ALTERATION AND MINERALIZATION IN THE JARILLA MOUNTAINS,

OTERO COUNTY, NEW MEXICO

by

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AN INDEPENDENT STUDY PRESENTED TO

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ABSTRACT

Most of the mineral deposits in the Ohaysi Valley area in South-Central New Mexico are products of metasomatism and thermal metamorphism produced by the intrusion of Tertiary igneous masses, varying in composition from syenodiorite to quartz monzonite, into a Paleozoic sedimentary sequence consisting mostly of cherty, calcareous beds and shaly siltstone. Magnetite developed in calcareous beds, adjacent to igneous contacts. Associated with the magnetite is more or less specularite, almost always pyrite, and little chalcopyrite; and ordinary contact silicates including garnet, diopside and minor wollastonite and hornblende.

In the hornblende monzonite stock, second stage within the intrusive sequence, hydrothermal alteration has been intense. The intrusive rock is host to zones of potassic, phyllic and argillic-propylitic assemblages. Copper metallization is overlapping the potassic and phyllic zones. Supergene alteration has been superimposed on the preexisting hypogene hydrothermal alteration and makes difficult the interpretation of mineral assemblages in the different alteration zones. Intense oxidation within the potassic and phyllic zones has destroyed hypogene sulfides so an estimation of the distribution of pyrite and chalcopyrite through these zones could not be done.

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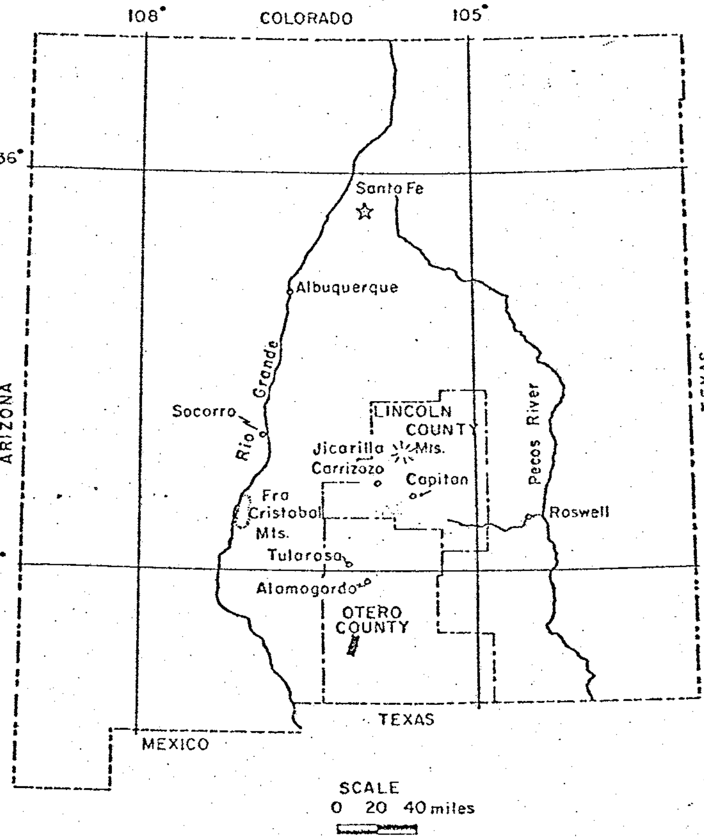
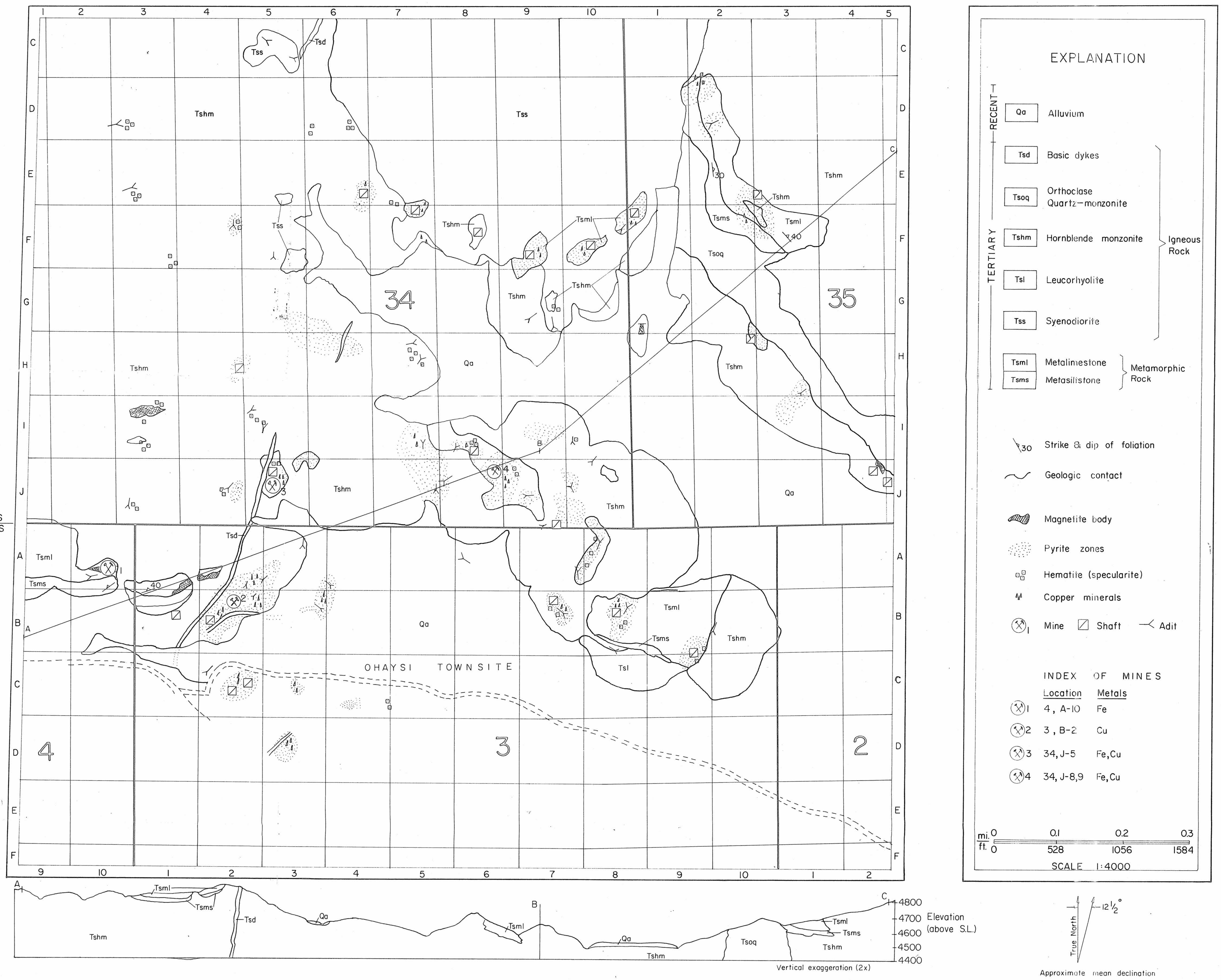


Figure 1
LOCATION MAP.

FIGURE 2. GEOLOGIC MAP OF THE OHAYSI VALLEY, JARILLA MOUNTAINS, OTERO COUNTY, NEW MEXICO



A

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Figure 3. View of the Ohaysi Valley area.

A. Looking north.

B. Looking east.

M, Hornblende monzonite; S, syenodiorite.

INTRODUCTION

Purpose

The purposes of this study were: 1) Discussion of the igneous activity and related thermal metamorphism and mineralization; and 2) to determine the types of alteration present within the hornblende monzonite stock and its relation with the disseminated copper mineralization.

Location

The Jarilla Mountains are located south-southwest of Alamogordo, in the south-central New Mexico (fig. 1). The area is bounded on the east by the U.S. Highway 54. It can be easily reached by 3 miles of dirt road travelling north from the town of Orogrande, New Mexico.

Method of Investigation

Geologic mapping at a scale of 1:4.000, and collection of field data and samples was done during the spring of 1973. A total period of 30 days were spent in the field.

Aerial photographs provided by the New Mexico State Bureau of Mines and Mineral Resources were used to locate samples and to delineate contacts between intrusive rocks and metamorphic skarns (roof pendants or xenoliths).

More than 240 specimens were collected of which, 70 thin sections were cut; these 70 samples were also analyzed by X-ray flouresence and 9 major oxides and 3 minor elements were determined.

Point counts (1000 points) were made on thin sections, considered to be representative of the units described.

Acknowledgements

This project was done under the direction of Dr. R. E. Beane to whom I want to express my sincere appreciation for valuable assistance and encouragement. Appreciation is expressed to Drs. A. J. Budding and C. W. Walker for their assistance and suggestions.

GEOLOGY

A sequence of igneous rocks varying in composition from syenodiorite to quartz monzonite intruded marine sediments of the Upper-Paleozoic. Metasomatism and thermal metamorphism, accompanied the intrusions.

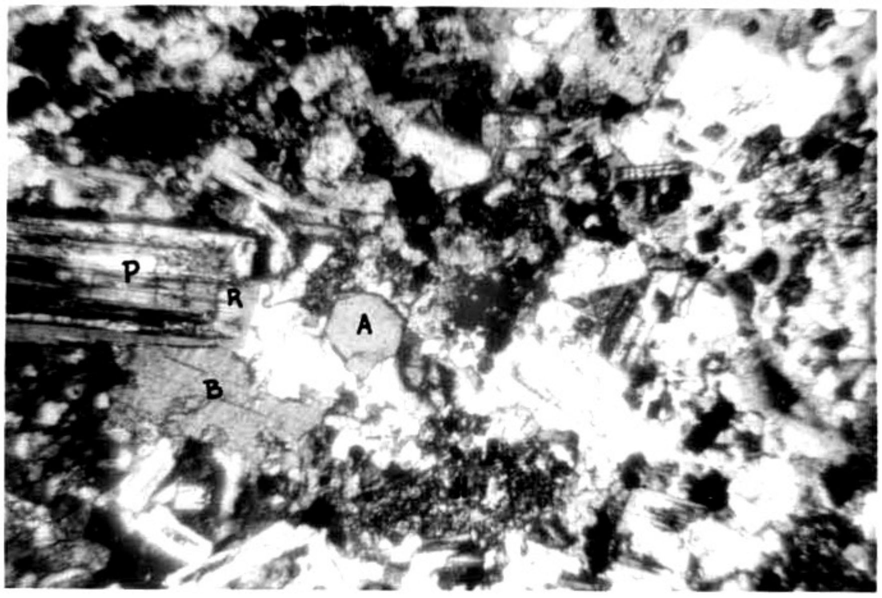
Igneous Rocks

At least three major intrusive bodies may be distinguished in the area: 1) Syenodiorite, 2) hornblende monzonite, and 3) Ortoclase quartz-monzonite. These may represent succesive stages of a normal magmatic-differentiation, in a magma of intermediate composition and, probably all three were intruded during a short interval of time. Basic dikes were intruded along fractures in the igneous masses and may represent later stages of intrusive activity.

Syenodiorite

This intrusive rock occurs in the north-central part of the area in secs. 34 and 35. It is a dark, massive, fine to medium-grained syenodiorite. A modal analysis of a typical sample (LJ 210.Sec.35,D-1) gives the following composition.

Plagioclase (An.65)	29.5
Plagioclase: An.8.(Albitic rims on plagioclase An.65)	9.8
Orthoclase	33.1
Biotite	8.0
Hornblende	6.3
Augite	1.8



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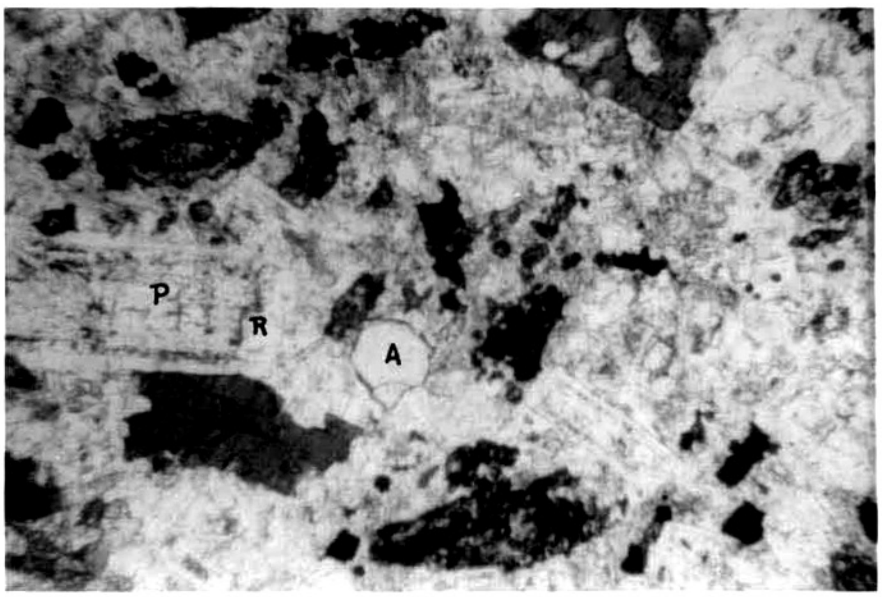

B

Figure 4. Thinsection of syenodiorite.

