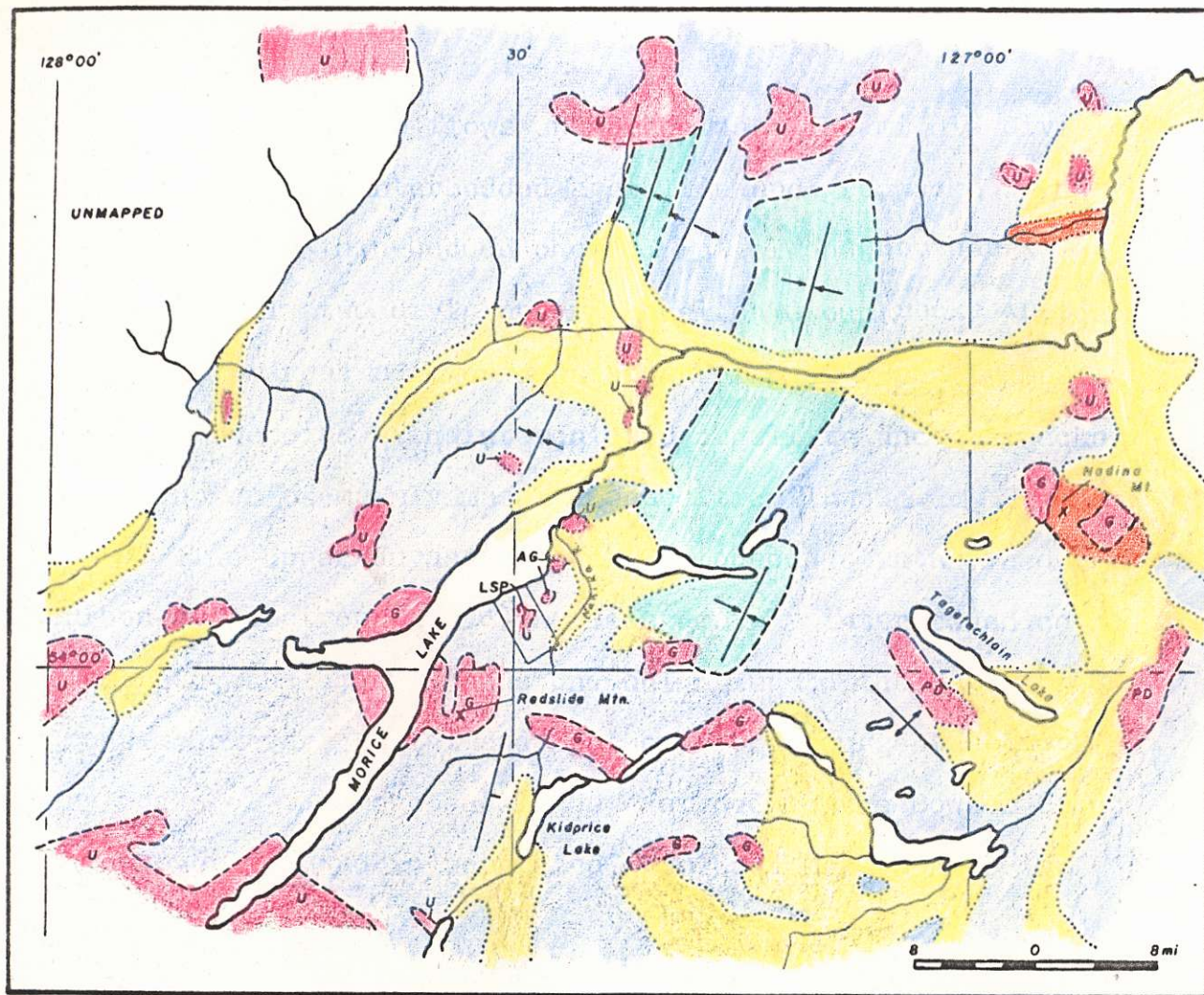
LEGEND

Pleistocene	🟨	Gravel, till.
Upper Cretaceous-Paleocene	🟧	Sustut Group: conglomerate, sandstone, shale, greywacke, argillite.
Lower Jurassic-Early Tertiary	🟥	Coast Intrusions: undifferentiated(U), granite(G), aplitic granite(AC), porphyritic diorite(PD), Lucky Ship porphyries(LSP).
Upper Jurassic-Lower Cretaceous	🟦	Bowser Group: conglomerate, shale, sandstone.
Jurassic	🟦	Hazelton Group: andesite, basalt, argillite, greywacke.
	⬛	Lucky Ship Property.

REGIONAL   GEOLOGY

Fig. 2

.porphyritic andesite flows and breccias. The middle division
is predominantly interbedded argillite and greywacke with
minor tuff and thin-bedded chert. Duffel and Souther (1964)
recognize only two divisions in Hazelton Group rocks in the
Terrace Map Area; a lower consisting of predominantly massive
andesite breccias with intercalated argillite and greywacke
and an upper of mainly massive andesitic flows.

The Upper Jurassic-Lower Cretaceous strata are des-
cribed by Armstrong (1944) as being mainly interbedded con-
glomerate, shale, and sandstone belonging to the Hazelton
Group. However, Duffel and Souther (1964) suggest sediment-
ary rocks of this age should be assigned to the Bowser Group
which overlies and is separated from Hazelton rocks by an
unconformity.

The Upper Cretaceous strata are described by Lang
(1942) as being mainly sandstone, greywacke, and conglomerate.
Rice (1949) correlates these rocks to the Sustut Group of
Upper Cretaceous and Paleocene age in his compilation of the
Smithers-Fort St. James sheet.

Structurally, the Hazelton Group and Bowser Group
rocks are depicted as being folded into a series of north-
easterly trending synclines and anticlines. This feature is
a departure from the general northwesterly trend of folding
present in rocks adjacent to the Coast Range batholithic

complex.

The plutons shown in figure 2 consist of a granitic suite collectively described in the literature as being granodiorite, quartz diorite, diorite, granite, and related rocks. Together with the major batholithic rocks of the largely granitic terrain of the Coast Range proper, they are grouped under the classification of Coast Intrusions (Duffel, 1959; Duffel and Souther, 1964). Their emplacement ranges over a period of possibly Lower Jurassic to early Tertiary, with perhaps the majority emplaced during the Cretaceous period (Duffel, 1959).

Very few of the individual plutons are described in terms of specific rock type. Lang (1942) states that the granitic stock of Nadina Mountain is a red granite; elsewhere the intrusions are classified as granite and diorite. Armstrong (1944) does not describe any individual pluton. Duffel (1959) is the most precise calling the intrusion at Redslide Mountain granite; those northeast of Kidprice Lake granite, and those in the vicinity of Tagetochlain Lake porphyritic diorites. The intrusive rock at the south end of Morice Lake is an apophysis extending eastward from the main batholithic complex and is not described as to specific rock type in the literature. However, Souther's work (Duffel and Souther, 1964) on similar apophyses in the Terrace Map

Sheet indicates that it is most likely a complex of rock types ranging from granite to gabbro, with the bulk being granodioritic in composition.

Local Setting

The Lucky Ship Property covers an area of approximately 5 square miles situated astride the heavily wooded ridge between Morice Lake and the Nanika River. The slopes of the ridge are steep, rising from an elevation of approximately 2600 feet at the base to 4400 feet at the crest. The terrain is rugged with numerous bluffs.

The ridge is largely underlain by volcanic rocks and to a lesser extent by sedimentary rocks of the Hazelton Group. These have been intruded by several small plutons and dykes. Overburden consisting of glacial till and gravel is fairly extensive, particularly at elevations below 3500 feet.

The volcanic rocks comprising the Hazelton Group are dark green to red andesites, tuffs, agglomerates, and black to red amygdaloidal basalts. The sedimentary rocks are argillite, greywacke, and greywacke conglomerate. Their predominant strike direction is believed to be north-northeast, with dips to the southeast.

The plutons and dykes include two small (less than 2000 feet in diameter), aplitic granite stocks, several

quartz porphyry and felsite dykes, and a complex containing

a variety of fine-grained porphyries and dark green aphan-

itic dykes. This latter complex is the most significant

feature of the area because of its associated molybdenite

mineralization. The general geology of this complex is

described in the following section

General Geology of the Igneous Porphyries

Figures 3, 4, and 6 (included in back pocket) refer

to surface geology and diamond drill-hole sections.

The surface geology of the complex is shown in fig.

4. The igneous rock types of the complex form a highly irr-

egular shaped mass located at the crest and on the south-

east slopes of the ridge between the elevations of 3200 and

4300 feet. The dimensions of the complex are approximately

4000 feet in a N-S direction and 2500 feet in an E-W direct-

ion.

The host rocks for the igneous rock types of the

complex are interbedded cherty argillites, argillites, grey-

wackes, and greywacke conglomerates. Argillites predominate

in the eastern half of the map-area of fig. 4; greywacke and

greywacke conglomerate predominates in the western half. No

obvious andesite flows were observed, but the majority of the

rock fragments in the greywackes are andesite.

Lateral and vertical gradational variations in the
sedimentary rock types are very common and make it difficult
to determine bedding planes. Distinct bedding planes are
most frequently observed in the argillites, but the few
observations recorded do not fall into any set pattern (see
fig. 5). The only interpretation that can be made from these
few measurements is that the rocks are folded and dips are
generally greater than 40°.
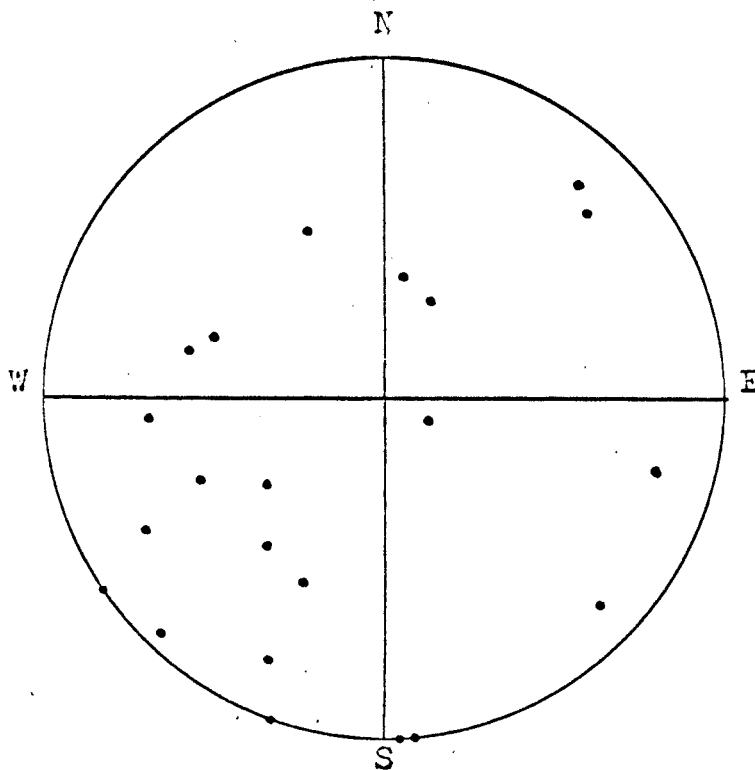
 – 22 attitudes plotted from field observations.
 – lower hemisphere stereographic projection.

Fig. 5 – Poles to bedding planes in argillites

The igneous complex consists of fine-grained silicic porphyries and dark green aphanitic dykes. The rock types fall into five mappable units on the basis of megascopic appearance:

(i) Pink quartz porphyry. This rock type is light red and contains 2 to 3 per cent glassy quartz phenocrysts 0.5 to 1 mm in diameter and minor disseminated flakes of specular hematite. The matrix is light red in colour and exceedingly fine-grained.

(ii) White quartz-feldspar porphyry. The megascopic appearance of this rock type is variable due to alteration and differences in the amount of phenocrysts. Its most characteristic feature is its brilliant white color. The phenocrysts are quartz, feldspars, and biotite, ranging from 0.1 to 4.0 mm in diameter. Quartz phenocrysts are always visible. The biotite content varies from nil to approximately 1 per cent. The feldspars are generally visible, but in some instances blend in with the white colored matrix or are masked by alteration. Alteration minerals visibly recognized are fine-grained sericite, "clay", epidote, and pyrite.

White quartz-feldspar porphyry also contains angular, light to dark colored fragments. The dark fragments are visibly recognized as inclusions of the surrounding sedimentary rocks. The abundance of the fragments varies from nil

to approximately 40 per cent of the total rock volume. Where concentrations are high, outcrops take on a breccia appearance.

(iii) Alaskite dykes. These dykes appear to be equigranular in handspecimens and are light green to cream in color. They are composed of 2 to 4 mm quartz and feldspar crystals. The dykes contain abundant quartz-molybdenite veinlets.

(iv) Dark green aphanitic dykes. Dykes of this rock type are dark green in color and very fine-grained. They contain disseminated pyrite and are cut by carbonate shears.

(v) Grey biotite-quartz-feldspar porphyry. This is a medium-grey colored rock containing visible biotite, white plagioclase, and glassy quartz phenocrysts set in a light grey, aphanitic matrix. The phenocrysts are 0.1 to 4 mm in diameter.

In the above classification, the term "porphyry" is used in the same sense as defined by Tyrell (1926):

> " A porphyry is a hypabyssal form of plutonic
> magma, exhibiting one or more of the phenocrysts
> in an aphanitic groundmass."

The term is therefore used in a genetic as well as a textural sense.

The major problem encountered in mapping (see fig. 4) was the difficulty in establishing the boundaries of the

above igneous rock units. The reasons for this are:

(i) A general lack of outcrop.

(ii) Relatively intense alteration and quartz-
veining, particularly in the southern portion of the complex,
masks the true character of the rock units. Consequently, in
many areas only the approximate position of the boundaries
between rock types could be determined.

The white quartz-feldspar porphyry is the major rock
type in the complex in terms of volume. Grey biotite-quartz-
feldspar porphyry appears to be restricted to the south-
eastern portion of the complex. The dark green aphanitic
dykes were discovered only in drill-core (see fig. 6, back
pocket). The alaskite dykes were found only in the sediment-
ary host rock at the south contact of the complex. The pink
quartz porphyry occurs at the western part of the complex.

The greatest intensity of fracturing, quartz veining,
and alteration occurs in the south part of the complex.
Molybdenite occurs as very fine-grained flakes in the quartz
veinlets.

In the following chapter, descriptions of igneous
rock types, alteration, and molybdenite mineralization are
given with reference to petrology, geochemistry and mineral-
ogy.

CHAPTER III

IGNEOUS ROCK UNITS

The unaltered or least altered igneous rock units of
the complex are described. References to particular thin-
section and chemically analyzed specimens have been made in
the descriptions. Locations of specimens from outcrops are
shown in fig. 7 (in back pocket). The locations of drill-
core specimens are given in the text of the descriptions.

Petrology

(i) Pink Quartz Porphyry

This rock type occurs in the west portion of the
complex (see fig. 4). Its outcrop distribution suggests a
northwest trending body with an apparent width of 500 feet.
Its contact with sedimentary rocks, observed in only one
locale, was determined to have an attitude of $320^{\circ}/90^{\circ}$.
Its contact relationship with white quartz-feldspar porphyry
is unknown.

The rock is highly fractured and sheared. One pre-
dominant set of fractures trends northwest and dips vertically.

The most characteristic feature of the pink quartz
porphyry is that it contains fine-grained (0.5 to 1 mm),
disseminated flakes of specular hematite. This mineral was

also observed in the sedimentary rocks in contact areas.
Glassy quartz phenocrysts are rare. The rock, in general,
has a pink, porcelaneous appearance.

In thin-section, (see plate 1) the matrix appears as
a very fine-grained (< 0.05 mm) mixture of sericite, feld-
spar, and quartz. The quartz phenocrysts appear as subhedral
crystals ranging from 0.5 to 2 mm in diameter. Potash feld-
spar occurs as anhedral and subhedral crystals, with specular
hematite and sericite in the centers.

In the one observed contact area (see fig. 4, north-
ern contact), the sedimentary argillite rocks are slightly
metamorphosed to a dark green, epidote-chlorite hornfels.
This feature indicates the pink quartz porphyry is intrusive.

(ii) Grey Biotite-Quartz-Feldspar Porphyry

Observed surface exposures of this rock unit general-
ly contain a high frequency of quartz veinlets and are
altered to a white aplitic mixture of quartz, "sericite", and
"clay" which makes altered equivalents of this rock unit
easily confused with the highly quartz-veined white-quartz-
feldspar porphyry (see plate 2). Consequently, its bound-
aries shown on fig. 4 are uncertain and should be regarded as
only approximate. The surface distribution of this rock type
was based on the occurrence of remnant biotite (and/or
chlorite), which is a characteristic mineral of unaltered

X 37, crossed nicols

Photomicrograph of pink quartz porphyry showing partially resorbed quartz phenocrysts (Q), potash feldspar (K), and specular hematite (H), set in a matrix of quartz, feldspar, and sericite. Taken from thin-section L.S.-53, outcrop.

Plate 1 - Pink Quartz Porphyry.

segments of this rock type. In drill-core, the two rock types are easier to determine. Altered grey biotite-quartz-feldspar porphyry is a dark green color, due to its relatively high chlorite content. Altered white quartz-feldspar porphyry is a very pale green color.

The suggested surface configuration is that of an oval-shaped body, approximately 800 feet long in a north-easterly direction and with a maximum width of 450 feet. One five foot thick dyke of this rock unit, having an attitude of N 30° E/90°, outcrops in sedimentary rocks south of the main body and was intersected in drill-holes 1 and 3.

The subsurface distribution of this rock unit, inter-preted from an examination of drill core, is shown in fig. 6. Drill-hole 4 encountered no grey biotite-quartz-feldspar porphyry and therefore confirms the approximate northeastern termination as suggested from surface geology. Drill-hole 3 intersected alternate sections of grey biotite-quartz-feld-spar porphyry, argillite and greywacke, and white quartz-feldspar porphyry. Drill-holes 1 and 2 cut through the max-imum width of the body and subsequently contain the largest intersections. The projection of intersections in drill-core to surface indicates that the dip of the contacts of this rock unit are probably steep, 70° to vertical, and variable in direction.

