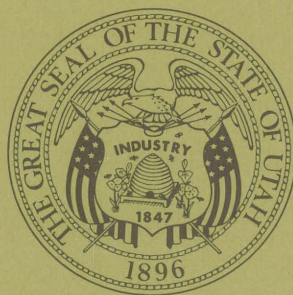


Geology and Mineralogy  
of the Milford Flat Quadrangle,  
Star District, Beaver County, Utah

*by*

*S. Abou-Zied and J. A. Whelan*



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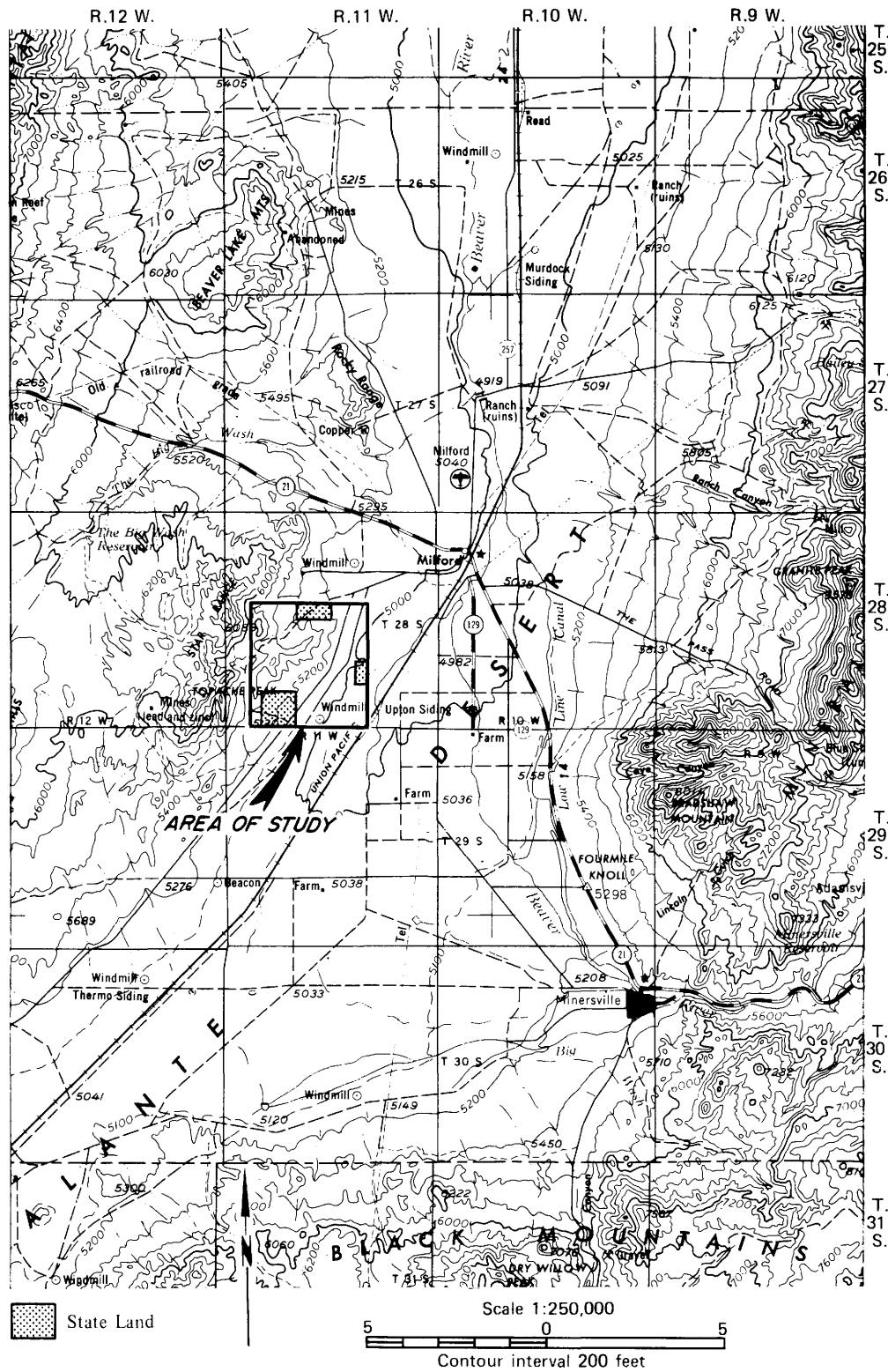


Figure 1. Location map showing area of study and state lands, Milford Flat quadrangle, Utah.

# GEOLOGY AND MINERALOGY OF THE MILFORD FLAT QUADRANGLE, STAR DISTRICT, BEAVER COUNTY, UTAH

by *Saleh Abou-Zied*<sup>1</sup> and *James A. Whelan*<sup>2</sup>

## ABSTRACT

Sedimentary and igneous rocks outcrop in the northwest corner of the Milford Flat quadrangle and the remainder are alluvium.

Sedimentary rocks, excluding alluvium, range from Permian to Jurassic age. The Permian is represented by the Talisman Quartzite, Toroweap Formation and Kaibab Limestone, the Triassic by the Moenkopi Formation, Shinarump Conglomerate and the Chinle Formation, and the Jurassic by the Navajo Sandstone.

The sedimentary rocks represent the east limb of a northeast-trending fold. They are cut by faults of several ages, the oldest being northeast-southwest normal faults. East-west cross-cutting faults are pre- and post-intrusion. Northeast-southwest normal faults are contemporaneous with the intrusion. Fissures on which no movement is evident trend east-west, northeast and northwest.

Granodiorite, quartz monzonite and several lamprophyric and aplitic dikes intrude the sedimentary rocks. The granodiorite and quartz monzonite occur in separate masses and outcrop over an area of approximately one square mile. The igneous rocks are probably of Tertiary age. Lamprophyric dikes, several inches to 3 feet thick, are highly altered and have east-west or northerly trends. The aplitic dikes are a few feet thick and strike northwestward.

Hydrothermal alteration of sedimentary rocks in the area include bleaching and recrystallization of limestones and dolomites, and argillic, propylitic, siliceous and hematitic alteration of the igneous rocks.

The mapped area has produced lead, zinc, silver, gold and copper. Mineralization is divided into: (1) deposits within the granodiorite mass, (2) contact metasomatic deposits, and (3) hydrothermal replacement and fissure filling deposits. No distinct zonation of the mineralization is encountered.

## INTRODUCTION

### Purpose and Scope

The Star district is a small mining district with complex geologic relationships. Intermittent explora-

tion in the area since 1872 has resulted in the establishment of such mines as the Vicksburg, Estelle and Gold Crown.

The northwest corner of the U. S. Geological Survey 7½-minute Milford Flat quadrangle covers the easternmost part of the Star district. This study was made, however, because no detailed geologic data on the area were available.

### Acknowledgements

J. Lindsay, American Smelting and Refining Company, Salt Lake City, Utah, permitted use of stereoscopic, colored aerial photographs of the mapped area. G. B. Baetcke assisted with the stratigraphy and underground mapping of the area.

Abou-Zied was supported partially by a scholarship from the United Arab Republic Atomic Energy Establishment.

### Location and Accessibility

The Milford Flat quadrangle map area is located in the east half of Beaver County (figure 1), about 5 miles southwest of Milford, Utah. Milford, population about 1,400, lies at the intersection of State Highways 21 and 257, and is about 200 miles south and west of Salt Lake City. Mining and ranching supplies are available at Milford, on the Salt Lake City-Los Angeles line of the Union Pacific Railroad. The mapped area is served by many fair to good gravel and dirt roads, and a small airfield lies approximately one-half mile north of Milford. Wells in the valley supply water. There are no permanent settlements within the mapped area, but sheepherders maintain temporary camps.

Bedrock is exposed only in the northwest corner of the Milford Flat quadrangle in an outcrop comprising about 12 square miles. The remainder of the quadrangle is alluvium.

The area is bounded on the east by Milford Flat, an extension of Escalante Valley, and on the southwest by the north-south portion of Elephant Canyon.

The area rises gently from elevations of 5,100 feet on the east to approximately 5,900 to 6,200 feet on the west. The southwest boundary changes abruptly from crest line altitudes of 6,000 feet to altitudes of approximately 5,400 feet along Elephant Canyon. The highest elevation, approximately 6,200 feet, is in the northwest corner of the area.

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Table 1. Meteorological conditions at Milford, Utah, 1964 through 1966.

Year	Precipitation (inches)			Temperature (°F)		
	Annual	Snow fall	Mean annual	Mean monthly	Maximum for year	Minimum for year
1964	4.66	62.3	4.74	{ June 63.3 July 75.1 Aug. 71.8 Sept. 60.1	102 on July 29	-10 on Nov. 17
1965	10.80	54.8	4.86	{ June 61.8 July 72.2 Aug. 69.9 Sept. 56.3	98 on July 20	-12 on Dec. 24
1966	7.40	51.8	4.96	{ June 66.3 July 74.9 Aug. 73.4 Sept. 64.1	101 on July 28 and Aug. 8	-20 on Dec. 28

The west side of the area drains northeasterly and the east side drains southeasterly, both into Milford Flat. Several artesian and irrigation wells for domestic use and farming occur in the east part of the quadrangle.

#### Climate

The meteorological conditions in the area during 1964, 1965 and 1966, according to Milford Weather Station records, are shown in table 1.

#### METHODS OF INVESTIGATION

##### Field Work

Field work was done during the summers of 1964, 1965 and 1966. Surface geology of the area was plotted on aerial photographs with a scale of approximately 1 inch to 400 feet. Section corners and quarter-section corners were used for control. The geology then was transferred with a proportional divider from the aerial photographs to an enlarged U. S. Geological Survey Milford Flat topographic quadrangle map, scale 1 inch to 800 feet.

Underground mapping of all accessible workings was done to a scale of 1 inch to 40 feet with a Brunton compass and tape.

##### Laboratory Work

The geology of the mapped area was checked at the Geophysical Laboratory of the American Smelting and Refining Company in Salt Lake City, with stereoscopic, colored aerial photographs. Petrographic, mineralographic, infrared absorption, X-ray diffraction, and X-ray fluorescence studies were conducted at the University of Utah.

#### PREVIOUS WORK

Lee (1908) investigated Beaver Valley waters and reported methods to increase their usefulness. The study determined flow from streams and springs, manner of occurrence, and quantity and quality of underground water shown by geologic and geographic conditions of the Milford Flat area.

Butler (1913) mapped the Milford Flat quadrangle as part of the Star district. He discussed the geology, stratigraphy, alteration and ore deposits of the area. Townsend (1950) mapped and sampled the Vicksburg mine in the Milford Flat quadrangle. In 1950, seven holes were drilled by the U. S. Bureau of Mines—four from the surface and three from underground, aggregating 25,555 feet. Diamond drill sludge samples from fissures and altered zones along the mine were analyzed to determine minerals present and their concentration.

Baer (1962) mapped the Milford Flat quadrangle, part of the Star Range, scale approximately 1 inch to 24,000 feet. He was interested mainly in the stratigraphy of the area and he revised Butler's stratigraphy to conform with the current stratigraphy in this part of the Great Basin.

Mitchell and others (1966), in an aeromagnetic map of the San Francisco Mountains and vicinity, including the Milford Flat quadrangle, show the extent of the Milford Flat stock under alluvium.

Articles in the *Salt Lake Mining Review* have described various mining operations.

## STRATIGRAPHY

## General Statement

Sedimentary rocks occupy approximately four-fifths of the mapped area and consist of south-east-dipping Pennsylvanian to Jurassic strata which are folded, faulted and metamorphosed (plates 1 and 2). The Milford Flat stock and several lamprophyric and aplitic dikes, which intrude the sedimentary rocks, also have altered them.

The oldest rocks exposed in the area are fault block outcrops of Permian Talisman Quartzite. The youngest rocks, Jurassic Navajo Sandstone, also occur as isolated fault blocks.

Toroweap and Kaibab formations of Permian age outcrop in the northeast corner of the mapped area adjacent to the intrusive igneous mass. These formations are metamorphosed and altered, and were mapped together as undifferentiated Permian sediments where their differentiation was uncertain.

