BASEMENT PORPHYRITIC QUARTZ MONZONITE AND ITS RELATIONSHIP TO ORE NEAR ELY, NEVADA

by

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May 1, 1973
Date

PREFACE

Explorational drilling for porphyry copper mineralization in the Robinson Mining District, Nevada, by the Kennecott Copper Corporation resulted in the accumulation of widespread intervals of cored igneous basement rock. The igneous basement rock is only poorly exposed in one small portion of the district (Weary Flat) and underlies the rest of the district at considerable depth. Twenty drill holes intersected the relatively fresh quartz monzonite mass in an area of approximately four square miles that coincides with the east-west elongation of alteration and mineralization.

The situation at Ely is unique, because here is a district of mineralization with a suite of cored basement rock, that historical "unknown source at depth". In addition, only a very small portion of the basement rock has been lost by weathering.

A master's degree thesis can hardly be expected to do justice to the wealth of data contained within the basement complex. If nothing else, this thesis will provide useful geologic data on this hereto undescribed mass so that more detailed, more specialized studies can be initiated.

The author wishes to express his appreciation to the Kennecott Copper Corporation for financial aid and permission to pursue the topic of this thesis. Mr. W. H. Winn, General Manager of Nevada Mines Division, granted permission to do the thesis on the Nevada property and acquire the necessary information. During the summer of 1969, the geology department at Nevada Mines Division helpfully provided a place to work and access to their geological data. The author is particularly indebted to the Kennecott Research Division for granting financial aid covering the major portion of the thesis' expenses and to Richard Neilson of the Research Division who provided valuable suggestions, guidance and interest.

The University of Arizona and particularly Dr. W. C. Peters, thesis advisor, and Dr. W. Lacy, Head of the Department of Mining and Geological Engineering, contributed valuable suggestions, time and guidance from the start of the thesis to the time it was completed.

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ABSTRACT

Structural interpretation, total sulfide data, petrography, mineralization, and alteration indicate that the Liberty Pit block was located above the Weary Flat area and that individual units in the Weary Flat and Liberty general rock types reflect various stages of hydrothermal activity and/or magmatic recrystallization. The granitic textured groundmass of the basement porphyritic quartz monzonite grades upward into the aplitic-textured groundmass of the ore-bearing quartz monzonite porphyries in the area of the igneous basement rock-sedimentary rock contact.

The basement rock and overlying altered and unaltered quartz monzonite appear to have been of the same composition prior to alteration and mineralization. Pervasive hydrothermal alteration took place above the crestal portion of basement rock.

CHAPTER I

INTRODUCTION

The Ely porphyry copper deposits (the small town of Ruth is actually much closer to the deposits than Ely) are located in the Robinson Mining District of mid-eastern Nevada. The district is composed of at least six bodies of ore-grade mineralization (0.4 percent copper or greater). From west to east bodies of ore-grade mineralization of interest to this paper are the Tripp-Veteran (once mined as two separate ore bodies), Liberty, Ruth (the Deep Ruth ore body is the western portion of the Ruth ore body at depth), Ruth Extension, and Kimbley (see Fig. 1). In addition to the porphyry copper deposits the district has an outer fringe of economically minor base and precious metal vein and replacement deposits.

The district is composed of complexly faulted, Upper Paleozoic sediments that host Cretaceous intrusive rock of quartz monzonite composition and Tertiary intrusive rock of granite (rhyolite) composition. Alteration and mineralization of the sedimentary rocks and quartz monzonite porphyries took place during or shortly after the close of Cretaceous intrusive activity.

Objective

The purpose of this thesis is to examine basement porphyritic quartz monzonite and relate this weakly altered, weakly mineralized

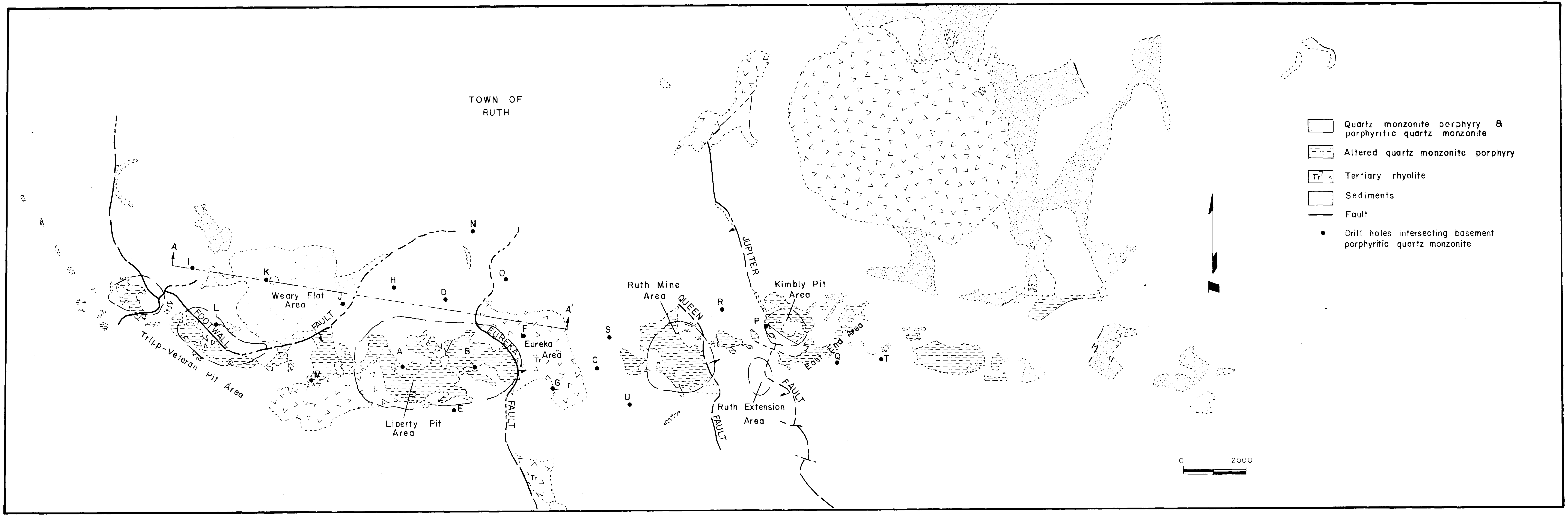


Fig. 1. Geologic map of the Ely area.

Robinson Mining District Nevada.

igneous body to the overlying altered and mineralized quartz monzonite porphyries. The problem is approached from an explorational point of view so that the thesis may help guide and interpret future explorational drilling in the district. At the time of this investigation explorational premises still incorporated the idea that the basement porphyritic quartz monzonite could have intruded before, during, or after mineralization; and the Footwall Fault, a major fault truncating ore-grade mineralization and separating the basement porphyritic quartz monzonite from the overlying ore porphyries, could be either a reverse (thrust) or normal fault. The ideas of other geologists will be considered along with seemingly pertinent observations made during the course of this investigation in an attempt to resolve some of the basic geologic relationships at Ely.

Approach to the Problem

Prior to the early 1960's knowledge of the basement porphyritic quartz monzonite was limited to a few observations made in the Weary Flat area. Exposures of the basement rock on Weary Flat were undoubtedly better in the past before mine dumps and towns were built, but probably were still few and far between. Today there is one good road cut and a few localities where porphyritic quartz monzonite is very close to the surface of the ground. The area could not have been mapped with any more accuracy or detail than had been done in the past; consequently, "field work" was limited to collecting samples of the Weary Flat rock, samples of altered and unaltered dikes and sills, data from deep holes (relogging of approximately 18,000 feet of split diamond drill core;

see Table 1 for drill hole statistics), and existing data on the basement rock.

The summer of 1969 was spent collecting samples and logging core at Ely, Nevada, and the summer of 1970 was then spent preparing this report while in Tucson, Arizona. One and a half years previous experience in the district aided greatly in understanding and, hopefully, resolving some of the geologic problems.

The porphyritic monzonite body was studied by making detailed drill logs, vertical cross sections (one inch to 500 feet), one block diagram depicting four separated blocks, structural contour maps (one inch to 500 feet), mylar overlays showing the distribution of various geologic features (not presented with but discussed in this paper), and about 100 thin sections.

During the logging of the quartz monzonite, intervals of rock having uniform and reasonably distinct characteristics were identified and described as units. (The units are named by the drill hole that intersects the unit and the sequence of units in the hole is denoted by the last letter, for example, unit A is the top unit in hole A.) In general the basis for separation of units was made on texture and general appearance. In a few instances compositional changes and changes in the color of rock forming minerals were deemed important enough to identify a new unit, and more often than not in a particular drill hole, small changes in mineral percentages were overshadowed by textural changes. The physical characteristics of rock forming minerals (size, shape, and color), mineralization, and alteration were noted for each

Table 1. Drill hole and surface sample data.

Hole Number	Collar Elev.	Bottom Elev.	Depth	Interval Logged From	To	Total
A	6533	3972	2561	391	2561	2170
B	6511	4764	1747	0	1747	1747
C	7065	4125	2940	1350	2940	1590
D	7039	4501	2538	672	2538	1866
E	7267	4267	3000	2400	3000	600
F	7110	5236	1874	630	1874	1244
G	7255	4377	2878	2100	2878	778
H	7121	5727	1394	405	1394	989
I	7299	6060	1239	340	1239	899
J	7118	6150	968	0	968	968
K	7115	6513	602	0	602	602
L	7005	5929	1076	450	1076	626
M	7318	4705	2613	1850	2613	763
N	6911	6181	730	200	730	530
O	7043	5036	2007	725	2007	1282
P	6725	5318	1407	956	1407	451
Q	7000	5207	1793	1685	1793	108
R	7037	5750	1287	1100	1287	187
S	6988	5043	1945	1620	1950	330
T	6953	5607	1346	1130	1346	216
U	7298	5341	1957	1780	1957	177
V[1]	7192	ND	ND	-	-	-
W[1]	ND	ND	ND	-	-	-
X[2]	ND	ND	ND	-	-	-
Y[2]	ND	ND	ND	-	-	-
Surface Samples						
6-18-1[3]	-	-	-	-	-	-
6-20-4[4]	-	-	-	-	-	-
LCity[5]	-	-	-	-	-	-
LVArea[6]	-	-	-	-	-	-

[1]Tripp-Veteran Pit Area; [2]Ruth Mine Area; [3]5 miles northeast of Kimbley Pit; [4]3/4 mile north of Veteran Pit; [5]1 mile northeast of Kimbley Pit; [6]2 miles east of Kimbley Pit

unit; and a representative hand sample was taken for reference. Units could be projected between certain drill holes, and the units provided flexibility in observing small scale (drill hole) and large scale (district) trends. In the following discussion units may be viewed individually, collectively in terms of a drill hole, or collectively in terms of a particular area (These groups of units are referred to as general rock types, for example, the Eureka general rock type is found in the Eureka fault area.) of the district.

Point counting was done on thin sections thought to be as nearly representative of a rock unit as possible. Rapid point counts consisting of 100 to 200 counts per slide were made of a number of slides so that they could be averaged together to give a more representative count for rock in a selected area or drill hole. A larger number of counted points, ranging up to 700 points, was made for more important intervals. A thin section area of 800 square millimeters was normally used with 1400 square millimeter-sized sections used for more porphyritic rock, and in every case point counts were taken over the entire area of a thin section with a similar number of counts on the other half showed the most variance in the percentage of K-feldspar and plagioclase because of the variable porphyritic nature of K-feldspar.

Geologic Summary

The reader is urged to consult an article on porphyry copper deposits in the Robinson Mining District, Nevada (Bauer, et al. 1966, pp. 232-244) for detailed information. The following geologic summary on sedimentary rocks is taken from this article.

Sedimentary Rocks

Premineralized sedimentary rocks in the Robinson Mining District range from Ordovician to Permian in age, and post mineralization sediments are of Tertiary and Quaternary (alluvium) age. Premineral sediments in the vicinity of mineralization include Devonian Nevada Limestone (totaling approximately 4,000 feet in thickness), Mississippian Pilot Shale (350 feet in thickness), Mississippian Joana Limestone (400 feet thick), Mississippian Chainman Shale (400 - 1,500 feet in thickness), Pennsylvanian Ely Limestone (2,300 feet thick), Permian Riepe Spring Limestone (250 feet in thickness), Permian Rib Hill Sandstone (1,100 feet thick), Permian Arcturus Formation (dominantly siltstone and limestone totaling 2,900 feet in thickness), and Permian Kiabab Limestone (90 - 150 feet thick) (Bauer et al. 1966, pp. 234-235).

Igneous Rocks

Intrusive rocks resulted from two distinctly time-separated periods of igneous activity. The quartz monzonite and quartz monzonite porphyries with which the ores are associated have an average age of 109±3 million years, and rhyolite intrusives have an age of 37±1 million years (McDowell and Kulp 1967, p. 907).

The Gretaceous intrusives consist of a large, elongate, stock-like mass of locally porphyritic quartz monzonite (often referred to as basement rock since it underlies the porphyry copper deposits) and dikes, sills, and irregular masses of altered and unaltered quartz monzonite porphyry. Many of the dikes, sills, and small irregular masses of quartz monzonite porphyry form the nucleus of the ore bodies over the basement quartz monzonite rock and some occur as generally fresh, though locally hydrothermally altered, bodies in the east and northeast portion of the district.

Rocks of rhyolite composition include numerous dikes and irregular masses of either porphyritic-aphanitic or glassy textured rocks that intrude quartz monzonite porphyries, basement quartz monzonite, and sediments. Intrusive masses of rhyolite and breccia form several, large, irregularly shaped bodies and are termed "rhyolite breccias". In many of the drill holes logged by this author, rhyolite is found intruded between igneous rocks of contrasting texture and degree of alteration and mineralization. Continuous, strong fault zones project into these rhyolite contact zones, but little or no faulting evidence is apparent except for contrasting rock types. It is not unreasonable, therefore, to assume that fault zones of gouge and breccia were conducive to the intrusion of rhyolite masses. The rhyolite magmas may have flushed out most of the breccia and gouge in certain fault zones and into the hanging-wall blocks where they are most abundantly found today. Much of the shale-like rock in the rhyolite breccias may actually be baked fault gouge.

District Structure

A northwesterly-trending anticlinal fold structure whose age predates the mineralization and alteration cuts across the west end of the district. Overturned sediments in the northwest portion of the district return to their normal southwesterly dip just to the south of the district. Major thrust faulting accompanied the development of the fold, and the resulting thrust horizons have locally controlled mineralization and alteration. There is a possibility that gravity slides are present north of the district, and evidence indicates that some thrusting may be post mineral in age. Normal faulting is both pre- and post-ore in age.

Alteration and Mineralization

The east-west elongated zone of alteration and mineralization includes distinctive alteration types for both the sediments and the quartz monzonite porphyries. The basement porphyritic quartz monzonite is altered by a propylitic type of alteration and mineralization. The ore-bearing quartz monzonite porphyries are separated into major alteration mineral assemblages: quartz sericite and biotite argillic. In general, quartz sericite altered rock will have a higher total sulfide content and a lower grade of copper mineralization than that of biotite argillic altered porphyry. Details of porphyry alteration assemblages are discussed by Bauer et al. (1966, p. 239) and Fournier (1958, 1967). Shale and limestone are both silicified and/or silicated, and quartzite is mainly silicified. The alteration and mineralization of sedimentary rocks will be discussed (James 1972). Sediments in contact with fresh and weakly altered porphyritic quartz monzonite and unaltered quartz monzonite porphyry dikes and sills show very minor contact effects.

Sulfides of the ore zones occur in veinlets and disseminations. The most abundant sulfide mineral is pyrite, the most abundant primary copper ore mineral is chalcopyrite, and chalcocite is the most abundant secondary ore mineral. Small amounts of molybdenite and locally abundant magnetite are found in and near ore zones. In general the sulfides may be pervasively oxidized to depths of 100 to 400 feet beneath the surface.

CHAPTER II

ROCK TYPES

The basement rock should technically be called porphyritic hornblende quartz monzonite with granitic to porphyritic textural variations. The average of modal analysis is 40 percent plagioclase, 31 percent K-feldspar, 31 percent quartz, 10 percent hornblende, 2 percent augite, and 4 percent other minerals (pyrite, magnetite, epidote, sphene, zircon and apatite). Plagioclase accounts for 56 percent of the total feldspar; 50 to 60 percent of the plagioclase is zoned; and the average composition of albite-twinned plagioclase is about 32 to 35 percent anorthite and 65 to 68 percent albite.

As previously discussed the porphyritic quartz monzonite in each drill hole was subdivided into intervals of uniform characteristics called units. Then similar units were grouped and described by general rock type (see following cross section A-A', Fig. 2).

Units

The units identified and described are summarized in Table 2. This table is basically a mineralogical summary, and when the mineralogy of a particular unit is viewed collectively the table gives an idea of the general appearance of each unit. The photographs (shown in Figs. 3a - 3z) illustrate most of the textural variations in hand samples and thin sections. Mineral percentages estimated during logging are not

Fig. 2. Generalized geologic cross section A-A'.

Robinson Mining District Nevada.

Table 2. Unit Description Summary

Footnotes and Abbreviations for Unit Summary Table

Depths in drill hole in feet.
All measurements of minerals in millimeters.
Percent fine grained groundmass: % f-g GM.

Color of K-feldspar:
- O - orange
- P - pink
- S - smoky
- C - cream or light tan
- W - white
- Gy - grey
- PC - cross between the two colors; pinkish cream for example

Color of Plagioclase:
- W - white
- Gy - grey
- Gn - green
- S - smoky
- Y - yellow
- B - brown

Shape:
- E - euhedral
- S - subhedral
- A - anhedral
- (if underlined, the underlined shape is the more abundant)

Igneous-Igneous Contacts:
- g - gradational and if preceded by a number this is the number of feet that has gradational aspects
- s - sharp
- i - interlayering of units

Size: Average large size refers to the average size in millimeters of an arbitrarily defined population which is roughly the largest 20%.

* Important amounts of partial or total alteration of hornblende.

Table 2. Unit description summary.