The least altered portions of this rock unit contain

megascopically recognizable white feldspar, black biotite, and glassy quartz phenocrysts, set in a medium grey, aphanitic matrix.

Under the microscope (see plate 3), the matrix appears as a very fine-grained (< 0.05 mm) aggregate of quartz and both potash and plagioclase feldspars. Quartz phenocrysts occur as euhedral to subhedral, partially embayed crystals. Biotite appears as dark to light brown pleochroic flakes, partially altered to light green chlorite containing yellowish brown needles of rutile and fine-grained, earthy aggregates of leucoxene. The feldspar phenocrysts are plagioclase, showing strong normal zoning from andesine (approx. An_{35}) in the centers to oligoclase (approx An_{25}) at the rims. Phenocrysts of the above minerals range from 0.1 to 4 mm in diameter and average 1.0 mm. Trace amounts of apatite, closely associated with biotite, appears as the only recognizable accessory mineral.

The plagioclase phenocrysts show incipient alteration to fine-grained epidote and carbonate in the more calcic centers. This, and the weak chloritic alteration of biotite, likely represents deuteric reaction during final stages of crystallization. Where the rock is cut by numerous quartz veins, the plagioclase phenocrysts are completely altered to olive green, "clay" pseudomorphs.

Modal analyses of five specimens of grey quartz-feldspar porphyry are shown in Table I and were derived by the

Plate 2 - Outcrop of grey biotite-quartz-feldspar
porphyry, with abundant quartz veins.
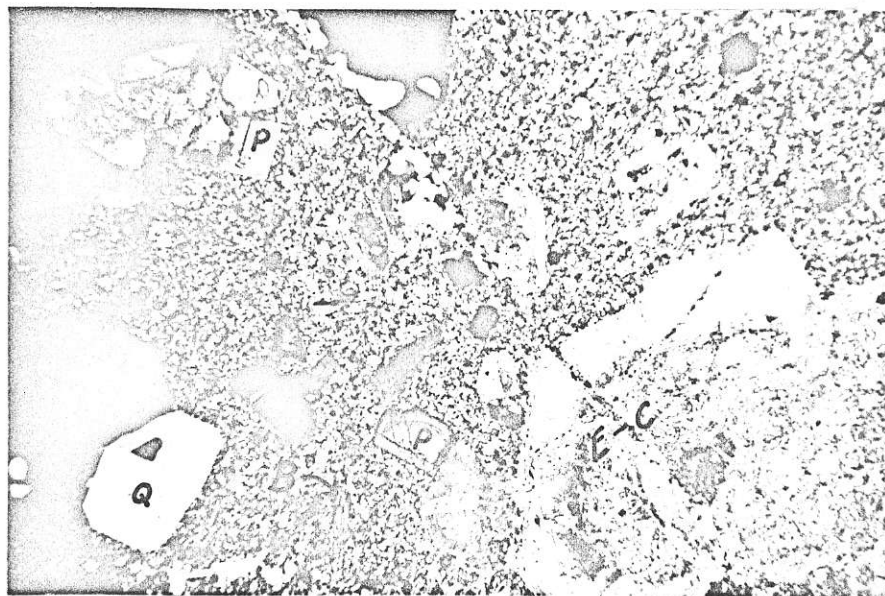
X 20, crossed nicols

Q = quartz
P = plagioclase
B = biotite
E-C = epidote-carbonate

Plate 3 - Photomicrograph of least altered grey
biotite-quartz-feldspar porphyry.

point count method (Chayes, 1949). For each section at least
2000 points were counted, using an intercept distance of
0.3 mm and a traverse spacing of 0.5 mm. If a hole occurred
during a traverse, the counting was stopped and a new trav-
erse begun. Only phenocrysts are distinguished in their
mineralogy; the minerals occurring in the matrix are too fine-
grained to accurately determine their identity.

Table I

Modal Analyses of Grey Biotite-Quartz-Feldspar Porphyry

Volume %

Specimen Number	Matrix	Plagioclase	Quartz	Biotite Chlorite	Apatite
L.S.-10	77.9	15.0	6.0	1.8	X
M-146	73.7	13.0	6.0	2.3	X
H-339	65.5	20.4	11.1	3.0	X
H-309	68.5	24.7	4.2	2.6	X
J-182	69.0	24.1	2.2	4.7	X
Average	70.8	20.4	5.9	2.9	X

X = presence noted

Location of above specimens

L.S.-10 and M-146: outcrop, center portion of dyke, south-
east of main body

H-339 and H-304: drill-core, hole 1, 339 and 304 footage

J-182: drill-core, hole 2, 182 footage.

Field evidence indicates that the grey biotite-
quartz-feldspar porphyry is intrusive. The evidence is in
the form of a dyke of this material cutting sedimentary

rocks which was intersected in drill-holes 1 and 3, and by
the intrusive contact displayed in the core from drill-hole
2. The relationship of grey biotite-quartz-feldspar porphyry
to white quartz-feldspar porphyry however, has been obscured
by intense quartz veining in their contact areas. A discuss-
ion of the relations between these two rock units is included
in the section postulating the environment and history of the
complex.

(iii) Dark Green Aphanitic Dykes

Dykes of this rock unit were observed only in core
from drill-holes 1, 2, and 3 cutting grey biotite-quartz-
feldspar porphyry and argillite-greywacke (see fig. 6).
Core length intersections vary from 6 inches to 19 feet.
The single dyke intersected in drill-hole 1 also occurs in
hole 3. Its strike was determined to be N 38°E, because
of the fact that the elevation of the intersections in both
holes are the same. The attitudes of the other dykes are
unknown.

The dykes are aphanitic, dark green in color, and
contain fine-grained, disseminated pyrite. They are cut by
carbonate shears and quartz-calcite veinlets containing
pyrite and sparse molybdenite.

In thin-section (see Plate 4), the rock appears as a
fine-grained (0.1 to 1 mm) aggregate of biotite and plagio-
clase. Biotite (50%) occurs as dark brown pleochroic clots
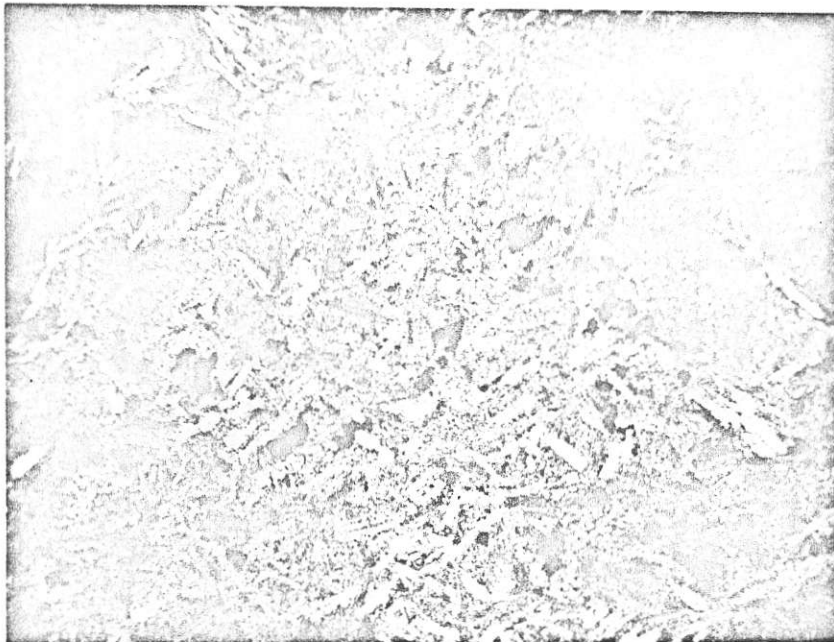
X 28, crossed nicols

Photomicrograph of dark green aphanitic dyke rock showing plagioclase (white laths), biotite (grey), and pyrite (black). Taken from drill-core, hole 1, footage 14.

Plate 4 - Dark green aphanitic dyke rock.

and disseminated flakes. Plagioclase (40%) forms tabular, albite-twinned crystals, whose composition is estimated as An_{10-20} (relative index of refraction slightly less than 1.54; average of maximum angles $x' \wedge a=5^{\circ}$). Pyrite (10%) appears to be the only accessory mineral and occurs as scattered, anhedral grains averaging 0.5 mm in diameter. The high biotite content of this rock type suggests it is a lamprophyre.

(iv) White Quartz-Feldspar Porphyry

As shown in fig. 4, white quartz feldspar porphyry, the most abundant of the igneous rock types, forms a highly irregular shaped body, approximately 3400 feet long in a northwesterly direction and 1000 to 1600 feet wide. A strong system of northeast striking and steeply dipping dykes project from the main body to the northeast and south-west. The north part surround what is believed to be a roof pendant of sedimentary rocks.

Very little is known of the subsurface shape of this rock type. On surface, contact inclinations are obscure because of the general lack of outcrop and the lack of distinct planar contacts with the sedimentary host rocks. Drilling information indicates that the southern contact is steeply dipping (see fig. 6).

Fracturing is most intense in the southeast portion, particularly in the proximity of the grey biotite-quartz-feldspar porphyry and the contact with the sedimentary rocks. It decreases towards the central and northern portions where recognizable joint planes spaced 6 inches to 2 feet apart can be measured. Their attitudes however, do not indicate any outstanding set (see fig. 8). At best it can only be said that jointing appears to be highly irregular in strike and predominantly steep in dip, with a 5 pole maximum in fig. 8 suggestive of a predominant (weak) northeast strike and near vertical dip. The northern portion shows a well developed shear direction, trending north to northwest and variable in the direction of dip.
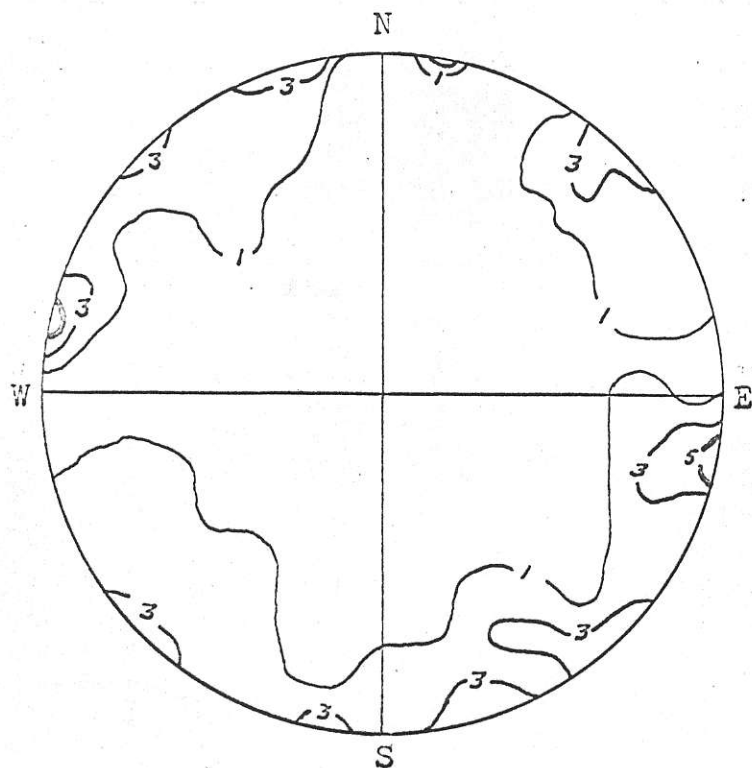
- 57 poles plotted from field observations.
- lower hemisphere equal area projection.
- contour interval 1, 3, and 5 poles.

Fig. 8 - Contour diagram of poles to joints in white quartz-feldspar porphyry.

The white quartz-feldspar porphyry varies in the degree of alteration, the size and number of phenocrysts, the biotite content, the pyrite content, and the presence of inclusions. The inclusions are of sufficient number in some places to make the rock appear as a breccia. The distribution of pyrite and inclusions is shown in fig. 4.

For the most part, the rock is a brilliant white color, and contains one to three mm phenocrysts of quartz and feldspar set in an aphanitic matrix. Biotite and chlorite are rare, with a patchy distribution, but are most frequently observed in the central part of the porphyry in the vicinity of specimens M-60 and L.S.-41 (see fig. 7). In drill-core, it appears in the lower intersections of the white porphyry in drill-holes 1, 2, and 3.

Disseminated pyrite appears in the white quartz-feldspar porphyry in the north-central portion, and in the southern portion northeast and southwest of the grey biotite-quartz-feldspar porphyry. In the highly pyritic areas depicted in fig. 4, the pyrite content is estimated to be 1 to 5 volume per cent.

North of the northern highly pyritic area, dendritic coating of manganese dioxide (pyrolusite) are frequently observed on outcrop surfaces and joint planes. East of the pond, the porphyry is light grey and contains small (2 to 3 mm) clots of light green epidote (L.S.-56). To the west of

the pond (L.S.-57), the porphyry is a brilliant white and contains visible feldspar phenocrysts. Pyrite also occurs in this northern part but does not approach the concentration of that in the highly pyritic areas.

Very fine-grained porphyry, in which 0.5 to 1 mm diameter phenocrysts of quartz can be recognized, occurs in the contact area of the southern part of the complex. This variation is typical of specimens from the dyke areas northeast and southwest of the grey biotite-quartz-feldspar porphyry and core from drill-hole 4.

The inclusions, which range from one-tenth to one inch in diameter, are found in the highly pyritic white quartz-feldspar porphyry in the north and throughout the contact portions of white quartz-feldspar porphyry in the south part of the complex. Drill-hole 4 is reported to contain abundant inclusions within the porphyry intersection. Most of the inclusions can be visibly recognized as sedimentary rock fragments. In the northern pyritic area, quartz-veined, quartz-feldspar porphyry fragments occur within the white quartz-feldspar porphyry in the outcrops of specimens L.S.-50, -54, and -59. In outcrops of L.S.-50 and -59, the quartz veinlets in the fragments contain molybdenite. Similar occurrences are reported from drill-hole 4.

In the microscopic examination of thin-sections of white quartz-feldspar porphyry, it was found that all contain at least some signs of alteration. The most common alteration mineral was fine-grained, white mica of high birefringence, hereafter called "sericite". The thin-sections showing the least alteration are L.S.-42, -43, -47, -48, -49, and -57. Modal analyses (point count method) of these are given in Table II. The rocks in these thin-sections are similar; they contain 0.5 to 3.0 mm euhedral to subhedral phenocrysts of quartz, unzoned plagioclase (see Plate 5), potash feldspar that appears to be optically homogenous, and very minor amounts of medium to light brown biotite partially altered to chlorite. The matrix is very fine-grained (0.05 mm) potash feldspar and quartz. Minor amounts of sericite occur as scattered flakes throughout the matrix and in plagioclase phenocrysts. Apatite and zircon (0.1 mm) are present in very minor quantities.

Table II

Modal Analyses of White Quartz-Feldspar Porphyry
Volume %

Thin-section Number	Matrix	Albite	Potash Feldspar	Quartz	Biotite	Pyrite	Sericite
L.S.-57	82.5	7.57	4.75	5.93	X	X	X
L.S.-42	85.0	7.31	1.61	5.61	X	X	X
L.S.-48	83.0	7.70	.70	8.22	.35	X	X
L.S.-47	84.2	7.45	1.30	6.90	.15	X	X
L.S.-43	81.7	7.50	2.20	8.20	.40	X	X
L.S.-49	84.9	7.60	3.00	5.50	X	X	X
Average	83.50	7.52	2.26	6.72	.15	X	X

X = presence noted
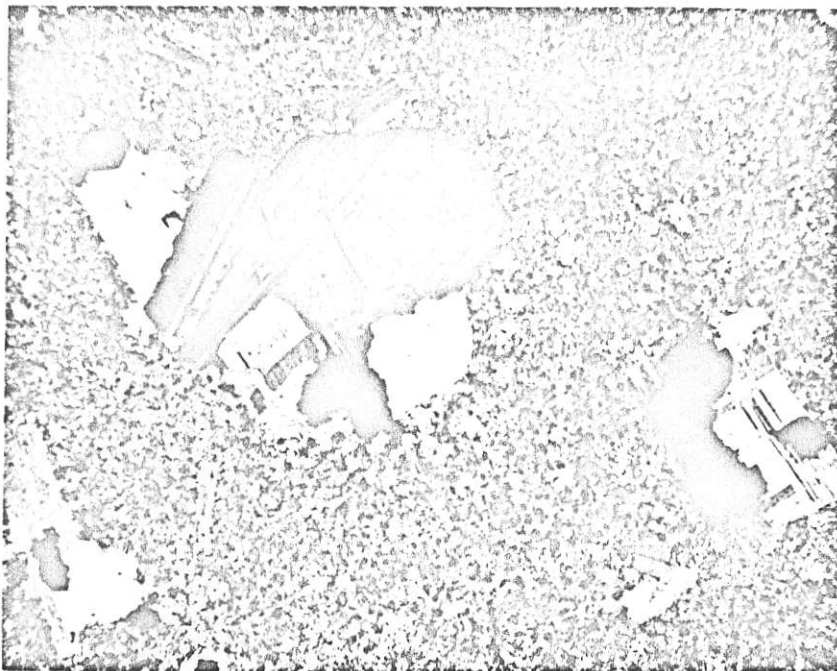
X 20, crossed nicols

Photomicrograph of unzoned albite phenocrysts
in white quartz-feldspar porphyry. Taken from
thin-section L.S.-49, outcrop.

Plate 5 - White quartz-feldspar porphyry.

The phenocrysts of quartz, unzoned plagioclase, and optically homogeneous potash feldspar are interpreted as primary minerals produced during the crystallization of the porphyry magma. This origin is indicated by their euhedral outline and porphyritic texture. Potash feldspar phenocrysts appear to be later in terms of the crystallization sequence of the phenocrysts as they are commonly observed partially surrounding quartz and plagioclase.