The Permian strata are overlain conformably by the Triassic Moenkopi, Shinarump and Chinle formations. The Moenkopi outcrops in the mapped area are of varied lithology.

The Shinarump and Chinle outcrops are non-fossiliferous, and because their contacts appear gradational, they were mapped without differentiation.

Because of its silicification, the Navajo Sandstone of Triassic-Jurassic age is here easily confused with the Talisman Quartzite of Pennsylvanian age. The Talisman generally forms talus slopes which are not usually associated with the Navajo Sandstone.

## Permian System

## Talisman Quartzite

The Talisman Quartzite in the mapped area is represented by isolated outcrops and fault blocks. It makes scree slopes and is recognized easily on aerial photographs. Talisman orthoquartzite outcrops are light brown to red, medium-bedded, and weakly cross-bedded. Weathered Talisman is highly fractured, and broken fragments are covered with desert varnish. Scree slopes have a dark chunky appearance.

Butler (1913, p. 36) measured a 440-foot section of Talisman Quartzite. Baer (1962, p. 35) measured a 1,088-foot section north of Elephant Canyon.

## Toroweap Formation

The Toroweap Formation outcrops in the northeast and southwest of the mapped area. Generally, it is not well exposed and consists of blue-gray to light gray limestones and dolomites. The northeast outcrop in the vicinity of the stock is bleached.

Baetcke measured a section of 339 feet of the Toroweap Formation in the Star Range, and according to him (1966, personal communication), the lower and upper units are silty and dolomitic and the middle ones are medium-bedded, light gray, phosphatic limestones.

## Kaibab Limestone

The Kaibab Limestone is exposed as isolated outcrops in the north and south portions of the mapped area. Adjacent to intrusions, it is generally bleached and metamorphosed. It is mainly dark gray and medium-bedded. The limestones are commonly fossiliferous, and they contain poorly preserved brachiopods, bryozoans, crinoids, gastropods and sponges.

Dark to light gray thin-bedded dolomites occur in the middle and upper parts of the formation; orthoquartzites and sandstones alternate with limestones and gypsum beds in the upper part. The upper part is characterized by gray chert and case-hardened limestone nodules with layered chert.

Baer (1962) placed the Kaibab Limestone in middle Permian. Baetcke (1966, personal communication) measured a 695-foot section of Kaibab in the Star Range.

## Triassic System

## Moenkopi Formation

The Moenkopi Formation covers almost 50 percent of the mapped area and is mostly located in the west half. It generally is faulted and metamorphosed, especially near the intrusions. It represents the most varied lithology of any formation in the area.

The lower portion of the Moenkopi is dark gray limestone and green shale. Red, brown and green shale with limestone interbeds compose the top of the formation. Near the top, limestone grades into sandstone. Some of the upper sandstones are thin-bedded and display liesegang banding. Ripple marks and fossil rainprints are common in the shales. Near the intrusive body the Moenkopi Formation is metamorphosed to green hornfels, marble, bleached limestones and meta-

quartzite. Pelecypods, gastropods and *Meekoceras* are found in the formation.

The lower part of Butler's Harrington Formation is equivalent to the Moenkopi Formation.

Baetcke (1966, personal communication) measured a 2,593-foot section of Moenkopi in the Star Range.

#### Shinarump Conglomerate

The Shinarump Conglomerate mostly occurs in sec. 29, T. 28 S., R. 11 W. in faulted blocks. It is a pebble conglomerate that is, for the most part, highly silicified; pebbles are quartzitic and generally well rounded. Fragments of silicified fossil wood occur in parts of the formation. Although bedding is not distinctive, a series of discontinuous lenses makes up most of the Shinarump. No fossils were found in the conglomerate.

Butler (1913) included the Shinarump Conglomerate in the Harrington Formation. Baer (1962) considered the Shinarump as partly or all middle Triassic or early-late Triassic. He noted thicknesses of 6 inches to 30 feet.

#### Chinle Formation

The Chinle Formation with the Shinarump Conglomerate crops out as faulted blocks mostly in sec. 29, T. 28 S., R. 11 W. Characteristically outcrops are red to orange. The formation consists mainly of red-brown siltstone and shales with pink coarse-grained sandstone, but isolated round pebbles and cross-bedded sandstone occur at the top of the exposures. The formation is not fossiliferous. Because of its stratigraphic position, Baer (1962) considered the Chinle Formation late Triassic in age. Baetcke (1966, personal communication) measured a 318-foot section of Chinle Formation in the Star Range.

#### Triassic-Jurassic System

##### Navajo Sandstone

In the northwest corner of the Milford Flat quadrangle, the Navajo Sandstone outcrops in sec. 20, T. 28 S., R. 11 W., and forms faulted blocks northwest and west of the Gold Crown mine.

The Navajo Sandstone is mostly light gray to white sandstone with aeolian cross-bedding and light pink to red bands. It is friable and weathers to rounded pebbles. The formation, especially where silicified, is easily confused with the Talisman Quartzite;

brownish scree slopes, however, generally characterize the Talisman. The Navajo Sandstone is nonfossiliferous.

Baer (1962) considered the Navajo Sandstone of the Star Range Lower Jurassic. Baetcke (1966, personal communication) measured an incomplete section of 400 feet of Navajo Sandstone in the Star Range.

#### Quaternary System

The Quaternary system covers about 95 percent of the Milford Flat quadrangle. It includes talus, slide deposits, fan gravels, gravel veneers, stream gravels and related Pleistocene lake deposits. These were mapped as alluvium proper, alluvial talus and alluvial fans.

#### INTRUSIVE ROCKS

##### Milford Flat Stock

##### General Statement

The Milford Flat stock is exposed in the northwest corner of the Milford Flat quadrangle. It crops out over approximately one square mile area and constitutes about one-fifth of the mapped area. It is exposed in secs. 15, 16, 20, 21, 22, 28 and 29, T. 28 S., R. 11 W. The stock is generally irregular in shape and crops out in separated masses. The widest part, in sec. 28, T. 28 S., R. 11 W., is about a mile across.

Eastward the stock disappears under alluvium, but separated cone-shaped igneous masses rise about 80 feet high above the valley floor. They are exemplified by Mollies Nipple and those masses south of it.

Bold outcrops, angular jointing and barren steep slopes are characteristic features of granodiorite portions of the stock. The area of quartz monzonite is characterized by rounded, massive outcrops.

Medium- to coarse-grained granodiorite porphyry dominates the stock. Quartz monzonite outcrops on the east edge of the map area, as shown on plate 1.

##### Granodiorite

The predominant rock of the Milford stock is granodiorite porphyry, with the typical mottled salt-and-pepper appearance of granitoid rocks. The overall color of the rock ranges from gray to pinkish gray depending on the degree of alteration of the mafics and feldspars.

Quartz, constituting about 10 percent of the rock, appears in rounded to irregular grains. Brown-

black biotite, with cleavage plates averaging 2 to 6 millimeters (mm) in diameter, makes up about 15 percent of the rock. Hornblende, commonly altered, seldom exceeds 6 percent of the rock. Altered brown augite is more abundant than hornblende and constitutes about 9 percent of the rock.

Feldspars make up about 60 percent of the rock, with cleavage surfaces 2 to 6 millimeters in diameter. They generally are altered.

In thin section, the texture of the granodiorite porphyry is holocrystalline, hypidimorphic and porphyritic. Accessory minerals—zircon, apatite, magnetite, sphene and pyrite—have the most perfect crystal boundaries. The ferromagnesian minerals are euhedral except where they interfere with one another. The plagioclases occasionally show crystal forms, but their polysynthetic twinning gives the impression of more perfect outlines than they actually have. Quartz is usually anhedral. The following is a microscopic description of the salic, mafic and accessory minerals comprising the Milford Flat stock granodiorite.

#### Salic Minerals

*Quartz.* Quartz usually fills interstices between other minerals and it is anhedral. Most quartz grains are free of inclusions; no fluid inclusions were observed. The boundaries between quartz and plagioclases are generally straight, as the shape of the plagioclase usually prevails. Chalcedony occurs rarely in cavity fillings.

*Plagioclase Feldspar.* Andesine is usually euhedral, although in contact with quartz or orthoclase, it is subhedral. It generally exhibits polysynthetic twins on the albite law. Zoning is rare. Primary inclusions were not observed because the mineral is highly altered. Secondary inclusions include the alteration products kaolinite, sericite, quartz and possibly albite.

*Orthoclase.* Orthoclase is anhedral. Simple Carlsbad twins are common, polythentic twins are absent. Zoning, apparently caused by growth of concentric shells oriented in slightly different positions, is not common. Microperthite occurs in some thin sections, but is not common. Primary inclusions are not abundant, but include pyrite and zircon, which are generally randomly oriented. Secondary inclusions are prevalent and include kaolinite, sericite and quartz, which generally are unoriented.

#### Mafic Minerals

*Biotite.* Biotite is distributed randomly throughout the rock. Seen normal to (001), it has straight edges and ragged ends, and, if parallel to (001), it has an irregular shape. It is commonly altered to chlorite and limonite and some grains are altered completely. Primary inclusions of zircon in biotite are rare. Some thin sections show strain effects as bent and broken lamellae.

*Augite.* Brown augite is generally subhedral with fresh cores. Boundaries tend to be altered to chlorite and actinolite. Uralitization is seen in some thin sections. Some crystals tend to have fresh cores, but are altered to amphiboles (hornblende) along the boundaries. Inclusions in augite are mainly euhedral pyrite, which generally is altered to limonite.

*Hornblende.* In thin section, hornblende is generally brownish green to brown and subhedral with pseudo-hexagonal cross sections which show the characteristic cleavage of amphiboles. Twinning on (100) is common. Hornblende shows restricted alteration to chlorite and epidote, chlorite being the most common.

#### Accessory Minerals

Accessory minerals (magnetite, pyrite, zircon, apatite, sphene and epidote) constitute less than 3 percent of the rock, with magnetite the most common (one-half to 1 percent). Pyrite occurs as chadacrysts in other minerals such as augite. Generally pyrite occurs near the other mafics. Most of the accessory minerals are euhedral and clear.

On the basis of its texture and table 2, the Milford Flat stock is classified as granodiorite porphyry.

#### Quartz Monzonite

Quartz monzonite occurs in a series of discontinuous outcrops on the east flank of bedrock exposures in the quadrangle. It comes in contact with granodiorite in several places, but the contacts are obscured with float, making age relationships between the two intrusives impossible to determine.

In hand specimen the rock is uniform in appearance, medium-grained, and pinkish due to orthoclase. Grain size of the minerals other than orthoclase and sphene is about 1 mm. Orthoclase averages 1 mm, but grains to 4 mm are present. Sphene is visible to the naked eye and averages 0.2 mm. The rock is lightly iron-stained where weathered.

Under the microscope, quartz monzonite has hypautomorphic granitoid texture. Quartz is anhedral

Table 2. Modal analyses of Milford Flat granodiorite.

Mineral	Percent	
	Average	Range
Quartz	11	8-12
Plagioclase (andesine)	53	46-59
Orthoclase	15	12-19
Biotite	10	8-15
Augite	5	4-10
Hornblende	4	3-7
Accessory minerals (including weathering products)	2	1-4

and has a grain size somewhat smaller than the feldspars, 0.5 mm. Orthoclase and plagioclase are subhedral. Biotite with an average size of 0.5 mm is euhedral, but shredded. The opaques are anhedral and average about 0.2 mm; sphene is euhedral and averages about 0.2 mm.

A modal analysis is given in table 3. The high silica and orthoclase content indicate the rock is close to a true granite in composition.

The quartz monzonite is altered slightly; about 15 percent of the orthoclase grains are unaltered, 65 percent show incipient alteration, and 20 percent are sericitized.

About 40 percent of the plagioclase crystals exhibit slight alteration and about 25 percent are sericitized. About 35 percent show normal zoning and are unaltered. The presence of zoned and unzoned feldspars may indicate two generations of plagioclase in the rock. The mean composition of the plagioclase is  $An_{35}$ , but the cores of the zoned plagioclase are as basic as  $An_{44}$ .

