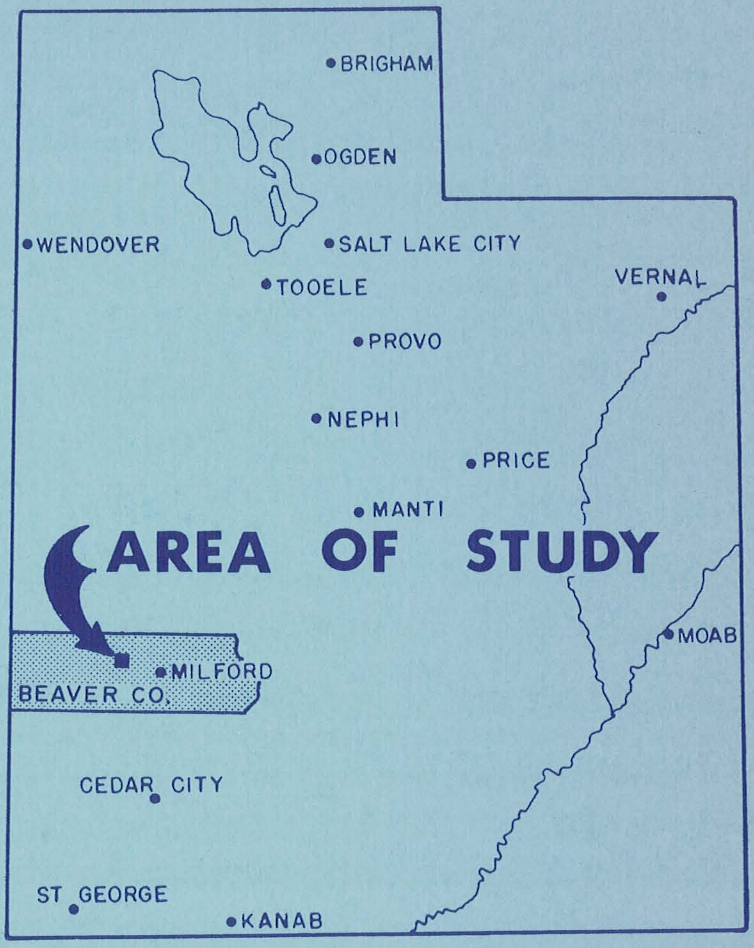
# HYDROTHERMAL ALTERATION NEAR THE HORN SILVER MINE, BEAVER COUNTY, UTAH




*Utah Geological and Mineralogical Survey*

*SPECIAL STUDIES 16*

# HYDROTHERMAL ALTERATION NEAR THE HORN SILVER MINE, BEAVER COUNTY, UTAH

*by Bronson Stringham*

View looking west into Horn Silver caved area.

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY
*affiliated with*
THE COLLEGE OF MINES AND MINERAL INDUSTRIES
*University of Utah, Salt Lake City, Utah*

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# ILLUSTRATIONS

# ABSTRACT

This study of rock alteration in the vicinity of the Horn Silver mine is part of an investigation of alteration and mineral deposits in the Milford region of Beaver County, Utah, designed to assist in the search for exploitable mineral deposits in Utah. Although the Horn Silver mine has been examined intensively by many geologists, including private consultants, the hydrothermal alteration in the volcanic rocks east of the Horn Silver fault has never been studied.

The Horn Silver ore body, one of the most productive lead-silver deposits in Utah, was formed along the Horn Silver fault. The adjacent sedimentary rocks are Upper Cambrian limestones and dolomites in fault contact with Ely Limestone. The sequence of volcanic rocks begins with the Needles Range Formation ignimbrite at the base overlain by Horn Silver Andesite. An ignimbrite known as the Isom Formation overlies the Horn Silver Andesite and is followed by a gray basalt which, in turn, is overlain by ignimbrite of the Quichapa Formation. Quartz latite porphyry flows lie unconformably on most of the other volcanic units. Intrusion of quartz monzonite followed the accumulation of volcanic rocks and both sedimentary and volcanic rocks are transected to and including the Horn Silver Andesite. Emplacement of quartz monzonite was followed closely by the intrusion of quartz monzonite porphyry. Numerous breccia pipes, many of which contain quartzite and limestone fragments as well as cognate materials, have been found in the area, especially in the Horn Silver Andesite. Alteration stages are propylitization, hematitization, silicification, alunitization, argillic alteration and pyritization.

Only one mine in the area, the Horn Silver, has been productive although many attempts to find other ore bodies have been made. Though the Horn Silver mine was not available for entry during the study, maps, reports and personal communications indicate that the emplacement of ore minerals in the Horn Silver followed the stages of alteration. Barite found in the Horn Silver ore body possibly is a guide to ore, but unfortunately it was not found elsewhere in the district.

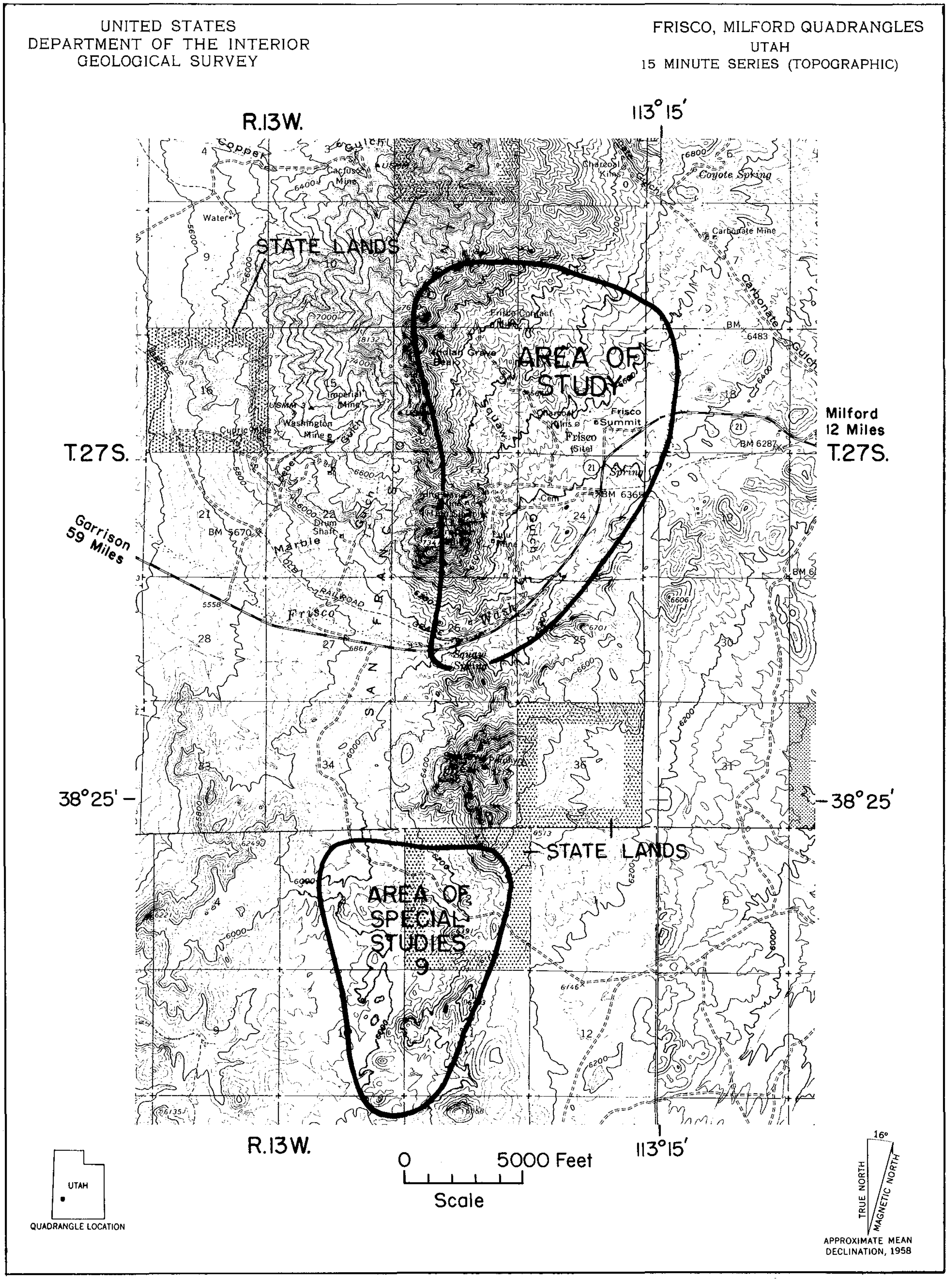



**Plate 1.** Index map of the Horn Silver area.

# HYDROTHERMAL ALTERATION NEAR THE HORN SILVER MINE, BEAVER COUNTY, UTAH

*by Bronson Stringham*

## INTRODUCTION

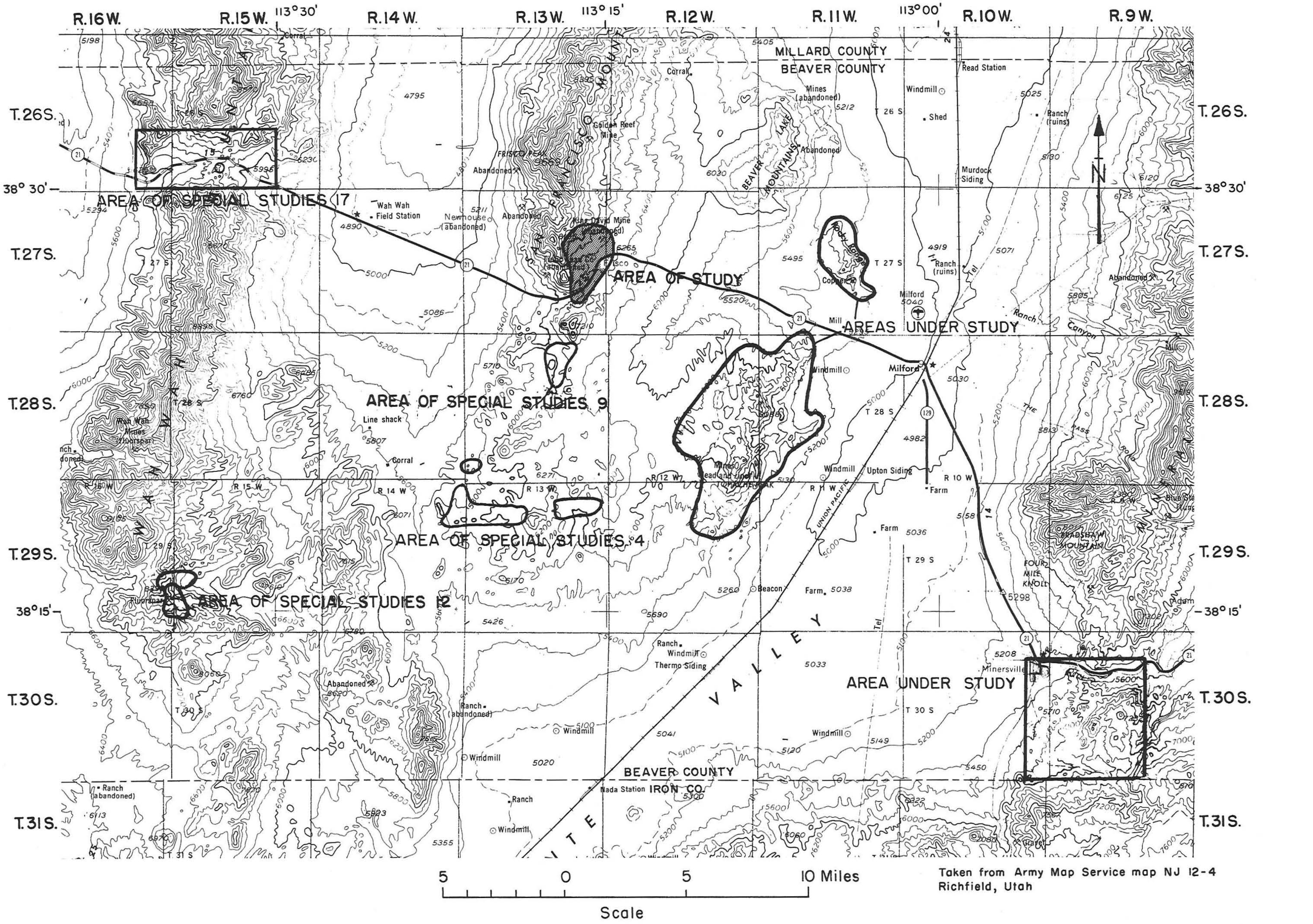
The study of types of alteration in volcanic rocks as possible guides to concealed ore was initiated in 1962 by the Utah Geological Survey and the College of Mines and Mineral Industries as part of a regional study of mineral deposits in the vicinity of Milford, Beaver County, Utah. The present report covering only a part of the San Francisco mining district is third in a series of alteration studies by Stringham (see pl. 1); two have been published, one on an area 12 miles south of the Horn Silver mine (Stringham, 1963a) and another on an area 3 miles south of the Horn Silver mine (Stringham, 1964). Published reports by M. P. Erickson and E. Julius Dasch (1963), by J. A. Whelan (1965), and by M. P. Erickson (1966) also discuss alteration. Erickson has completed a study of the mineralogy and geology of the Wah Wah Pass region. The entire Star Range immediately west of Milford where many mines and prospects exist now is being studied by Dr. Whelan. Here considerable underground mapping is being accomplished, the results of which should be available in a year. In the future, it is intended to expand these studies to areas to the north, west and east of Milford. Locations of all these projects are shown on figure 1.

The objective of this report is to show the distribution of the several types of alteration--propylitization, silicification, alunitization, argillization, pyritization and hematitization--and to show their relation to the ores of the Horn Silver mine. With a production record of $54 million, mainly in lead and silver, the Horn Silver was one of the great mines of Utah. The underground workings of this mine, which reached a depth of 1,600 feet, were inaccessible at the time of this study so reliance must be placed on the description by Butler (1913, 1920) and on personal communications from E. A. Hewitt, formerly geologist at the mine, and Page Blakemore, the present operator. As the mine was not available for study, only a summary account is presented in the effort to relate economic mineralization to alteration.

Detailed mapping, undertaken during the summers of 1963, 1964 and 1965, was confined largely to the volcanic rocks in a reentrant slope at the southeast foot of the San Francisco Range. Only a narrow strip of Paleozoic sedimentary rocks and the intrusive quartz monzonite which make up the high part of the range was included. The regional geology is shown on the Geologic Map of Southwestern Utah (Hintze, 1963), on the maps by Butler (1913, 1920) and a map by Edwin H. East (1956), part of which is reproduced in this report. Mapping was done on enlargements of air photos at a scale of about 350 feet to the inch and adjusted to the land net which is a modern survey. Owing to the deposition of slope wash from the high mountains, the outcrops of volcanic rocks and their altered equivalents have a patchy distribution. Mine dumps cover much of the critical area around the Horn Silver mine.