Unzoned plagioclase and optically homogeneous potash feldspars are generally found in all the thin-sections examined. Plagioclase in some cases has been obliterated by alteration. Universal stage techniques, using the Fedorow method outlined in Emmons (1943) were used to determine their optical properties with respect to their crystallographic elements. The results of this work follows.

(a) <u>Plagioclase feldspar</u>

The composition and the structural state of the plagioclase feldspars was derived through application of the optical properties to graphs given in Slemmons (1962). In brief, Slemmons method consists of measuring optic orientations in two adjacent individuals in a twinned plagioclase, the composition plane, and any crystallographic directions such as cleavages, or crystal faces. These are plotted on a lower hemisphere stereographic projection from which ang-

ular measurement can be derived and applied to migration
curves to determine the composition and the structural state
of the plagioclase feldspar. The migration curves for feld-
spars formed under plutonic conditions differ from those
formed under volcanic conditions. Thus, depending upon
which curve the plagioclase feldspar plots follow, an inter-
pretation of the crystallization conditions can be derived.
If the angles derived fall between the two curves, Slemmons
thinks that hypabyssal conditions likely prevailed. An ex-
ample universal stage determination of the angles considered
in this method, using an albite-twinned plagioclase pheno-
cryst, is illustrated in fig. 9 .

In this study, 5 separate plagioclase phenocrysts
were studied in the above manner. In each, adjacent twins
of the albite twin law were used. In all 5, the feldspar is
optically unzoned and the refractive index is slightly less
than that of Canada balsam ($n_{rel.} < 1.54$). The refractive
index alone suggests the composition to be $Ab_{75}An_{25}$. In all
5, the derived angles are similar (see Table III).
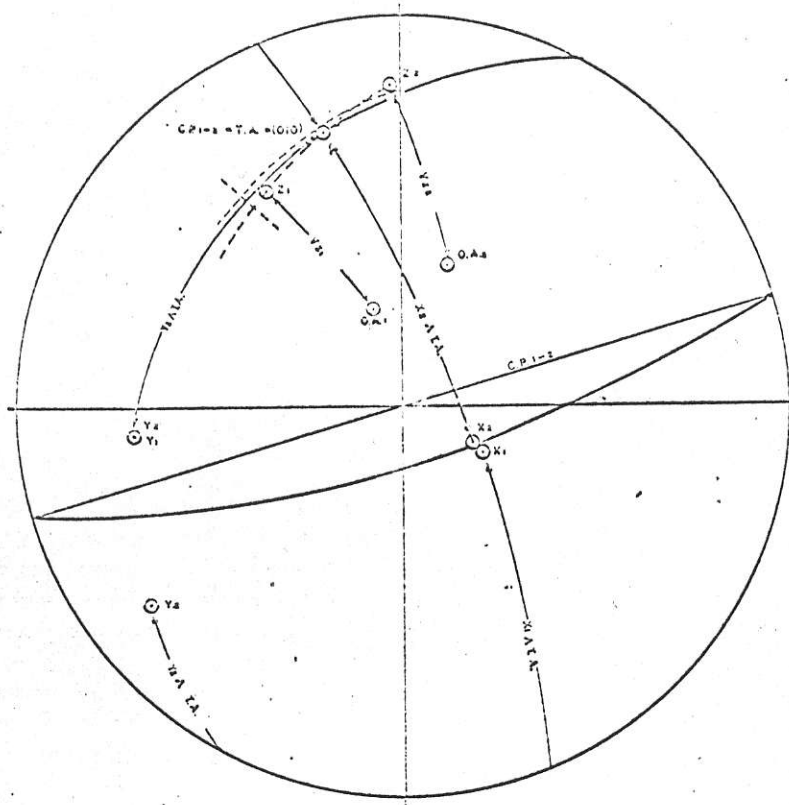
1,2 = two adjacent albite twin lamellae
C.P.= composition plane
T.A.= twin axis
O.A.= optic axis
X,Y,Z= optic directions

  - example from thin-section L.S.-21
    plotted on lower hemisphere stereographic
    projection.

Fig. 9 - Universal stage orientation and derivation
          of X∧TA and Y∧TA for two adjacent albite
          twin lamellae in plagioclase.

Table III

2V, X∧TA, and Y∧TA of Albite-twinned
Plagioclase in White Quartz-Feldspar Porphyry

Thin-section	$2V_z$	Y∧TA	X∧TA
M-5	79°	74°	89.5^o
L.S.-14	79°	74°	89°
L.S.-21	77°	74°	88°
L.S.-49	78°	74°	89.5^o
L.S.-57	81°	74°	88°

The application of the angles for X∧TA and Y∧TA to the migration curves for the albite twin law (see fig.10) indicates one of two plagioclase compositions derived under plutonic conditions: $Ab_{98}An_2$ or $Ab_{32}An_{68}$. However, the $2V_z$ values are positive, and range from 77° to 81°. Therefore, the composition is derived as being $Ab_{98-95}An_{2-5}$ (see fig. 11).

Thus, the unzoned plagioclases of the white quartz-feldspar porphyry are albite in composition and crystallized under plutonic conditions.

(b) <u>Potash Feldspar</u>

The 2V values and extinction angles on (010) (X'∧ (001) cleavage) were obtained from optically homogeneous potash feldspar phenocrysts in 4 separate thin-sections. The results are listed in Table IV. All except specimen L.-534 (baveno-twinned) are measurements of Manebach-twinned crystals.
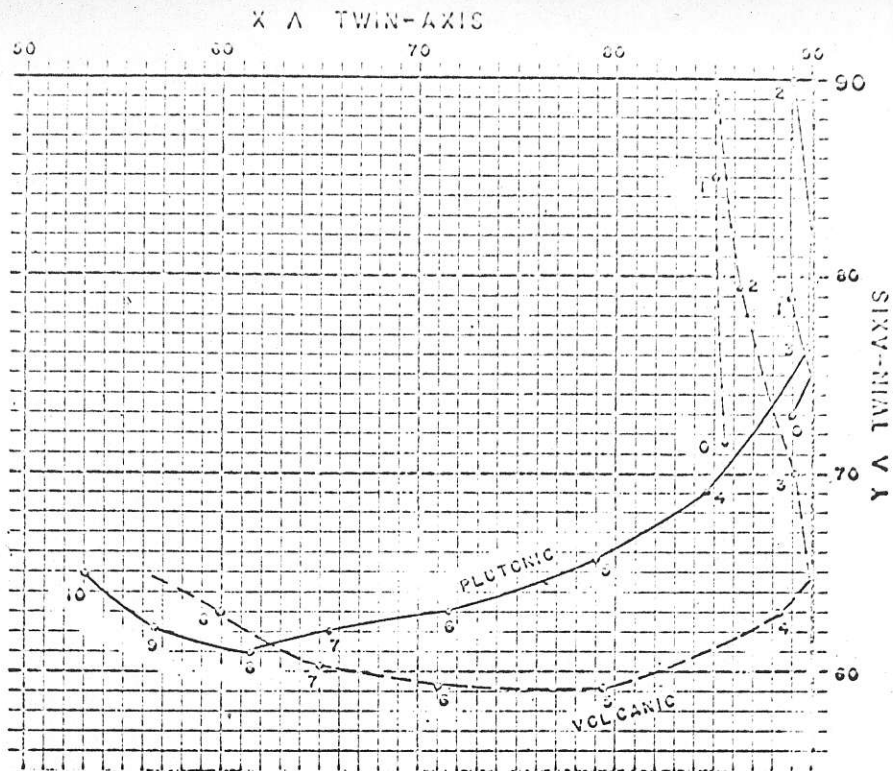
Fig. 10 - Twinning-axis Curves for the Albite Twin Law.
(after Slemmons, 1962)
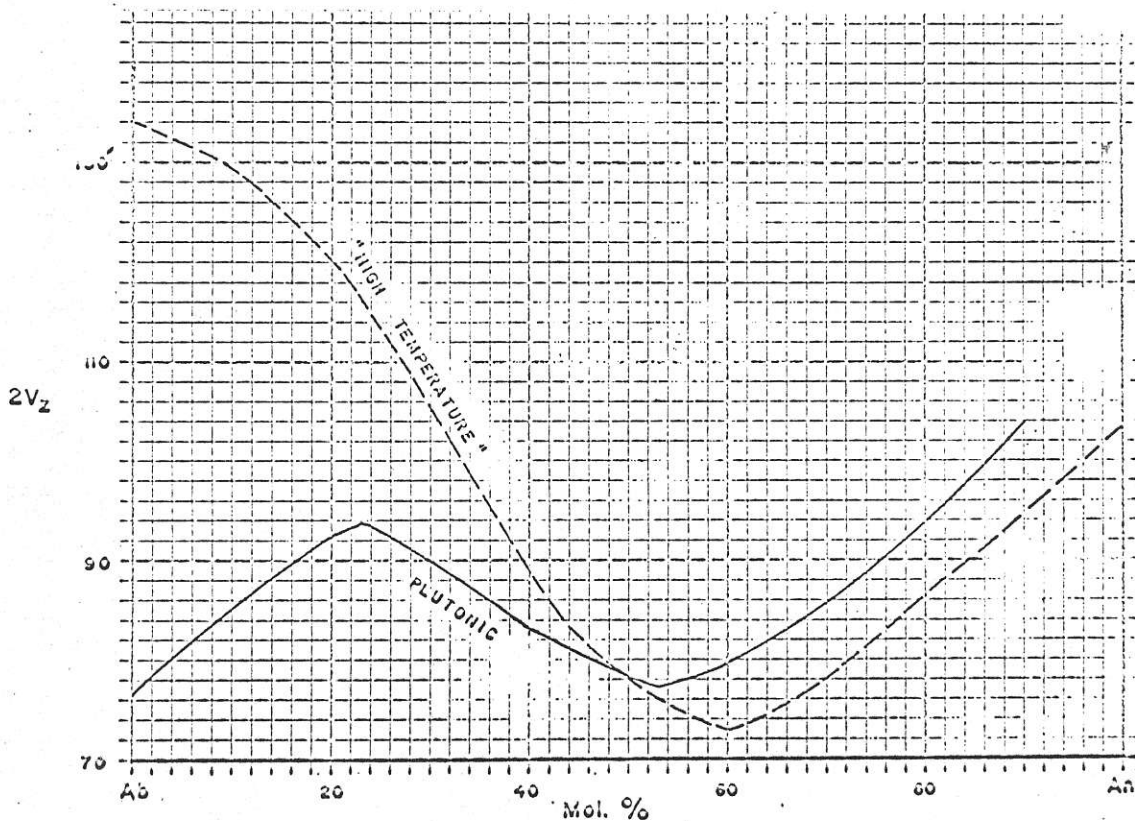
Fig. 11 - 2Vz Values for Plutonic and "High Temperature"
Plagioclases. (after Slemmons, 1962)

Table IV

2V Values and Extinction Angles on
(010) for Potash Feldspar Phenocrysts.

Thin-section	Location	(-)2V	Extinction on (010)
L.S.-43	see fig. 7	58°	5°
L.S.-57	"	58°	5°
L.S.-38	"	56°	6°
L.-534-B	drill-hole 4, 534 footage	61°	4°

The Baveno-twinned crystal of L-534-B is shown in
stereographic projection in fig. 12. The fact that the
pole to (010) coincides closely with Z is important as it
shows that the potash feldspar is orthoclase. In microcline,
Z makes an angle of 18° with the perpendicular to 010; in
anorthoclase, the angle is 5° (Deer, Howie and Zussman, 1963).
The writer therefore interprets the optically homogeneous
potash feldspar phenocrysts as being orthoclase, having a
(-)2V ranging from 56° to 61° and an extinction on (010) of
4° to 6°. This derivation is supported by the evident lack
of combined albite and pericline twinning, which is char-
acteristic of microcline.

In summation, the basic character of white, quartz-
feldspar porphyry resulting from the primary crystallization
of the responsible magma is: 0.5 to 3 mm phenocrysts of quartz,
unzoned plagioclase (Ab_{92-98} An_{8-2}), optically homogeneous
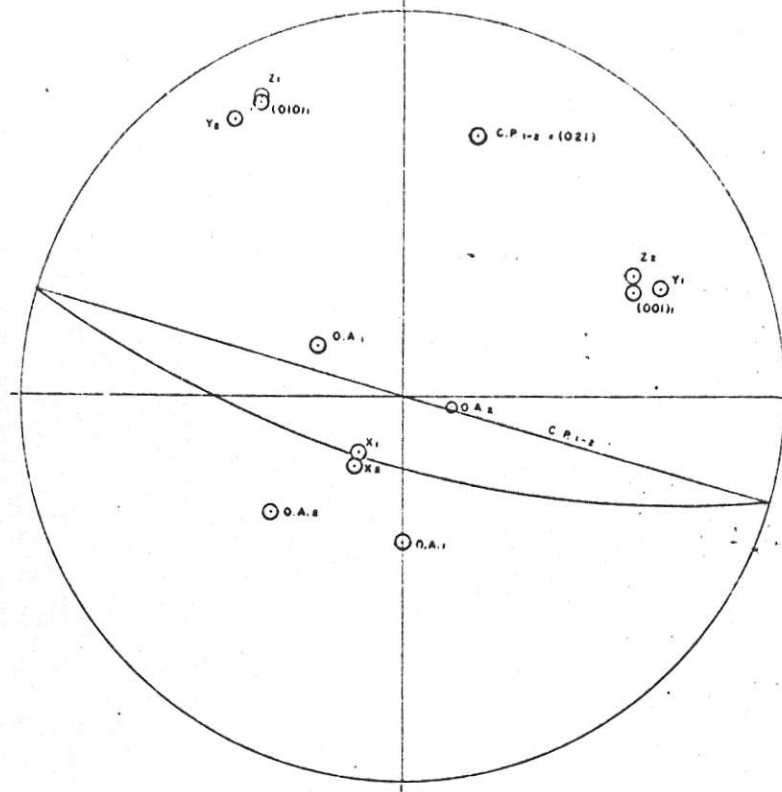
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    1,2 = two adjacent baveno twin lamellae.
    C.P. = composition plane.
    O.A. = optic axis.
  X,Y,Z = optic directions.

