Petrology and Mineralogy of a Molybdenite Occurrence in the Raft Batholith South Central British Columbia

by

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PETROLOGY AND MINERALOGY OF A MOLYBDENITE OCCURRENCE IN THE RAFT BATHOLITH SOUTH CENTRAL BRITISH COLUMBIA

by

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B.Sc. Thesis
Honours Geology

412 West Bench Drive,
Penticton, B.C.,
April 1, 1974.

Dr. H.R. Wynne-Edwards,
Head, Department of Geology,
The University of British Columbia,
Vancouver 8, British Columbia.

Dear Dr. Wynne-Edwards:

I respectfully submit my thesis, "Petrology and Mineralogy of a Molybdenite Occurrence in the Raft Batholith, South Central British Columbia", in partial fulfillment of the requirements for the degree of Bachelor of Science in Honours Geology.

Yours Truly,

Brian Hughes

Brian B. Hughes

This thesis meets the standards and requirements of the Department of geology.

Thesis Supervisor

ABSTRACT

Detailed investigation of a molybdenite showing in the Raft Batholith, located between Sicily and Patricia lakes approximately 20 miles west of Clearwater, British Columbia, was undertaken to determine the origin of mineralization, controls of mineralization and dykes, their effect on the host rock, and the relationship of these features with the Raft Batholith.

Mineralization is deposited in two phases: the first is molybdenite associated with quartz veining and the second phase is molybdenite and minor chalcopyrite deposited along barren fractures. Both occur in fractures in the quartz monzonite host rock of the Raft Batholith.

A zone of argillic alteration is surrounded by a zone of propylitic alteration which grades into fresh country rock. Mineralization is within the propylitic zone and has an aureole of potassic alteration associated with all mineralized fractures.

Two phases of dykes are present: aplites, which are genetically related to the crystallization of the quartz monzonite, and rhyolitic to quartz latite porphyry dykes which are second phase intrusion after emplacement of the Raft Batholith. Mineralization post-dates all dykes of the map area.

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I INTRODUCTION

Purpose of Study

The purpose of this thesis is to investigate a molybdenite occurrence in the Raft Batholith. Genesis of mineralization is studied and compared to known stockwork molybdenum environments of economic interest.

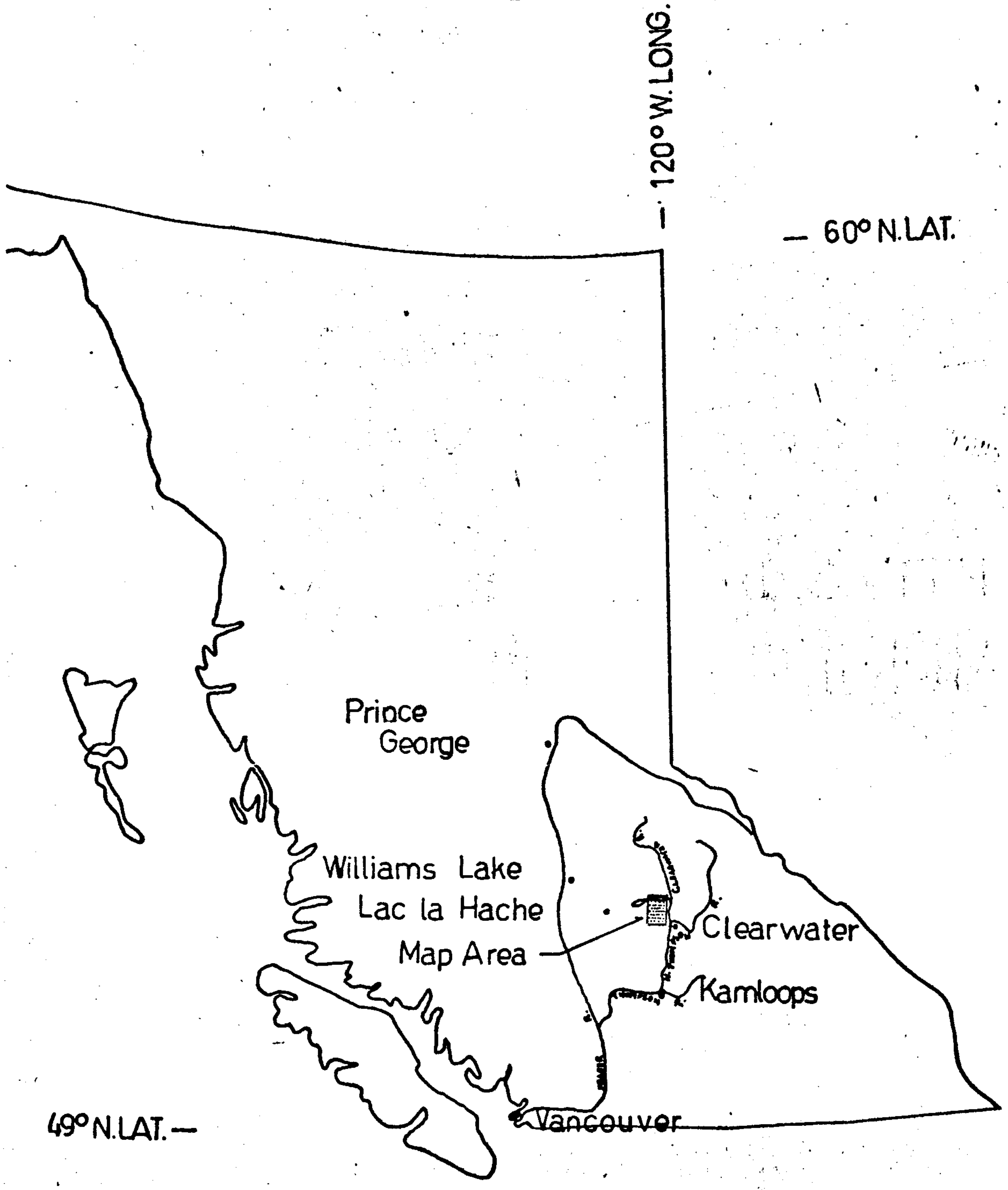
Location

The study area, part of the Raft Batholith, is approximately 20 miles west of Clearwater, British Columbia, at longitude 120°25' west and latitude 51°47' north (Map 1, 2). Access to the study area from Clearwater is by approximately 23 miles of good gravel road constructed and maintained by Clearwater Timber Products Company Limited.

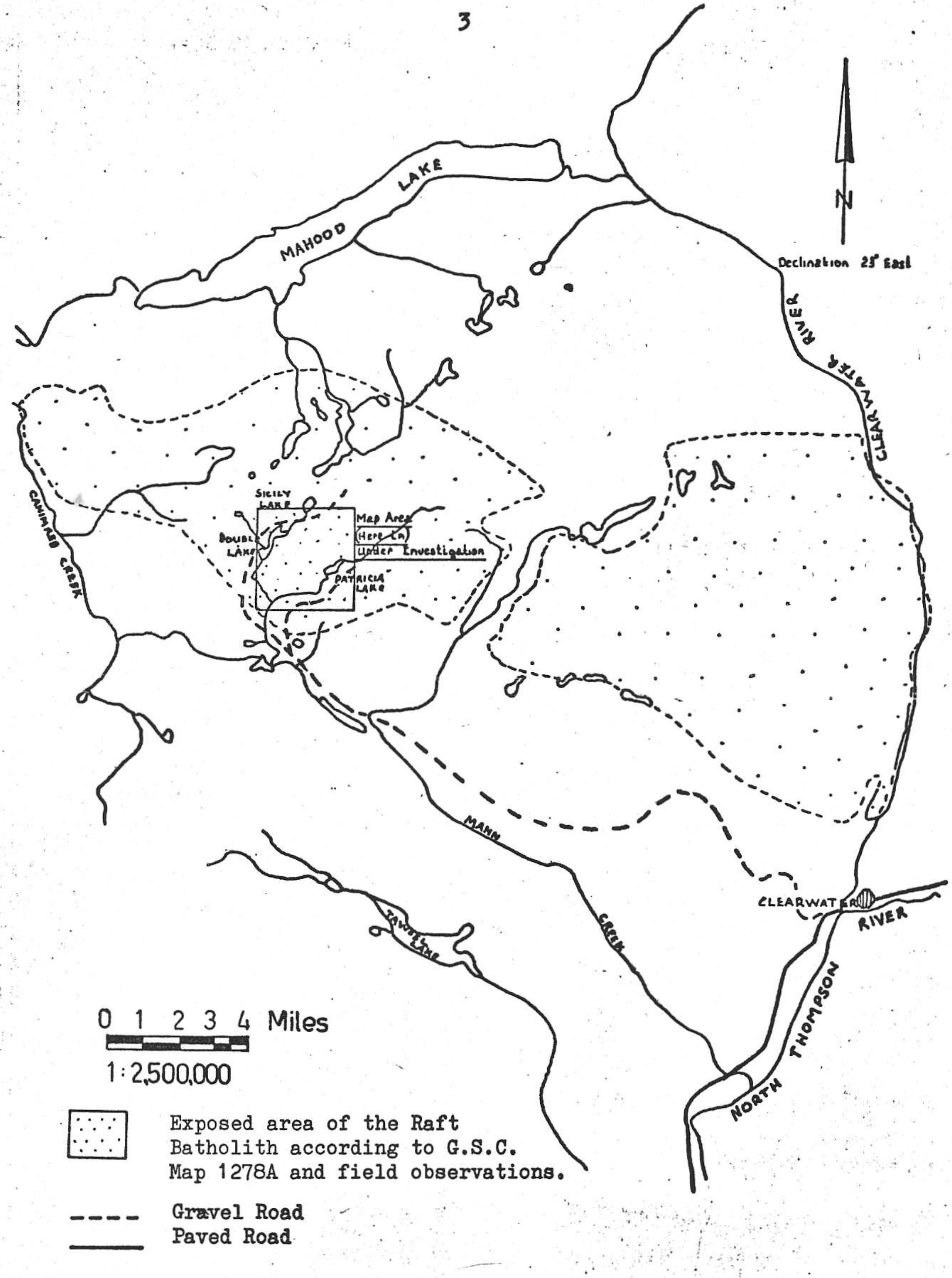
The Raft Batholith is a granitic body elongated in a north-west, south-east direction. Its westerly extent is about 5 miles from Canim Lake and its eastern boundary is the Clearwater River. The area of this thesis is situated in the western part of the batholith and is some 8 square miles in area.

Topography

The area is characterized by heavily wooded rolling topography. Altitudes vary between 4000 feet and about 5000 feet above sea level. Outcrop is poor due to the dense forests and covering of glacial till. Drainage in the map area is controlled by north-east, south-west



Map 1 Location in British Columbia.



Map 2 Location and Access to Map-Area.

trend of the topography, with direction of flow to the south-west. Creeks in the area drain into Canimred Creek, which eventually swings north into the Mahood Lake - Canim Lake drainage system. Mahood Lake empties into the Clearwater River, which connects with the North Thompson River at Clearwater, British Columbia.

Climate

The climate is wetter than that of the Ashcroft-Nicola area to the south, but dryer than that typical of the Cariboo and Monashee Mountains to the north. Seasonally, there is a pronounced spring dryness, followed by a wet June, while rainfall is equally distributed through the rest of the summer, autumn and winter months.

Soils and Vegetation

The rolling glaciated uplands contain glacial till soils. Till soils are, on the whole, too steep, shallow, stony and heavily forested to be adequately cultivated. This area is heavily forested with Douglas fir trees which attain heights up to 100 feet. Trees are usually present right to the edges of lakes, leaving little or no shore line clear. In the major valleys and flat areas clearings are common as grass covered swamps.

Previous Work

In the early 1960's Noranda Exploration Company Limited held claims on the area of this thesis. In the mid-1960's Canadian Superior Exploration Company Limited held the claims and drilled five holes on the property. Regional geology of the area was done by the Geological Survey of Canada in the late 1960's and compiled by R.B. Campbell and H.W. Tipper (1971). During the 1973 field season Amoco Exploration

Company Limited staked the area and the author, employed by that Company, prospected and mapped the property.

Acknowledgements

The author is indebted to all individuals who provided assistance during the collection of data and preparation of this thesis. Special recognition is due Mr. H. Neugebauer, of Amoco Exploration Company Limited, who suggested the area as a possible thesis topic.

The author is grateful to Professor W. R. Danner, Department of Geological Sciences, University of British Columbia, for his guidance during the writing of this thesis. Thanks are also credited to Professors A. E. Soregaroli and P. B. Read for their assistance and discussion concerning specific sections.

Amoco Exploration Company Limited defrayed the cost of material beyond the Department of Geological Sciences' thesis budget, and other services.

II GENERAL GEOLOGY

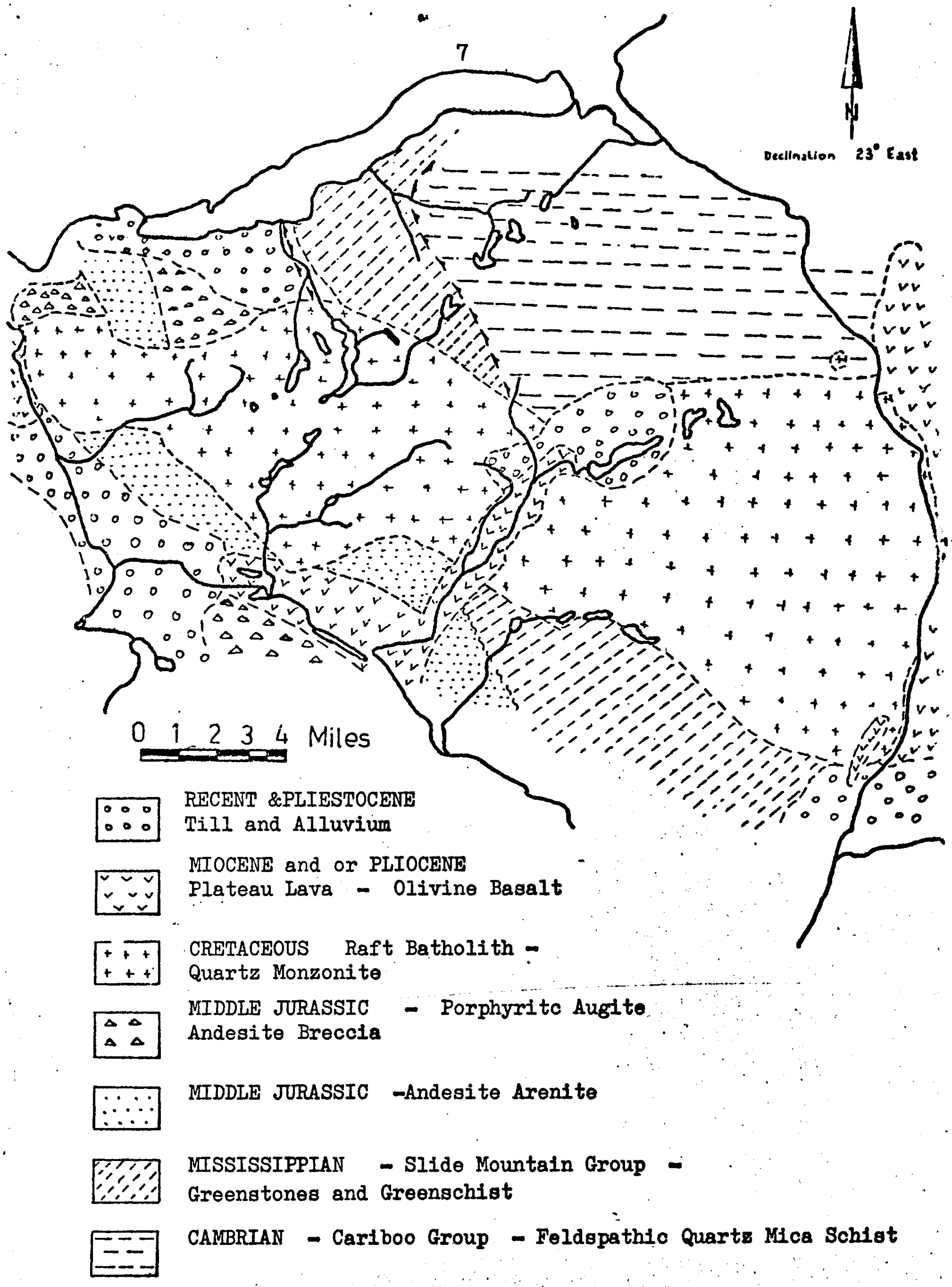
The following description of the regional geology of the general area around the Raft Batholith is taken from work by Campbell (1961, 1963a, 1963b) and Campbell and Tipper (1966, 1971).

The Raft Batholith has intruded older rocks of Cambrian, Mississippian and Jurassic age, the youngest being on the westernmost parts of the Raft Batholith's border. The contact between these older rock types has a general north-northwest trend. (Map 3).

To the north of the eastern part of the Raft Batholith the Koza or Cariboo group of quartz-mica schist and micacious quartzites of early Cambrian age is intruded by the quartz monzonite of Raft Batholith. These granite rocks cut and warp structures within the layered rocks and apparently were intruded followingthe deformation.

Rocks of the Cariboo group appear to be thrust over younger rock of Mississippian age to the west. The Mississippian rocks,called the Slide Mountain group, consist mainly of greenstone with minor argillite and phyllite, bedded chert and breccia. The greenstone is medium grey to grey-green and is characteristically aphanitic or very fine grained. These rocks are intruded by Raft Batholith and are exposed to the north and south of the batholith.

Further to the west,middle Jurassic andesitic arenites, siltstone breccias and tuffs are conformably overlain by porphyritic augite andesite breccias and conglomerates of similar age. The older Slide Mountain group appear to be thrust over these younger rocks. The Jurassic rocks are intruded by Raft Batholith and are exposed to the



Map 3 General Geology

north, south and west of the batholith.

Late Miocene Plateau Lavas lie unconformably over parts of the Raft Batholith and surrounding rocks. Flows up to 4500 feet above sea level filled valleys and low lands. The eastern border of the Raft Batholith is the Clearwater River with granitic rocks on its western banks and Plateau Lavas on the eastern banks present as steep cliffs. These lavas are easily eroded and commonly form steep cliffs adjacent to creeks and rivers of the area.

III PETROLOGY OF THE MAP AREA

Host Rock

Quartz monzonite is the dominant rock type of the Raft Batholith. Contacts between the quartz monzonite and the surrounding rocks are quite sharp and characterized by chilled margins where exposed. Contacts were only observed megascopically.

In hand specimen the quartz monzonite is characterized by dark biotite crystals surrounded by subhedral quartz, plagioclase and orthoclase. The rock generally is fresh, but a thin weathered surface is usually present where in contact with the atmosphere.

Modes of six specimens of the host rock (Table 1) as determined from point counts of thin sections, classify the host rock as a quartz monzonite (Figure 1). Euhedral to subhedral crystals of oscillatory zoned plagioclase (Plate 1) range in composition from An_{35} cores to An_{24} rims and locally to An_{10} rims.

The orthoclase content, which varies considerably (14 - 27%), consists of both large and small interstitial grains. Quartz content consists of large and small clear anhedral grains. Quartz is quite abundant (32%) and easily recognizable in hand specimen and in thin section.