P, plagioclase (An 60); R, albitic rim

B, biotite; H, hornblende; A, apatite

A. Crossed nicols. B. Ordinary light. X 30

Quartz	5.2
Pyrite	2.5
Accessories (Magnetite, epidote, apatite, sphene)	3.8
TOTAL	100.0%

The syenodiorite shows some variation in composition. Potash feldspar increases close to the contact with the hornblende monzonite. On the other hand biotite almost disappear and hornblende content is very high in contact with metamorphic skarns (Sample LJ 218 A Sec. 35, F.1).

Plagioclase feldspar is represented by euhedral crystals showing good albite, and combined Albite-Carlsbad twinning. The anorthite component of the plagioclase averages 60 per cent.

The plagioclase (An 60) crystals have a noticeable rim of light colored albite (An 8). Quartz and orthoclase appear in anhedral grains which are interstitial to the plagioclase crystals. Hornblende sometimes rims and replaces augite and it is also replaced by biotite. Typical iron biotite is present as small unoriented flakes. The pleochroic formula is X = yellowish brown, Y = reddish brown, Z = dark brown. Pyrite and magnetite replace and envelop hornblende and biotite.

The general picture suggests that the syenodiorite was emplaced in tow different episodes. During the first, deeper stage, plagioclase (An 60) and piroxenes crystallized, and with the residual fluids were emplaced in a shallower intrusion from which quartz and orthoclase were deposited from residual fluids. These fluids also reacted but failed to completely dissolve the plagioclase (An 60) crystals producing the albitic rims. During the same late magmatic process, biotite replaced hornblende and hornblende in turn rimmed and replaced pyroxene. The process

Figure 5. Syenodiorite intruded by hornblende monzonite.
M, hornblende monzonite; S, syenodiorite.
Looking north.

of cooling was probably very rapid and so a complete equilibrium between residual fluid and former palgioclase and pyroxene could not be attained.

Syenodiorite is the oldest intrusive in the area and later igneous rocks exhibit intrusive relations to the syenodiorite. Particularly clear is the contact with the hornblende monzonite in Sec. 34 E-7, F-7 (fig. 5). Monzonite dikes and apophyses cut the syenodiorite and on the other hand numerous xenoliths of syenodiorite enclosed in the hornblende-monzonite are present along the contact.

Leucorhyolite

A single small out-crop of a white, hard, aphanitic rock occurs in Sec. 3, C-8. Petrographically this rock is a leucorhyolite porphyry with the following estimated composition: sodic plagioclase phenocrysts 15 per cent; matrix quartz 25 per cent; matrix potash feldspar 50 per cent; calcite, 5 per cent; accessories (sericite, pyrite, limonite), 5 per cent. (From sample LJ 56A, Sec. 3, C-8).

The plagioclase phenocrysts showing a weak sericitization are contained in a fine-grained matrix of quartz and potash feldspar. Calcite disseminated throughout the matrix seems to be a product of contamination by reaction with the nearby metamorphic skarn.

The leucorhyolite in this area may represent a chilled border of the hornblende monzonite in contact with the sedimentary sequence. The igneous rock becomes finer-grained, mafics disappear and gradually pass into the aphanitic leucorhyolite. Some pyrite develops close to the contact.

Hornblende Monzonite

Succeeding the syenodiorite in the intrusive sequence is the

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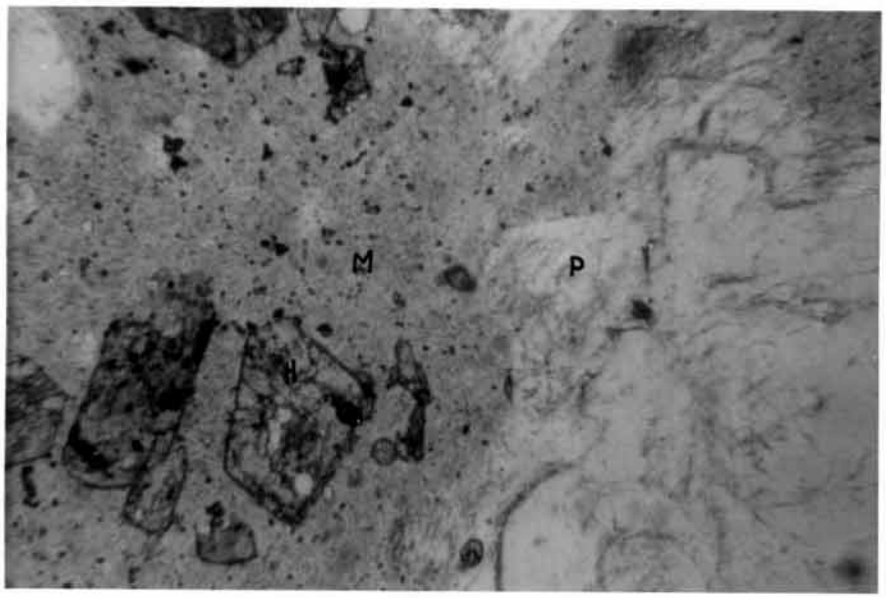


B

Figure 6. Thinsection of hornblende monzonite

P, plagioclase (An 30); H, hornblende

M, quartz-potash feldspar matrix

A. Crossed nicols. B. Ordinary light. X 30

hornblende monzonite. This is the most abundant rock in the Ohaysi Valley area, and probably in the Jarilla Mountains. The hornblende monzonite is a gray to tan color, porphyritic rock (fig. 6). A modal analysis of a sample (LJ 101, Sec. 3, A-3) gives the following composition:

Plagioclase (An 29)	31.8
Orthoclase	43.6
Quartz matrix	5.0
Quartz "eyes"	1.6
Hornblende	13.4
Epidote	2.2
Accessories (Sericite, biotite, sphene, zircon apatite, pyrite)	2.4
TOTAL	100.0%

Some variation in composition was observed specially in the contact with the syenodiorite (Samples LJ 160 and LJ 161, Sec 34, E-6 and LJ 191 and LJ 192 Sec. 34, G-9). Quartz increases up to 20 per cent and the composition of the rocks falls in the quartz monzonite range. Hornblende is less abundant along the syenodiorite-hornblende monzonite margin. Some diopside is present close to metamorphic skarns.

Plagioclase feldspar is represented by phenocrysts averaging about 2 millimeter in size. The anorthite component of the plagioclase averages 30 per cent (oligoclase, andesine). Twinning according to the albite law is present and zoned crystals are rather common.

Potash feldspar with minor quartz form the groundmass of the porphyritic rock. Quartz is also present as small anhedral grains but almost never constitutes more than 5 per cent of the rocks.

Hornblende is present as prismatic crystals. Biotite and chlorite

Figure 7. Basic dike intruded into hornblende monzonite.

D, diabase dike; M, hornblende monzonite

Looking north.

(probably prochlorite) when present, envelop and replace hornblende. Epidote is rather common alteration product of hornblende and sometimes in plagioclase. Calcite commonly replaces epidote and hornblende. It is also locally abundant in irregular masses and veinlets and is probably due to contamination by metamorphic xenoliths. Apatite, zircon, and sphene are common accessories.

Magnetite and pyrite are present in two different forms: 1) grains with rectangular, square or rombic cross-sections are disseminated throughout; and 2) aggregates of magnetite and pyrite replace or are present around hornblende crystals.

Titanium minerals (rutile, sphene and leucoxene) are also present within hornblende crystals.

Hornblende monzonite has been highly altered by hydrothermal solutions. Some sulfide mineralization accompanied the hydrothermal alteration. This will be discussed in detail in the alteration section.

Orthoclase Quartz Monzonite

Following the hornblende monzonite in the intrusive sequence is a light, brown to gray, porphyritic rock with large, pink, euhedral crystals of orthoclase. This rock named orthoclase quartz monzonite (fig. 8), occurs in the northeast part of the area in Sec. 35. A modal analysis of a sample (LJ 228, Sec. 35, G-3), gives the following composition:

Plagioclase (An 13)	26.1
Orthoclase phenocrysts	12.4
Orthoclase matrix	28.7
Quartz matrix	7.0
Quartz "eyes"	2.8

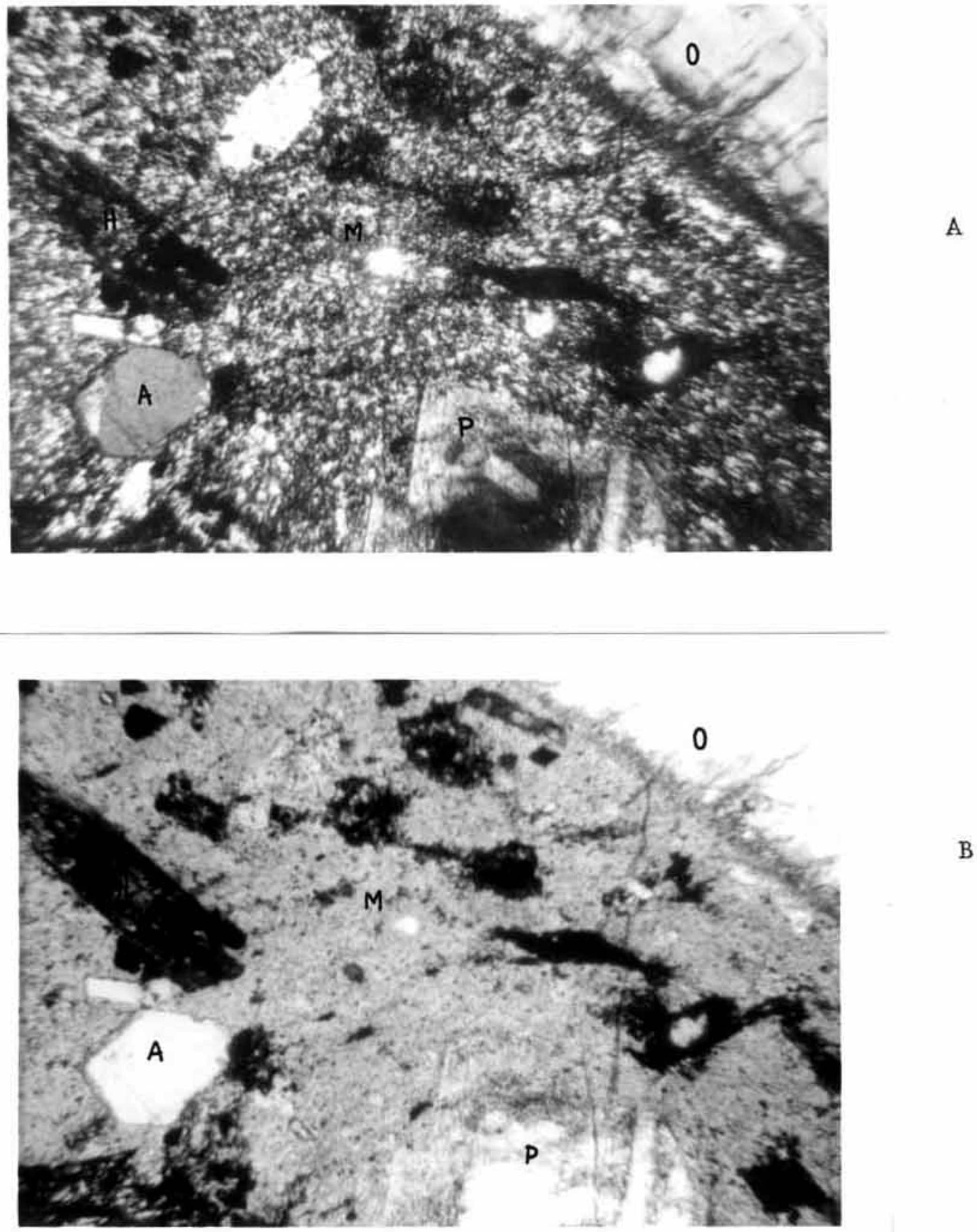


Figure 8. Thinsection of orthoclase quartz monzonite.
O, orthoclase; H, hornblende; P, plagioclase
M, quartz-potash feldspar matrix; A, apatite
A. Crossed nicols. B. Ordinary light. X 30

Hornblende	10.6
Calcite	3.9
Accessories (Biotite, epidote, sphene, apatite, zircon, pyrite)	8.5
TOTAL	100.0%

The orthoclase phenocrysts probably constitute only 5 or 6 per cent of the rock. A big phenocryst in the thin section makes the volume per cent of orthoclase phenocrysts too high.

The plagioclase feldspar is represented by euhedral to subhedral phenocrysts, most of them showing a complex zonation. The anorthite content of the plagioclase averages 15 per cent. Zoned crystals show a progressive increasing in calcium to the center of the crystal. Plagioclase is rimmed by sericite and clay.

Potash feldspar is the main component of the matrix and is moderately argillized giving to the matrix a cloudy appearance. Minor quartz is present in the matrix. Quartz is also present as small to large, clear "eyes".

Hornblende is present as phenocrysts mostly replaced by epidote, calcite and sphene. Some whitish earthy material seems to be leucoxene.

Aggregates of pyrite and magnetite are present in or around hornblende crystals.

The rock shows some symptoms of hydrothermal alteration but none as intense as in the hornblende monzonite. Sericite and clay are rimming feldspar phenocrysts and the matrix is moderately argillized. Propylitization is in general moderate but sometimes the hornblende crystals are largely to completely destroyed.

Orthoclase quartz monzonite intrudes the hornblende monzonite.

This relation is clearly seen in Sec. 35, G-3, H-3. The whole outcrop of the orthoclase quartz monzonite (fig. 2) resembles a big dike striking north westerly and cutting the hornblende monzonite.