      - example from thin-section from drill-
        hole 4, footage 534, plotted on
        lower hemisphere stereographic projection.
```

Fig. 12 - Universal Stage Orientation of Baveno
         Twin, Potash Feldspar Phenocryst.

orthoclase, and erratically distributed pale brown biotite,
all set in a very fine-grained matrix of potash feldspar,
sericite, and quartz.

Under the microscope, thin-sections of the fine-
grained porphyry (L.S.-20, -21, -22), have minerals similar
to those present in the average white quartz-feldspar por-
phyry (thin-sections of Table II). The phenocrysts total
about 5 per cent of the volume of the rock and tend to blend
in with the matrix, thus giving a porcelaneous texture to
the rock.

Thin-section studies indicate that most, but not all,
of the inclusions are fragments of sedimentary country rock.
A few fragments of quartz-veined, quartz-feldspar porphyry
(see Plate 6), similar to the white quartz-feldspar porphyry
host, are present. The thin-sections containing this type
of fragment are from the north part of the complex (L.S.-50,
-54, -59) and a number of thin-sections of core from drill-
hole 4. In both localities, the quartz veinlets in the
fragments contain minor amounts of molybdenite. In drill-
hole 4, the fragments and the rock surrounding them are in
turn cut by quartz-molybdenite veinlets, indicating two
periods of mineralization.

One inclusion observed in a thin-section (see plate 7)
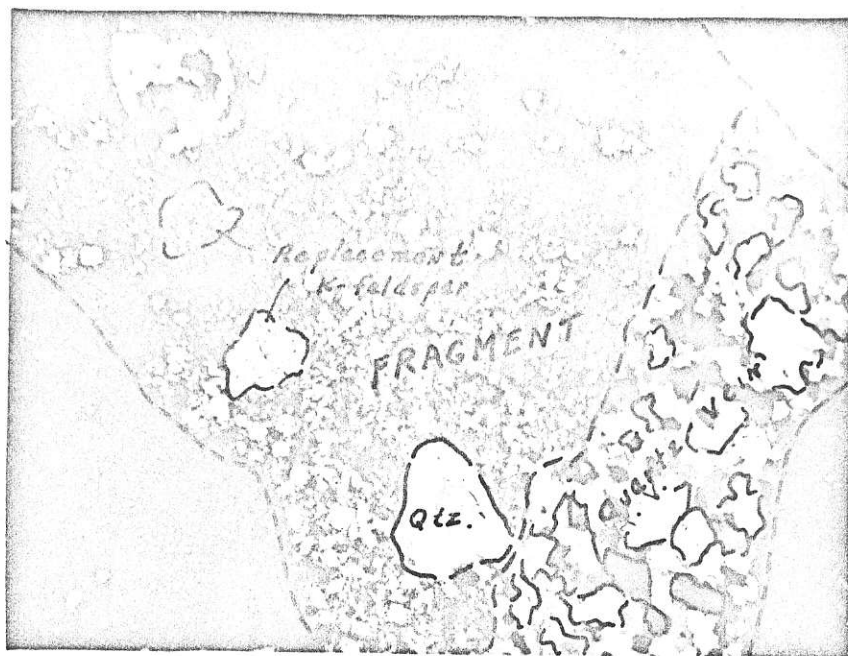
X 27, crossed nicols

Photomicrograph shows a quartz-veined frag-
ment of white quartz-feldspar porphyry surrounded
by very fine-grained white quartz-feldspar por-
phyry. The fragment (outlined by the dotted
orange line) occupies the center of the photo-
graph. The quartz vein occurs on the right
side of the fragment.

Plate 6 - Quartz-veined fragment of white quartz-
feldspar porphyry included in a groundmass
of very fine-grained white quartz-feldspar
porphyry.

Replacement
K-feldspar

Quartz

INCLUSION

Pyrite

plagioclase

Altered white
quartz- feldspar
porphyry
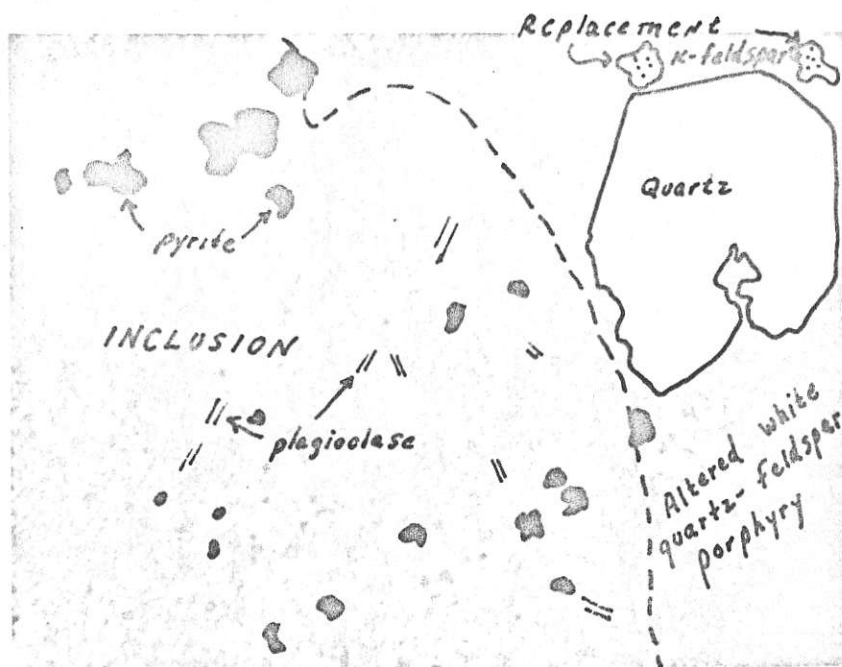
X 30, crossed nicols

Photomicrograph of possible inclusions (middle
and left side of photo) of dark green aphanitic
dyke rock in white quartz-feldspar porphyry
(right side of photo). Plagioclase occurs as
white laths, chlorite (after biotite?) as dark
grey grains, pyrite as black grains. The tex-
ture and mineralogy bears a very close resembl-
ance to the dyke unit (compare with plate 4).
Taken from drill-core, hole 4, footage 652.

Plate 7 - Possible inclusion of dark green aphanitic
dyke rock in breccia portion of white
quartz-feldspar porphyry.

from drill-hole 4, footage 652, resembles the dark green
aphanitic dyke rock in that it contains similar albite-
twinned plagioclases, abundant chlorite (after biotite?) and
fine-grained pyrite. This observation implies that the dark
green aphanitic dykes were emplaced prior to the white
quartz-feldspar porphyry.

Thin-sections from core in drill-hole 4 where there
is a high number of inclusions (approximately 20 to 40 per
cent by volume), show cataclastic features in which the
phenocrysts have been broken into angular fragments (see
plate 8).

Portions of the white quartz-feldspar porphyry are
intensely altered. The alteration types recognized are:
intense sericitization, feldspathization, epidote-calcite
replacement of plagioclase, the development of clay minerals
in intensely quartz-veined areas, and pyritization. A more
detailed description is included in the section on alteration.

(v) Alaskite Dykes

Surface exposures of this rock type occur as north-
west to northeast trending dykes, 1 to 4 feet thick, cutting
the argillite-greywacke sequence on the southeast edge of
the complex. Similar dykes were seen in core from drill-
holes 1, 3, and 4, all within sedimentary rock.

The alaskite is light green to cream in color with
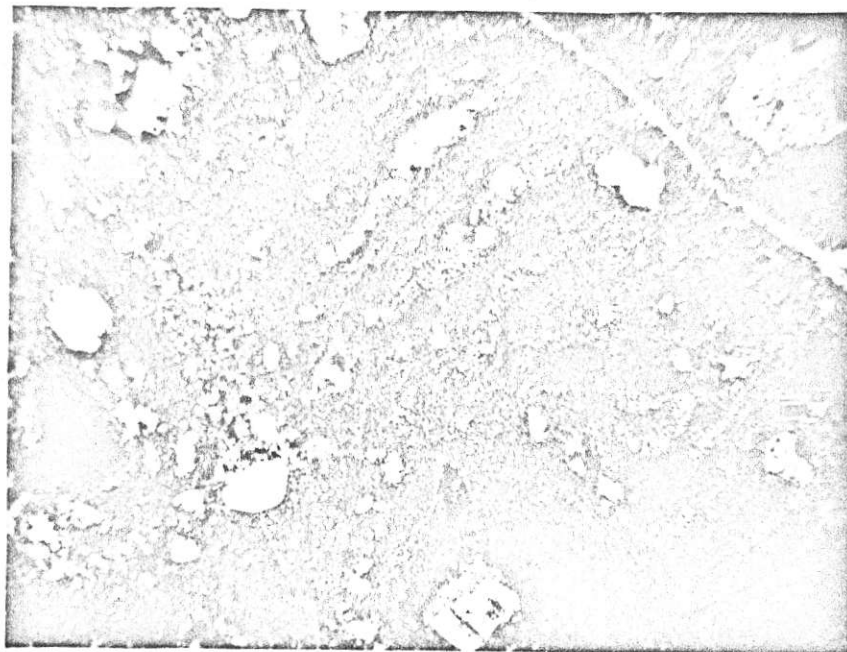
X 27, crossed nicols

Photomicrograph of white quartz-feldspar porphyry showing granulation and flow structures. Taken from thin-section of drill-core, hole 4, footage 652.

Plate 8 - Cataclastic structure in white quartz-feldspar porphyry.

a granitic appearance in hand specimen. The feldspar and quartz grains average 2 to 4 mm in diameter. The dykes are highly fractured and cut by narrow quartz veinlets, both barren and mineralized with pyrite and fine-grained molybdenite.

Thin-sections show that this rock actually has a porphyritic texture (see plate 9). The phenocrysts present are quartz and unzoned plagioclase feldspar that has been extensively replaced by potash feldspar and to a lesser extent by sericite. The matrix is a very fine-grained (0.1 mm and less) aggregate of quartz, potash feldspar, and minor sericite. The phenocrysts are estimated as being 80% of the volume of the rock.

The very ragged outline of the potash feldspar-rimmed plagioclase crystals makes it difficult to determine if this is a true porphyry. It is possible that the porphyritic texture may be a result of either protoclasis or cataclasis.

A single measurement of an albite-twinned plagioclase phenocryst by universal stage methods gave $(+)2V=78^{\circ}$, $X \wedge TA = 90^{\circ}$, $Y \wedge TA = 73^{\circ}$. According to Slemmons graphs (figures 10, 11), the composition is in the vicinity of $Ab_{98}An_{2}$. The similarity to the plagioclase composition in the white quartz-feldspar porphyry suggests the two rock types are related.
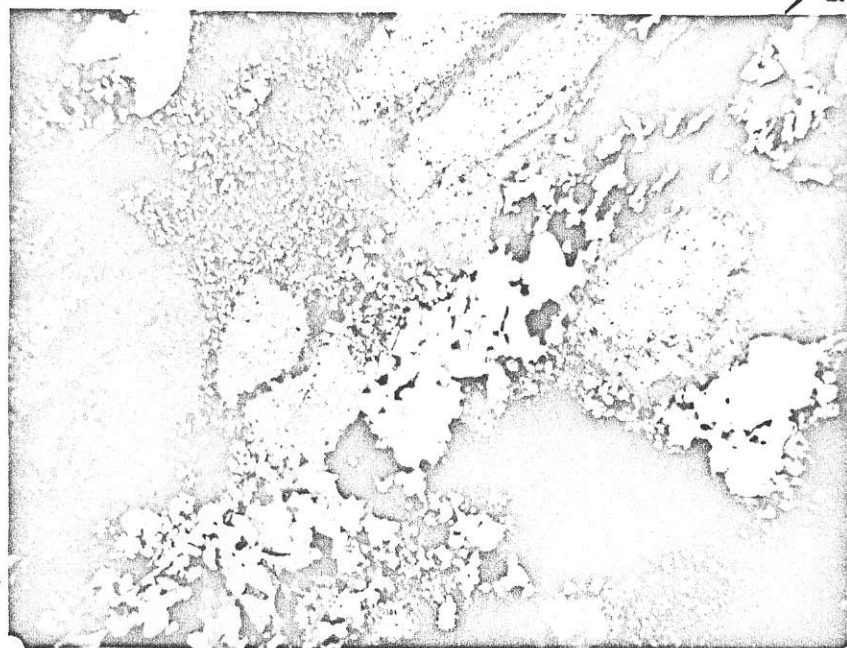
Quartz veinlet.

X 20, crossed nicols

Photomicrograph of the alaskite showing
extensive replacement of plagioclase (white)
by potash feldspar (grey). Quartz-molyb-
denite veinlet cuts section from top right
corner to lower left corner. Taken from
thin-section L.S.-31, outcrop.

Plate 9- Alaskite dyke unit.

Chemical Analyses and Classification of the Igneous

Rock Units of the Complex

Chemical analyses of the igneous rock units of the complex are given in Table V. In the case of the alaskite dyke rock unit, only K_2O, CaO, and Na_2O analyses are given. Comparative analyses from Nockolds (1954) are given in Table VI. The locations of the analysed samples are shown in fig. 7. Thin-sections were cut from all specimens which were chemically analyzed. On the basis of these studies, the following conclusions may be stated.

(i) Pink quartz porphyry

The pink quartz porphyry (analysis 1 in Table V) is relatively rich in K_2O and poor in Na_2O and CaO. No minerals or textural features indicating potash metasomatism processes were observed in thin-sections of this rock type. Therefore, the analysis is interpreted as giving the primary composition of this rock unit. No comparative analyses having as high K_2O and low Na_2O and CaO content are listed by Nockolds (1954). The closest comparative analyses is alkalic granite. Thus, a suitable classification term for pink quartz porphyry is a very high potash granite.

(ii) Grey biotite-quartz-feldspar porphyry

The two analyses of grey biotite-quartz-feldspar porphyry correspond closely to those of muscovite-biotite-adamellite listed in Nockolds' tables. Adamellite is more

Table V

Chemical Analyses of Igneous Rock Types

Analysis No. (Thin-section)	SiO₂	TiO₂	Al₂O₃	Fe₂O₃	MnO	CaO	Na₂O	K₂O	MgO	H₂O	P₂O₅	CO₂	Total
1. (L.S.-53)	74.60	n.d.	13.00	1.24	n.d.	0.14	0.16	10.20	n.d.	0.59	0.06	n.d.	99.99
2. (H-339)	73.50	0.24	14.20	1.60	n.d.	1.48	2.16	4.92	1.20	1.04	0.06	n.d.	100.40
3. (M-146)	74.80	0.20	14.50	0.60	n.d.	1.20	2.77	4.08	1.45	0.62	0.08	n.d.	100.30
4. (H-14)	48.35	1.19	18.60	9.70	0.22	2.65	2.51	7.29	6.72	1.27	0.43	0.08	99.06
5. (L.S.-57)	74.20	0.10	13.65	1.00	0.05	0.20	2.05	6.45	1.06	0.83	0.11	n.d.	99.75
6. (L.S.-47)	74.40	0.10	14.05	0.95	n.d.	0.25	2.42	5.02	1.00	0.65	0.07	n.d.	98.91
7. (L.S.-49)	74.40	0.09	14.00	1.16	n.d.	0.36	1.75	5.40	1.00	0.48	0.10	n.d.	98.74
8. (H-1165)	73.70	0.10	13.65	1.40	n.d.	1.25	2.65	4.80	1.30	0.77	0.10	0.74	100.46
9. (M-5)	76.00	0.06	13.65	n.d.	n.d.	0.12	2.45	5.60	0.95	0.55	0.08	n.d.	99.46
10. (L.S.-38)	76.65	0.02	11.80	0.02	n.d.	Tr.	0.50	8.22	0.60	0.47	0.07	n.d.	98.35
11. (T-14)	74.00	0.01	13.20	n.d.	n.d.	n.d.	0.56	9.83	0.85	0.55	0.11	n.d.	99.11
12. (L.S.-31)	------Partial analysis--------------					0.30	3.08	5.38	--------------------------				
13. (L.S.-31)	------Partial analysis--------------					0.35	4.70	5.88	--------------------------				

n.d. = not detected

Tr. = trace

Fe₂O₃ = total iron as Fe₂O₃

- Na₂O by flame photometer
- P₂O₅ by colorimetric method
- CO₂ by acid treatment
- remaining oxides by X-ray fluorescence, K. Ramlal, analyst, University of Manitoba.

Analysis No.	Rock Types
1. =	pink quartz porphyry, from outcrop.
2. =	grey biotite-quartz porphyry, from drill-hole 1, footage 339
3. =	grey biotite-quartz-feldspar porphyry, from dyke, south end of complex.
4. =	dark green aphanitic dyke, from drill-hole 1, footage 14.
5,6,7, =	least altered white quartz-feldspar porphyry, from outcrops.
8. =	altered white quartz-feldspar porphyry, cut by quartz-calcite veinlets, contains approximately 1.5% biotite/chlorite. From drill-hole 1, footage 1165.
9. =	altered white quartz-feldspar porphyry, moderate replacement potash feldspar, from outcrop.
10,11. =	altered white quartz-feldspar porphyry, intense replacement potash feldspar, from outcrop.
12,13. =	alaskite dykes, from outcrop.

Table VI

Comparative Analyses From Nockolds (1954)

	Muscovite-biotite Adamellite	Average Alkali Granite
SiO₂	71.86	73.86
TiO₂	00.30	0.20
Al₂O₃	14.73	13.75
Fe₂O₃	0.64	0.78
FeO	1.61	1.13
MnO	0.04	0.05
MgO	0.67	0.26
CaO	1.51	0.72
Na₂O	3.18	3.51
K₂O	4.64	5.13
H₂O	0.66	0.47
P₂O₅	0.16	0.14

commonly known as quartz monzonite.

(iii) Dark green, aphanitic dykes

The analysis of the dark green, aphanitic dyke unit
is characterized by high K_2O, Na_2O, MgO, and Fe_2O_3 content.
According to Turner and Verhoogen (1951) rocks having this
chemical aspect are in general typical of lamprophyres:

> "Chemically the lamprophyres are basic to
> ultrabasic rocks with a high content of both
> (FeO + MgO) and (Na_2O + K_2O), expressed min-
> eralogically by abundance of biotite and
> barkevikitic hornblende."

(iv) White quartz-feldspar porphyry

Six analyses of white quartz-feldspar porphyry were
completed. The thin-sections of the rocks corresponding to
analyses 5, 6, and 7 contain only scant sericite as a definite
alteration mineral. A thin-section of the rock corresponding
to analysis 9 shows scant amounts of potash feldspar as a
replacement of the plagioclase phenocrysts, but this analysis
is not markedly different from analyses 5, 6, and 7. There-
fore, analyses 5, 6, 7, and 9 are considered to be closely
representative of the primary composition of this rock type.