Topographic features are shown on the Frisco and Milford quadrangles (1:62,500, contour interval 40 ft; see pl. 1) of the U.S. Geological Survey. Elevations in the area covered by

1. Department of Mineralogy, University of Utah


R.16W.
R.15W.
113°30'
R.14W.
R.13W.
113°15'
R.12W.
R.11W.
113°00'
R.10W.
R.9W.
T.26S.
T.27S.
T.28S.
T.29S.
T.30S.
T.31S.
38°30'
38°15'
MILLARD COUNTY
BEAVER COUNTY
IRON CO.
AREA OF SPECIAL STUDIES 17
AREA OF STUDY
AREAS UNDER STUDY
AREA OF SPECIAL STUDIES 9
AREA OF SPECIAL STUDIES 4
AREA OF SPECIAL STUDIES 12
AREA UNDER STUDY
Wah Wah Field Station
Newhouse (abandoned)
Frisco Peak
Golden Reef Mine
King David Mine
Milford
Minersville
Beaver Lake Mountains
Bradshaw Mountain
Four Mile Knoll
Wah Wah Mines (fluorspar)
Upton Siding
Thermo Siding
Nada Station
Murdock Siding
Read Station
Union Pacific
VALLEY
N
5
0
5
10 Miles
Scale
Taken from Army Map Service map NJ 12-4
Richfield, Utah

the accompanying geologic map range from 5960 feet in Squaw Springs Wash at the southwest corner to 7200 feet at the northwest corner near the Frisco Contact shaft. With the exception of a strip on the east side of Frisco summit, drainage is southward and westward into Wah Wah Valley. Most of the surface in the mapped area on Tertiary volcanic rocks is gentle and rolling. There are no springs or permanent streams and the water surface is said to stand below the 1100 level in the Horn Silver mine. The area is crossed by paved highway, U. S. 21, at a distance of 14 miles from Milford. The dumps and cave of the mine can be viewed from the highway about 4,500 feet west of the historic roadside marker which announces the importance of the old Horn Silver mine.

Property ownerships in the district go back to early days when many patented claims were obtained. A claim map is presented in figure 2.

Field work was supported from the Uniform School Fund of the University of Utah, which is gratefully acknowledged. Kenneth C. Thomson, Tom Lotts and Blaine Day ably assisted the writer in the field and in the laboratory. Hossein Salek and John Balsley contributed effectively in the field and laboratory procedures. Laboratory work, carried on during the winters of 1963-64 and 1964-65, involved determinations made with x-ray diffraction, x-ray fluorescence, differential thermal analysis, infrared, flame photometry, and petrographic study of many thin sections.

## GENERAL GEOLOGY

The general geology of the San Francisco Mountains and of the San Francisco mining district, in particular, has been adequately covered by Butler (1913; 1920) and East (1956). Butler's earlier work was reexamined by East and some notable changes were made in the stratigraphy and structure. It is appropriate here, however, to outline the geology of the more restricted area covered by this report shown in plate 2. The southern portion of East's map (fig. 3) is reproduced to clarify his interpretations, particularly in the faulted sediments of Grampian Hill.

Squaw Creek Pass represents essentially the southern boundary of this study. Rocks south of the pass are principally extrusive, although two rather small outliers of Paleozoic rocks occur (fig. 3), both of which are surrounded by extrusives and alluvial cover. The principal structural feature is a north-south fault long known as the Horn Silver fault since the ore of the Horn Silver mine occurred along and adjacent to it. Several small east-west or cross faults offset the main fault in different directions. West of the main fault are the gently dipping Upper Cambrian limestone (Grampian of Butler, 1913) and the Ely Formation of Pennsylvanian age (East, 1956), separated by an east-west-trending pre-Horn Silver normal fault. (See fig. 3 and plate 2.) a large, coarse-grained quartz monzonite intrusive exposed north of the Horn Silver mine makes up the southern core of the San Francisco Mountains.

Very little detailed work was done by the writer on either the sedimentary rocks or the quartz monzonite. The contact of the quartz monzonite was traced around the northern part of the area. The position of the eastern boundary of the area was selected to include several large exposures of altered rock and breccia pipes within the extrusives. The mapped area so defined, includes extrusive porphyry, intrusive rocks, and breccia pipes. Many intrusive plugs were found in the extrusive rocks, but owing to poor exposures these were determined with the utmost difficulty, and faithful representation of their precise outline is not presumed. A large number of breccia pipes have also been mapped.

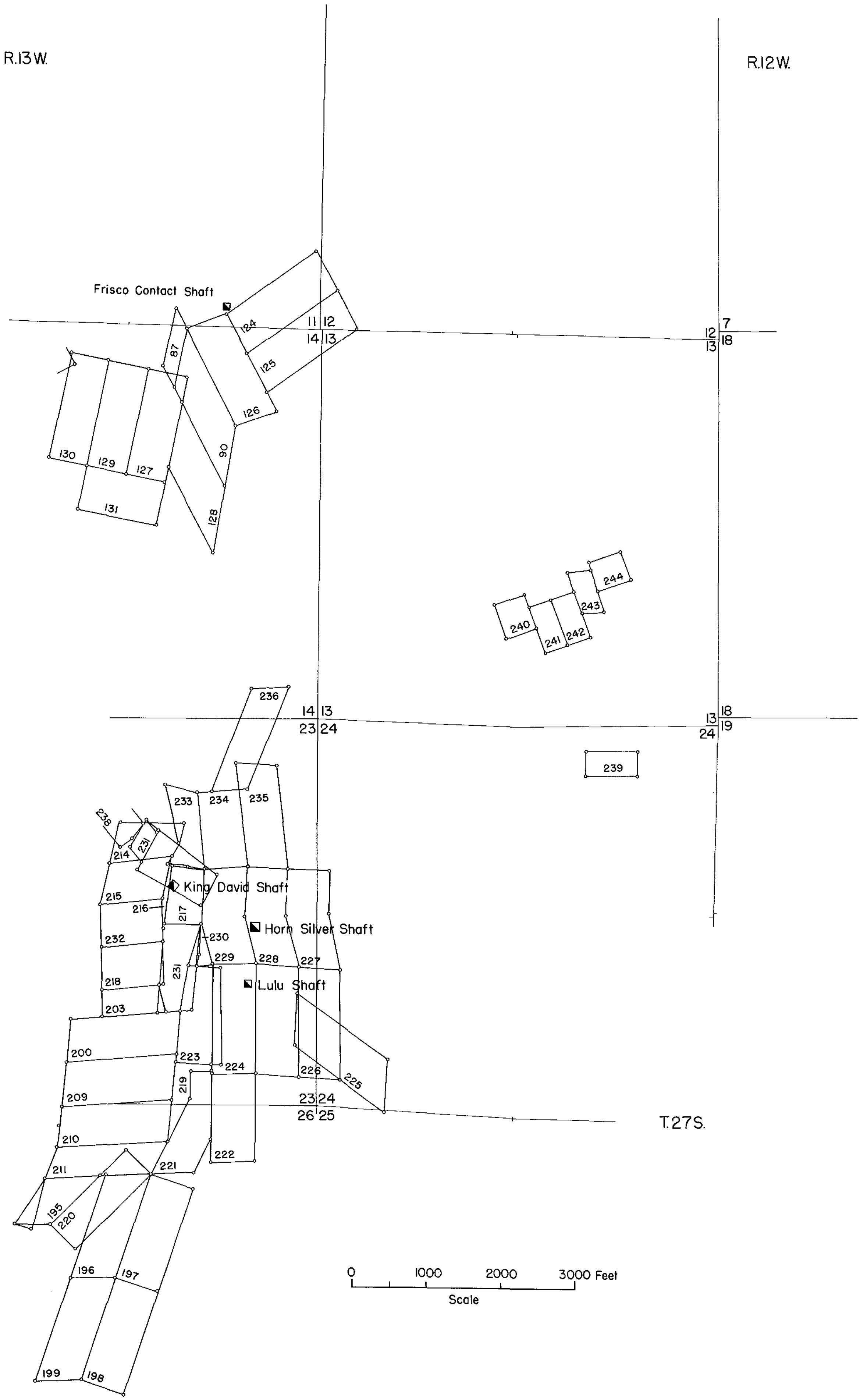
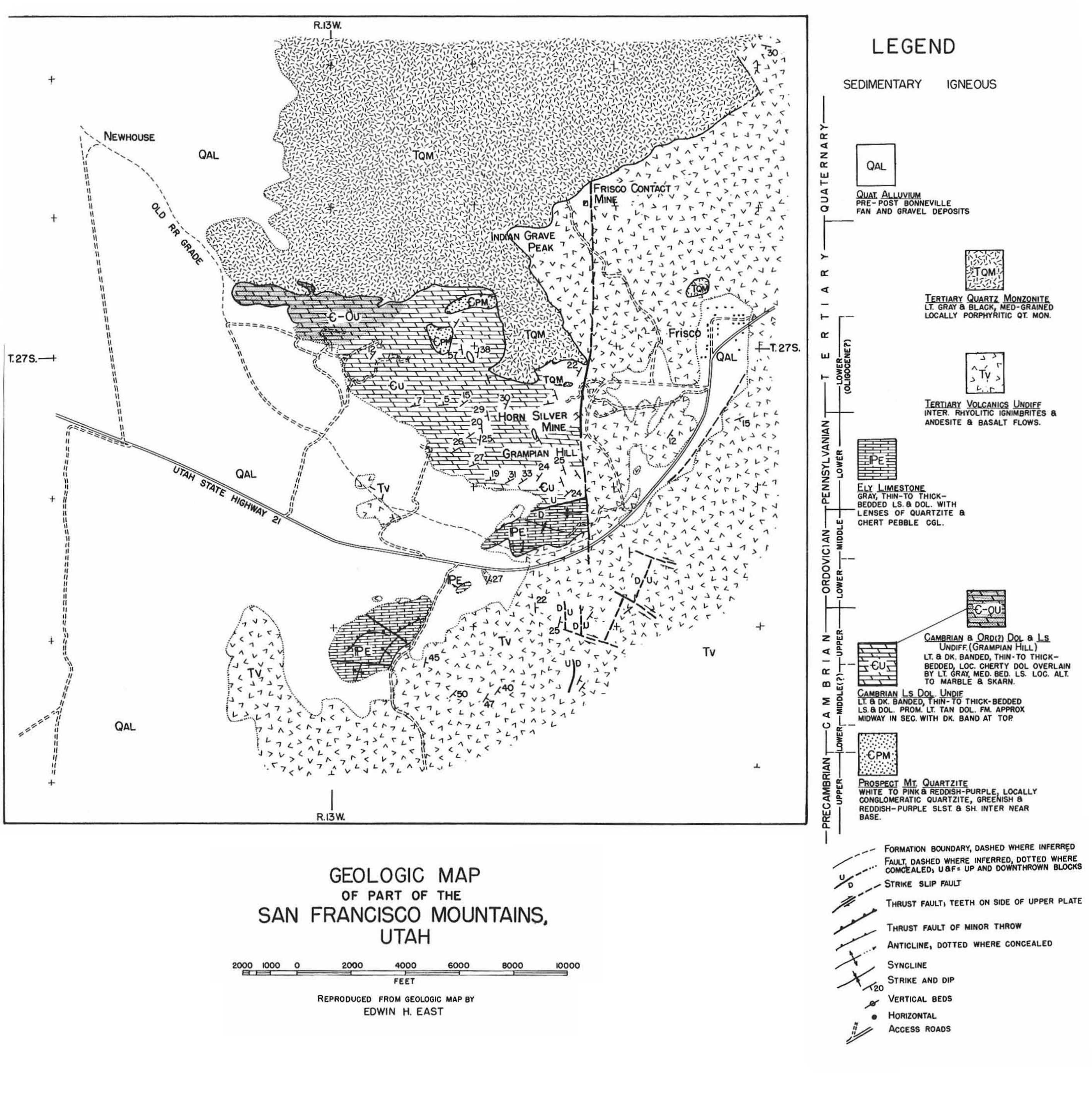



**Figure 2.** Map showing patented claims in the vicinity of the Horn Silver mine.

Figure 3.



R.13W.
NEWHOUSE
QAL
TQM
OLD RR GRADE
FRISCO CONTACT MINE
INDIAN GRAVE PEAK
Є-Ou
ЄPM
Frisco
T.27S.
ЄU
HORN SILVER MINE
GRAMPIAN HILL
UTAH STATE HIGHWAY 21
Tv
IPE
LEGEND
SEDIMENTARY
IGNEOUS
QUATERNARY
TERTIARY
LOWER (OLIGOCENE?)
PENNSYLVANIAN
ORDOVICIAN
CAMBRIAN
PRECAMBRIAN
QUAT. ALLUVIUM
PRE-POST BONNEVILLE FAN AND GRAVEL DEPOSITS
TERTIARY QUARTZ MONZONITE
LT. GRAY & BLACK, MED-GRAINED LOCALLY PORPHYRITIC QT. MON.
TERTIARY VOLCANICS UNDIFF
INTER. RHYOLITIC IGNIMBRITES & ANDESITE & BASALT FLOWS.
ELY LIMESTONE
GRAY, THIN-TO THICK-BEDDED LS. & DOL. WITH LENSES OF QUARTZITE & CHERT PEBBLE CGL.
CAMBRIAN & ORD(?) DOL & LS UNDIFF. (GRAMPIAN HILL)
LT. & DK. BANDED, THIN-TO THICK-BEDDED, LOC. CHERTY DOL OVERLAIN BY LT. GRAY, MED. BED. LS. LOC. ALT. TO MARBLE & SKARN.
CAMBRIAN LS DOL. UNDIF
LT. & DK. BANDED, THIN-TO THICK-BEDDED LS.& DOL. PROM. LT. TAN DOL. FM. APPROX MIDWAY IN SEC. WITH DK. BAND AT TOP.
PROSPECT MT. QUARTZITE
WHITE TO PINK & REDDISH-PURPLE, LOCALLY CONGLOMERATIC QUARTZITE, GREENISH & REDDISH-PURPLE SLST. & SH. INTER NEAR BASE.
FORMATION BOUNDARY, DASHED WHERE INFERRED
FAULT, DASHED WHERE INFERRED, DOTTED WHERE CONCEALED; U&F= UP AND DOWNTHROWN BLOCKS
STRIKE SLIP FAULT
THRUST FAULT; TEETH ON SIDE OF UPPER PLATE
THRUST FAULT OF MINOR THROW
ANTICLINE, DOTTED WHERE CONCEALED
SYNCLINE
STRIKE AND DIP
VERTICAL BEDS
HORIZONTAL
ACCESS ROADS
GEOLOGIC MAP
OF PART OF THE
SAN FRANCISCO MOUNTAINS, UTAH
2000 1000 0 2000 4000 6000 8000 10000
FEET
REPRODUCED FROM GEOLOGIC MAP BY
EDWIN H. EAST

## SEDIMENTARY ROCKS

In view of the detailed study by East (1956) and the earlier work of Butler (1913) only a general statement concerning the sedimentary rocks is offered here.

The oldest formation within the mapped area, named Grampian Limestone by Butler (1913) from its exposure on Grampian Hill, has been assigned to the Upper Cambrian by East (1956). It is composed principally of dolomitic limestone and limestone, which in many places has been extensively bleached and altered and exhibits typical skarn characteristics. The limestone is in intrusive contact with quartz monzonite to the north but is in fault contact with the volcanic rocks to the east. Cambrian exposures on the west side of the Horn Silver fault extend southward about one mile from the intrusive contact and end against an east-west fault which presumably antedates the Horn Silver fault. The Ely Limestone south of the fault is readily recognized by its fossil content and has been established conclusively by East (1956) to be of Pennsylvanian age. The east-west fault separating the two formations was found and mapped in the field to the limits of the present map area. From East's map (fig. 3), it is apparent that the Ely Limestone occurs not only north of Squaw Springs Pass but also in two small patches south of the pass (fig. 3), indicating that Ely Limestone underlies the extrusive rocks and alluvial cover in this area.