Biotite is the predominant mafic mineral, comprising 6 to 9% of the rock. Biotite occurs as euhedral crystals and commonly shows alteration to chlorite and magnetite. It is common to see small euhedral apatite crystals within the biotite and a few euhedral zircons. An aureole of discoloured biotite (Plate 2) is seen around the zircon

Specimen Number	Quartz	Orthoclase	Plagioclase	An %	Biotite	Hornblende	Chlorite	Sphene	Allanite	Magnetite	Zircon	Apatite	Zoisite	Carbonate
p-11	32	23	36	24	6	3	x	x	-	x	x	x	-	-
314214	27	27	36	28	7	1	x	x	x	x	-	x	-	-
306331	18	27	33	33	21	1	x	x	-	x	x	x	-	-
DDH-1	35	20	38	25	7	2	2	1	-	x	x	x	-	-
301916	48	14	34	28	4	1	x	x	x	x	x	x	-	-
301776	32	28	34	35	6	1	x	x	x	x	x	x	-	-

x= Mineral Present
-= Mineral Not Present

Table 1 Modes of Six Quartz Monzonite Specimens from the Map-Area.

crystals, resulting from the radioactivity of the zircon destroying the crystal lattice of the biotite. A small amount of hydrothermal biotite is present locally replacing hornblende (Plate 3).

Hornblende is only observed in certain regions of the map area, south of Sicily Lake and east of Patricia Lake. Hornblende occurs as euhedral crystals, a few replaced partially by hydrothermal biotite. A common alteration of hornblende is to chlorite but this has not been observed in these rocks.

Sphene content is less than ½% and this mineral occurs in all thin

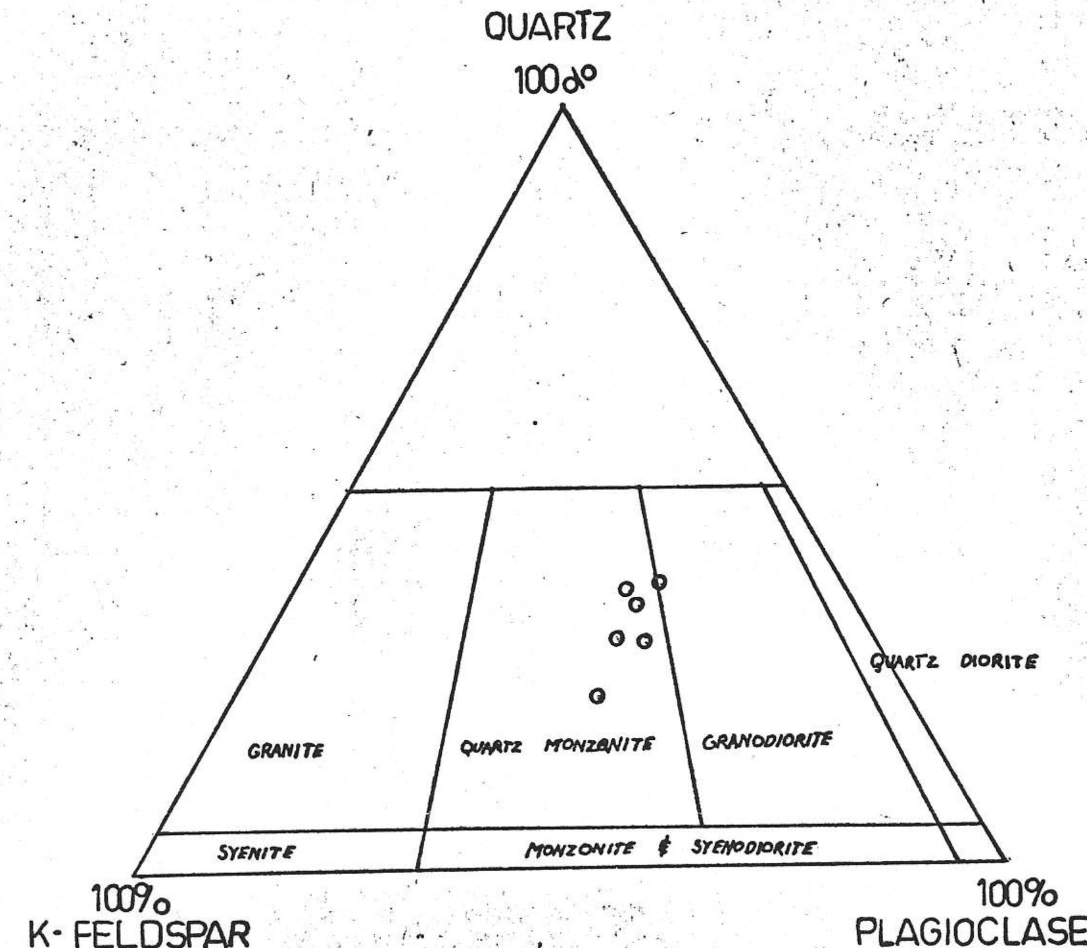


Figure 1 Plot of Six Specimens of the Raft Batholith from the Map - Area .

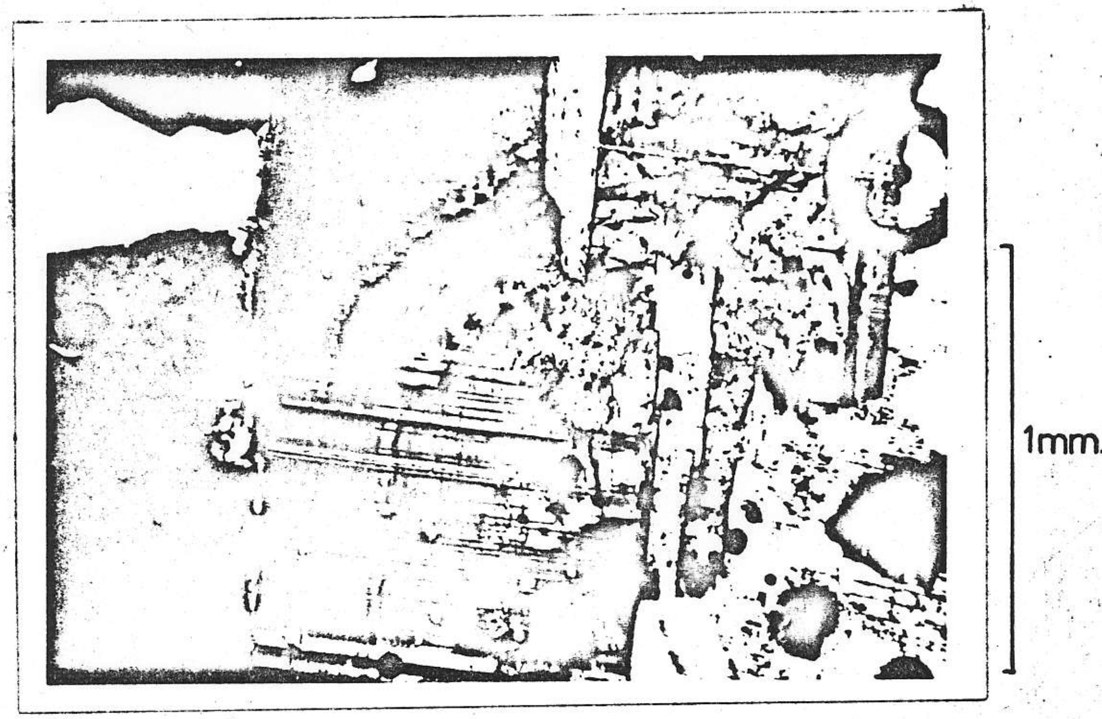


Plate 1 Photomicrograph (crossed nicols) of oscillatory zoned plagioclase in the quartz monzonite.

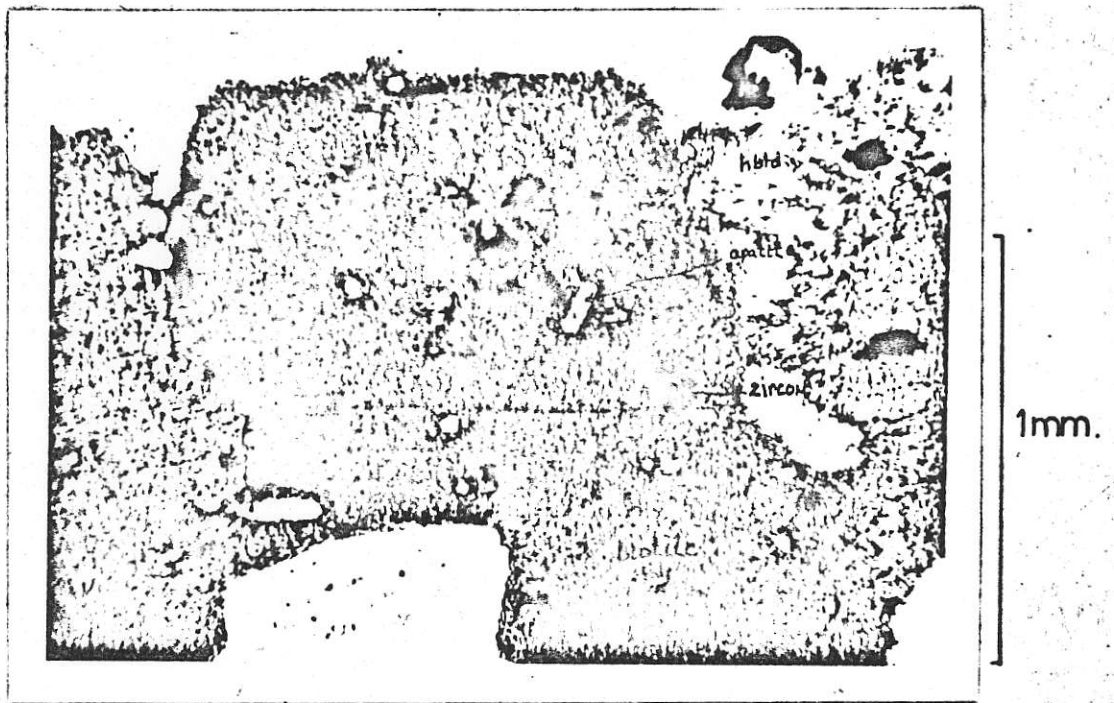


Plate 2 Photomicrograph (plane polarized light) of intergrown biotite and hornblende,and euhedral zircon and apatite within the biotite.

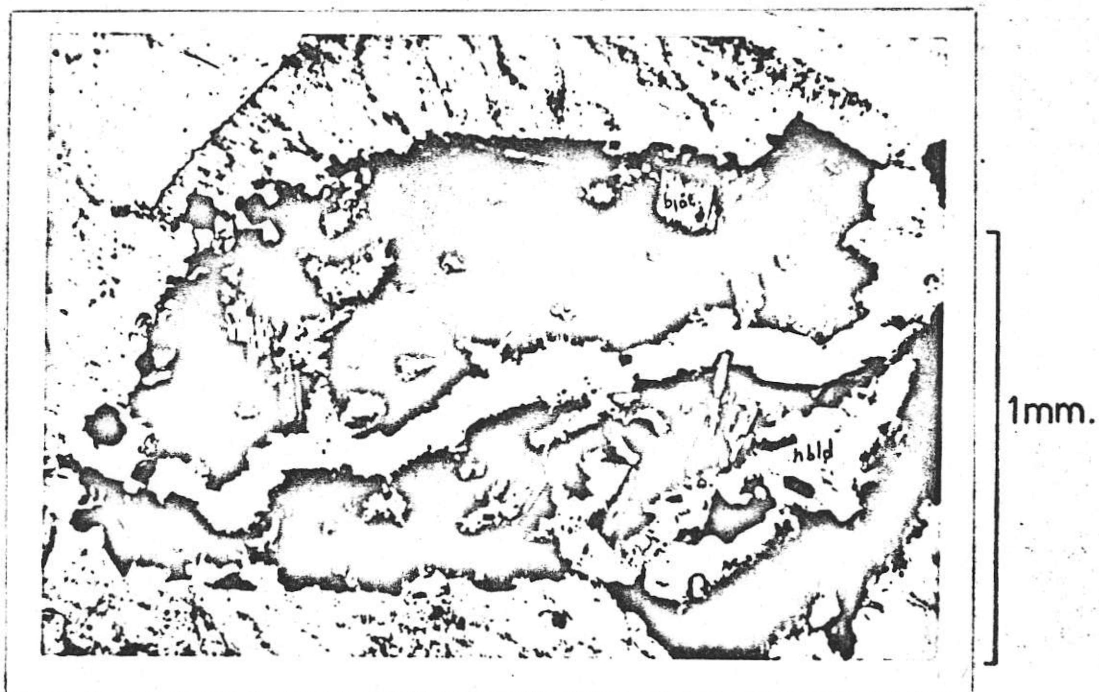


Plate 3 Photomicrograph(plane pol. light)of hydrothermal biotite replacing magmatic hornblende.

sections as euhedral and subhedral rhombs, 0.005 to 0.01 millimeters in size (Plate 4).

Allanite, a member of the epidote group, occurs in the host rock (Plate 5) and also in the porphyritic dykes. Rutile is also present in minor amounts associated with the chloritization of biotite (Plate 7). Rutile occurs as thin needles, dark in colour, and is visible only with the microscope, under medium or high power. Titanium can occur in biotite in higher concentrations than in chlorite, so when biotite is altered to chlorite the excess titanium is exsolved as rutile.

Age

Potassium - Argon age determinations (Wanless, et al, 1967) were made from two samples from eastern parts of the Raft Batholith. Ages of 105 $\pm$ 9 m.y. and 140 $\pm$ 9 m.y. were obtained. These ages would place the crystallization of the quartz monzonite in the late Jurassic to early Cretaceous (R.B. Campbell and H.W. Tipper et al, 1971).

Aplite Dykes

Aplite dykes range in size from one inch up to six inches and commonly strike 100° and 103° and have a near vertical dip. Poles to dyke planes are summarized on an equal area projection (Figure 2).

These dykes are fine grained equigranular rocks of rhyolitic composition, and are common throughout the map area. Two ages of aplite dykes are observed, classed with respect to their grain size and the character of their contacts with the host rock. The first class shows a gradational contact between the host rock and the dyke (Plate 8). Dyke average grain size is one millimeter. This aplite appears to have intruded the quartz monzonite while the host rock was still relatively hot.

Plate 4 Photomicrograph (plane pol. light) of euhedral rhomb of magmatic sphene in the quartz monzonite.

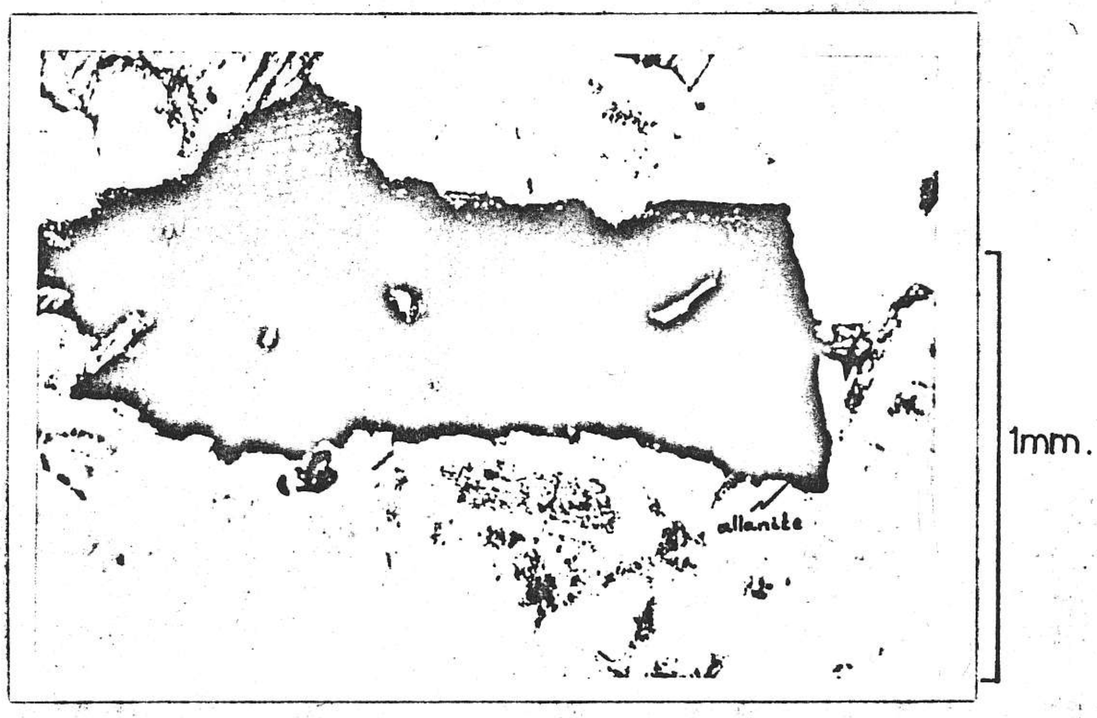


Plate 5 Photomicrograph (plane pol. light) of subhedral allanite in the quartz monzonite.

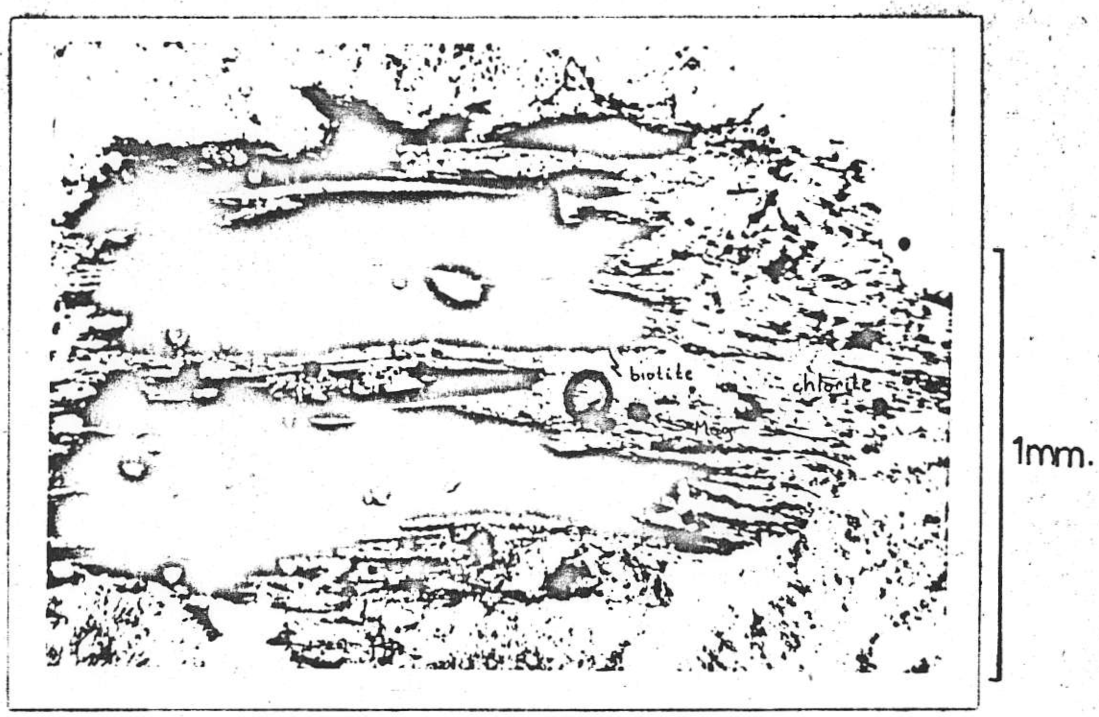


Plate 6 Photomicrograph (plane pol. light) of magmatic biotite altering to chlorite along basal cleavages and exsolving magnetite.