The analyses of samples 5, 6, 7, and 9 are in close corres-
pondence to the average alkali granite listed in Nockold's
tables but have somewhat lower CaO and Na_2O contents.

Analysis 8 is white quartz-feldspar porphyry which is
cut by quartz veinlets and contains approximately 1.5 per
cent biotite. In thin-section, it was found that the calcite

is associated with the quartz veins, thus accounting for the relatively high CaO content. A correction for calcite using the 0.74 per cent CO_2 present in the analysis suggests the original CaO content may be in the order of 0.3 per cent.

The thin-sections of rocks corresponding to analyses 10 and 11 show that the plagioclase phenocrysts have been replaced almost entirely by potash feldspar. In comparison with analyses 5, 6, 7 and 9, the analyses of 10 and 11 are relatively richer in K_2O and poorer in Na_2O and CaO. It is believed that the increase in K_2O is due to hydrothermal alteration processes.

(v) <u>Alaskite dykes</u>

Only partial analyses of this rock type have been obtained (analyses 12, 13). However, the K_2O, Na_2O and CaO content of this rock unit classifies it as an alkali granite. The analyses may not be truly representative of the primary composition as corresponding thin-sections show extensive replacement of plagioclase by potash feldspar. The replacement processes are believed to be hydrothermal in view of the highly quartz-veined aspect of this rock.

A triangular diagram of the weight percentages of K_2O, Na_2O, and CaO of the analyses of the igneous rock units of the complex is shown in fig. 13. C.I.P.W. normative minerals are listed in Table VII.

In summation, chemical analyses classify the five
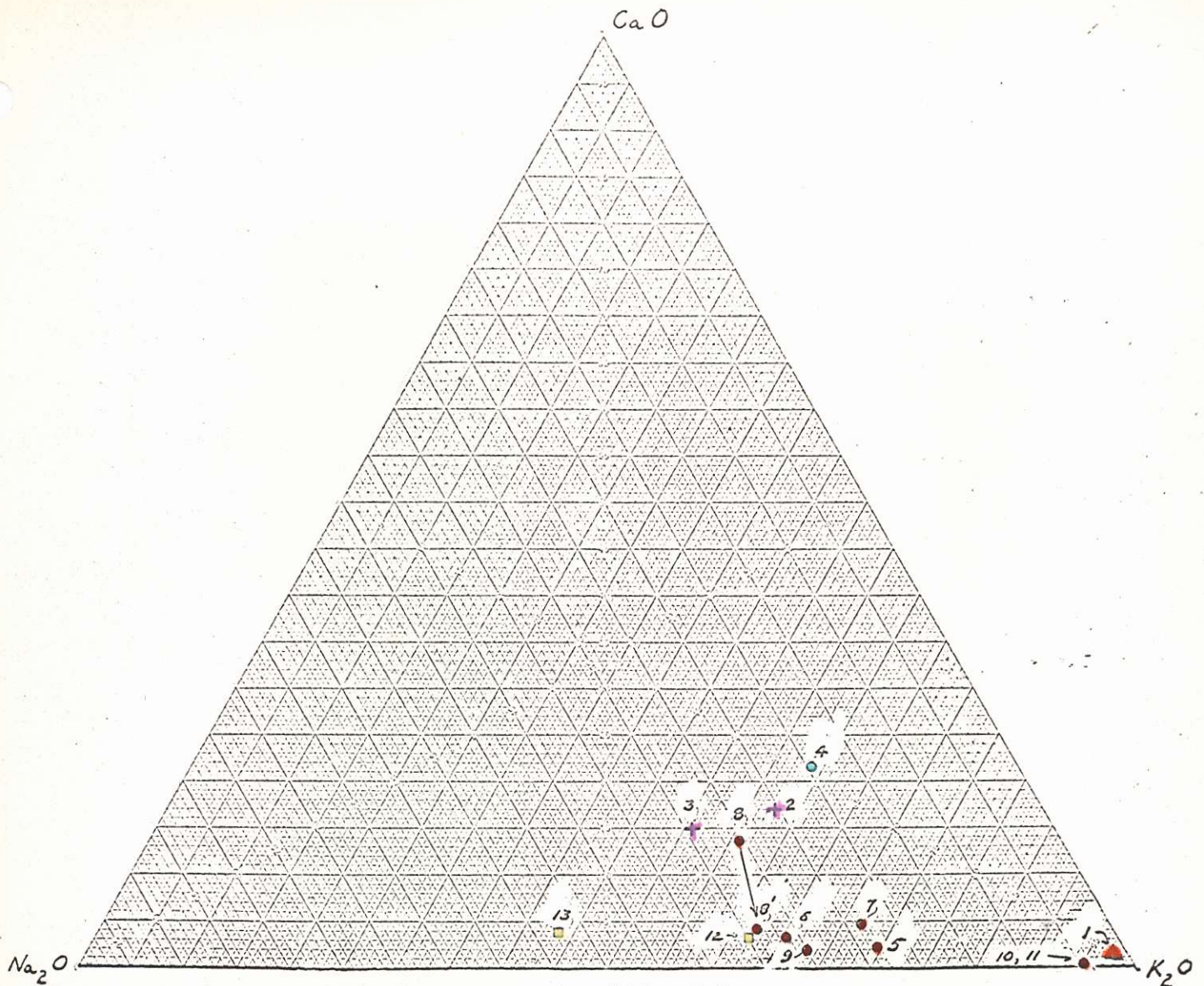
= dark green aphanitic dyke
= grey biotite-quartz feldspar porphyry
= white quartz-feldspar porphyry
= alaskite dykes
= pink quartz porphyry

Note: numbers correspond to analyses in Table V.
The plot of 8' corresponds to analysis 8
after correcting for CaO and CO_2 in calcite.

Fig. 13 - Triangular diagram of the weight % of K_2O, Na_2O,
and CaO from analyses of Table V.

Table VII

C.I.P.W. Normative Minerals of the Four Porphyry Rock Units

Norm in Weight %

Analysis Number	Quartz	Orthoclase	Albite	Anorthite	Apatite	Calcite	Corundum
1.	64.85	30.00	1.85	.57	.03	--	1.45
2.	39.02	29.03	18.23	7.22	.03	--	2.66
3.	40.53	24.12	23.42	5.73	.11	--	2.93
5.	37.23	38.14	17.29	.77	.15	--	2.99
6.	40.67	29.63	20.43	1.08	.09	--	4.23
7.	42.80	31.91	14.77	1.53	.14	--	4.66
8.	33.40	26.70	22.71	1.22	.14	1.68	3.64
9.	40.15	33.07	20.89	.54	.11	--	3.42
10.	45.20	47.90	4.00	--	--	--	2.11
11.	33.13	58.11	4.71	--	--	--	1.62
12.	--	30.93	25.45	1.47	--	--	--
13.	--	34.76	39.67	1.72	--	--	--

note:

   Normative minerals are calculated according to C.I.P.W.
rules, with the exception that instead of allotting one-
half of CaO to form wollastonite, all CaO is used to form
anorthite after allowing for calcite and apatite. This
is in keeping with the observed mineralogy of the rock units.
Ilmenite, magnetite, hematite, enstatite, and ferrosilite
have been deleted from the norm calculations.

rock units of the complex as:

    (i)   Very potash-rich granite = pink quartz porphyry.

   (ii)   Biotite-muscovite adamellite (or quartz monzon-
          ite) = grey biotite-quartz-feldspar porphyry.

  (iii)   Lamprophyre = dark green aphanitic dykes.

   (iv)   Alkali granite = white quartz-feldspar porphyry.

    (v)   Alkali granite = alaskite dykes.

The significance of the differences in mineralogy
and chemical composition of the rock units with regard to
the environment and history of the complex is discussed in
the final chapter on interpretations and conclusions.

CHAPTER IV - MOLYBDENITE MINERALIZATION AND
HYDROTHERMAL ALTERATION

Molybdenite Mineralization

All the observed molybdenite mineralization on the
Lucky Ship property occurs as very fine-grained (0.5 mm and
less) flakes in quartz veinlets. Sparse quantities of pyrite
are associated with the molybdenite. Chalcopyrite was noted
in drill-core, but only in trace amounts. Calcite occurs
in varying quantities in both mineralized and barren quartz
veinlets. The thickness of individual veinlets vary from
"hair-line" to 6 inches and average one-quarter inch in
thickness. Several periods of mineralized and barren quartz
vein emplacement are indicated by cross-cutting relationships.
The number and apparent randomness of the veinlets classifies
the mineralization as a stockwork type of deposit.

The known distribution of molybdenite mineralization
in outcrops and diamond drill-holes is shown in figures 4
and 6. Except for the pink quartz porphyry, mineralization
has been found in every rock type of the igneous complex and
the immediately surrounding sedimentary rocks. The greatest
known intensity of both mineralized and non-mineralized
quartz veinlets occurs in the southeastern part of the complex.
The best molybdenite mineralization observed in outcrop
occurs in the alaskite dykes south of the south tie-line/63

and in the white quartz-feldspar porphyry north of the base line/63.

The outcrops of grey biotite-quartz-feldspar porphyry have many quartz veins, but the molybdenite is scarce.

Scattered minor occurrences of molybdenite are present in outcrops in the central and northern part of the white quartz-feldspar porphyry. In these outcrops, the molybdenite occurs in quartz-veined angular fragments of white quartz-feldspar porphyry included in the white quartz-feldspar porphyry. Similar mineralization occurs in drill-hole 4.

Very scant molybdenite in minor quartz veinlets was observed in a single outcrop of white quartz-feldspar porphyry approximately 800 feet south-southeast of the pond.

The distribution of molybdenite mineralization encountered in diamond drilling is shown graphically by plotting the number of mineralized veinlets per 10 feet of core length (see fig. 6). Generally, the number of mineralized veinlets bears a direct relationship to the MoS_2 assays. Drill core indicates that the best mineralization occurs in the white-quartz feldspar porphyry and alaskite dyke intersections. The grey biotite-quartz feldspar porphyry is relatively poor in MoS_2 (assays of 0.05 and lower).

From a general view, based on observed mineralization in outcrop (see fig.4), it appears that molybdenite mineralization is arranged concentrically about the grey biotite-

quartz-feldspar porphyry. This suggests a genetic relation-
ship of the mineralization to this rock type. The more
detailed picture obtained from drill-core shows that the
mineralization is more closely related to the marginal portions
of the white quartz-feldspar porphyry. The upper intersection
of drill-hole 2 contained very little mineralization; a result
which may be explained by the absence of white quartz-feld-
spar porphyry. Therefore, the apparent concentric distrib-
ution of mineralization about the grey biotite-quartz-feldspar
porphyry as derived from observed outcrop mineralization does
not hold true, in terms of relative abundance of molybdenite,
in the drill-core from hole 2.

Alaskite dykes contain relatively abundant mineral-
ization. This is particularly evident in drill-hole one.
The dyke intersected in the upper part of the hole contains
up to 50 mineralized veinlets per 10 feet of core, whereas
the immediately surrounding sediments contain less than 20
veinlets per 10 feet of core.

The distribution of barren quartz veining in the
drill-holes is also shown in fig. 6. The drill-core indicates
that the fracturing and veining is in zones. The marginal
portions of the white quartz-feldspar porphyry and the grey
biotite-quartz-feldspar porphyry contain the highest number
of barren veins. Therefore, the generalized picture obtained
from outcrops, that the entire body of grey biotite-quartz-

feldspar porphyry is uniformly cut by numerous barren quartz
veins, is incorrect.

Hydrothermal Alteration

White quartz-feldspar porphyry, grey biotite-quartz-
feldspar porphyry, and alaskite dykes are hydrothermally
altered. In the dark green aphanitic dykes, the alteration
appears to be mainly chloritic alteration of biotite in prox-
imity with quartz-carbonate veinlets. In the pink quartz
porphyry, it is difficult to determine if significant alter-
ation has taken place because of its extremely fine-grained
texture. The sedimentary rocks have been intensely seric-
itized where in contact with the white quartz-feldspar por-
phyry and the alaskite dykes.

In the white quartz-feldspar porphyry, grey biotite-
quartz-feldspar porphyry, and alaskite rocks, the alteration
minerals present are typical of hydrothermal alteration
(Schwartz, 1955). The principal alteration types recognized
are sericitization, potash feldspathization, argillization,
and saussuritization. Intense pyritization appears to be
restricted to the portions of the white quartz-feldspar porphyry
containing inclusions and the sedimentary rocks in contact
with the igneous rocks of the complex. A description of
the alteration types, with reference to thin-sections from
outcrops (fig. 7) and drill core follows.

(i) Sericitization

Sericite occurs as very fine-grained flakes disseminated throughout the matrix and the plagioclase phenocrysts of the porphyries, and as seamlets adjacent to fractures and quartz veinlets. Thin-section studies indicate the least sericitized rock is the central part of the white quartz-feldspar porphyry (thin-sections L.S.-41, -42, -47, and -48), and the central part of the grey biotite-quartz-feldspar porphyry intersected by drill-holes 1 and 2 (see fig. 6).

The greatest quantities of sericite observed occur in the inclusion-rich portions (see fig. 4) of the white quartz-feldspar porphyry, and in the drill-core of the porphyries cut by abundant barren and mineralized quartz veinlets (see fig. 6).

(ii) Potash Feldspathization

Potash feldspar which has developed as an alteration mineral is apparent only in thin-sections. Furthermore, its development appears to be restricted to white quartz-feldspar porphyry and the alaskite dykes in the southern part of the complex. All the thin-sections of these two rock types from south of the North Tie Line/63 (see fig. 7) show some potash feldspars developed as an alteration mineral.

In thin-sections, the potash feldspar appears in two forms:

(a) As discrete crystals with anhedral though somewhat rounded outlines which include portions of the matrix
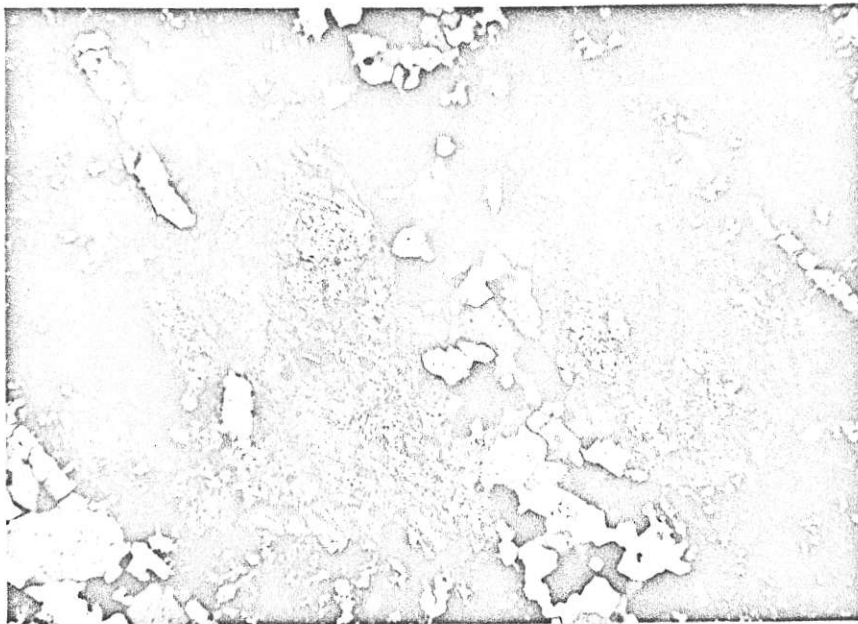