Hole & Unit	Interval From	Interval To	% f-g	K-Feldspar Largest Pheno	K-Feldspar Av.Larg. Cryst.	K-Feldspar Av. Size	Color	Plagioclase Largest Cryst.	Plagioclase Av.Larg. Cryst.	Plagioclase Av. Size	Hornblende Color	Hornblende Largest Cryst.	Hornblende Av.Larg. Cryst.	Hornblende Av. Size	Hornblende Shape	Ig.- Ig. Depth	Contacts Nature	Dip of Flow Structure
A -a	391	436	20	-	27x14	10x4	O-P	7x3	4x2	3x1	W	7x2	4x1	2x1?	E&A	436	g	60
-b	436	568	0-10	35x30	20x10	9x3	O-P	9x4	6x3	4x2	W	7x2	4x2	2x1	E&A	568	s-g	60/50
-c	605	766	0	20x9	10x6	6x3	P-C	8x2	-	4x2	GyGn	9x2	5x3	2x1	E&S	766	g	60
-d	766	820	0	30x15	10x4	8x3	CP-S	8x2	6x2	4x3	GyGn	7x4	6x2	4x2	E&S	-	-	50
-e	879	907	0	-	-	-	P	-	-	3x2	GyW	-	-	Altn.	-	-	-	70
-f	930	1110	0	12x3	6x2	4x2	P-S	-	4x2	3x1	GyGn	5x4	3x2	1x1	A&S	-	-	50
-g	1121	1171	0	15x5	10x2	5x2	S-C	6x5	7x3	4x2	GyGn	5x3	4x2	2x1	S	1191	1g-s	55
-h	1171	1191	0	35x22	10x4	4x3	S	-	6x2	4x2	GyGn	-	3x3	2x2	S	-	-	50
-i	1191	1418	0	22x12	10x4	7x2	P-S	-	7x3	4x2	W	4x4	4x2	2x1	E&S	1418	4g	40
-j	1418	1553	0	10x10	11x3	4x1	P-S	9x5	4x2	2x1	W	7x2	4x2	2x1	S&A	1553	40g	30
-k	1553	1732	0	-	15x6	8x5	P-S	6x2	6x2	2x1	W	7x7	6x3	2x1	E&S	1732	10g	35
-l	1732	1767	0	18x15	16x7	10x5	PC-S	-	6x1	3x1	W	9x2	7x2	3x2	E&S	1767	20g	40
-m	1767	2262	0	25x15	11x5	7x3	PC-S	11x2	8x3	3x1	W	10x3	5x1	3x1	E&S	2262	s&i	35
-n	2262	2293	0	35x25	15x7	10x5	S	9x3	6x2	4x2	W	6x3	4x2	2x1	E&S	2293	s	50
-o	2293	2387	0	20x20	10x8	6x3	P-S	7x5	6x2	4x2	W	10x4	7x2	4x2	E&S	2387	1g	45
-p	2387	2478	0	14x7	10x5	6x3	PS-PC	14x3	6x2	4x1	SW	-	6x2	2x1	E&S	2478	2g	35
-q	2478	2561	0	25x13	15x8	10x5	S-PS	10x2	5x3	4x1	W	-	5x2	2x1	E&S	-	-	35
B -a	0	548	20	35x18	15x8	10x3	C	6x3	-	3x2½	Gn&YB	14x3	6x3	3x1	E&S	-	-	50
-b	560	580	0-15	-	25x12	13x9	P-C	7x3	5x4	4x2	Gy	10x4	-	3x1	E&S	-	-	80
-c	597	607	15	40x20	25x12	13x9	-	-	-	-	-	-	-	-	-	-	-	-
-d	974	1075	0	15x3	6x2	2x1	S-C	-	5x1	2x1	GyS	10x4	3x2	1x1	A	-	-	30
-e	1075	1095	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-f	1113	1231	0	-	8x2	3x1	S	3x2	2x2	2x1	GyGn	-	3x2	2x1	S&A	-	-	-
-g	1241	1747	0	35x18	15x5?	4x1	S	15x10	5x5	3x1	GyW	10x6	6x2	1x1	S&A	-	-	40
C -a	1368	1865	0	20x7	10x5	8x4	S-C	7x5	4x2	3x1	GnGy	7x4	4x2	1x½	S	-	-	45
-b	2046	2940	0	40x40	6x3	3x1	S	14x5	8x4	3x2	Gy	6x2	3x1	1x1	S&A	-	-	30
D -a	705	836	0	10x3	4x2	2x1	W	-	3x1	1x1	SGy	5x2	3x2	2x1	E&S	-	-	50
-b	1155	1540	0	45x25	6x5	3x2	P-S	9x6	7x5	3x1½	GyW	5x5	4x2	2x1	E&S	1540	40g	55
-c	1540	1660	0	40x30	20x10	4x2	PS	11x9	6x5	3x2	W	5x4	3x2	2x1½	S	-	-	40
-d	1660	1756	0	40x30	10x7	7x2	S-Gy-P	-	7x4	3x2	GyGn	10x5	4x2	3x2	S	1756	2g	45
-e	1756	1878	0	-	10x4	3x2	PS	9x5	7x2	3x1	W	6x4	6x2	2x1	S	1876	5g	50
-f	1878	2150	0	15x9	13x8	10x5	P	10x5	5x5	4x1	W	7x3	4x2	2x1	E	2150	8g-s	40
-g	2150	2196	0	-	15x6	10x4	P&S	10x5	6x2	4x2	GyW	7x3	4x4	4x2	E	-	-	40
-h	2196	2538	0	26x10	12x6	6x3	PC	10x8	6x2	3x1½	Gy/GnGy	9x5	5x2	2x1	S	-	-	40
E -a	2490	2493	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45
-b	2493	2504	0	-	10x4	6x2	S	8x3	6x2	3x1	GnGy	4x2	4x1	2x1	E&S	-	-	45
-c	2504	2663	0	17x10	10x3	8x2	PS	-	8x2	4x2	GnGy	6x3	4x1	2x1	E&S	2663	20g	50
-d	2663	2929	0	12x5	10x4	5x3	PC-S	-	7x2	3x2	GnGy	7x2	4x1	2x1	S&E	2929	8g	60/45
-e	2929	3000	0	15x7	10x5	8x4	PS	10x3	7x2	3x2	GyW	-	6x3	1x1	S&E	-	-	35
F -a	650	1285	0	40x20	12x6	4x2	GyW	5x3	4x2	2x2	SGy	10x6	5x2	2x½	E&S	-	-	65
-b	1340	1607	0	20x7	15x15	4x5	PS	4x4	5x2	3x1½	GnGy	8x3	4x1	2x½	E&S	-	-	40
-c	1652	1874	0	40x38	8x4	3x1	S	8x4	7x3	3x2	GyW	6x5	2x2/2x1	1½x1/1x½	S	-	-	45
G -a	2242	2282	0	-	16x6	1x1	SC	-	3x2	2x1½	Gn	-	5x3*	2x1*	E	-	-	60
-b	2351	2878	0	55x20	10x5	3x1	S	-	7x3	3x1	Gy	5x3	3x1	1x1	S&A	-	-	45

Table 2. Continued

Hole & Unit	Interval From	To	% f-g	K-feldspar Largest Pheno	K-feldspar Av. Large Cryst.	K-feldspar Av. Size	Color	Plagioclase Largest Cryst.	Plagioclase Av. Larg. Cryst.	Plagioclase Av. Size	Color	Hornblende Largest Cryst.	Hornblende Av. Larg. Cryst.	Hornblende Av. Size	Hornblende Shape	Ig.-Ig. Depth	Contacts Nature	Dip of Flow Structure
H -a	411	484	0	20x15	-	3x1½	S	7x7	6x3	3x2	GnGy	8x3	2x1	1x1	S&A	-	-	60
-b	484	963	0	65x40	8x4?	3x1½	S	8x5	-	3x2	Gy	11x4	2x2	2x1	S&A	484	10g	65
-c	1012	1394	0	15x15	9x5	6x3	SP	-	5x4/5x2	4x2/2x1	GnGy/W	8x5	4x2	2x1	E&S&A	-	-	50
I -a	473	900	0	18x13	10x3	3x1½	CW	6x3	4x2	3x1½	SGy	13x4	3x3	1x1	S	900 to	-	55
-b	900	1088	0	-	-	-	-	-	-	-	-	-	-	-	-	1088	s&i	55
-c	1088	1239	0	42x20	20x10	15x7	C-S	-	7x3	4x2	GnGy	10x5	3x2	1x1½/3x1	E&S	-	-	65
J -a	21	43	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-b	43	113	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-c	113	283	0	20x20	10x10	10x5	S&W	9x5	5x2	3x1½	GnGy	10x8	3x2	2x1	E	283	1g-s	55
-d	283	312	0	-	-	10x5	S&W	-	-	3x1½	GnGy	6x3	4x1	1x1	S&A	312	s	50
-e	312	436	0	20x10	10x4	8x4	C	10x5	5x2	3x1½	GnGy	7x2	6x2	2x1	E&S	-	-	50
-f	436	535	0	-	-	8x4	C	-	-	3x1½	GnGy	-	-	1x1	A	535	1g	55
-g	535	607	0	-	-	-	-	-	-	3x1½	GnGy	-	-	coar/fin	-	603	2g	40
-h	607	968	0	50x25	12x5	5x3	C	-	5x5	3x1	GnGy/W	7x3	5x2	1x1	S&A	-	-	50
K -a	75	193	0?	22x10	12x5	5x3	C	-	5x3	4x1	GyGn	4x4	5x2	2x2	E	193	3g	40
-b	193	207	0	-	-	-	-	-	-	-	-	-	-	fine	-	-	-	-
-c	207	220	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-d	260	419	0	20x10	10x5	5x3	W-C	-	5x2	4x2	GyGn	9x4	5x3	2x2	S	419	1g	50
-e	419	544	0	20x10	11x5	6x3	W-C	-	5x3	4x2	Gy	8x4	3x3	1x1	A&S	-	-	50
-f	554	602	0	26x15	10x5	6x3	C	-	3x2	2x1	GnGy	7x5	4x2	3x2	A	-	-	60(?)
L -a	438	580	0	25x12	15x7	10x5	PC	8x4	-	3x1	GyW	7x3	5x2	2x1	A	580	25g	70
-b	580	837	0	40x38	18x9	15x10	PC-S/P	8x4	7x5	4x2	GyW	10x4	4x3	2x2	S&A	837	fault(?)	65
-c	837	884	0	-	-	-	-	-	-	-	-	-	-	3x2	-	884	s	-
-d	884	1008	0	25x15	16x8	12x7	PC	8x4	7x5	4x2	GyW	12x2	3x3	2x1	S	1008	s	60
-e	1008	1052	0	-	16x8	12x7	PC	-	7x5	4x2	GyW	-	5x3	4x2	S&A	1052	20g	45
-f	1052	1076	0	-	16x8	12x7	PC	-	7x5	4x2	GyW	-	5x3	2x2	E&S	-	-	65
M -a	1903	1975	0?	15x8	8x4	4x2	C	-	-	3x2	S	-	4x2	1x½	E&S	-	-	70
-b	2152	2210	0	15x15	15x6	6x1½	SC	10x2	-	4x1½	GnGy	7x5	5x3	4x2	E&S	-	-	45
-c	2210	2613	0	35x25	10x5	5x4/3x2	SC	-	5x4	3x2	GyW	8x2	4x1	1½x½	E&S	-	-	50
N -a	203	453	0	65x38	12x6	8x4	P	12x4	6x3	4x2	GnGy	-	6x2	2½x1	E&S	-	-	50
-b	520	558	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-c	558	730	0	60x28	15x7	2x2	S	8x9	4x3	2x2	GyW	7x3	4x2	1x1½	S&A	-	-	50
O -a	765	1018	0	40x20	10x5	3x½	S-CS	5x5	4x2	3x1	GnGy	4x4	2x1	1x½	S&A	-	-	55
-b	1168	1171	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-c	1189	1743	0	75x40	6x1	4x1	S	8x4	4x4	3x2	GyW	5x5	2x1	1x½	S&A	-	-	45
-d	1878	2007	0	12x5	8x4	4x3	C&S	-	5x3	3x2	GyW	4x4	2x2	1x½	S&A	-	-	40
P -a	959	1047	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-b	1057	1288	0-10	15x8	7x3	5x2	GyW	9x2	4x2	3x1	GnW	6x3	1x1	1x½	S&A	1288	s-g	60
-c	1288	1407	0	11x4	6x2	2x½	Gy	4x3	-	2x1	GnGy	6x3	1½x½	½x½	-	-	-	30/60
Q -a	1693	1793	0	18x7	6x3	2x1	GyW	7x5	4x2	2x1	GnGy	13x5	2x1	½x½	A	-	-	45/70
R -a	1222	1287	0	14x9	6x4	4x1	C-GyW	-	4x1	2x1	GnGy	3x3	3x1	1x½	S&A	-	-	50
S -a	1692	1707	0	25x15	10x5	7x3	P	7x3	6x2	4x2	W	-	15x3	2x1	E	-	-	45(?)
T -a	1260	1346	0	10x8	6x3	4x2	SW	4x4	4x2	3x1½	GnGy	6x4	3x2	1x½	S	-	-	50
U -a	1870	1957	0	10x10	6x4	4x2	S	4x3	3x2	1½x½	GnGy	-	3x2	1x½	S&A	-	-	55

presented in the unit summary table since the individual thin section point counts in Table 3 are thought to be more reliable. Representative hand samples were collected and photographed for reference and use in comparing units.

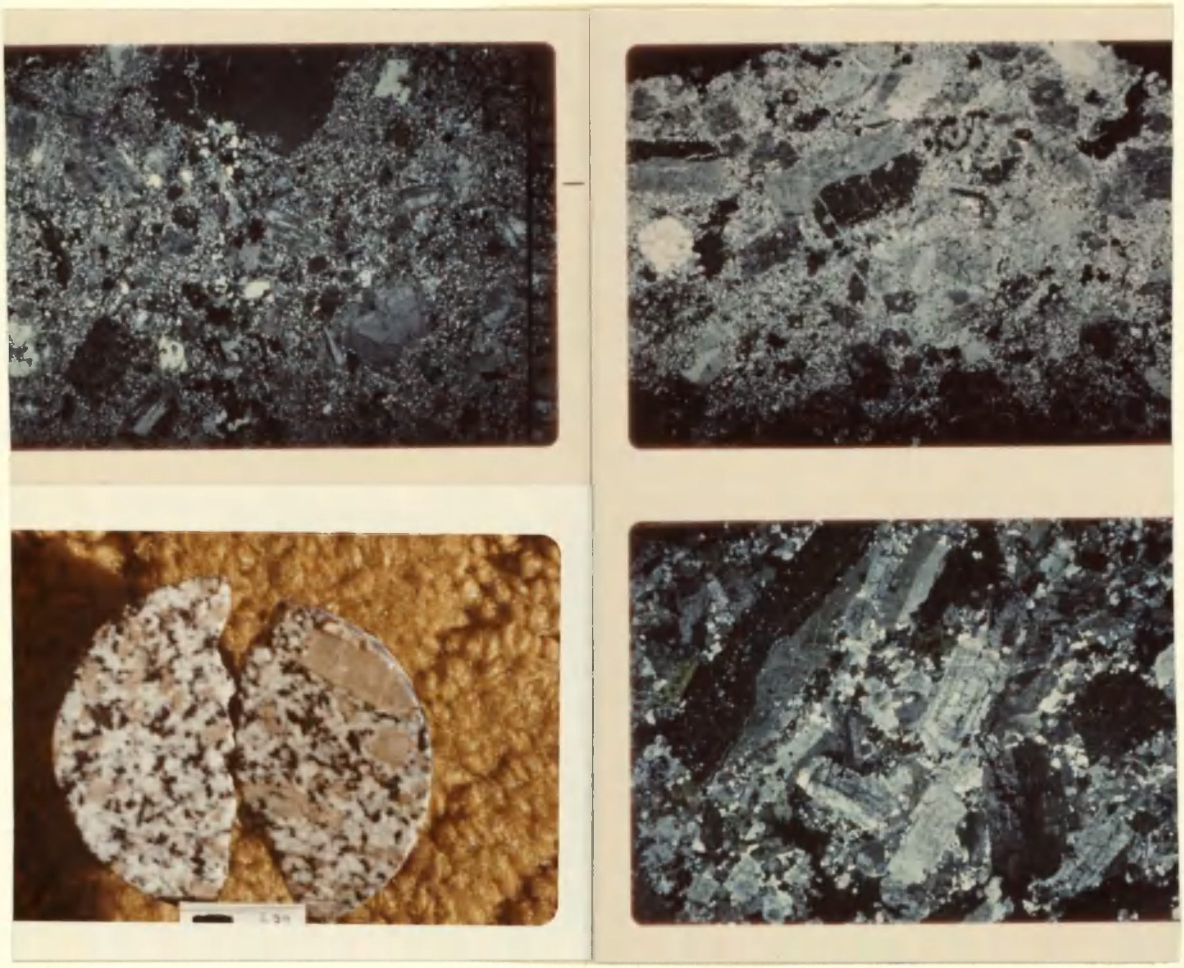
The following photographs (Figs. 3a - 3z) display textural variations of the basement rock. Figure (3a) is a relatively fresh dike rock in the Ruth Caved Area that is texturally similar to the altered, ore-bearing quartz monzonite porphyries. The plastic scale in the handle sample photographs is the same scale as on the edge of the thin section photographs (smallest subdivision in millimeters).

Units correlated with similar units are summarized in Table 4. Relatively insignificant changes in mineral size, shape, and color tended to confuse individual correlations. The most reliable correlations were obtained when successive units could be matched since the units seemed to retain their positions relative to each other in the drill holes. Units of the Liberty general rock type could be correlated with reasonable certainty between neighboring drill holes. A few units of the Liberty general rock type roughly correlated with units of the Weary Flat general rock type (as noted in Table 4). Correlation of units of the Weary Flat general rock type between neighboring holes was difficult and the difficulty may be related to variable rock textures in the area, wide spaced drill holes, and/or steeply dipping units. The rock of the general Eureka type could not be definitely correlated with any of the units of the Liberty and Weary Flat general rock types; however, the

Table 3. Individual thin section point counts.

Hole or Location	Depth (ft.)	No. of Counts	Plag. %	K-feld. %	Qtz. %	Hbln. %	Aug. %	Other %
A	432	200	47	24	21	Altn.	Altn.	8
A	804	700	39	33	15	10	-	3
A	882	600	43	29	12	8	2	6
A	1153	100	33	44	12	7	1	3
A	1513	100	43	29	18	6	2	2
A	1653	200	40	30	19	10	-	1
A	2278	100	32	38	15	13	-	2
A	2544	200	50	15	13	17	-	5
B	1292	100	32	34	13	9	8	4
B	1563	200	35	32	12	13	4	4
B	1610	100	30	36	15	9	4	6
B	1732	100	39	26	9	16	6	4
C	2267	100	40	23	13	15	2	7
C	2906	100	32	38	14	6	5	5
D	1270	100	41	40	7	9	1	2
D	2044	200	39	34	11	12	-	4
D	2523	200	42	26	12	11	2	7
E	2537	200	40	32	13	11	-	4
E	2747	300	36	37	15	10	-	2
F	1095	100	29	38	10	18	-	5
F	1712	200	36	35	10	12	4	3
G	2685	300	42	31	7	9	6	5
G	2866	300	36	27	13	17	2	5
H	870	100	33	41	6	14	2	4
I	764	100	35	26	12	23	-	4
I	1229	300	44	24	20	8	-	4
J	220	100	38	39	11	9	-	2
J	960	100	49	16	5	Altn.	Altn.	30
K	393	100	46	27	11	7	6	3
K	452	100	36	24	23	13	-	4
L	585	300	53	24	12	7	-	4
M	2604	300	35	24	27	9	-	5
N	422	300	31	43	19	5	-	2
N	726	200	35	38	12	9	3	3
O	1286	100	40	26	12	13	1	8
O	2000	200	42	29	19	9	-	1
P	1220	200	33	44	12	3	-	8
P	1348	500	37	37	8	13	-	5
Q	1728	200	40	40	8	5	5	2
R	1286	100	45	25	13	7	-	10
T	1320	300	41	33	13	10	-	3
X	1065	400	30	21	19	Altn.	Altn.	30
V	399	500	34	29	23	1	-	13
LV Area	Surf.	500	44	27	10	4	1	14

a. b.