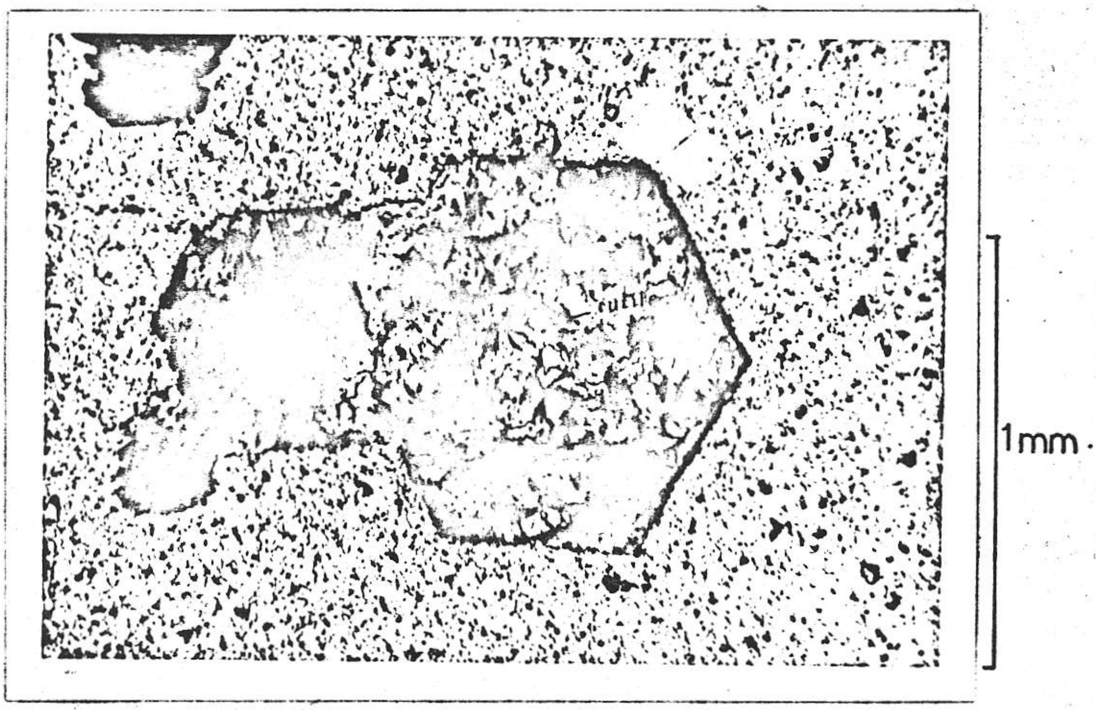


Plate 7 Photomicrograph (plane pol. light) of magmatic biotite completely altered to chlorite and exsolving fine prismatic crystals of rutile , note that apatite is unaltered.

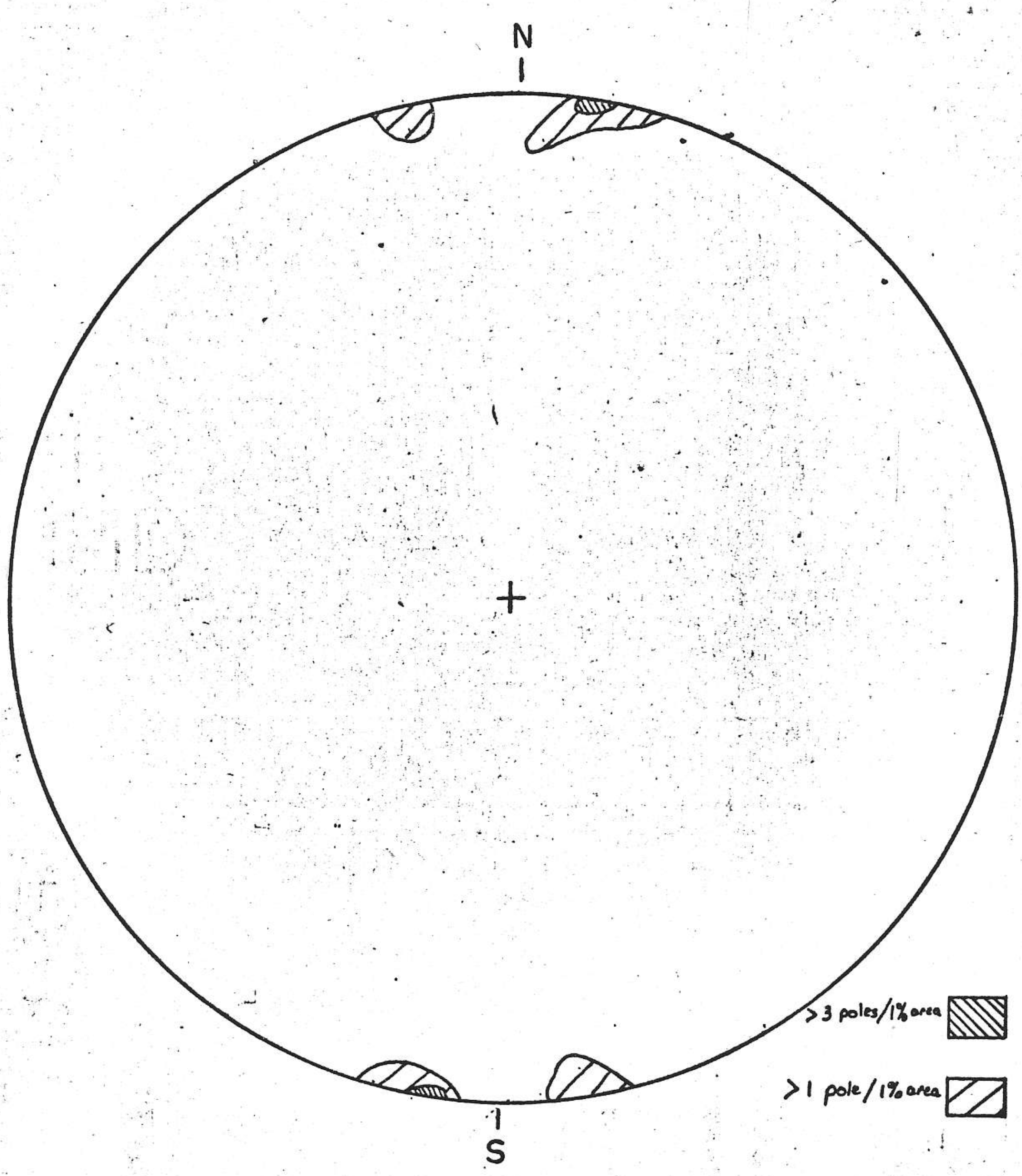


Figure 2 Equal Area Projection of Poles to Planes of Aplite Dykes.

based on how many poles?

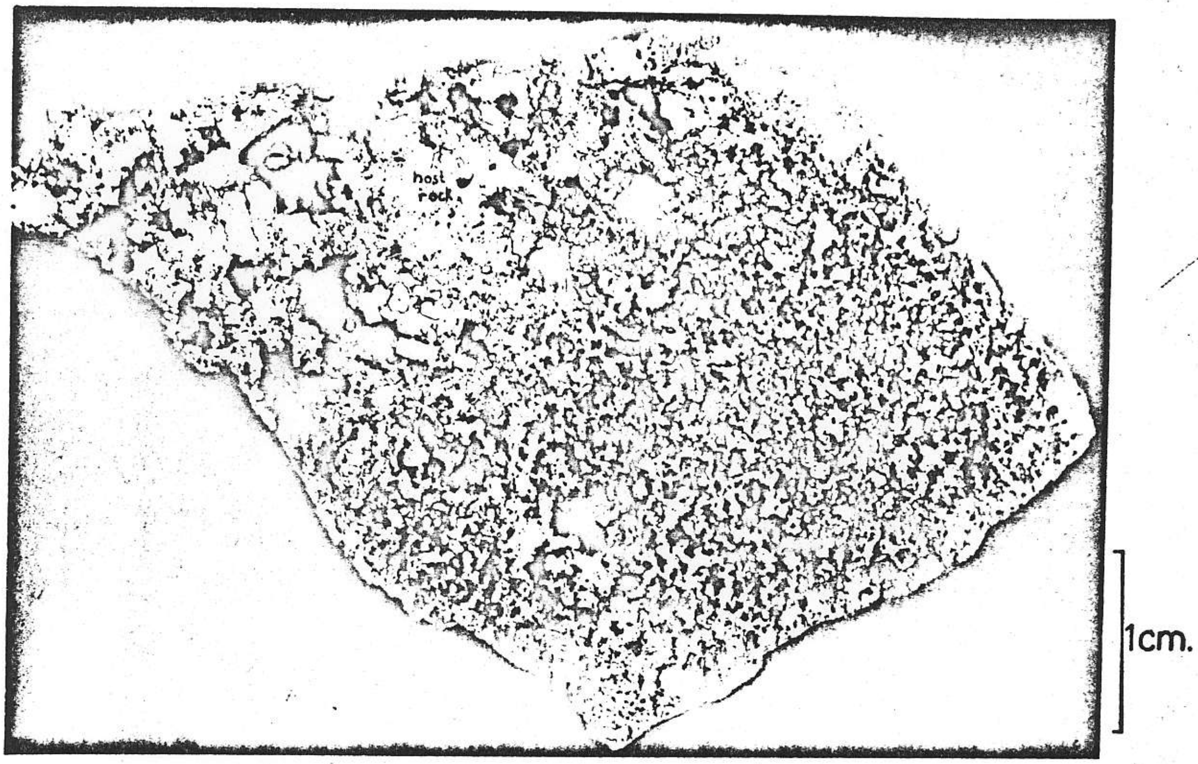


Plate 8 Photographed peel (negative) of gradational contact between first phase aplite dykes and the quartz monzonite host rock.

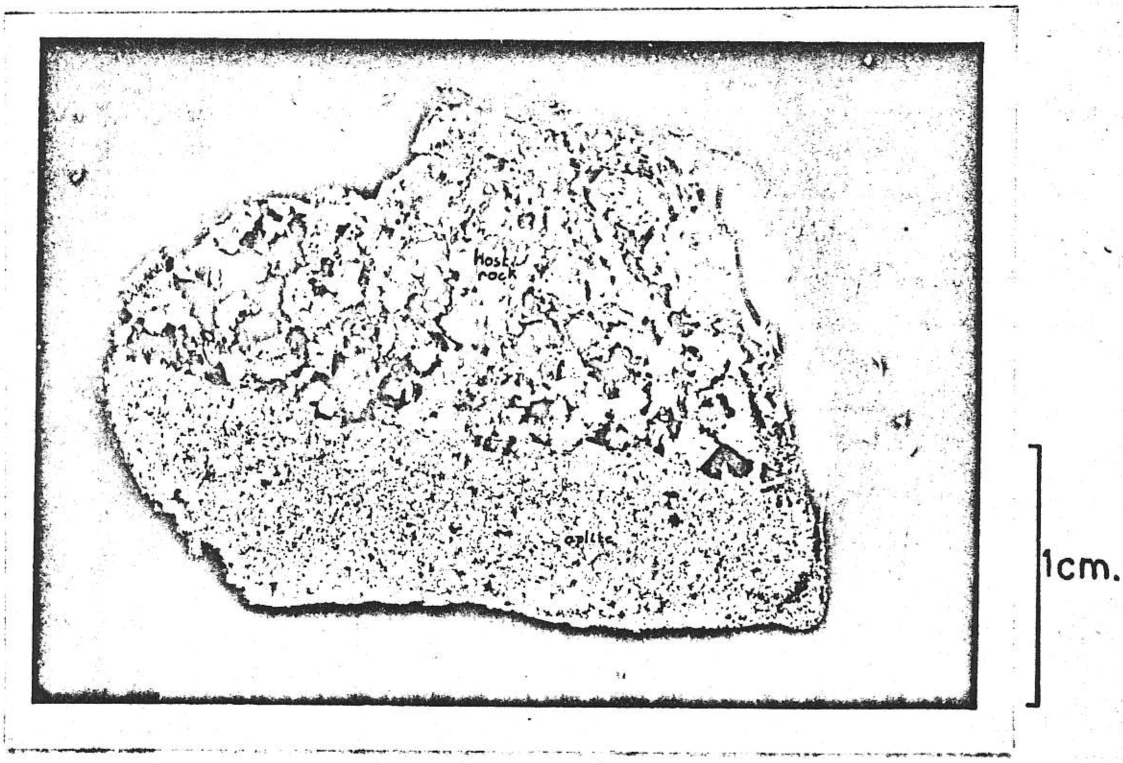


Plate 9 Photographed peel (negative) of sharp contact between second phase aplite dykes and the quartz monzonite host rock.

The second class of aplite dykes have a pronounced chilled margin where in contact with the quartz monzonite (Plate 9). This suggests that intrusion of this aplite must have been into a relatively cooler host rock and resulted in a chilled margin and a finer grain size (.09 to 0.4 millimeters).

Both types of aplite dykes have the same composition and characteristic pinkish colour.

Staining and thin section point counts (Table 2) indicate the quartz, orthoclase, plagioclase ratio to be 5:5:2.

A very minor amount of biotite is present and the only opaque mineral seen is specularite, which appears to fill open spaces between crystals.

Porphyritic Dykes

Most porphyritic dykes strike 102^{o} and have a near vertical dip. Poles to dyke planes are summarized on an equal area projection (Figure 3). Dykes range in width from six inches to ten feet.

The dyke rock is generally porphyritic with phenocrysts of colourless quartz, plagioclase and minor orthoclase, set in an aphanitic matrix. Matrix colours are translucent greys and grey browns.

Dykes contain 15 to 25% phenocryst of orthoclase, quartz, and plagioclase in a ratio of 3:3:2. The ground mass shows a subgraphitic (Plate 10) to equigranular (Plate 11) texture. The ground mass is extremely fine grained and mode determinations are difficult and approximate (Table 2). Modal analysis places these dykes in the rhyolite-quartz latite range. Throughout the map-area porphyry dykes show a common porphyritic texture with phen ocrysts of plagioclase, quartz and less commonly hornblende and orthoclase. In thin section

Specimen Number		Quartz	Orthoclase	Plagioclase	An %	Biotite	Hornblende	Chlorite	Sphene	Allanite	Magnetite	Zircon	Apatite	Zoisite	Carbonate
PORPHYRITIC DYKES															
312583b	P	20	15	50	26%	2	5	3	x	x	x	–	–	x	–
	G	40	40	20		x	x	–	–	–	x	–	–	–	–
312579	P	20	5	65	18%	5	–	5	–	–	x	–	x	–	–
	G	40	40	20		x	–	x	–	–	x	–	x	–	–
312561	P	10	5	80	25%	5	–	x	–	–	x	–	x	x	x
	G	45	41	14		x	–	x	–	–	x	–	–	–	x
312574	P	15	15	65	20%	4	x	1	–	–	x	–	x	–	–
	G	35	45	15		4	x	1	–	–	x	–	–	–	–
APLITE DYKES															
301777		40	43	17		x	–	x	–	–	x	–	–	–	–
p-8		42	39	18		x	–	x	–	–	x	–	–	–	–

P = Phenocryst
G = Ground Mass or Matrix

x = Mineral Present
– = Mineral not Observed

Table 2 Modes of four Porphyritic Dyke Specimens and two Aplite Dyke Specimens from the Map - Area.

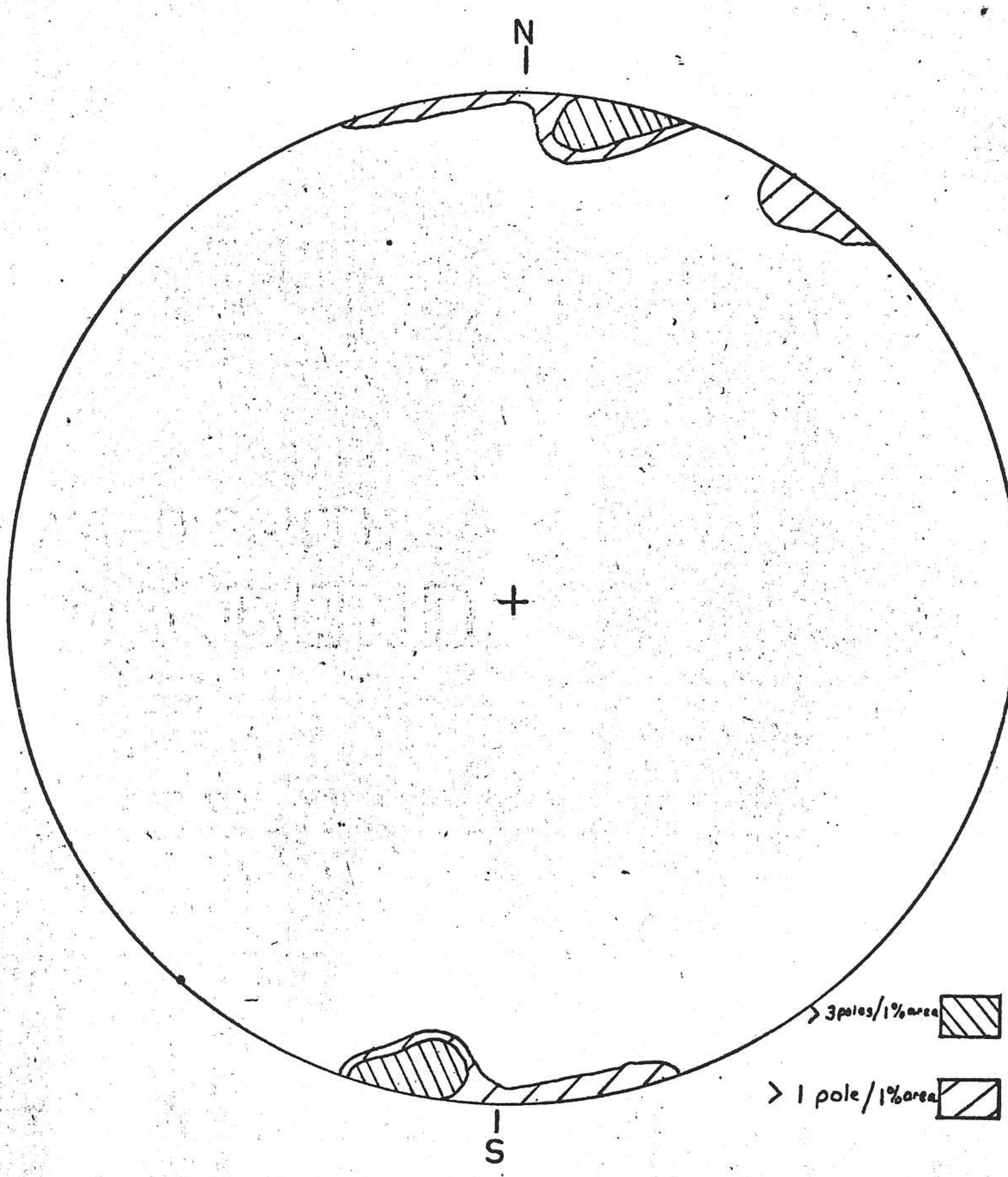


Figure 3 Equal Area Projection of Poles to Planes of Porphyritic Dykes.