All of the hornblende is partially altered to chlorite and about half of the chlorite crystals are after hornblende. The other chlorite crystals are after biotite. About 15 percent of the biotite shows no alteration, about 70 percent is partially altered to chlorite, and the remainder is highly altered to chlorite.

#### Age of the Milford Flat Stock

No age dating has been done on the Milford Flat stock. The youngest sedimentary rocks affected by the granodiorite mass are the Moenkopi Formation of Triassic age. The intrusions are probably Tertiary in age.

#### DIKES

##### General Statement

Dikes of the Milford Flat quadrangle are granodiorite, lamprophyric or aplitic. Lamprophyre dikes,

Table 3. Modal analyses of Milford Flat quartz monzonite.

Mineral	Percent	
	Average	Range
Quartz	26.9	15-33
Orthoclase	34.5	30-50
Plagioclase	26.8	20-30
Biotite	5.7	3-6
Hornblende	5.1	3-7.5
Magnetite and other opaques	0.5	1-5
Sphene	0.5	

the most predominant, cut igneous and sedimentary rocks; aplite types are confined to igneous rocks. The dikes generally trend east-west, northeast-southwest or northwest-southeast, and range in size from several inches to several feet. Alteration of lamprophyric dikes is pronounced.

#### Lamprophyric Dikes

Lamprophyric dikes are abundant in the mapped area. Their general strike is east-west with low south dips. The dikes are generally dark grayish green to black, and they range from several inches to 4 feet thick. They can be traced for distances ranging from several feet to a quarter of a mile. Their texture varies from fine-grained to porphyritic. The large dikes are confined to the granodiorite mass, whereas the small ones are located in sedimentary rocks.

Generally the largest lamprophyric dikes trend east-west. They form jointed, vertical or near vertical outcrops, which stand as ridges in contrast to the surrounding granodiorite igneous mass.

Five thin sections of representative samples of lamprophyric dikes were studied (table 4). The texture of the rock is holocrystalline, ranging from porphyritic in the large dikes to lamprophyric in the small ones. The phenocrysts are plagioclase of andesine composition. The groundmass consists mainly of andesine and augite, with a high percentage of dark minerals.

Generally the dikes are altered—the degree of alteration being inverse to their size. Accessory minerals include magnetite, sphene, apatite and pyrite.

The dikes are considered spessartite on the basis of the above mode and textures.

#### Aplite Dikes

Aplite dikes are comparatively rare, shorter and thinner than the lamprophyric dikes, and are restricted

Table 4. Modal analyses of lamprophyric dikes.

Mineral	Average (percent)
Quartz	3
Andesine (altered to sericite and kaolinite)	55
Augite (including uralitization)	28
Biotite	12
Accessories (including weathering products)	2

to the granodiorite mass. In hand specimen they are light pink to gray, fine to porphyritic, and consist of phenocrysts of quartz and feldspar in a fine-grained groundmass of plagioclase. Biotite is seldom seen.

The most prominent aplite dike is located in NW¼ sec. 28, T. 28 S., R. 11 W. It is about 3 feet wide and strikes approximately 60° NW for about a quarter of a mile and dips 83° S. It stands as a ridge in the granodiorite mass.

Three thin sections of aplite were examined (table 5). The following are general microscopic characteristics of the sections:

1. Graphic texture is occasionally present;
2. Mermykite is present, but does not prevail;
3. Quartz is generally in phenocrysts with pseudohexagonal cross sections, but it also makes up a small portion of the groundmass as resorbed crystals;
4. Inclusions in quartz consist of zircon, pyrite and magnetite, which are in parallel to subparallel orientations;
5. Perthite is common;
6. Microcline occurs in small quantities compared to orthoclase;
7. Biotite is commonly altered to chlorite and epidote;
8. Orthoclase with some biotite inclusions is altered to sericite and kaolinite;
9. Andesine plagioclase generally is zoned and altered to sericite and kaolinite; and
10. Pyrite is generally euhedral and altered to hematite. It occurs as inclusions in other minerals and as separate crystals.

Table 5. Modal analyses of aplite dikes.

Mineral	Average (percent)
Quartz	20
Orthoclase and microcline (including perthite)	55
Plagioclase (andesine)	15
Biotite and hornblende	7
Accessory minerals (including alteration products)	3

### Granodiorite Sills and Sheet

A granodiorite sill is located in sec. 21 of the mapped area, about 600 feet northeast of the Vicksburg mine, with a strike of about N15°E. The sill is about 50 feet wide and extends about 600 feet from the stock. It has the general character and appearance, and the same minerals and textural features, as the stock. Granodiorite sills are present in other parts of the mapped area (plate 1).

A granodiorite sheet of the general character and minerals of the stock is located in sec. 22, T. 28 S., R. 11 W., between Permian and Pennsylvanian formations.

The granodiorite sills and sheet are believed formed contemporaneously with the granodiorite stock and are, therefore, considered an earlier age than the aplite and lamprophyre dikes.

The aplite dikes are confined to the granodiorite stock, and the lamprophyres cut the stock and sedimentary rocks. Nowhere, however, do they cut each other, so their relative ages cannot be ascertained.

### STRUCTURE

#### General Statement

The general structural feature of the northwest corner of the Milford Flat quadrangle is a southeast limb of a northeast-trending fold. The fold consists of southeast-dipping sedimentary rocks through which a relatively small granodiorite stock had been injected in the northeast area. The area is bounded by a north-south normal fault on the west and alluvium on the east.

Faults in the area occur with north-south, east-west, northeast-southwest and northwest-southeast trends. Most of them are pre-intrusive, but minor post-intrusive faulting occurs. It is believed the intrusive emplacement was accomplished by injection through these pre-intrusive faults and fissures. Stoping was of major importance in emplacement.

## Folds

The general feature of the area appears to be a southeast limb of a north-trending fold. There are no prominent small folds in the area. In the Moenkopi Formation in secs. 20 and 29, T. 28 S., R. 11 W., drag, along faulting, makes a small fold with a north-east gentle plunge.

## Faults

Faults in the area (plate 1) are divided into four categories according to their general strike: (1) north striking, (2) east-west striking, (3) northwest-southeast striking, and (4) northeast-southwest striking faults.

Fault planes and traces are not well exposed. Slickensides and brecciations were associated with smaller rather than larger faults. Faulting in the area is either normal or transverse.

### North Striking Faults

The area is bounded on the west by a major normal fault along Elephant Canyon. Movement appears nearly vertical with the west side downthrown, and stratigraphic displacement is nearly 2,000 feet. Another north trending fault is located in NE¼ sec. 21, T. 28 S., R. 11 W., where the Kaibab Limestone on the west forms a downthrown block against the Talisman Quartzite on the east. This fault can be traced northward until the Moenkopi Formation makes contact with the Kaibab Limestone.

### East-West Striking Faults

East-west trending faults in the area are pre- and post-intrusion. They are transverse faults where net slip along the fault planes amounts to as much as 1,000 feet. Three east-west striking faults were mapped. A post-intrusive transverse fault is located in the vicinity of the Vicksburg mine in S½ sec. 21, T. 28 S., R. 11 W., with a net displacement of approximately 300 feet.

A pre-intrusive transverse fault occurs west of the Gold Crown mine, sec. 29, T. 28 S., R. 11 W. It dips approximately 50° S with a net displacement of about 1,000 feet.

### Northwest Striking Faults

Northwest striking normal faults, causing graben and horst structures, are located in N½ sec. 29. They terminate to the south at a major east-west transverse fault, and are terminated in the northwest by a northeast-southwest fault.

## Northeast Striking Faults

A large number of northeast striking normal faults occurs in the area. A graben structure results from such faulting and is exemplified by the wedge-shaped block in NW¼ sec. 29, T. 28 S., R. 11 W., between the Talisman Quartzite and the Kaibab Limestone.

Based on strike and dip of the outcrops, a concealed fault of this trend is located in the area of alluvium between secs. 20 and 21. The fault may be important in ore exploration.

### Age Relation of Faulting

Most faulting is pre-intrusion and most served as channelways during the emplacement of the invading magma.

In the area (plate 1), the northeast-southwest set of faults terminates at the north-south faults and is, therefore, older. The northwest-southeast faults terminate at the northeast-southwest faults; therefore, they are older. The east-west faults terminate at the north-south and the northeast-southwest faults; consequently, they are older than both. East-west faulting in the Vicksburg area is evidently post-intrusion.

## Fissures

Three sets of fissure systems with no observed displacement served as passageways for ore-bearing solutions, as well as loci for the different dikes (plates 1 and 2). The fissures occur in the Milford stock and the surrounding sedimentary rocks.

The fissures trend east-west, northwest and northeast.

### East-West Trending Fissures

The east-west trending fissures are loci of lamprophyric and aplitic dikes; they occur in sedimentary rocks and in the stock. The fissures are nearly vertical and range from several inches to several feet thick.

### Northeast Trending Fissures

The general strike of the northeast trending fissures, which include mineralized fissures and lamprophyric dikes, ranges from N10°E to N60°E and dip varies from 25° to 80° SE. They range from a few inches to several feet thick. Most of the new prospects in the area are along these fissures. They are in the Vicksburg area, near the Woodhouse Shafts and north of the Gold Crown area. The lamprophyric dikes strike

approximately N20°E to N30°E and are almost vertical.

#### Northwest Trending Fissures

The northwest trending fissures are loci of the aplitic dikes in NW¼ sec. 28, T. 28 S., R. 11 W. They are several feet wide, generally strike about N45°W and are almost vertical.

The mineralized fissures in the area are believed true fissures rather than fault planes as evidenced by underground mapping and surface examination of such fissures. No apparent movement was determined along these mineralized fissures.

### HYDROTHERMAL ALTERATION AND CONTACT METAMORPHISM

#### General Statement

Most of the sedimentary rocks of Permian and Triassic age adjacent to intrusive igneous masses and parts of the igneous masses have been hydrothermally altered and, in some areas, subjected to contact metamorphism.

Bleaching, argillic, propylitic, siliceous, limonitic and hematitic alterations occur.

Endogene effects in the granodiorite mass adjacent to sedimentary rocks are accomplished mainly by the removal and/or alteration of the ferromagnesian minerals and the feldspars, and formation of contact metamorphic minerals. Exogene alteration is most pronounced in sedimentary rocks of Permian and Triassic age.

Sedimentary rocks of Permian age, especially limestones and dolomites adjacent to or within the igneous masses, are bleached. In some places the bleaching is accompanied by recrystallization and formation of contact metamorphic minerals: quartz, garnet, epidote, specularite, pyrite, diopside and magnetite.

Argillic alteration generally is displayed in the lamprophyre dikes, the granodiorite mass, and to a lesser extent in the aplite dikes. Such alteration results in such minerals as sericite and kaolinite. Epidote, chlorite, serpentine and calcite propylitic alteration products are most noticeable in the Triassic shales of the Moenkopi Formation, adjacent to igneous masses, and to a lesser extent in the igneous mass.

Siliceous alteration is represented by silicification of the rock masses and the introduction of chalcedony

veinlets. Chalcedony is found mainly as fracture fillings in the granodiorite porphyry and in parts of sedimentary rocks. Most sandstones in the area are silicified. The Chinle Formation contains silicified wood. Some faults, especially the small ones, have silicified fault planes.

Hematitic and limonitic oxidation products occur without other alteration as fissure fillings, or are imposed over the above types.

The bleaching effects and the percentage of contact metamorphic minerals decrease away from the igneous masses.

#### Alteration of the Milford Flat Stock

Localized hydrothermal and deuteric alteration in the granodiorite stock has changed the appearance of the rock in places, especially along fissures where the rock is bleached to varying degrees.

In less altered rock, dark silicates are still recognizable, but feldspars have a dull white appearance. Plagioclase feldspars are more altered than potash feldspars. Such alteration begins with sericite along the cleavage cracks, which spreads until the whole crystal is altered completely. Kaolinite, a widespread alteration product of feldspar, gives feldspar a dull appearance in hand specimen.