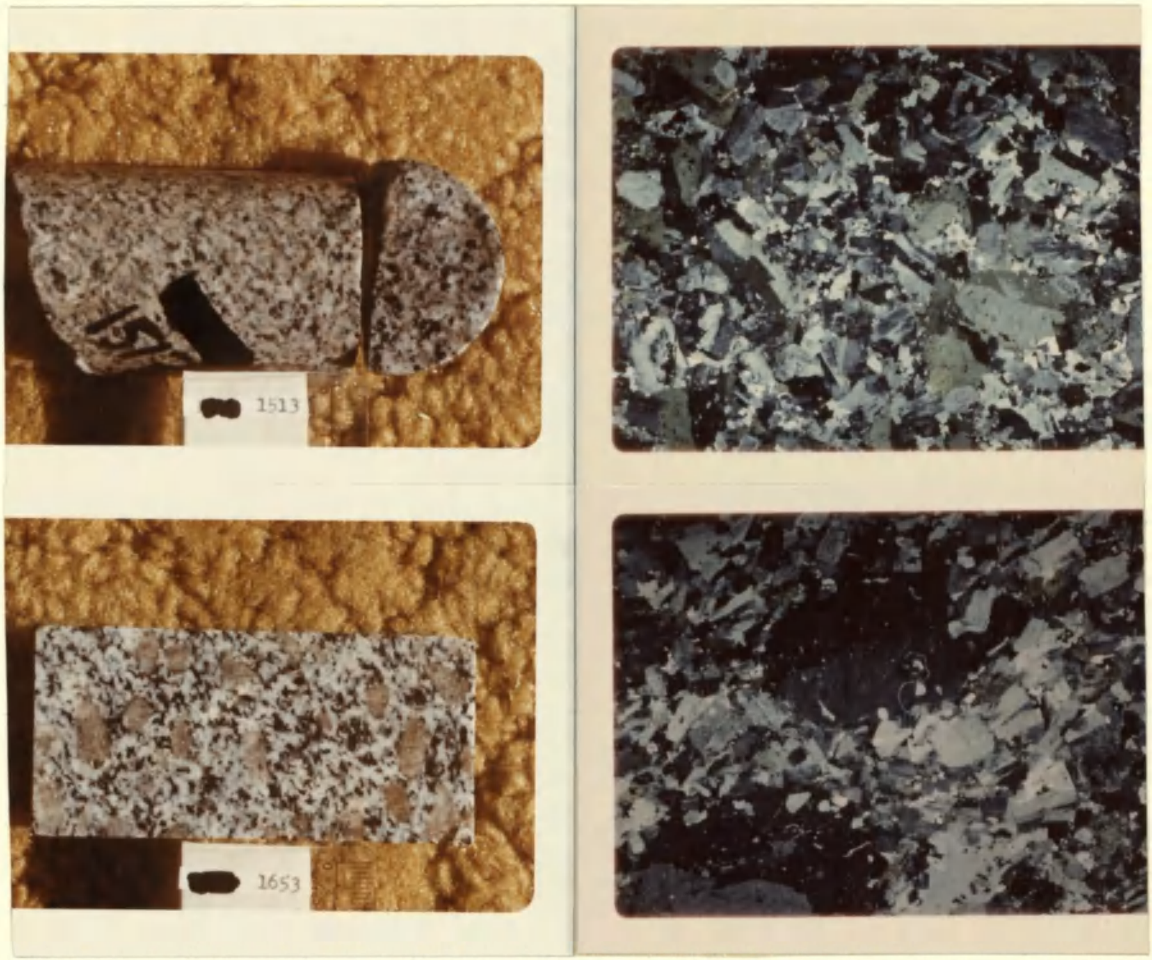


c. d.

Fig. 3. Drill Holes

a. Hole X, 1065 feet
b. Hole A, 399 feet
c. Hole A, 432 feet
d. Hole A, 432 feet

e. f.

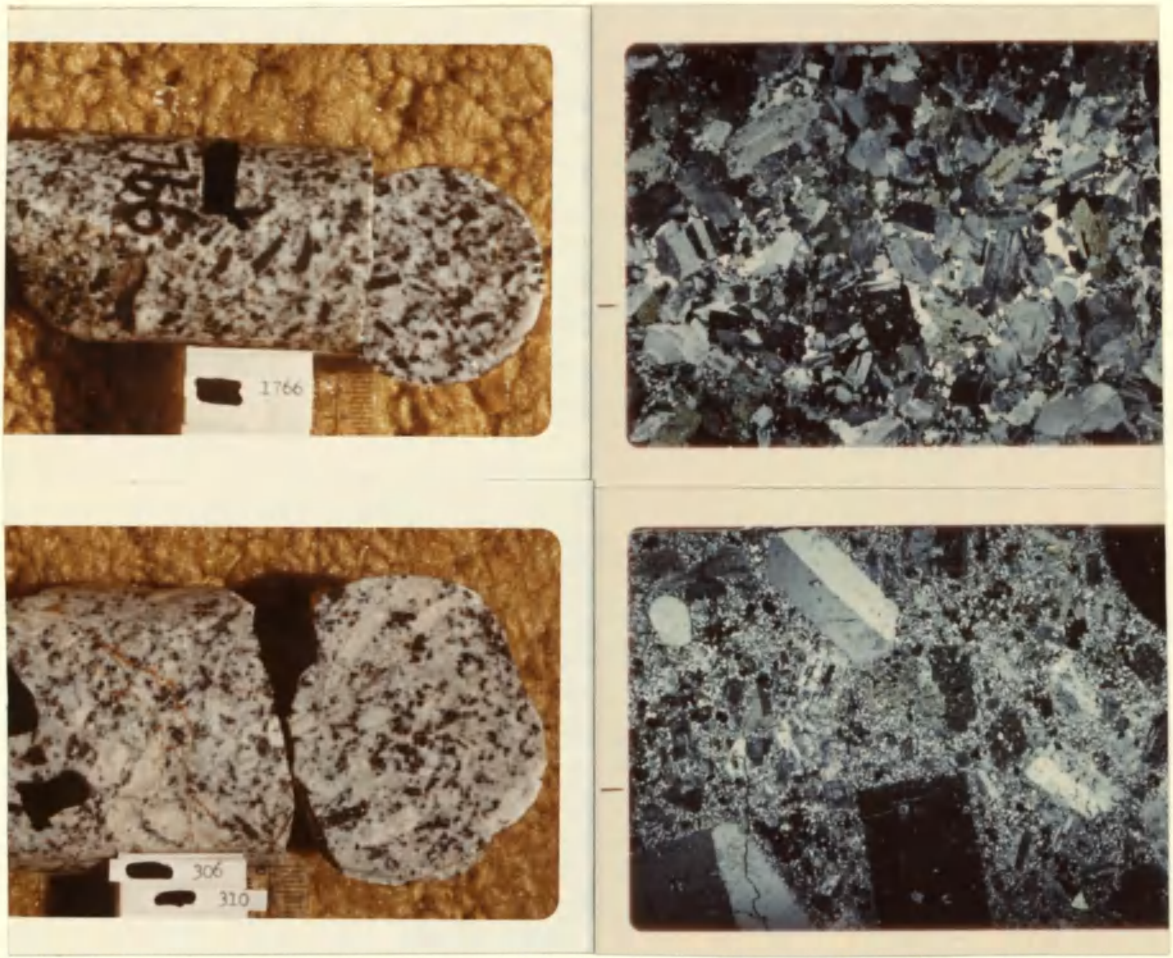


g. h.

Fig. 3. Drill Holes, Continued.

e. Hole A, 1513 feet
f. Hole A, 1513 feet
g. Hole A, 1653 feet
h. Hole A, 1653 feet

i. j.

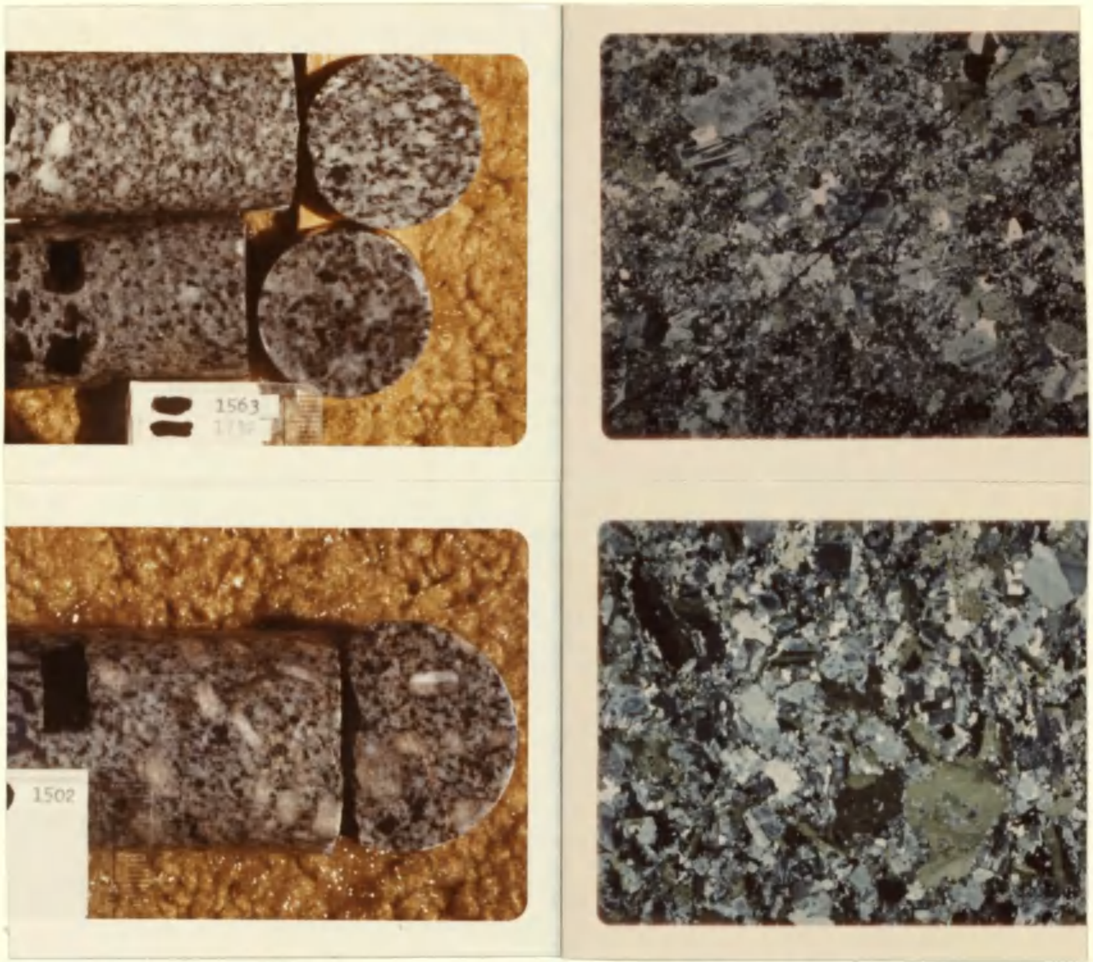


k. l.

Fig. 3. Drill Holes, Continued.

i. Hole A, 1766 feet
j. Hole A, 1766 feet
k. Hole B, 306 and 310 feet
l. Hole B, 310 feet

m. n.

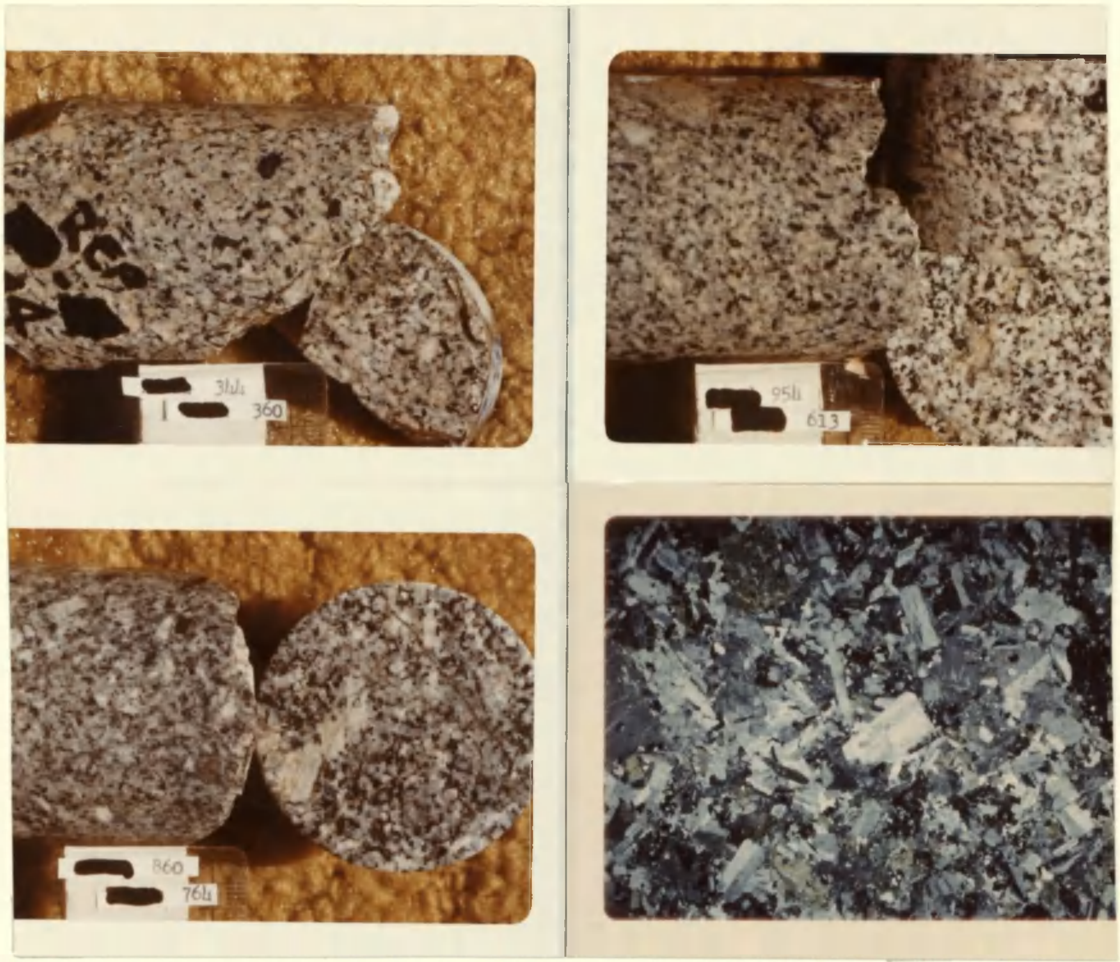


o. p.

Fig. 3. Drill Holes, Continued.

m. Hole B, 1563 and 1732 feet
n. Hole B, 607 feet
o. Hole C, 1502 feet
p. Hole B, 1563 feet

q. r.

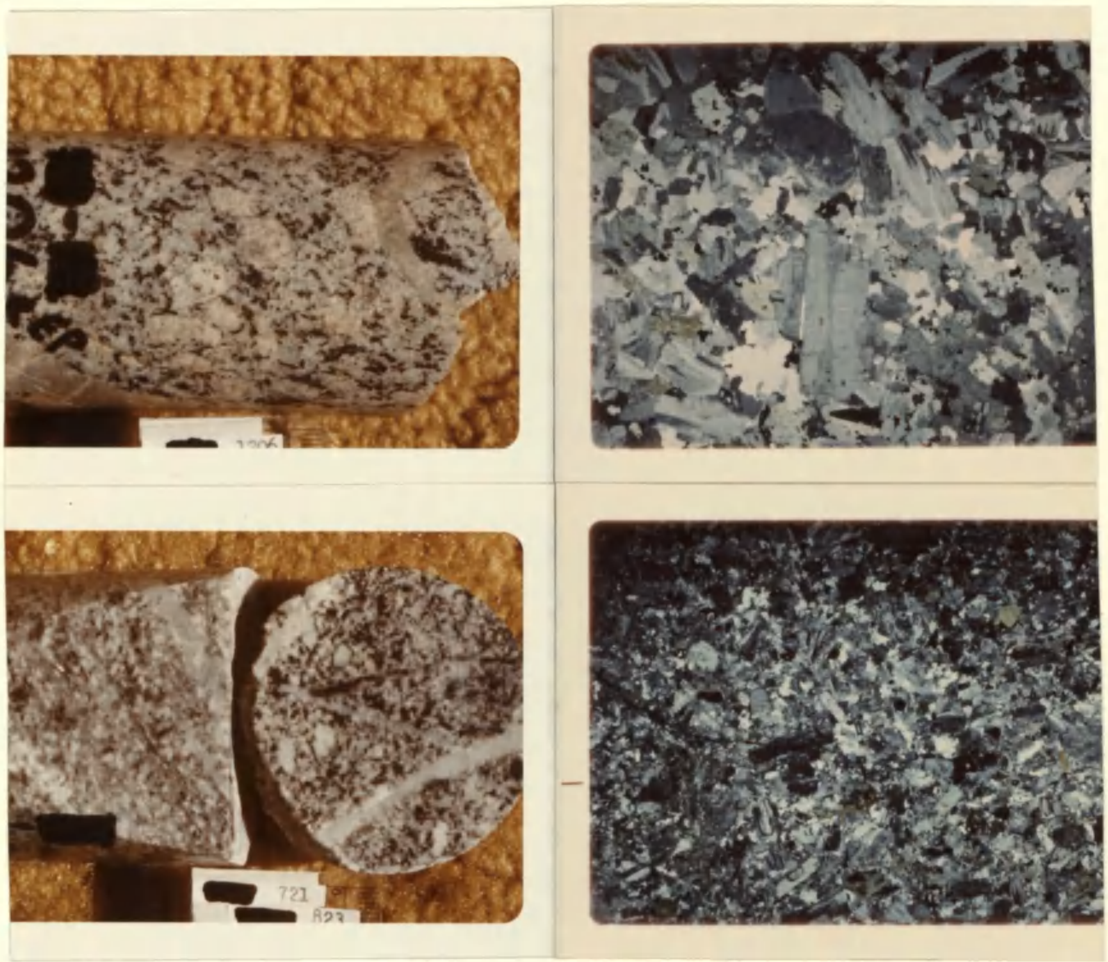


s. t.

Fig. 3. Drill Holes, Continued.

q. Hole J, 344 and 360 feet
r. Hole J, 613 and 954 feet
s. Hole I, 860 and 764 feet
t. Hole I, 764 feet

u. v.