Dikes

Some small dikes, 3 to 5 feet wide and varying in composition from basalt to diabase cut the hornblende monzonite. Most of them where intruded along fractures produced by cooling of the igneous mass. Most of the joints (fig. 9B) dip very steeply and more strike northeasterly which coincides with the position of the basic dikes.

METAMORPHIC ROCKS

The intrusion of igneous masses into Paleozoic sediments was accompanied by thermal metamorphism. Siltstone and limestone beds were intruded by the syenodiorite and the hornblende monzonite. The mineralogical effects are most obvious in the calcareous beds. Skarns derived from these beds consist of some combination of diopside, calcite, garnet and wollastonite, while the siltstones were recrystallized into a rock mostly consisting of quartz and muscovite. Some pure limestone beds recrystallized into a lighter gray, saccharoidal marble (Sec. 34, I-8).

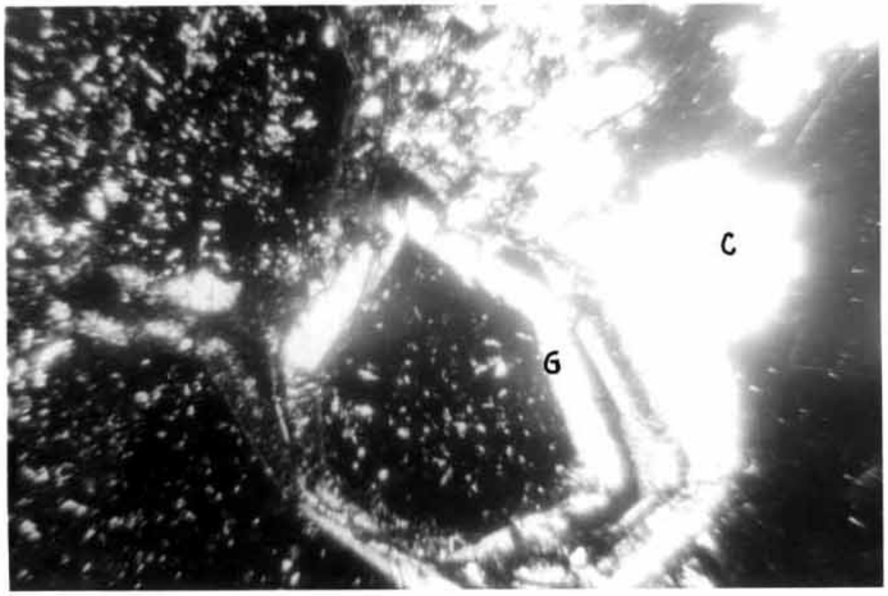
In the Ohaysi Valley area all the metamorphic rocks are isolated masses completely enclosed within the igneous stocks, so trying to define zones representing different physical conditions of metamorphism (isogrades) is practically impossible. Moreover in calcareous beds the mineral assemblage and the distance of the contact to which it develops, seems to be a function of the chemical composition and the permeability of individual calcareous beds. The present study is limited to describe the mineral assemblages present in the different xenoliths and try to show in a tentative P-T diagram the possible field for the metamorphic rocks in the Ohaysi Valley area.

In the south west part of the area, Sec. 4, A-1,2 and Sec. 3 A-1, B-1, the metamorphosed sedimentary rocks are cherty dolomitic limestone and a thin bed of argillaceous siltstone. The calcareous beds were recrystallized into a rock mostly consisting of diopside, 80 per cent; calcite 10 per cent; pyrite, 7 per cent; and minor hornblende and wollastonite. Right in the contact with the hornblende, magnetite masses occurred, some of which have been partially mined.

In a specimen collected from the siltstone, the sedimentary bedding is still preserved and the rock consists mostly of quartz, 80 per cent; muscovite, 17 per cent; and minor pyrite and limonite.

In the central part of the area Sec. 34, I-8, J-8,9 in a xenolith within the hornblende monzonite, the rock consists mostly of garnet (andradite), 95 per cent; and minor calcite, hornblende and pyrite. The garnet occurs as individual strongly zoned crystals (fig. 9). In an outcrop, Sec. 34, J-8 the limestone was recrystallized into a massive, lighter gray, saccharoidal marble. A specimen in a calcareous bed in Sec. 3, B-8, consists of calcite 65 per cent; garnet 30 per cent; and minor diopside, wollastonite and pyrite.Some copper mineralization is also present.

In the north central part of the area four small xenoliths are enclosed in the syenodiorite. A sample collected from a calcareous bed, right in the contact between hornblende monzonite and syenodiorite in Sec. 34, F-9, consists of garnet, 50 per cent; calcite, 35 per cent; diopside 12 per cent; and minor wollastonite, quartz and pyrite. Some nice wollastonite specimens were seen in the outcrop. Pyrite, chalcopyrite



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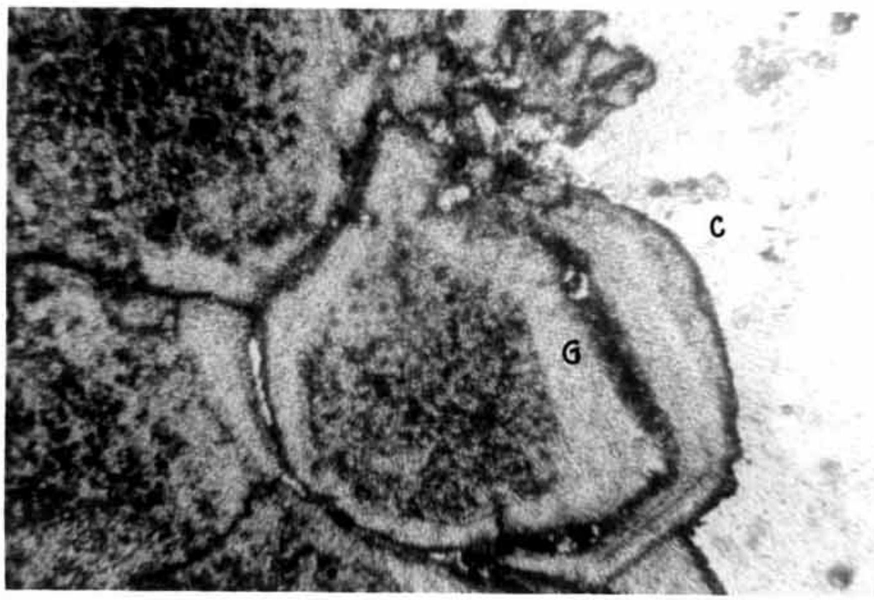


B

Figure 9. Thinsection of garnet hornfels

G, anomalous zoned garnet (andradite).

C, calcite

A. Crossed nicols. B. Ordinary light. X 30

and green copper occur throughout. A specimen from a dolomite bed in Sec. 34, F-10 consists of diopside 85 per cent; and garnet 15 per cent. Abundant pyrite and some chalcocite and green copper occur in the outcrop. Another specimen from a similar dolomitic bed consists mostly of diopside, 45 per cent; hornblende, 35 per cent; calcite 12 per cent; and minor wollastonite, epidote, and pyrite.

Conditions of metamorphism

Most of the mineral assemblages described above are typical of the Hornblende-Hornfels facies. The P-T fields of this facies are shown in fig. 9A and table 1 (Turner, 1968). Diopside is by far the most abundant index mineral and must have been derived from cherty dolomite according to the reaction:

$$Ca\ Mg\ (CO_3)2 + 2\ SiO_2 \rightleftharpoons Ca\ Mg\ Si_2O_6 + 2\ CO_2$$

Wollastonite is the other typical index mineral and could develop from limestone according to the reaction:

$$Ca\ CO_3 + Si\ O_2 \rightleftharpoons Ca\ SiO_3 + CO_2$$

The first appearance of diopside is above 490° C at $PH_2O = PCO_2 =$ 500 bars, and 540° at 1000 bars. Under the same conditions wollastonite appears at 570 and 630°C respectively. If 500 bars is considered as a reliable pressure, temperatures between 490 and 570°C may be expected at contacts.

This is consisting with the models of Lovering, Jaeger and Hori who suggest the following inferences: "Temperatures at contacts with granatic plutons are normally 500 to 550°C; temperatures of 650 to 700°, may be expected at contacts with basic plutons under deep cover. Xenoliths derived from the invaded rocks and immersed in magma may attain considerably higher temperatures approximating that of the magma at the

Index minerals		Limiting temperatures (°C) at P as below					
		P_{CO_2} (water absent)			$P_{H_2O} = P_{CO_2}$		
First appear	Disappear	500 bars	1000 bars	1400 bars	500 bars	1000 bars	1400 bars
Tremolite					400°	450°	480°
	Dolomite-quartz	440°	490°	520°	400°	450°	480°
Diopside		440°	490°	520°	490°	540°	580°
	Tremolite				570°	630°	670°
Wollastonite	Calcite-quartz	570°	630°	670°	570°	630°	670°
Forsterite	Dolomite-diopside	640°	700°	730°	640°	700°	730°
Monticellite	Calcite-diopside-forsterite	770°	850°	900°	770°	850°	900°
Periclase	Dolomite	830°	900°	950°	830°	900°	950°

Table 1. Possible temperature gradients of progressive metamorphism involving calcium-aluminum silicates (From Turner, 1968)

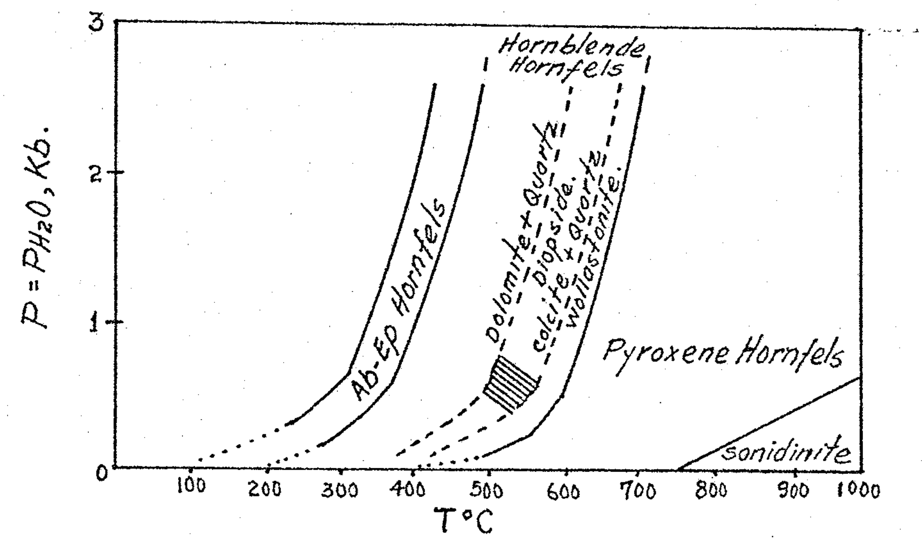


Figure 9A. Tentative diagram showing P-T fields of the four facies of low-pressure metamorphism, (From Turner, 1968). Hatched area limits a possible field for metamorphic rocks in the Ohaysi Valley area.

time of intrusion".

The metamorphic rocks in the Ohaysi Valley area are xenoliths, completely enclosed within the igneous rocks, so it is possible to assume for the magma at the time of the intrusion temperatures similar to those in the contacts, or maybe slightly higher.

On the other hand the emplacement of the igneous masses in the Ohaysi Valley area seems to have occurred at shallow depth (1 to 2 kilometers are suggested). Under these conditions some fractures could develop, and produce an open system between the magmatic chamber and the surface, with the resulting release of pressure. The decarbonation reactions producing diopside and wollastonite might have occurred at P_{co_2} pressures as low as 100 to 200 bars. Under these P conditions, diopside could occur at about 370°C; and wollastonite at about 430°C. Winkler (1967) considers that the lower limit for the formation of wollastonite is at 425°C. Based on the common assemblage diopside-wollastonite, if is possible to assume temperatures of at least 425°C at the contacts.

It seems to be that the syenodiorite and the hornblende monzonite produced similar thermal effects in the sedimentary sequence. It was seen before, that the syenodiorite was probably intruded in two different episodes. From the anorthite content of the plagioclase (An 60) a temperature about 1150°C would be expected for the magma at the time of crystallization of the plagioclase during the first episode. During the second episode the albitic rims around the original plagioclase suggest a temperature of about 650°C for the magma in this later intrusion. The author considers that the thermal metamorphism was produced during this second episode in which the temperature in the syenociorite was similar or probably slightly higher than it was in the monzonite. This might explain the presence of similar mineral assemblages in xenoliths enclosed in both intrusive rocks.

More detailed study has to be done to set a more reliable hypothesis dealing with the physical conditions prevailing during the thermal metamorphism.

Mineral deposits related to metamorphism

The stages of consolidation of the hornblende monzonite and syenodiorite produced pyrometasomatic mineral deposits in adjacent metamorphosed sedimentary rocks. Some of the mineralization is present in the adjoining intrusive rock. Close to the contact the intrusive rock is more or less altered by sericitization. Epidote, calcite and more rarely garnet; and diopside, develop in the intrusive rock by replacement through the mass or replacement in veinlets.