Alteration products of the ferromagnesian minerals include: uralite, chlorite, sericite, epidote, hematite and limonite. Hematitic and limonitic oxidation products after pyrite and magnetite are common.

Silicification is not common in the Milford stock; a few chalcedonic veinlets, however, are seen as resistant ribs in the granodiorite mass, especially in the vicinity of the Vicksburg mine. Most of the prospects in the igneous mass show chalcedony and/or secondary quartz crystallization. Quartz and accessory minerals are the least altered.

#### Alteration of Sedimentary Rocks

##### Permian Sediments

The Kaibab Limestone and Toroweap Formation are altered, particularly in the vicinity of the granodiorite stock. The alteration varies considerably in intensity and character, from bleaching to recrystallization to formation of contact metamorphic minerals. The alteration is restricted to certain beds or parts of beds (plate 2).

The most conspicuous alteration is bleaching which is seen on aerial photographs and in the field as

white-bleached patches of sedimentary rocks forming a mosaic with the gray granodiorite masses intruded into them. It was presumably accomplished by the removal of carbonaceous materials during metamorphism.

Alteration of limestones involves the formation of white marble consisting of very fine to medium crystalline calcite. Dolomite members are also partially marbleized. Serpentine is present as yellow streaks or bands in parts of marbleized and bleached Permian sediments.

Silicification of parts of the Permian sediments, especially along the contacts with the stock, are common. This includes the introduction of chalcedony, opal and/or crystallization of quartz. Fissure fillings of small irregularly shaped masses of chalcedony are common.

In the prospects and fissures of the area hematite and limonite oxidation products, presumably after pyrite, generally are superimposed on the above types of alteration and are thought to represent supergene alteration.

#### Triassic Sediments

Triassic sediment alteration occurs mostly in sec. 21; T. 28 S., R. 11 W., adjacent to intrusive igneous masses (plate 2). The most conspicuous and spectacular alteration is selective—red and brown shales are altered to hornfels, and limestones are bleached and/or altered to fine- to medium-grained marbles. Silicification and bleaching of the sandstone members are common. Epidote is a common mineral in the altered zones, with chlorite, actinolite, green garnet and pyrite.

The grade of metamorphism of the Triassic sediments is assigned to Escola's "Epidote green schist facies." Some ripple marks and rainprints can be observed in the metamorphosed shales of Triassic age, but fossils generally can not be identified with any degree of certainty.

#### Alteration of Other Mapped Formations

Alteration of Permian, Triassic and Jurassic formations in the northwest corner of the Milford Flat quadrangle generally is restricted to silicification and/or bleaching. Silicification usually is accompanied by hematitization. Talisman Quartzite is highly silicified. Desert varnish which covers broken fragments is a weathering, not an alteration, effect.

The Shinarump Conglomerate, which is a pebble conglomerate, is highly silicified; pebbles are quartzitic and generally well rounded. Silicified fragments of

fossil wood occur in some parts of the Shinarump Conglomerate.

Parts of sandstones of the Chinle Formation are silicified to an orthoquartzite and they then may be confused with the Talisman Quartzite.

#### Contact Metamorphism

Contact metamorphism in the area occurs where granodiorite is in contact with carbonate and shaly rocks. Limestone in contact with granodiorite stock is altered to white marble. Shales are altered to hornfels with the development of contact metamorphic minerals.

Typical contact minerals are localized, as exemplified by the Vicksburg, Estelle and Maud-S mines vicinity. The minerals include quartz, garnet, diopside, tremolite, pyrite, magnetite, actinolite and muscovite. The minerals are not always restricted to contact zones, but can be found in fissures in carbonate rocks away from the igneous body.

#### GEOLOGIC HISTORY

The oldest rocks in the Milford Flat quadrangle are of Permian age. At that time parts of the area were covered by a shallow sea, and Talisman sands were deposited. This was followed by deposition of calcareous Toroweap and Kaibab sediments in the seas. The area was then positive for a period, followed by submergence and deposition of the Moenkopi Formation, Early Triassic. The Moenkopi Formation shows a variety of lithologies in which marine shales and limestones grade upward to sandstones. The Moenkopi probably was deposited on a shallow marine shelf that gradually became continental. Following, the Shinarump Conglomerate was deposited, and the area emerged. The area was submergent for a short time during deposition of the lower part of the Chinle Formation, followed by continental conditions which probably continued throughout the following times. Sand dunes that later formed the Navajo sandstones encroached on tidal flats.

The area shows no record of sedimentary events between the deposition of the Navajo Sandstone of Jurassic age and deposition of the Lake Bonneville beds. Sediments between the Navajo Sandstone and Lake Bonneville beds, if deposited, were entirely eroded and removed.

The Milford Flat stock was intruded in the area after the Moenkopi was deposited. It apparently used pre-existing faults and fissures, at least in part, during its emplacement. Ore deposition associated with

contact metasomatism and hydrothermal solutions probably occurred during the emplacement and cooling of the Milford stock.

Faulting in the area is pre- and post-intrusive, and folding was pre-intrusive.

## ECONOMIC GEOLOGY

### General Statement

Since 1872 intermittent periods of exploration and production have resulted in lead, silver and gold mines such as the Estelle, Gold Crown and Vicksburg. With the exception of the Vicksburg mine, no maps or production figures are available for the mines and prospects in the area.

### Deposits in Granodiorite

Deposits in granodiorite are small and of minor importance. They generally are localized along east-west fissure systems in the igneous mass. Most of the new prospects in the area show few primary sulfides—mainly pyrite, chalcopyrite and galena, associated with magnetite, hematite and limonite. Secondary copper mineralization, including malachite, is common.

The most abundant gangue minerals, including quartz, sericite, kaolinite and chlorite, result from the alteration of the granodiorite mass.

### Contact Metasomatic Deposits

Contact metasomatic deposits occur as replacements of carbonate rocks within and near the granodiorite mass. Consequently they are generally irregular in shape and they show diversity in occurrence and mineralization. Replacement was selective because some parts of the limestone are either partially or completely replaced by contact minerals.

### Hydrothermal-replacement and Fissure-filling Deposits

The Vicksburg, Gold Crown and Estelle are included as hydrothermal-replacement and fissure-filling deposits. They are the most important type of ore deposit in the area and are larger than the above mentioned types.

These deposits consist of hydrothermal veins replacing sedimentary rocks along fissures. Replacement may occur uniformly and parallel to the fissure, or may extend from the fissure in certain beds for a considerable distance. Such mineralization is governed by the structure and the character of the replaced beds, resulting in tabular or chimney-shaped ore bodies.

The mineralization of such deposits includes mainly lead and silver, with varying amounts of zinc and copper. Secondary alteration has been extensive in such deposits and the main output generally was derived from secondary ores.

### Mineralization Controls

Northeast fissures provided channels for ore-bearing solutions. They generally strike from about N60°E to nearly east-west and have dips from nearly vertical to 37° SE. The fissures occur in sedimentary rocks adjacent to and in the stock. The Kaibab Limestone appears especially favorable for replacement and localization of ores along fissures.

### Zonal Distribution of Mineralization

In the northwest corner of the Milford Flat quadrangle, mineralization is restricted within or closely adjacent to the igneous body.

No clear zonation is represented in the area. On a broad scale, however, lead, zinc and silver deposits generally are localized within or close to the intrusive mass, as at the Vicksburg and Estelle mines. Gold and silver are localized away from the igneous mass, as at the Gold Crown mine.

Pyrite, chalcopyrite and arsenopyrite are the only abundant sulfides in the typical contact mineral deposits; galena and sphalerite are among the principal constituents of the replacement fissure type deposits.

## DESCRIPTION OF MINES

### General Statement

The mines and prospects in the Milford Flat quadrangle are shown on plate 1. With the exception of the Vicksburg mine, no maps or systematic production figures from workings in the area are available. The accessible workings were examined during the course of study. Sampling of the underground workings was done by grab or chip samples, or by channel samples across veins.

### Vicksburg Mine (Vicksburgh<sup>1</sup>)

The Vicksburg mine is located in NW¼ SE¼ sec. 21, T. 28 S., R. 11 W. The property includes seven patented claims: Vicksburg Lode, Copper Belt Lode, Jumbo No. 2, Marguerite, Copper Belt Extension, Jumbo No. 3 and Homestake (figure 2).

<sup>1</sup> Alternate spellings in the literature are in parentheses.

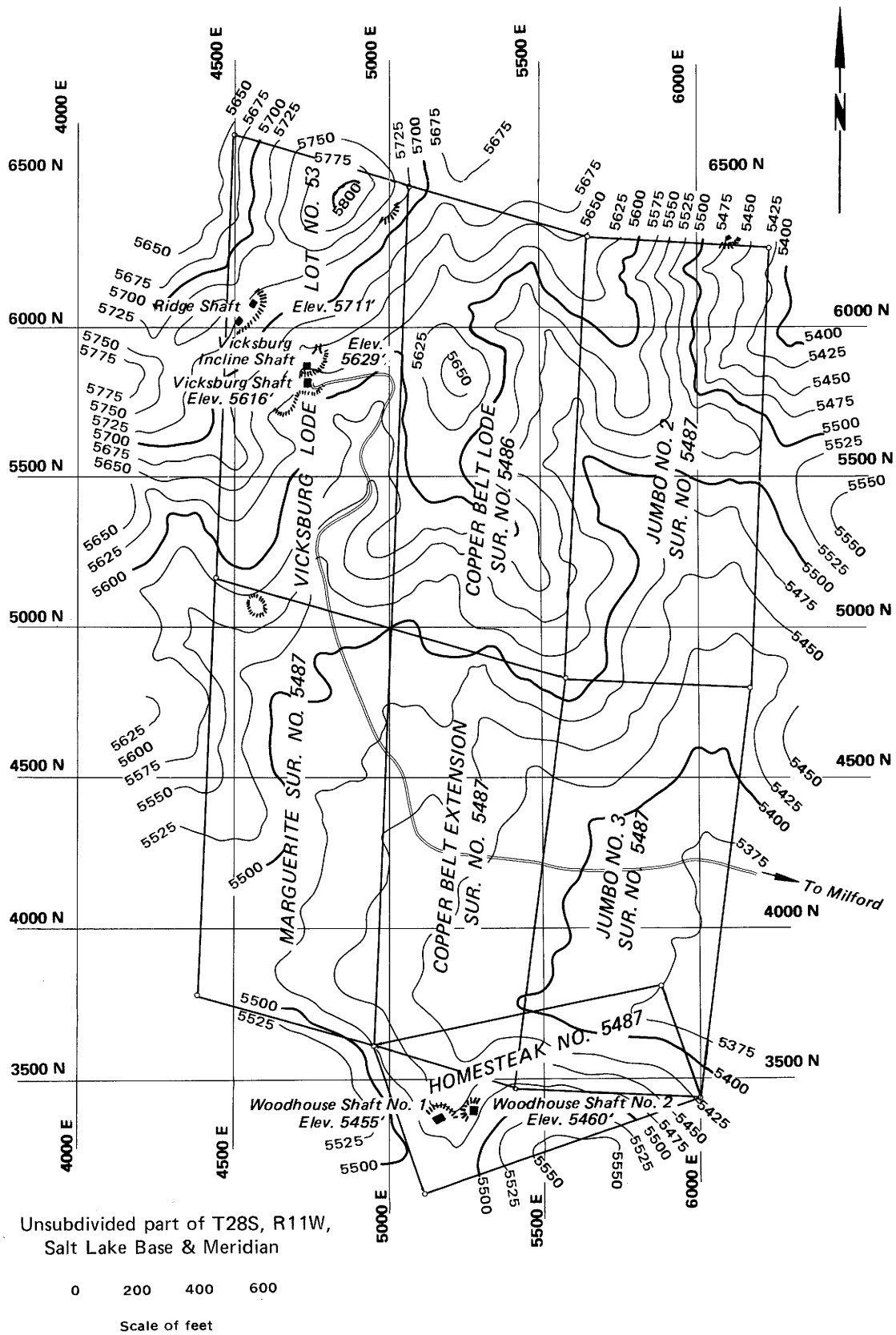


Figure 2. Topographic and claim map, Vicksburg mine, Beaver County (after Townsend, 1950).