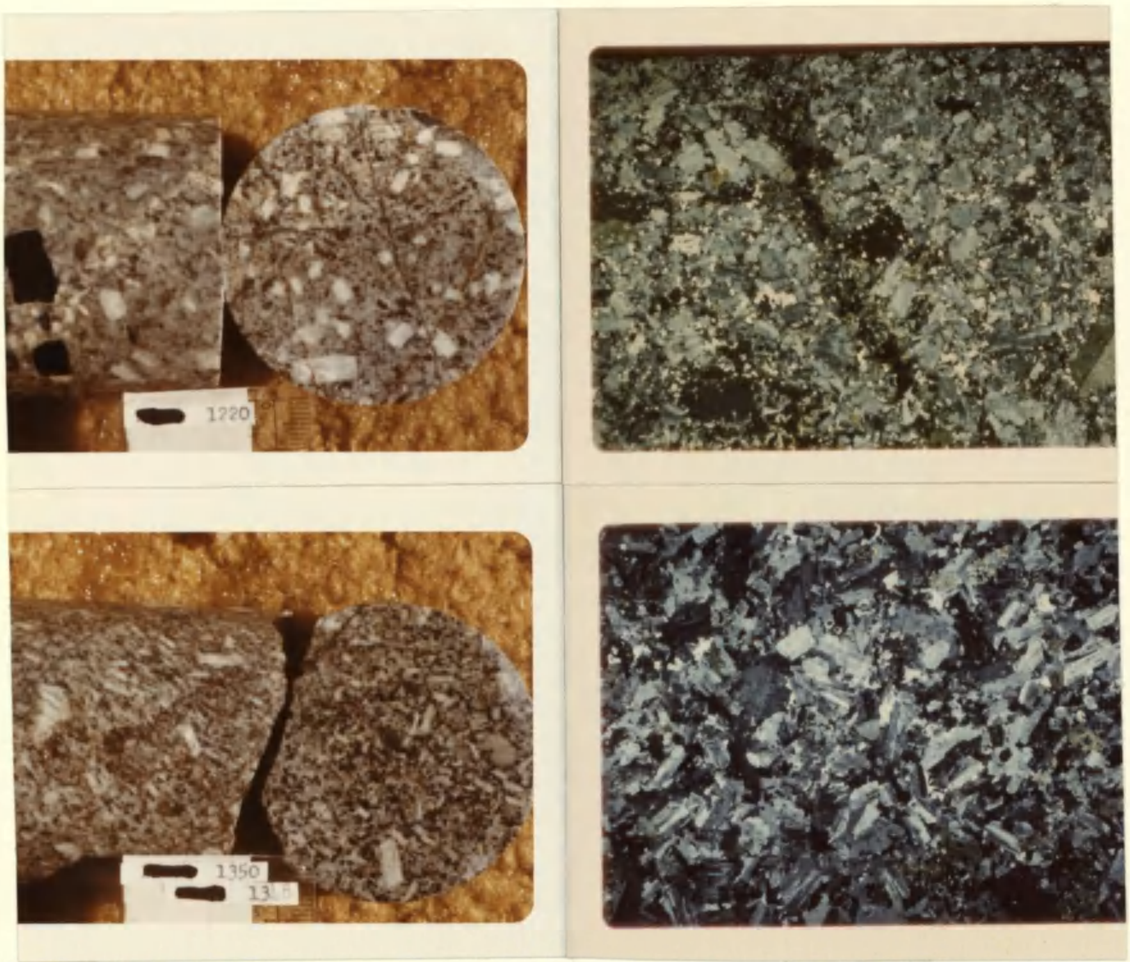


w. x.

Fig. 3. Drill Holes, Continued.

u. Hole I, 1206 feet
v. Hole I, 1229 feet
w. Hole P, 721 and 823 feet
x. Hole P, 823 feet

y. z.



aa. bb.

Fig. 3. Drill Holes, Continued.

y. Hole P, 1220 feet
z. Hole P, 1220 feet
aa. Hole P, 1350 and 1348 feet
bb. Hole P, 1348 feet

Table 4. Unit correlations, general rock types, and degree of porphyritic development.

K-feldspar Phenocryst Size	General Rock Type	Units	Similar Units
PORPHYRITIC ROCKS			
Large	Weary Flat Type	I -c L -a to f	Similar Units
Variable Intermediate	Hanging Wall Footwall Fault	A -a B -a C -a F -b G -a	Similar Units
	Weary Flat Type	J -c K -a	
	Liberty Type	A -q	Approximately similar to J -h and K -f
Small	Liberty Type	A -k D -f E -e H -c O -d	Similar Units
	East End	P -a P -b T -a	Similar Units (somewhat to I -a, F -a and M -a)
WEAKLY PORPHYRITIC ROCKS			
	Liberty	A -f,g,h,i,j B -e D -b,c,d,e E -a,b,c,d H -b (?)	Similar Units Similar Units
		O -c A -c B -f U -a	Similar Units
		A -l D -g A -m	Similar Units
		D -h A -o	Similar to XD-14-e and XD-15-c and -d
		M -b A -b M -c	Similar to XD-14-f and XD-15-e

Table 4. Continued

Eureka Type	B -g	Similar Units
	C -b	
	D -b(?)	
	F -c	
	G -b	
	H -a(?)	
	H -b(?)	
	N -b	
	N -c	

upper units of H and D (H-b and D-b) appeared to be gradational units between the Liberty and Eureka general rock types.

General Rock Types

Weary Flat Group

The units penetrated by I, J, K, and L are the Weary Flat group (see photographs in Figs. 3 , 3 , and 3). The appearance of the Weary Flat group of rocks is slightly greenish to slightly greenish-white plagioclase, white to cream colored (locally smokey) K-feldspar, and dark mafic minerals. The rock and mineral textures vary as in the Liberty group of units, but seem to fluctuate between limits of variation.

Table 5 gives an indication of the modal variation between drill holes based on a limited number of point counts. Table 6 shows the mode as compared to other general rock types and the mass as a whole. Note that for each mineral and ratio of K-feldspar to total feldspar the Weary Flat group of units represents one modal extreme with the Eureka type on the other end and the Liberty type in the middle. Similar relationships can also be seen in the composition of albite-twinned plagioclase (see Table 7) and the ratio of zoned plagioclase crystals to the total number of plagioclase crystals (see Table 8).

A certain porphyry unit(s) in the Weary Flat group bears a strong resemblance to some of the ore porphyries having large (10 x 5mm approximately) K-feldspar phenocrysts. Unit I-c (see Figs. 3 and 3) and the units of drill hole L have a degree of K-feldspar phenocrysts and hornblende crystal development more closely related to the ore

Table 5. Mode for individual drill hole intersections of general rock type.

General Rock Type	Hole or Location	No. of Counts	Plag. %	K-feld. %	Qtz. %	Hbln. %	Aug. %	Other %	K-s % of Feld.
Weary Flat	I	400	42	24	18	12	-	4	36
	J	200	43	28	8	5	-	16[1]	39
	K	200	41	25	17	10	3	4	38
	L	300	53	24	12	7	-	4	31
Liberty Type	A	700	41	29	16	10	1	3	41
	D	500	40	32	11	11	1	5	44
	E	500	38	35	14	10	-	3	48
	O	300	41	28	17	10	-	4	41
Eureka Type	B	500	34	32	12	12	5	5	50
	C	200	36	31	13	10	4	6	46
	F	200	36	35	10	12	4	3	49
	G	600	39	29	10	13	4	5	43
	H	100	33	41	6	14	2	4	55
East End	P	700	35	40	10	8	0	7[1]	53
	Q	200	40	40	8	5	5	2	50
	R	100	45	25	13	7	-	10[1]	33
	T	300	41	33	13	10	-	3	45
Dikes and Sills	V	500	34	29	23	1	-	13[1]	46
	X	400	30	21	19	Altn.	-	30	41
	LV Area	500	44	27	10	4	1	14[1]	38
Misc.	A[2]	200	47	24	21	-	-	8[1]	34
	A[3]	1300	41	31	14	9	1	4	43
	F[4]	100	29	38	10	18	-	5	57
	M[5]	300	35	24	27	9	-	5	41
	N[6]	500	33	41	16	7	1	2	55

[1]Partial alteration of mafic minerals
[2]At 432 feet
[3]At 804 and 882 feet
[4]At 1095 feet
[5]At 2604 feet
[6]At 422 and 726 feet

Table 6. Model analysis for general rock types.

General Rock Type	No. of Counts	Plag. %	K-feld. %	Qtz. %	Hbln. %	Aug. %	Other %	K-s % of Feld.
Weary Flat	1100	45	25	16	10	-	4	36
Liberty Type	2000	40	31	15	10	1	3	44
Eureka Type	1600	36	32	11	12	4	5	47
East End	1300	39	32	10	9	1	5	45
Dikes-Sills	1400	37	26	17	2	0	18[1]	41
Above and all other counts	9800	39	30	15	10	2	4	43
Total of Weary Flat, Liberty Eureka, and East End	6000	40	31	13	10	2	4	44

[1]Partial alteration of mafic minerals

Table 7. Composition of albite twinned plagioclase by general rock type.

General Rock Type	No. of Meas. Cryst.	Plagioclase Composition					
		Average		Range			
				High An		Low An	
		%An	%Ab	%An	%Ab	%An	%Ab
Weary Flat	55	35	65	54	46	22	78
Liberty Type	106	33	67	46	54	23	77
Eureka Type	42	32	68	48	52	24	76
East End	35	34	66	60	40	24	76
Dikes-Sills[1]	39	36	64	66	34	23	77

[1]Samples from V, W, Y, LV Area, LCity, and 6-18-1

Table 8. Percentage of albite rich, zoned plagioclase to total plagioclase in each general rock type.

General Rock Type	No. of Thin Sections	% of Plag. Zoned
Weary Flat	11	40
Liberty Type	22	70
Eureka Type	11	70
East End	6	50
Dikes and Sills[1]	3	50
Miscellaneous:		
A above 568 and B above 548	4	20
A 696 and 882	3	30
Porphyritic units in C, F, G	5	50
M 1953	1	30
M 2170 and 2604	2	50
S 1695	1	50

[1] Samples 6-18-1, 6-20-4 and W at 521 feet

porphyries (having biotite pseudomorphs or hornblende) in the Liberty Pit and Tripp-Veteran Pit area than any of the other basement rock units. These units have the largest average size of hornblende and K-feldspar phenocrysts in the entire basement complex and unusually coarse-grained plagioclase.

Table 9 is a summary chart of Tables 6, 7, and 8.

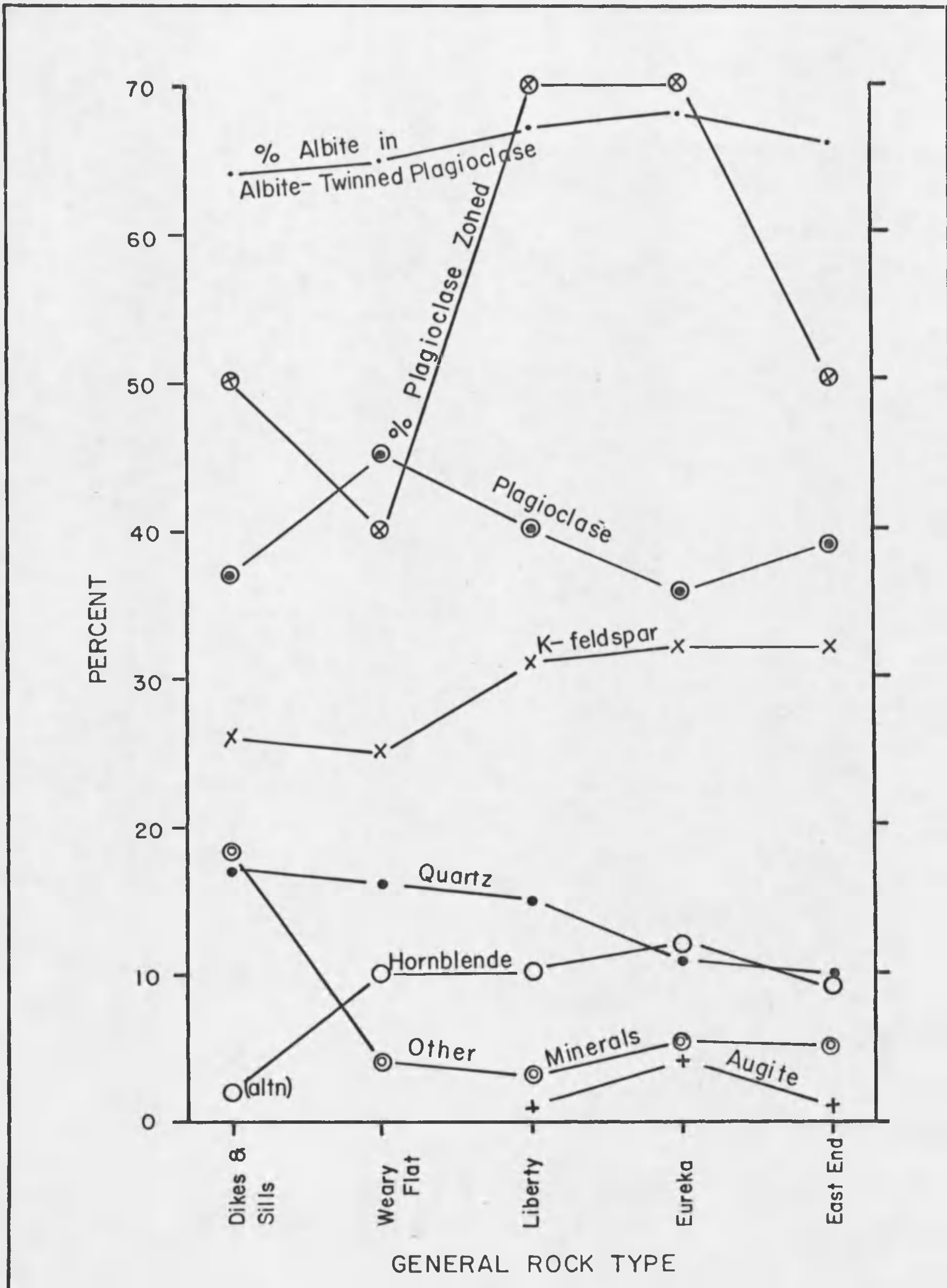
Hanging Wall Footwall Fault

The units in the hangingwall of the Footwall fault are structurally separated from the other general rock types but are most similar to units in the Weary Flat group (see Table 4). One of the best correlations between similar units of the basement rocks can be made between I-a and F-a.

Liberty Group

The units of the Liberty group of units are all exposed in drill hole A below unit A-f. Units of the Liberty group in other drill holes are correlated in Table 4; drill holes intersecting units of the Liberty group include A, D, E, H, M, and O. The general appearance of the Liberty group of units is that of white-colored (locally greenish-gray) plagioclase, pinkish colored (much is partly smoky) K-feldspar, and black hornblende. The units are characterized by variable amounts of K-feldspar phenocrysts, size of K-feldspar phenocrysts, and size and shape of hornblende (see Figs. 3e, 3g, and 3i). The mode is listed in Tables 5 and 6, the composition of albite-twinned plagioclase in Table 7,

Table 9. Summary chart of previous three tables.



and the percentage of zoned plagioclase in Table 8. No obvious trends in texture or mineral composition were observed in the Liberty group.

Eureka Group

The units of the Eureka group are listed in Table 4. During logging this type of rock appeared uniform so there was not more than one unit per hole, but upon the completion of logging the group was subdivided into upper, middle (essentially a gradational unit) and lower units (see Table 10).

The overall color of the Eureka group of rocks is a uniform light to dark smoky gray with black and dark green mafic minerals, a few large white plagioclase crystals, and a few pink colored K-feldspar phenocrysts in the upper portions. The color of the Eureka group is somewhat similar to the East End group, I-a, and F-a (battleship gray) but is more smoky in appearance and has less color contrast between the plagioclase (light gray) and K-feldspar (smoky) grains.

The upper portions of the Eureka group of rocks contains pink K-feldspar phenocrysts whose abundance diminishes with depth. Large (approximately 18 square millimeters in cross section) white plagioclase crystals are more abundant in the upper portions of the Eureka group along with the pink K-feldspar phenocrysts, and persist in abundance to greater depths within the Eureka group than pink K-feldspar phenocrysts. Relatively large plagioclase crystals can be found in units of other general rock types but are not as abundant or distinctive in appearance as in the Eureka group. In general the hornblende in this group

Table 10. Subdivision of Eureka general rock type.

Eureka Group	Drill Hole and Depth of Sample	Description
Upper Eureka Group	B 1289 C 2079 and 2427 D 1170 F 1814 G 2466 and 2564 H 817(?) and 870(?) N 548	Large pink K-feldspar phenocrysts, K-feldspar in general more tan color (lighter color than below) and large white plagioclase phenocrysts.
Middle Eureka Group	B 1563 and 1670 C 2792 and 2922 G 2634 N 676	Few large pink K-feldspar phenocrysts if present and slightly fewer white plagioclase phenocrysts than above.
Lower Eureka Group	B 1732 G 2739	No pink K-feldspar phenocrysts and much fewer, smaller white plagioclase phenocrysts than above.

maintains a relatively uniform intermediate grain size in contrast with the hornblende of the Weary Flat and Liberty groups of units.

The mode of the Eureka group of rocks is given in Tables 5 and 6 for comparison with other groups of rocks. The Eureka group of rocks is notably rich in K-feldspar and contains a high percentage of zoned, albite-rich plagioclase (Tables 7 and 8). The mode of the upper, intermediate, and lower portions of the Eureka group shows no definite trend within the Eureka group (Table 11).

This group is characterized in thin section by local "reaction cell" or cells of mineral inequilibrium, and myrmekitic intergrowths along plagioclase grain boundaries in contact with K-feldspar are much more commonly observed in the Eureka group of units than in any other group of units.

East End Group

The East End group of rocks include units of the P-b and P-c types. P-b unit is the same as T-a and P-a which grades upward into the ore bearing porphyries of the Kimbley Pit. Units similar to P-c are R-a and Q-a.

The color of the East End group of rocks is that of slightly greenish-gray plagioclase, white K-feldspar, and dark mafics that are often replaced by a brown colored carbonate mineral (discussed previously in the text). The overall color is similar to I-a and F-a with the exception of the brown coloration imparted on the East End rock by partially altered mafic minerals. I-a, M-a, and F-a are texturally similar to T-a and P-b (see Table 12). The entire group of I-a, F-a,

Table 11. Modes of units in Eureka group.

	Hole	Depth	No. of Counts	Plag.	K-feld.	Qtz.	Hldn.	Aug.	Other	%K-feld. of Total Feld.
Upper Unit	B	1292	100	32%	34%	13%	9%	8%	4%	
	C	2267	100	40	23	13	15	2	7	
	D	1270?	100	41	40	7	9	1	2	
	F	1712	200	36	35	10	12	4	3	
	H	870?	100	33	41	6	14	2	4	
	Average		600	36	34	10	12	4	4	49
Intermediate Unit	B	1563	200	35	32	12	13	4	4	
	B	1610	100	30	36	15	9	4	6	
	C	2906	100	32	38	14	6	5	5	
	N	726	200	35	38	12	9	3	3	
	Average		600	34	35	13	10	4	4	51
Lower Unit	B	1732	100	39	26	9	16	6	4	
	G	2685?	300	42	31	7	9	6	5	
	G	2966	300	36	27	13	17	2	5	
	Average		700	39	29	10	13	4	5	43

Table 12. Contact phases.