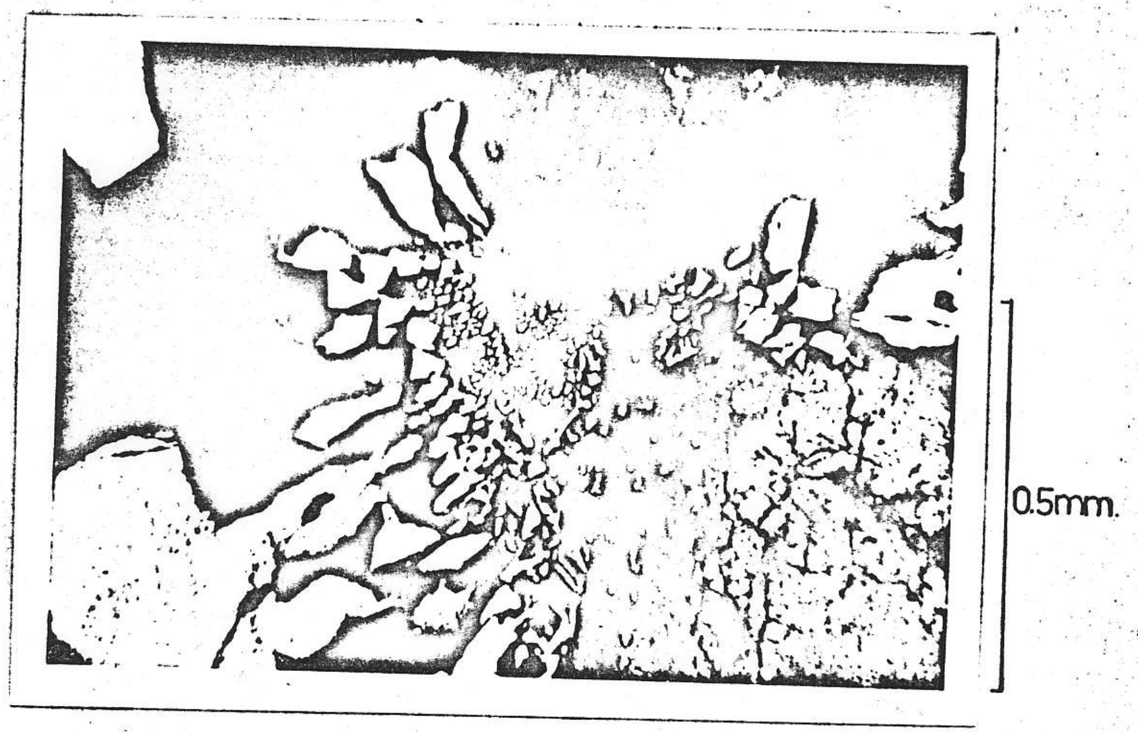


Plate 10 Photomicrograph (crossed nicols) of graphitic texture of aphanitic matrix between phenocrysts in some porphyritic dykes.

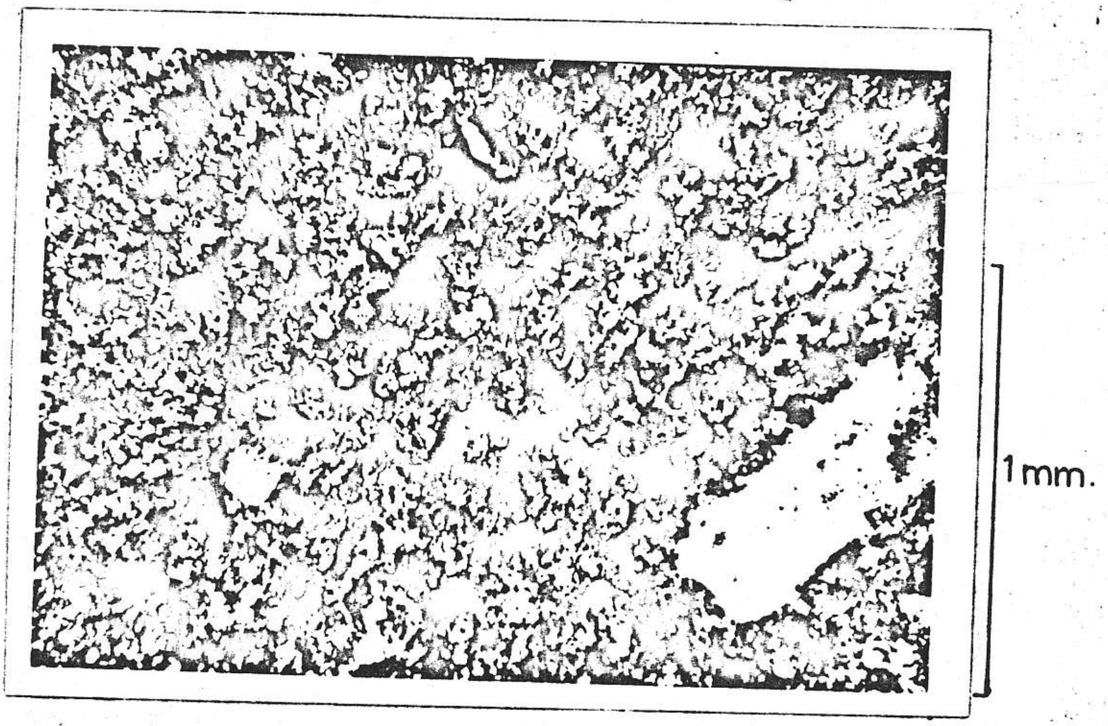


Plate 11 Photomicrograph (crossed nicols) of equigranular aphanitic matrix of some porphyritic dykes.

the quartz, plagioclase and orthoclase phenocrysts have a round anhedral shape (Plates 12, 13). These are resorption textures caused by remelting of an already formed crystal. A mineral will crystallize and grow as a euhedral form in a slowly cooling magma if the environment is within the stability range of that mineral. Once the stability range of the mineral is passed or exceeded, the crystal will no longer be the stable phase and it will be resorbed back into the magma or to a more stable state.

Hornblende, where present, is always fresh and euhedral (Plate 14). Hornblende crystals must not have been resorbed and are present as euhedral rhombs. These phenocrysts are noticeably smaller than the other phenocrysts present, due to a shorter time of growth.

Experimental work by T.H. Green (1972) of crystallization of calc-alkaline andesite under controlled high pressure hydrous conditions, shows experimental stability fields of minerals under different hydrous conditions. Source of water for a magma can be from the magma itself. As it cools and the pressure decreases, water is exsolved out of the magma (White, 1972).

These results can be used to explain the textures seen in the porphyry dykes of the map area.

The second-phase intrusion of the porphyry dykes into the first-phase intrusion, of the quartz monzonite, starts at depth, with pressures and temperatures in the order of 25 kilobars and 1300° Centigrade. As the magma rises, the temperature and pressure decrease adiabatically and water is exsolved. Quartz is stable at high pressures and temperatures and is the first to crystallize from the magma. At lower temperatures and pressures the stability field of plagioclase is intersected and quartz and plagioclase crystallize together. Water exsolving from

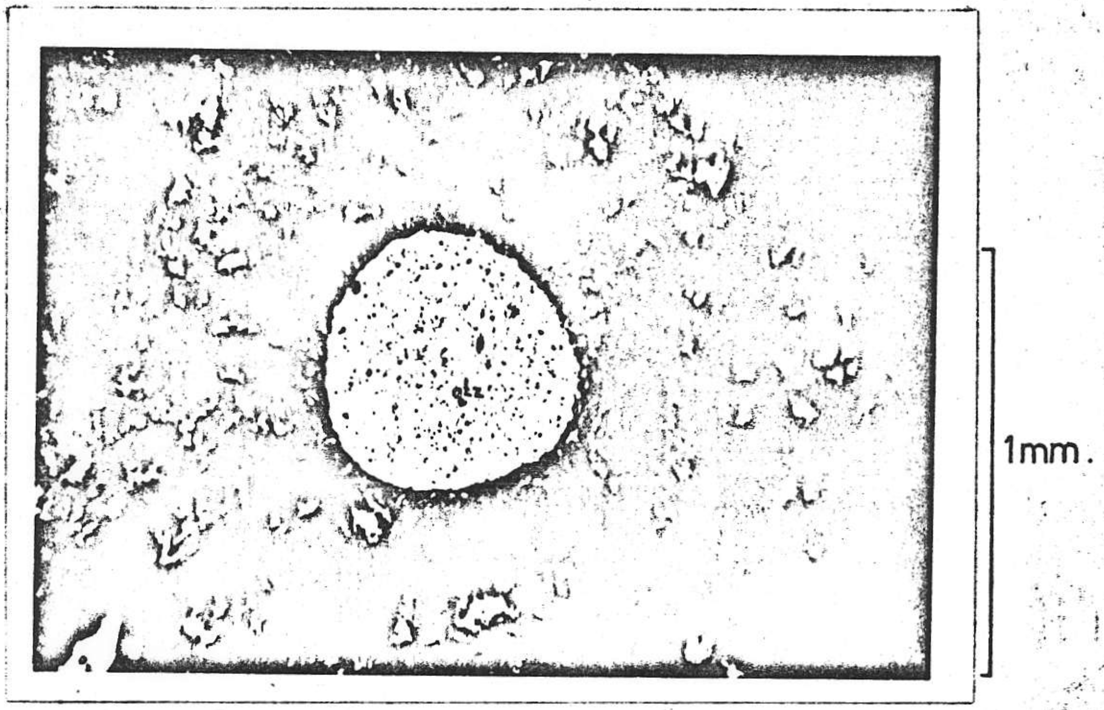


Plate 12 Photomicrograph (crossed nicols) of resorption textures of quartz in porphyritic dykes.

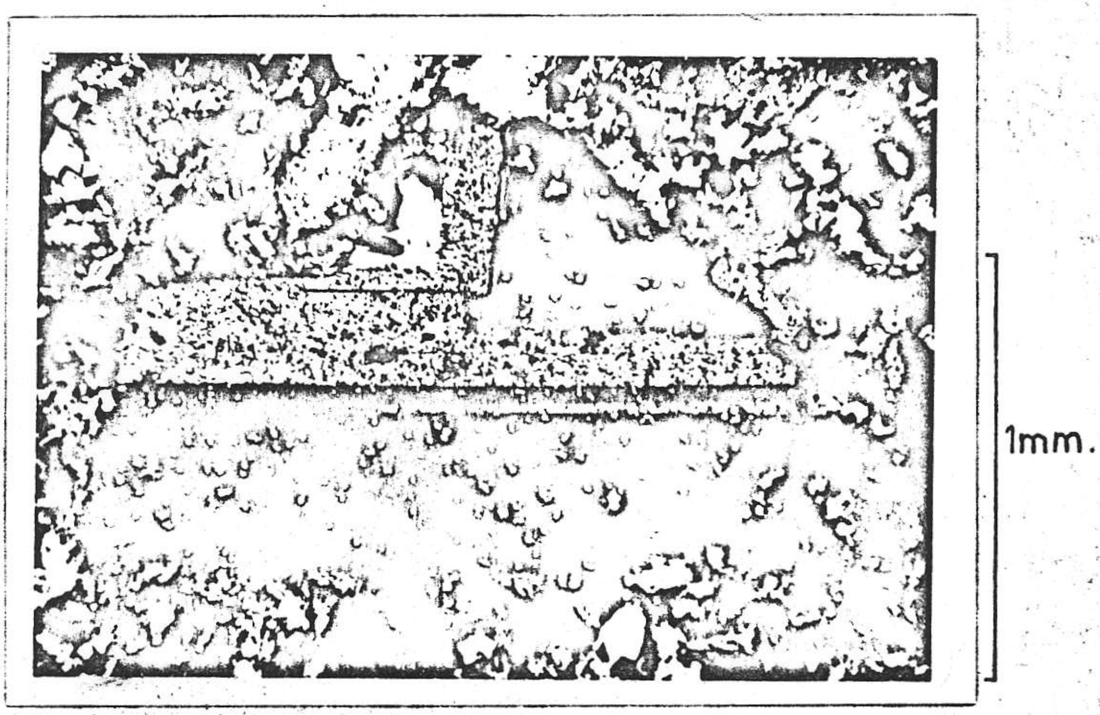


Plate 13 Photomicrograph (crossed nicols) of resorption texture of plagioclase in porphyritic dykes.

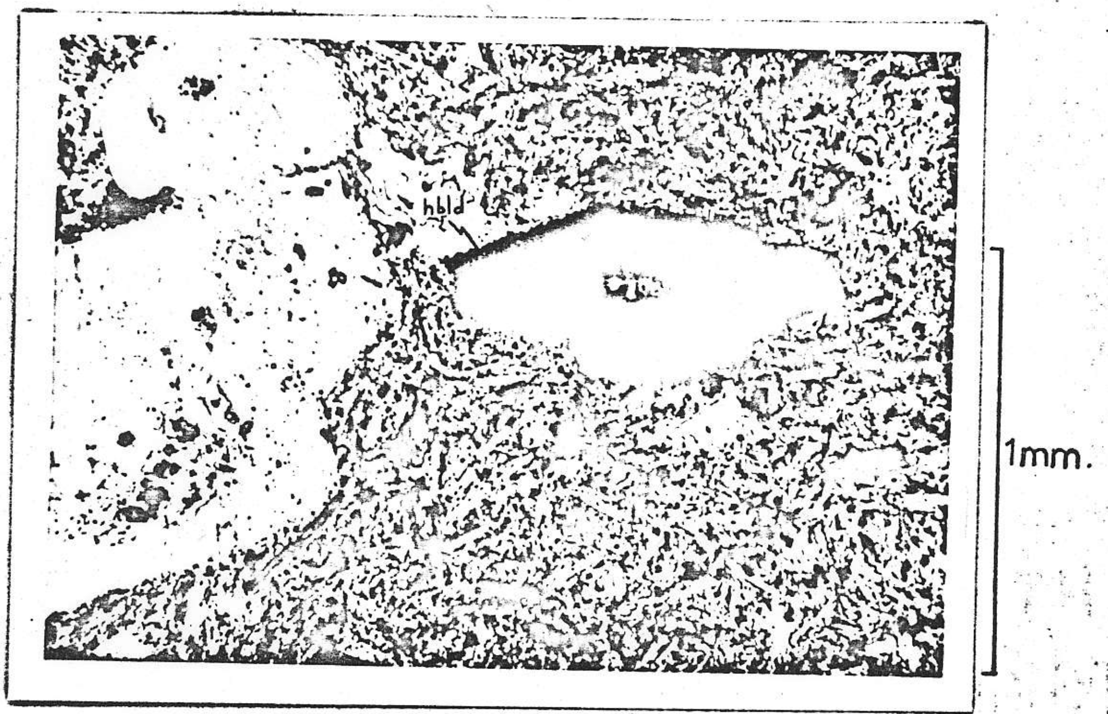
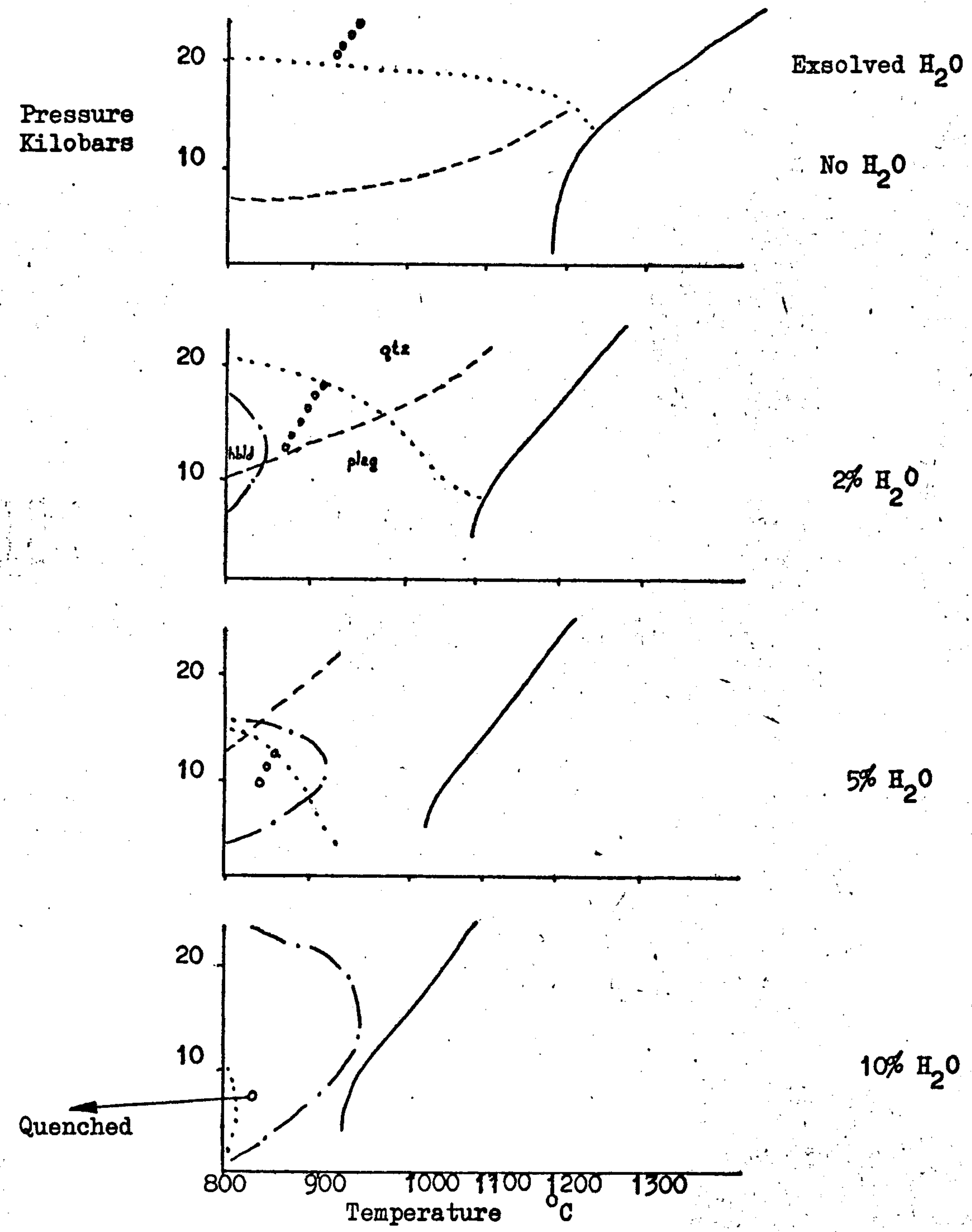


Plate 14 Photomicrograph (crossed nicols) of euhedral hornblende phenocrysts in the porphyritic dykes.

the rising magma into lower pressure areas tends to decrease the stability fields of quartz and plagioclase, and increase the stability field of hornblende (Green, 1972). The stability field of quartz is exceeded in this process and the crystallized quartz begins to be resorbed. Again, as temperature and pressure decrease into the range of 15 kilobars and 950^{o} Centigrade, plagioclase and hornblende crystallize together. Very soon after the crystallization of hornblende is introduced, the stability field of plagioclase is exceeded and plagioclase begins to be resorbed. At this point quartz has been resorbed for some time, plagioclase has just started to be resorbed and hornblende has just started to crystallize. This is the approximate time of injection of the second phase into the quartz monzonite. Upon injection, the magma is quenched and the above textures are preserved in an aphanitic ground mass of quartz, orthoclase and plagioclase.