(b) As a replacement of plagioclase phenocrysts (see plates 10 and 11). The degree of replacement is variable even within a single thin-section. The highest intensity observed occurs in thin-sections L.S.-38 and T-14 where the replacement of plagioclase by potash feldspar appears as replacement microperthite (see plate 11). Chemical analyses of specimens corresponding to these two thin-sections indicate a very marked increase in K_2O and a decrease in Na_2O and CaO (see analyses 10, 11, Table V).

The absence of "grid" twinning, characteristic of microcline, suggests that the potash feldspar is orthoclase.

(iii) Argillization

Argillization also appears to be restricted to the south part of the complex. It is related to both barren and mineralized quartz-veinlets. This spatial relationship to quartz-veining is best observed in drill-holes 1 and 2. The amount of clay minerals increases towards zones of high quartz-veining in the grey biotite-quartz-feldspar and possibly in veined sections of the white quartz-feldspar porphyry. Its megascopic recognition is by the characteristic "clay" odor and the occurrence of soft, green pseudomorphs after the plagioclase phenocrysts.

In the white quartz-feldspar porphyry, the pseudomorphs are a light green color. Approximately 10 of these pseudomorphs were picked out with a needle and formed into a rolling for the X-ray powder camera. After accounting for

X 70, crossed nicols

Photomicrograph of plagioclase (white) phenocrysts indicating extensive replacement by orthoclase (grey). Albite twinning in the plagioclase is shown by alternating light grey and white bands running from top left corner to lower right corner. Taken from thin-section L.S.-38, outcrop.

Plate 10 - Potash feldspar replacement of plagioclase.

X 70, crossed nicols

Photomicrograph of plagioclase (white) showing very extensive replacement by orthoclase (grey) to produce a replacement microperthite. Taken from thin-section L.S.-38, outcrop.

Plate 11 - Potash feldspar replacement of plagioclase.

the d-spacings due to albite, the remaining d-spacings and their intensities match either muscovite, illite, or hydromica (see appendix, page 84, specimen from drill-core, footage 884).

In thin-sections, the pseudomorphs appear as an aggregate of 0.1 to 0.2 mm colorless micaceous flakes replacing the plagioclase. Similar flakes border quartz veinlets (see plate 12). Their maximum interference color is first order grey, the index of refraction slightly greater than quartz. Because the flakes lack the strong birefringence generally characteristic of sericite (that is, fine-grained muscovite or paragonite), it is believed that they are illite or hydromuscovite.

In the grey biotite-quartz-feldspar porphyry, the pseudomorphs are a dark olive green. In thin-section (see plate 13), under plane polarized light, they appear as a very light green aggregate of fine-grained (< 0.05 mm), ill-defined flakes. The flakes have maximum interference colors of first order grey to yellow.

The d-spacings and relative intensities obtained from a single x-ray powder picture from these pseudomorphs are given in the appendix on page 85 (specimen from drill-hole 1, footage 671). Approximately 5 altered phenocrysts were picked
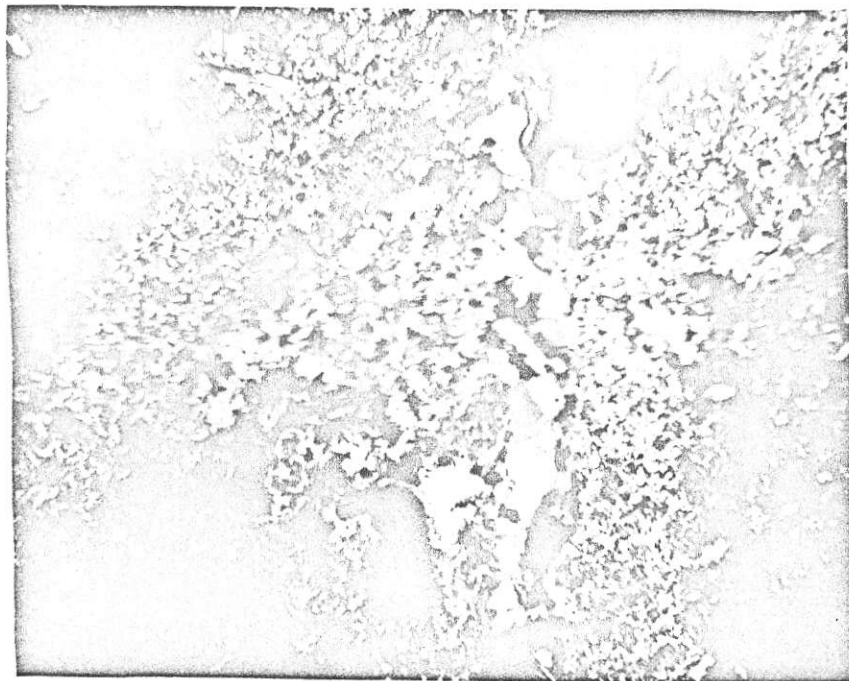
X 30, crossed nicols

Photomicrograph of illite (?) or hydro-
muscovite (?) (white flakes) bordering quartz
veinlets in white quartz-feldspar porphyry.
Taken from thin-section of drill-core, hole 1,
footage 884.

Plate 12 - Argillization of white quartz-feldspar
porphyry.
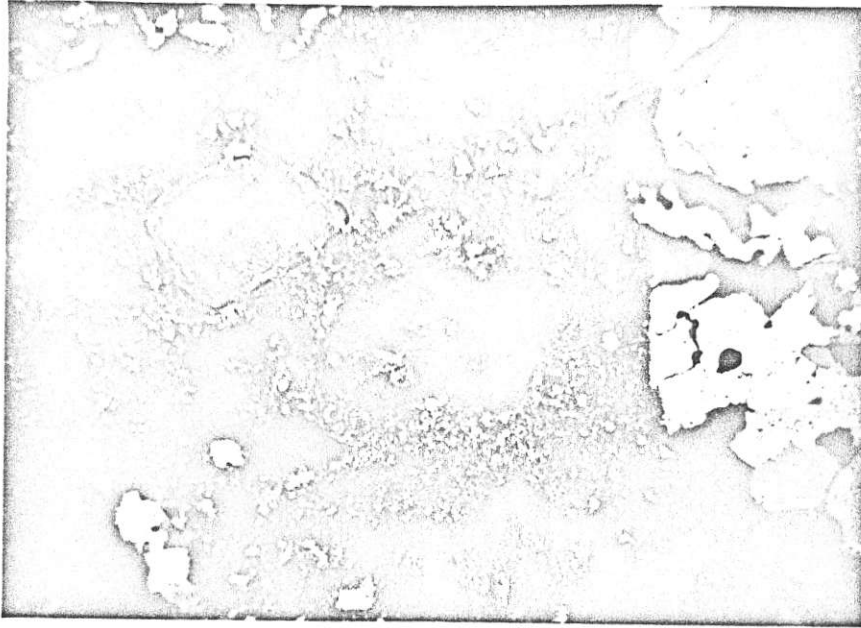
X 30, crossed nicols

Photomicrograph of montmorillonite-hydromuscovite-
kaolinite pseudomorphs after plagioclase. From thin-
section of drill-core, hole 1, footage 671.

Plate 13 - Argillization of plagioclase phenocrysts in grey
biotite-quartz-feldspar porphyry.

, out with a needle and formed into a rolling for the x-ray
powder camera. The pattern obtained indicates a combination
of montmorillonite, hydromuscovite, and kaolinite. Montmor-
illonite appears to be the most abundant.

(iv) <u>Saussuritization</u>

Intense saussuritization of the plagioclase pheno-
crysts in the^white quartz-feldspar porphyry occurs in the north
part of the complex, east of the small pond (about specimen
L.S.-56). In thin-section (see plate 14), this type of alt-
eration is observed as pseudomorphs of epidote, calcite, and
sericite after plagioclase. The presence of epidote is con-
firmed by an x-ray powder pattern (see appendix page 86).
The distribution and significance of this type of alteration
is not known completely. It does not appear in the white
quartz-feldspar porphyry south of the pond. Incipient sauss-
uritization does occur in the grey biotite quartz-feldspar
porphyry in the center of the plagioclase phenocrysts. The
alteration in this rock type may be due to deuteric processes,
not hydrothermal effects.

(v) <u>Pyritization</u>

Intense pyritization occurs in the sedimentary rocks
immediately adjacent to the contacts with the white quartz-
feldspar porphyry and the alaskite dykes, and in parts of the
white quartz-feldspar porphyry containing inclusions. In the
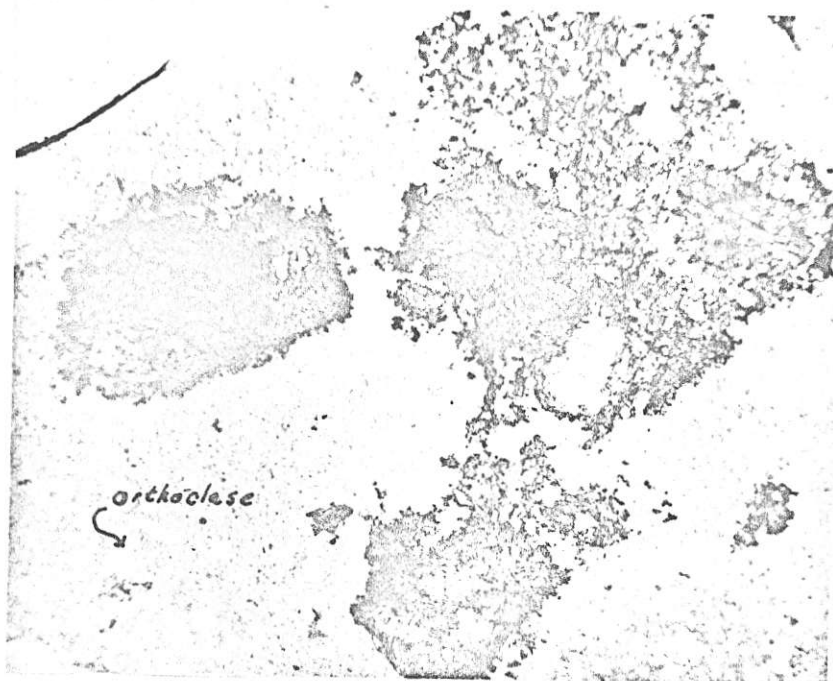
orthoclase

X 20, uncrossed nicols

Photomicrograph of epidote-calcite-sericite
pseudomorphs from the alteration of plagioclase
phenocrysts. An orthoclase phenocryst is in the
lower left corner. Taken from thin-section
L.S.-56, outcrop.

Plate 14 - Saussuritization of plagioclase phenocrysts
in white quartz-feldspar porphyry.

sedimentary rocks, the pyrite occurs as disseminated crystals
and as one-eighth to one-quarter inch seams along fractures.
The pyrite in the white quartz-feldspar porphyry appears to
bear a direct relationship to the presence of sedimentary
inclusions (see fig. 4). Where there are abundant inclusions
in the porphyry, the pyrite content reaches an estimated 5
per cent by volume. Where there are no inclusions, the pyrite
is absent or present only in trace amounts.

Very minor amounts (less than 0.5 per cent by volume)
of pyrite are associated with the molybdenite in the quartz
veinlets. Drill core intersections, particularly those in
the lower parts of holes 1, 2, and 3, indicate there is no
defined pyrite halo about the molybdenite mineralization.

In addition to these typical hydrothermal alteration
minerals, the selenite variety of gypsum and the zeolite
stilbite were found in drill-hole 1. Both are found in frac-
tures. Selenite was found only in the white quartz-feldspar
porphyry. Its determination is confirmed by an x-ray powder
pattern (see appendix, page 87). Stilbite occurs in the grey
biotite-quartz-feldspar porphyry as milky grey, prismatic
crystals in fractures. Its identification is confirmed by
an x-ray powder pattern (see appendix, page 88). Neither of
these minerals occur in abundance.

The alteration of biotite to chlorite is commonly

observed in the grey biotite-quartz-feldspar porphyry.

It is doubtful that silicification in the strict sense
has taken place. All quartz veinlets observed in thin-section
show very sharp contacts with the host rocks into which they
have intruded (see plate 15).

The alteration types described above are exceedingly
complex and somewhat ill-defined as to distribution. No def-
inition of a zonal pattern can be made in view of the present
knowledge. For example, it is not uncommon to find potash
feldspathization, argillization, and sericitization in a
single thin-section from the southern parts of the white
quartz-feldspar porphyry. Similarly, in the northern part,
the intense saussuritization is accompanied by intense ser-
icitization. Only the argillization has a definite distrib-
ution: clay minerals bear a close spatial relationship to
both mineralized and barren quartz veinlets.

Intense potash metasomatism appears to be a signif-
icant alteration process, particularly in the white quartz-
feldspar porphyry and alaskite. Every thin-section of these
two rock types contains some development of sericite or
potash feldspar resulting from alteration. The intensities
of these two alteration minerals varies; sericite is most
abundant along the peripheries and in the inclusion-rich
portions of the white quartz-feldspar porphyry whereas
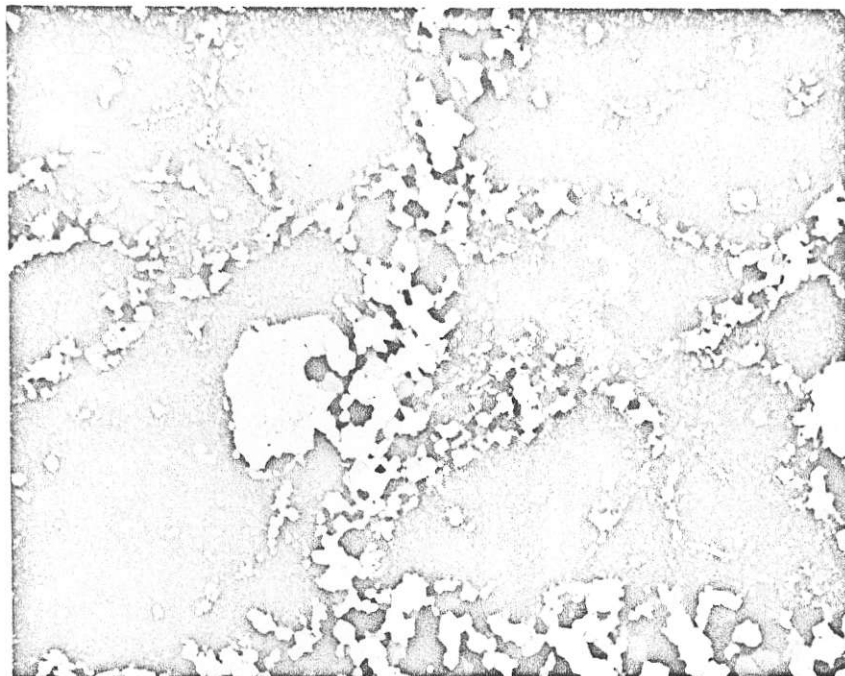
X 16, crossed nicols

Photomicrograph of quartz veinlets cutting
white quartz-feldspar porphyry. Taken from
thin-section L.S.-12, outcrop.

Plate 15 - Abundant quartz veins in white quartz-
feldspar porphyry.

potash feldspar appears to be restricted to the southern part
of the complex. The potash feldspar may be closely related
spatially to mineralization, because its abundance increases
in mineralized portions. It may have preceeded mineralization
however, as indicated by quartz-molybdenite veinlets that cut
cleanly through the replaced plagioclase phenocrysts (see
plates 10 and 11).

The formation of abundant amounts of pyrite appears
to be more closely related to the presence of sedimentary
rocks and inclusions derived from the sedimentary rocks,
rather than to the molybdenite mineralization.

CHAPTER V - INTERPRETATIONS AND CONCLUSIONS

Three main points of contention concerning the interpretation of the Lucky Ship Property have been:

(i) The environment of the emplacement of the igneous rocks of the complex, in particular, the white quartz-feldspar porphyry.

(ii) The relative ages of the white quartz-feldspar porphyry and the grey biotite-quartz-feldspar porphyry.

(iii) The most likely igneous rock type responsible for molybdenite mineralization.

In view of the preceeding descriptive chapters, the writer makes the following interpretations.

Environment of the Igneous Rock Types

Prior to the field-mapping done in 1964, it was suggested that the white quartz-feldspar porphyry may be extrusive in its emplacement. The evidence used to support this concept was:

(a) The fine-grained, "rhyolitic" appearance.

(b) The apparent lack of defined intrusive contacts.

(c) The observation in thin-sections of "flow structures" in some of the portions containing inclusions.

Data presented in the foregoing chapters indicate an

intrusive origin for the white quartz-feldspar porphyry
because of:

(a) The recognition of intrusive contacts and off-
shoot dykes.

(b) The development of a weak thermal metamorphic
halo of biotite hornfels in the sedimentary rocks adjacent
to all the igneous rock types of the complex.

(c) The optical properties of the plagioclase phen-
ocrysts imply plutonic conditions for the crystallization of
white quartz-feldspar porphyry. Their $2V_z$ values correspond
to albite which has crystallized under plutonic conditions
(see Table III and fig. 11).

(d) The parts of the white quartz-feldspar porphyry
with inclusions display features characteristic of intrusive
brecciation processes rather than an explosive volcanic form-
ation. Both Gates (1959) and Bryner (1961) in describing