* Monitor Mine, D level, 6470 feet elevation, immediately north of Liberty Pit
**Possibly a dike or sill

Location	Unit	Similar Units
East End	P -c Q -a R -a	Similar Units
Weary Flat Hanging Wall of Footwall Fault	I -a M -a F -a HS 2033*	Similar Units (somewhat similar to T -a, P -a, and P -b)
Central	B -d H -a O -a**	Similar Units having Lath-like Plagioclase

and the East End rocks may have been a more or less continuous crestal phase of quartz monzonite that was subjected to varying amounts of alteration and mineralization. B-d and H-a, two similar units, are a contact phase(s) that bears little resemblance to the East End group.

Minor Rock Types

Quartz-K-feldspar veins, aplites, alaskites, and pegmatites are found throughout the basement rock. Often there is little distinction between these rock types because they commonly are gradational into each of the other rock types. Gradational features between these rock types, alaskite in particular, and the basement porphyritic quartz monzonite are commonly observed. These rock types with the exception of quartz-K-feldspar veins are generally not found outside the basement rock; Fournier (1958, p. 93), however, noted a few aplites cutting sediments and quartz monzonite porphyry in the Liberty Pit.

Drill holes I, mid to lower A, and M seemed to have more of an abundance of dikes and veins than other holes. M below 2350 feet is particularly notable because of the great abundance and exceptionally well displayed gradational features of these dikes and veins. The K-feldspar in A-a and A-b in the dikes, and at one place in M large clumps of biotite, up to 100 square millimeters in cross section, coexisted with pinkish-orange K-feldspar.

Most of the aplites, pegmatites, and alaskites were of granitic composition and contained hornblende and/or biotite in amounts that ranged from one percent to 10 percent when gradational relationships existed with the porphyritic quartz monzonite. Plagioclase in one aplite dike contained 80 percent albite.

Sediments at Contact

Shales and carbonate sediments exhibiting various degrees and thicknesses of contact metamorphism are found in contact with porphyritic quartz monzonite in drill holes C, E, G, I, K, M, R, and U. The contact effects may be limited to bleaching and recrystallization, the development of metamorphic silicate minerals, or both (see geologic summary in Appendix A). Garnet, a light gray colored mineral (pyroxene), and a soft light brown mineral (montmorillonite) are present in some sediments exhibiting contact metamorphism. Commonly the quartz monzonite near the contact has its hornblende replaced by a brown carbonate mineral. The apparent width (vertical measurement) of pervasive visual contact metamorphism is 10 feet, 28 feet, 92 feet, and 90 feet in drill holes E, U, G, and I, respectively. Extensive zones of bleached, recrystallized carbonate sedimentary rock extend hundreds of feet from the intrusive contact in the Weary Flat area. In holes K, I, and M contact metamorphism of sediments is present but does not grade into reasonably fresh rock because of hydrothermal alteration.

The contact effects in C between quartz monzonite (C-b unit) of the Eureka general rock type and dolomite is particularly noteworthy because no contact metamorphic silicate minerals were noted in hand sample. Here the contact effects are limited to bleaching and recrystallization of the dolomite and alteration of plagioclase and hornblende in the quartz monzonite along the contact. Similarly an inclusion of recrystallized, bleached limestone with only minor amounts of garnet was present in quartz monzonite of U-a about 34 feet (vertically) from the contact.

Rock Inclusions

The basement rock contained inclusions of rock of unknown origin in addition to the easily recognized sedimentary rock inclusions in the basement rock-sedimentary rock contact area. These inclusions were easily recognized by their darker color and fine-grained texture. The estimated mode of an inclusion in H at 1,312 feet is 52 percent plagioclase, 15 percent K-feldspar, 15 percent quartz, 10 percent hornblende, 4 percent biotite, 2 percent apatite, and 2 percent other minerals. The plagioclase crystals show zoning and albite twinning and contain about 40 percent anorthite. Abundant, thin prismatic crystals of apatite contained in other minerals is a distinctive characteristic.

In general the inclusions appeared to develop textures similar to that of the quartz monzonite (but having finer grain size) while always maintaining sharp contacts with the host rock. No gradational features between these inclusions and the sedimentary rock inclusions were observed.

CHAPTER III

MINERALOGY

The rock forming minerals and minerals resulting from post magnetic mineralization and alteration are discussed in this section.

Rock Forming Minerals

Hornblende

Hornblende varies from less than one cubic millimeter to clumps reaching up to 13 by 5 millimeters in cross section. The color of hornblende in hand sample is black, (pleochroic green to light tanish green in thin section) and its shape varies from euhedral to anhedral (often interstitial-like). In one thin section hornblende fills a fracture in a plagioclase crystal. In the Eureka group of rocks it is not uncommon to observe hornblende replacing augite. In the altered crestal positions biotite and chlorite often partially replace hornblende. Hornblende like K-feldspar exhibits a very pronounced poikilitic texture.

The coarsest- and finest- sized hornblende and the most variable sized hornblende are found in the Weary Flat and Liberty groups of units. The Eureka and East groups of rock contain much more uniform, intermediate sized hornblende.

K-Feldspar

K-feldspar colors include smoky, white, cream, and pinkish orange (flesh colored). White and cream colored K-feldspar is most common in the Weary Flat, East Units, and in some units in the hanging wall of the Footwall Fault. Pinkish-colored K-feldspar, the color of K-feldspar in A -a,-b, and -k, is generally found in the Liberty group of units; the only pinkish colored K-feldspar west of drill holes A and H is in L. Feldspar in dikes and veins tends to be pinkish in color. Hues of smoky coloring in K-feldspar are often found in the Liberty suite of rock units but the only "pure" smoky coloring is in the Eureka suite of rocks. Rims of smoky K-feldspar are often found around pinkish and cream colored K-feldspar phenocrysts, and smoky K-feldspar is altered to cream and pinkish colors adjacent to mineralized veins.

Generally the more euhedral K-feldspar becomes the more porphyritic the rock texture. The more euhedral K-feldspar is found in porphyritic units in the basement quartz monzonite and in the dikes and sills of quartz monzonite porphyry. In the Weary Flat and Liberty suites of units the amount of groundmass K-feldspar is inversely proportional to the amount of K-feldspar in phenocrysts; A -k (small-to medium-sized K-feldspar phenocrysts) and L -d (large-sized K-feldspar phenocrysts) are strongly porphyritic units with only small amounts of K-feldspar in the groundmass. In general most of the K-feldspar is subhedral, and anhedral K-feldspar is either interstitial in nature or occurring in finer grained groundmass exhibiting allot-riomorphic-granular (aplitic or xenomorphic-granular) texture. K-feldspar replacing plagioclase is irregular in shape. Larger grains of K-feldspar commonly are Carlsbad twinned.

The average size of K-feldspar grains is greater in the Weary Flat and A suite of rocks. The East and B suites of rock contain finer sized K-feldspar. The average K-feldspar grain size in the quartz monzonite porphyries would not be significant because of the two distinctly different populations of K-feldspar, large phenocrysts and fine grained aplitic groundmass (less than one fourth square millimeter in cross section). The largest K-feldspar phenocrysts in the basement rock are in the range of 1,000 to 3,000 square millimeters in cross section, average about 1,5000 square millimeters, and are generally in the Eureka series of rock units and the upper units of H and D. A few of these large K-feldspar phenocrysts were somewhat rounded and scalloped as though they were being resorbed. Some of the relatively fresh dikes and sills in the eastern portion of the district (Lane Valley area) carry abundant anomalously euhedral phenocrysts that are often much larger than the largest found in the basement rock.

Small amounts of K-feldspar may replace plagioclase along veins of mineralization but the amount is insignificant in comparison to the amount of rock forming K-feldspar which replaces plagioclase. Characteristically K-feldspar can be found replacing plagioclase, but the amount of plagioclase replaced by K-feldspar is a small fraction of the total plagioclase grain. Usually the replacement is just along a plagioclase grain. Usually the replacement is just along a plagioclase grain boundary, but very small amounts of K-feldspar have been observed within the confines of the grain boundaries.

While plagioclase is often included in K-feldspar phenocrysts of the basement rock the inclusion of small amounts of quartz near the K-feldspar grain boundaries is not as commonly observed (Table 13). Thin sections of porphyry with aplitic textured groundmass characteristically have K-feldspar with inclusions of quartz having about the same size as grains in the groundmass (see Figs. 3a and 3b), but only certain porphyritic units in the basement rock have quartz inclusions (larger in size than the aplitic quartz grains) in the K-feldspar phenocrysts. Porphyry units such as A and those in L did not have quartz in the K-feldspar phenocrysts.

Plagioclase

The color of plagioclase varies from white in the Liberty group of units to smoky in the Eureka and East End group of units. Weary Flat units vary from white to smoky. A definite greenish hue is present in much of the plagioclase of either color and seems to be a characteristic of the upper units in drill holes A, E, H, J, M, N, U, the East End group of holes, and some units in the hanging wall of the Footwall Fault. The greenish color may be due to small amounts of alteration minerals, possibly montmorillonite or green sericite. The green coloration of plagioclase is notably lacking in the Eureka series of units.

Some of the coarser plagioclase was observed in L units and in A -b and A -o. Scattered large white plagioclase phenocrysts (15-30 square millimeters in cross section) gave much of the Eureka type of rock

Table 13. Thin sections with quartz grains in K-feldspar phenocrysts. Drill hole and depth in feet

Drill Hole	Depth
A	1653, 399, 432
B	310
C	1502
D	2044
F	1494
G	2256
H	1350 and 1149
J	220
K	147 and 452
M	1953
O	2000 (minor)
P	1220
T	34

a distinctive appearance. The Eureka type of rock has a smaller average plagioclase size and a larger population of smaller sized plagioclase grains than most of the basement rocks.

Measurements of albite-twinned plagioclase were made following the Michel-Levy statistical method. These measurements (Tables 14 and 7) do not represent an average plagioclase composition because many other plagioclase crystals are zoned (Tables 8 and 15), and a few are in the form of peric-line and carlsbad twins. Zoned plagioclase is optically positive and more albitic than the albite-twinned plagioclase. Some plagioclase crystals are partially zoned and partially albite-twinned.

Emmons and Mann's (1953) studies suggest that zoning is replaced by albite twinning, an unzoned crystal of plagioclase may represent equibrium between crystal and liquid, phenocrysts in porphyritic rock are not twinned while crystals in equigranular rock are twinned, and untwinned plagioclase is found in the metasomatic type of rock.

Quartz

Quartz grains rarely exceed one square millimeter in size and are generally one-half to one-quarter square millimeter in size or smaller. Only one, "quartz eye" was noted (B at 310 feet) during the entire study. One to several grains of quartz occupy interstitial positions. Mixtures of quartz and K-feldspar grains can occupy interstial positions or form fine grained allotriomorphic-granular-textured groundmass. The color of quartz is a characteristic smoky grey.

Table 14. Composition of albite twinned plagioclase.

Hole or Location	Depth (ft.)	No. of Meas. Cryst.	Plagioclase Composition: Average %An	Average %Ab	Range: High An %An	High An %Ab	Low An %An	Low An %Ab
A	432	9	35	65	40	60	27	73
A	530	10	33	67	43	57	28	72
A	696	6	38	62	56	44	24	76
A	804	6	34	66	44	56	24	76
A	882	9	33	67	41	59	23	77
A	1012	8	30	70	40	60	27	73
A	1153	12	30	70	44	56	22	78
A	1172	7	32	68	40	60	28	72
A	1220	7	35	65	44	56	25	75
A	1513	5	32	68	38	62	25	75
A	1653	6	29	71	33	67	23	77
A	1766	9	36	64	46	54	27	73
A	2278	6	32	68	38	62	23	77
A	2544	6	36	64	52	48	25	75
B	310	6	38	62	46	54	29	71
B	563	6	30	70	44	56	22	78
B	1227	12	32	68	48	52	26	74
B	1610	6	32	68	40	60	30	70
C	2906	6	33	67	41	59	24	76
E	2490	6	31	69	40	60	26	74
G	2866	12	31	69	38	62	24	76
I	764	7	42	58	54	46	33	67
J	220	10	31	69	44	56	24	76
J	304	6	40	60	50	50	25	75
J	960	3	38	62	42	58	37	63
K	147	7	26	74	35	65	22	78
K	393	3	37	63	43	47	30	70
K	596	4	31	69	36	64	28	72
L	490	8	35	65	45	55	26	74
L	922	7	40	60	45	55	35	65
O	898	8	30	70	36	64	23	77
P	1220	8	35	65	50	50	26	74
P	1348	10	34	66	40	60	28	72
R	1286	9	32	68	43	57	27	73
S	1595	8	27	73	37	63	24	76
T	1320	8	35	65	60	40	26	74
U	1945	6	35	65	42	58	29	61
V	399	4	33	67	48	52	24	76
W	521	7	35	65	45	55	23	77
Y	408	8	38	62	50	50	28	72
6-18-1	Surface	10	35	65	54	56	17	83
LV Area	"	3	32	68	34	66	29	71
L City	"	7	40	60	56	44	30	70

Table 15. Percentage[1] of albite rich[2], zoned plagioclase to total plagioclase in individual thin sections.

Hole or Location	Depth (ft.)	% of Plag. Zoned	Hole or Location	Depth (ft.)	% of Plag. Zoned
A	399	low[3]	E	2490	50
A	432	20	E	2495	50
A	530	10	E	2537	60
A	696	30	E	2963	70
A	804	40	F	1095	40
A	882	30	F	1494	40
A	1012	70	F	1712	60[3]
A	1153	70	G	2256	50
A	1172	70	G	2685	80
A	1220	70	G	2866	80
A	1513	90	I	764	70
A	1653	90	I	1229	50
A	1766	80	J	220	20
A	2069	80	J	304	30[3]
A	2278	50	J	360	30[3]
A	2357	50	K	147	50
A	2457	70	K	393	50
A	2544	60	K	452	50
B	310	30	K	596	60
B	1227	50	L	490	50
B	1292	70	L	1015	20
B	1610	70	M	1953	30
B	1653	90	M	2172	50
B	1732	60	M	2604	60
C	1502	60	P	823	60
C	1733	70	P	1220	30
C	2267	70	P	1348	40
C	2858	80	Q	1728	40
C	2906	90	R	1286	50
D	728	30	S	1695	50
D	1270	40	T	1320	50[3]
D	1684	30	6-18-1	Surface	50
D	1767	50	6-20-4	Surface	60[3]
D	2044	50	W	521	40
D	2167	40			
D	2523	60			

[1]Eye estimation of thin section; [2]zoned plagioclase are albite rich oligoclase in composition; [3]estimation questionable due to alteration.

Augite

Augite, when present in a unit, is fine grained and often euhedral and/or subhedral. Augite may be partially or nearly totally replaced by hornblende.

Mineralization and Alteration

Mineralization and alteration in the basement porphyritic quartz monzonite is best described as propylitic. Magnetite, pyrite, chlorite, calcite, epidote, a brown colored carbonate (?) mineral, zeolite, and small amounts of biotite and sericite are the more commonly found minerals.

Pervasive Forms

Quartz monzonite porphyry units in the basement rock do not exhibit alteration features different from that of the rest of the basement rock. In the ore zones, however, pervasive alteration is present in the quartz monzonite porphyry; and in the "unaltered" quartz monzonite porphyry away from the pervasive zones of alteration and mineralization minor deuteric alteration is found (Fournier 1958, p. 116). More pervasive alteration occurs in the crestal positions of the basement quartz monzonite than in the rest of the basement igneous complex. Units displaying this crestal alteration are T -a, Q -a, P -c, R -a, F -a, M -a and I -a to -c. Biotite, phlogophite (?), calcite, brown carbonate (?) dusting of feldspar and partial replacement of mafic minerals, flecks of sericite, and occasional small amounts of chlorite replacing mafic minerals are the most common alteration products. Pyrite and magnetite are more abundant in these altered areas. In drill hole I and unit F -a, the alteration extends at least 100 feet (vertical measurement) into the quartz monzonite. The mineralization and alteration appear to be fracture controlled, and the alteration is pervasive in the sense that it is reasonably continuous throughout the interval even though every mineral grain does not exhibit evidence of alteration. This alteration may be the result of the migration of hydrothermal fluids or the collection of residual solutions in the crestal portion of the quartz monzonite. The abundance of calcite in the altered quartz monzonite suggests the contribution of carbon dioxide to the residual or hydrothermal fluids by contact calcareous sediments. Contacts along the flanks of the intrusive do not exhibit pervasive alteration over tens to hundreds of feet; instead, the quartz monzonite may exhibit up to a few feet of pervasive alteration.

Veins and Fracture Coatings

The most common fracture-filling minerals are carbonates, silicates, and sulfides with oxides and sulfates being less common. These minerals are not restricted to veins and may occur as disseminations in the near proximetry to veins. The carbonates, sulfates, and silicates may occur in fin- to medium-sized grains when disseminated and from scattered grains on fractures to veins tens of millimeters in thickness when fracture filling. The oxides (magnetite) and sulfides are fine- to medium-rained when disseminated and may occur as scattered fine grains on fractures but seldom occur as scattered fine grains on fractures but seldom occur in veins of more than a few millimeters in thickness.

Sulfide Mineralization

Pyrite is by far the most abundant sulfide mineral, and molybdenite and chalcopyrite are present in trace amounts. Pyrite commonly occurs as an accessory mineral, in veins without associated minerals, and in veins with various combinations of calcite, epidote, and quartz. Pink colored alteration selvages are usually formed if more than just pyrite is present in a vein. Zones of disseminated pyrite and/or magnetite with pervasive green sericitic alteration (from several centimeters up to a meter in thickness) occur sporadically in the Liberty Pit-Weary Flat area and to the east of drill hole A in units of porphyritic quartz monzonite in the hanging wall block of the Footwall Fault. Pyrite, molybdenite, and less commonly chalcopyrite can be found in quartz-K-feldspar veins, aplites, and pegmatites.

Molybdenite, a common mineral in and near copper ore grade rock, coated fractures in units above A -d, I, upper H, B -a and -b, and F -a and -b. Of these units the more significant amounts were present in B -a, F -a, and I.

The total sulfur content is high in the Weary Flat area, in porphyritic quartz monzonite units in the hanging wall block of the Footwall Fault, and the East units (KCC assay and spectrographic data). In L -g, K, and J the total sulfur content is high and increases with depth. The fault between 544 and 554 feet in K may be of significant consequence as the total sulfur and visual pyrite content abruptly increase across the fault. Small amounts of gypsum in A between 930 and 1553 feet account for some of the reported total sulfur content, but elsewhere gypsum is not present. Analytical sulfur data agreed closely with plots of the relative abundance of pyrite veins.

Sulfate Mineralization

Gypsum was the only positively identified sulfate mineral, and anhydrite may be present in trace amounts. All of the gypsum observed during logging was probably deposited by ground water.