The author considers that almost all the mineral deposits in the Ohaysi Valley area, may be classified as pyrometasomatic deposits. Magnetite deposits are the most common in the area and were largely mined until about 1930 (Schmidt, 1961). Associated with the magnetite is more or less specularite, almost always pyrite and little chalcopyrite and ordinary contact silicates including garnet (mostly andradite), and minor diopside, wollastonite and hornblende. Most of the mineral deposits were developed in limestone skarns. The intrusive rock in this vicinity is rather strongly leached and contains veins of epidote, calcite, garnet, pyrite and malachite. The hornblende monzonite on the east side of a metamorphic skarn in Sec. 3, A-8, is strongly sericitized, and contains abundant calcite and minor quartz, diopside, and epidote. The alteration here may have taken place simultaneously with the metamorphism of the sedimentary rock. The alteration here, resembles the phyllic alteration zone except for the presence of typical contact minerals.

In general in xenoliths enclosed in hornblende monzonite the iron minerals magnetite and specularite and minor pyrite, and probably some chalcopyrite are the most important. Garnet (andradite) is by far the most abundant contact mineral. The appearance of these mineral phases may be correlated with introduction of iron presumably from the intrusive magma.

In xenoliths enclosed in syenodiorite magnetite and specularite almost disappear and pyrite and chalcopyrite are the most important ore minerals. Among the contact metamorphic minerals, garnet is still present but large amounts of diopside and minor wollastonite are also present. For some reason the introduction of iron was less important in xenoliths enclosed in syenodiorite.

Some patches within the hornblende monzonite showing pyrite and hematite mineralization are not directly related to metamorphic skarns. In Sections 34 G-6, 7 and G H-7, the hornblende monzonite is mineralized with disseminated pyrite and specularite as veinlets. In this area the appearance of some calcite, and garnet in veins suggest the presence of a former metamorphic skarn which probably disappear by effects of the erosion. A similar situation was observed in Section 34, E-6. Here are some diopside in the igneous rock was probably derived from a metamorphic skarn now eroded. A magnetite body in Section 34, I-2 is completely enclosed in the hornblende - monzonite and is not apparently related to any skarn, but the presence, 200 feet to the south of some contact minerals such as garnet, epidote, and calcite may indicate that this area was originally occupied by a metamorphic skarn.

In general the evidences suggest that most of the mineralization is closely related to the thermal metamorphism. A disseminated copper mineralization in Sections 3, A-2, 3; B-2, 3; C-2, 3, shows different characteristics and is fully described later in this paper.

Geologic Structure

The general structure of the Jarilla Mountains is that of a somewhat faulted dome with the sedimentary beds dipping away from the intrusive bodies at gentle to moderate angles (Schmidt, 1964).

In this type of emplacement the magma pushes the older rocks aside and upward. During the doming of the sediments numerous fractures could have developed and igneous masses intrude along these fractures. Probably some sedimentary blocks were isolated rotated and sank into the magma. This might be true especially toward the crest of the dome, where stresses are greater. This seems to be the situation produced by the emplacement of the hornblende monzonite in the Ohaysi Valley area. The diversely oriented isolated skarns in this area suggest they are xenoliths instead of roof pendants. Apophyses and small dikes of the intrusive rock cut through the xenoliths.

During the chilling of the hornblende monzonite numerous tension joints occurred. The orientation of these joints is shown in a Rose diagram (Fig. 9B). Practically all the joints are vertical or dip very steeply. From the diagram is clear that most strike northeasternly than in any other direction. This coincides with the orientation of the basic dikes suggesting that they were intruded along this fractures. No

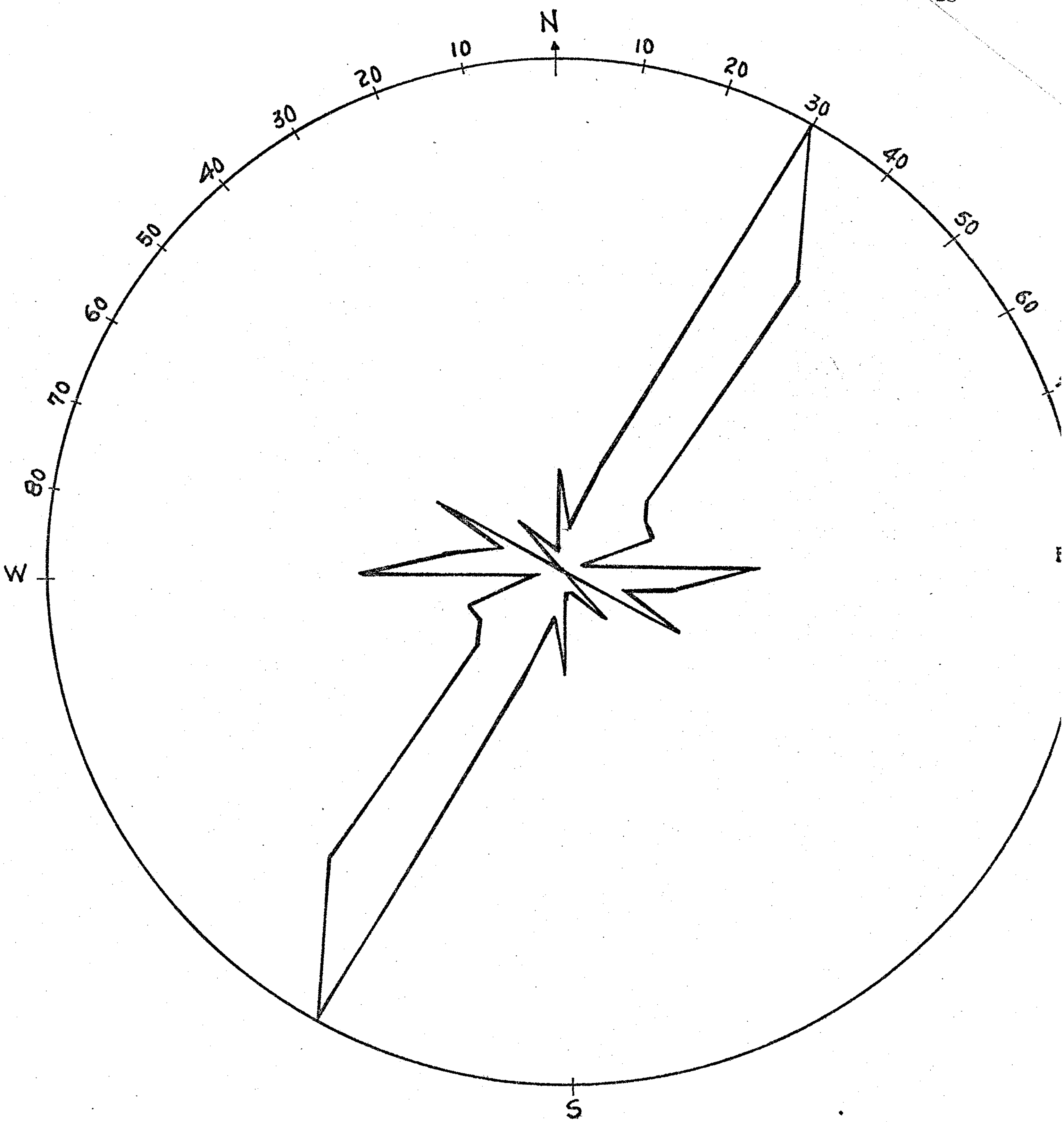


Figure 9B. Rose Diagram to 120 joints in the hornblende monzonite.

major faults were recognized in the study area.

Recent Alluvial Deposits

One third of the study area is covered by recent alluvial deposits. These consist mostly of gravel and sand derived from igneous and metamorphic rocks. In the east border of the Jarilla Mountains, some placer gold was mined from the alluvial deposits.

DISSEMINATED COPPER MINERALIZATION

Hydrothermal alteration and mineralization

Hydrothermal alteration accompanied by some metallization is present within the hornblende monzonite stock in the Ohaysi Valley area. Four types of hydrothermal alteration are recognized in the hornblende monzonite stock (Fig. 10): 1) Potassic, 2) Phyllic, 3) Argillic, and 4) Propylitic. The alteration zones are classified according to the scheme of Lowell and Guilbert (1970), which is based on mineral assemblages.

Potassic zone

The potassic alteration zone as defined by Lowell and Guilbert (1970), involves pervasive and veinlet replacement of primary minerals by secondary biotite, K-feldspar, quartz, sericite and minor anhydrite.

Some evidence of potassic alteration occurs within the hornblende monzonite stock in Section 3, B-2. Here the intrusive rock has been completely shattered (Fig. 11). Quartz veinlets are abundant. Iron oxides and malachite also occur with quartz as veinlets and were probably derived from original pyrite and chalcopyrite. The petrographic study of samples collected in this area show some evidence of potassic alteration.

K-feldspar, probably orthoclase occurs with quartz as micro veinlet fillings (Fig. 12).

Alteration biotite is very scarce and occurs in two modes: 1) as sparce replacement of plagioclase phenocrysts; and 2) as locally replacements of groundmass feldspars. The biotite was the light to medium brown pleochroic variety, suggesting it is phlogopitic in composition.

A light blue, high birefringence mineral probably anhydrite is present as micro veinlet filling. Delessite, a high-iron content variety of chlorite is present as veinlets. A magnesium chlorite probably prochlorite occurs mostly as fan-shaped aggregates and seems to be an alteration product of other silicates.

Mafics, have been completely destroyed and only some chlorite, iron oxides, and leucoxene? were seen in former hornblende skeletons.

Sericite, sometimes abundant is replacing plagioclase phenocrysts and also occurs as replacements of groundmass feldspar.

Clay (probably montmorillonite and kaolinite) is present as replacement of plagioclase phenocrysts and also as replacement of groundmass feldspar.

The potassic zone in the hornblende monzonite stock is distinguished by the assemblage biotite - K feldspar. These two minerals are present in minor amounts whereas sericite and quartz are more abundant. This might indicate an overlapping of the phyllic zone into the potassic zone. The presence of some chlorite and clay (probably montmorillonite and kaolinite) metastable phases in the potassic zone, probably involve later stages of alteration including retrograde and supergene alteration.

The mineralization in the potassic zone consists mostly of limonite, probably derived from pyrite and chalcopyrite (live limonite was seen throughout the area). Limonite is usually present as veinlets with quartz and malachite (Fig. 12). A few pyrite is still present as veinlets and disseminated grains but most of it has been completely oxidized. Pyrite which is a stable phase in the potassic alteration probably forms by sulfidization of the original iron silicates and oxides present in the host rock. This is suggested by chemical analysis (Plate 2) which shows no increase-sometimes a loss in total iron during alteration.