Much of the area of volcanic rocks is covered by gravels and outwash materials found at the bottom of the stream channels and on the broad slopes leading to the higher areas near the northern part of Grampian Hill. The boulders on these slopes, which range in diameter from a few inches to as much as four feet, are composed principally of quartz monzonite and limestone derived from the mountain front. Boulders of volcanic rock are generally smaller. The gravels in the outwash appear to be mainly less than 25 feet thick. However, the cover is extensive and the bedrock is commonly obscured, seriously restricting observation of areas which are critical for interpretation.

## EXTRUSIVE ROCKS

Full comprehension of the characteristics and relationships of the volcanic rocks of the Horn Silver area proved to be critical for this work since most of the hydrothermal and weathering alteration, porphyry intrusion and breccia pipes are found within these rocks. The unaltered rocks were studied carefully in order to understand more thoroughly the true relationships between the different extrusive units. Although Butler (1913) described several of these extrusive units within the Horn Silver area he made no attempt to map them individually. However, he did relate the various units to those in adjacent areas. Since Butler's time the studies of Mackin (1960), Cook (1957; 1965), and others in southern Utah and Nevada have shown that many ignimbrite formations are extensive throughout southern Utah and Nevada, and many of these may now be correlated with some confidence over wide distances (Cook, 1965).

In the Horn Silver area, three ignimbrites, named by Mackin (1960) the Needles Range, Isom and Quichapa Formations were recognized and correlated with those found elsewhere. (See fig. 4.) A local unit lying between the Needles Range and Isom Formations is the most important extrusive rock in the vicinity and is here named the Horn Silver Andesite from its occurrence near the Horn Silver mine. Most of the hydrothermal alteration of all types occurs in this andesite. Also, a very local basalt flow was found between the Isom and Quichapa Formations, and a coarse-grained extrusive quartz latite porphyry rests unconformably upon all of the older formations except the Needles Range. The

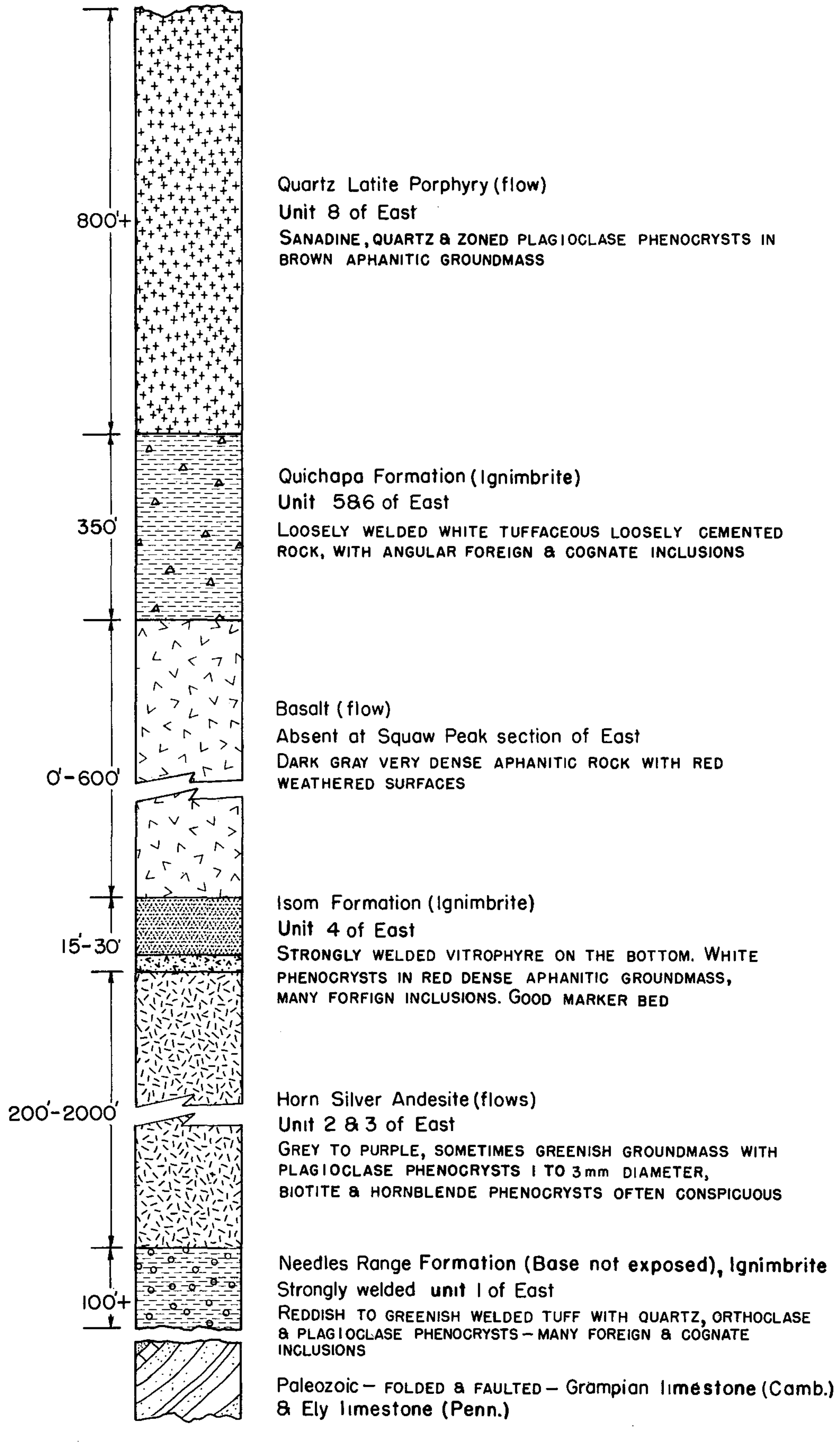



**Figure 4.** Sequence of Tertiary extrusives at Horn Silver mine and vicinity.

minimum thickness of the extrusive rocks is 1,600 feet, and the maximum is probably in excess of 3,500 feet. With the aid of the correlative ignimbrites in the area, it has been possible to delineate some faults which have not appeared on earlier published maps. See pl. 2.) East (1956) has described a section of extrusive rocks to the west of Squaw Peak (the highest peak south of Squaw Springs Pass) within 1.5 miles of the southernmost part of the mapped area. East divided this section into units, numbered from one to nine. His descriptions and measurements were found to be useful in unravelling the extrusive sequence near the Horn Silver mine where faulting and gravel cover obscure relationships. Professor Max P. Erickson of the University of Utah examined East's section as well as the rocks exposed in the Horn Silver area. J. Hoover Mackin and Paul Williams also visited the area briefly with the author and concurred with his identification of ignimbrites herein proposed. Butler (1913; 1920) and East (1956) judged these extrusives to be Tertiary in age and no evidence was found during the present study to alter this conclusion. Cook (1965) assigned them to the Oligocene. Armstrong (1963, p. 79) gave K-Ar dates of 24 ($^{+4}_{-1}$) million years for the Needles Range Formation exposed in the Needles Range of western Utah, and 24 ($^{+2}_{-1}$) million years for the Quichapa Formation in southeastern Nevada.

## Needles Range Formation

The Needles Range Formation was named by Mackin (1960) from an area in the Needles Range about 30 miles west of the Horn Silver mine. Although Mackin does not give the thickness of the type section, it appears to be at least 1,000 feet thick. Other excellent exposures of the Needles Range Formation occur on the east side of the Wah Wah Range, 15 miles west of the San Francisco Mountains. So far as is now known, no rocks correlative with the Needles Range Formation have yet been recognized to the north and northeast of the Horn Silver area.

The Needles Range Formation may be readily identified because of its position in the extrusive sequence and its very distinctive lithology. It is the lowest, or oldest, Tertiary extrusive rock to be found in this region and consequently lies directly upon older rocks (Cook, 1965). In detail, it often bears a strong suggestion of bedding or appears to be stratified. Numerous crystals of quartz and feldspar are embedded in the very dense, commonly glassy groundmass. Angular cognate and foreign inclusions 3 mm to 3 cm in diameter are frequent. Pumiceous inclusions are somewhat collapsed and resemble discoids, with elongated directions parallel to the layering of the formation. The color of the rock is deep reddish to apple greenish where extensively weathered.

The outcrops of the Needles Range Formation are confined to areas immediately south of the mine, where 11 exposures, isolated from each other by alluvial cover, were mapped. The southernmost of these occurs near the main highway about 100 yards east of Squaw Springs and in Squaw Springs wash. Two exposures adjacent to the Horn Silver fault and slightly south of the Lulu shaft (see pl. 2) are altered to greenish-colored minerals. Where weathering and stream wash have had a chance to affect the rock, the deep reddish color is somewhat faded and is more greenish than normally expected.

Microscopically, the rock is composed of a dense groundmass of glass containing many shards which have largely been collapsed and welded together, sometimes with a small amount of devitrification. Phenocrysts up to 3 mm in diameter consist principally of broken sanadine crystals, plagioclase ($An_{25}$ to $An_{24}$), and some quartz, together with angular foreign and cognate fragments. East (1956) reported plagioclase of $An_{64}$ composition in his Unit no. 1 which he calls "grayish-green crystal tuff". Plagioclase of this basic composition was not found in the Horn Silver area.

The base of the formation was not observed within the mapped area, but to the west and southwest of Squaw Springs it appears to rest unconformably on Ely Limestone. The lower contact is very irregular and the thickness of 875 feet measured by East (1956) may not be the true maximum thickness. Exposures in the Horn Silver area suggest a thickness in excess of 200 to 300 feet. The Horn Silver shaft was drilled to a depth of 1600 feet entirely in volcanic rocks. Although dump material and stream wash largely cover the outcrops in the vicinity of the Horn Silver mine, it is believed that the shaft of the Horn Silver mine collared in Isom Formation, proceeded through an unknown thickness of Horn Silver Andesite, and reached the Needles Range Formation below. Although it was not possible to check the section in the shaft, it is believed that 800 to 900 feet of the total 1,600 may have been drilled through the Needles Range Formation.

## Horn Silver Andesite

Two flow units measuring nearly 1,900 feet in thickness and corresponding to the andesite of the Horn Silver area were described by East (1956) as his Units 2 and 3 in his section west of Squaw Peak. East's classification of both units as leuco-basalts was based largely on his determination of plagioclase as $An_{43}$ to $An_{57}$ to $An_{59}$. His rock appears so similar to other andesites of the general area that a special effort was made by the writer to measure the optical properties of some 15 of the plagioclases by means of the universal stage and the Berek (1924) method. Results showed a range in composition between $An_{35}$ and $An_{45}$, so the rock was reclassified as andesite and is named here the Horn Silver Andesite since it occurs in and near the Horn Silver mine. For the purpose of this report, it was deemed desirable to lump East's two units (shown in figs. nos. 2,3, and 4) together since they are both andesites and are more difficult to separate in the Horn Silver area than west of Squaw Peak.

The Horn Silver Andesite, probably the most widely exposed extrusive rock in the mapped area, is not an ignimbrite, but is distinctly a series of flow rocks (East, 1956). The andesite appears to be quite limited in its regional geographic extent, so far as can be determined at the present time. None has been noted to crop out more than 2 to 3 miles to the south of the mine area and it appears to be absent to the west as well as to the east of the Horn Silver area. It can be recognized north and northeast of the map area for a distance of several miles.

The Horn Silver Andesite lies upon the Needles Range Formation at a point slightly east of Squaw Springs near the main road and is overlain by the Isom Formation where a basal black vitrophyric member is commonly observed in direct contact with the andesite. The thickness of the andesite varies a great deal. Unless there has been repetition or cutting out of the section by faulting, which cannot be determined at the present stage of study, a full thickness involving both top and bottom is observed south and west of the Lulu shaft where the andesite appears to lie on Needles Range Formation. Just east and south of the mine the Isom lies directly on top of the andesite. Maximum thickness here appears to be in the neighborhood of 200 to 300 feet. There are no further Needles Range outcrops north of the Horn Silver mine, hence the base of the andesite is not determinable in this direction. The outcrop of the Isom Formation, which lies above, is readily traced toward the east and slightly north with a low southeastward dip, thus making it appear that the Horn Silver Andesite is thickening greatly eastward and northward. From drilling information it is estimated to be in excess of 2,000 feet at least as far north as the Frisco Contact mine.

Although the Horn Silver Andesite occupies a relatively small proportion of the southern part of the area, it underlies the entire area to the north and the east except where cut by

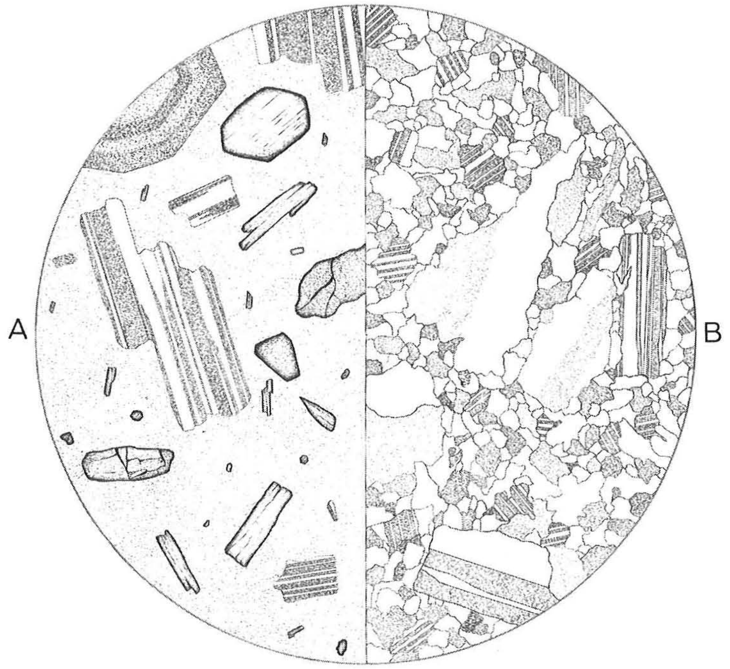



**Figure 5.**

(a) Horn Silver Andesite X 40, camera lucida drawing, showing plagioclase hornblende and biotite phenocrysts imbedded in a glassy though somewhat devitrified groundmass.

(b) Intrusive porphyry X 40, camera lucida drawing, showing orthoclase, plagioclase and quartz phenocrysts with scalloped borders imbedded in a granular groundmass of quartz, orthoclase and plagioclase.

intrusive rocks and breccia pipes. The wide variety of lithologic units can be grouped in two general types. South of the line between secs. 13 and 24 the andesite generally appears grayish and contains white to gray plagioclase phenocrysts about 2 mm in diameter. Hornblende, biotite and augite phenocrysts appear to be partly altered to greenish minerals. North of this line the color of the andesite becomes more of a reddish purple, although locally the color may be grayish and greenish in patches. Feldspar phenocrysts seem to be less altered and in many places fresh hornblende and biotite are very prominent in hand specimen. Discontinuous layers of intraformational breccia or agglomerate are common and in a few areas have been mapped. They are composed of angular, cognate, lithic fragments up to 3 inches in diameter imbedded in normal andesite. There is no reason as yet to regard the two predominant types as necessarily different flows. It is believed, however, that an extensive and lengthy detailed field and petrographic study of the entire Horn Silver Andesite would lead to discernment and mapping of individual units. Faults could then be recognized and perhaps considerable exploration value would ensue.