Gypsum has been found in the ore bodies from the lower levels of oxidation (native copper may be included in the mineral) to the deeper extremities of unenriched, primary copper mineralization. The formation of large, relatively unstrained gypsum crystals bridging wide open fractures beneath the zone of secondary enrichment indicates that gypsum in the ore bodies was deposited by ground water after all structural stresses ceased.

The only gypsum noted during the logging of the core was in A, and nearly all of the gypsum in this hole was between 930 and 1553 feet, units A -k to -j. Gypsum, some in the form of satin spar, was noted in fault gouge between 1110 and 1115 feet in A. It appears that all the gypsum in A may have been deposited from ground water that was envolved with the oxidation of sulfide minerals.

There is the possibility that anhydrite exists or existed before being hydrated to form gypsum. A thin section of rock from B at 1732 feet contained several grains giving an extinction angle of 37 degrees to the cleavage (that for gypsum) but had a birefringence reaching at least second order green (the birefringence for gypsum is straw yellow and anhydrite reaches up to third order green).

Carbonate Mineralization

The only positively identified carbonate mineral in the quartz monzonite was calcite. A brown colored mineral in thin section and hand sample appears to be the product of reaction between calcite and neighboring minerals.

Calcite is abundant in the Robinson Mining District, and it is not uncommon to find calcite veins a mile or two from known porphyry ore deposits. Locally in the altered quartz monzonite porphyries of the ore bodies, calcite is so abundant that the rock will react with acid as if it were limestone. The great abundance of calcite and other carbonate minerals is to be expected because of the voluminous amounts of limestone and limey sedimentary units that were intruded and altered by the quartz monzonite and associated hydrothermal activity. The occurence of calcite throughout the basement complex is so common that no particularly calcite rich areas were found to exist.

Calcite in the basement rock coats fractures in thin veneers without associated alteration, but when filling a fracture with pyrite and/or epidote pink colored alteration envelopes are present. Disseminated calcite is closely associated with mineralized veins. Calcite was nearly always clear or white in color, but greyish-purple and green varieties were noted locally.

Silicate Mineralization

The most common silicate minerals found in mineral filled or coated fractures are zeolites, quartz, K-feldspar, and epidote. The distribution of silicate minerals is so widespread that it is difficult to identify areas containing an anomalous abundance of silicate minerals. In most instances the silicate vein abundance may be more of a local phenomenon related to fracture zones, but there are noteworthy exceptions.

"Pure" quartz veins without K-feldspar or other commonly associated minerals are a rarity within the quartz monzonite body, but are found abundantly in ore zone areas where the quartz monzonite porphyry grades into porphyritic quartz monzonite, and in porphyritic quartz monzonite beneath these transitional zones. B and P are the best examples of quartz veins diminishes below the zones of more pervasive alteration. A few quartz veins in the upper half of J all considered to be of importance because these quartz veins may represent the downward extension (root zone) of mineralization that has been faulted (Footwall Fault) to some other position (Liberty Pit area). A few quartz veins were also noted in G -a, F -a, and I -a. Veins of quartz with K-feldspar and minor plagioclase are common throughout the basement complex and were discussed in a previous section.

Veins of quartz with any or all of the following minerals are a common occurence: pyrite, epidote, and calcite. In general these veins are a few millimeters in thickness and have associated pink colored alteration of the quartz monzonite. The lower halves of H and J contained an anomalously high amount of quartz-pyrite veins.

Veins of K-feldspar in the ore bodies and basement quartz monzonite are rarely found. A few K-feldspar veins were noted in hybrid quartz monzonite in B. A thin section of quartz monzonite at the contact with metamorphosed limestone (E, 2490 feet) showed much of the K-feldspar exhibiting crosscutting and replacement relationships; but another thin section, three feet below the contact, did not have crosscutting K-feldspar. In other thin sections of the basement rock, it is not uncommon to find a plagioclase crystal with one small, discontinuous, K-feldspar filled fracture. Mineral filled fractures close to the prevasively altered areas may have small amounts of K-feldspar along the outer edges of the mineral filled fracture. In summary, there are very few crosscutting veins resulting from K-alteration, and that K-feldspar exhibiting crosscutting relationships in the quartz monzonite has migrated distances measured in millimeters.

Epidote veins and veins of epidote with clinozoisite, pyrite, quartz, and/or calcite are a common occurence and are characterized by pink colored alteration envelopes that are often 10 to 30 times the width of the vein. Veins of epidote with associated minerals seem to be most common in a zone that lies beneath and parallels the Footwall Fault (East) zone (M and O have the least amount of epidote and may be the lateral limits of the epidote zone). Epidote veins seem to be less abundant in the Weary Flat area about J, in rock beneath ore zones, and in the quartz monzonites and quartz monzonite porphyries in the hanging wall of the Footwall Fault. Disseminated epidote occurs near mineralized fractures in the quartz monzonite and in the less throughly altered, transitional areas beneath pervasive mineralization. It is not uncommon to find scattered grains of epidote in the entire basement complex.

Zeolites are another common silicate, fracture coating minerals. The color of zeolite minerals were used for logging purposes, and the abundance and distribution were plotted. Zeolites are abundant in more pervasively mineralized and altered areas and are locally abundant elsewhere in the basement rock. Orange colored zeolite (chabazite) is more common in mineralized areas than pinkish white and white colored zeolite (stilbite), and shite colored zeolites are more common than orange colored zeolites in fringe areas and possibly at depth. Difficulty was experienced in identifying zeolites; but the names of some tentatively identified zeolites in the district include chabazite, laumonite, heulandite, phrenite, hillebrandite, and stilbite (Fournier 1958, p. 112).

One vein of biotite and another of pyroxene (augite and/or diopside) were observed in the basement rock and their locations are noteworthy. In the western portion of the basement rock a biotite vein, 5 to 10 millimeters in thickness, was intersected in I at 1215 feet; and under the Liberty Pit at 1761 feet in A was a 3 to 4 millimeter thick vein of a dark green pyroxene mineral.

Oxide Mineralization

Limonites occurred in the weathered rock of the Weary Flat area (capping in J) and on a few fractures at considerable depths in some drill holes. Hematite rims about magnetite were noted in more thoroughly altered quartz monzonite. About one percent magnetite is disseminated throughout the basement rock as an accessory mineral. In zones of alteration the amount of disseminated magnetite, if present, increases to several percent and may coexist with pyrite. Rarely in the quartz monzonite does magnetite occur in veins; this is in contrast to the abundant disseminated magnetite and magnetite bearing veins in the metamorphosed sediments of the lower central and eastern portions of the Liberty Pit. However, both vein and disseminated magnetite is abundant in units H -a and H -b, and unit C -a is also anomalously rich in magnetite. The abundant magnetite in H and the high total sulfur content of quartz monzonite to the west of H can be related to similar spacial distributions in the hanging wall block of the Footwall Fault (Liberty Pit).

Vein- and Fracture-Associated Alteration

Most of the alteration in the subcrestal portions of the quartz monzonite is clearly associated with individual fractures or relatively thin zones of strong shearing. As previously discussed not all mineralized fractures have associated alteration.

Quartz monzonite in shear zones is commonly altered to quartz, sericite, kaolinite, and chlorite. The mafics are altered to chlorite, and plagioclase and K-feldspar (stable in some cases) are altered to white colored sericite and/or kaolinite. Pyrite is often abundant in these altered zones.

Zones of distinctive green colored alteration containing disseminated pyrite, magnetite, or both are due to sericite replacement of feldspar. Quartz-carbonate veins commonly are found in these altered zones. K-feldspar becomes pinkish orange in color towards the fringes of these alteration zones.

Alteration associated with veins of various combinations of epidote, pyrite, quartz, and calcite imparts a distinctive pinkish orange coloration on the quartz monzonite. K-feldspar and possibly plagioclase or plagioclase that was replaced by K-feldspar is changed to a pinkish orange color that is similar to the color of K-feldspar in upper A. Sericite, possibly a clay mineral, and brown dust type of alteration are present in both plagioclase and K-feldspar. Chlorite (some of which has the anomalous deep purple birefringence of pennenite) replaces mafic minerals, and sphene is replaced by leucoxene. Hematite was present in at least one such zone of alteration.

Thin dark selvages of alteration occur about some pyrite and quartz veins. One quartz-K-feldspar vein containing minor plagioclase has an alteration zone in which hornblende is partially replaced by calcite; K-feldspar is relatively uneffected; and plagioclase contains specks of sericite, possibly a mineral of the kaolinite group, and the brown dust-like mineral. It should be noted that many quartz, pyrite, and quartz-K-feldspar veins lack obvious alteration selvages in hand sample.

Alteration of quartz monzonite along rhyolite contacts is not to be genetically associated with other types of earlier alteration. This alteration is easily recognized by the soft, waxy, yellowish green montmorillonite which replaces hornblende. The alteration of quartz monzonite by the intrusion of rhyolite is usually only a few feet in width.

CHAPTER IV

STRUCTURE

Both the igneous structures of the porphyritic quartz monzonite mass and faulting as related to the study of the igneous basement rock are discussed in this section. Because of the pluton's size and unavailability to inspection most of the conclusions must be qualified in view of the limited amount of data.

Porphyritic Quartz Monzonite

Intrusive Shape

The true shape of the basement intrusive cannot be determined with any great degree of certainty. Drill hole intersections of quartz monzonite sediment contacts number less than a dozen and the outcrop area (Weary Flat) is nearly totally covered by dumps and soils. The shape of the intrusive at Weary Flat, as mapped in the past (Fig. 1), is not necessarily a true reflection of the original shape of the intrusive. In the Weary Flat area there undoubtedly has been significant faulting other than by just the Footwall Fault (southeastern contact) since strong fault zones of unknown attitudes were intersected in L and K and have not been observed on the surface.

Aeromagnetic and drill hole data suggest that at least the crestal portion of the quartz monzonite intrusive is elongated in an eastwest (N85W) direction. Aeromagnetic data indicates the intrusive has a steeply dipping northern contact as will be discussed in the following test. The establishment of good east-west structural and petrographic continuity in the quartz monzonite is hindered by a lack of depth in holes east of C and the distance between R and holes to the west.

Flow Structure

An easily recognized alignment of minerals exists in most portions of the igneous basement rock. In a few areas of weak flow structure and in certain units with little mineral color contrast the flow structure was more difficult to determine. Table (2) summarizes the dip of the flow structure in each unit and represents an average value for readings taken every 25 to 50 feet.

The flow structure appears to be more of a planar than linear alignment of K-feldspar, plagioclase, and hornblende. A surface sample, 8-29-1, was sawed parallel to the plane of flow. A noticeable orientation of the minerals in the plane of the flow varied from alignment along the direction of dip to orientations making angles of up to 40 degrees with the dip in the plane of flow. In several peices of core hornblende crystals exhibited a circular alignment which may represent a relict structure formed during the digestion of included rock.

The dip of the flow structure in the footwall block, Footwall Fault, as determined from holes A, B, C, D, F, and G, varies from 35 to 45 degrees. In the Weary Flat area the holes H, I, J, K, and L have dip values from 50 to 60 degrees. Units in the hanging wall, Footwall Fault, generally have dip values similar to the Weary Flat area. In the eastern portion of the district, quartz monzonite units, P -c and Q -a, had 30 to 45 degree dips near their upper contact but steepened to 60 to 70 degrees with depth. One measurement on a very weakly foliated rock, 8-29-1 (Weary Flat), had an east-west strike and a dip of 70 degrees to the north. This was the only direct measurement of the direction of dip but in a following paragraph the probable dip direction in the Liberty Pit area is discussed.

Mineralized Fractures

Throughout the entire basement complex mineralized veins, (generally a few millimeters or less in thickness) with or without associated alteration, can be found dipping nearly perpendicular to the attitude of the flow structure. The veins are obviously fracture controlled, and the two most commonly mineralized sets of fractures are those that dip about 30 to 40 degrees and 60 to 80 degrees. It is not known how the strikes of these fractures vary throughout the district, but they do tend to retain a dip nearly perpendicular to the flow structure. This close spacial relationship suggests that fractures controlling mineralization in the basement rock were formed as a result of the intrusive events. Mineral coated or dusted fractures include additional and possibly more random sets of fractures.

Igneous-Igneous Contacts

Whether or not an igneous-igneous contact in the basement rock is gradational, sharp, or faulted is summarized in Table (2). The values presented in the table represent the number of feet of gradational aspects. The values are by no means absolute because of incomplete core recovery, and more so, because of the somewhat arbitrary criteria used to distinguish one unit from another. Most contact zones are uniformly gradational and in a few instances the contact zone may have an interlayed appearance. Contacts classified as sharp were ones in which the contact could be placed between pieces of core. Only a couple of contacts were such that they existed in a single peice of core; a very sharp contact in one piece of core was found in the -b unit (unit I -b is composed in interlayered I -a and I -c units).

The significance of sharp and gradational igneous-igneous contacts in the basement rock will be discussed in a following section. Similarly, the sharp and gradational contacts between igneous rocks have been observed in the Liberty Pit ore body; for a discussion of the nature and significance of these contacts and the different igneous rocks involved refer to Fournier (1958, 1967).

The upper contact of the A -k unit was contoured and is presented in Fig. (4). In the area of best contour control, A, D, and H, the slope of the contoured surface (30 degrees to the southeast) is only about 5 to 10 degrees less than the average dip of the flow structure for the A -k unit in these three holes. Therefore, it is thought that the direction of the flow structure's dip in the Liberty Pit area is to the southeast and parallel or nearly parallel to the dip of the unit contacts.

Igneous-Sedimentary Contacts

Contacts in the basement rock and those in the ore bodies between intrusive rock and sedimentary rock have similarities and some notable

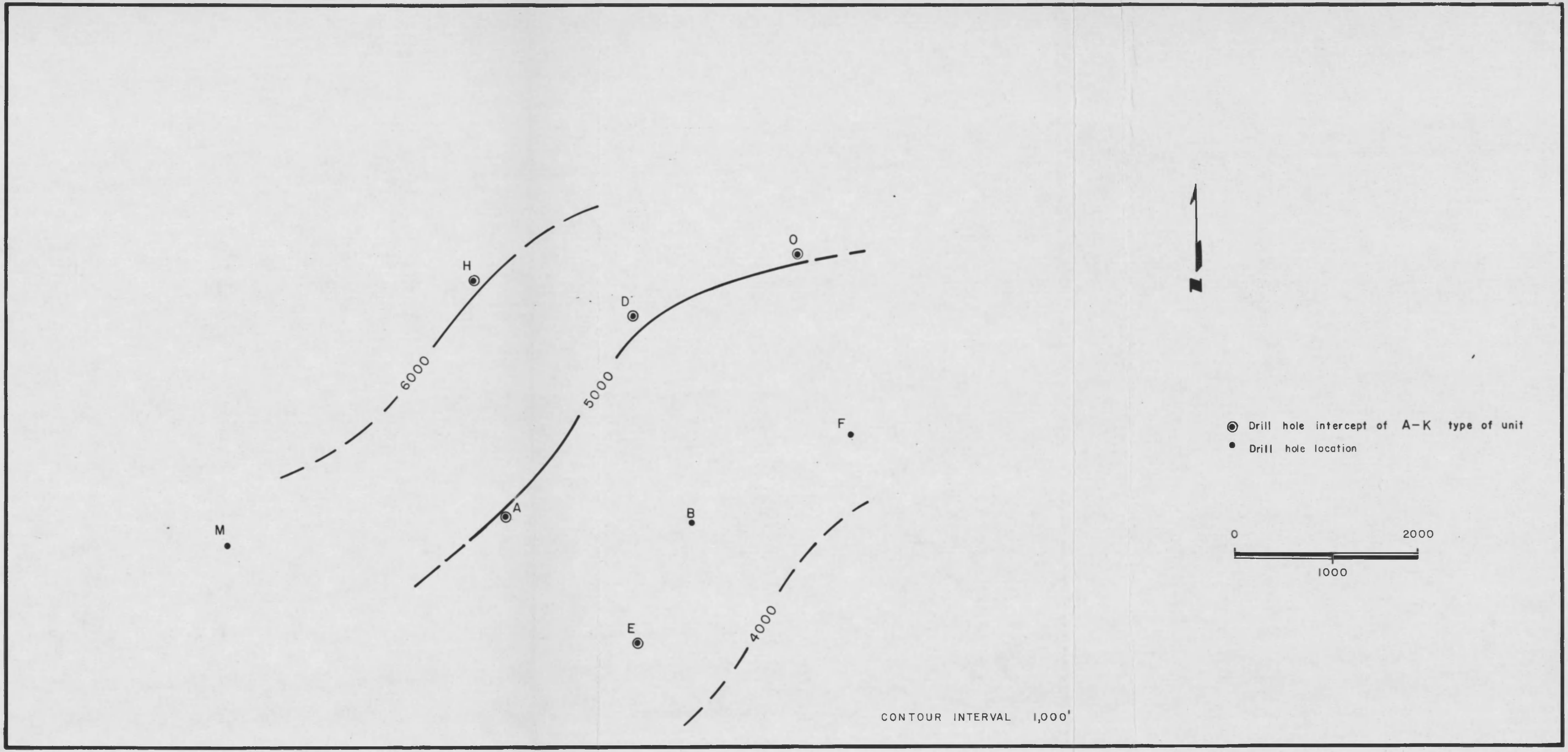


Fig. 4. Structural contours top of A -k unit.

dissimilarities. Contacts between intrusives and limestone are sharp whether in the basement rock or ore bodies. Contacts between shale and basement quartz monzonite (including hybrid rocks) are sharp, but in the ore bodies these contacts may vary from sharp to gradational. (Note: Pervasive quartz-sericite alteration in shale and quartz monzonite porphyry is so similar that contacts between the two often appear gradational.) The weakly altered rock with a small percentage of fine grained groundmass in B below 500 feet can be thought of as having a gradational contact with altered shale because of the development of hybrid rock.

Contacts of basement igneous rock with sediments are often characterized by a few thin dikes of quartz monzonite in the sediments above the contact and inclusions of altered sediments in the quartz monzonite near the contact. Contact metamorphic effects were discussed in a previous section.

Faults

Footwall Fault

Thrust and normal faulting is abundant in the district, but the Footwall Fault is the only fault of major concern to this paper. In both the Tripp-Veteran and Liberty Pit areas the Footwall Fault separates altered and ore-grade rocks in the hanging wall block from relatively fresh rocks in the footwall block and the post-ore age of the Footwall Fault is generally accepted by geologists. It is not known if the Footwall Fault (west) in the Tripp-Veteran area is continuous with the Footwall Fault (east) in the Liberty Pit area. The hanging wall block of the

Footwall Fault in the Tripp-Veteran area was not studied because drill holes to date have not intersected any porphyritic rock having granitic-textured groundmass.

The contour map of the Footwall Fault (east), shown in Fig. (5), represents an approximation since the Footwall Fault zone appears to be composed of several thick, interwoven bands of fault gouge and breccia. In some holes up to 30 to 50 feet of gouge were intersected along the projection of the Footwall Fault. More than a half dozen cross sections were prepared to project and study the Footwall Fault (east) and the possibility of cross faults offsetting the Footwall Fault exists, but nothing was found to indicate their presence.