The Vicksburg deposit was discovered in 1872 and was worked until about 1877 (Butler, 1913). The old workings were along a north and south vertical vein, from 5 to 10 feet wide, in limestone.

The Vicksburg Gold and Copper Company was incorporated in 1901 (*Salt Lake Mining Review*, 1901, v. 3, Oct. 15, p. 12). In 1904, ore running \$43.00 in gold was struck at a depth of 60 to 80 feet (*Salt Lake Mining Review*, 1904, v. 6, Sept. 15, p. 30).

An ocherous ore containing from 15 to 50 ounces of silver and 15 to 50 percent lead was encountered in a chimney dipping about 40° N. Several tons of pure granular sulfur were found in a layer 2 to 20 inches beneath the ore (Townsend, 1950). One body reportedly had visible native gold (*Salt Lake Mining Review*, 1902, v. 4, Nov. 15, p. 34).

Workings were done on several mineralized outcrops on the property, the largest of which was stopping on the Incline and Ridge fissures (figure 3 and plate 3).

The Little Beaver Mining and Reduction Company assumed control of the Vicksburg mine in 1908 (*Salt Lake Mining Review*, 1908, v. 10, April 15, p. 34). About 1909 the Majestic Mining Company acquired the property and they sank a vertical shaft to 200 feet near the collar of the Vicksburg inclined shaft. They ceased operation after a few feet of drift were made.

The mine was reported active in 1914 (*Salt Lake Mining Review*, 1914, v. 15, Jan. 15, p. 8) and was leased by United States Mines (*Salt Lake Mining Review*, 1916, v. 18, May 30, p. 33).

The New Majestic Mining Company acquired the property in 1939. In an effort to locate the continuation of the minerals in the Incline and Central fissures, the company drifted about 500 feet on the 200 level to the northwest and southeast. No activities are documented, however.

Townsend (1950) lists the following fissures on the property (in order of significance; figure 3): (1) Incline, (2) Ridge, (3) Central, (4) Gossan, (5) East, (6) Contact, and (7) Copper.

These fissures, according to Townsend, are of pre-mineral origin and strike northward. The major portions of the workings on each fissure are given in column 2 (Townsend, 1950).

	<u>Feet</u>
Ridge fissure	
One-compartment shaft	90
Stope	100 x 90
Incline fissure	
Two-compartment vertical shaft	200
Drifts and cross-cuts	650
One-compartment inclined shaft	287
Stope (approximately)	120 x 40
One-compartment prospect shaft	45
Gossan fissure	
Two-compartment vertical shaft	80
One-compartment inclined shaft	50
Stope	20 x 50
Central fissure	
Three one-compartment shafts aggregating	60
Copper fissure	
One-compartment shaft	30
East fissure	
Three one-compartment shafts aggregating	75
Contact fissure	
Limited to shallow prospect shafts	

In 1946 the U. S. Bureau of Mines initiated a project to examine and survey the surface and underground workings of the Vicksburg mine (plate 3 and figure 4); in 1948 they started diamond drilling. The results of the investigation and analyses of several core samples are described by Townsend (1950).

The minerals identified in the dumps of the mine include galena, sphalerite, cerussite, smithsonite, quartz, pyrite, hematite, magnetite, calcite, dolomite and chalcopyrite.

There are no records of production from the property during the early years. Townsend (1950), however, estimated it would not exceed a few hundred tons of lead and iron ores. The iron ores were used for smelter flux.

The mine was inaccessible for examination during the course of this study. A dump sample, however, was analyzed with the results shown in table 6.

#### Woodhouse Shafts

The Woodhouse shafts are located in NW¼ NE¼ sec. 38, T. 28 S., R. 11 W. (plate 1). The mine workings were not accessible for investigation during the course of this study. No published information is available about the mine.

The property consists of two vertical shafts about 150 feet apart on an east-west line. One shaft is on a vein 1.5 feet wide striking N65°E and dipping 60° SE. Minerals identified in the dumps of the shafts

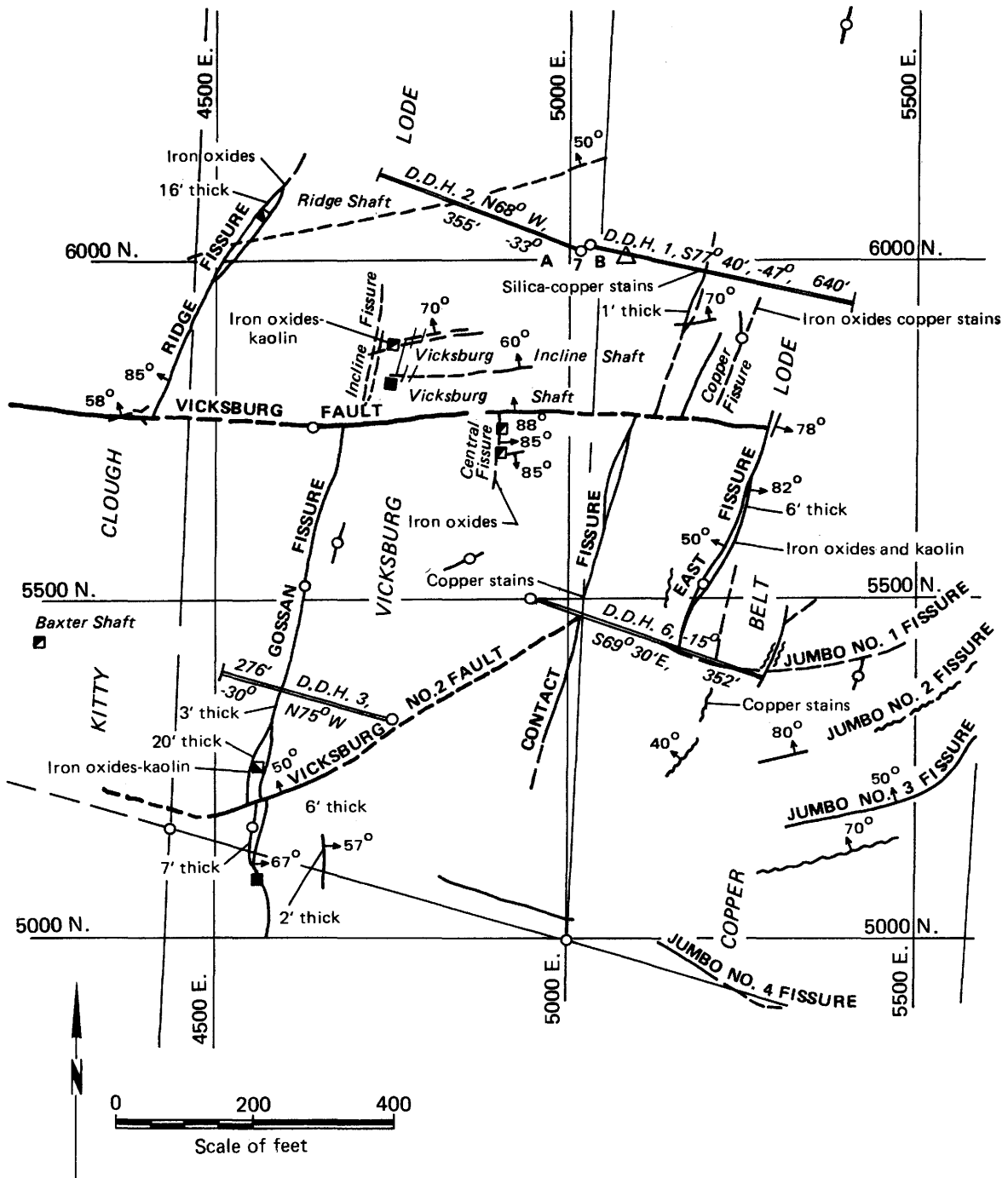


Figure 3. Surface plan showing fissures and diamond-drill holes, Vicksburg mine (after Townsend, 1950).

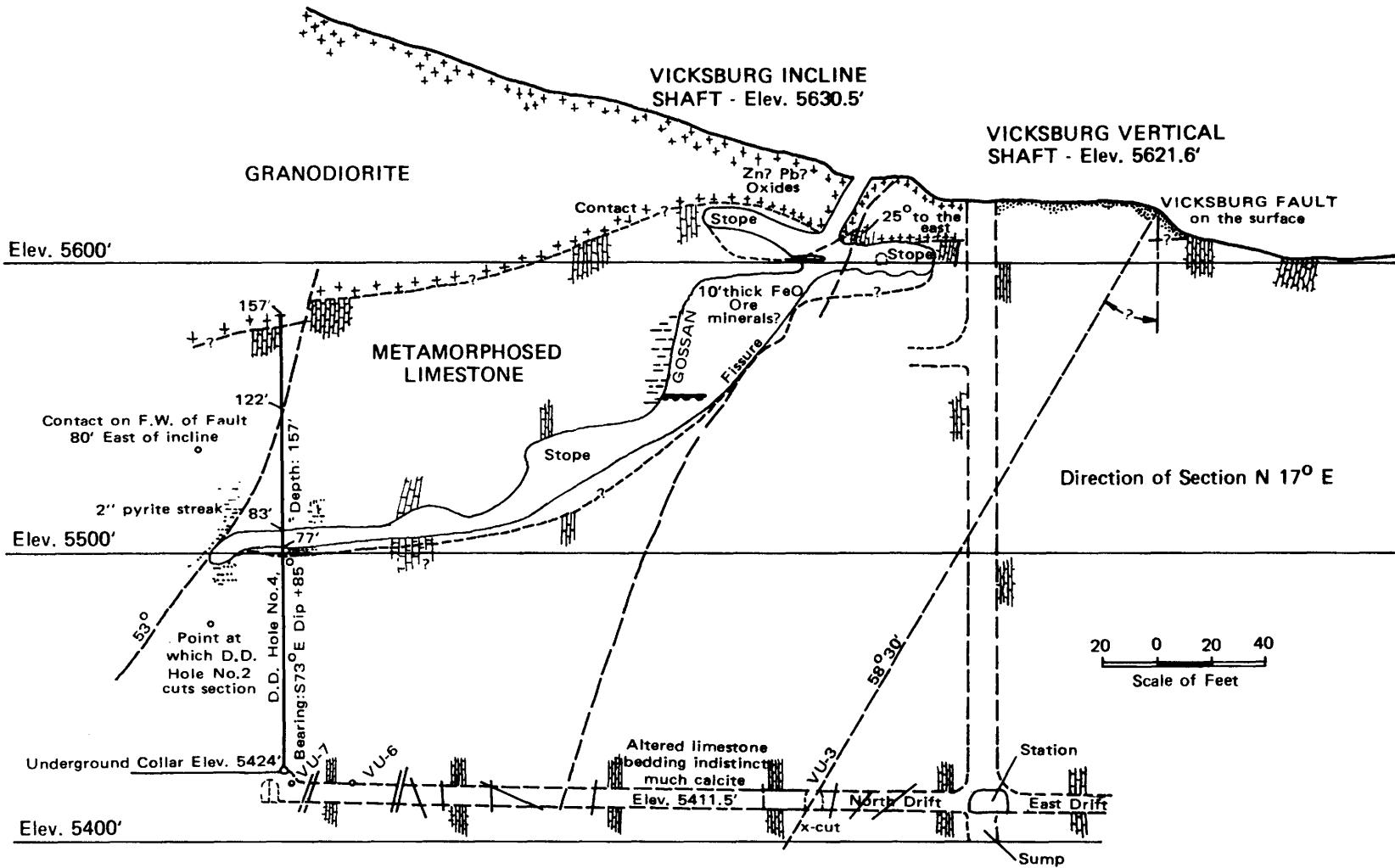


Figure 4. Longitudinal section through inclined shaft, Vicksburg mine (after Townsend, 1950).

Table 6. Commercial analyses of samples from dump and vicinity of Vicksburg mine.