FIGURE 10. GENERALIZED ALTERATION MAP OF THE HORNBLENDE MONZONITE STOCK

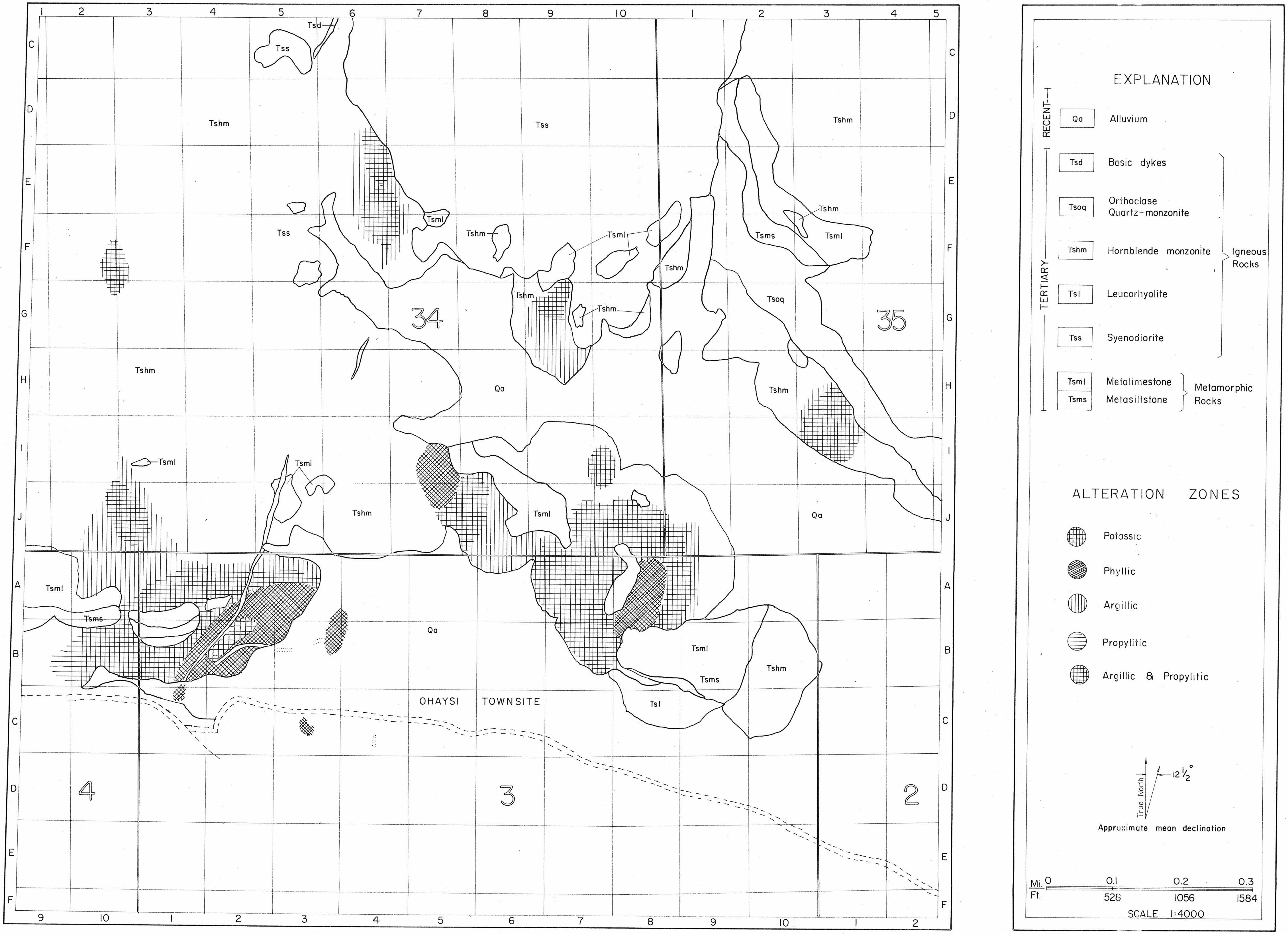
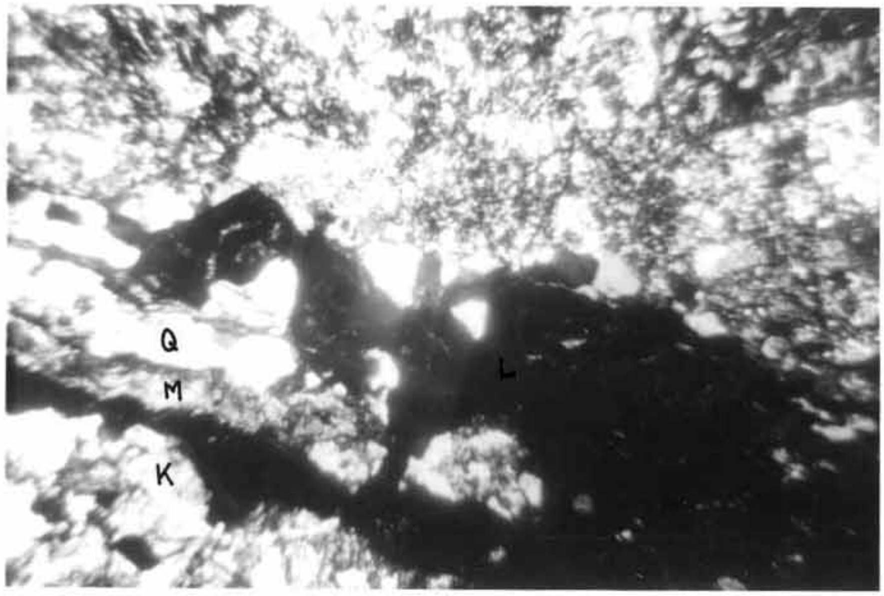
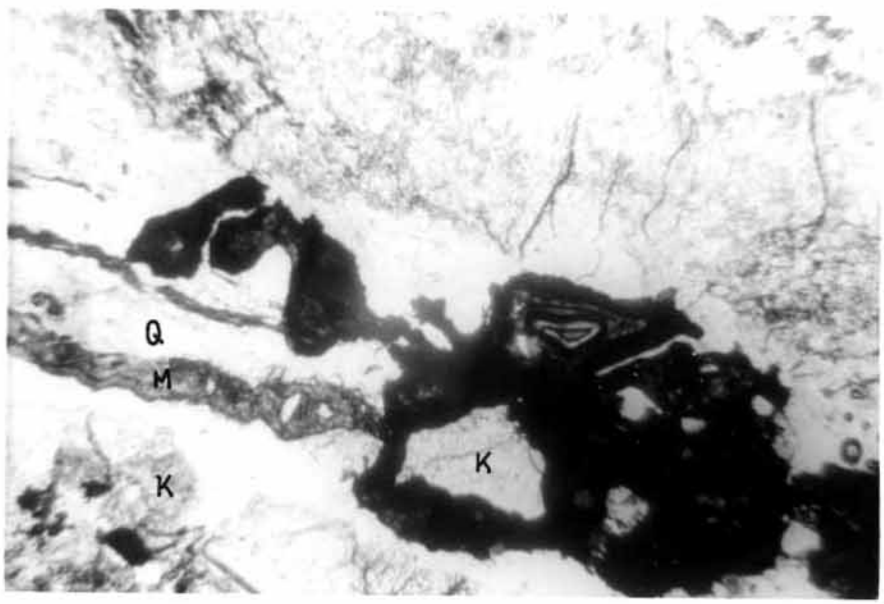


FIGURE 11. Disseminated copper in hornblende monzonite.

Looking to the northwest.



A



B

FIGURE 12. Thin section of potassic alteration zone

Q, quartz; K, potash feldspar

M, malachite; L, limonite

A. crossed nicols. B. Ordinary light. X30

Some changes in chemical composition of the rocks within the potassic zone are shown by the X-ray fluorescence analysis of the samples (Plate 2). The potassic alteration effected a moderate loss in CaO; minor loss in MgO and slight increase in K_2O. Small but no conclusive changes in Al_2O_3 and SiO_2 are shown.

Phyllic Zone

The phyllic alteration zone is characterized by quartz, sericite, pyrite, and minor chlorite, clay and rutile (Lowell and Guilbert, 1970). Sericite predominates in the inner part of this zone, and clay minerals in the outer margins.

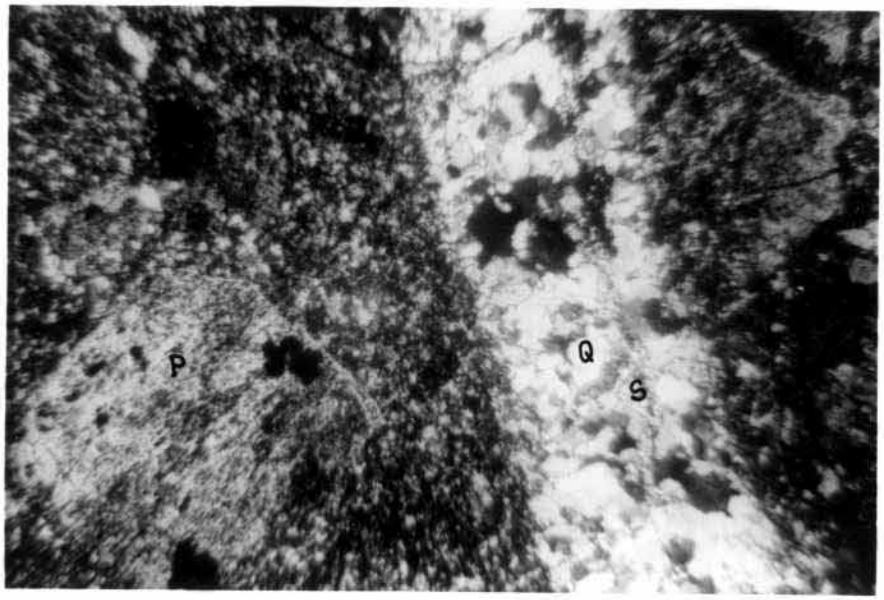
In the Ohaysi Valley area the phyllic zone is surrounding and to some extent overlapping the potassic zone (Fig. 10). Petrographic study of the specimens collected in this zone show the following characteristics:

Plagioclase phenocrysts are pervasively replaced by fine-grained sericite flakes and to a minor extent by clay. Sericite plates in some instances are oriented following cleavage or twin planes. Sericite and clay also occur rimming the plagioclase phenocrysts.

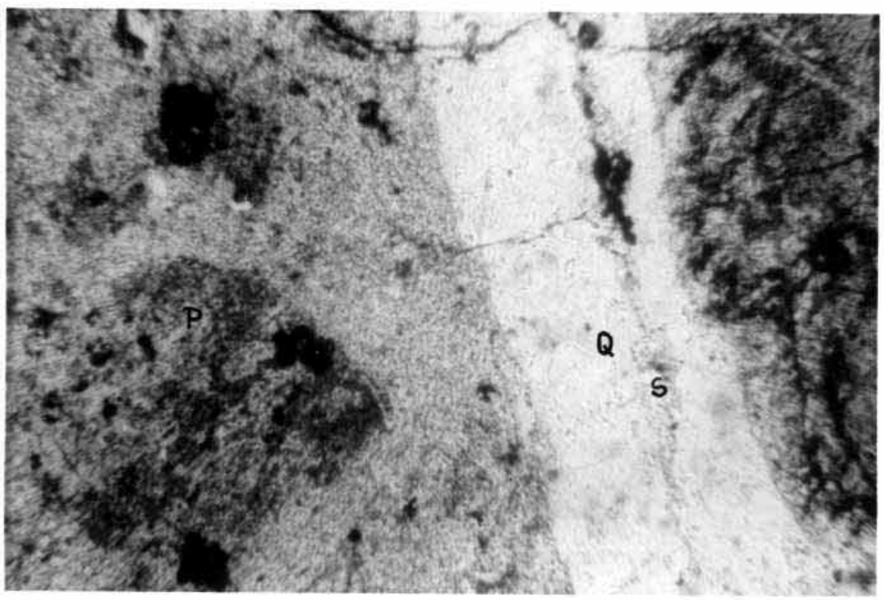
Quartz is present mostly as veinlets and also as "eyes" in the groundmass. In veins (Fig. 12A) is associated with some sericite and iron oxides. Sometimes a reaction rim of sericite develop in the contact between the quartz veins and the host rock.

K feldspar main component of the groundmass is largely replaced by clay (probably montmorillonite and kaolinite) and to a minor extent by sericite. It always shows cloudy appearance.

The mafics have been almost completely destroyed. Chlorite, minor epidote, and some rutile and leucoxene are present in hornblende skeletons.



A



B

FIGURE 12A. Thin section of phyllic alteration zone

P, plagioclase; Q, quartz

S, sericite

A. Crossed nicols. B. Ordinary light. X30

Sometimes malachite stains hornblende ghosts producing an anomalous green color.

The phyllic alteration in the study area is distinguished by the quartz-sericite association and the destruction of the mafic components. Clay (montmorillonite and kaolinite) is not uncommon but as in the potassic zone may have been produced by supergene alteration. If some K feldspar is still present especially in the matrix should be considered as a metastable phase.

The mineralization in the phyllic zone consists mostly of "limonites". They must have been derived from pyrite and chalcopyrite, the two stable phases in this alteration. Some pyrite is still present as veinlets. Unfortunately the samples from the potassic and phyllic alteration were collected in the oxidation zone where the hypogene sulfides were completely oxidized. This makes difficult an evaluation of the relative abundance and ratio chalcopyrite-pyrite through the alteration zones.

X-ray fluorescence analyses show some changes in composition of the host rocks within the phyllic zone. Iron remains constant, which would indicate that pyrite was produced as in the potassic zone by sulfidization of the original iron silicates (mostly hornblende). The phyllic alteration affected a moderate loss in CaO and MgO. K_2O is slightly higher in this zone. Small changes in Al_2O_3 are not conclusive.

Chemical changes in the potassic and phyllic zones are very similar. The presence of the quartz-sericite pair in both alteration assemblages indicate a maximum temperature of formation of about 600°C (Creasey, 1965). The absence of clay minerals (not considering those produced by supergene alteration) means either the temperatures exceeded 400°C to 480°C or the K^+/H^+ or Na^+/H^+ ratio was too high (Creasey, 1965). These temperature values are similar to those found for thermal metamorphism assemblages (Page 17).

Argillic - Propylitic zone

The argillic zone is distinguished by the presence of clay minerals (members of the kaolinite or montmorillonite group). Plagioclase is converted either to kaolin near the orebody or montmorillonite farther away from the orebody center.

Argillic alteration is irregularly dispersed throughout the hornblende monzonite stock and is less well understood. Petrographic study fails to give an idea of the composition of the clays, and on the other hand clay minerals may have been produced by supergene alteration. If present in the study area, argillic alteration has been overlapped to a large extent by the propylitic alteration. In the present paper the alteration zone surrounding the phyllic zone is mostly classified as argillic - propylitic alteration.

Propylitic alteration according to Lowell and Guilbert (1970), contains the most widely distributed and least distinctive of the alteration assemblages. Plagioclase generally remains fresh, although it is locally ribbed with either montmorillonite, kaolin or an apparent mixture of the two minerals. Chlorite, epidote, calcite and albite occurs in various combinations. Sericite, pyrite and potash feldspar are locally present.

Petrographic study of the samples collected in the argillic - propylitic zone show the following characteristics:

Plagioclase phenocrysts are rimmed and sometimes completely replaced by clay and to a minor extent by sericite. Some epidote and calcite are locally present in the plagioclase phenocrysts.

The K feldspar of the groundmass is also moderately to strongly altered to clay minerals.

Hornblende has been moderately to completely altered to various combinations of epidote, calcite and chlorite. Epidote is the most important alteration mineral. Some rutile and leucoxene seem to form during the destruction of hornblende. Biotite sometimes appears to envelop and replace hornblende. Magnetite and pyrite occur as isolated grains and also within or around hornblende crystals.

X-ray fluorescence analyses do now show conclusive changes in the chemical composition of the rocks. Slight addition of MgO is perhaps the only change suggested.

The widespread distribution of clay mineral whether stable or unstable phases, indicates the temperature never exceeded 400°C to 480°C, providing that the clay is not supergene (Creasey, 1965).

Relation of Alteration to Copper Mineralization

Anomalous copper values (Fig. 13) in the Ohaysi Valley area are restricted to the potassic and phyllic alteration zones. This is also true in almost all the commercial porphyry copper mineralization. Unfortunately in the study area the anomaly seems to be too small and the ore grade too low as compared with those present in commercial deposits. Another discouraging factor is the absence of molybdenum minerals especially molybdenite which is a typical mineral in porphyry copper deposits. The molybdenum content in samples from the potassic and phyllic zones (Plate 2), averages less than 2 parts per million.