breccias formed by volcanic or collapse mechanisms imply such
breccias are generally pipe-like or concentric in form.

In the brecciated portions of white quartz-feldspar
porphyry on the Lucky Ship Property, the breccia as known is
extremely irregular in form and distribution. There is no
intense shattering or jointing marking the peripheries.
Jointing appears to be equal in intensity in both brecciated
and non-brecciated portions. The number of fragments does

not decrease sharply towards non-brecciated portions; the change appears gradational. The brecciated portions thus best fit the description of the formation of non-effusive breccias given by Bryner (1961):

> "...A magma, in the process of intrusion, may entrain enough solid material to form a breccia. This material can be derived by magmatic stoping, by abrasion of wallrocks, if the magma is viscous, or by engulfment of other breccias. An intrusive breccia also can originate where a chilled border or front is brecciated and then inundated by a surge of underlying magma....."

The above process of formation is thought to be the case for the formation of the brecciated portions present in the white quartz-feldspar porphyry on the Lucky Ship Property. Thus the breccia now appears as angular fragments of argillite-greywacke, fragments of the dark green aphanitic dykes, and white quartz-feldspar porphyry fragments, held in a matrix of white quartz-feldspar porphyry. The presence of white quartz-feldspar porphyry fragments surrounded by white quartz-feldspar porphyry matrix implies the brecciation occurred during the crystallization of the white quartz-feldspar porphyry magma. Most significantly, the brecciation is intra-mineralization. This is indicated by brecciated portions seen in core from drill-hole 4 and in outcrops where fragments are mineralized and both matrix and fragments are in turn cut by quartz-molybdenite veinlets.

The Relative Ages of White Quartz-Feldspar
Porphyry and Grey Biotite-Quartz-Feldspar Porphyry,
and the Genesis of Molybdenite Mineralization

In the foregoing descriptive chapters it has been
shown that the grey biotite-quartz-feldspar porphyry and the
white quartz-feldspar porphyry differ in their mineralogy
and geochemistry. The alaskite dykes are similar and thus
are believed to have a genetic relationship to the white
quartz-feldspar porphyry. A genetic relationship of the
white quartz-feldspar porphyry to the grey biotite-quartz-
feldspar porphyry is indicated by the following chemical and
textural relationships.

In thin-sections of the white quartz-feldspar por-
phyry it appears that the plagioclase phenocrysts are earlier
in the sequence of crystallization than the primary potash
feldspars. If the normative minerals, albite, anorthite, and
orthoclase feldspar are plotted (see fig. 14) on the schematic
crystallization system of albite-anorthite-orthoclase (Barth,
1962), it is seen that the potash feldspar should have
crystallized first, not plagioclase, thus conflicting with
the thin-section interpretation.

The normative feldspars for both the alaskite and

the white quartz-feldspar porphyry in fig. 14 plot on a line,
with the most altered rocks closest to the orthoclase corner,
thus indicating a relative increase in K_2O and a decrease in
Na_2O and CaO. In the opposite direction, the normative
feldspars progress towards the boundary line L-D. It is
conceivable that the position of the normative feldspars
representing the primary composition of the melt is on the
plagioclase side of the boundary line in the vicinity of X,
thus explaining the sequence interpreted from thin-sections.
Potash metasomatism, represented by sericite and potash-
feldspar as alteration minerals, has resulted in normative
plots in the alkali feldspar field.

In the crystallization of grey biotite-quartz-
feldspar porphyry, the plagioclase phenocrysts would have
crystallized first, followed by simultaneous crystallization
of plagioclase and potash feldspar. In thin-section, the
crystallization sequence appears in this manner. During
crystallization, the melt composition would have progressed
from the compositions plotted as + (plots 2 and 3) to the
boundary line L-D and then along the boundary line towards
D. Presumably in the later stages of crystallization, the
melt could have attained the composition corresponding to
that postulated for the primary composition of the white
quartz-feldspar porphyry at point X. Thus a melt responsible
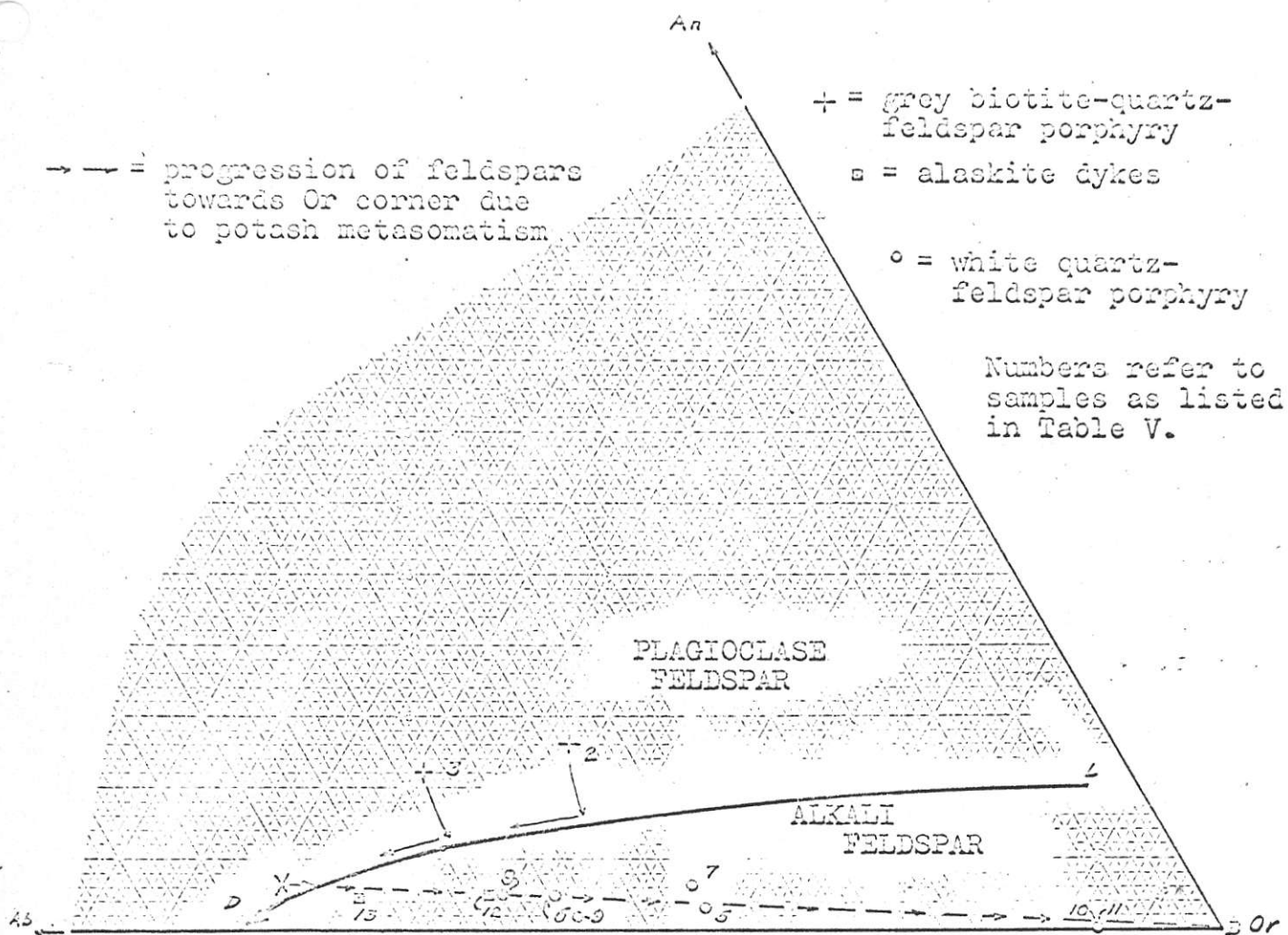
X = proposed primary composition of white quartz-feldspar
porphyry and alaskite dykes.

L-D = boundary line marking the simultaneous crystallization
of plagioclase feldspar and alkali feldspar, and
separating the fields of plagioclase feldspar and
alkali feldspar.

Fig. 14 - Schematic crystallization of the System Albite-
Anorthite-Orthoclase showing the derivation of
white quartz-feldspar porphry from grey biotite-
quartz-feldspar porphyry (after Barth, 1962).

for the white quartz-feldspar porphyry showing the albitic
plagioclase phenocrysts to be earlier than the potash feld-
spar may have been derived from the late stage melt of the
grey biotite-quartz-feldspar porphyry.

The writer believes that in the elevations from
surface to the depths tested by diamond drilling, these two
rock types bear an intrusive relationship to one another.
This is indicated by drill-core which shows that the two
rock types have cross-cutting relationships. However, where
mutual contacts likely exist (for instance in drill-holes 1,
2, and 3), the actual contact is masked by intense quartz
veining and alteration, thus making it impossible to assign
relative ages on the basis of contact relationships. There-
fore, the writer believes the following features are signif-
icant in interpreting the relative ages of these two rock
types.

(a) In a general aspect, based solely on outcrop
observations, it appears that the molybdenite mineralization
is arranged about the grey biotite-quartz-feldspar porphyry.
A more detailed knowledge of the distribution of molybdenite,
obtained from drill-core, indicates that the white quartz-
feldspar porphyry and the alaskite dykes contain the best
mineralization.

(b) Drill-core indicates that the grey biotite-
quartz-feldspar porphyry is often separated from the white

quartz-feldspar porphyry by sedimentary rocks. Furthermore, these sedimentary rock intersections (in particular, see the central footages of drill-hole 3) are relatively poor in molybdenite mineralization.

(c) Some molybdenite mineralization is associated with the white quartz-feldspar porphyry. This is indicated by the occurrence of mineralized fragments in this rock type. Both the fragments and the surrounding rock are in turn cut by a second period of mineralization.

(d) The dark green, aphanitic dykes have been found cutting only sedimentary rocks and the grey biotite-quartz-feldspar porphyry rock. What appears to be fragments of the dykes have been found in the white quartz-feldspar porphyry.

Two different sequences of intrusion and mineralization can be derived from the above features:

(i) White quartz-feldspar porphyry, followed by grey biotite-quartz-feldspar porphyry and the molybdenite mineralization.

(ii) Grey biotite-quartz-feldspar porphyry followed by white quartz-feldspar porphyry and the molybdenite mineralization.

The first of the above sequences is indicated only by the vague suggestion in outcrop that molybdenite mineralization occurs peripherally to the grey biotite-quartz-feldspar porphyry. This peripheral arrangement suggests that

the intrusion of this rock type provided the shattering
mechanism and that the mineralization was derived from its
late hydrothermal solutions. Since there is molybdenite
in the white quartz-feldspar porphyry, this body of rock would
have preceeded the emplacement of the grey biotite-quartz-
feldspar.

The writer believes that the above features (a, b, c,
d) indicate the second sequence happened; the grey biotite-
quartz-feldspar porphyry preceeded the white quartz-feldspar
porphyry and the molybdenite mineralization. The reasons
for this belief are as follows.

(i) The presence of dark green aphanitic dykes in
the grey biotite-quartz-feldspar porphyry and their absence,
except as inclusions, in the white quartz-feldspar porphyry,
suggests a sequence of:

(1) Grey biotite-quartz-feldspar porphyry
(earliest).

(2) Dark green aphanitic dykes.

(3) White quartz-feldspar porphyry (latest).

(ii) The distribution of the highest grades of
molybdenite mineralization is closely associated with the
distribution of the white quartz-feldspar porphyry and the
alaskite dykes, not with the distribution of the grey biotite-
quartz-feldspar porphyry. This feature is clearly indicated
in the core from drill-hole 2. Furthermore, mineralized

fragments occur in the white quartz-feldspar porphyry. The porphyry and the fragments are in turn cut by a second period of molybdenite mineralization. Therefore, the writer believes that these features indicate some, if not all, of the mineralization is associated with the crystallization history of this rock type. Since there is minor quartz-molybdenite veinlets in the grey biotite-quartz-feldspar porphyry, this rock type was in place before mineralization and therefore before the white quartz-feldspar porphyry.

(iii) If there is a genetic relationship (see fig. 14) between these two rock types, then the white quartz-feldspar porphyry is the last rock in the sequence because it was presumably derived from the late stage melt portion of the grey biotite-quartz-feldspar porphyry.

In summary, the writer believes that the white quartz-feldspar porphyry was the last rock to be emplaced. The molybdenite mineralization is believed to be tied in closely with the crystallization of this rock type, in keeping with the genetic concepts pointed out by Vokes (1963):

> "The close association of deposits of the pegmatitic, pegmatitic-quartz vein, and quartz-vein types with igneous intrusions, particularly acid intrusions, is strong evidence for regarding that the two have a common origin. The metal appears to have concentrated in the last crystallizing fractions of the intrusions, with the deposits forming at or near the margins of the igneous bodies."

Conclusions

(i) The igneous rocks of the Lucky Ship Complex are intrusive and were emplaced in a shallow environment.

(ii) The white quartz-feldspar porphyry and the alaskite dykes are related. This is indicated by similar plagioclase and bulk chemical compositions.

(iii) An intrusive sequence, from oldest to youngest, is suggested as: (a) grey biotite-quartz-feldspar porphyry (b) dark green aphanitic dykes (c) white quartz-feldspar porphyry and alaskite dykes. The position of the pink quartz porphyry is unknown due to the lack of knowledge of contact relations.