Microscopically, most of the thin sections of andesite showed many similarities and a few differences. Most specimens have some amount of glass in the groundmass in which are embedded plagioclase phenocrysts with composition of $An_{35}$ to $An_{45}$. (See fig. 5a.) Plagioclase also occurs in the glass as small crystals or crystallites and these generally show flow alignment. The composition of these very small crystallites was not determinable with the universal stage, but their index seems to be about the same as that of the phenocrysts, suggesting a similar range of composition. Most of the phenocrysts show very little alteration, except an occasional patch of illite, or a sericite veinlet. The dark-colored phenocrysts are mainly hornblende which is very conspicuous in some areas as crystals as much as 1 cm long. Microscopically, hornblende crystals usually show considerable denteric alteration with magnetite formed around the rims, suggesting that this hornblende may originally have been quite high in iron. A little biotite and augite were also noted in some of the thin sections. Magnetite may be present in amounts up to 5 per cent and in some of the rocks magnetite is so abundant that the compass needle may be affected and the dry beds of streams which drain the hornblende andesite outcrop areas commonly are marked by black streaks of magnetite sand.

Two partial analyses of fresh Horn Silver Andesite were made by David L. Barber at the University of Utah analytical laboratory with the following results:

| Identification | % $SiO_2$ | % CaO | % $Na_2O$ | % $K_2O$ |
|---|---|---|---|---|
| H-100 | 53.2 | 5.66 | 3.14 | 2.75 |
| HSD-2 | 57.8 | 3.78 | 4.60 | 0.71 |

These figures fall well within the range of expected andesite analyses. The different percentages here support the variable mineralogical nature of the andesite as determined by microscopic examination.

## Isom Formation

The Isom Formation, named by Mackin (1960) from exposures near Cedar City, Utah, has been traced by the writer (Stringham, 1963b) from its type locality to the Horn Silver area where it overlies the Horn Silver Andesite. (See fig. 4.) The local unit of the Isom Formation corresponds to Mackin's lowest member, an ignimbrite which he named the "Baldhills". This is the Unit 4 which East (1965) classified as "red rhyolitic vitric tuff" and is exposed in his measured and described section west of Squaw Peak. The Isom Formation crops out in the mapped area immediately east of the Horn Silver mine dump as well as elsewhere to the south and southeast where it is readily recognized by its strong red color and its ability to form cliffs and hogbacks. It is the most satisfactory marker formation within the Tertiary sequence. Owing to its gentle inclination ($0^{o}$ - $20^{o}$), the Isom forms low sloping hogbacks or cuestas. Though displaced by occasional major faults, the Isom can easily be traced from the vicinity of the mine northeastward to a point about $2\frac{1}{2}$-3 miles beyond the map boundary, where it forms several prominent hogbacks just north of the main highway, whence the outcrop curves to the northward and disappears along strike underneath the heavy gravel cover of Milford Valley.

The principal rock type of the Isom Formation has a very dense, deep reddish, hard groundmass due to strong welding of the tuffaceous materials in which are imbedded sparse white to gray, to glassy-appearing, feldspar phenocrysts and occasional quartz phenocrysts which range from 0.5 mm to as much as 5.0 mm in diameter. The rock also contains many lithic fragments, commonly grayish and of various kinds ranging to maximum sizes of about one inch. The fragments are composed of extrusive foreign and cognate types with pumice being an abundant component. Many of the pumice fragments are collapsed and now form discoids oriented parallel to the layering of the formation which is eroded to equidimensional blocks with pitted weathered surfaces.

In places, a black welded tuff with a crumbly type of weathering underlies the red rock and may be as much as 10 feet thick. Both the black and the red rocks are included in the Isom Ignimbrite. Together they may attain a maximum thickness of 30 feet but average 25 feet near the mine. Toward the east and south, however, beyond the area mapped, much thicker sequences up to 50 feet were observed.

The microscope shows the groundmass to be composed of many shards, most of them collapsed and welded together with much partly devitrified glass, in which are imbedded crystals, usually broken, of sanadine, plagioclase ($An_{33}$) and quartz amounting to around 10 to 15 per cent of the whole. Only one biotite crystal was found in one of the slides. Minute granules of red hematite are prolific throughout the rock, occurring in the glass, shards, and in some lithic fragments as well as many larger pellets. As in the Isom type locality (Mackin, 1960), the ignimbrite here has a latitic or quartz latitic composition. Nowhere was the Isom found to be altered either hydrothermally or by late magmatic processes.

## Basalt

In the vicinity of the Horn Silver mine an unusual basalt lies directly on the Isom Ignimbrite (see fig. 4). The best and largest exposures west of the main highway are on a series of rounded knolls immediately adjacent to the highway and slightly south and east of the mine itself. Larger and more extensive unmapped exposures occur east of the main road.

The fresh rock in hand specimen is very dense and dark gray. No phenocrysts can be seen with the naked eye. Upon weathering, the rock breaks into flat to irregular chunks ranging in size from $\frac{1}{2}$ inch on a side to as much as 6 inches. Very few actual outcrops are seen and the broken surface rubble is generally all that is observed. Hence rolling, soft topography is the erosional characteristic of this formation. A very thin layer of brownish red hematite usually coats the loosened and weathered blocks giving the fa se impression that the rock is fundamentally red, though the dark gray color is seen on fresh fracture.

This extrusive, though near 600 feet in thickness in the Horn Silver area, thins very rapidly to the south and is entirely absent in East's (1956) section west of Squaw Peak about two miles to the south and it does not appear to the north. Thus it may be assumed to be of rather local extent. The rock is so thoroughly massive that no megascopic flow lines or other primary structures were discerned. Microscopically, however, a strong alignment of plagioclase laths indicates flowage. The feldspar, which amounts to around 80 - 90 per cent (estimated) of the rock, proves on universal stage measurements, employing the Berek (1924) method, to be labradorite, ranging from $An_{60}$ to $An_{67}$. Iron-poor or pigeonitic augite is present in amounts ranging from about 10 per cent to about 20 per cent. Universal stage measurements show that the 2V angle of the augite ranges from 26 degrees to 55 degrees, establishing it as an iron-poor pyroxene. Magnetite is particularly scarce (0.1-0.5 per cent) in this basalt and its near absence probably ac0[-counts for the lack of the typical black color of normal basalts. In some thin sections glass is a minor constituent. There is no question but that this rock is an extrusive flow and not an ignimbrite, since flow structures are very much in evidence microscopically and no shards of any kind have been observed in any of the thin sections examined.

Within the basalt is a 10-foot-thick layer which has a dense, reddish, aphanitic groundmass with prominent white phenocrysts and which weathers to a rubble of very irregular fragments about $\frac{1}{2}$ to 1 inch in diameter. This red unit was also found west of Squaw Peak at about the same "stratigraphic" horizon, with tuffs and ignimbrites above and below. Under the microscope, this rock shows an abundance of strongly welded glass shard, collapse features, and broken fragments of crystals, all typical of ignimbrites. This unit is classified as a quartz latite welded tuff due to the presence of feldspar phenocrysts, acidic andesine ($An_{37}$), together with some quartz and orthoclase.

Several brecciated bodies were found within the basalt. In one of them the fragments are almost equidimensional while others are strongly elongated. In detail, the breccias are composed of variously oriented blocks ranging from about ½ inch to as much as 2 feet in size and composed not only of basalt but also of what appears to be foreign extrusive, chiefly andesite imbedded in a fine-grained matrix of basalt. The origin of these breccias is not clear. They are found only within the basalt, suggesting that they are not true breccia pipes; yet the presence of foreign fragments in these very restricted areas suggests that they may not be entirely intraformational.

On the whole the basalt is quite fresh and unaltered but a few specimens show minor celadonite, probably developed during a late magmatic or propylitic stage.

## Quichapa Formation

The Quichapa Formation as named by Mackin (Cook, 1957), includes ignimbrites which occur near Cedar City, Iron County, Utah, and in which he recognized four distinct units. The Quichapa Formation as a whole has very distinctive lithology and has been traced through southwestern Utah from the type locality near Cedar City discontinuously to the Horn Silver area where its identity and correlation seem to be in good order (Stringham, 1963a, 1964; Hintze, 1963).

The Quichapa of the mapped area is exposed in only two rather small outcrops near and east of the main highway in the extreme southeastern part of the district (pl. 2). Here the relationships of the Quichapa to the subjacent formations are not revealed. However, on a large hill about 2,000 feet to the east, outside of the mapped area, the Quichapa Formation lies directly upon basalt. This position is further verified in outcrops located a considerable distance to the east near State Highway 21.

Within the mapped area, a younger quartz latite porphyry lies unconformably upon the Quichapa. In the type section near Cedar City, the Quichapa lies directly on the Isom Ignimbrite. At the Horn Silver, however, there is the thick basalt between them. (See fig. 4.) East's (1956) section west of Squaw Peak described rocks which resemble parts of the Quichapa Formation at the Horn Silver in his Units 5, 6, and 7. Immediately outside the mapped area the normal Quichapa sequence seems to be complicated by interbedded glassy flows containing large lithophysae and also by firm welding in some of the tuffaceous beds.

The two outcrops within the mapped area are nearly white and are composed mainly of glassy, loosely cemented tuffaceous material, and small to large, angular blocks of foreign and cognate inclusions. In thin section the rock is composed of normal tuffaceous material containing abundant shards and broken fragments of glass, many of which have been changed by weathering to montmorillonite and kaolinite; no hydrothermal alteration was noted. As nearly as can be determined, the Quichapa Formation in the Horn Silver area is not in excess of 350 feet thick.

## Quartz Latite Porphyry

Lying unconformably on Quichapa, basalt, Isom, and the Horn Silver Andesite is an unknown thickness of flow rocks classified as quartz latite porphyry. (See fig. 4.) In the vicinity of the Horn Silver mine, the top of the porphyry is not observable, but on the west side of Squaw Peak two miles to the south there is a dark colored augite latitic vitrophyre which East (1956) estimated to be at least 800 feet thick. The quartz latite porphyry is equivalent to East's number 8 unit which he classified as "light brown porphyritic latite"

The porphyry is exposed in many large, rough to rugged hills east of State Highway 21 where the principal outcrops are sharp and steep. It is also exposed west of the highway and almost directly southeast of the Horn Silver mine in four small patches separated by Squaw Creek stream wash. One good, readily accessible exposure is a prominent, ragged outcrop near the center of Squaw Creek wash, about 2,000 feet southeast of the Horn Silver mine.

In hand specimen, the rock varies in appearance within rather narrow limits. The most typical specimens show phenocrysts of water-clear sanadine and white plagioclase about 3 to 5 mm in greatest dimension together with smaller, irregularly shaped clear to milky-colored quartz phenocrysts. Occasionally, small hornblende and/or augite crystals are present. These are all embedded in a dense aphanitic groundmass which varies in color from dark brown to light grayish brown. The amount of phenocrysts compared to groundmass ranges from an average of 35 - 40 per cent phenocrysts to as little as 5 per cent. Prominent flow lines in the groundmass and aligned phenocrysts show that the rock is definitely a flow and not an ignimbrite. Rare lithic fragments, less than 2 cm in diameter, are present though some have been noted as much as 3 to 6 inches in size. Invariably, vugs are present, most of which are irregular in shape and not larger than 5 mm. Others are rounded and contain deposits of carbonate encrusted on the walls in lithophysal fashion. Of particular interest are some prominently zoned plagioclase phenocrysts in which a clear core contains a white, milky rim. No other rock in the area exhibits this phenomenon.

Under the microscope all specimens proved to have a fine crystalline groundmass of quartz, orthoclase and plagioclase with no glass. Phenocrysts also are composed of strongly resorbed quartz, sanadine and plagioclase; the latter, when measured with the universal stage, showed a range of composition from $An_{32}$ to $An_{39}$. Brownish hornblende or pale green augite (or rarely both) were observed in some sections. Biotite is very rare. One specimen showed some relatively large zircon crystals. A rimmed or zoned feldspar was found to contain a sanadine core and an untwinned plagioclase rim of albitic composition . Nothing was seen to suggest that rock is an ignimbrite and there are no evidences of alteration.

One analysis of quartz latite porphyry has been made by David L. Barber at the University of Utah analytical laboratory with results as follows:

| | % | | |
|---|---|---|---|
| $SiO_2$ | $CaO$ | $Na_2O$ | $K_2O$ |
| 60.0 | 2.70 | 2.50 | 4.94 |

The results are entirely in line with expected quartz latitic analysis.

## INTRUSIVE ROCKS

Two types of intrusive rocks were recognized in the Horn Silver area: quartz monzonite with granitoid texture in which all of the minerals except the accessories may be seen with the naked eye; and quartz monzonite porphyry with a fine, dense, alphanitic groundmass in which are embedded phenocrysts of various minerals. The quartz monzonite is probbably of Tertiary age and it intrudes the Horn Silver Andesite as well as the Paleozoic rocks. Without question, the porphyry intrudes both the andesite and the quartz monzonite. The quartz monzonite also cuts off the Horn Silver fault. It is remarkable that essentially no contact effects are noted in the intruded lavas whereas large bleached areas and skarn occur along the contact in limestone. No direct evidence is available to show whether or not the intrusive rocks are younger than the volcanic units that succeed the Horn Silver Andesite, but this possibility should be entertained.

## Granitoid Intrusives (Quartz Monzonite)

The granitoid rocks of the Horn Silver district are readily distinguished from other rocks of the area since they are of rather coarse grain with crystals generally exceeding 2 mm in greatest dimension. Butler (1913) described this rock very completely and classified it as a quartz monzonite. No reason was found in this study to modify Butler's descriptions or classifications. However, a brief resume may be helpful. The rock is generally grayish but in places has a pinkish or lavender tinge due to the presence of pinkish or lavender orthoclase. The dark minerals are usually hornblende and/or biotite but in some areas a diopsidic augite has been noted. The rock is very durable under weathering attack and is found on many rock-strewn slopes where the bedrock is other than quartz monzonite.

The quartz monzonite is in intrusive crosscutting contact with Upper Cambrian limestone and dolomite about 1,200 feet north of the New King David mine. In detail, this contact is very sharp and is extremely irregular with pods of granitoid material often occurring within the limestone. Thin sections of the quartz monzonite near this contact show it to be low in quartz and orthoclase, so that it could be classified as diorite or syenodiorite. Pinkish aplite dikes up to 1 foot in width are of frequent occurrence in the southeastern portion of the intrusive. About 200 feet to the northeast of the point where the quartz monzonite cuts the Horn Silver fault, it is in contact with Horn Silver Andesite. The contact can be traced from here toward the northwest, and at a point south of the Indian Grave Peak the contact can be observed.

Butler (1913) and East (1956) both indicated that the contact between quartz monzonite and the extrusive rocks was gradational with a chilled quartz monzonite margin. A particular effort was made during this study to check this feature. The quartz monzonite is in sharp contact from a point northwest of the Van Horn prospect to a point slightly northwest of Indian Grave Peak. There is very little alteration along the contact and it did not appear to the writer to be a gradational contact.