Supergene Alteration

Supergene alteration seems to be widely distributed through the hornblende monzonite stock. This alteration is present in two different modes: 1) weathering; and 2) acid solutions derived from pyrite.

The author considers that much of the clay present in the different alteration zones within the intrusive rock was produced by supergene alteration. This may explain the presence of clays as metastable phases in the phyllic and potassic alteration zones. In the study area the petrographic samples were collected in the oxidation zone and the evidences suggest that sulfuric acid derived from pyrite produced much of the clay minerals.

Supergene alteration by weathering is probably responsible by the confusing situation in the argillic and propylitic zones. Petrographic samples were collected in the surface where weathering and related near surface processes may have produced some alteration minerals especially clays. A specimen from a deep shaft far from surface processes in Section 34, J-8 is relatively unaltered and clay appears as a very minor constituent.

Some workers of porphyry copper deposits consider that much of the kaolinite and montmorillonite, some sericite and quartz, and possibly some chlorite were produced by supergene alteration.

Oxidation and supergene enrichment

Oxidation is irregularly dispersed in the monzonite stock and also in some of the metamorphic xenoliths. The process is more evident where pyrite is abundant. Within the disseminated copper mineralization Section 3, B-2 occurred a strong oxidation. Secondary minerals of copper, iron and manganese are present. The principal copper minerals are: malachite, crysocolla, turquoise and tenorite. Limonite form pyrite and live limonite from chalcopyrite are also present. Manganese oxides are not uncommon. The presence of this oxidation makes difficult the appraisal of the pyrite-chalcopyrite ration, and distribution in the two innermost alteration zones.

An interesting situation is present in a garnet skarn in Section 34, J-8. Here in a big pit, in less than 15 feet from the surface, the oxidation zone, the zone of supergene enrichment, and the zone of primary sulfides are well exposed. The oxidation zone about 6 feet thick is characterized by abundant "limonites", malachite, crysocolla, jarosite gypsum and clay. In the zone of secondary enrichment, 3 feet thick, the only important supergene sulfide is chalcocite. It occurs as a replacement of pyrite. For the most part replacement has been incomplete and sometimes only a thin film is coating pyrite. Finally, beneath these zones is found the zone of primary sulfides. The rock consists almost exclusively of garnet probably andradite. The presence of abundant pyrite in the skarn must have been the principal reagent of the oxidation processes.

A similar situation is present in other metamorphic skarn in Section 35, F-1. Here the situation is not so clear. Limonite and copper carbonates are present in the oxidation zone, chalcocite is coating pyrite in the zone of supergene sulfides (less than 1 feet thick), and beneath these zones is a garnet-diopside rock.

Supergene enrichment zones are very thin and only appear locally. They do not represent deposits of economic importance.

CONCLUSIONS

Most of the mineral deposits in the Ohaysi Valley area are related to thermal metamorphism and metasomatism. The better prospects have been already mined, and the others are too small to be considered as commercial deposits.

A disseminated copper mineralization is present in the south-west part of the area and shows some favorable conditions. Mineralization is conformable to hydrothermal alteration zones and is overlapping the potassic and phyllic zones. These characteristics are similar to those exhibited by commercial porphyry type copper deposits. Size of the copper anomaly and very low ore grade limit the economic possibilities of this prospect, unless strong oxidation and leaching has produced a good enrichment blanket at depth. It has to be proved by exploration drilling but field evidences make unlikely the possibility to find good enrichment zones. On the other hand molybdenum minerals, typical in commercial deposits of this type, are absent in the Ohaysi Valley area.

More geologic work has to be done, especially to the south of the copper anomaly where alteration and copper mineralization are similar to those in the north portion of the area.

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APPENDIX 1

DEFINITION OF TERMS FOR ALTERATION

1. In plagioclase and orthoclase phenocryst.

Unaltered: Less than 10 per cent of the crystal has been altered.

Weak : Between 10 to 30 per cent of the crystal has been altered.

Moderate : Between 30-70 per cent of the crystal has been altered.

Strong : More than 70 per cent of the crystal has been altered.

Alteration minerals and mode of occurrence.

Sericite : Mostly as small flakes in cleavage or twin planes. To a less extent rimming phenocrysts.

Clay : Mostly rimming phenocrysts. Sometimes following cleavage or twinning planes.

Epidote : In clusters or aggregates.

Calcite : In clusters or aggregates sometimes with epidote.

2. In potash feldspar matrix.

Unaltered: The matrix is clear (colorless), like quartz.

Weak : The matrix is slightly cloudy showing a pale brown color.

Moderate : Brownish color is more intense.

Strong : Dark brown matrix.

Alteration minerals and mode of occurrence.

Sericite : Small flakes as replacements in the matrix.

Clay : Massive aggregates of brownish color.

3. In hornblende crystals

Unaltered: Less than 10 per cent of the crystal has been altered.

Weak : Between 10 to 30 per cent of the crystal has been altered.

Moderate : Between 30 to 70 per cent of the crystal has been altered.

Strong : More than 70 per cent of the crystal has been altered.

Alteration minerals and mode of occurrence.

Epidote : Massive replacement and clusters.

Calcite : As massive replacements in hornblende and epidote.

Chlorite : Mostly as fan-shaped aggregates in hornblende ghosts.

Sphene : Isolated crystals within the hornblende.

Rutile : Reddish to yellowish grains.

Leucoxene: Disseminated earthy, whitish material.

Pyrite : In small grains in or around hornblende.

Magnetite: As pyrite.

4. Late magmatic alteration in syenodiorite.

Albitic rims make between 15 to 25 per cent of the original plagioclase (An 60).

Hornblende: Envelop and replace augite.

Biotite : Envelop or replace hornblende, sometimes along cleavage planes.

APPENDIX 2

RECOGNITION OF MINERALS

Apatite. Occurs in small six-sided crystals or elongated tabular crystals. It is easily distinguished by form, moderate relief, and weak birefringence. Elongated sections show parallel extinction. It was found to be a very common accessory in hornblende monzonite and syenodiorite.

Augite. Occurs in small prismatic crystals, showing high relief. Moderate birefringence, mostly second order yellow. In syenodiorite is common and usually shows a pale brown color; it is also replaced by hornblende. In the hornblende monzonite is scarce and is almost always colorless.

Biotite. In syenodiorite is a common mineral. Occurs as diversely oriented flakes showing strong pleochroism. A very distinguishing feature is the stronger absorption when the cleavage traces are parallel to the vibration plane of the lower nicol. Also parallel extinction.

In hornblende monzonite only occurs replacing hornblende. This variety is moderately pleochroic.

The biotite in the potassic zone occurs as minute flakes in plagioclase phenocrysts. Weak absorption. Probably phogopitic variety.

Calcite. In the metamorphic skarns occurs in anhedral crystals sometimes showing good rhombohedral cleavage. The most distinguishing features are the extreme birefringence, and variation of relief.

In hornblende monzonite and syendiorite occurs as veinlets evidently as a contamination product by metamorphic skarns.

It also occurs as an alteration product especially in the propylitic zone. Occurs as aggregated in hornblende and plagioclase - phenocrysts and also in the groundmass.

If magnesite and dolomite are present in some of the thin-sections they were classified as calcite.

Chlorite. In the potassic alteration zone some delessite (high iron content chlorite) is present in veins. It shows light green color, strong birefringence and spherulitic texture.

In the hornblende monzonite chlorite is usually present replacing hornblende. Occurs mostly as fan-shaped aggregates of light green color and weak birefringence. Probably prochlorite.

Diopside. In metamorphic skarns is very common and occurs as short prismatic crystals. Colorless, strong birefringence, and maximum extinction angle varying from 40^{o} to 45^{o}, are distinguishing features.

Some crystals are present in the hornblende monzonite close to metamorphic skarns. In this rock is distinguished from augite by stronger birefringence.

Epidote. Important alteration product in hornblende monzonite. Aggregates in the groundmass and plagioclase crystals. Mostly as replacement of hornblende. The most distinguishing features are the apple green color and strong birefringence.

Garnet. (Undifferentiated). Abundant in metamorphic skarns. Occurs either as masses or euhedral crystals showing very high relief. Isotropic but anomalous birefringet areas are often arranged in zones. Very distinctive mineral. (Probably grossularite-andradite end members).

Hornblende. Important constituent of the hornblende monzonite. Primatic crystals with pseudohexagonal cross sections. Pleochroism: Yellow green, to green, to greenish brown. The most distinguishing features are pleochroism, cleavage and extinction angle.

In syenodiorite, replaces augite and it is also rimmed and -

replaced by biotite. A distinguishing feature is the presence of numerous opaque minerals within the crystals.

In metamorphic skarns mostly occurs as prismatic green to dark green crystals.

In the potassic phyllic alteration zones, some hornblende skeletons have been stained by malachite producing an anomalous blue-green color.

Muscovite. (Sericite). In metasiltstones occurs as flakes oriented parallel to the original sedimentary bedding.

Sericite is an important alteration mineral in the potassic and phyllic zones. Small flakes and aggregates sometimes along cleavage or twinning planes in plagioclase phenocrysts. Distinguishing features are form parallel extinction, and strong birefringence.

Orthoclase. In the orthoclase quartz monzonite is present as large euhedral phenocrysts, rimmed with some clay.

In syenodiorite as anhedral grains interstitial to the plagioclase phenocrysts.

In the hornblende monzonite is present in the groundmass. Here it is difficult to distinguish (would be better to stain the thin section). Low-relief is probably the most distinguishing feature.

Plagioclase. Always present as phenocrysts in the intrusive rocks. Good albite and combined albite-Carlsbad (twinning). Michel-Levy's and albite-Carlsbad twins were used for determination of anorthite content. Zoning is rather common.

Quartz. In the intrusive rocks is present as minute grains in the matrix and as clear rounded "eyes". Very rare as euhedral crystals. Distinguishing features are lack of alteration and absence of cleavage. In some thick sections quartz showed an anomalous yellow birefringence (in syenodiorite).

Sphene. It was found to be a common accessory in the intrusive rocks. Sometimes present in altered hronblende crystals. Relief and extreme birefringence are distinguishing features. Rhombic cross section are very characteristic. Some rutile and leucoxene are found with sphene in destroyed hornblende crystals.

Wollastonite. Occurs mostly as fibrous aggregates in the matamorphic skarns. Colorless and weak birefringence. Parallel extinction. If some tremolite is present in the thin sections it was classified as wollastonite.

Zircon. It is also a very common accessory in intrusive rocks. Always present as minute prysmatic crystals sometimes was found as inclusions in biotite and hornblende. High relief, form, and strong birefringence are distinguishing features.

Pyrite. Shows a brass-yellow color with reflected light. Occurs as euhedral crystals or disseminated grains.

Chalcopyrite. Yellow brass color with reflected light. May be easily confused with pyrite. These two minerals were probably present in the potassic and phyllic alteration zones but now they have been completely oxidized.

Hematite. Mostly black in reflected light. Distinguished by red margins. Occurs as grains or as veinlets.

Magnetite. Steel blue black in reflected light. Occurs as isolated prismatic crystals or small grains especially in hornblende.

<u>Limonite</u>. Reddish to brown in reflected light. It is a very common secondary mineral, product of oxidation of high iron content minerals. In the phyllic and potassic alteration zones is abundant and occurs in veins sometimes associated with malachite. Some nice concentric banding of these two minerals was seen in one or two thin sections.