.... Cooling Path of Magma

—— Liquidus

---- Boundary of Stability Field of Quartz

. . . . Boundary of Stability Field of Plagioclase

—.— Boundary ofStability Field of Hornblende

Figure 4 Approximate cooling path that produced the textures in the porphyritic dykes (diagrams after Green 1972).

IV Genetic Relationship of Rock Types

Field observations have noted the following relationships:

1. Two injections of aplite dykes are present, one is coarser grained and has a gradational contact with the host rock; the other, a later injection of aplite, is finer grained and shows chilled margins with the host rock.

2. Quartz veins were formed after the injection of the aplite dykes and also were formed after the injection of the porphyritic dykes.

3. The writer has never seen any cross-cutting relationship between the two types of dykes.

Grain size decreases from aplites to porphyries, which suggests later injection of the porphyritic dykes into a cooler host rock than the aplites were injected.

The gradational nature of one set of aplite contacts with the host rock also implies earlier injection than the porphyries. The gradational contact would result from injection of the aplite into a relatively hot host rock. The latest structure formed appears to be the quartz veins, which are fracture filling parallel and subparallel to the aplite and porphyritic dykes. The quartz veins have an early barren phase, followed closely by a mineralized phase. An equal area projection of the poles to quartz vein and mineralized quartz vein planes shows a strike of 102° with a near vertical dip (Figure 5). Non-quartz filled fractures with mineralizations are also plotted on the diagram and display the same orientation. A later set of mineralized fractures

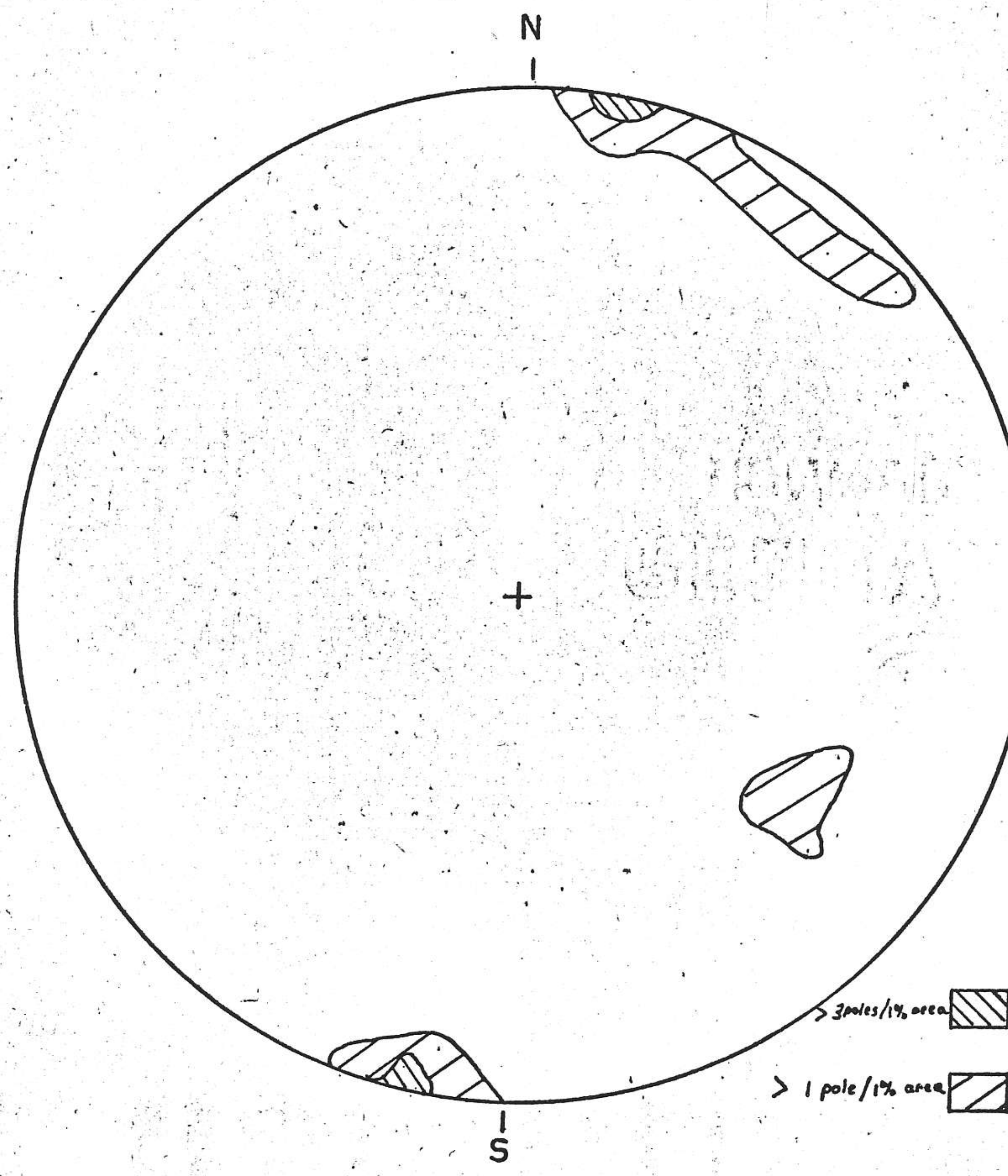


Figure 5 Poles to Planes of Quartz and Mineralized Veins.

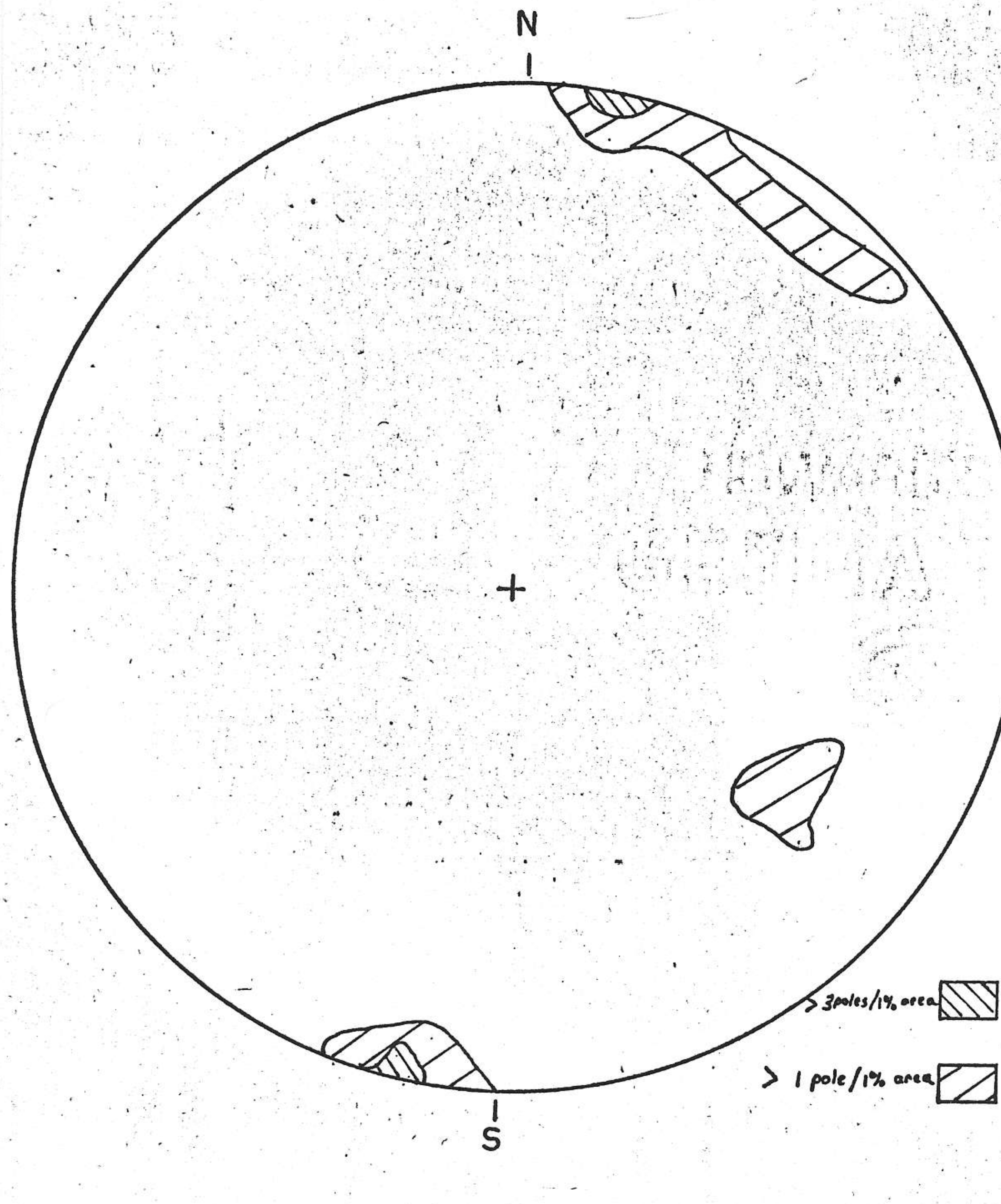


Figure 5 Poles to Planes of Quartz and Mineralized Veins.

indicate shear movement. This set of fractures strike 25° and have a 60° to 70° easterly dip.

The author has the impression that both sets of fractures, as noted on the equal area projection of poles to fracture planes (Figure 6), were formed at the same time. It appears as though the set of fractures containing the aplite, porphyry, quartz and mineralized dykes and veins were in a relaxed state and allowed intrusion along them. A good example that illustrates this situation is found well exposed 200 feet west of the most westerly extent of Patricia Lake. Here, a porphyry dyke has intruded along a fracture in the quartz monzonite. This dyke has also been fractured as the country rock relaxes and another porphyry dyke of similar composition has intruded into and is parallel to the direction of strike and dip of the first dyke. It is also noted that continued opening along this fracture has been filled with a late phase of quartz occurring as thin veins along dyke contacts.

The other set of fractures noted on the poles to planes projection (Figure 7), must have been held tightly closed during the time of dyke emplacements and only showed movement and signs of relaxation during the last phase of non quartz filled mineralization of fractures. Molybdenite smeared along these fractures indicates movement after mineralization was deposited.

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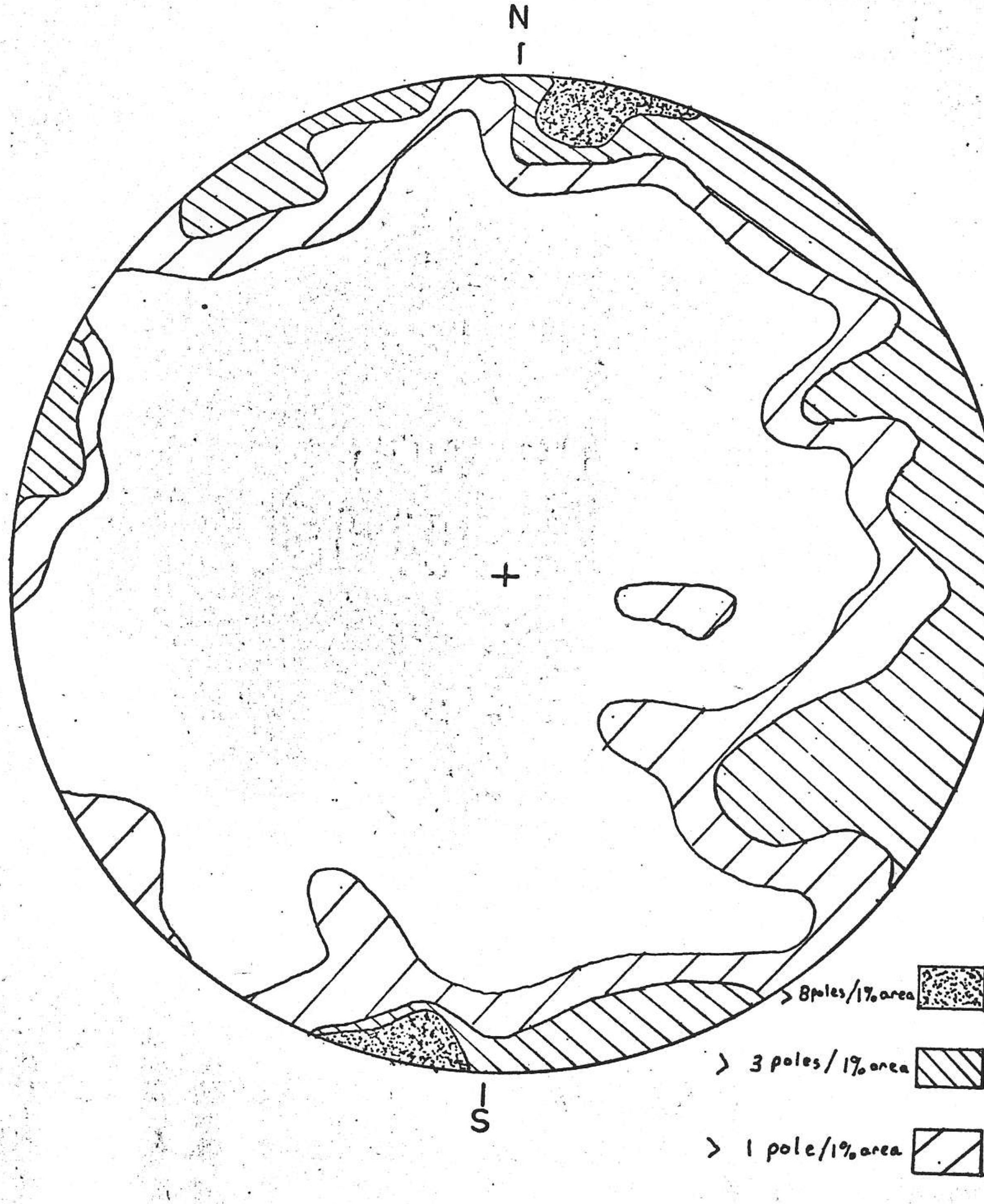
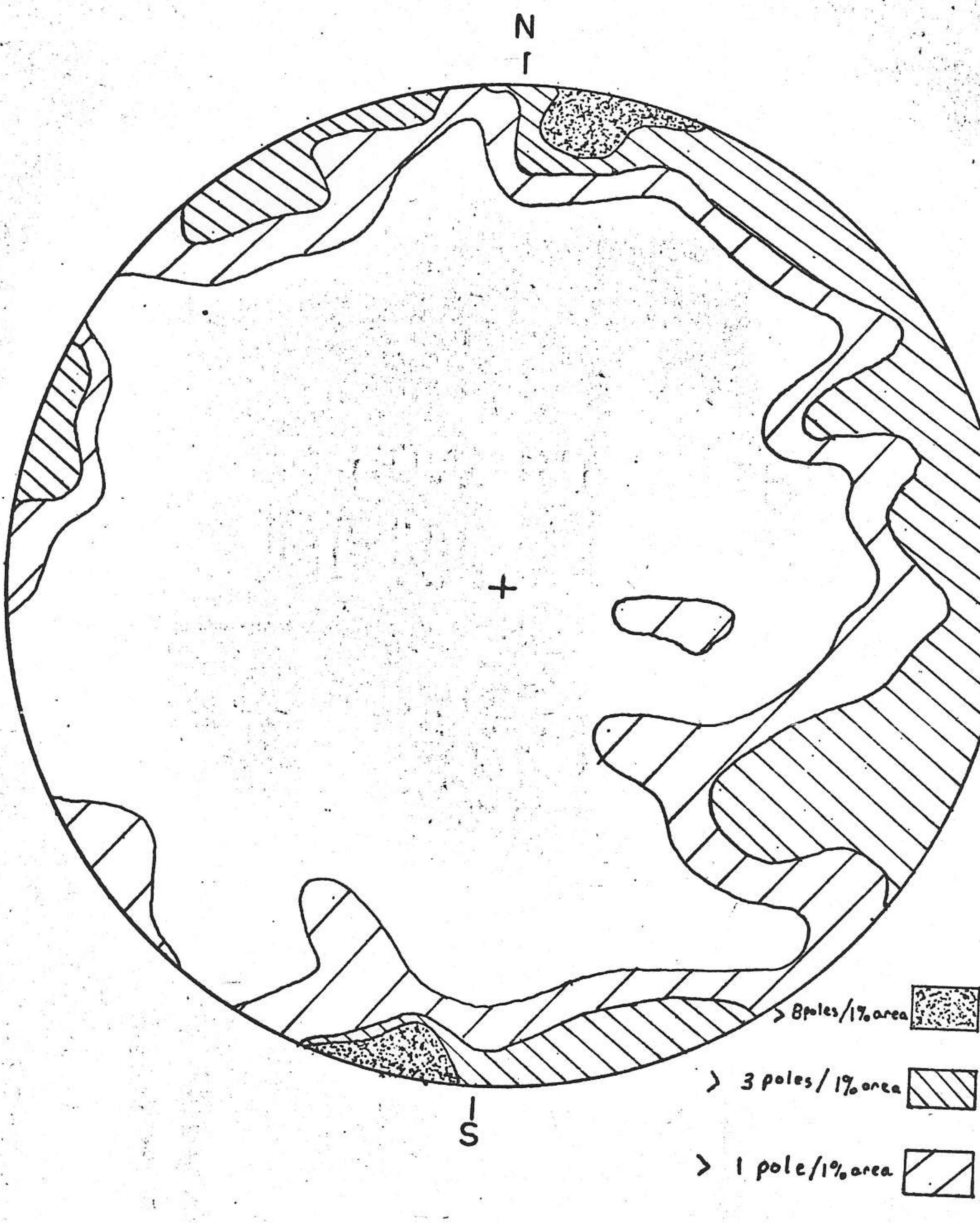


Figure 6 Equal Area Projection of Poles to Planes of all Fractures and Dykes.