From Indian Grave Peak the contact swerves eastward and it is here that irregular intrusive porphyry masses are found between the quartz monzonite and the extrusive rocks and this could account for the statements by East and Butler concerning a gradational border. (See fig. 6 and pl. 2.) Close examination during this study showed that the contact between the intrusive porphyry and the quartz monzonite though not directly observed on any one outcrop, was found by float evidence to be sharp. At other places east of Indian Grave Peak and past the Frisco Contact mine the quartz monzonite is in direct contact with the extrusive rocks.

Under the microscope, the quartz monzonite shows a distinct hypautomorphic granular texture. The minerals are quartz; perthitic orthoclase which is generally clouded with a dusty weathering type of alteration; and plagioclase ranging in composition between $An_{12}$ and $An_{55}$ with an average of $An_{25-30}$. The dark minerals are hornblende, biotite and augite with accessories of apatite, zircon, sphene, some rutile and a great deal of magnetite. The magnetite of the quartz monzonite is so abundant that sands weathered from the

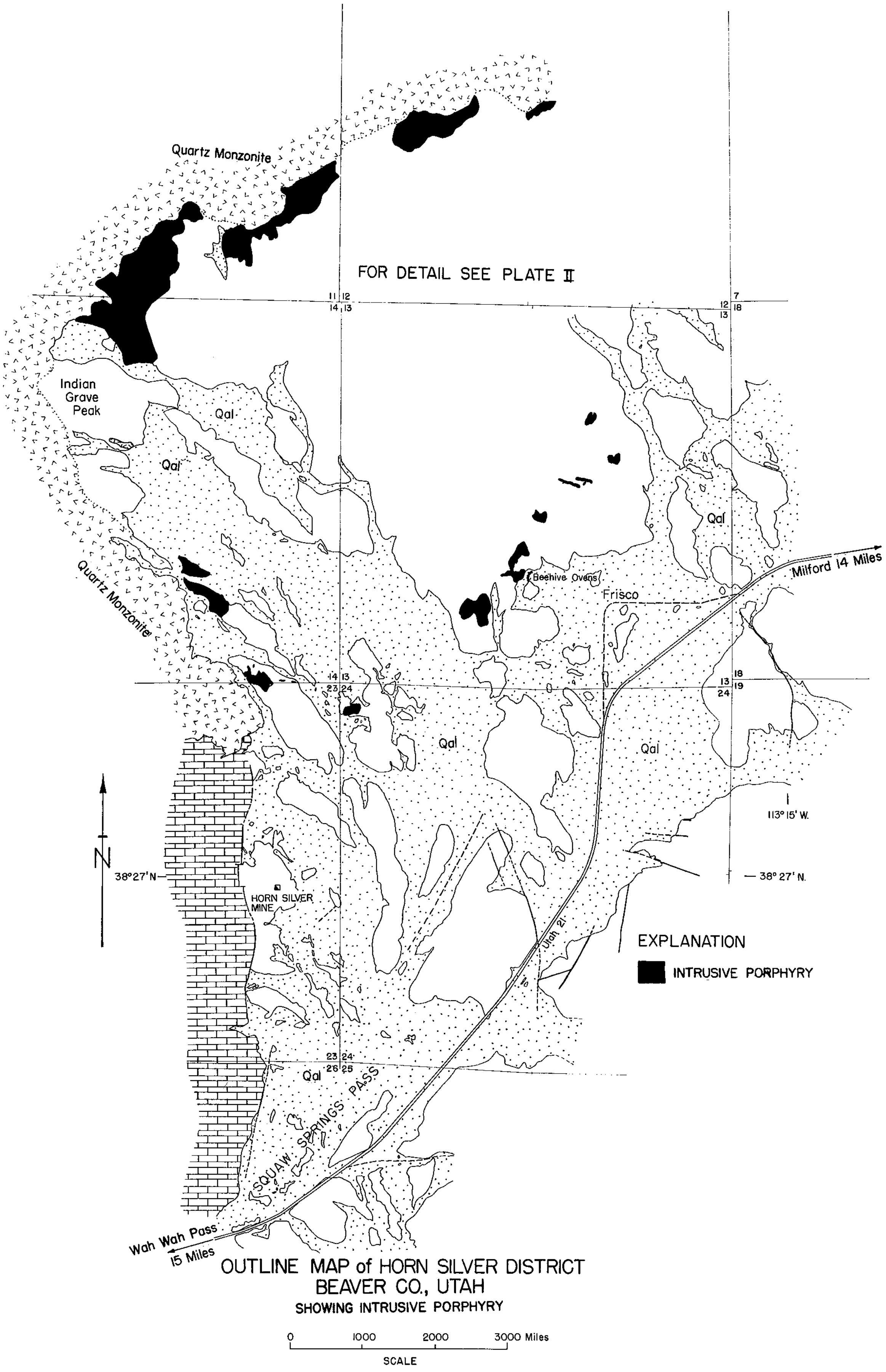

Quartz Monzonite
FOR DETAIL SEE PLATE II
Indian Grave Peak
Qal
Quartz Monzonite
Beehive Ovens
Frisco
Milford 14 Miles
113° 15' W.
38°27'N
38° 27' N.
HORN SILVER MINE
Utah 21
EXPLANATION
INTRUSIVE PORPHYRY
SQUAW SPRINGS PASS
Wah Wah Pass 15 Miles
OUTLINE MAP of HORN SILVER DISTRICT
BEAVER CO., UTAH
SHOWING INTRUSIVE PORPHYRY
0 1000 2000 3000 Miles
SCALE

**Figure 6.**

quartz monzonite after being worked over by streams are streaked with the black mineral. From the various specimens studied, it may be concluded that generally in this area the intrusives should be classified as quartz monzonite, although variations such as granite, granodiorite, diorite, syenodiorite and even syenogabbro may occur locally.

## Porphyritic Intrusives (Quartz Monzonite Porphyry and Quartz Latite Porphyry)

The porphyritic intrusive rocks were rather difficult to distinguish in the field from extrusive types, and many thin sections were made and examined before the distinction could be made with a fair amount of confidence. Butler (1913) roughly delineated 8 areas where porphyritic rocks intruded the extrusive rocks. Each of these was checked and of the 8, 5 were found and mapped. These 5 occur immediately north and west of the town of Frisco. Three fairly large areas on Butler's (1913) map are shown not far from the corner of secs. 12 and 13 and these areas were searched thoroughly with negative results. Butler mentions other intrusive rocks in his text (Butler, 1913, p. 62). One is three quarters of a mile north of the town of Frisco and another, a mile to the north; but these he did not map. A determined effort was made to locate as many of the unmapped intrusive rocks as possible. However, it will probably be realized that discovery of unmapped intrusive rocks may be largely by chance since the distinction between the intrusive porphyry and the extrusive porphyry is very often subtle, and exposures are not prominent topographically. East (1956) mapped only one of these intrusive bodies. Butler (1913) further mentioned fine-grained intrusive porphyry which he found near the quartz monzonite - extrusive rock contact. Most of these have been mapped.

Where the intrusive porphyry outcrop is larger than a dike, the rock, though having a distinctly aphanitic groundmass, shows a certain amount of grain when examined with a hand lens. Within the groundmass are embedded phenocrysts of feldspar about 2 mm in size and sparse quartz. In the smaller dike-like masses, where the groundmass appears much more dense and may be glassy, the feldspar phenocrysts attain larger sizes up to as much as 5 mm in greatest dimension. The intrusive porphyries in general seem to show a more granular character in the aphanitic groundmass than the extrusive rocks but this conclusion may be found to be in error when checked with the microscope. There is usually a slight pinkish tinge to the freshly broken groundmass surface of the intrusive porphyries, whereas the extrusive rocks do not ordinarily have this feature. If quartz was recognized in hand specimen this automatically took it out of the Horn Silver Andesite class and the area was mapped as intrusive. The phenocrysts of the extrusive rocks also seem to be larger in general than those of the intrusive rocks. Features such as flow, vugs, lithophysae, etc. are entirely absent in the intrusive rocks.

Under the microscope (see fig. 5b) the intrusive porphyry is composed of a granular groundmass consisting of equidimensional quartz and orthoclase and rare plagioclase in which are embedded phenocrysts of plagioclase having compositions ranging in different intrusives from $An_{33}$ to $An_{44}$. The dark minerals include minor amounts of biotite, augite and hornblende with accessories of apatite, zircon, abundant magnetite up to a maximum pf 5 per cent and rare rutile. The dike types contain much finer grained groundmass of quartz, orthoclase, plagioclase, and usually some glass with fairly large phenocrysts of plagioclase of $An_{32}$ to $An_{44}$. Quartz, orthoclase, biotite, augite and hornblende are also found as phenocrysts with magnetite, apatite, zircon and rutile as accessory minerals. According to the mineral content and general texture, the rock is classified as a quartz monzonite porphyry though in many outcrops the groundmass predominates and quartz latite porphyry is a more appropriate term.

Butler (1913) and East (1956) regarded the intrusive porphyries on the borders of the quartz monzonite as a chill facies but this concept is not borne out with careful mapping. The isolated intrusive masses of identical rock occurring entirely within the extrusive rocks are not to be regarded as a chilled facies of the quartz monzonite. The view taken here is that the porphyry intrusives are a separate phase of intrusion producing not only border intrusives near the quartz monzonite but also plugs and dikes in the extrusive area. Abundant aplitic dikes resembling the porphyries are found within the quartz monzonite but these are not precisely identical to the porphyry intrusives and are not regarded as being the same intrusive sequence. Wherever the quartz monzonite and the intrusive porphyry were found together, an effort was made to determine the contact relations between the two. Due to heavy mantle cover and alteration all along the contact, no diagnostic outcrops were observed. In one of the outlying porphyry plugs, however, near the north-central part of the area, the porphyry contains fairly large angular inclusions of quartz monzonite up to 6 inches in diameter, suggesting very strongly that the porphyry is later in age and is a distinct and separate later phase of intrusive activity from the quartz monzonite, though no doubt broadly related.

## STRUCTURE

Butler (1913) discussed the structure of the Horn Silver area in considerable detail. East (1956) agreed in part with Butler's work but added an east-west fault between the Pennsylvanian and Upper Cambrian rocks. The structure of Grampian Hill, which is underlain largely by Cambrian limestones and dolomites, has been covered in recent years in private maps and reports. A map by E. A. Hewitt of the Park Utah Mining Company shows in some detail the formational attitudes, fault displacements and mineralization. Butler (1913) mentioned the Squaw Springs fault which he considered an east-west feature cutting the north-south Horn Silver fault and thus accounting for its apparent discontinuance further to the south of Squaw Springs. Neither Butler nor East made significant efforts to unravel the structure within the extrusive rocks.

Owing to its association with the Horn Silver ore body, the north-south trending Horn Silver fault is the most notable structural feature of the area and brings Cambrian sediments against Oligocene volcanic rocks. The Horn Silver shaft was sunk 1,600 feet in volcanic rocks, suggesting that the fault has at least 1,600 feet of displacement at this point. South of the Horn Silver shaft, several smaller east-west cross faults and sympathetic faults parallel to the Horn Silver were found. In one place near the south line of section 23, the main fault is considerably offset. It is not possible to determine from outcrops whether this offset is due to cross faulting or to a curve in the main fault because the surface here is covered with alluvial material and no known underground workings have penetrated this area. Further south, the Horn Silver fault is identified on the surface by several small prospects and thence is projected under the alluvial cover. It is in this covered area that the east-west fault separating Ely Limestone from Upper Cambrian rocks apparently comes in contact with the Horn Silver fault. The fact that the extrusive rocks to the east of the known position of this east-west fault are not displaced suggests strongly that it is a pre-Horn Silver fault. The Horn Silver fault, though having a minimum displacement of 1,600 feet, is not found south of the Squaw Springs pass along its normal projection. The extrusive rocks here are not displaced and it is not known why this fault should discontinue southward unless it stops against an east-west fault through the Squaw Springs pass. Observations in the Squaw Springs area and further to the west would suggest strongly that there is no fault here with a large displacement.

North of the shaft, the Horn Silver fault is traced rather definitely through good exposures and pits to a point where it ends against the quartz monzonite. This point has been examined several times and there is no question but that the quartz monzonite is later in age than the fault. No evidence of any further continuity of the fault to the north was found. It is believed, though not confirmed, that the Frisco Contact shaft in sec. 11 was sunk in an effort to find the fault. An alternative purpose may have been exploration under a large, elongated area of brecciated and silicified extrusive rock slightly to the south of the shaft.

The Horn Silver fault at the surface is, in places, accompanied by a considerable width of gouge. In some openings it appears to be fairly tight with only a foot or two of fault breccia but the maximum is noted in the north part of the south pit of the Horn Silver caved area where as much as 10 feet of breccia occurs in volcanic rocks. The old underground maps of the mine all show a great deal of brecciation along the fault, in some cases as much as 150 feet in thickness (fig. 9), but this could be a breccia pipe rather than a true fault breccia.

Correlation of ignimbrite layers has permitted recognition of several additional faults. Two large faults trending northwest-southeast have been mapped. One in the central lower portion of sec. 24 has a probable displacement of more than 400 feet. A fault nearly parallel to the first one was found in the southeastern part of sec. 18 and the northwestern part of sec. 19. The displacement on this fault could be from 300 to 400 feet. Several smaller faults of varying direction have been noted and one apparent fault, trending to the northwest but covered by alluvium, is plotted in the west central part of sec. 24. Drawing of this fault is necessary to account for the differences in elevation of the Isom Formation between the two hills on either side of the shallow valley.

Structure within the Horn Silver Andesite, which occupies most of the area to the north and to the east of the Horn Silver mine, is very difficult to interpret. The Horn Silver Andesite is so thick and commonly so uniform in its appearance that there is no real basis for judging the position of any flow or fault in this area although it is believed that many are present. Intensive study of the Horn Silver Andesite must be made in order to recognize the detailed structure of this area.

One further structural element should be pointed out. The isolated intrusive porphyry bodies occurring only in the extrusive rocks form a generalized trend which can be traced from northeast to southwest to an intersection with the Horn Silver fault at the Horn Silver mine. (See fig. 6 and pl. 2.) Projection of this intrusive line toward the northeast beyond the mapped area places it in the area of the Beaver Carbonate mine.

## BRECCIA PIPES

Breccias which occur in abundance in the Horn Silver area are of three types: tectonic breccias, intraformational breccias, and breccia pipes. Tectonic breccia is formed by crushing of rock within a fault zone, due to relative movement of adjoining walls. Such breccias occur along the Horn Silver fault though the thick lens of breccia in the mine may be a true breccia pipe. Intraformational breccias which are considered original components of the rock as it was formed are composed of cognate fragments and inclusions of foreign fragments in varying proportions. Examples of these were found in basalt of the Horn Silver Andesite and in the tuff breccias of the Quichapa ignimbrite. Breccia pipes are cylindrical to irregular masses of breccia formed subsequent to the implacement of the enclosing rocks.