Movement on the Footwall Fault has been of primary concern in exploration programs and in the development of basement rock ore porphyry relationships. Breitrick (1965, p. 12) concluded that the most logical interpretation seems to be that the movement (of the Footwall Fault east) was normal; however, there is some evidence of possible post-ore thrust faulting in the Tripp area. The author of this paper has concluded that the movement on the Footwall Fault (east) was normal for reasons which will be presented in the concluding portions of this paper.

Other Faults

Both the Eureka (contoured in Fig. 5) and Queen faults are approximately north-south striking faults having moderately steep, easterly dips. Geologists at the mine in both the past and at present have accepted the idea that the hanging wall blocks of these two faults contain ore bodies that once formed a more or less continuous span of ore grade

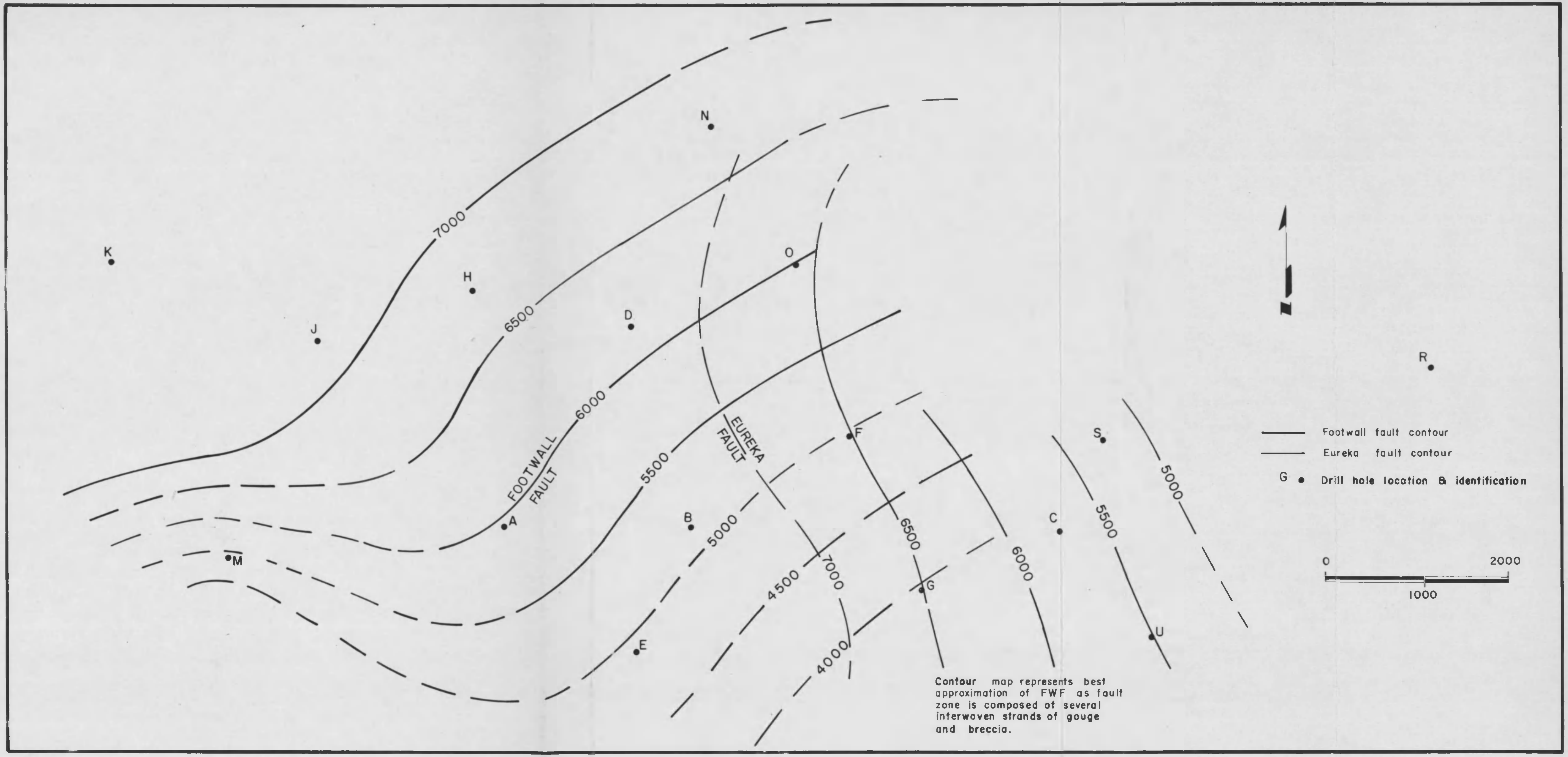


Fig. 5. Structural contour map Footwall East Fault and Eureka Fault.

mineralization. This mineralized span would have included the Liberty, Ruth (Deep Ruth), and Ruth Extension ore bodies. The only location where quartz monzonite porphyries of this continuous span of mineralization could have graded downward into basement porphyritic quartz monzonite would have been beneath the Liberty Pit, since altered quartz monzonite porphyry in both the Ruth and Ruth Extension ore bodies are separated from the basement rock by altered sediments.

CHAPTER V

RELATIONSHIP TO OVERLYING ORE AND QUARTZ MONZONITE PORPHYRY

Dikes, sills and irregular masses of quartz monzonite porphyry occur throughout the district; but those of immediate concern to this paper are those that are altered, mineralized, and located immediately above the basement quartz monzonite. These hydrothermally altered igneous bodies are characterized by medium and large sized K-feldspar. Vertical alteration zoning is apparent in the Liberty Pit area (Bauer et al. 1966, p. 235). Here the alteration consists of quartz-sericite near the surface which is the result of probably both hydrothermal and weathering agents, and this alteration in general grades downward into and/or is intruded by biotite-argillic altered rock. In the Ruth Extension area alteration zoning appears to grade laterally (west to east) from a large mass of quartz-sericite altered porphyry to biotite-argillic altered porphyry lenses in metamorphosed shale.

Kimbley Pit

From the core of P which was drilled from the bottom of the Kimbley Pit it appears that porphyry in the pit area was the result of only one intrusive event. The porphyry in P is the same as that in T except that the porphyry in P increases in the percentage of fine-grained groundmass towards the surface. The P drill hole gradation from altered, mineralized, fine-grained groundmass rock to prophylitic altered, granitic-textured rock with depth definitely exists but is somewhat separated by shale units and one strong fault zone. The sediments and fault zone in P do not significantly dispute the gradational aspects of alteration, mineralization, and texture. It is not uncommon in P or the Liberty Pit area to alternate between fresher more granitic textured rock and altered more aplitic textured rock throughout the zones of gradation.

Alteration in the Kimbley Pit consists of strong, pervasive quartz-sericite replacement of mafic minerals, plagioclase, and orthoclase in the quartz monzonite porphyry. The Chainman shale is likewise altered to quartz and sericite. At 721 feet in P a thin section of core showed clumps of sericite after plagioclase, pyrite and no magnetite, a mica mineral having the color of phlogophite and the stong pleochroism of biotite, K-feldspar phenocrysts, minor sericite after K-feldspar and the brown mica, apatite, quartz veins with traces of K-feldspar, and abundant aplitic quartz and K-feldspar groundmass.

At 823 feet a thin section of the moderately altered quartz monzonite porphyry occurring as a unit less than 15 feet in thickness in the middle of a thick hornfels (altered shale) mass showed a granitic textured groundmass that appeared to be reacting, crystallizing, or recrystallizing, or recrystallizing toward an aplitic textured groundmass. The alteration minerals include brown mica and plagioclase being replaced by minor sericite. The thin section did not show any abnormal amounts of apatite. This less altered and more granitic textured rock suggests that either the fluids with the intruded magma were dispersed into the shale or the shale acted as a physical and/or chemical barrior to altering fluids. The thin section showed about 60% of the plagioclase crystals are zoned and are more albitic than the twinned crystals.

The rock in P -a unit appears to be the same rock as that above the dominantly hornfelsic shale zone from 728 to 959 feet (see Figs. 3w to 3z). The rock in unit P -a is not as thoroughly altered and mineralized as the overlying quartz monzonite but does contain abundant quartz veins and strong vein and disseminated pyrite. Less than half of the disseminated pyrite is associated with mafic sites. In addition there are very small amounts of chalcopyrite and chalcocite, traces of molybdenite, and moderate amounts of calcite in fractures by itself and associated with pyrite. Approximately 20 percent of the unit is composed of fine grained aplitic-textured groundmass. A thin section at 1006 feet contained approximately 50 percent fine grained aplitic groundmass, sericite pseudomorphs of plagioclase, apatite, calcite, small amounts of brown mica, and K-feldspar phenocrysts with sericite along fractures and inclusions of quartz the size of quartz grains in the groundmass.

A fault in P between 1047 and 1057 feet separates more altered quartz monzonite porphyry (P -a unit) in the hanging wall block from less altered quartz monzonite porphyry (P -b unit) in the footwall block and suggests that the Kimbley Pit mineralization could be separated from more altered rock somewhere in the footwall block.

Below the fault zone between 1047 and 1057 feet the rock type (P -b unit) is essentially the same as above the fault zone. However, this rock is less altered and mineralized and contains a smaller percentage of aplitic-textured groundmass. Quartz veins are most abundant in the upper portion of the unit where they are only one tenth as abundant as above the fault. Biotite and/or phlogophite are alteration products of hornblende in the upper 150 feet of the unit. Pyrite veins with minor chalcopyrite are abundant and the plane of pyrite and quartz-pyrite veins dip approximately perpendicular to the dip of the flow structure. Aplites are present, but no pegmatites or epidote mineralization were noted. Calcite and chabazite (?) zeolite are anomalously abundant. A thin section at 1220 feet showed some of the hornblende was altered to brown mica, sphene was unaltered, and plagioclase alteration ranged from fresh to fully clouded by sericite and kaolinite. A pyrite vein was accompanied by K-feldspar replacement of plagioclase.

The percentage of aplitic-textured groundmass varies from nill to ten percent in unit P -b. A thin section at 1220 feet contains five to ten percent of mixed quartz and K-feldspar groundmass that is not as fine grained as that with a higher percentage of aplitic groundmass. Some of the quartz is in large "undissociated" grains and a minor amount is in K-feldspar phenocrysts near the crystal edges. The groundmass constitutes a gradation between aplitic-textured and granitic-textured groundmass.

At 1288 feet in P a contact was placed between two texturally different igneous rock types. Starting at about 1320 feet going upwards towards 1288 feet in the hole the texture appears to be grading from P -c rock type into P -b rock type and then returns to its original texture to form an apparently sharp contact at 1288 feet, but the degree of certainty is weakened by crushed rock and shearing in the contact area. The rock in the interval from 1288 to 1407 feet has an appearance much like the quartz monzonite in R and Q, and its difference from the P -a and -b rock type is this intervals fine grained, more lath-like, much fewer phenocryst sized K-feldspar, and finer grained hornblende. This interval notably lacks the quartz in the K-feldspar near its rims; the K-feldspar phenocrysts do, however, contain much included plagioclase near its rims. The plagioclase crystals seem to contain anomalous amounts of apatite crystals which may relate this upper contact phase to the apatite rich inclusions of fine grained rock distributed throughout the basement rock.

The rock of the P -c interval is relatively fresh and granitic textured. It contains epidote associated with some pyrite veins and in disseminations. Pyrite occurs mostly in veins but also in disseminations. Magnetite is mostly disseminated, and calcite commonly occurs in veins. Hornblende is present but mostly replaced by brown mica and chlorite. This unit with 13 percent hornblende by mineral count may have been slightly richer in hornblende than the upper P -a and -b units before alteration. Both units have about the same percentage of zoned, albitic plagioclase, and if the point count of P -b at 1220 feet is averaged with the same rock unit of T -a at 1320, the modal percentages of P -b and P -c are nearly identical.

Liberty Pit

Drill Hole A

Hole A was collared in the west end of the Liberty Pit and was rock-bit drilled to a depth of 391 feet. The change from aplitic textured to granitic textured groundmass takes place in the interval between 391 and 568 feet at a depth of 436 feet or a few feet shallower in the hole.

The overall appearance of the quartz monzonite porphyry in A above 568 feet is that of light colored rock with about ten percent mafics (see Fig. 3c). The plagioclase crystals (approximately 50 percent by volume) are white in color, the K-feldspar phenocrysts (15 percent) are pinkish orange or flesh colored, the biotite pseudomorphs after hornblende are black (local chlorite after mafics is greenish), and the quartz K-feldspar aplitic textured groundmass (0-40 percent), where present, is a uniform smoky grey. The overall color of the rock above 568 feet in A is the lightest color that was observed in the entire study with the exception of the highly altered quartz monzonite porphyry in the upper parts of P.

Above 436 feet the rock contains from a few to 30 or 40 percent fine grained groundmass composed of quartz and K-feldspar. About two percent of the rock by volume is disseminated pyrite and very little pyrite exists in veins. Traces of epidote were associated with the pyrite and mafic minerals. Magnetite in disseminations is probably slightly more abundant than pyrite. Biotite is pseudomorphic after hornblende and may be replaced by a chlorite mineral (some of the chlorite has an anomalous blue birefringence and is probably pennine; an anomalous brown color is also common). A thin section at 399 feet showed that the K-feldspar, phenocrysts and groundmass alike, were generally clouded and dusted by a brown colored mineral which may be calcite. The plagioclase grains were also dusted with the fine brown colored mineral and flecks of sericite. The hornblende was replaced by clacite, magnetite, chlorite, and a few remaining traces of biotite. Magnetite was more abundant than pyrite and traces of hematite were present. Leucoxene replaced sphene where altered, and there were numerous blebs and veins of calcite as was also apparent from examination of the core. Grains of quartz occurred in K-feldspar phenocrysts near the scalloped edges. Apatite was present but was not anomalously abundant in either the plagioclase grains or the whole rock.

The contact between granitic and aplitic textured groundmass is not a uniform gradation but is marked by variations between the two extremes over a short interval measured in tens of feet. Although the contact between the two textures of groundmass was placed at 436 feet, a thin section of rock at 432 feet showed a form of granitic textured groundmass that appeared to be gradational with aplitic texture. Here the quartz and K-feldspar occurred in small clusters of mixed grains that filled interstitial positions. More commonly in the quartz monzonite an interstitial position is filled with one or a few grains of either quartz or K-feldspar. A few grains of quartz are found in the K-feldspar phenocrysts and a fair quanity of quartz is found jutting into the K-feldspar phenocryst along the crystal boundaries. The feldspar in this thin section is fresher than that at 399 feet, but the plagioclase still is partially altered by flecks of sericite and the brown dusting of possibly calcite. Biotite after earlier mafics still exists and is locally partially replaced by a chlorite mineral(s). The sphene is unaltered; and pyrite, magnetite, and epidote are present in very small quantities.

The granitic textured rock between 436 and 568 feet in A is marked by a lack of or a much smaller percentage of aplitic textured groundmass, slightly finer grained K-feldspar, fewer K-feldspar phenocrysts, and slightly larger plagioclase than above. A thin section at 530 feet showed the rock to be very coarse grained with coarse interstitial quartz. A small percentage of hornblende still remains, but most was replaced by biotite which is partially replaced by a chlorite mineral. Magnetite is present, but no epidote or pyrite were noted in the thin section. The K-feldspar phenocrysts do not contain included quartz and a small amount of K-feldspar replaces plagioclase. As in all the core above 568 feet in A, the quantity of calcite in veins and disseminations is anomalously high and the occurrence of an orange colored zeolite is common. The scarcity of epidote above 568 feet should be noted.

The gradation from aplitic to granitic textured groundmass is essentially complete before the porphyritic quartz monzonite section is interupted by hornfels (568 to 586 feet), fault gouge (586 to 597 feet), and rhyolite (597 to 605 feet).

Drill Hole B

The gradational aspects of B, located in the east end of Liberty Pit are not as obvious as in A and P but are, nonetheless, present. Fault gouge, rhylolite, and several layers of shale are intersected just as the groundmass becomes granitic textured. The gradational aspects are confined to an interval between 510 feet and 580 feet where granitic textured groundmass alternates with aplitic textured groundmass. Unfortunately, a sizeable length of granitic textured groundmass was not intersected to complete the gradational aspects before going into shale.

B starts in altered, mineralized quartz monzonite porphyry having 10 to 15 percent phenocrysts and 20 to 40 percent fine grained aplitic groundmass and continues down to 210 feet where cut by faulting (210 to 224 feet). Mineralized hornfels is also intersected (106 to 136 feet and 147 to 165 feet) in this interval. Abundant quartz veining and disseminated and vein pyrite are the major products of mineralization. Chalcopyrite, molybdenite, zeloite, calcite, but no epidote are present. Important alteration minerals include sericite, chlorite, and biotite and/or phlogophite.

The quartz monzonite porphyry between 234 and 544 feet is essentially the same as that described above only less thoroughly altered and much less mineralized. A thin section at 310 feet showed the plagioclase to be surprisingly fresh but containing flecks of sericite and, more commonly, brown calcite (?) as alteration products. Some hornblende remains unaltered and where altered biotite, possibly some phlogophite, calcite, probably some magnetite, and chlorite are the products of alteration. No pyrite or epidote were noted, and the sphene is unaltered. A rounded quartz eye, three square millimeters in size and the only one noted in this and other sections, had an embayment of fine grained K-feldspar along the edges of the crystal and appeared to be breaking down along the edges to fine grained quartz of groundmass size. Likewise, smaller sized K-feldspar phenocyrsts had scalloped edges and appeared to be breaking down into the fine grained size of the groundmass. Plagioclase does not appear to be undergoing significant replacement by the aplitic groundmass, but some quartz grains were embayed into the plagioclase crystals.

Below about 510 feet there is a significant decrease in the amount of aplitic textured groundmass, and from 560 to 570 feet (548 - 560 feet is rhyolite) the groundmass is granitic but increases to about 15 percent aplitic groundmass between 570 and 580 feet. A thin section at 563 feet shows the rock is porphyritic with coarse grained granitic textured groundmass. K-feldspar appears to be dissociating into more interstitial positions, some has moved into fractures, and small amounts of plagioclase have been replaced by K-feldspar. The plagioclase is generally flecked with sericite and more thoroughly sericitized near mineralized fractures. Very small amounts of hornblende still remain as most has been replaced by calcite and traces of chlorite. Sphene is replaced by leucoxene where altered. Minor amounts of epidote were noted and calcite fills numerous fractures. The brown mineral often found in plagioclase and some K-feldspar was noted along the edges of a calcite vein and appeared to be a reaction product between the calcite and the neighboring minerals. Traces of hematite occurred around edges of magnetite grains.

Between 570 to 580 and 616 feet the rock (hybrid porphyritic quartz monzonite) is thought to be granitized shale or a product of reaction between a magma of quartz monzonite composition and shale. The rock has an overall grey colored hue which sets off the flesh colored K-feldspar phenocrysts. At 577 feet the rock is composed of 30 percent fine grained groundmass, plagioclase which ranges from fine grained up to 5 by 5 millimeters, K-feldspar phenocrysts ranging up to 14 by 7 millimeters, and hornblende which is not unlike that in the immediately above quartz monzonite.