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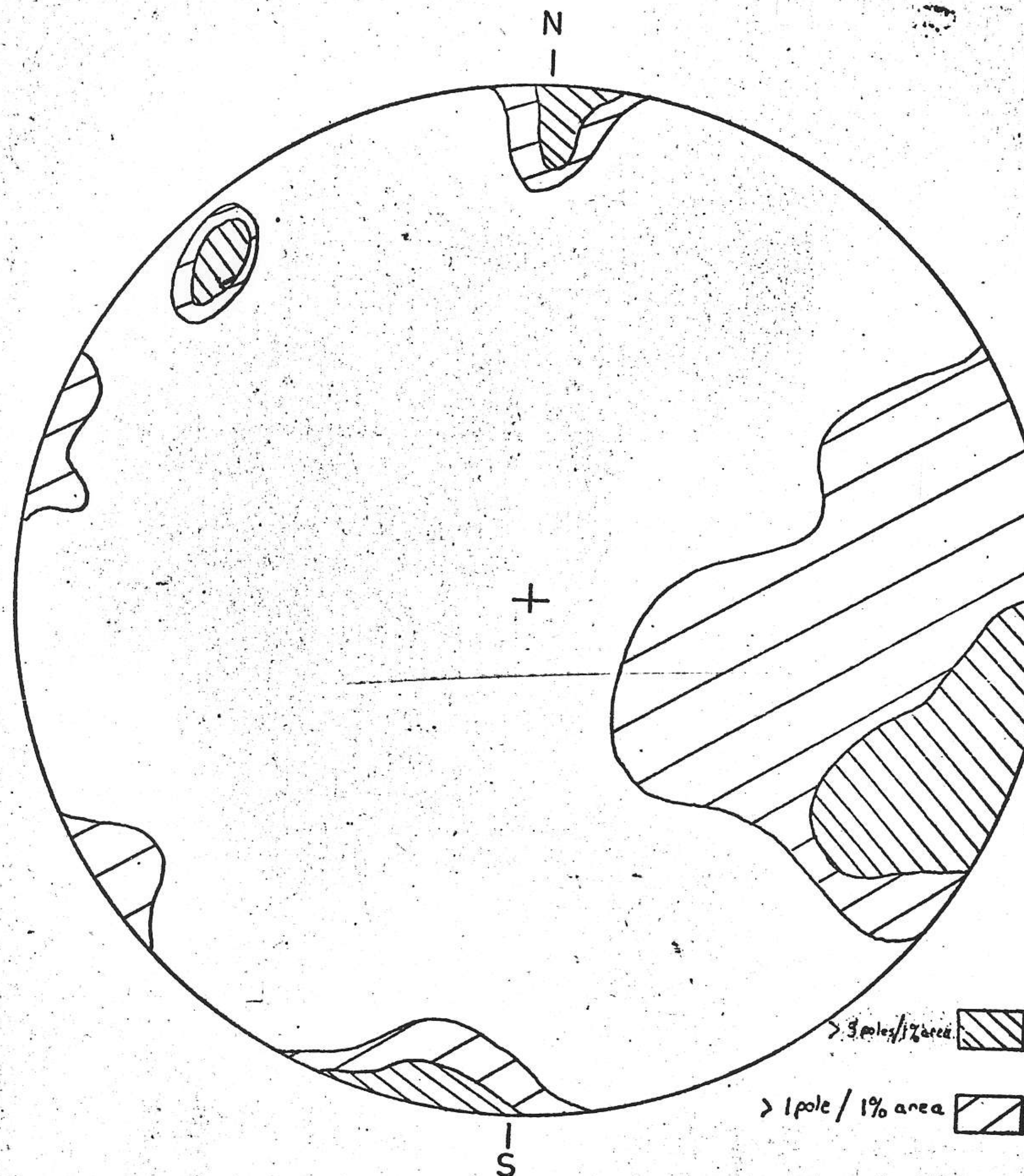

Figure 7 Equal Area Projection of Poles to Non-Mineralized Fractures.

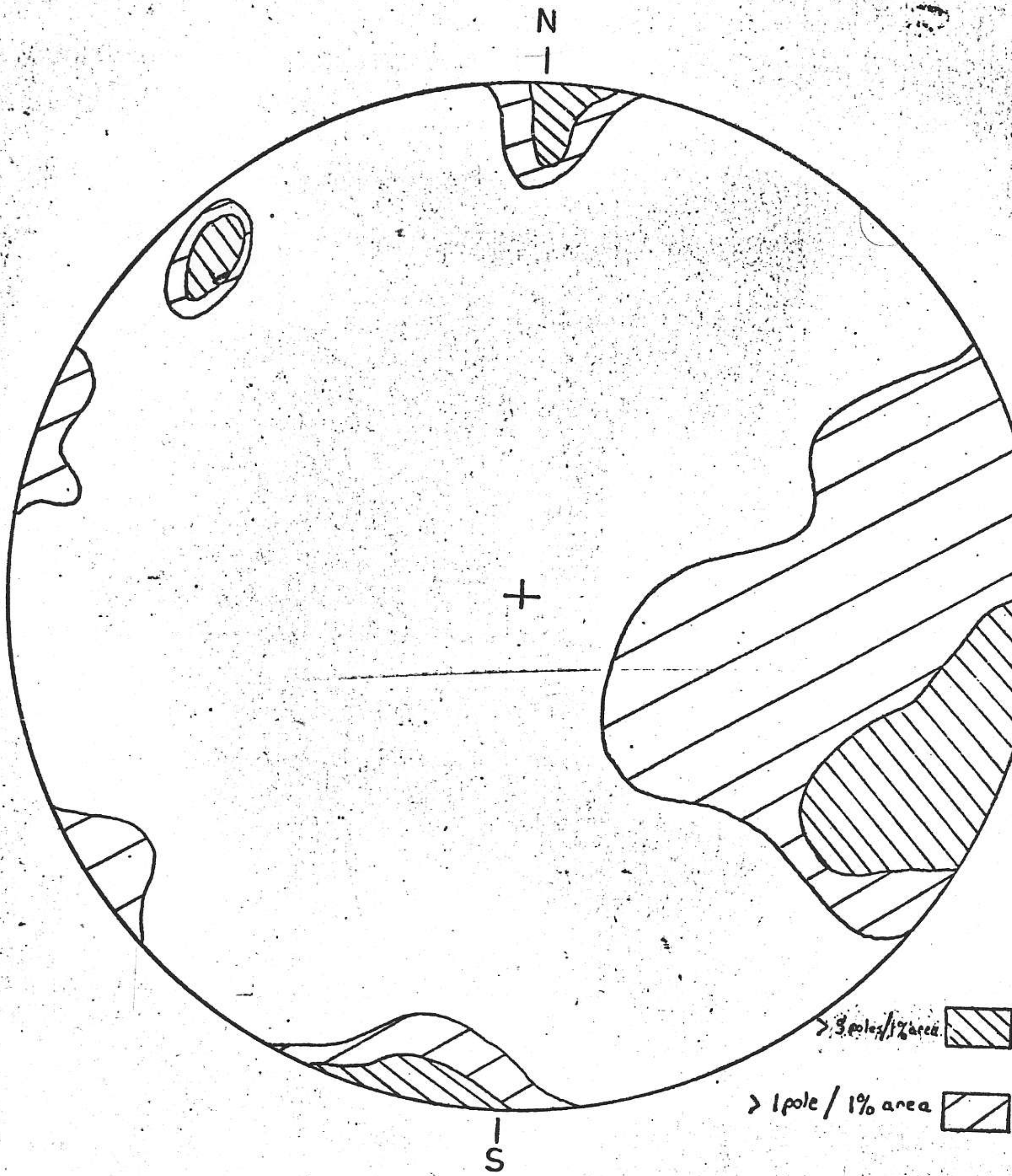

Figure 7 Equal Area Projection of Poles to Non-Mineralized Fractures.

V Relative Silica Content of the Rock Types

Investigation of the relative silica content of the three main rock types, the quartz monzonite, the aplite and the porphyrite dykes, using the glass bead method.

That the refractive index of a glass is determined by its chemical composition has long been known. The application of Harker's variation diagrams (Harker, 1909, pp 118-125) to selected groups of igneous rocks, of one general locality and age, shows that within such groups two rocks with similar silica contents have similar bulk compositions and, if glassy, can be expected to have similar refractive indices. Mathews (1950) has shown that fusing a representative sample of Quaternary volcanic rock of the Garibaldi area, British Columbia, an inverse relation of the refractive index of the fused sample to its silica content. The lower the silica content the higher the refractive index of the glass. Similar experiments by Messrs. G. H. Curtis and D. B. Slemmous, also of the University of California, have concluded similar results from other volcanic suites (Mathews, 1950).

Glass bead analysis (see Appendix) of four porphyritic dykes, three quartz monzonite samples, and two aplite dykes gave relative silica content of these different rock types (Figure 8).

Results from the writer's experiments show a relatively low silica content for the quartz monzonite, a slightly higher silica content for the porphyritic dykes and the highest silica content was measured from the aplite dykes.

Considering the genetic relation of these rock types already determined, the silica content helps to determine different phases of intrusion of the rock types.

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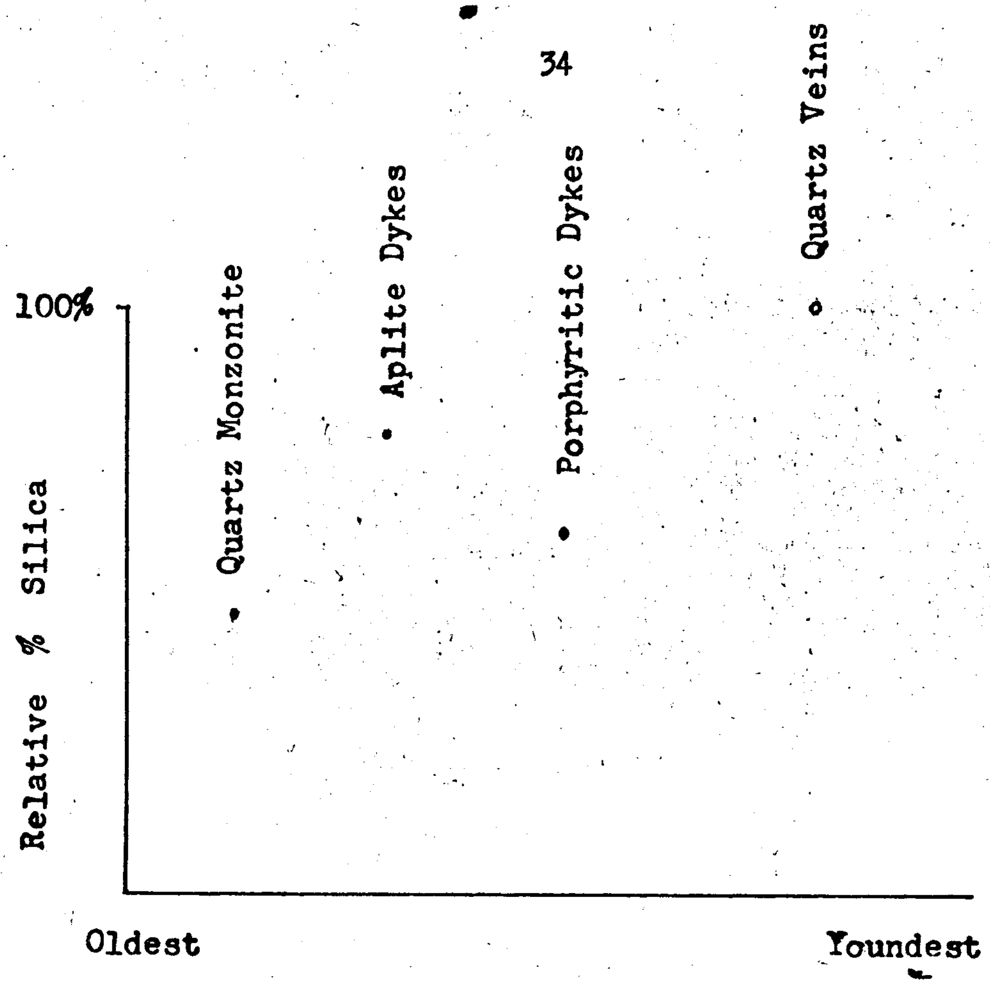

Figure 8 The Bulk Composition, Silica Content, of the Different Rock Types Compared with Their Relative Time of Emplacement.

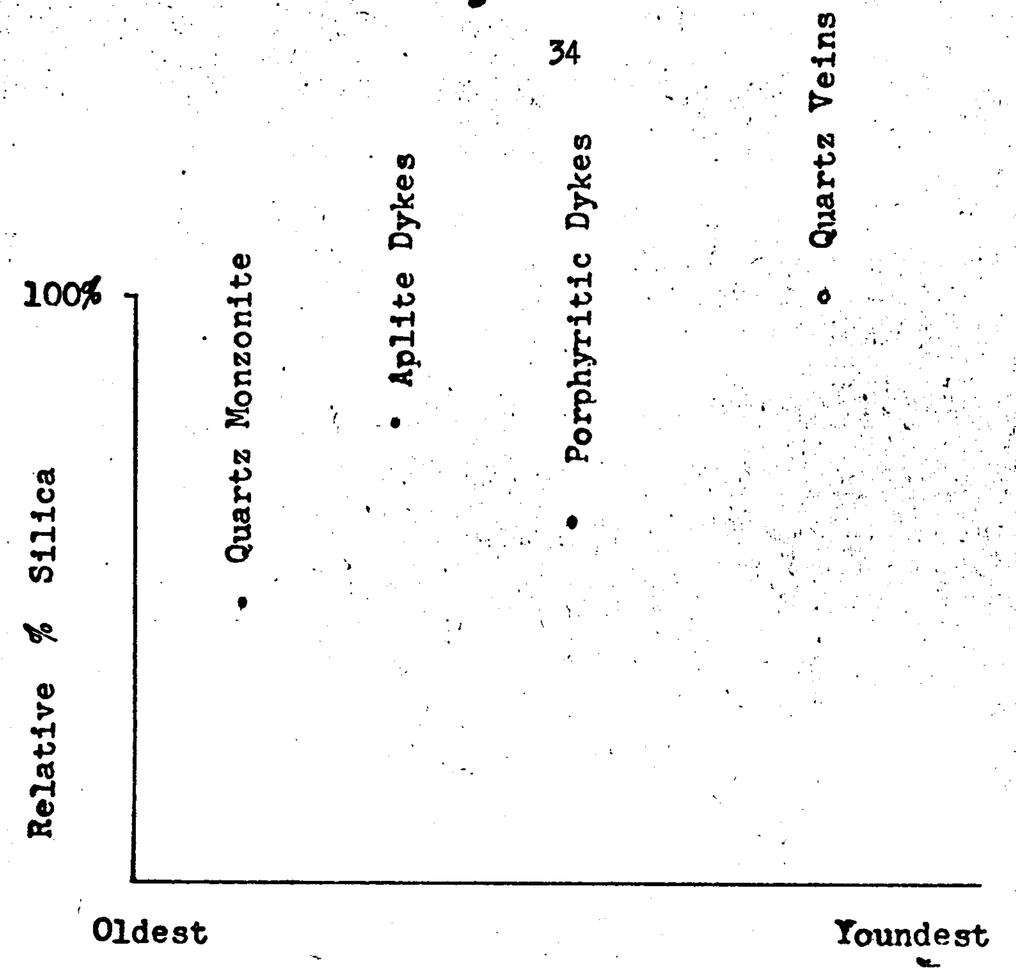

Figure 8 The Bulk Composition, Silica Content, of the Different Rock Types Compared with Their Relative Time of Emplacement.

An increase in relative silica content from the quartz monzonite to the aplite dykes suggests an enrichment of the residual solutions and a late intrusion of the first phase intrusion with silica. This is shown by mineral composition as well; the quartz monzonite contains hornblende, biotite, quartz, orthoclase and plagioclase, while the aplite contains mainly quartz, orthoclase and some plagioclase which has a relatively higher silica content than the mineral assemblage of the host rock.

The porphyritic dykes have a relative silica content slightly higher than the quartz monzonite. This suggests that the intrusions of the porphyry dykes are not directly related to the crystallization or fractional crystallization of the quartz monzonite.

The appearance of plagioclase in all porphyries is clean and hardly, if at all zoned as compared to those of the quartz monzonite, which are extensively zoned. The crystallization of plagioclase in these two rock types was not in the same environment and therefore not associated with the same intrusion. Also the absence of plagioclase phenocrysts in the aplitic stage, related to the host rock intrusion, does not agree with the porphyries being part of the crystallization of the host rock. To get an agreement you would expect physical characteristics of plagioclase to be similar in all phases and perhaps a general increase in silica towards the final stages of crystallization, such as in fractional crystallization.

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VI Alteration

Chloritic and sericitic alterations are the most intense in the north-western part of the map area. This is also the area of greatest mineralization. Alteration is most intense in diamond drill holes 3 and 4, where feldspars are highly altered to clays, micas, and minor epidote, and magmatic biotite is almost completely altered to chlorite and magnetite (Plate 6). Potassic alteration is found mainly as aureoles around mineralized quartz veins and has a characteristic salmon-pink colour. Aureoles are also noted around non-quartz filled mineralized veins.

Outward from this part of the map area alteration tends to decrease in intensity and becomes practically absent on the western side of Patricia Lake. Alteration such as biotite to chlorite, again becomes recognizable further east towards the Falconbridge property (Map 4).

In the case of diamond drill holes 3 and 4, there is relatively little or no mineralization, but about 400 feet south of this intensely altered area in the area of diamond drill holes 1 and 2, molybdenite and small amounts of chalcopyrite occur.

In drill holes 1, 2, 3 and 4 no noticeable change in the degree of alteration was noted over the average drilled depth of 120 feet. In diamond drill hole 5, a slight increase in feldspar alteration is seen to a depth of 330 feet.

Sericite alteration of orthoclase appears as a dusty brown with white mica specs in plane polarized light. Argillic alteration with minor epidote (saussuritization) alteration of plagioclase is similar in intensity to orthoclase but occurs as a much darker brown colour.