A large number of breccia pipes were discovered and mapped. (See pl. 2 and fig. 7.) One of the larger pipes (fig. 7, T) west and slightly south of the Frisco Contact Shaft is

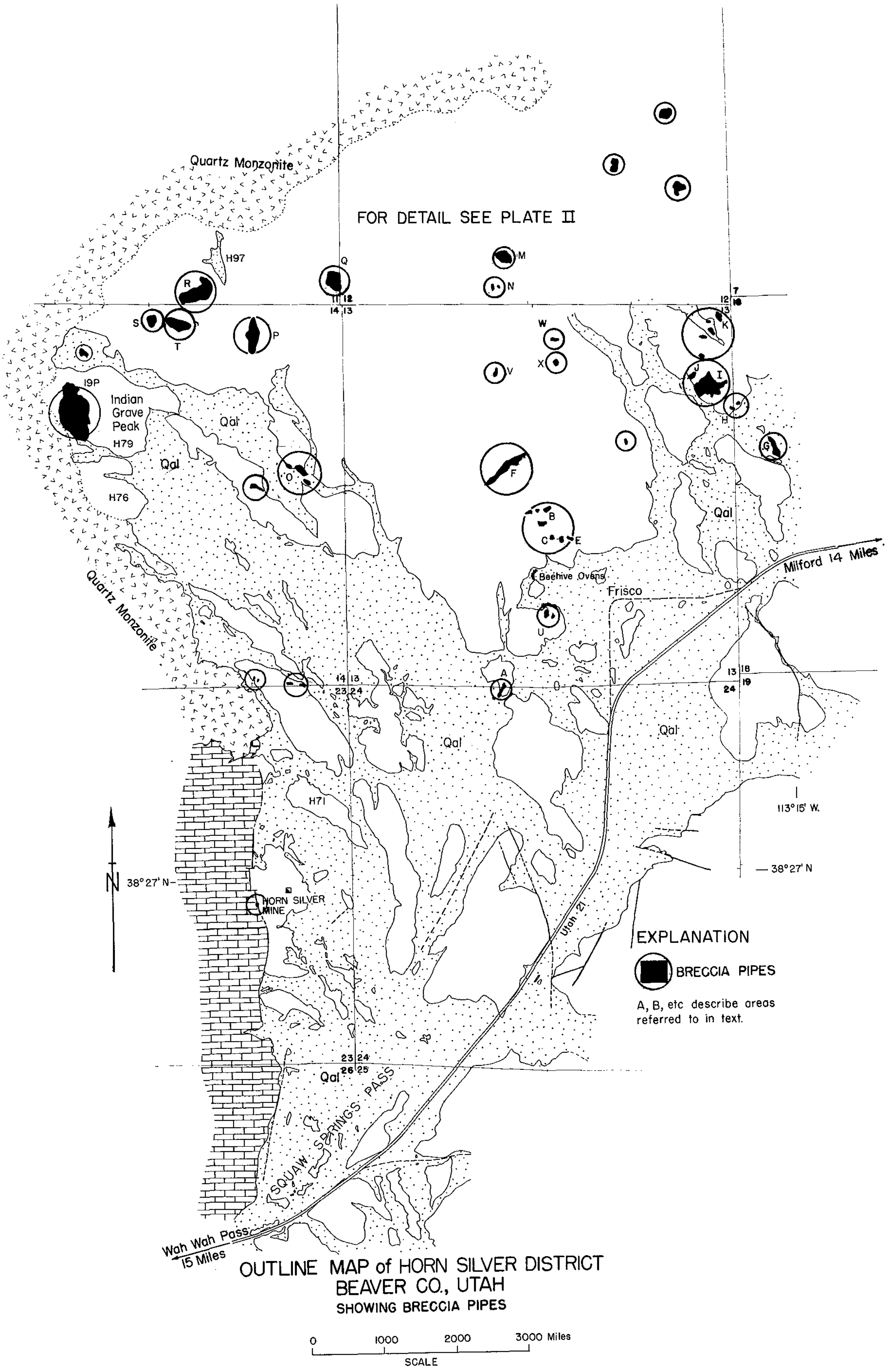

FOR DETAIL SEE PLATE II
Quartz Monzonite
Quartz Monzonite
Indian Grave Peak
Qal
Beehive Ovens
Frisco
Milford 14 Miles
HORN SILVER MINE
SQUAW SPRINGS PASS
Utah 21
Wah Wah Pass 15 Miles
113°15' W.
38°27' N
EXPLANATION
BRECCIA PIPES
A, B, etc describe areas referred to in text.
OUTLINE MAP of HORN SILVER DISTRICT
BEAVER CO., UTAH
SHOWING BRECCIA PIPES
0 1000 2000 3000 Miles
SCALE

**Figure 7.**

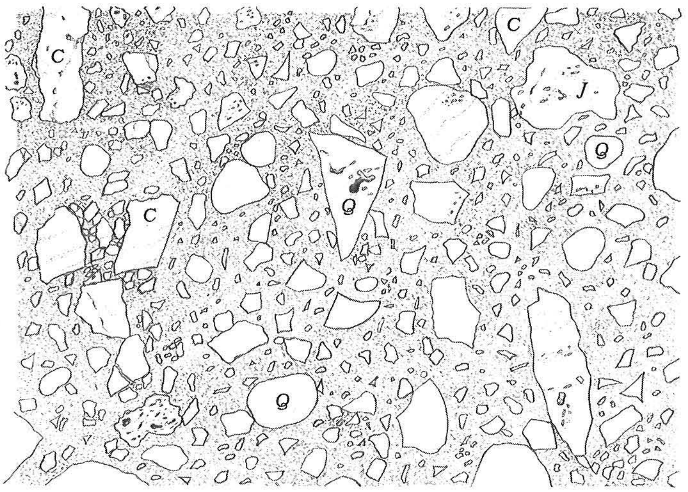



**Figure 8.**

Drawing of polished slab of breccia (1/2 natural size). Quartzite (Q), jasperoid (J) and silicified cognate fragments (C), in comminuted matrix.

about 200 feet long and 75 feet wide with most of the material within it composed of breccia fragments and comminuted material. However, larger areas were found which show breccia features, but most of these are composed of silicified and alunitized rock together with smaller irregular zones containing brecciated fragments. This is especially true of the Indian Grave Peak locality (IGP, fig. 7 and pl. 2) where the altered area is much larger than that which shows breccia fragments. The breccia pipes vary from the larger sizes to rather small ones such as at B and C in fig. 7 where dimensions from 10 feet up to 50 feet in diameter are common.

There are two kinds of breccia pipes. One contains fragments ranging in size from 1 mm to 2 in. which may be considered cognate, composed mainly of the rock in which they are emplaced, embedded in fine comminuted matrix of the same rock. The fragments, as well as the matrix, commonly are intensely silicified and alunitized. The fragments generally are rotated with respect to one another and, being more resistant to erosion, often stand out in relief from the matrix of the pipe.

The second type shows fragments of quartzite and jasperoid intermixed with cognate fragments embedded in a matrix of comminuted quartz and altered wall rock. Limestone fragments were found in one pipe. The fragments are generally less than 1.5 in. by 1 in. (see fig. 8). Occasionally the quartzite and jasperoid fragments are rounded, suggesting a pebble-dike type of origin. The breccia pipes, in general, are very light yellowish to tan to white. Where alunitic alteration is strong, the color may grade from tan to pinkish. Where disseminated pyrite has been oxidized, the pipe may be marked by a network of brown to yellowish streaks.

Wherever the breccia pipes have been mapped, the silicified area is shown in its broadest outline and the brecciated areas have not been delineated since the breccia fragments are to be found within the altered mass as irregular and patchy areas. Figure 8 is a drawing of a polished slab from one of the breccia pipes which shows a matrix of comminuted silica in which are embedded quartzite, jasper and silicified cognate breccia fragments, some of which are fairly well rounded.

The mapped boundaries of most of the breccia pipes indicate that they are probably not formed as the result of tectonic forces. They are quite commonly equidimensional and only occasionally are they elongated as though their form was controlled by a fracture or a fault. Two readily accessible small pipes (fig. 7, B and C) with abundant foreign fragments in each occur on the hills immediately north of Frisco and slightly northeast of the Beehive Ovens. There are, however, two additional pipes in the same vicinity which contain cognate fragments only. Of the breccia pipes mapped, 21 contained abundant quartzite and other foreign fragments.

Table 1.. Results of x-ray fluoresence determination on breccia samples and fresh Horn Silver Andesite.

| SAMPLE | CONCENTRATIONS/PPM | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| | Zn | Cu | Mn | Hg | Pb | Ag |
| A | 5 | 100 | 320 | 1 | 1 | 0 |
| B | 8 | 80 | 200 | 0 | 2 | 0 |
| C | 3 | 80 | 120 | 1 | 0 | 1 |
| D | 4 | 70 | 195 | 1 | 2 | 0 |
| E | 3 | 90 | 390 | 0 | 1 | 0 |
| F | 2 | 80 | 310 | 1 | 1 | 0 |
| G | 0 | 130 | 560 | 0 | 1 | 1 |
| H | 5 | 90 | 120 | 1 | 0 | 0 |
| I | 0 | 120 | 380 | 1 | 1 | 1 |
| J | 4 | 110 | 300 | 0 | 1 | 1 |
| K | 0 | 50 | 185 | 0 | 2 | 0 |
| M | 6 | 100 | 190 | 1 | 0 | 1 |
| N | 1 | 60 | 315 | 0 | 1 | 1 |
| O | 5 | 90 | 295 | 1 | 0 | 0 |
| P | 5 | 70 | 315 | 0 | 1 | 0 |
| Q | 1 | 150 | 520 | 0 | 2 | 1 |
| R | 0 | 120 | 540 | 1 | 2 | 0 |
| S | 80 | 80 | 560 | 1 | 2 | 1 |
| T | 1 | 70 | 320 | 1 | 1 | 1 |
| U | 0 | 30 | 390 | 1 | 0 | 1 |
| V | 2 | 50 | 315 | 0 | 2 | 1 |
| W | 1 | 60 | 330 | 0 | 0 | 0 |
| X | 3 | 20 | 210 | 0 | 1 | 1 |
| 1GP* | 0 | 150 | 790 | 1 | 0 | 0 |
| H79 | 22 | 20 | 550 | 0 | 1 | 1 |
| H71 | 19 | 10 | 610 | 1 | 0 | 1 |
| H97 | 26 | 20 | 580 | 0 | 1 | 0 |
| H76 | 23 | 10 | 720 | 1 | 0 | 0 |

Reference samples H79-71-97 and 76 unaltered latite porphyry.
* Location Indian Grave Peak

The quartzite pebbles appear to be Prospect Mountain quartzite and thus to be Cambrian to Precambrian in age. The problem of how they reached their present position in extrusive rocks of Oligocene age calls for discussion beyond the limits of this paper.

Samples taken from 24 of the breccia pipes, both with and without foreign fragments, were tested by x-ray fluorescence for zinc, copper, manganese, mercury, lead and silver. The results are shown in table 1 together with the results of tests for the same metals taken on samples of Horn Silver Andesite. It will be noted that in only one sample was the zinc content high enough to arouse some interest; the zinc in the unaltered andesite appears to be on the whole distinctly higher than in the breccia pipes. The reason for this discrepancy is not known unless the process which produced the alteration of the breccia pipes washed out the metals as the pipe was being formed or altered.

## ALTERATION IN THE SEDIMENTARY ROCKS

For information on the alteration of the sedimentary rocks the reader is referred to the excellent account by Butler (1913). In summary, it may be stated that serpentinization, dolomitization and marblization of the dolomites and limestones on Grampian Hill vary in extent and intensity. Adjacent to the quartz monzonite contact, considerable amounts of epidote, idocrase, chlorite, magnetite and a little scapolite have been formed in the skarns. The alteration found in the sedimentary rocks seems to have no particular spacial relation, other than in a broad regional way, to the ore body of the Horn Silver mine.

## PROPYLITIC ALTERATION

Propylitic alteration is expected in a region of andesite flows and several outcrops of propylite have been mapped, some south of the Horn Silver mine, one directly along the fault, and several to the north. One area of such alteration wraps almost entirely around the silicified rock of Indian Grave Peak.

Aside from its green color the propylite in hand specimen appears identical with hornblende andesite. The alteration minerals are too small to identify in the field but under the microscope were found to consist primarily of varieties of chlorite immediately adjacent to one another in the same rock. Practically all of the original mafic minerals have been altered to chlorite. In some samples fine-grained epidote was found intermixed with chlorite. Plagioclase phenocrysts are not immune to the propylitization and commonly contain grains of epidote and flakes of chlorite. Under typical conditions, albite and some quartz are formed as products of propylitization along with chlorite and epidote; but neither was found anywhere in the greenish propylitic rocks of the Horn Silver area.

In many places propylitization is believed to be related to an end-stage magmatic process in the formation of andesites and therefore may not have any significance with respect to the occurrence of ore or other mineralization.

## HEMATITIZATION

Several small areas of disseminated hematite were mapped; two are near the Frisco Contact shaft, three near the corral at the eastern edge of the mapped area and two slightly west of the town of Frisco. The hematite appears to have been deposited directly from solutions rather than originating as an oxidation product. It occurs in blebs and stringers without indication of former pyrite. Therefore, it is not thought to be related to a pyritic mineralization. Whether the deposition of hematite preceded or followed that of pyrite is not known since the two were not found together. Prospect pits were dug in two of these areas suggesting that small values either were present or were expected by the prospector.

## SILIFICATION

Except in the region to the south and east of the Horn Silver mine silicified rocks occurring in numerous irregular and isolated patches are widespread throughout the entire district.

The largest silicified area, that on Indian Grave Peak (fig. 7 and pl. 2), is nearly 700 feet long and approximately 400 feet wide. The boundaries are not entirely definite since strongly silicified rubble spills over the lower slopes from the higher elevations and may give a false impression as to the actual size. Smaller silicified patches are distributed throughout the northern part of the area and those attaining dimensions of 10 to 20 feet or more were mapped. Many smaller ones were left unmapped as some outcrops were no larger than 2 or 3 feet in greatest dimension. Though surface outcrops do not indicate it, silicification is widespread in the Horn Silver mine and much of the dump material is silicified rock.

The silicified rock is always lighter in color than the unaltered Horn Silver Andesite. More often than not, these outcrops are stained brown and light yellowish brown due to the production of limonite and jarosite from former pyrite. Silica takes the form generally of chalcedonic or jasperoidal material; no coarsely crystalline silicified rock was observed. In some areas, opal of dull lustre was the chief silica mineral formed and in one or two places a distinctly porous opal was noted. One of these is near the Horn Silver mine and is believed to have been deposited by solutions of hot springs origin. The silicified areas show elongate to sub-elongate shapes with many equi-dimensional outcrops. Their distribution throughout the area seems to show no order or pattern which would lead one to believe that they are related to major tectonic alignments within or below the hornblende andesite. Some degree of silicification was found in all of the breccia pipes mapped in the area.

The ore minerals in the Horn Silver ore body are accompanied by considerable amounts of quartz, deposited contemporaneously, thus a certain amount of silicification is certain to have accompanied the ore stage but the breccia replaced by the ore minerals was silicified prior to ore deposition thus establishing that there are probably two stages of the development of silica. The first stage of silicification was completely barren but the second was productive. Since none of the silicified areas which were mapped at the surface show values, it is presumed that they represent the first stage and are, therefore, presumed not to be guides to ore.