The rock at 577 feet looks very much like it could be just another, yet distinctive variety of quartz monzonite; but upon seeing the fine grained material between 580 and 597 feet it becomes apparent that sediments (shale) are involved. The rock at 577 feet is very similar in appearance to that unit in the bottom of N. The rock at 577 feet is different from other "normal" quartz monzonite with its distinct grey color, the size range of plagioclase with a few large crystals (5 by 5 millimeters), the size of small K-feldspar phenocrysts, and its fine grained groundmass.

The rock between 580 and 597 feet is a much finer grained less porphyritic variety of the rock than at 577 feet. In this interval the rock contains about 5 to 10 percent K-feldspar phenocrysts which range up to 14 by 7 millimeters in size, 10 to 20 percent plagioclase which can be seen with the unaided eye and averages around 3 to 2 millimeters in size, and fine to medium grained hornblende. Abundant amounts of disseminated fine grained magnetite and sphene are characteristic of this rock.

The rock between 597 and 607 feet is more granitic and contains only 15 to 20 percent fine grained groundmass and between 607 and 616 feet the rock is again a fine grained, very weakly porphyritic unit. Between 607 and 694 feet the rock is more of a metamorphosed shale unit with locally developed phenocrysts or porphyroblasts.

Examination of a thin section at 607 showed the rock to contain medium grained plagioclase, K-feldspar, and quartz set in a fine grained groundmass of these same minerals. In thin section the texture of the larger K-feldspar masses are so poikilitic that the K-feldspar almost has lost its porphyritic or porphyroblastic appearance. One large area of exceptionally coarse K-feldspar and quartz grains has an outer edge containing smaller, included minerals as though the rock were recrystallizing. Quartz and particularly K-feldspar are replacing the very large plagioclase phenocrysts. As before, the rock contained anomalous amounts of sphene (now altered to leucoxene), finely disseminated magnetite, and a range of sizes of plagioclase crystals. The quartz monzonite shale sequence is terminated by gouge and crushed rock in the fault zone from 694 to 735 feet.

CHAPTER VI

CONCLUSION

Basement Rock

Size and Shape

The basement porphyritic quartz monzonite is continuous from I and L on the west end to C and probably all the way to T on the far east end. It's known width extends from the mapped northern contact (Weary Flat area) and N on the north to M, E, G, and possibly U on the south. The mass could be sill, dike, or stock like in shape; but an elongated stock like intrusive with a steep northern contact and a moderately dipping southern contact is indicated.

Groups of Units

The Eureka and Weary Flat groups of units represent textural and modal extremes. The Liberty group of units has a mode intermediate to the Eureka and Weary Flat groups, but is texturally most like the Weary Flat group. Units H and D -b could be interpreted as gradational units between rocks of the Liberty and Eureka types. The dip of Liberty units is to the southeast and the presence of Liberty and Eureka gradational units in the upper parts of drill holes H and D indicates that deepening of drill hole B should intersect units of the Liberty general rock type.

The East group of units with the exception of units T -a, P -a, and P -b have the appearance of a contact phase. It is not known if the texture of the rock is resulted from the digestion of sediments (shale) or more rapid colling in the contact area. The I -a, M -a, and F -a units are present along the contact in the Weary Flat area which is similar to T -a, P -a, and P -b.

The mineral composition and rock textures of the dikes, sills, and irregular intrusive masses are most like the Weary Flat group of units. Fournier (1967, p. 57-81) observed several stages of porphyry intrusion into the Liberty pit area. His late staged and early staged northeastern porphyries may relate respectively to Weary Flat units such as I -c and some other less porphyritic unit such as I -a, J -c, or K -a. The porphyry in the Kimbley pit is the same P -a, P -b, and T -a.

Texture

The texture of the basement rock varies from weakly porphyritic hypridiomorphic granular to porphyritic with hypridiomorphic granular textured groundmass. Above the basement rock sedimentary rock contact the porphyritic quartz monzonite grades into quartz monzonite porphyry with aplitic quartz and K-feldspar groundmass that appears to be a primary or secondary magmatic crystallization feature; however, the close spacial relationship of hydrothermal alteration with aplitic textured groundmass suggests hydrothermal affects may be partly or totally the cause of this particular texture.

Variations in the size, shape, and texture (particularly poikilitic texture) of hornblende, plagioclase, and K-feldspar; the local replacement of plagioclase by K-feldspar; and the replacement of augite by hornblende, and the development of porphyritic or possibly porphyroblastic textures suggest recrystallization of partially consolidated quartz monzonite. The inverse relationship between K-feldspar in phenocrysts and K-feldspar in the groundmass, the relatively uniform K-feldspar modes, and poikilitic textures of K-feldspar and hornblende indicate the K-feldspar is of magmatic or metasomatic origin rather than of late stage introductory origin.

The "bleached" white and green coloration of plagioclase and the white and pink coloration of K-feldspar seem to be the result of late stage magmatic events or hydrothermal activity. Rims of smoky K-feldspar about pink and white K-feldspar may possibly indicate the termination of K-feldspar color alteration prior to the end of magmatic crystallization.

Differentiation and Cupola Theory

The drill holes of this study were drilled deep into the basement quartz monzonite to search for possible mineralized conduits or feeder zones and also to test the possibility that the basement rock could be a post-mineralization sill like intrusive separating known mineralization at the surface from that at depth. The exploration drilling did not penetrate the bottom of the quartz monzonite mass nor did it intersect any geologic structure which appeared to resemble a feeder zone. Towards the latter stages of the exploratory drilling program it was concluded that (Breitrick 1965, p. 5):

> the porphyry originated as a differentiate of the parent monzonite as its upper portion became enriched in potash, silica, and water. Also being concentrated in the porphyry fraction were copper, iron, sulfur and the hydrothermal fluids. When the porphyry intruded the sedimentary roof rocks, it carried with it, in the fluid portion of the crystal mush, all the necessary constituents which would affect the alternation and mineralization on the porphyry

> ore bodies. Deuteric, rather than hydrothermal, would best describe the process which produced the vertical zoning of alteration (quartz sericite alteration above biotite argillic alteration) and primary sulfide distribution (pyrite to chalcopyrite ratio and total sulfide content increase upward).

Fournier (1967, p. 80) and Breitrick (1965) both felt that the upper portions of the magma were enriched in K, S, Cu, and volatile components in general.

After studying the basement rock, comparing it with the ore porphyries, and noting the affects of contact metamorphism and hydrothermal alteration and mineralization there is little supporting evidence for rock differentiation and cupola enrichment (in the sense of retaining late differentiates). The only obvious differentiation was in the formation of aplites, alaskites, pegmatites, and quartz K-feldspar veins.

The only rock that suggests an enrichment of potassium and sodium is the Eureka general rock type. The Eureka type has the highest K-feldspar to total feldspar ratio but also contains the highest percentage of mafic minerals, particularly augite. The Eureka general rock type contains about the same percentage of zoned, albite rich plagioclase as the Liberty group of units. The Eureka type may be a phase of the magma that contained the lowest amounts of volatiles as exhibited by very minor contact metamorphism. From a structural and petrographic point of view the Eureka group is further from being associated with hydrothermal activity than any other group. The dikes and sills exhibit characteristics more like the Weary Flat and Liberty groups of units than the Eureka type. The Weary Flat area which is thought to have been the "root zone" of the Ely deposit (discussion follows) contains the lowest percentage of albite rich plagioclase, the most calcic average composition of plagioclase, the lowest K-feldspar to total feldspar ratio, the least augite, but the most quartz (which is still minor).

Bauer, et al. (1966, p. 240) put together a table of chemical compositions based on weight percent for altered quartz monzonite porphyry and unaltered basement rock, dikes, and sills. The difference of SiO_2 in altered rock verses that in unaltered rock is approximately 65 percent SiO_2 compared to about 58 percent SiO_2. The percent of K_2O shows an approximately 50 percent increase in biotite argillic rock over fresh and quartz sericitic rock which are about the same. Without knowing the addition and depletion of elements from given volumes of rock but realizing the lack of much mineral variance in the fresher rock it is reasonable to suspect that the original composition of all the intrusive rocks in the district were generally the same (the Eureka group may show the most variance from this generalization). The variance in the composition of igneous rocks, as seen today, may be wholly the result of hydrothermal affects. James (1972) study of metamorphism, alteration, and mineralization in the sediments should add greatly to understanding the addition and depletion of elements in the ore zones.

The units may represent more of a crystallization or recrystallization phenomena than a multiple intrusive phenomena. If the basement complex represents a body of multiple intrusion there would have been intrusions of lower units into consolidated or partially consolidated units as the wall of the area being intruded expanded (separated or was digested) to allow room for younger intrusives. The dikes, sills, and irregular bodies appear to represent a series of multiple intrusions into the wall rock during different periods of crystallization or recrystallization of the basement rock and prior to, during, and after hydrothermal mineralization.

The conclusion is that the mineralization did not take place at once nor did mineralizing fluids collect in cupola positions. Instead the magma, in the Weary Flat and Liberty Pit area as registered by the different units, released or was affected by continuous yet varying amounts of fluids.

Some evidence points to the fact that the initial stages of the intrusive rock or magma were reasonably "dry". Contact effects outside the zone of hydrothermal mineralization are minor for the basement rock, dikes, sills, and irregular intrusive bodies. The alignment of K-feldspar in every unit suggest that the final stages of consolidation for all units coincided, for all practical purposes, with the close of intrusive activity.

The wedge shape of the basement intrusive rock, the folded and broken sediments, and the reactive mineralogy of the sediments made the area above the crestal position of the intrusive basement rock conducive to the intrusion of quartz monzonite porphyry and mineralization.

Faults

The Liberty Pit ore zone is in the Liberty Pit block which forms the hanging wall block of the Footwall Fault (east). The Ruth ore zone and the Ruth Extension ore zone are believed to be down faulted segments of Liberty Pit mineralization (in the opinion of the author and most company geologists). It is not known if the Tripp-Veteran mineralization was once more or less continuous with Liberty Pit mineralization. The author believes the Liberty Pit intrusion of quartz monzonite porphyry and the subsequent alteration and mineralization took place over the Weary Flat area (near the outcrop of the Footwall East Fault) for the following reasons.

The porphyry units, I -c and L -a to -f, in the Weary Flat area are very much like the ore porphyries (which are familiar to the author) and upper A -a and upper B -a porphyries). The main difference is in the groundmass textures, aplitic verses granitic, but these groundmass textures are gradational into one another as seen beneath the Liberty and Kimbley Pits. The I -c and L -a to -f units may correspond to Fournier (1967) late stage quartz monzonite porphyry intrusive, and the I -a unit or some other unit may correspond to the early intrusive stage. Units C -a, F -b, M -a, and G -a are also in the hanging wall of the Footwall Fault and bear textural similarities to Weary Flat units. Textural similarities to Weary Flat units. Textural similarities of importance include strong porphyritic development, large K-feldspar phenocrysts, unusually large plagioclase grains, extreme coarseness of some hornblende, a few large euhedral hornblende crystals, and the inclusion of small amounts of quartz near the edges of K-feldspar phenocrysts.

The modal analysis of rock at 432 feet in A is most similar to the average modal analysis of the Weary Flat group. The average composition of albite twinned plagioclase of the A and B units in the hanging wall block of the Footwall Fault is between the average for Liberty and

Weary Flat groups of units. More importantly, the percentage of zoned plagioclase in these units is much closer to that for the Weary Flat units than for either Liberty or Eureka B groups of units.

The steepness of flow structure in the hanging wall block of the Footwall Fault (east) is more like the steep dips in the Weary Flat area than the shallower dipping Liberty and Eureka groups of units. The steep dips may be related to the intrusion of the quartz monzonite porphyry into the overlying sedimentary host rocks.

An unusual intrusive breccia composed of porphyritic quartz monzonite breccia in an aphanitic matix of what may have been rock flour, was noted in only one drill hole, H at 751 feet. The same type of breccia was mapped by the author during 1968 in the bottom of the southeast and east side of the Liberty Pit. The apparently limited distribution of this breccia suggests that the eastern portion of the Liberty Pit area was once in the vicinity of drill hole H.

The total sulfur values indicate that pyrite mineralization was strongest in those units in the hanging wall of the Footwall Fault (east), in the crestal units (particularly in the east group), and in the Weary Flat group of holes. Anomalously high sulfur values in the hanging wall of the Footwall Fault and high sulfur values in the Weary Flat area also support the hypothesis that the Liberty Pit fault block was once closer to or positioned above the Weary Flat area. The increase in total sulfur content with depth in the Weary Flat area suggests that three dimensional contour surfaces of total sulfur values might be shaped like an inverted funnel in this area. Therefore, the actual "root" or "feeder" zone for the Liberty Pit mineralization in the Weary Flat area is probably relatively confined in lateral extent. The very high total sulfur content and relatively high geochemical copper content intersected beneath a strong fault zone in drill hole K (K -f unit) points out the fact that less weakly mineralized rock may be faulted over more strongly mineralized rock in the Weary Flat area.

The spacial distribution of high sulfur content to the west and high magnetite (with sulfides) to the east is apparent in both the Weary Flat area and the Liberty Pit block. The anomalously high magnetite content in the upper half of drill hole H may be correlated with the high magnetite content in the eastern basal portions of the Liberty Pit mineralization and in G -a (hanging wall of Footwall Fault).

Small amounts of molybdenite in the top of H and more abundant in the top of I may be related to the high molybdenite content of the Liberty Pit block. A geochemical soil survey of molybdenum values in the Weary Flat area might be useful in locating the root zone of the Liberty Pit mineralization.

The scarcity of reasonably pure quartz veins in the basement rock and their abundance in the Liberty Pit block places additional emphasis on the small population of quartz veins in the upper half of J. Approximately 100 feet of limonite cap rock in the top of J is significant because in the few areas where the porphyritic quartz monzonite outcrops, the amount of limonites is not significant. The distribution of zones of disseminated pyrite and/or magnetite with associated green sericitic alteration suggests hydrothermal activity occurred to the west of drill holes B, E, and H.

Biotite commonly occurs in the crestal rocks and is relatively rare in deeper portions of basement rock. The development of relatively anomalous amounts of biotite in the bottom of drill hole K is thought to be significant and the occurrence of a vein biotite in I may also be significant.

The author could find no data contrary to the fact that the Footwall Fault (east) is a normal fault. The possibility of a strike slip component (hanging wall movement from west to east) cannot be eliminated.

APPENDIX A

DRILL LOG GEOLOGIC SUMMARY

Geologic summary of important intervals other than those reported under the quartz monzonite summary can be found below. A number of thin intervals of rhylolite, sediment, aplite, alaskite, and small fault zones have been left out.

Hole	Interval	Geology
A	568-586	Hornfels and quartz monzonite porphyry
	586-597	Fault gouge
	597-605	Rhyolite
	820-824	Fault gouge
	824-873	Rhyolite
	873-879	Fault gouge and breccia
	907-920	Rhyolite
	920-930	Fault gouge
	1110-1115	Fault zone
	1115-1121	Rhyolite and glass
	1245-1332	Rhyolite
	1472-1478	Rhyolite
	2436-2448	Rhyolite
B	106-136	Hornfels
	147-165	Hornfels

	210-224	Fault gouge
	2224-234	Hornfels
	438-452	Rhyolite
	452-472	No Core
	548-560	Rhyolite and glass
	580-597	Shale quartz monzonite hybrid rock
	607-616	Shale quartz monzonite hybrid rock
	616-694	Shale and shale quartz monzonite hybrid rock
	694-735	Fault zone
	735-817	Locally bleached shale
	817-974	Rhyolite
	1095-1103	Rhyolite
	1103-1112	Fault gouge and breccia
	1112-1113	Rhyolite
	1164-1183	Rhyolite
	1192-1210	Rhyolite
	1237-1241	Glass
C	1352-1368	Fault zone
	1792-1828	Rhyolite
	1865-1923	Rhyolite
	1923-2046	Bleached and recrystallized dolomite
D	672-684	Weakly metamorphosed shale
	684-698	Fault zone
	698-705	Glass and rhyolite
	733-740	Silicified (?) shale
	816-821	Weakly silicified (?) shale

	836-890	Weakly altered shale
	890-923	Fault gouge
	923-1155	Rhyolite
	1305-1343	Rhyolite
	1711-1734	Rhyolite
	2094-2105	Rhyolite
	2323-2385	Rhyolite
E	2400-2406	Rhyolite
	2406-2438	Bleached, recrystallized limestone
	2438-2470	Rhyolite
	2470-2480	Bleached, recrystallized limestone
	2480-2490	Metamorphosed limestone
F	640-650	Fault gouge and rock fragments
	1285-1340	Fault gouge and breccia
	1607-1652	Rhyolite
G	2100-2150	Argillite
	2150-2242	Metamorphosed argillite
	2282-2351	Rhyolite
H	300-363	Metamorphosed shale
	363-411	Fault zone
	963-1012	Rhyolite
	1199-1241	Rhyolite
I	300-383	Shale
	383-473	Metamorphosed shale
	540-550	Rhyolite breccia

J	0-21	Rock bit
	21-43	Geothite boxwork after quartz monzonite
	43-113	Weathered quartz monzonite and goethite
	850-872	Rhyolite
K	0-25	Rock bit
	25-28	Shale with goethite
	28-75	Hornfels (?) and quartz monzonite
	220-260	Fault gouge and breccia
	544-554	Fault gouge
L	381-438	Fault gouge
M	1850-1903	Metamorphosed limestone
	1913-1917	Metamorphosed limestone
	1942-1949	Glass
	1975-2152	Rhyolite
N	453-520	Rhyolite
O	735-754	Black, locally bleached and recrystallized limestone
	754-765	Silicified limestone
	1018-1021	Fault gouge
	1021-1069	Bleached, recrystallized limestone
	1069-1117	Fault gouge and breccia
	1117-1135	Partially bleached and recrystallized limestone
	1135-1168	Bleached, recrystallized, and locally dolomitized limestone
	1171-1189	Rhyolite
	1360-1433	Rhyolite

	1699-1711	Rhyolite
	1935-1978	Rhyolite
	1984-1989	Rhyolite
P	0-588	Quartz sericite altered porphyry(KCC)
	588-728	Biotite argillic altered porphyry(KCC)
	728-959	Hornfels and local minor porphyry(KCC)
	1047-1057	Fault gouge
Q	1627-1693	Rhyolite
R	1119-1131	Fault gouge and breccia
	1131-1168	Metamorphosed shale
S	1660-1692	Fault zone
	1707-1760	Silicified shale
	1760-1881	Metamorphosed shale and limestone
	1881-1950	Bleached, recrystallized dolomite
T	1137-1208	Metamorphosed shale
	1208-1260	Sandy material probably from rock bit
U	1767-1852	Limestone with abundant calcite veins
	1852-1870	Metamorphosed limestone
	1904-1907	Bleached, recrystallized limestone with minor metamorphic minerals

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