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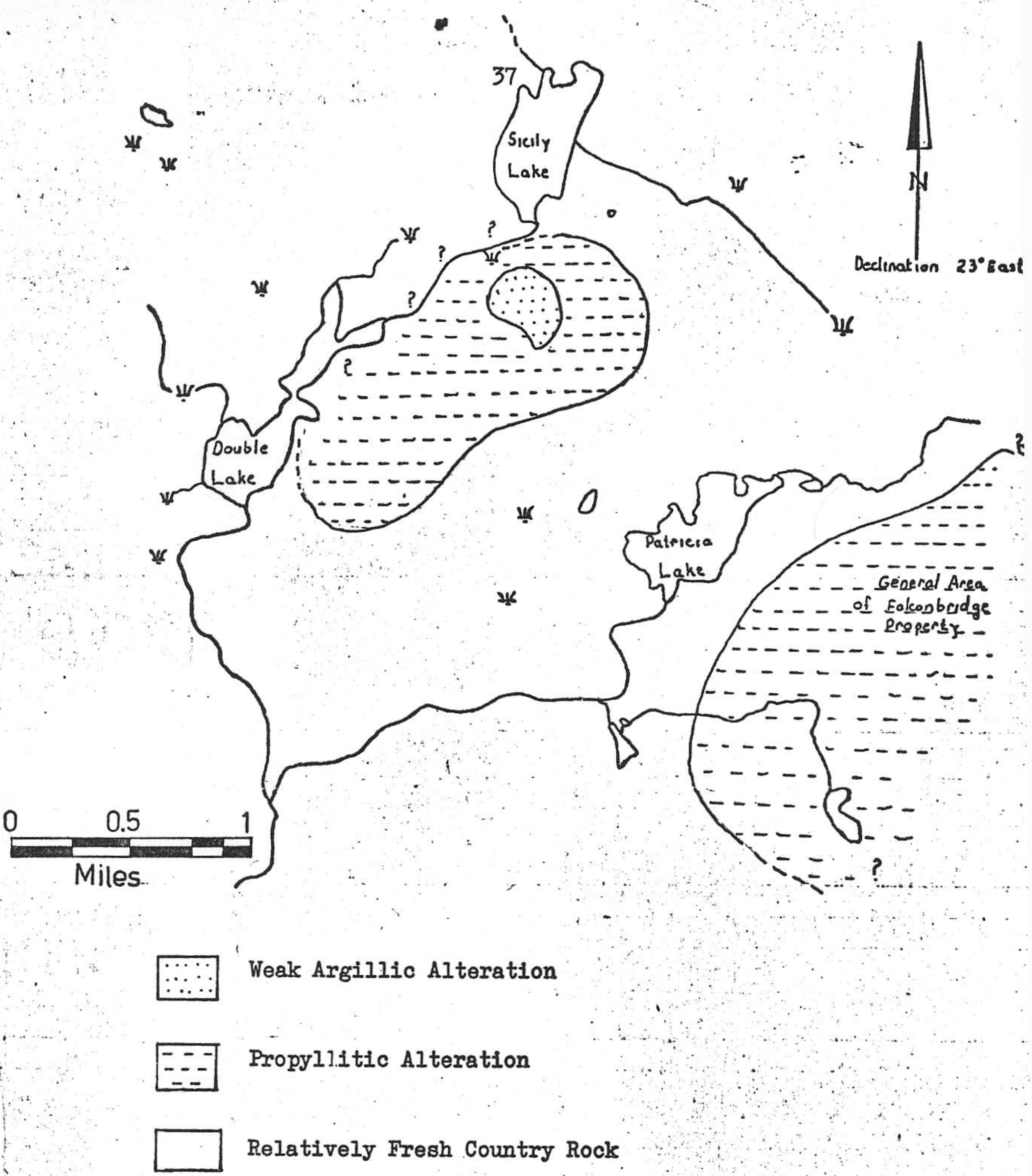
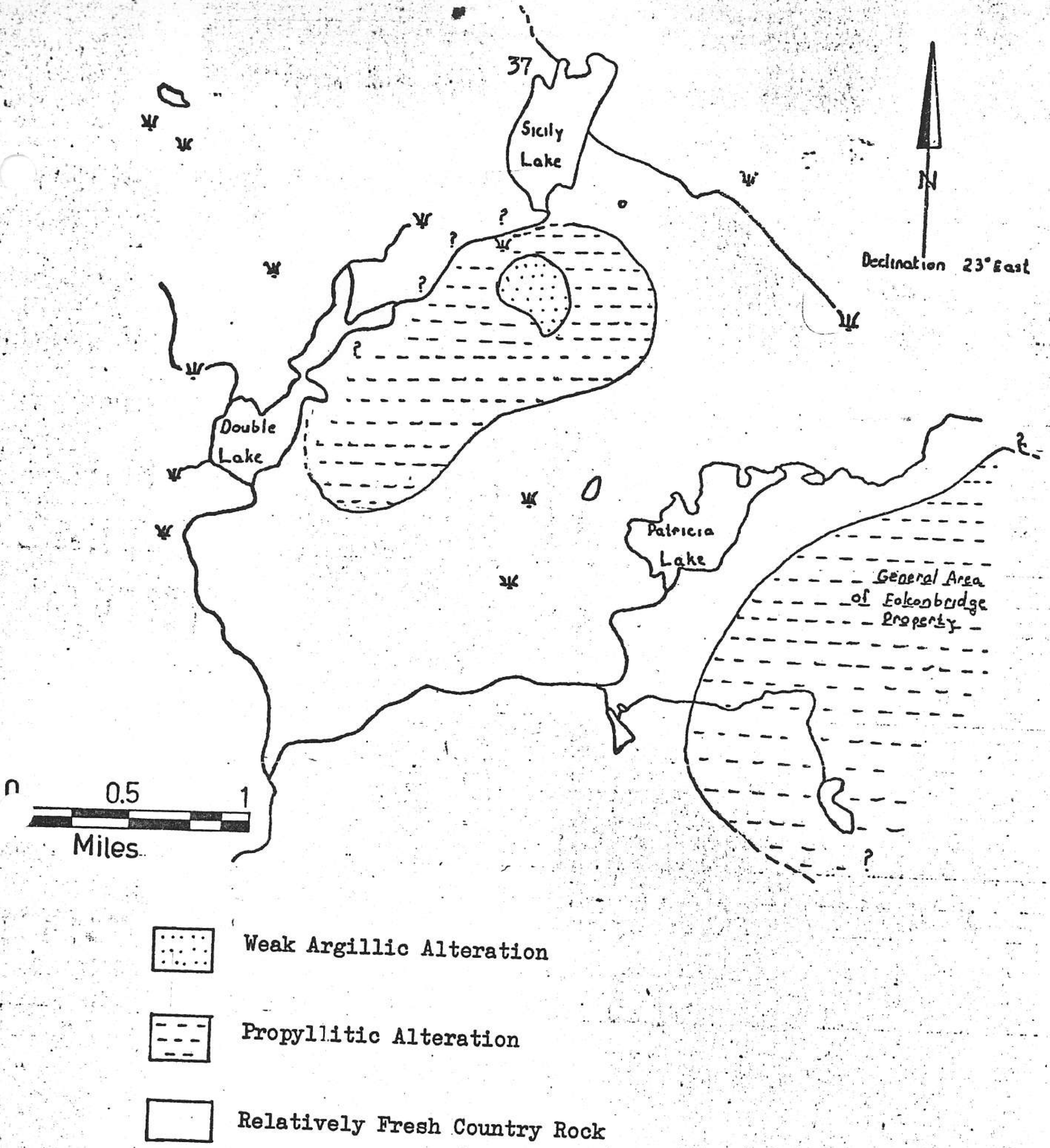


Map 4 Alteration Zones in the Map - Area.



Map 4 Alteration Zones in the Map - Area.

In the intensely altered areas plagioclase is hardly recognizable and is altered to clays and epidote; orthoclase alters mainly to clays and sericite. In the highly altered rocks, small veins of calcite cut all grains; the calcite may be related to albitization of plagioclase (Plate 16).

The degree of alteration of the quartz monzonite is readily judged by rock colour in hand specimen. Weakly altered rocks have only a light pink coloured orthoclase. This is usually accompanied by propylitized plagioclase, which looks green and waxy. More intense alteration gives the whole rock a salmon-pink colour and has a "clay smell" to it; here only the quartz appears unaltered.

Chlorite alteration forms from biotite in the intensely altered areas. In thin section, the biotite is wholly or partially replaced by chlorite and appears light green in contrast to the pleochroic brown of biotite. Chlorite will not accept as much iron or titanium into its lattice as will biotite and therefore it is common to see euhedral magnetite, and less commonly, rutile in and around altered biotite.

Minor hydrothermal biotite is associated with mineralization in quartz-free fractures. Small tabular biotite is the result of potassic alteration associated with the emplacement of the molybdenite.

Quartz is fresh and unaltered throughout the map area. Quartz overgrowths are often seen associated with fractures in the highly altered area, probably related to migration of hydrothermal solutions along these fractures mobilizing silica in the rocks.

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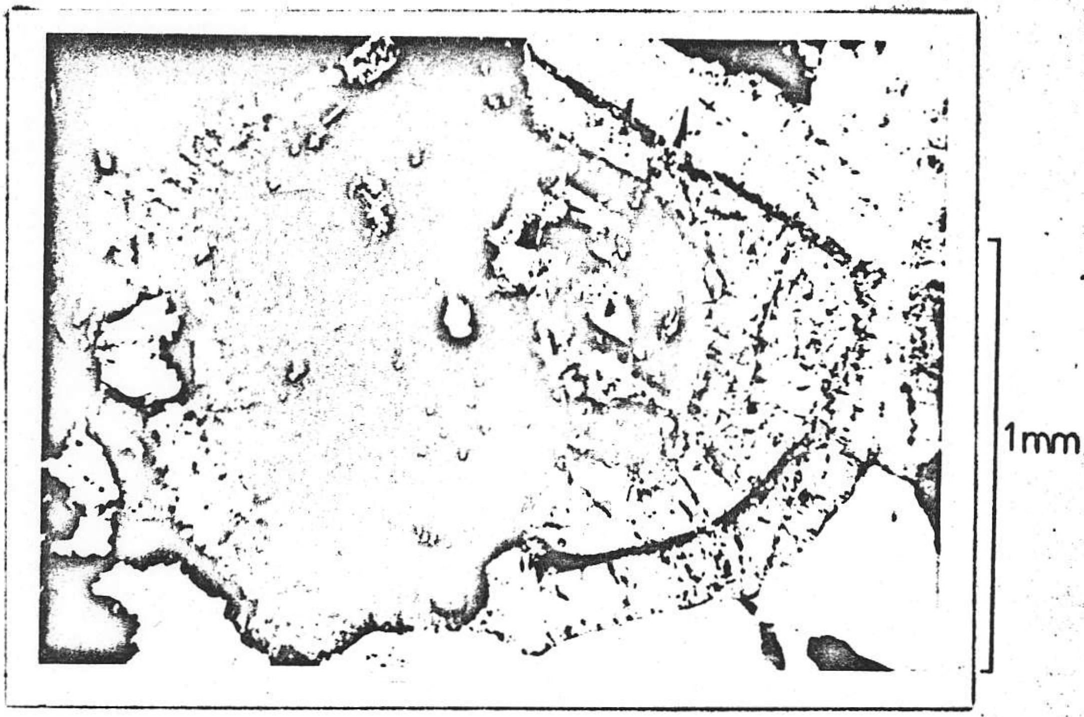


Plate 15 Photomicrograph (crossed nicols) of selectively altered zone in plagioclase of the quartz monzonite.

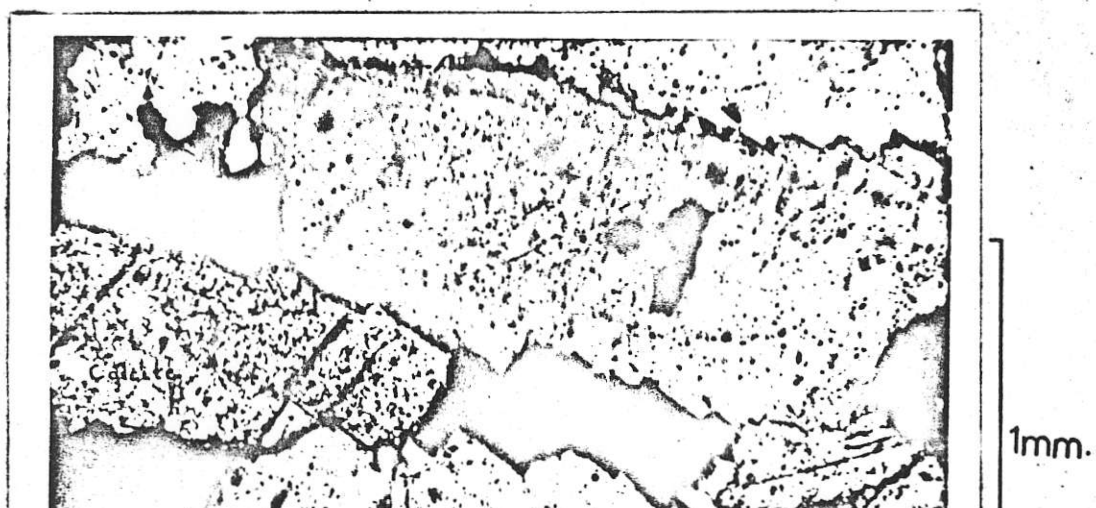
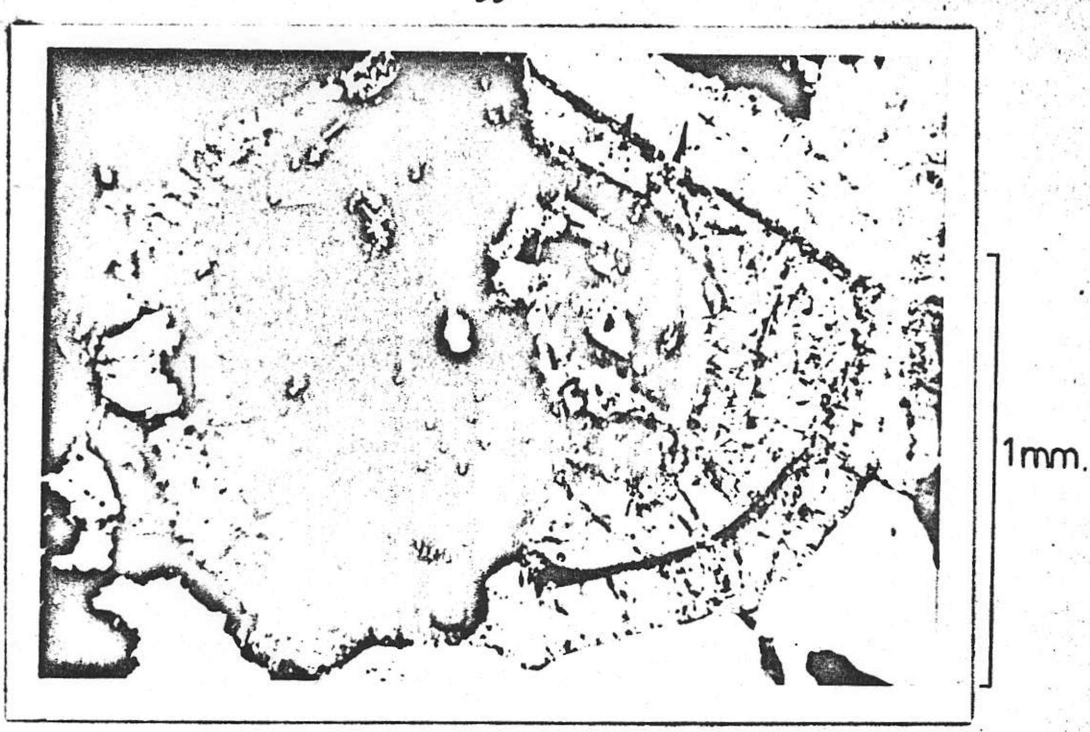


Plate 16 Photomicrograph (crossed nicols) of calcite vein cutting the quartz monzonite in the most intensly altered part of the map area.



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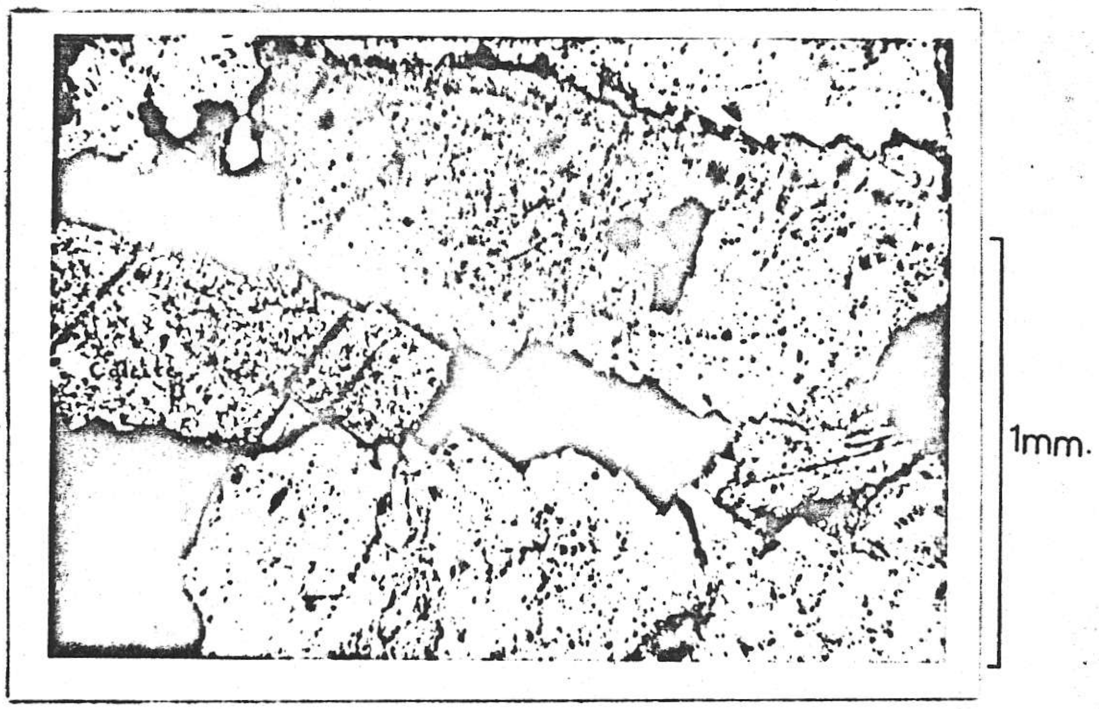

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Mineralization

Mineralization appears to have been deposited in two stages. The first stage is in open spaces in quartz veins; the second stage is into empty fractures. The main area of mineralization has been drilled by diamond drill holes 1 and 2. Quartz-molybdenite veining is common in this area. These veins are usually associated with potassic alteration haloes and often contain vugs with rosettes of molybdenite. The veins commonly strike 102° and have a vertical dip.

The second stage mineralization in quartz-free veins consists of molybdenite associated with minor chalcopyrite and pyrite (Plate 17). This stage of mineralization has two common orientations at 102° dipping vertically and 25° dipping 60° to 70° easterly. The latter set shows shear movement along the fractures, which is post-mineralization. This stage, like the first stage, has a potassic alteration halo of pink feldspar. This halo varies from 1 to 4 inches in width, but is usually dependent upon the width of the mineralized vein.

Molybdenite characteristically forms fibrous masses, irregularly spaced along quartz veins and barren fractures. Molybdenite is deposited later than chalcopyrite but usually shows an intergrown contact with the last phases of the chalcopyrite deposition. Sharp molybdenite-pyrite contacts are noted, suggesting early deposition of the pyrite.

Chalcopyrite is a minor constituent and is related to second-stage mineralization. Chalcopyrite consists of blebs in open spaces within the fracture, not usually larger than 2 millimeters in diameter. Chalcopyrite comprises less than 5% of the total sulfides.

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Plate 17 Photomicrograph (reflected plane pol. light) of chalcopyrite and molybdenite mineralization in quartz barren fracture.