(iv) It is probable that the alaskite dykes and the white quartz-feldspar porphyry are genetically related to the grey biotite-quartz-feldspar porphyry; their magma(s) being derived from the latter's late stage liquid portion. This derivation presumably could have taken place at a deeper level than present observations by a process of "filter press-ing". This concept is based on the fact that chemical anal-yses of the alaskite and the white quartz-feldspar porphyry give normative feldspar plots which trend in a manner contra-dictory to the observed crystallization sequence when consid-ered in view of the crystallization system of albite-anorthite-orthoclase. Potash metasomatism, represented mineralogically by sericite and replacement potash feldspar, and chemically

by a linear trend of the normative feldspars towards the orthoclase corner of the feldspar phase diagram, is interpreted to be the cause of this contradiction.

(v) White quartz-feldspar porphyry has undergone a complex intrusive history. It is suggested that the emplacement has been repetitive, marked by the breaking and the alteration of partially crystallized portions and the sedimentary wall-rocks. This complexity is amply demonstrated by the number and types of inclusions present in parts of this rock type.

(vi) The molybdenite mineralization is associated with the crystallization history of the alaskite dykes and the white quartz-feldspar porphyry. This is indicated by the mineralized fragments in the brecciated portions and the close spatial relationship of the highest grades of mineralization to these two rock types.

(vii) Argillization is associated with quartz veining and mineralization. Mineralizing solutions are interpreted as being hydrothermal in nature, derived from late stage differentiates of the alaskite and the white quartz-feldspar porphyry. The potash feldspar developed by replacement processes may be closely related but prior to molybdenite mineralization.

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APPENDIX

X-Ray Powder Picture Data For

Albite-Illite-Muscovite-Hydromuscovite

Montmorillonite-Hydromuscovite-Kaolinite

Epidote

Gypsum

Stilbite

Altered Plagioclase		Albite ASTM 9-466		Illite ASTM 9-334		Muscovite ASTM 7- 42		Hydromuscovite ASTM 2-0462	
I	dA°	I	dA°	I	dA°	I	dA°	I	dA°
80	10.009			80	9.9	80	9.9	80	10.00
10	6.363	20	6.39						
		1	5.94						
		1	5.59						
10	4.89			60	4.9	53	4.99	80	5.03
30	4.506			100	4.46	19	4.46	60	4.52
				40	4.29				
				40	4.11				
30	4.038	15	4.03						
10	3.840	7	3.85						
20	3.77	25	3.78	60	3.88	10	3.87		
30	3.663	20	3.684	50	3.65	8	3.60	80	3.63
		15	3.663						
		10	3.509						
		1	3.484						
		1	3.375						
50	3.339			100	3.36	100	3.33	100	3.35
100	3.189	100	3.196						
		9	3.151	50	3.10	10	3.11	80	3.10
10	2.973	9	2.964						
10	2.921	15	2.933					80	2.90
		7	2.866	60	2.86	16	2.88		
		1	2.843						
		1	2.787						
		5	2.639			15	2.60		
60	2.576	7	2.563	100	2.57	27	2.57	100	2.60
		1	2.538						
		1	2.51			5	2.50		
		5	2.496						
10	2.447	5	2.460	50	2.45	7	2.45	60	2.47
10	2.394			60	2.39	8	2.38	80	2.39
		+ weak		50	2.24			40	2.27
+ weak		lines		60	2.14			40	2.18
lines		to		60	1.992			80	2.14
		1.889		40	1.94			100	1.99
				60	1.650			20	1.72
								80	1.65
20	1.498			80	1.50			80	1.51
				+ others to 1.245					

Camera Type: Circular X-ray
powder camera

Size: 114.6 mm

Radiation: Fe/Mn

Comparison of intensities and d-spacings of altered plagioclase phenocrysts in white quartz-feldspar porphyry with those of ASTM index cards 9-334(illite), 7-42(muscovite), 9-466(albite), and 2-0462(hydromuscovite). The altered phenocrysts are from drill-core, hole 1, footage 884.

Altered Plagioclase		Montmorillonite ASTM 13-135		Hydromuscovite ASTM 2-0462		Kaolinite ASTM 6-0221	
I	dÅ	I	dÅ	I	dÅ	I	dÅ
100	14.416	100	15.0				
80	10.06			80	10.00		
80	7.159					100	7.18
10	5.019	60	5.01	80	5.03		
90	4.472β	80	4.50	60	4.52	80	4.48
10	3.784	20	3.77				
10	3.652			80	3.63		
20	3.572					100	3.58
		10	3.50			80	3.56
70	3.349			100	3.35		
		10	3.30				
30	3.189	--strongest line for plagioclase--					
				80	3.10		
10	3.042	60	3.02	80	2.90		
40	2.565β	40	2.58	100	2.60	80	2.565
		40	2.50	60	2.47	80	2.502
+ very				80	2.39	80	2.386
weak		10	2.26	40	2.27	90	2.341
lines				80	2.18	10	2.206
		10	2.15	80	2.14		
10	2.002			100	1.99	40	1.939
		10	1.88			40	1.789
10	1.705	30	1.70	20	1.72		
				80	1.65	50	1.666
20	1.493β	50	1.50	80	1.51	10	1.541
		50	1.493			100	1.488
		20	1.285			+ lines to	
		20	1.243			1.194	

Camera type: Circular X-ray powder camera.

Size: 114.6 mm

Radiation: Fe/Mn

Comparison of intensities and d-spacings of altered plagioclase phenocrysts in grey biotite-quartz-feldspar porphyry with those of ASTM index cards 13-135 (montmorillonite), 2-0462(hydro-muscovite), and 6-0221(kaolinite). The altered plagioclase was obtained from drill-core, hole 1, footage 671.

Altered (epidote) Plagioclase Phenocrysts		Epidote ASTM 9-438	
I	dA°	I	dA°
80	8.5	5	7.98
		3	7.02
60	5.0	40	5.018
		1	4.621
60	3.9	40	3.997
		1	3.762
		40	3.492
90	3.38	7	3.372
10	3.15	15	3.197
		1	3.080
100	2.88	100	2.900
10	2.8	50	2.809
10	2.65	60	2.677
10	2.55	55	2.593
		10	2.525
		7	2.449
40	2.38	70	2.396
30	2.27	25	2.289
		25	2.161
20	2.12	40	2.11
20	2.08	11	2.065
		1	2.043
		1	2.020
		1	2.003
		1	1.914
40	1.85	60	1.869
10	1.80	1	1.773
		1	1.742
		1	1.705
		1	1.687
		1	1.669
70	1.64	65	1.638
		11	1.622
		11	1.590
20	1.56	13	1.574
30	1.525	7	1.539
		15	1.453
30	1.42	7	1.435
30	1.39	30	1.404
+ weak lines		25	1.389

Camera type: circular X-ray powder camera.
Size: 57.3 mm
Radiation: Fe/Mn

Comparison of intensities and d-spacings of epidote in altered plagioclase phenocrysts from white quartz-feldspar porphyry with those of the ASTM index card 9-438 (epidote). The epidote was obtained from specimen L.S. 56 (see fig. 7 for location, east of the pond).

GYPSUM Lucky Ship Property		GYPSUM ASTM 6-0046, 47		γ $CaSO_4$ ASTM 2-0184	
I	dA°	I	dA°	I	dA°
100	7.618	100	7.56		
10	6.022			100	6.05
100	4.279	51	4.27		
80	3.789	21	3.79		
10	3.449	3	3.163	60	3.48
100	3.0747	57	3.059	90	3.01
70	2.8715	27	2.867	90	2.80
20	2.796	5	2.786	10	2.70
70	2.677	28	2.679	20	2.33
10	2.601	4	2.591	10	2.17
10	2.503	1	2.530	5	2.14
80	2.299	6	2.495	10	2.09
50	2.079	4	2.450	10	2.00
10	2.025	4	2.400	20	1.91
20	1.846	6	2.216	60	1.85
20	1.811	1	2.139	20	1.74
20	1.779	10	2.080	40	1.69
10	1.667	8	2.073	5	1.54
10	1.619	4	1.990	5	1.51
10	1.579	2	1.953	20	1.48
10	1.523	16	1.898		
10	1.433	10	1.879		+ others
10	1.366	4	1.864		to
10	1.323	1	1.843		0.992
10	1.233	10	1.812		
10	1.202	4	1.796		
10	1.155	10	1.778		
10	1.153		+		
10	1.085		lines		
10	0.996		to 1.19		

Camera Type: Circular x-ray powder camera.
Radiation: Fe/Mn
Camera size: 57.3 mm

note: lines corresponding
to γ $CaSO_4$ ---

γ $CaSO_4$ in x-ray powder
picture from Lucky Ship
due to dehydration of
gypsum resulting from
grinding of sample for
x-ray powder?

Comparison of intensities and d spacings of gypsum from
Lucky Ship Property with those of A.S.T.M. index card 6-0046,
47. The gypsum occurs in a fracture in white quartz-feldspar
porphyry from drill-core, hole 1, footage 1135.

	Stilbite Lucky Ship Property		Stilbite ASTM 10-433
I	dÅ°	I	dÅ°
90	9.184	90	9.1
5	5.387	20	5.4
60	4.675	70	4.68
5	4.303	30	4.30
100	4.072	100	4.08
10	3.752	40	3.74
20	3.388	50	3.41
15	3.201	50	3.20
30	3.042	70	3.03
10	2.783	30	2.79
+ very		20	2.69
weak		20	2.59
lines		30	2.26
5	2.05	20	2.04

Camera type: circular X-ray powder camera.

Size: 57.3 mm.

Radiation: Fe/Mn.

Comparison of intensities and d-spacings of stilbite from the Lucky Ship Property with those of ASTM index card 10-433. The stilbite occurs in a fracture in grey biotite-quartz-feldspar porphyry from drill core, hole 1, footage 239.

LEGEND FOR FIGURES 4, 6, and 7

To accompany M. Sc. thesis:
    Petrology and Molybdenite
    Mineralization of the Lucky
    Ship Igneous Complex.

By: D. A. Silversides

Figure 3
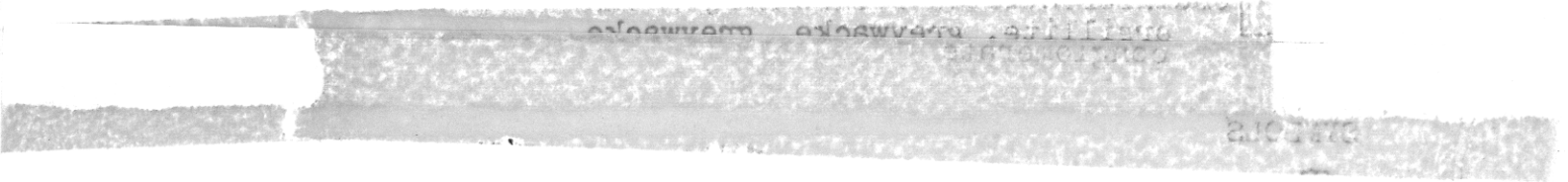
LEGEND

ROCK TYPES

Pink quartz porphyry

White quartz-feldspar porphyry

Alaskite dyke

Dark green aphanitic dyke

Grey biotite-quartz-feldspar porphyry

Undifferentiated sedimentary rocks:
   argillite, greywacke, greywacke
   conglomerate

SYMBOLS

Outcrop

Geologic contact: observed, assumed

Bedding and contact attitudes

Jointing attitude

Fault

Shear; closely spaced joints

Fragments of sedimentary and white
   quartz-feldspar porphyry rocks
   present as inclusions in white
   quartz-feldspar porphyry

1 to 5% by volume disseminated pyrite.
   Unstippled areas have trace to nil
   amounts of pyrite

Biotite

Abundant barren quartz in drill core

Attitude of quartz-molybdenite veinlets

Molybdenite-mineralized fragments of
   white quartz-feldspar porphyry

Minor molybdenite mineralization

Molybdenite mineralization in drill core:
   histogram showing number of quartz-
   molybdenite veinlets/10 ft. of core length

Diamond drill hole

Picket lines

Intermittent creek

Contour line

POND

North tie-line /63

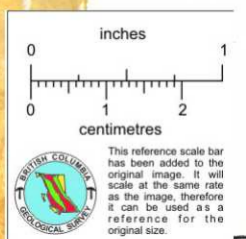South tie-line /63

Base line /63

N
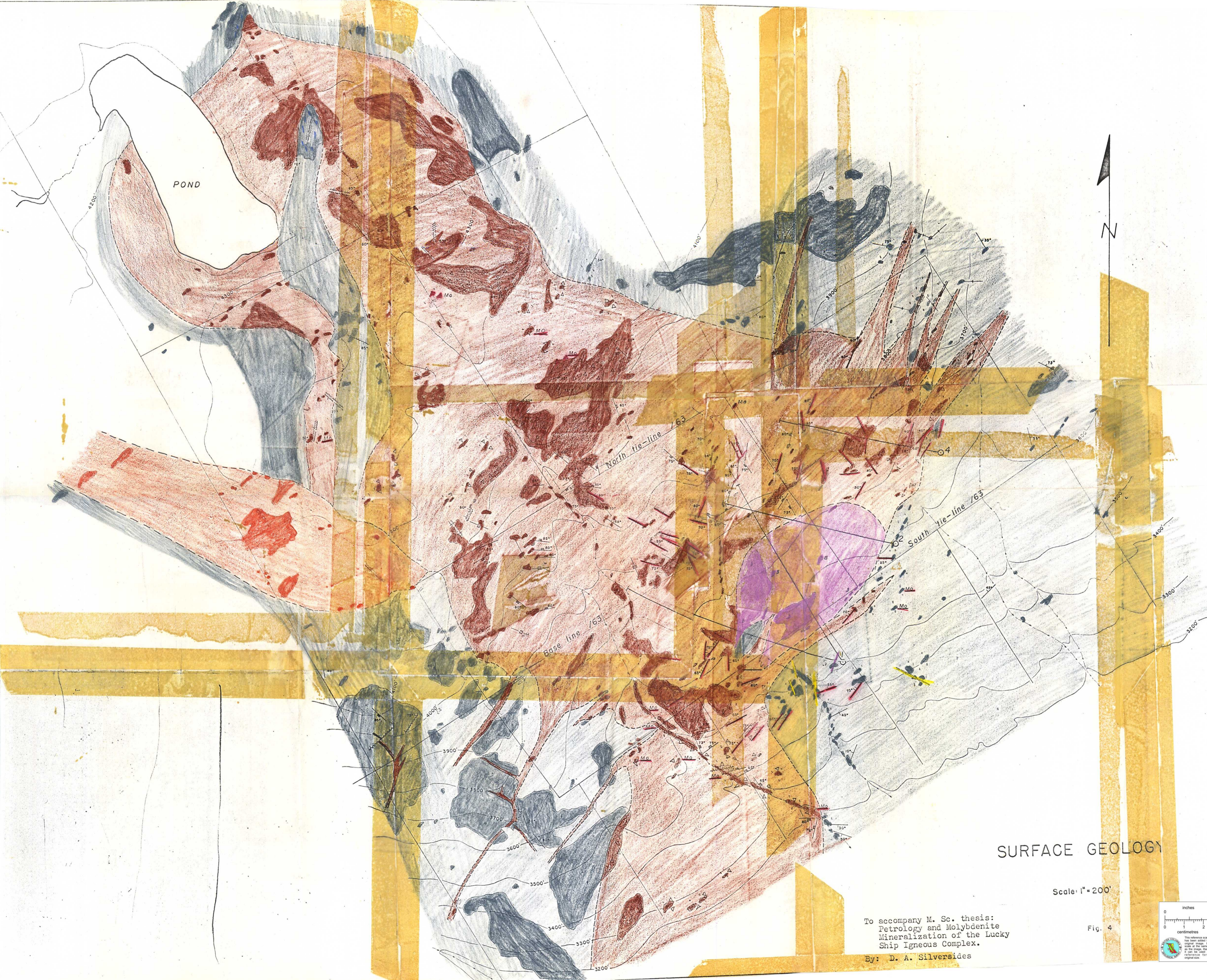
SURFACE GEOLOGY

Scale: 1" = 200'

To accompany M. Sc. thesis:
Petrology and Molybdenite
Mineralization of the Lucky
Ship Igneous Complex.

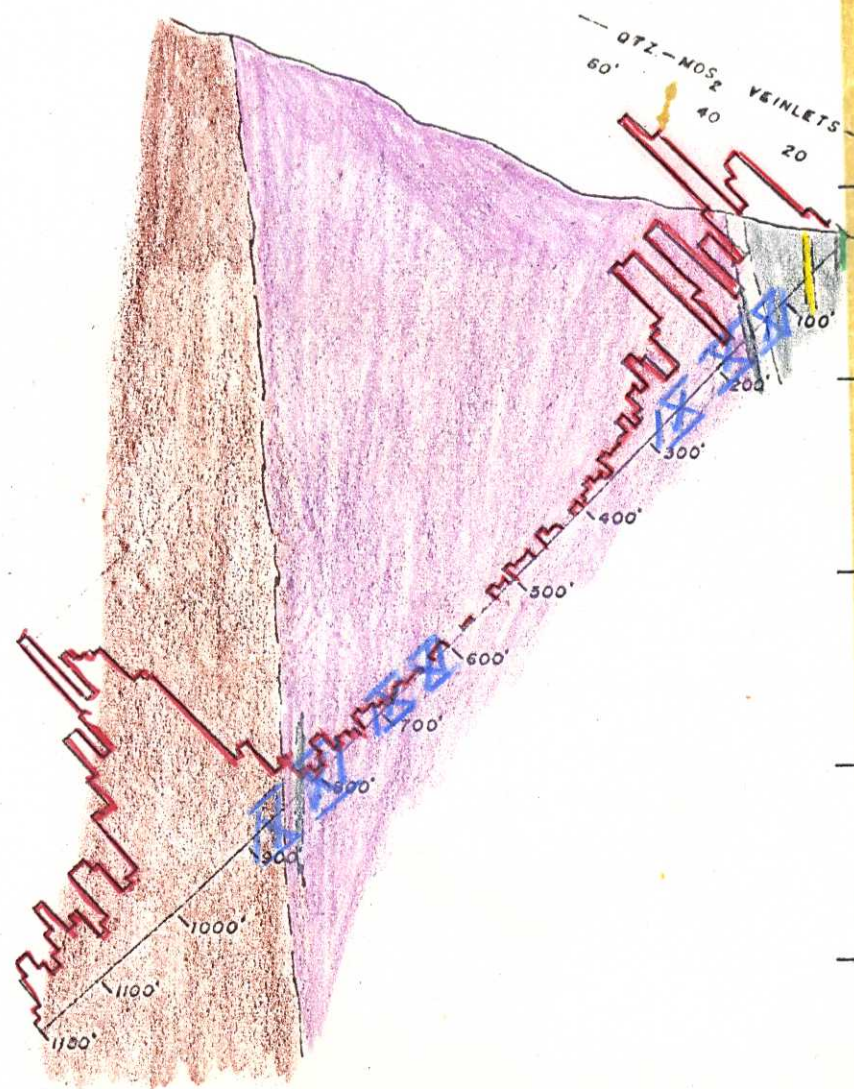By: D. A. Silversides

Fig. 4

ELEVATION

3800' —

3600' —

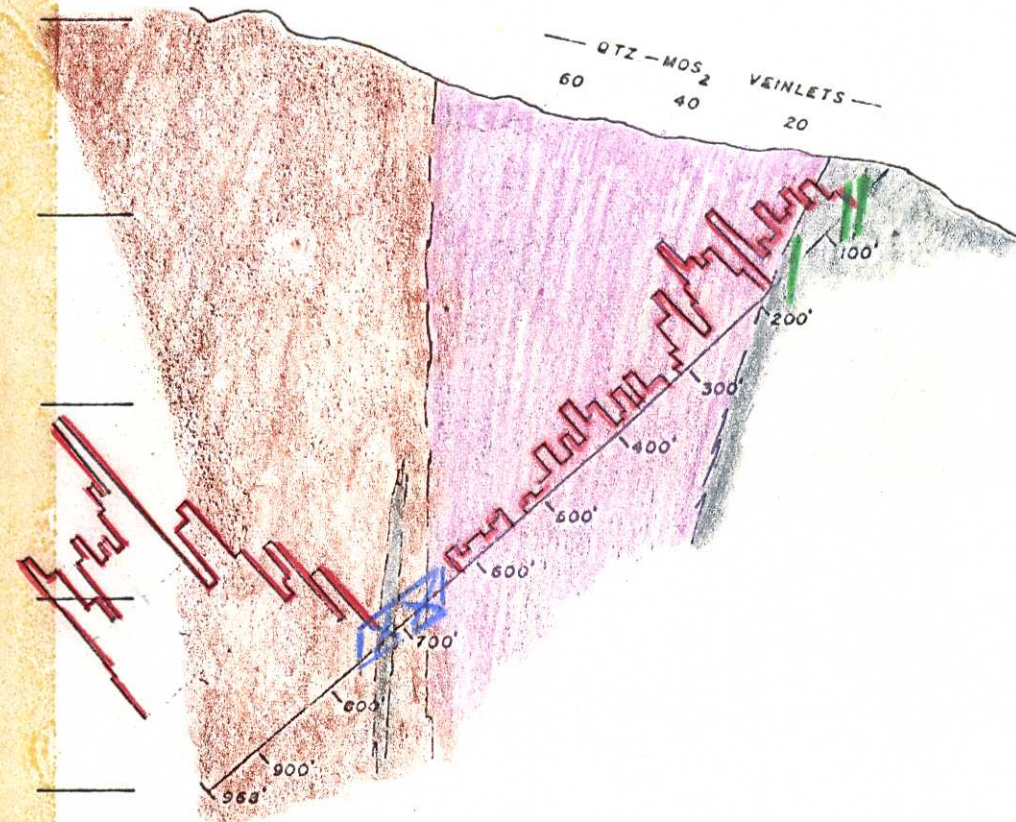3400' —

3200' —

3000' —

2800' —

— QTZ.—MOS₂ VEINLETS —
60   40   20

100'
200'
300'
400'
500'
600'
700'
800'
900'
1000'
1100'
1180'

DRILL-HOLE   1

ELEVATION

— 3800'

— 3600'

— 3400'

— 3200'

— 3000'

— QTZ.—MOS₂ VEINLETS —
60   40   20

100'
200'
300'
400'
500'
600'
700'
800'
900'
958'

DRILL-HOLE   2

DRILL-HOLE   3

ELEVATION

3600' —

3400' —

3200' —

3000' —

2800' —

— QTZ.—MOS₂ VEINLETS —
60   40   20

100'
200'
300'
400'
500'
600'
700'
800'
1000'
1100'
1197'

DRILL-HOLE   4

ELEVATION

— 3800'

— 3600'

— 3400'

— 3200'

— 3000'

— QTZ.—MOS₂ VEINLETS —
40   20

100'
200'
300'
400'
500'
600'
700'
800'
901'
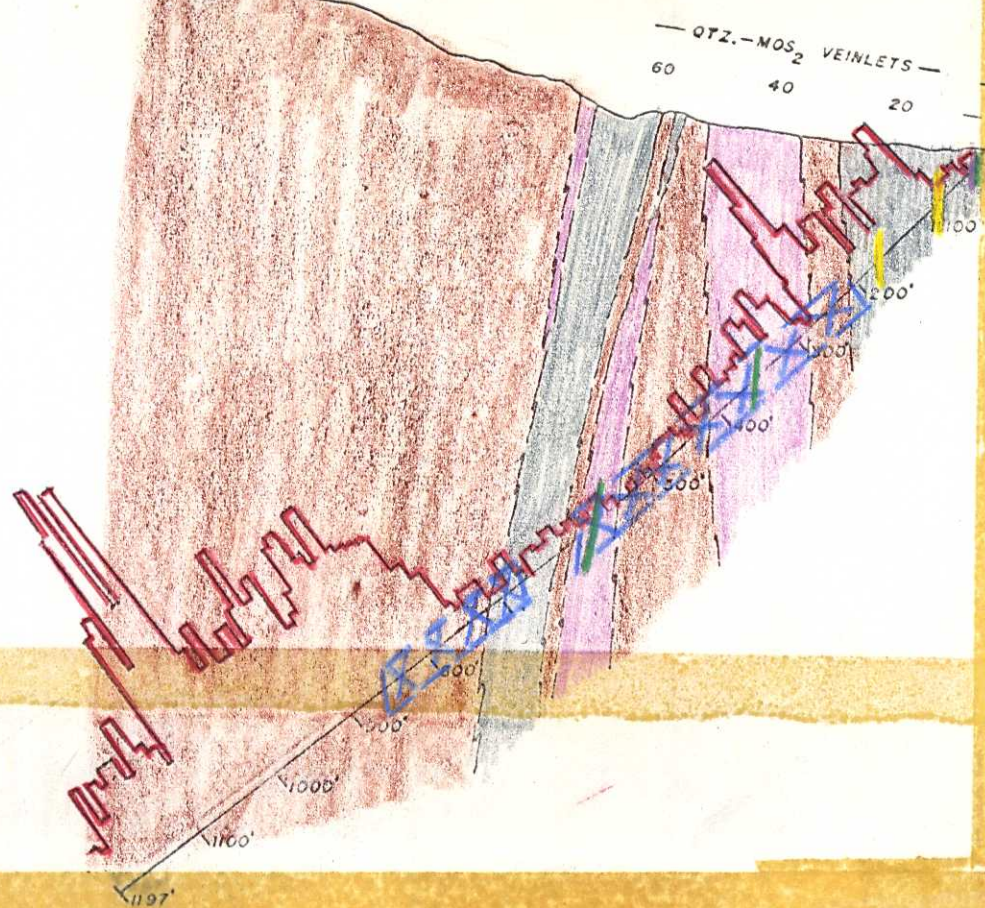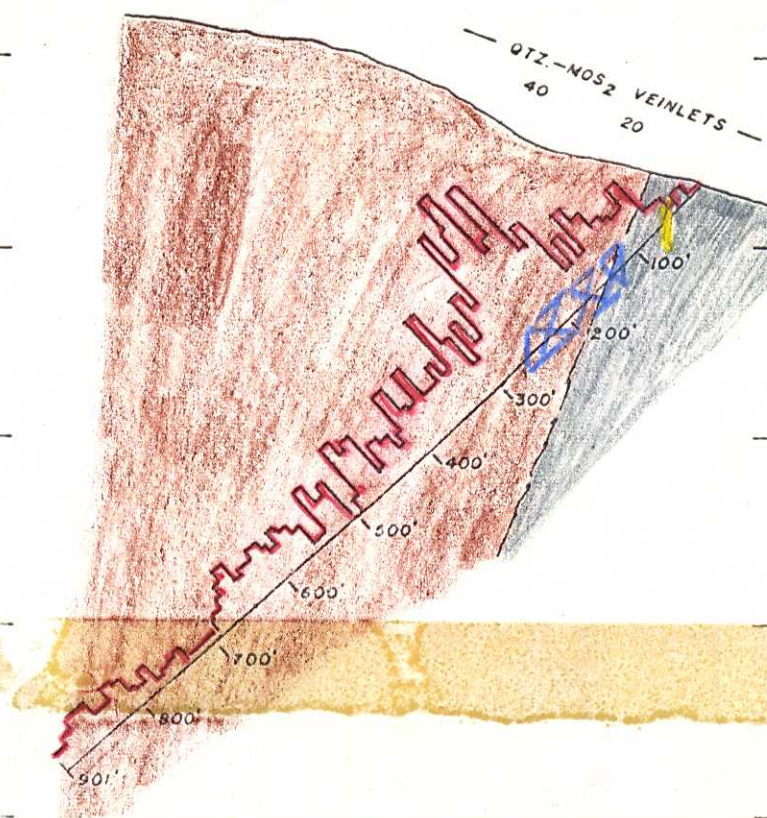
All drill-holes viewed looking northeast

inches
0   1   2

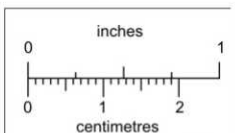0   1   2   3   4   5
centimetres
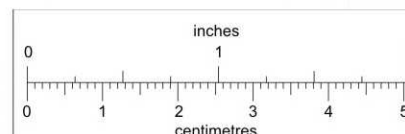
This reference scale bar
has been added to the
original image. It will
scale at the same rate
as the image, therefore it
can be used as a reference
for the original size.

BRITISH COLUMBIA
GEOLOGICAL SURVEY

LOCATION OF THIN-SECTIONS
AND
CHEMICAL ANALYSES

scale: 1" = 400'

FIG. 7

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