FIGURE 13. MAP SHOWING SAMPLE LOCATIONS

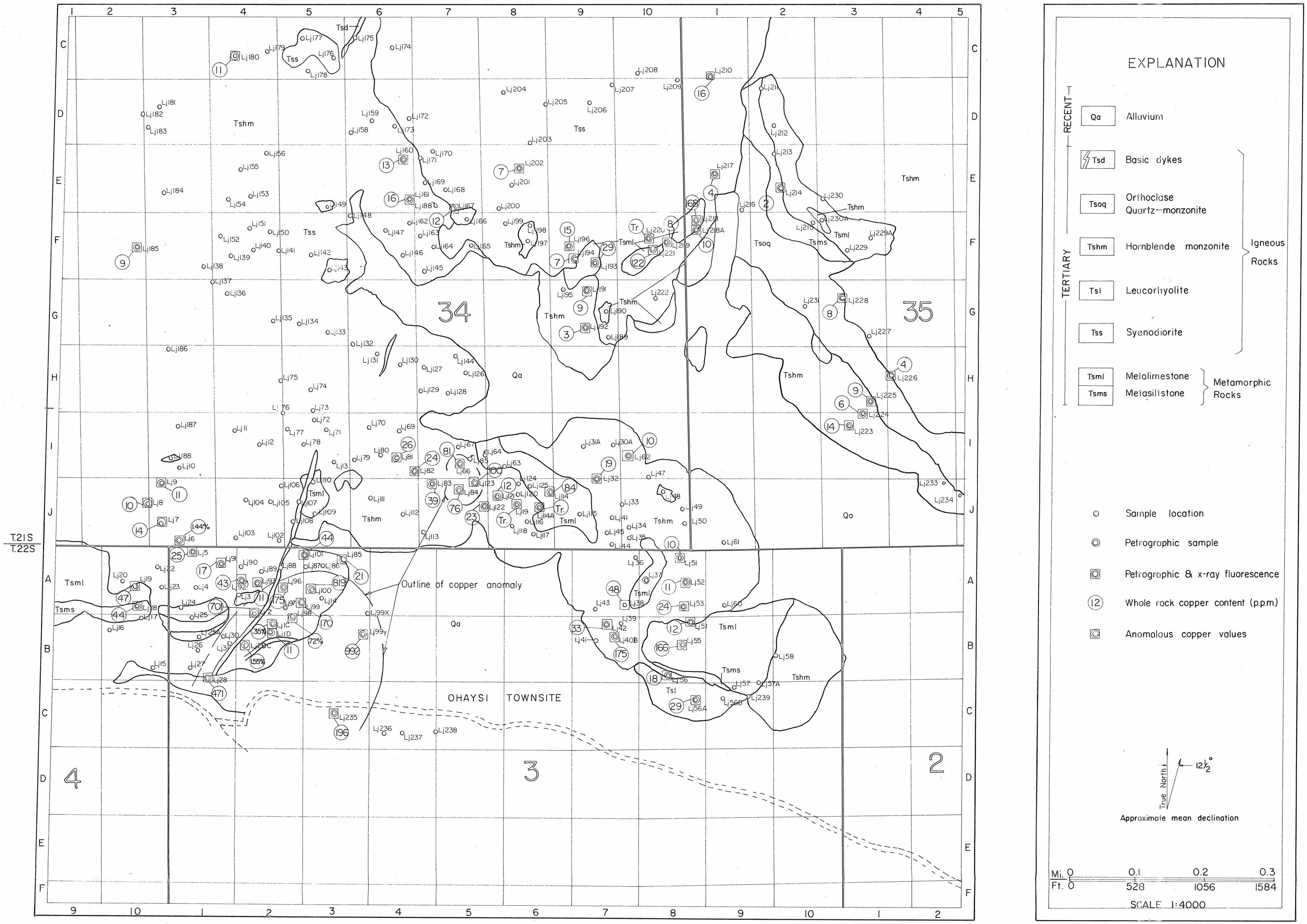

PLATE 1 . THINSECTION DATA

	Sample No	Location	Rock Type.	Texture	Plagioclase	Orthoclase	Quartz.	Horblende	Biotite	Augite	Diopside	Garnet	Chlorite	Calcite	Epidote	Wollastonit	Apatite	Sphene	Zircon	Pyrite	Fe-oxides	Limonite	Cu-Minerals	ALTERATION PRODUCTS Potassic zone	Phyllic zone	Argillic zone	Propylitic zone	Dominant Alteration
E	LJ 1C	Sec 3, B-2	Horblende Monzonite	Porphyritic	An? 10	15	65						3	2?	X		X	X	X			3	mal, cp.?	K-si in veins & Q.	Ser. Q,	clay	Chl.	Potassic ?
E	LJ 1D	" 3, B-2	" "	"	An? 30	35	21	X	1				5		2				X			4	mal?	bi in pl., K-si in veins	Ser. Q,	clay	chl, ep.	Potassic ?
E	LJ 2	" 3, B-2	" "	"	An31 30	40	10	6		X?					5			X		1	he. 2	2			ser.	clay	chl, ep.	Argillic-Propylitic
E	LJ 5	" 3, A-1	" "	"	An? 40	35	9	8					1	3	1		X	X	X	1	he. 1	1			ser(-)	clay(+)	chl, ep, Ca.	Argillic-Propylitic
E	LJ 6	" 34, J-3	" "	"	An? 40	40	8	7	X	X ?			X		2		X	X	X						ser(-)	clay(+)	ep, chl, bi	Argillic-Propylitic
E	LJ 7	" 34, J-3	" "	"	An? 35	40	10								2					1	he, 2	10			Ser(+)	clay(+)	ep.	Argillic-Propylitic
E	LJ 8	" 34, J-2	" "	"	An28 35	30	12	8	1				1	3	1		X	X	X	1					Ser(+)	clay	ep, chl, ca.	Argillic-Propylitic
M	LJ 9	" 34, J-3	" "	"	An14 34.8	41.0	6.3	9.1	1						5.2		X	X	X	1.5					Ser(+)	clay(-)	ep.	Argillic-Propylitic
E	LJ 18	" 4, A-10	Metasiltstone	Sed. bedding			80.0		Mus 17											2	he, mg 1							
E	LJ 19	" 4, A-10	Diopside-Calcite. Hornfels	Xenoblastic				1			80			10		2				7		1						
E	LJ 28	" 3, C-1	Hornblende Monzonite	Porphyritic	An28 35.	45.	12.	6	X				X	X	X			X	X						Ser(+)	clay(-)	chl, ep.	Argillic-Propylitic
E	LJ 29C	" 3, B-2	" "	"	An? 25	35	18	1	1				2	X?	1		X		X	1		6	mal, cp?4	K-si in veins; bi in pl.	ser(+)	clay(-)	Chl.	Potassic ?
E	LJ 32	" 34, J-9	" "	"	An? 35	40	9	5	X				X	2	3		X	X	X	1	he 1	2			ser(-)	clay	chl, ep, Ca	Argillic-Propylitic
E	LJ 42	" 3, A-7	" "	"	An? 35	40	9	1						5	4					1					Ser(-)	clay(+)	ep, ca, leu.	Argillic-Propylitic
E	LJ 40B	" 3, B-7	" "	"	An? 35	40	12	4					3	1	1					2	he X?	1			ser(-).	clay(+)	chl, ep, ca.	Argillic-Propylitic
E	LJ 42	" 3, B-7	" "	"	An26 35	35	8	1					2	9	1					7					ser(-)	clay(-)	Chl, ep, cal	Propylitic
E	LJ 51	" 3, A-8	" "	"	An 10? 30	30	9	1					5	20			X			1					ser(++), Q	clay(-)	Chl	Phyllic.
E	LJ 52	" 3, A-8	" "	"	An30 35	40	10	1			X ?		1	10	1		X			1					ser	clay(+)	Chl	Phyllic.
E	LJ 53	" 3, A-8	" "	"	An? 35	35	10	X						15	X		X			1	he 1	X			ser(++) Q	clay(-)	ca	Phyllic.
E	LJ 54	" 3, B-8	" "	"	An? 35	45	10	6	X				X	4	1		X	X	X			X			ser(-)	clay(-)	Chl . ep	Argillic?-Propylitic
E	LJ 54	" 3, B-8	Garnet-Calcite. Hornfels	Idioblastic xenoblastic				1			x?	30		65		3				X					—	—		
E	LJ 56	" 3, B-8	Hornblende Monzonite	Porphyritic	An? 30	3.5	8	6	1				1	15	1					1					ser(-)	clay(+)	Chl, ep, ca	Argillic-Propylitic
E	LJ 56A	" 3, C-8	Leucorhyolite	Aphanite	An? 15	50	25							5						2		2				—		
E	LJ 62	" 34, I-10	Hornblende Monzonite	Porphyritic	An? 35	35	18	5					2	1	1		X	X.?	X	3		X			ser(-)	clay(+)	Chl, ep, ru, leu.	Argillic-Propylitic
E	LJ 66	" 34, I-7	" "	"	An? 35	40	6	8					X	2	2		X	1	X	3		X			ser(+), Q	clay	Chl, ep, ca	Phyllic?-Propylitic
E	LJ 81	" 34, I-6	" "	"	An28 35	40	7	8						X	3		X	X	X	1		X			ser	clay(-)	ep	Argillic-Propylitic
E	LJ 82	" 34, I-6	" "	"	An? 30	50	7	7							1			1		1		2			ser(-)	clay	ep	Argillic-Propylitic
E	LJ 83	" 34, J-7	" "	"	An26 30	50	7	7							1		X		X	1		1			ser(-)	Clay(-)	ep	± Unaltered.
E	LJ 84	" 34, J-7	" "	"	An? 35	40	11	2						2	2				X	5		2			ser, Q	Clay	ep	Phyllic.
E	LJ 85	" 3, A-3	" "	"	An31 30	45	7	10							1		X	X	X	4					ser(-)	—		± Unaltered
E	LJ 91	" 3, A-1	" "	"	An? 35	45	7	1						7			X	X		2	he 1	3			ser	Clay	ca	Argillic-Propylitic
E	LJ 92	" 3, A-2	" "	"	An27 35	40	8	6						4	4		X	X	X	X					ser	clay(+)	ep, ca	Argillic-Propylitic
E	LJ 93	" 3, A-2	" "	"	An? 35	45	7	7						3	2			X	X						ser(-)	clay(-)	ep, Ca	Propylitic
E	LJ 96	" 3, A-2	" "	"	An? 30	50	7	1						X	X			X	X	X		2			ser	Clay	ep.	Phyllic ?
E	LJ 98	" 3. B-2	" "	"	An? 30	45	8	3						X?	2		X		X	4			mal 1		ser(+), Q.	Clay	ep.	Phyllic
M	LJ 99	" 3 A-2	" "	"	An? 29.9	37.6	19.0	—							X					3		5.2			ser(+), Q.	Clay(+)	ep	Phyllic
E	LJ 99Y	" 3. B-3	" "	"	An? 35	40	10	2					X	5	6		X			3		X	mal		ser(+), Q	Clay	ep. ca	Phyllic
M	LJ 100	" 3, A-3	" "	"	An? 28.2	38.2	21.5	—							1		X			1.0	2.5				ser(+). Q.	Clay	—	Phyllic
M	LJ.101	" 3. A-3	" "	"	An29 31.8	43.6	6.6	13.4	X					X?	2.2		X	X		X					ser(-)	Clay	ep.	Argillic-Propylitic
M	LJ 114	" 34, J-8	" "	"	An24 26.3	39.9	6.4	8.5					X	10.3	3.0		X	X		3.0		X			ser(+)	Clay	ep, ca.	Argillic-Propylitic
E	LJ 114A	" 34.J-8	" "	"	An? 28	46	6	13						X	X		X		X	X					ser	Clay	ep	Argillic-Propylitic
E	LJ 119	" 34, J-8	" "	"	An31 35	40	9	8						1	4		X		X	4					ser(-)	Clay (+)	ep. ca	± Unaltered
E	LJ 121	" 34, J-8	" "	"	An? 35	40	13	7	X						2				X	3	he X				ser	Clay	ep. leu,	Argillic-Propylitic
E	LJ 122	" 34, J-7	" "	"	An? 35	45	10	1						X?	5				X	-		10			ser	Clay	ep.	Argillic-Propylitic
E	LJ 123	" 34, J-7	" "	"	An? 30	45	11	1							2					4		5			ser, Q	Clay(+)	ep.	Phyllic
E	LJ 160	" 34, E-6	Quartz monzonite	Porphyritic	An26 35	30	25	6					X		X			X		2		X			ser	Clay	ep. chl	Argillic-Propylitic
E	LJ 161	" 34, E-6	Quartz monzonite	Porphyritic	An? 30	35	17	1			4				3		X	X	X	5		X			ser	Clay(+)	ep.	Argillic-Propylitic
E	LJ 167	" 34, E7	Syenodiorite	Hypidiomorphic	An60 40	20	2	10	15	6					—					X	mg 2				—	Clay(-)		± Unaltered
E	LJ 180	" 34, C4	Hornblende monzonite	Porphyritic	An? 30	45	10	10	X						X		X			3					Ser	Clay	ep.	Argillic-Propylitic
M	LJ 185	" 34, F-2	" "	"	An21 30.2	43.7	7.8	9.3						2	X		X	X	X	3	mg 1				ser	Clay	ep, ca	Argillic-Propylitic
E	LJ 191	" 34, 6-9	Quartz monzonite	Porphyritic	An29 25	20	40	3	X				X	4	1					1	he 1	1			ser	Clay	ep.	Argillic-Propylitic
E	LJ 192	" 34, 6.9	Quartz monzonite	Porphyritic	An? 25	25	45	1		3?				X	X					X	he X				Ser	Clay	—	Argillic
E	LJ 193	" 34, F-9	Calcite-Garnet Hornfels	Xenoblastic			X				12	50		35						X						—		
E	LJ 194	" 34, F-9	Syenodiorite	Hypidiomorphic	An65 35	2		35		15				10											ser(-)			
E	LJ 196	" 34, F-9	Syenodiorite	Hypidiomorphic	An? 60	10	2	8	10	5							X		X	X	mg 2				ser(-)			
E	LJ 202	" 34, E-8	Syenodiorite	Hypidiomorphic	An? 50	10	15	7	8	3										X	mg 2				—			
M	LJ 210	" 35, D-1	Syenodiorite	Hypidiomorphic	An65 29.5 An8(rim) 9.8	33.1	5.2	6.3	8.0	1.8							X	X	X	2.5	mg 1.				—		—	
E	LJ 214	" 35, E-2	Metasiltstone ?	Sed. bedding																								
M	LJ 217	" 35, E-1	Syenodiorite	Hypidiomorphic	An54 32.1 An12(rim) 8.1	33.3	6.4	5.4	9.8	1.0					X					3.0							ep	
E	LJ 218	" 35, F-1	Garnet-Diopside Hornfels.	Xenoblastic							85	15										X						
E	LJ 218A	" 35, F-1	Syenodiorite ?	?	√0		1	35		4?				6	1		X	1	X	X								
E	LJ 219	" 34, F-10	Syenodiorite.	Hypidiomorphic	An61 45 albitic rims	20	5	8	12											2								
E	LJ 220	" 34, F-10	Syenodiorite	Hypidiomorphic	An57 50	20	6	12	7	2				1			X	X		3	mg?							
E	LJ 221	" 34, F-10	Hornblende-Diopside. Hornfels	Xenoblastic				35			45			12						8								
E	LJ 223	" 35, I-3	Horblende monzonite	Porphyritic	An? 40	40	8	1						2	4		X		X	1					Ser	Clay	ep, ca, leu	Argillic-Propylitic
E	LJ 224	" 35, I-3	" "	"	An? 30	45	8	1						3	3					4		2			Ser	Clay	ep. ca	Argillic-Propylitic
E	LJ 225	" 35, H-3	" "	"	An? 35	45	11	1						4	2					2		3			ser	Clay (+)	ep. ca	Argillic-Propylitic
E	LJ 226	" 35, H-d	" "	"	An17 30	32	17	10	1					2	2		X	1	X	3					ser(-)	—	ep.	Propylitic
M	LJ 228	" 35, G-6	Orthoclase quartz-monz.	Porphyritic	An13 26.1	41.1	9.8	10.6	1					3.9	2		X	X	X	4		2			Ser	Clay	ep, ca, leu.	Argillic-Propylitic
E	LJ 235	" 3, C-3	Hornblende monzonite	Porphyritic	An? 8	10	74		1				X	5			X	X		1.		X			ser, Q.		chl	Phyllic.