Sample	Description	Commercial assay				
		Oz/short ton		Lead	Percent	
		Gold	Silver		Copper	Zinc
Vicksburg dump	Grab-dump	Tr	4.0	4.0	Nd	Nd
Surface stope just west of Vicksburg shafts	Ocherous gossan	Tr	2.0	4.0	Nd	Nd

Tr = Trace. Nd = Not detected.

are pyrite, hematite, limonite, cerussite, quartz and chalcedony.

No production data from the property are available. According to the *Salt Lake Mining Review* (1912, v. 14, Aug. 15, p. 30-31), a hand specimen of rock showing free gold came from the property.

A small vein gave values of nearly \$6,000 in gold and 150 ounces of silver. A 40-ton carload of approximately \$200 a ton was shipped from the property in 1912 (*Salt Lake Mining Review*, 1912, v. 14, Aug. 15, p. 31).

No production data have come from the property since 1912. A dump sample, however, was analyzed and gave the results in table 7.

#### Maud-S Mine

The Maud-S mine is located in SE $\frac{1}{4}$  sec. 21, T. 28 S., R. 11 W. There is no information available about the property for the years prior to 1925. In 1926 the property was owned by the Utah Premier Mining Company (*Salt Lake Mining Review*, 1926, v. 27, Jan. 15, p. 37).

The property consists of two inaccessible vertical shafts. There are no underground maps or other information about the property. According to the *Mines Handbook* (1931, v. 18, p. 1856), a two-compartment shaft is sunk to a depth of 275 feet.

Early production data are unavailable. The *Salt Lake Mining Review* (1925, v. 27, Oct. 30, p. 22)

reports, however, several carloads of good ore on an 80-foot shaft and about \$20,000 of ore on the property's dump. Also, in 1927, the *Salt Lake Mining Review* (v. 29, May 30, p. 21) reported five carloads of ore shipped from the 85-foot level ran 30 to 60 percent lead and 2½ ounces of silver to the unit of lead with an average of about \$20 gold to the ton.

Ore minerals identified in dumps of the mine are cerussite, chalcopyrite, hematite, limonite and smithsonite.

A sample from the Maud-S mine dump was analyzed with the results shown in table 8.

#### Gold Crown Mine and Gold Crown Extension

The Gold Crown mine is located in SE $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 29, T. 28 S., R. 11 W. (plate 1). In 1920 it consisted of seven claims plus one on lease (*Mines Handbook*, 1920).

Information about the history and ownership of the property for the years prior to 1910 is not available. A vertical shaft was sunk to 130 feet and a drift was run for about 40 feet, which supposedly had ore averaging \$140 per ton (*Salt Lake Mining Review*, 1910, v. 11, March 15, p. 38).

By the end of 1910 the shaft was sunk another 100 feet (*Salt Lake Mining Review*, 1910, v. 12, Aug. 30, p. 38).

Table 7. X-ray fluorescence analyses of sample from dump of Woodhouse shafts.

Sample	Description	X-ray fluorescence (ppm)					
		Silver	Lead	Copper	Zinc	Manganese	Arsenic
Woodhouse dump	Dump-grab	Tr	Tr	Tr	Tr	Tr	Nd

Tr = Trace. Nd = Not detected.

Table 8. Commercial analyses of sample from Maud-S dump.

Sample	Description	Commercial assay				
		Oz/short ton		Percent		
		Gold	Silver	Lead	Copper	Zinc
Maud-S dump	Dump-grab	Tr	2.1	Nd	Nd	0.6

Tr = Trace. Nd = Not detected.

In 1917 the Gold Crown Mining Company acquired the property which consisted of six claims (*Salt Lake Mining Review*, 1917, v. 19, April 15, p. 39). In 1919 the residents of Pleasant Grove, Utah, owned the property (*Salt Lake Mining Review*, 1926, v. 28, Oct. 15, p. 18).

The authors were not able to document activity after 1926.

According to the *Salt Lake Mining Review* (1919, v. 21, May 30, p. 41), the ore which ran 45 ounces of silver and 20 to 25 percent lead came from the 300-foot level with shipment of nine carloads of ore. Another report states that ore, a lead-silver carbonate with an iron base, averaged more than \$1,500 per carload (*Salt Lake Mining Review*, 1923, v. 25, April 15, p. 18). The vein was reportedly 2 to 6 feet wide at the bottom of the shaft. The Gold Crown Extension mine supposedly had the same ore as the Gold Crown with 14 inches of exceedingly high-grade ore (*Salt Lake Mining Review*, 1920, v. 21, March 15, p. 41).

Small ore shipments were made in 1920 and 1921 (*Mines Handbook*, 1922). No shipments were made in 1923.

Up to 1923, \$25,000 worth of ore was mined from the property (*Salt Lake Mining Review*, 1923, v. 25, April 15, p. 18). Since 1923, however, no data are available on production from the property.

Dump minerals identified during the investigation include anglesite, cerussite, malachite, smithsonite, hematite, limonite, pyrite and goethite. Dump samples

were analyzed from the Gold Crown shaft and inclined shaft about 600 feet southwest of the mine (table 9).

#### Estelle Mine (Estella)

The Estelle mine is located in SW¼ sec. 21, T. 28 S., R. 11 W. Little information is available about the early history of the mine. In 1901 the property was owned by the Estelle Gold Mining Company (*Salt Lake Mining Review*, 1901, v. 3, Oct. 15, p. 14), and in 1906 the Estelle Mining Company owned the property (*Salt Lake Mining Review*, 1906, v. 8, May 26, p. 32).

In 1902 the first 25-HP steam-hoist in the Star district was erected on the property (*Salt Lake Mining Review*, 1902, v. 3, March 15, p. 21); by 1903 three shafts were constructed. In 1904 a mill was built to crush from 15 to 20 tons of ore per day, of which 71 percent of the gold was saved (*Salt Lake Mining Review*, 1904, v. 6, Nov. 30, p. 32). A 20-stamp mill was ordered by the Estelle Mining Company in 1906 (*Salt Lake Mining Review*, 1906, v. 8, May 15, p. 32).

The property consists of two vertical shafts. No maps or information are available about the underground workings of the mine.

According to the *Salt Lake Mining Review* (1902, v. 3, Jan. 30, p. 18), four distinct veins crossed the Estelle—three gold and one copper. Pay ore was opened up in six places along the property. One thousand tons of ore in sight with 500 tons more on the dump were reported. This was an iron ore carrying \$7.50 to \$8.00 free gold per ton and could be handled inexpensively (*Salt Lake Mining Review*, 1904, v. 6, May 30, p. 18). There are no figures of production from the mine. The mine was reported active in 1914 (*Salt Lake Mining Review*, 1914, v. 15, Jan. 15, p. 8).

A dump sample from the Estelle was analyzed (table 10).

The adit level of the Estelle mine is located in NW¼ NW¼ sec. 28, T. 28 S., R. 11 W. (plate 1). The portal is at an elevation of 5,400 feet. The level is 913

Table 9. X-ray fluorescence analyses of samples from dumps of the Gold Crown mine.

Sample	Description	X-ray fluorescence (ppm)					
		Silver	Lead	Copper	Zinc	Manganese	Arsenic
Gold Crown dump	Dump-grab	Tr	1,298	916	1,657	7,300	Nd
Inclined shaft 600 feet southwest of Gold Crown dump	Ocherous gossan	Tr	170	23,372	1,684	1,480	Nd

Tr = Trace. Nd = Not detected.

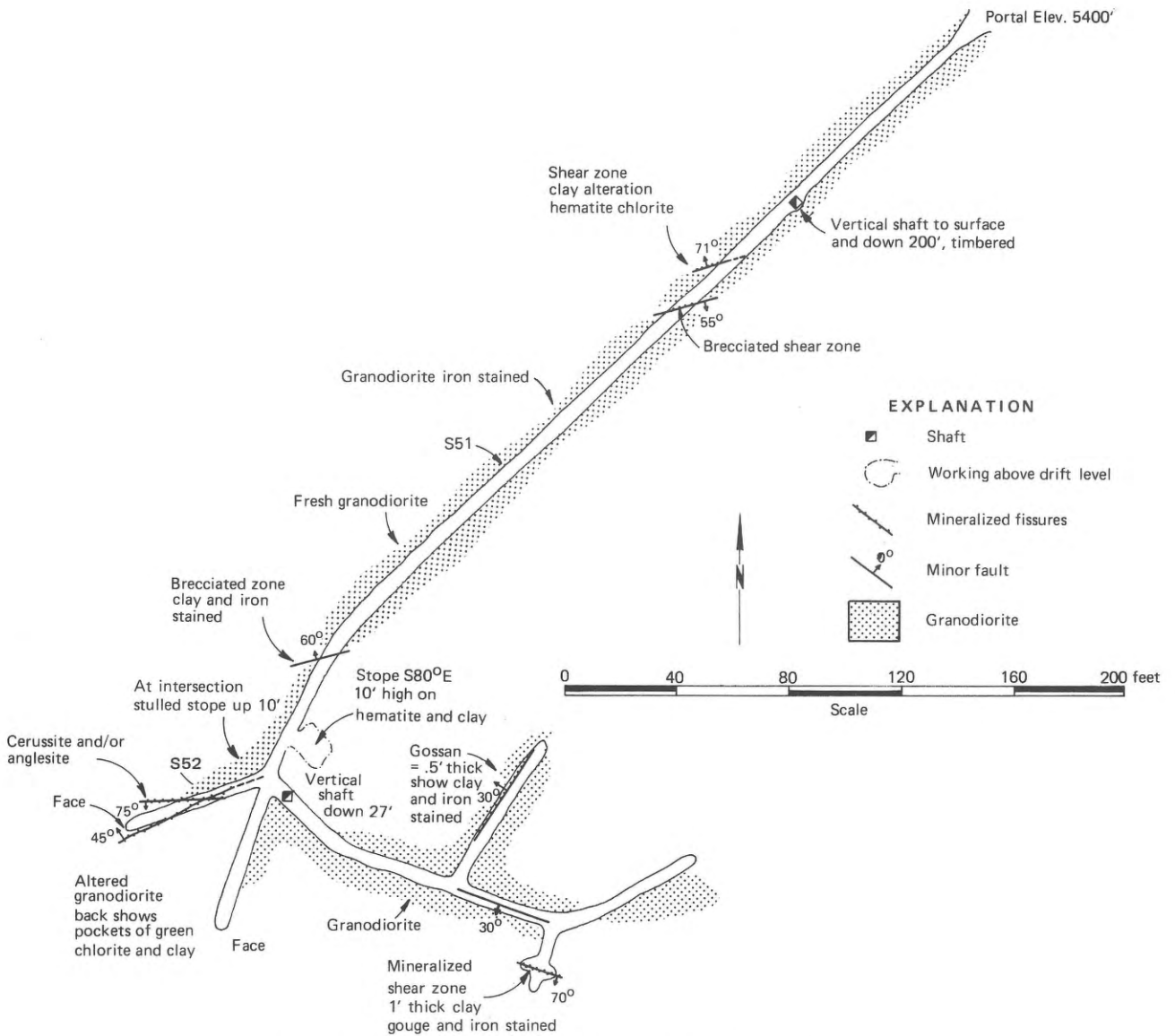


Figure 5. Underground plan view of the adit level of Estelle mine.

feet long and the mine workings consist of one main drift with several branches, cross-cuts, two stilled stopes and two vertical shafts. The main drift trends S45°W and S28°W. The level is 5 to 6 feet wide and 6 to 7 feet high. It is dry and generally has good air. It stands well except where there are shear zones (figure 5).

Granodiorite porphyry, the only rock exposed in the level, is generally fresh, but jointed, and in some places altered. Alteration of the ferromagnesian minerals, and sericitization and kaolinitization of the feldspars alter the rock to a light gray color. Pockets of chlorite flakes one-half inch in diameter are seen

Table 10. X-ray fluorescence analyses of samples from dumps of the Estelle mine.

Sample	Description	X-ray fluorescence (ppm)					
		Silver	Lead	Copper	Zinc	Manganese	Arsenic
Estelle dump	Dump-grab	Nd	Tr	Nd	Tr	Tr	Nd

Tr = Trace. Nd = Not detected.

along joints in some places in the granodiorite. In some places the granodiorite is hematitized.