## ALUNITIZATION

Alunite was identified in a thin section secured from the silicified andesite of Indian Grave Peak. Butler (1913) reported alunite in the Horn Silver mine in a "persistent band along the foot wall of the ore body on the upper levels", but no alunite was found on the dump during the present study. As a consequence of the Indian Grave Peak discovery, many thin sections were made of similar rocks. Except for two samples, the alunite was so fine grained and intimately mixed with other minerals that identification with the microscope was necessary. Thus it was not possible to map areas of alunitic alteration specifically. Essentially, all of the breccia pipes or silicified areas sampled north of the line between sections 13 and 14 contain alunite. The silicified and pyritized rocks from the Frisco Contact dump show extremely coarse-grained alunite intimately mixed with fine-grained quartz. Very little kaolinite was found in these occurrences. White to pinkish alunite occurs as small one-inch-wide veins in a large area of silicified rock with brecciated material which occurs west of the Frisco Contact shaft (fig. 7, R). Two Beckman flame tests for potassium and sodium gave the following results: a - Na = 3.01 per cent, K= 6.36 per cent; b - Na = 2.72 per cent, K= 5.71 per cent. Thus the mineral is in part natroalunite. The alunite veinlets contain no silica and since they cut the silicified rock this would suggest strongly that, at least in part, the deposition of alunite follows silicification.

The pure alunite, in hand specimens, is extremely dense and somewhat harder than the fingernail but is softer than a knife. It is colored white to grey with often a slight pinkish appearance. Several small prospects have been opened on these alunite outcrops, but the small silicified areas near the Horn Silver mine contain no alunite.

## ARGILLIC ALTERATION

By argillic alteration is meant the process by which rocks have been altered to minerals of the clay group. Kaolinite, halloysite, illite and montmorillonite have been identified. Argillization is usually accompanied by the formation of limonite and jarosite along cracks and fissures. Accordingly, although some of the argillized rock is whitish, much of it is stained deep brown, reddish or yellowish brown.

The argillic areas seem to be confined mainly to the hornblende and andesites in the northern part of the area. A few areas are near the Horn Silver mine and near the line between sections 13 and 24. In the hills northwest of the town of Frisco, large patches of whitish brown argillic rock can be viewed within the darker colored fresh Horn Silver Andesite. The outlines of these argillized areas have been mapped in detail.

No attempt was made to map the individual areas on the basis of the intensity of alteration. No particular pattern or regularity to the distribution of these areas is noted except that further north the alteration patches become larger and perhaps show a little more intense degree of development than those to the south. The small areas around the Horn Silver mine may be remnants of larger areas which were exposed before being covered by dumps or before the widespread alluvial cover was deposited.

In the field, most of the argillized rock is hard enough to resist breaking easily with a hammer but in some places, where alteration has been sufficiently intense, it is softened and may be crushed by the hand.

Examination under the microscope shows that the development of kaolinite in less intensely altered rocks is confined mainly to plagioclase phenocrysts but in more intensely altered material the groundmass is changed to kaolinite. In the areas of lower intensity halloysite is recognizable as an isotropic mineral with index near that of balsam (1.54) and illite is scattered in small solid patches throughout the rock. In the less intensely altered rock, the dark minerals have not been noticeably affected but with increasing intensity chlorite and more rarely epidote have formed. In the most intensely altered areas even the dark minerals have been changed to argillic minerals. The Frisco Contact shaft apparently penetrated an argillic, alumitized and partly silicified zone and entered into the zone below which contained much fresh pyrite and considerable alunite.

The surface of the argillized rock does not show fresh pyrite, but pyrite casts consisting of limonite or jarosite are common. Some shallow drilling in an intensely argillized area near the locality known as the "Slaughter House" southeast of the town of Frisco reached pyritic rock at comparatively shallow depths.

Throughout this study there has been a strong suggestion that the argillization may have been brought about by sulfuric acid released through weathering of disseminated pyrite. The rare montmorillonite is believed to have formed from the argillic minerals as a weathering product under modern alkaline desert conditions. As far as can be determined, the distribution of argillic minerals has no spacial relationship, except possibly in a broad, regional way to the Horn Silver ore body.

## PYRITIZATION

Pyrite is the most widespread hydrothermal sulfide present in the entire Horn Silver area. Fresh pyrite can be found in the dumps of the Frisco Contact shaft, the Horn Silver, Lulu and King David dumps and in several of the shallow unnamed prospects. At the Frisco Contact the pyrite is so plentiful that the dump smells strongly of sulfur. According to Mr. E. A. Hewitt (personal communication) who did much underground mapping in the Horn Silver mine, almost all of the rock found in or near the Horn Silver fault and the breccia associated with it was pyritized whether it carried values or not. He concluded that there was much more barren pyritized rock than pyritized rock with values. It is reasoned, therefore, that the pyrite of the ore body represents a second stage of pyrite formation.

Shallow holes drilled recently within intensely altered areas reach fresh pyrite within 100 feet of the surface. Pyrite is believed to have been present prior to weathering in much of the silicified, alunitic and argillic rocks. The abundance of limonite on many fractures suggests that pyrite was once present on these fractures as very fine grained coatings.

From these observations, it is evident that disseminated pyrite is not necessarily related to mineralization of economic interest such as occurred in the Horn Silver ore body and its discovery is not necessarily a guide to ore. It may be reasoned from this that, since the argillic alteration may have resulted from the weathering of pyrite, argillic areas are not good indicators for ore mineralization.

Many thin sections of fresh Horn Silver Andesite and quartz monzonite and quartz latite porphyry were examined under reflected light and in no instance was there found to be any primary pyrite.

Magmas of the Horn Silver area apparently were so deficient in sulfur, though they were high in iron content, that only magnetite has formed as a nonsilicate iron-bearing mineral.

## MINES AND PROSPECTS

The object of this study was a careful investigation of the igneous rocks and the various types of alteration to which they were subjected. Nevertheless, the reader may expect a brief review of the mines and prospects which follows:

### Horn Silver Mine

Although a very extensive and detailed account of the Horn Silver mine is found in Butler (1913), it is thought that a brief description and one level map (fig. 9), together with a longitudinal section (fig. 10) and a composite level map of the Horn Silver and Lulu mines (fig. 11), should be presented here for the interest of the reader. The Horn Silver ore body was formed on a major fault known as the Horn Silver fault which trends generally north-south with nearly vertical dip. To the west of the Horn Silver fault are Upper Cambrian limestones which have been dolomitized, bleached and in certain places serpentinized. To the east of the fault are to be found scattered outcrops of extrusive rocks but the large dump of the Horn Silver mine, together with the extrusive gravel and alluvial cover nearby, makes observation of these extrusive rocks fragmentary. The mine head frame is gone and the shaft is reported to be in very poor condition. Hence, the Horn Silver mine was not entered during this study. However, personal communication with E. A. Hewitt of Salt Lake City and Page Blakemore, the present operator, together with access to several private reports and underground maps, have provided some understanding of the conditions within the mine. The first ore was won from large open stopes which in 1885 caved

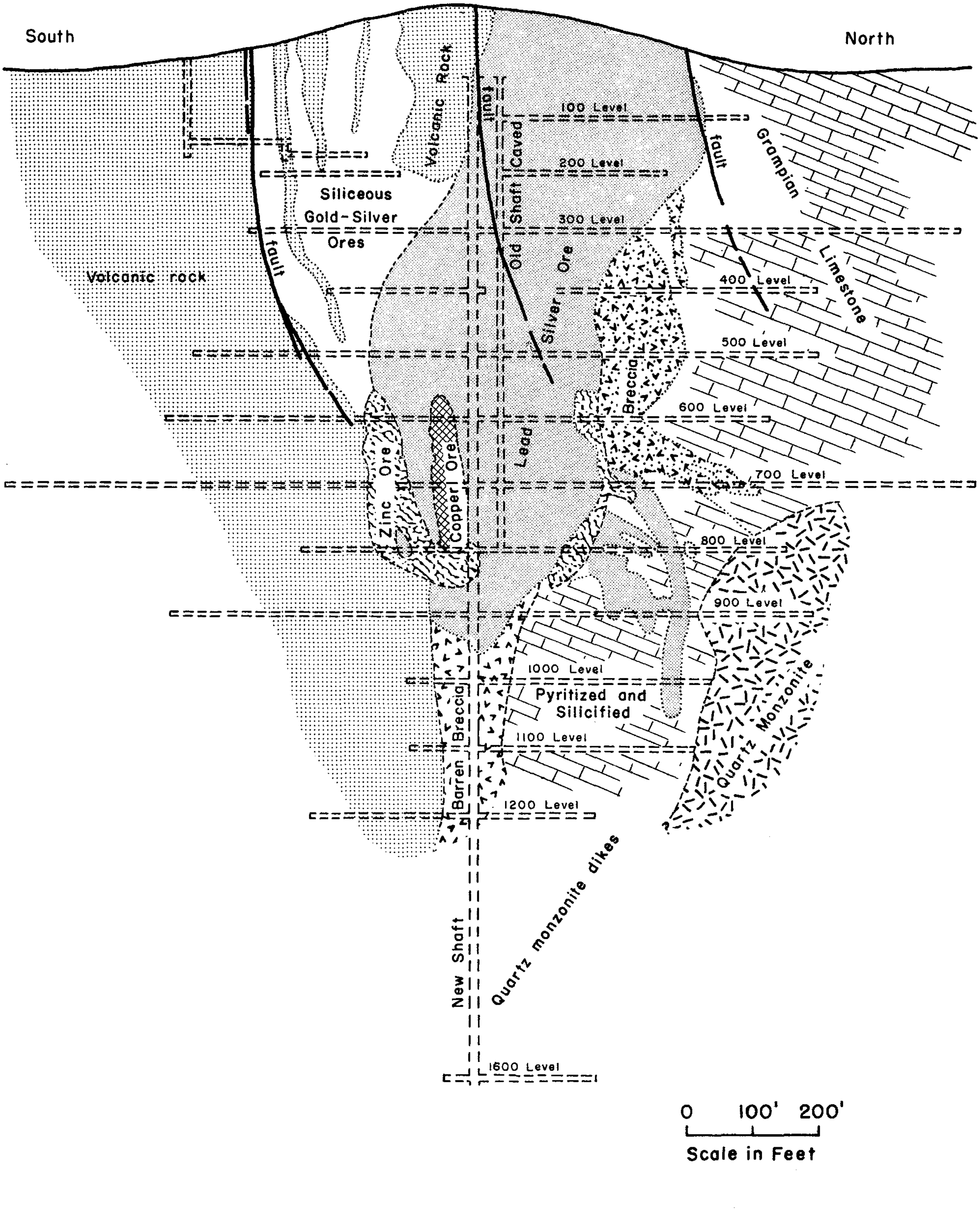



**Figure 10.** Generalized longitudinal section through the ore zone, Horn Silver mine.

through to the surface; the large opening west of the mine shaft is due to that caving and not to surface mining.

The ore body is localized along and within the main north-south fault where east-west cross faults of small movement exist. As will be seen on the accompanying map of the 900 level (fig. 9) [1], the ore body is well outlined and shown to be present chiefly within the brecciated mass between the limestones to the west and extrusive rocks to the east. The 916 slope (fig. 9), however, seems to be a replacement of undisturbed limestone as well as of breccia. On the surface, old stopes exposed when the 1885 cave-in occurred are partly in unbrecciated limestone. There is an area to the northeast end of the "Old Stope" (fig. 9) where the mapping indicates that the ore body replaced unbrecciated volcanic rocks.

The major primary minerals of the ore body were argentiferous galena and argentite, accompanied by sphalerite, wurtzite, chalcopyrite, pyrite, barite and quartz. The breccia is understood to be composed of strongly silicified and argillized limestone and extrusive fragments in gouge of the same material, and all of it has been strongly pyritized. Mr. Hewitt, during his many years underground at the mine, said he observed very little barren breccia which had no pyrite in it. Thus, there seem to be two stages of pyrite and quartz formation; the first which is barren and the second which accompanied the ore minerals. Butler (1913) reports alunite as a pre-ore mineral on the upper levels occurring as a "persistent band" along the foot wall of the ore body. At the surface on and near the fault and adjacent to the ore body, the volcanic rocks are argillized, propylitized and silicified and a small area of silicification in breccia is present within the limestone. It would have been helpful to have obtained samples from underground which were definitely located in relation to the ore body but this was not possible. From the generalized longitudinal section (fig. 10), it is evident that the shaft reached a depth of 1,600 feet, but the ore body bottomed above the 1,100 level. The zinc and copper stopes were mainly found in the lower portions of the main lead-silver ore body. It is reported by the present operator, Page Blakemore, that zinc oxides were apparently not mined extensively during the major producing period and that much zinc oxide ore remains in the mine in the upper levels. The water level in the shaft is said to be slightly below the 1,100 workings. Exploration proceeded along the fault to the north on the various levels until barren limestone or the quartz monzonite were encountered (fig. 10). To the south, exploration was limited by the end line of the Horn Silver claim, except for one drift. No connection through to the Lulu workings slightly to the south was made. Operators of the Lulu property extended a drift on the 400 level southward about 850 feet from the shaft but this unfortunately was drilled mostly in barren volcanic rock (fig. 11).

## Lulu Shaft

The Lulu Shaft apparently was excavated to explore the Horn Silver fault toward the south. The deepest level seems to be the 700. Silicified, argillized, and pyritized fault breccia were encountered on this level as well as on several shallower levels. Offsets of the main fault were also followed but no minerals of value were ever reported as being present.

## Van Cott Tunnel

The Van Cott tunnel is situated west and south of the Lulu Shaft but above it, and extends westward into the altered Cambrian limestones, an estimated distance in excess of 1,000 feet. It encountered no valuable mineralization of any kind.

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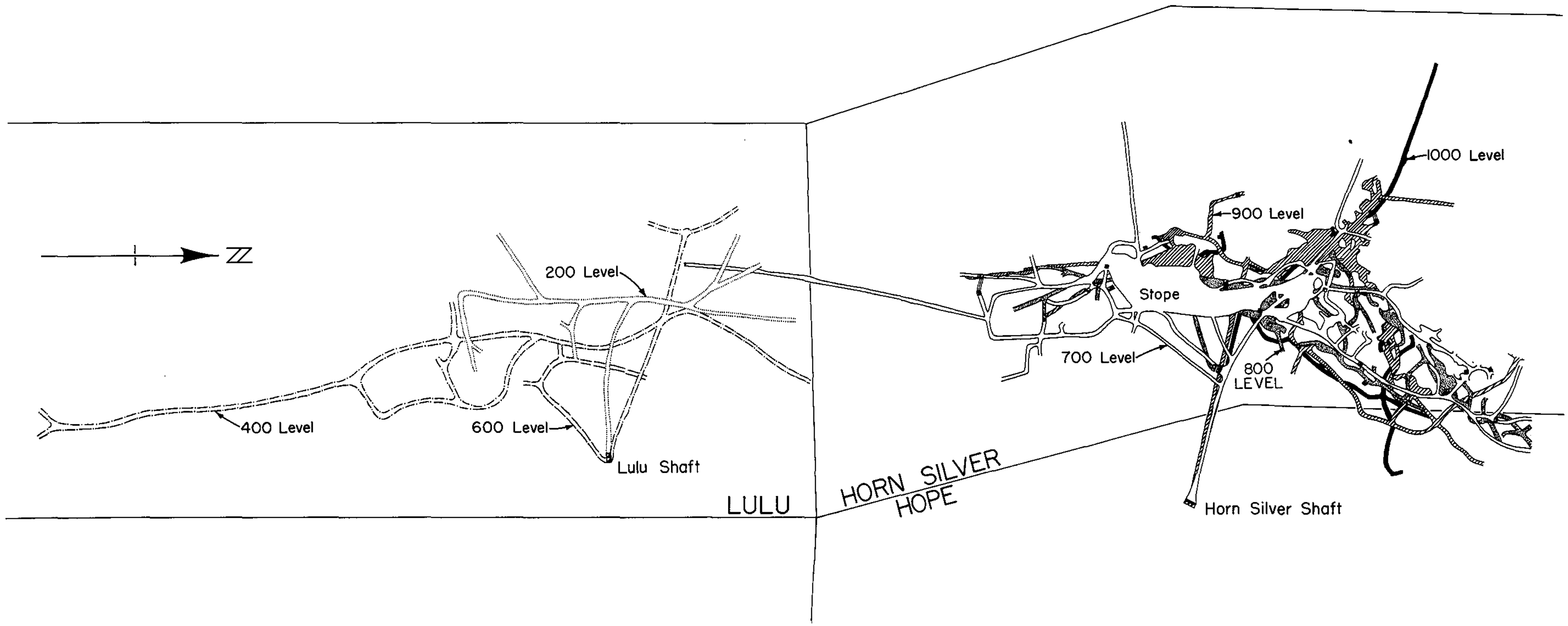
1. Level 9 of Butler (1913, p. 166).