ABBREVIATIONS.

M. Modal Analysis. (Volume per cent.)

E. Estimated. (Volume per cent.)

X. Mineral present but 1% or less.

anh. . anhydrite.
bi . biotite.
ca . calcite
cc . chalcocite.
chl . chlorite
cp . chalcopyrite.

cry. crysocolla
ep. epidote.
he. hematite
k-s. potash feldspar
mus. muscovite
leu. leucoxene

mg. magnetite.
mal. malachite.
py. pyrite.
pl. . plagioclase
Q. . quartz.
ru. rutile.

ser. sericite.
(+). abundant.
(-) minor.

PLATE 2 . X-RAY FLUORESCENCE ANALYSES.

Sample No.	Location	Rock Type	MAJOR OXIDES (%)									Minor Elements (p.p.m)			Total
			K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	SiO_2	TiO_2	H_2O	Mn	Mo	Cu	
LJ 1C	Sec.3, B-2	Horblende Monzonite	3.93		1.91	1.12	2.42	15.29	76.89	0.36		136	1.9	3,278	102.85
LJ 1D	Sec 3, B-2	Horblende Monzonite	4.09		2.77	2.71	1.43	14.90	65.66	0.42		327	0.3	11	92.01
LJ 2	Sec 3, B-2	Horblende Monzonite	0.38		3.36	2.47	2.28	15.16	67.81	0.45		182	0.4	701	91.99
LJ 5	Sec 3, A-1	Horblende Monzonite	3.87		3.37	1.62	1.58	14.74	23.35	0.45		341	0.4	25	49.02
LJ 6	Sec 34, J-3	Horblende Monzonite	4.74		1.89	2.67	5.16	15.08	64.28	0.50		164	3.6	14.428	95.77
LJ 7	Sec 34, J-3	Horblende Monzonite	0.30		1.76	0.30	9.37	15.27	66.51	0.59		53	0.4	14	94.11
LJ 8	Sec 34, J-2	Horblende Monzonite	4.29		1.92	3.19	1.31	14.44	68.52	0.64		311	0.3	10	94.34
LJ 9	Sec 34, J-3	Horblende Monzonite	3.51		2.65	2.67	2.46	13.97	70.28	0.43		338	0.2	11	96.00
LJ 18	Sec A, A-10	Metasilstone	4.08		1.76	3.32	4.98	14.62	55.02	1.13		106	1.4	44	84.93
LJ 19	Sec 4, A-10	Diopside Calcite Hornfels	0.11		13.78	16.47	5.55	14.68	69.42	0.33		3 000	1.3	47	120.64
LJ 28	Sec 3, C-1	Horblende Monzonite	4.08		3.90	1.66	2.04	14.75	64.57	0.46		102	0.2	471	91.51
LJ 29C	Sec 3, B-2	Horblende monzonite	4.70		1.79	2.84	2.90	14.52	68.75	0.58		48	0.6	15.508	97.64
LJ 32	Sec 34, J-9	Horblende Monzonite	4.85		2.42	3.49	1.81	15.16	66.86	0.42		293	0.4	19	95.04
LJ 38	Sec.3, A-7	Horblende Monzonite	4.28		2.89	2.99	1.91	15.18	79.23	3.95		519	0.4	48	110.49
LJ 40B	Sec 3, B-7	Horblende Monzonite	4.38		2.17	3.49	2.63	14.35	68.51	0.42		407	0.4	175	96.05
LJ 42	Sec 3, B-7	Horblende Monzonite	1.59		4.96	3.47	5.22	15.15	60.45	0.38		489	0.4	33	91.27
LJ 51	Sec 3, A-8	Horblende Monzonite	4.86		6.90	3.49	1.35	15.15	62.70	0.47		312	0.4	10	94.85
LJ 52	Sec 3, A-8	Horblende Monzonite	5.20		2.58	3.49	1.27	15.24	66.36	0.40		312	0.3	11	94.57
LJ 53	Sec 3, A-8	Horblende Monzonite	3.10		3.19	0.57	2.58	14.44	66.82	0.41		214	0.4	24	91.13
LJ 54	Sec 3, B-8	Horblende Monzonite	4.05		2.40	2.73	1.76	14.96	66.11	0.49		486	0.2	12	92.55
LJ 55	Sec 3. B-8	Garnet-Calcite Hornfels	0.48		2.43	0.53	11.70	7.49	34.18	0.04		16.29	Tr	166	57.02
LJ 56	Sec 3, B-8	Horblende Monzonite	4.27		4.13	3.48	2.02	14.10	64.87	0.53		434	0.2	18	93.45
LJ 56A	Sec 3, C-8	Leucorhyolite	3.74		9.56	0.29	0.65	13.39	67.32	0.08		54	8.6	29	95.04
LJ 62	Sec 34, I-10	Horblende Monzonite	3.75		2.10	3.36	2.81	15.24	66.19	4.18		292	0.2	10	97.71
LJ 66	Sec 34, I-7	Horblende Monzonite	4.03		2.42	3.45	2.88	15.00	66.34	0.51		232	0.4	81	94.66
LJ 81	Sec 34, I-6	Horblende Monzonite	3.41		3.65	2.95	3.43	14.78	66.69	0.53		341	0.3	26	95.48
LJ 82	Sec 34, I-6	Horblende Monzonite	4.03		3.13	2.60	2.33	13.69	67.06	0.47		196	0.3	24	93.33
LJ 83	Sec 34, J-7	Horblende Monzonite	3.76		4.22	2.45	2.71	2.29	66.82	0.51		264	0.4	39	82.79
LJ 84	Sec 34, J-7	Horblende Monzonite	4.44		1.82	2.86	2.31	11.43	68.83	0.57		49	0.4	76	92.27
LJ 85	Sec 3. A-3	Horblende Monzonite	3.49		3.27	2.69	3.06	13.58	67.80	0.45		325	0.3	21	94.37
LJ 91	Sec 3, A-1	Horblende Monzonite	4.64		3.22	2.02	1.34	14.52	67.03	0.44		330	0.3	17	93.24
LJ 92	Sec 3, A-2	Horblende Monzonite	4.29		3.52	1.55	1.33	12.64	66.74	0.48		282	0.4	43	90.58
LJ 93	Sec 3, A-2	Horblende Monzonite	3.13		3.06	1.03	0.86	15.05	63.22	0.50		34	0.1	11	86.85
LJ 96	Sec 3, A-2	Horblende Monzonite	3.49		2.34	0.26	1.62	13.21	68.66	0.59		61	0.6	175	90.19
LJ 98	Sec 3, B-2	Horblende Monzonite	3.92		2.36	0.10	1.44	14.91	66.02	0.45		265	Tr	7294	89.86
LJ 99	Sec 3, A-2	Horblende Monzonite	5.30		1.77	0.08	4.26	13.97	68.89	0.54		64	1.5	170	94.83
LJ 99Y	Sec 3, B-3	Horblende Monzonite	4.68		2.31	2.20	2.04	15.20	68.00	0.42		266	0.6	992	94.98
LJ 100	Sec 3. A 3	Horblende Monzonite	4.19		1.83	0.37	2.03	15.28	70.38	0.50		65	2.4	819	94.97
LJ 101	Sec 3, A-3	Horblende Monzonite	3.43		4.30	2.10	2.13	14.37	66.24	0.40		373	0.3	44	93.01
LJ 114	Sec 34, J-8	Horblende Monzonite	5.73		5.41	2.10	2.05	15.15	62.37	0.47		867	0.7	84	93.58
LJ 114A	Sec 34, J-8	Horblende Monzonite	0.34		3.98	2.75	0.74	14.45	66.68	0.55		183	0.4	Tr	89.51
LJ 119	Sec 34, J-8	Horblende Monzonite	3.55		3.60	2.91	2.73	13.31	66.48	0.45		253	0.3	Tr	93.06
LJ 121	Sec 34, J-8	Horblende Monzonite	3.97		1.91	2.88	1.61	13.47	67.70	0.69		140	0.4	12	92.25
LJ 122	Sec 34. J-7	Horblende Monzonite	4.06		1.87	3.19	1.40	12.88	69.39	0.48		54	0.3	23	93.28
LJ 123	Sec 34, J-7	Horblende Monzonite	5.50		1.70	3.97	3.98	14.98	69.54	0.53		77	0,5	100	100.22
LJ 160	Sec 34, E-6	Quartz monzonite	3.44		3.12	2.38	2.60	9.09	66.73	0.47		599	0.4	13	87.89
LJ 161	Sec 34, E-6	Quartz monzonite	2.65		4.39	1.90	2.61	11.21	65.23	0.39		363	0.3	16	98.42
LJ 167	Sec 34, E-7	Syenodiorite	4.42		3.78	3.19	3.67	13.97	66.41	0.61		676	0.5	12	96.12
LJ 180	Sec 34, C-4	Horblende Monzonite	3.77		2.50	2.41	3.31	12.23	66.99	0.41		484	0.4	11	91.67
LJ 185	Sec 34, F-2	Horblende Monzonite	3.79		2.71	6.76	2.28	13.98	66.25	0.44		557	0.5	9	92.27
LJ 191	Sec 34, G-9	Quartz monzonite	2.03		2.89	0.57	2.11	12.09	66.59	0.45		713	0.6	9	86.81
LJ 192	Sec 34, G-9	Quartz monzonite	1.53		2.51	0.53	0.98	13.94	67.26	0.44		497	0.7	3	87.24
LJ 193	Sec 34, F-9	Calcite-Garnet Hornfels	0.61		14.21	3.38	7.57	15.29	48.17	0.23		5165	0.4	29	89.98
LJ 194	Sec 34, F-9	Syenodiorite	0.17		13.42	9.19	0.71	12.87	49.51	0.80		2902	0.6	7	96.96
LJ 196	Sec 34, F-9	Syenodiorite	4.23		3.85	3.25	4.70	14.36	65.25	0.79		739	0.4	15	96.51
LJ 202	Sec 34, E-8	Syenodiorite	4.36		3.55	2.11	2.62	12.50	67.92	0.49		464	0.6	7	96.60
LJ 210	Sec 35, D-1	Syenodiorite	4.05		4.36	3.44	4.03	14.32	63.60	0.75		765	0.4	16	94.53
LJ 214	Sec 35, E-2	Metasiltstone?	0.24		12.65	9.00	3.43	15.26	55.41	0.57		1848	0.4	2	96.75
LJ 217	Sec 35, E-1	Syenodiorite	4.04		3.89	3.49	3.98	13.25	66.83	0.61		149	0.6	4	96.11
LJ 218	Sec 35, F-1	Garnet-Diopside Hornf.	0.01		1.78	17.38	4.97	6.84	47.93	0.60		5223	3.4	168	80.03
LJ 218A	Sec 35, F-1	Syenodiorite.	3.96		11.41	2.55	2.87	14.23	55.59	0.73		1286	1.2	10	91.47
LJ 219	Sec 34, F-10	Syenodiorite	0.35		3.78	3.46	3.90	14.53	65.20	0.62		852	0.3	8	91.93
LJ 220	Sec 34, F-10	Syenodiorite	0.47		4.05	3.46	4.07	14.15	66.30	0.59		766	Tr	Tr	93.17
LJ 221	Sec 34, F-10	Horblende-Diopside Hor.	3.91		13.28	17.39	7.50	10.73	47.57	0.35		2117	6.6	122	100.95
LJ 223	Sec 35, I-3	Horblende Monzonite	5.27		3.38	2.51	1.79	15.09	64.28	0.45		310	Tr	14	92.80
LJ 224	Sec 35, I-3	Horblende monzonite	4.16		2.48	2.49	2.51	14.69	65.38	0.43		321	1.0	6	92.17
LJ 225	Sec 35, H-3	Horblende monzonite	5.55		2.08	0.11	1.12	11.39	68.68	0.46		222	Tr	9	89.41
LJ 226	Sec 35, H4	Horblende monzonite?	3.79		4.09	3.44	3.61	13.90	64.73	0.53		524	0.6	4	94.15
LJ 228	Sec.35, G-6	Orthoclase quartz.mz.	3.41		4.34	2.71	3.30	14.14	65.37	0.47		604	2.2	8	93.80
LJ 235	Sec 3, C-3	Horblende Monzonite	3.90		2.84	2.68	1.35	12.62	77.61	0.34		2 54	7.3	196	101.39