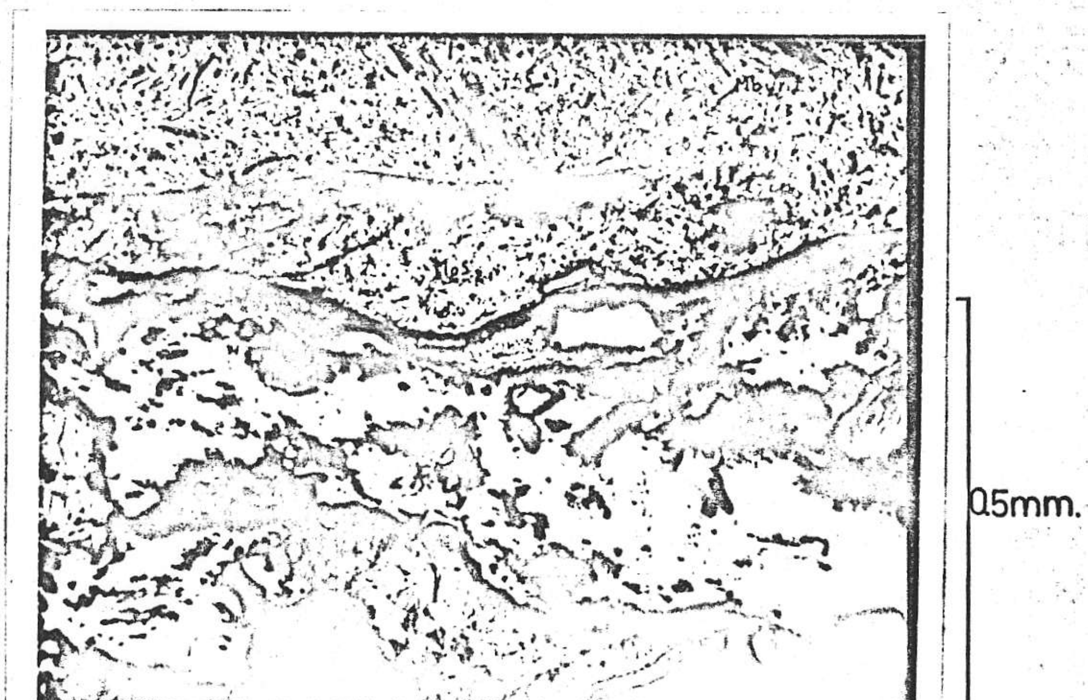
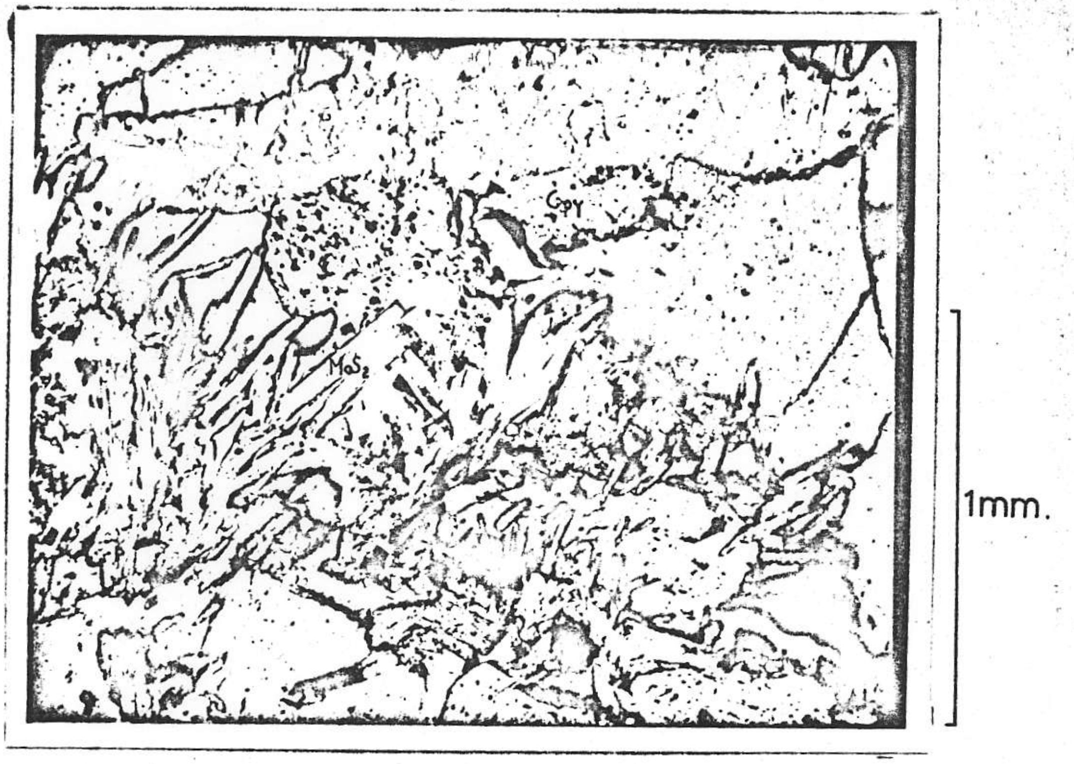


Plate 18 Photomicrograph (reflected plane pol. light) of molybdenite mineralization in the sheared fractures. Photomicrograph is perpendicular to the fracture plane and at right angles to the shear movement.



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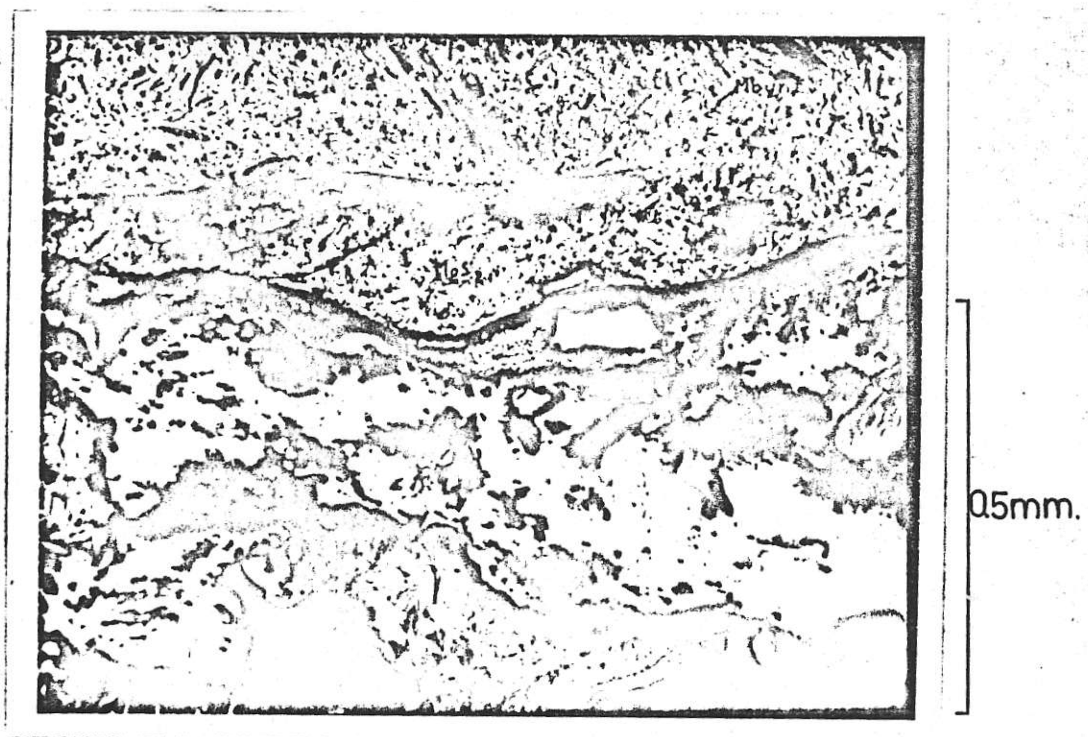

Plate 18 Photomicrograph (reflected plane pol. light) of molybdenite mineralization in the sheared fractures. Photomicrograph is perpendicular to the fracture plane and at right angles to the shear movement.

Pyrite occurs as euhedral crystals disseminated in the mineralized area and also associated with barren fracture filling, with and without molybdenite. Pyrite pre-dates chalcopyrite and molybdenite in the barren fractures.

Mineralization of this same type is found continuously down diamond drill holes 1 and 2, but still not of economic concentrations at this time.

In the mineralized area, that around diamond drill holes 1 and 2, the mineralized vein density is not greater than one vein every two feet. The veins are usually thin, 1 to 4 millimeters in width, with irregularly disseminated mineralization along them.

Several outcrops have been blasted around diamond drill holes 1 and 2, and show the same characteristics as the drill core; however, an additional feature is noted: several veins of epidote with irregular masses of magnetite along them. Vein width is approximately 5 millimeters, strikes 102° and has a near vertical dip. An aureole, 10 to 50 millimeters wide, of potassic alteration with lightly disseminated molybdenite surrounds the veins. Other epidote veins are noted in the more intensely altered rocks of the map area but are unmineralized.

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VIII Conclusion and Genesis

Intrusion of the Raft Batholith and its crystallization to a medium to coarse grained biotite quartz monzonite occurred in late Jurassic to early Cretaceous time. When the batholith cooled, two sets of fractures developed, striking 102°, 25° and dipping 90°, 65° easterly respectively. The first set of fractures, striking 102°, with a near vertical dip, have injections of aplite dykes along them, formed while the quartz monzonite was still relatively hot. This gives rise to gradational contacts with the host rock and fine to medium grained dykes. Aplite dykes are the last injection of the quartz monzonite phase.

A second phase of fracture injection, with a slightly higher silica content than the quartz monzonite batholith, has been emplaced as porphyry dykes of rhyolitic to quartz latite composition along the same set of fractures as the aplite.

The intrusion of the second phase has been into a relatively cool host rock, resulting in chilled margins and aphanitic ground masses in the porphyry dykes.

Quartz veining followed the intrusion of the porphyritic dykes. The late phases of quartz veining are accompanied by molybdenite mineralization. Molybdenite and minor chalcopyrite continued to deposit in barren fractures after quartz veining had ceased. During this time the second set of fractures, striking 25° and dipping 60° to 70° easterly, were the site of emplacement of molybdenite and chalcopyrite mineralization. Late movement along this set of fractures sheared and smeared the mineralization along the fracture

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The intense alteration found in the area of diamond drill holes 3 and 4 is the highest grade of alteration in the map area. Quartz has minor overgrowths, orthoclase has altered to clay and minor sericite, plagioclase has altered to clays and epidote, plus minor carbonate, and biotite is completely altered to chlorite. Only minor alteration of hornblende is present. This represents a zone of argillic alteration. Outward from this area, alteration grades into propyl itic alteration. Quartz is fresh, orthoclase has altered to clays, plagioclase has altered to clays and minor epidote, biotite is partially altered to chlorite, and hornblende is practically fresh. This trend is most visible towards diamond drill holes 1 and 2. This is also the area of mineralization and associated aureoles of potassic alteration. Further away from diamond drill holes 3 and 4, the host rock becomes fresh and very little alteration is noted.

According to Torwell and Guilbert (1970), this zoning of argillic to propyl itic alteration corresponds to the outermost zones of their idealized porphyry. The center of their idealized porphyry is a potassic alteration zone which grades out into a phyllic zone, and the argillic zone is next followed by a propyl itic zone. Their main ore shell is located on the boundary of the potassic and phyllic zones.

The alteration zones of the map area of this thesis can be likened to the outer zones of Torwell and Guilbert's idealized porphyry.

The geology of stockwork molybdenum deposits has many analogies with porphyry coppers (Lowell and Guilbert, 1970) although there are notable differences. The stockwork deposits are associated with siliceous intrusives. Molybdenite is often the only hypogene ore planes. Potassic alteration aureoles related to the veining and mineralization processes formed around the mineralized fractures.

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The geology of stockwork molybdenum deposits has many analogies with porphyry coppers (Lowell and Guilbert, 1970) although there are notable differences. The stockwork deposits are associated with siliceous intrusives. Molybdenite is often the only hypogene ore mineral present and is relatively uniformly distributed near the top of intrusives or at their contacts. Hydrothermal alteration is spatially associated with metalization, whereas supergene enrichment appears to be absent. (From Clark, 1972) not in V-fences !

The author believes the porphyry dykes of the map area represent a second-phase intrusion, and quartz veining and mineralization have a similar origin. The alteration zones noted are results of later hydrothermal activity than that related to the Raft Batholith. Clark (1972) has suggested that the presence of second-phase and multiphase intrusions are usually associated with caps of mineralization close to the intrusive contacts in known deposits in the Western Cordillera of North America.

To the north of the Raft Batholith, Soregaroli (1968) has shown that mineralization associated with the second-phase intrusion of the Boss Mountain Stock into the Takomkane Batholith, of slightly older age than the Raft Batholith, is in breccia pipes at and above the contact between the stock and the batholith. Contacts of the second-phase intrusion with the Raft Batholith appear to be an area of interest for further studies. Mineralization at depth, depending on the presence of the contact between the second-phase intrusion and the batholith, could be a possible stockwork molybdenum environment of economic interest.

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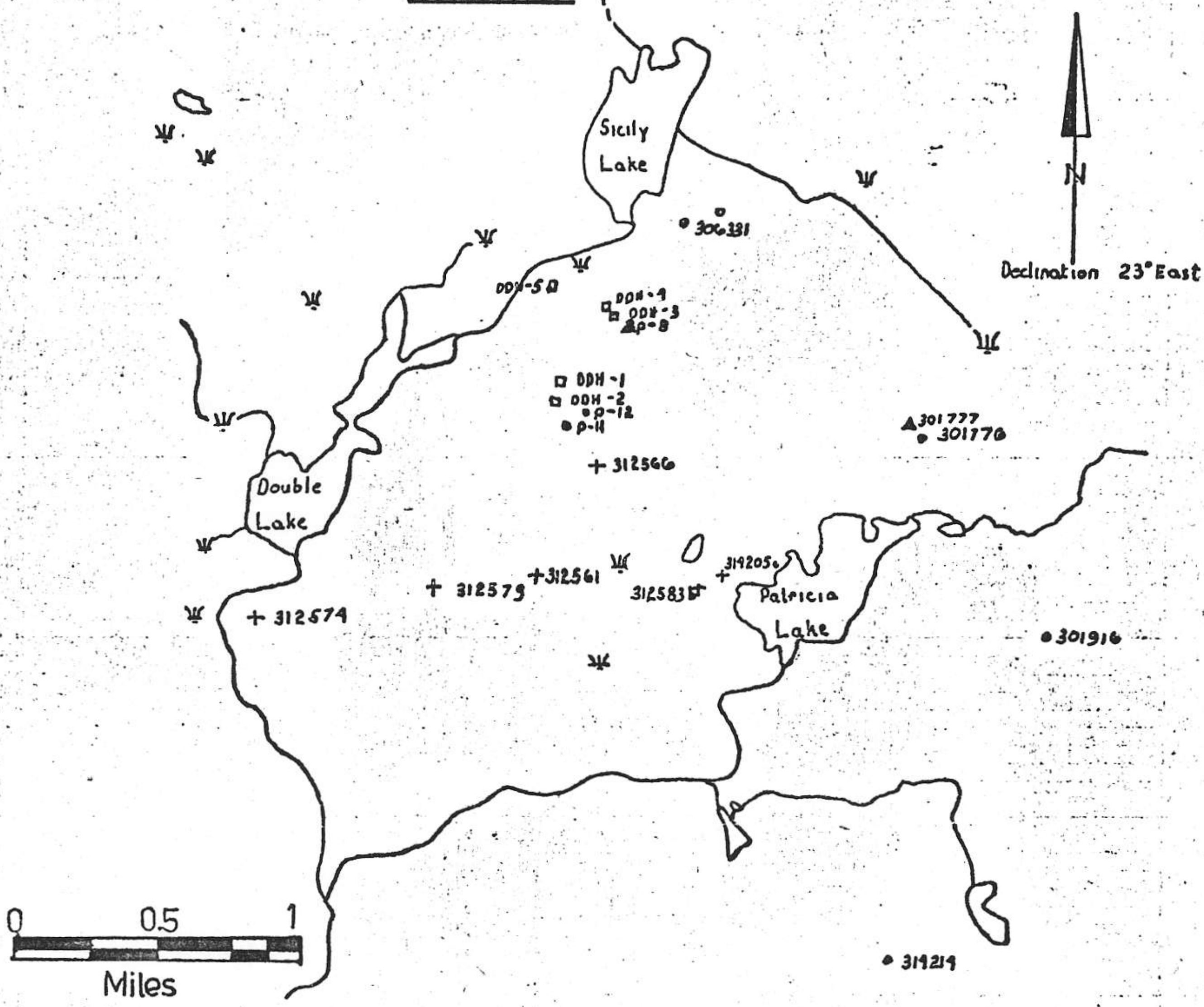
APPENDIX I



- DDH ▫ Diamond Drill Hole Rock Specimen of the Quartz Monzonite
- • Rock Specimen from Surface Exposure of the Quartz Monzonite
- + Rock Specimen from Porphyritic Dykes
- ▲ Rock Specimen from Aplite Dykes

Location of Rock Specimens Referred to in text.

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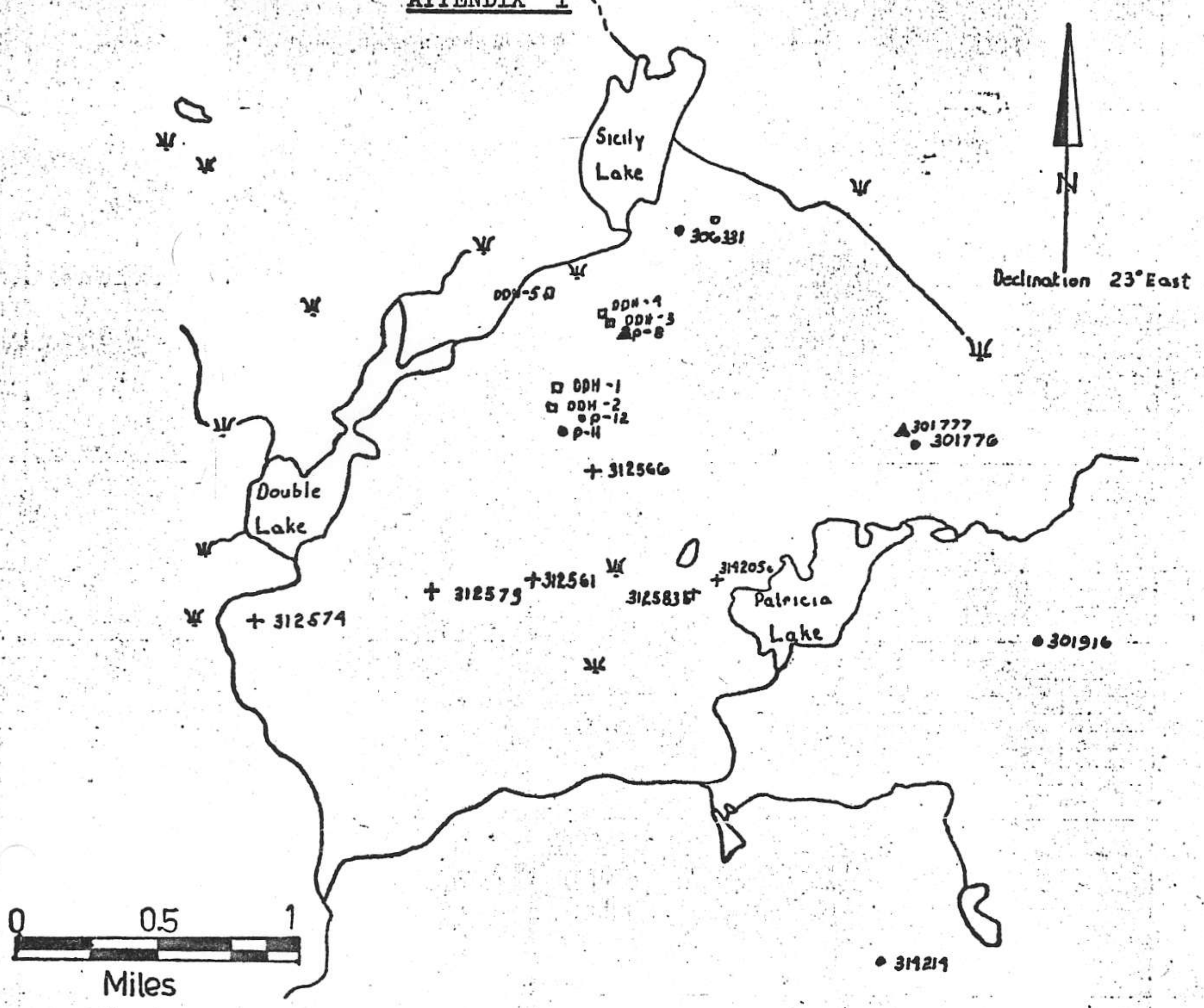

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APPENDIX II

Glass bead results:

ROCK TYPE	NUMBER	RANGE OF REFRACTIVE INDEX OF GLASS BEADS
Quartz Monzonite	p-12	1.528-1.523
	p-11	1.528-1.53
	306331	1.53-1.538
Aplite Dykes	p-8	1.496-1.5031
	301777	1.49-1.496
Porphyritic Dykes	314205c	1.503-1.5109
	312566	1.5031-1.5109
	312583b	1.5109-1.5141
	312579	1.5109-1.5141

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