Geology of the adit level is shown on figure 5. The mineralized veins range from a few inches to 0.5 feet thick. Mineralization in the veins is cerussite and/or anglesite; limonite, hematite, chlorite and kaolinite are also abundant.

Samples collected from the mine are shown on figure 5. Sample S52 was collected at the intersection of two veins; its analysis is given in table 11.

Adit West of Estelle Mine

The adit west of Estelle mine is located in SW¼ SW¼ sec. 21, T. 28 S., R. 11 W., about 400 feet northwest of the Estelle mine. The portal is at an elevation of 5,520 feet (plate 1).

The adit comprises a main level trending N28°W (figure 6). It is 5 to 6 feet wide and consists of 105 feet of accessible and untimbered drift.

The rock units exposed in the adit are granodiorite and altered limestone of Kaibab-Toroweap undifferentiated formations. The irregular contact, which strikes N20°E with undetermined dip, is 84 feet from the portal.

The granodiorite, especially along the contact, is highly altered and jointed. Alteration includes bleaching of the rock resulting from alteration of ferromagnesian minerals, and partial or complete sericitization and kaolinitization of feldspars.

The limestone is highly serpentized, generally bleached, and contains pockets of chlorite.

No mineralized veins or fissures were found in the altered limestone or granodiorite.

Sundown Mine

The Sundown mine is located in NW¼ sec. 22, T. 28 S., R. 11 W., at an elevation of 5,260 feet (plate 1). The mine workings are shown on figure 7.

Table 11. Description and X-ray fluorescence analyses of samples from the Adit level of the Estelle mine (sample locations shown on figure 5).

Sample no.	Description	X-ray fluorescence (ppm)					
		Silver	Lead	Zinc	Copper	Manganese	Arsenic
50	Granodiorite chip	—	—	—	—	—	—
51	Altered granodiorite	—	—	—	—	—	—
52	Vein	Nd	4,813	Tr	Nd	Tr	Nd

Tr = Trace. Nd = Not detected. — = Not determined.

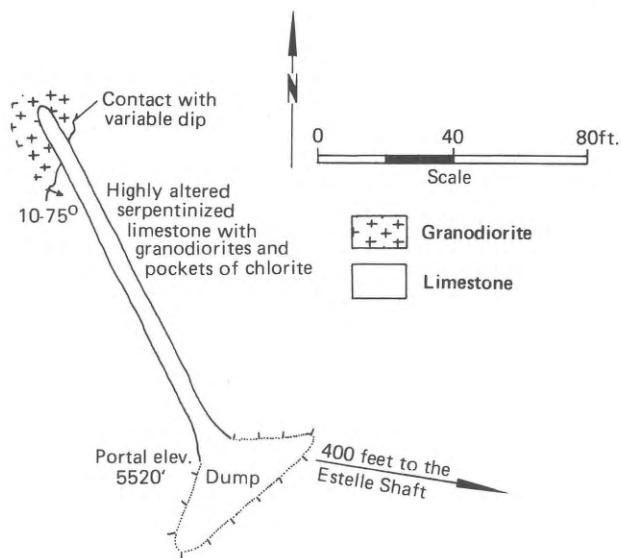


Figure 6. Adit level west of Estelle mine.

Exposed in the mine are granodiorite and Talisman Quartzite, with the contact at 160 feet from the portal. The contact is generally sharp, strikes N50°E and dips 35° NW. The contact shows clay and hematitic alteration. For the most part, the granodiorite exposed in the adit is unaltered except near the contact. Alteration is confined to bleaching of the ferromagnesian minerals and sericitization, accompanied by kaolinitization. The Talisman Quartzite is highly fractured. While exposures on the northeast side of the drift are highly altered, those southwest are unaltered. Alteration here includes hematitic alteration, probably after pyrite, and bleaching. The rock in some places is dense and very fine-grained. An inclined shaft at N16°W strike, 29° NW inclination, and about 52 feet deep, is located 255 feet from the portal. It is not connected with the underground workings of the Sundown adit.

Three veins are exposed in the underground workings of the mine. One vein, along a joint in the granodiorite, is 65 feet from the portal and is one-quarter foot thick. The vein strikes N35°W and dips 45° NW. It is hematized and shows clay alteration. Another 4-inch thick, mineralized vein in the Talisman Quartzite is 80 feet from the granodiorite-Talisman

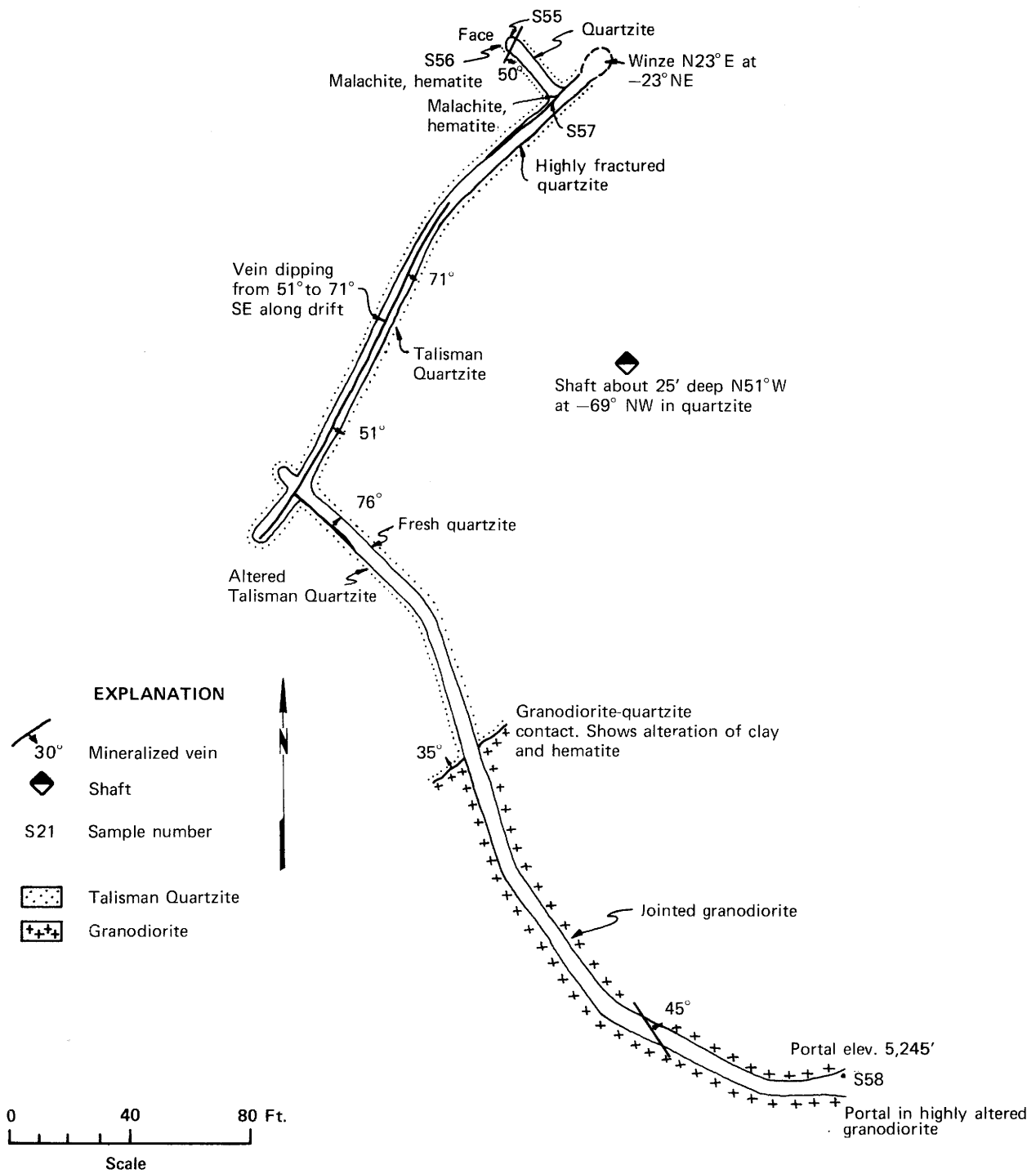


Figure 7. Underground plan of the adit level of the Sundown mine.

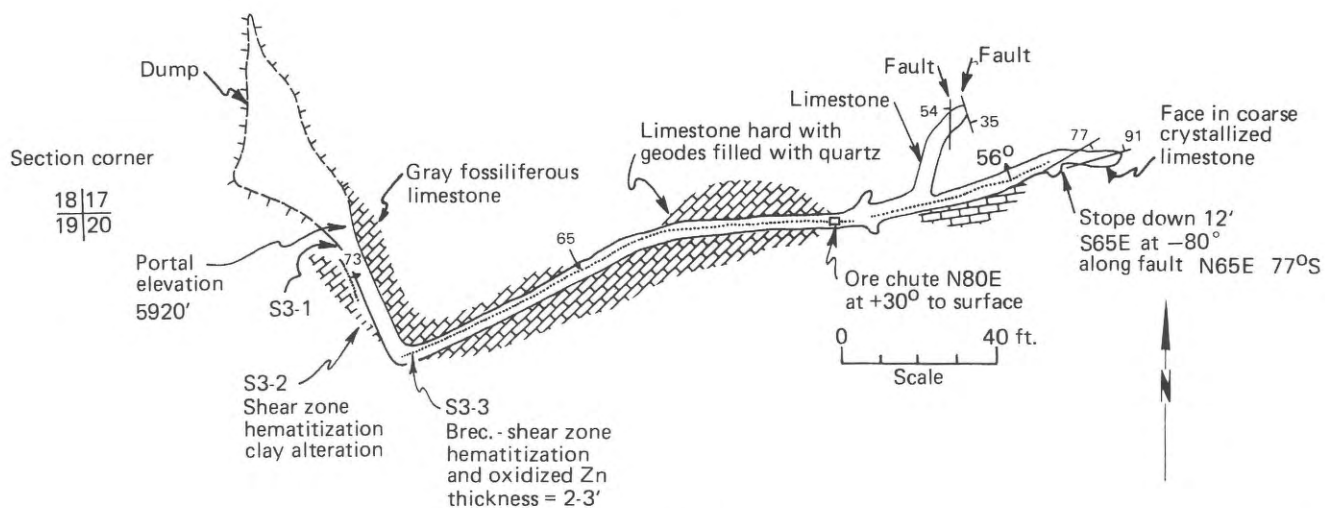


Figure 8. Adit level of the Emerson mine.

Quartzite contact. The vein strikes N50°W, dips 76° NE, and is terminated at an intersection by another vein which runs throughout the back of the drift as far as the winze. The dip of the vein at the back of the drift ranges from 51° to 71° SE.

Oxidized copper, lead and zinc mineralization is present along some parts of these veins. Mineralization includes malachite, cerussite, calamine and manganite, accompanied by hematite, limonite and kaolinite.

Samples S55, S56, S57 and S58 were collected from the underground workings of the mine. They are representative samples from the rock units exposed in the mine, as well as from the mineralized veins (figure 7).

Results of X-ray fluorescence analyses are shown in table 12.

#### Emerson Mine

The Emerson mine is located in SW¼ SW¼ sec. 17, T. 28 S., R. 11 W. (plate 1), 100 feet northeast of the corners of secs. 16, 17, 20 and 21. The portal lies at an elevation of 5,920 feet.

The mine workings consist of one main adit with a 356-foot drift, the initial 30 feet of which trend S22°E, and the rest trend N80°E to N70°E. The adit is 5 to 6 feet high and about 5 feet wide. The workings consist of branches, cross-cuts, stopes and ore chutes (figure 8). A stope 225 feet from the portal, with a general strike of S65°E and dipping 80° SE, is 12 feet high, 20 feet long, and 8 feet wide. It is along a mineralized fault of N65°E strike and 77° SE dip. An ore chute along another stope to the surface strikes N80°E and dips 30° N. The workings are in good shape and partially timbered, especially along the stopes.

The drift is in the Kaibab Formation. The rock unit exposed in the mine is a fractured, gray, fossiliferous limestone, which in part is bleached and contains geodes filled with chalcedonic quartz. At the end of the drift the limestone is coarsely crystalline.