COMPOSITE LEVEL MAP, LULU SHAFT and HORN SILVER MINE
Beaver County, Utah

0 100 200 300 400 FEET
Scale

**Figure 11.**

## New King David Shaft

Very little is known of the underground conditions in the New King David workings, situated north and west of the Horn Silver mine. The dump shows a great deal of altered limestone, dolomite, serpentine, a little asbestos, but no ore minerals to speak of. The ore bins at the New King David are in fairly good condition and were used in the last days of extracting ores from the Horn Silver through connections with the underground workings of the Horn Silver.

## Frisco Contact Shaft

The Frisco Contact shaft is situated 1½ miles directly north of the Horn Silver mine and probably was excavated in the hope of finding a continuation of the Horn Silver fault. Heresay has it that the Frisco Contact is a fairly deep shaft with drifts running principally to the north where the quartz monzonite was reached. The dump shows mainly silicified and alunitized extrusive and intrusive rocks which have been intensively pyritized.

## Van Horn Prospect

Recent work done by Mr. R. Van Horn of Milford included a shaft 120 feet deep with a drift extending to the west about 100 feet. These workings having been completed during the years 1963, 1964, and part of 1965, were entered and examined. The rock proved to be quartz monzonite which contained, in places, innumerable aplite dikes. In various places some pyrite pockets were discovered. No values of significance were reported. Of minor importance is the fact that this shaft and drift encountered ground water in sufficient quantities that pumping was necessary two or three times a day.

## Other Prospects

Throughout the area there have been many minor efforts at prospecting. However, none of these are large or extensive enough to be designated by name and none of them has shown any valuable mineralization. One prospect near the center of section 13 in a silicified area showed a slight coating of malachite on a few of the dump fragments. A prospect southeast of the mapped area showed a veinlet one inch wide of malachite, and two very shallow prospects in the central western part of section 25 showed a very slight amount of malachite. A prospect north of Indian Grave Peak had mineral fragments on its dump which proved to be hematite. Otherwise, outcroppings of valuable minerals are essentially absent.

# CONCLUSIONS

Hydrothermal alteration and mineralization in the Horn Silver area apparently began with silicification followed by alunitization, pyritization, argillic alteration and hematitization. From the evidence at hand, it appears that the ore body of the Horn Silver mine was deposited following all of these stages. The development of the ore body seems to be independent of all of these stages and reasoning can only bring out the fact that none of the types of alteration so far recognized could be used as a guide to ore. The fact that barite was a gangue mineral in the ore was encouraging as a possible guide to ore but no barite was found elsewhere in the district. If barite is discovered in the vicinity it may possibly be a guide to ore. Barite was searched for intensively on the surface and under the microscope with negative results. The face that pyrite and quartz both accompany the late ore stage does not mean that pyrite and silica of the early stage constitute guides to ore.

Several areas lend themselves as favorable for further exploration. The Horn Silver fault should be explored to its southern extremity at depth, especially where offsets and branch faults exist. The fault zone extending northward to the quartz monzonite, however, has been adequately explored by surface and underground observations. (See pl. 2 and fig. 10.) The intersection of the Horn Silver fault beneath the Horn Silver ore body with the base of the extrusives where limestone occurs on both sides of the fault may be of some interest. At what depth this may occur, however, is still to be determined.

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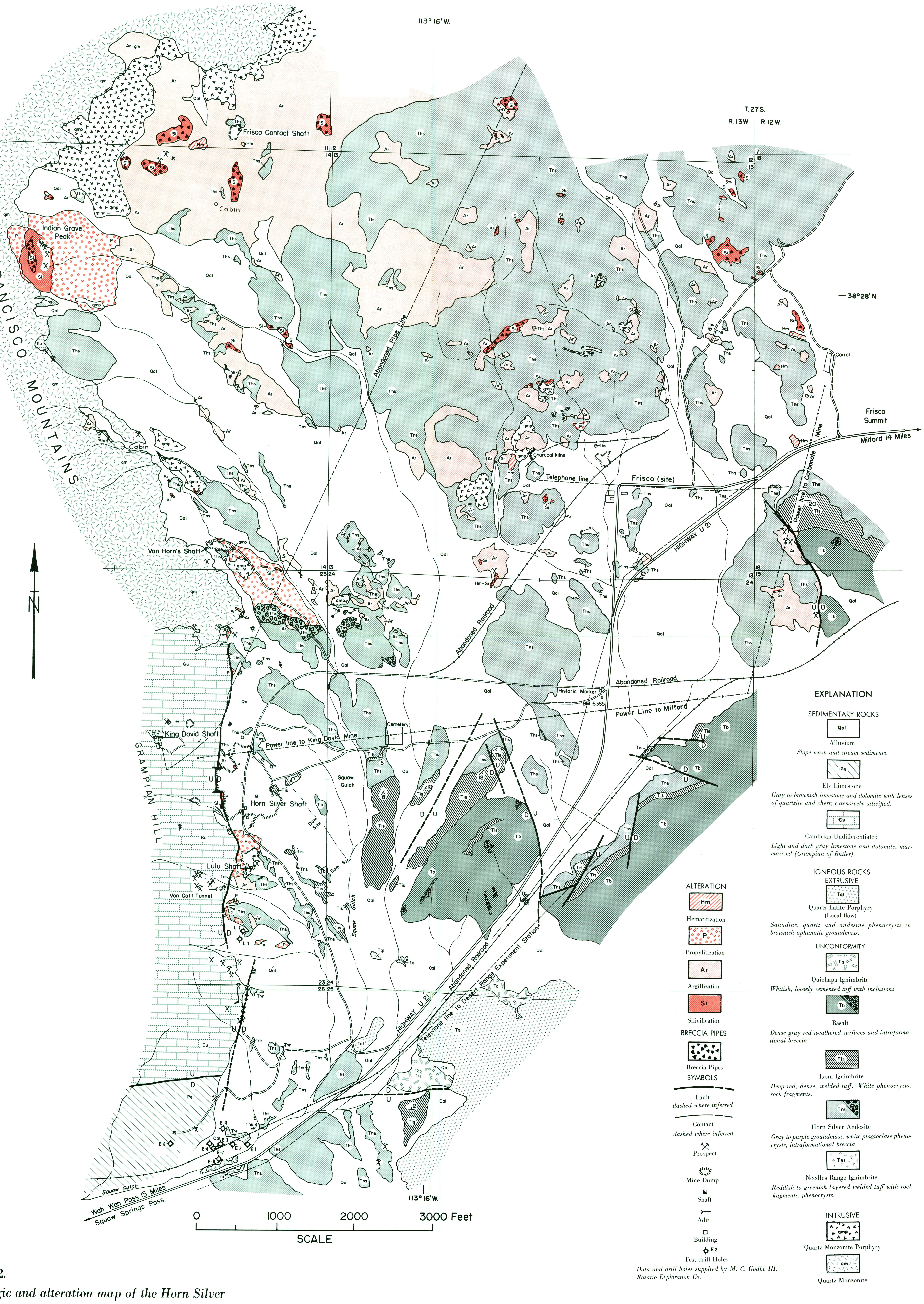


Plate 2.

*Geologic and alteration map of the Horn Silver mine and vicinity, Beaver County, Utah.*

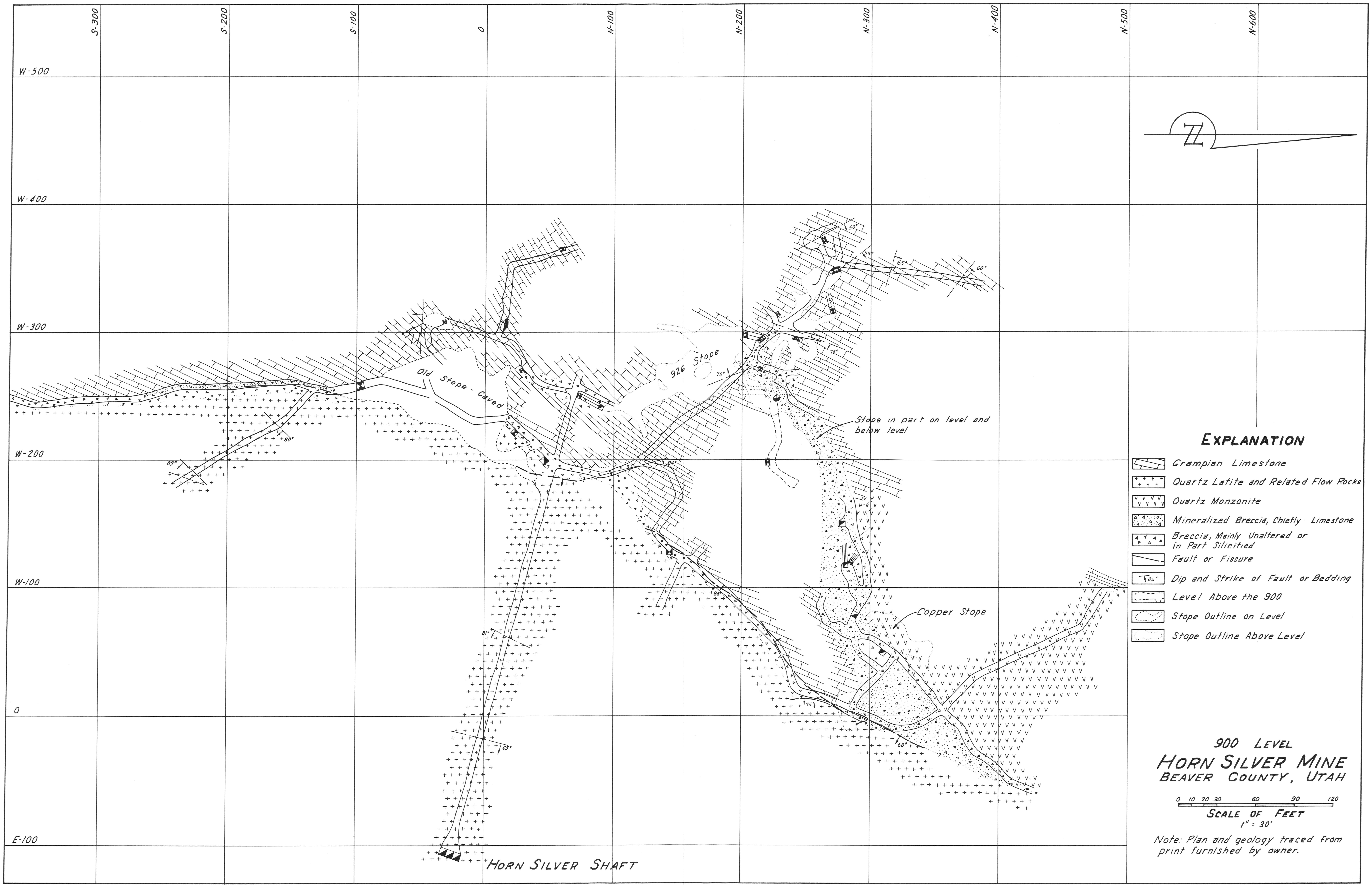
S-300
S-200
S-100
0
N-100
N-200
N-300
N-400
N-500
N-600
W-500
W-400
W-300
W-200
W-100
0
E-100
Old Stope - Caved
926 Stope
Stope in part on level and below level
Copper Stope
HORN SILVER SHAFT
EXPLANATION
Grampian Limestone
Quartz Latite and Related Flow Rocks
Quartz Monzonite
Mineralized Breccia, Chiefly Limestone
Breccia, Mainly Unaltered or in Part Silicified
Fault or Fissure
Dip and Strike of Fault or Bedding
Level Above the 900
Stope Outline on Level
Stope Outline Above Level
900 LEVEL
HORN SILVER MINE
BEAVER COUNTY, UTAH
0 10 20 30 60 90 120
SCALE OF FEET
1" = 30'
Note: Plan and geology traced from print furnished by owner.

Figure 9.

# UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

103 Utah Geological Survey Building
University of Utah
Salt Lake City, Utah 84112

THE UTAH GEOLOGICAL AND MINERALOGICAL SURVEY since 1949 has been affiliated with the College of Mines and Mineral Industries at the University of Utah. It operates under a director with the advice and counsel of an Advisory Board appointed by the Board of Regents of the University of Utah from organizations and categories specified by law.

The survey is enjoined to cooperate with all existing agencies to the end that the geological and mineralogical resources of the state may be most advantageously investigated and publicized for the good of the state. The *Utah Code, Annotated, 1953 Replacement Volume 5, Chapter 36, 53-36-2*, describes the Survey's functions.

Official maps, bulletins, and circulars about Utah's resources are published. (Write to the Utah Geological and Mineralogical Survey for the latest list of publications available).

THE LIBRARY OF SAMPLES FOR GEOLOGIC RESEARCH. A modern library for stratigraphic sections, drill cores, well cuttings, and miscellaneous samples of geologic significance has been established by the Survey at the University of Utah. It was initiated by the Utah Geological and Mineralogical Survey in cooperation with the Departments of Geology of the universities in the state, the Utah Geological Society, and the Intermountain Association of Petroleum Geologists. This library was made possible in 1951 by a grant from the University of Utah Research Fund and by the donation of collections from various oil companies operating in Utah.

The objective is to collect, catalog, and systematically file geologically significant specimens for library reference, comparison, and research, particularly cuttings from all important wells driven in Utah, and from strategic wells in adjacent states, the formations, faunas, and structures of which have a direct bearing on the possibility of finding oil, gas, salines or other economically or geologically significant deposits in this state. For catalogs, facilities, hours, and service fees, contact the office of the Utah Geological and Mineralogical Survey.

THE SURVEY'S BASIC PHILOSOPHY is that of the U. S. Geological Survey, i.e., our employees shall have no interest in Utah lands. For permanent employees this restriction is lifted after a 2-year absence; for consultants employed on special problems, there is a similar time period which can be modified only after publication of the data or after the data have been acted upon. For consultants, there are no restrictions beyond the field of the problem, except where they are working on a broad area of the state and, here, as for all employees, we rely on their inherent integrity.