The mineralized veins and faults exposed in the Emerson mine are shown on figure 8. A mineralized vein near the portal is 0.5 to 1 foot thick and strikes N22°W, dipping 57° SW. Another vein, which runs along the back of the drift, is 2 to 3 feet wide and has a dip of 70° to 60° S with a strike of N75°E. Several

Table 12. Description and X-ray fluorescence analyses of samples from the Sundown mine (sample locations shown on figure 7).

Sample no.	Description	X-ray fluorescence (ppm)					
		Silver	Lead	Zinc	Copper	Manganese	Arsenic
S55	Talisman Quartzite chip	—	—	—	—	—	—
S56	Channel-vein	Nd	8,155	491	Tr	4,385	Nd
S57	Channel-vein	Nd	3,512	995	33,115	1,000	Nd
S58	Granodiorite	—	—	—	—	—	—

Tr = Trace. Nd = Not detected. — = Not determined.

Table 13. X-ray fluorescence analyses and description of samples from the Emerson mine (sample locations shown on figure 8).

Sample no.	Description	X-ray fluorescence (ppm)					
		Silver	Lead	Zinc	Copper	Manganese	Arsenic
S3-1	Chip fossiliferous limestone	--	--	--	--	--	--
S3-2	Channel-mineralized vein	Tr	699	2,009	Nd	Tr	Nd
S3-3	Channel-vein	Tr	890	2,222	Nd	Tr	Nd
Dump	Grab sample	Tr	790	1,339	Nd	Tr	Nd

-- = Not analyzed. Tr = Trace. Nd = Not detected.

faults were mapped in the adit level. The strike and dip of these faults are: N180°S, 54° W; N20°W, 35° NE; N65°E, 71° SE; N75°E, 71° N. The faults show brecciation, pulverized calcite, and clay alteration along their fault planes.

Secondary minerals identified in veins include cerussite, hemimorphite and aurichalcite, with limonite, hematite, and gangue of kaolinite, calcite and quartz.

The results of X-ray fluorescence analyses of samples collected from the dump and the underground workings of the mine are shown in table 13. For sample locations see figure 8.

Table 14 summarizes mineralization and commercial and X-ray fluorescence analyses of samples from the Milford Flat quadrangle.

#### FUTURE OF THE AREA

#### Metals

The production from mines in the Milford Flat quadrangle has been small; analyses of dump samples indicate only low-grade rock to be present and the prospects examined showed small potential.

Several scattered new prospects on the east side of the area show oxidized copper mineralization;

Table 14. Summary of mineralization, commercial and X-ray fluorescence analyses of some samples from mines and prospects in the Milford Flat quadrangle.

Sample	Mineralization	Commercial assay					X-ray fluorescence (ppm)				
		Oz/short ton		Percent			Silver	Lead	Copper	Zinc	Manganese
		Gold	Silver	Lead	Copper	Zinc					
Emerson dump	Lead, zinc	--	--	--	--	--	Tr	790	Nd	1,399	Nd
Estelle dump	Silver, copper	--	--	--	--	--	Nd	Tr	Nd	Nd	Tr
Adit level Estelle (second property)	Copper	--	--	--	--	--	Nd	4,813	Tr	Nd	Tr
God's Acres dump	Copper, lead, zinc, manganese	0.04	Tr	1.0	7.70	0.5	--	--	--	--	--
Gold Crown dump	Copper, silver, lead, zinc, manganese	--	--	--	--	--	Tr	1,298	916	16,547	7,300
Gold Crown inclined shaft	Lead, copper, silver, manganese	--	--	--	--	--	Tr	170	23,372	1,684	1,480
Maud-S dump	Copper, silver, zinc	Tr	2.1	Nd	--	0.6	Nd	Tr	Nd	Tr	Tr
New prospects on the east side of the area	Lead, manganese	--	--	--	--	--	Tr	Tr	42,350	999	Tr
Sundown dump	Copper, lead, zinc, manganese	--	--	--	--	--	Tr	3,512	33,115	995	1,000
Vicksburg dump	Lead, silver	Tr	4.0	4.0	--	Nd	Tr	32,000	Nd	1,199	Nd
Vicksburg surface stopes	Lead, silver	Tr	2.0	4.0	Nd	Nd	Tr	28,000	Nd	543	Nd
Woodhouse shafts dump	Copper, silver	--	--	--	--	--	Tr	Tr	Tr	Tr	Tr

-- = Not analyzed. Tr = Trace. Nd = Not detected.

several anomalously high copper assays also were noted in the various samples examined.

#### Nonmetals

##### Gravels

Large quantities of low-quality gravel in alluvial fans are available.

##### Sandstone

Large quantities of thin-bedded liesegang-banded sandstone occur in the upper parts of the Moenkopi Formation and parts of the Navajo Sandstone. They are attractive in color, gray to light brown with red to brown concentric bands, and can be used as facing stone. The sandstones are exposed northwest of the Gold Crown mine in sec. 28, T. 28 S., R. 11 W. According to Mark Dotson of Milford, some shipments of the sandstone were made. Unfortunately, large markets are distant and generally have local sources of sandstone.

##### Limestone

The area has large quantities of relatively pure limestone, especially in sec. 21, T. 28 S., R. 11 W.

##### Marble

The area has some potential for marble production. The marble contains attractive yellow serpentine streaks and bands. At present, the actual reserve is low, but drilling in sec. 28 might reveal quantities of marble

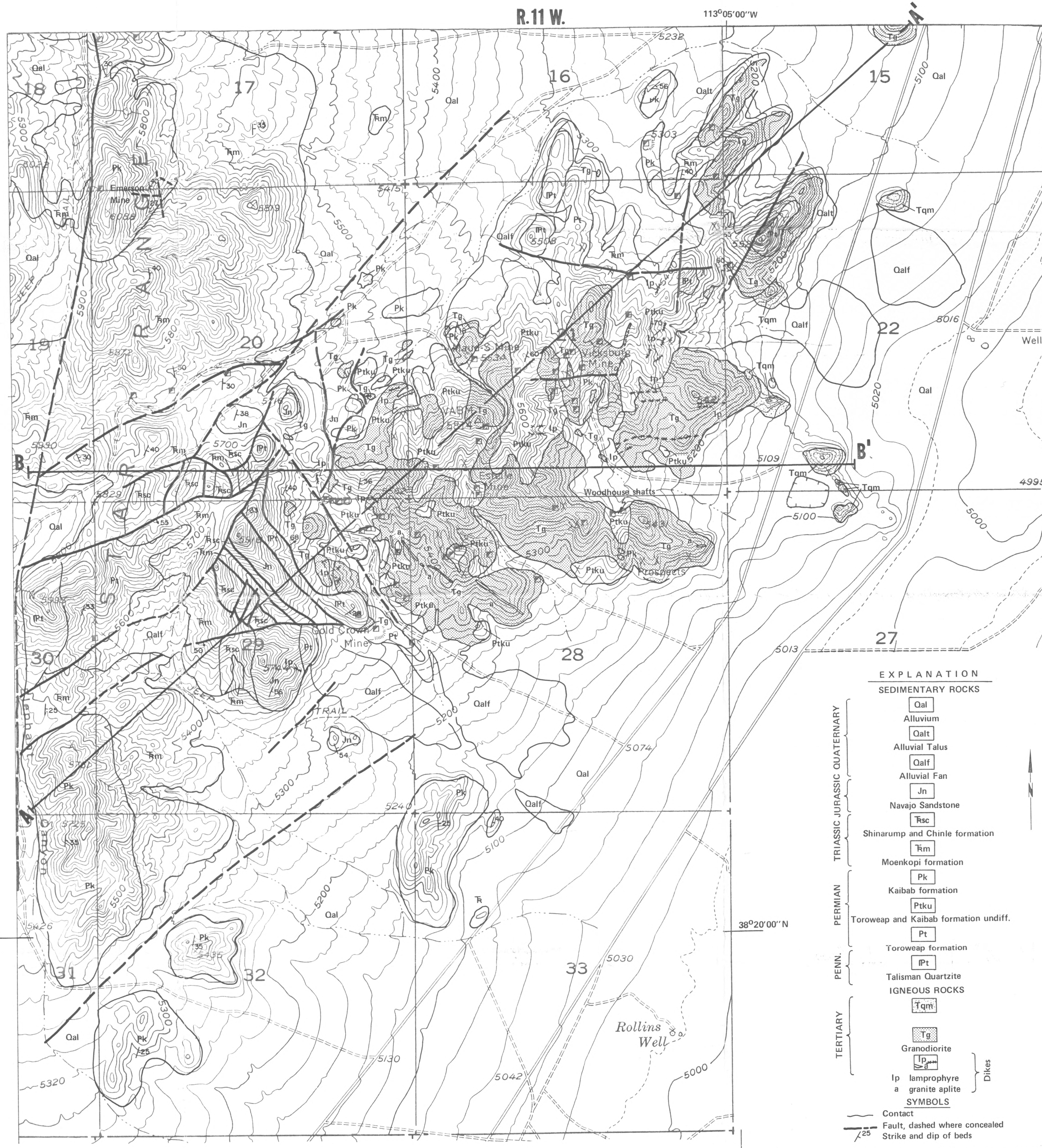
in the area. Fractures might prevent the production of large slabs.

#### Quartzite

The Talisman Quartzite Formation in the area is an extensive supply for a relatively pure quartzite. It is fractured, however, and has an unattractive weathered surface.

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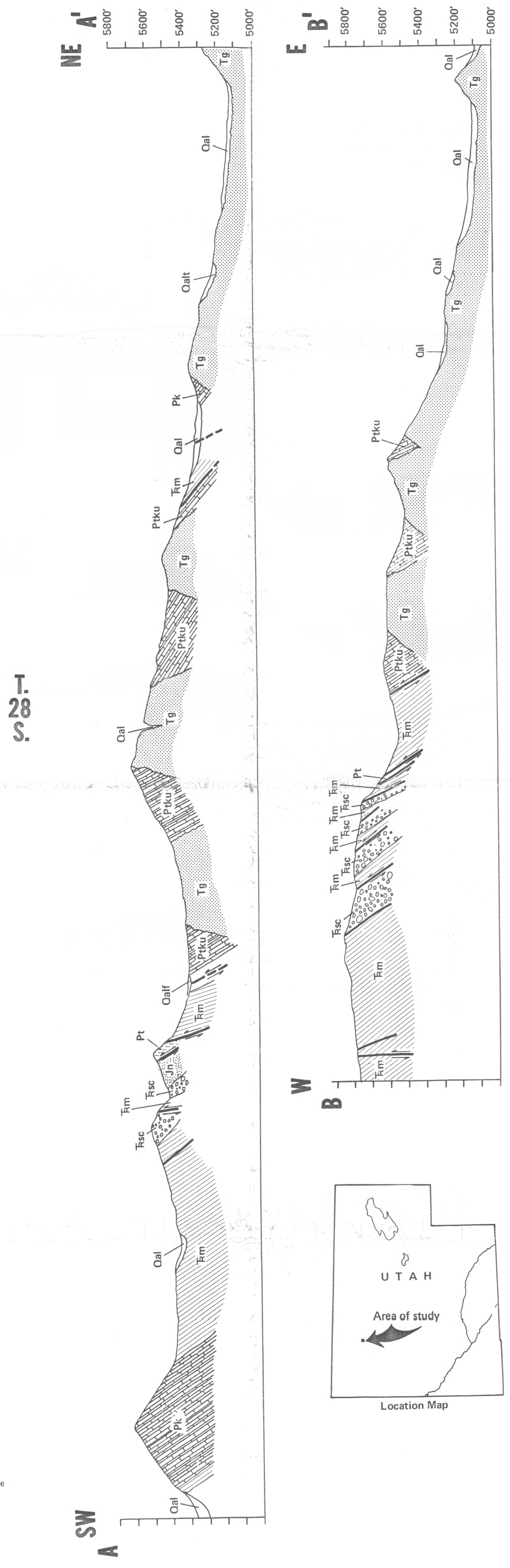
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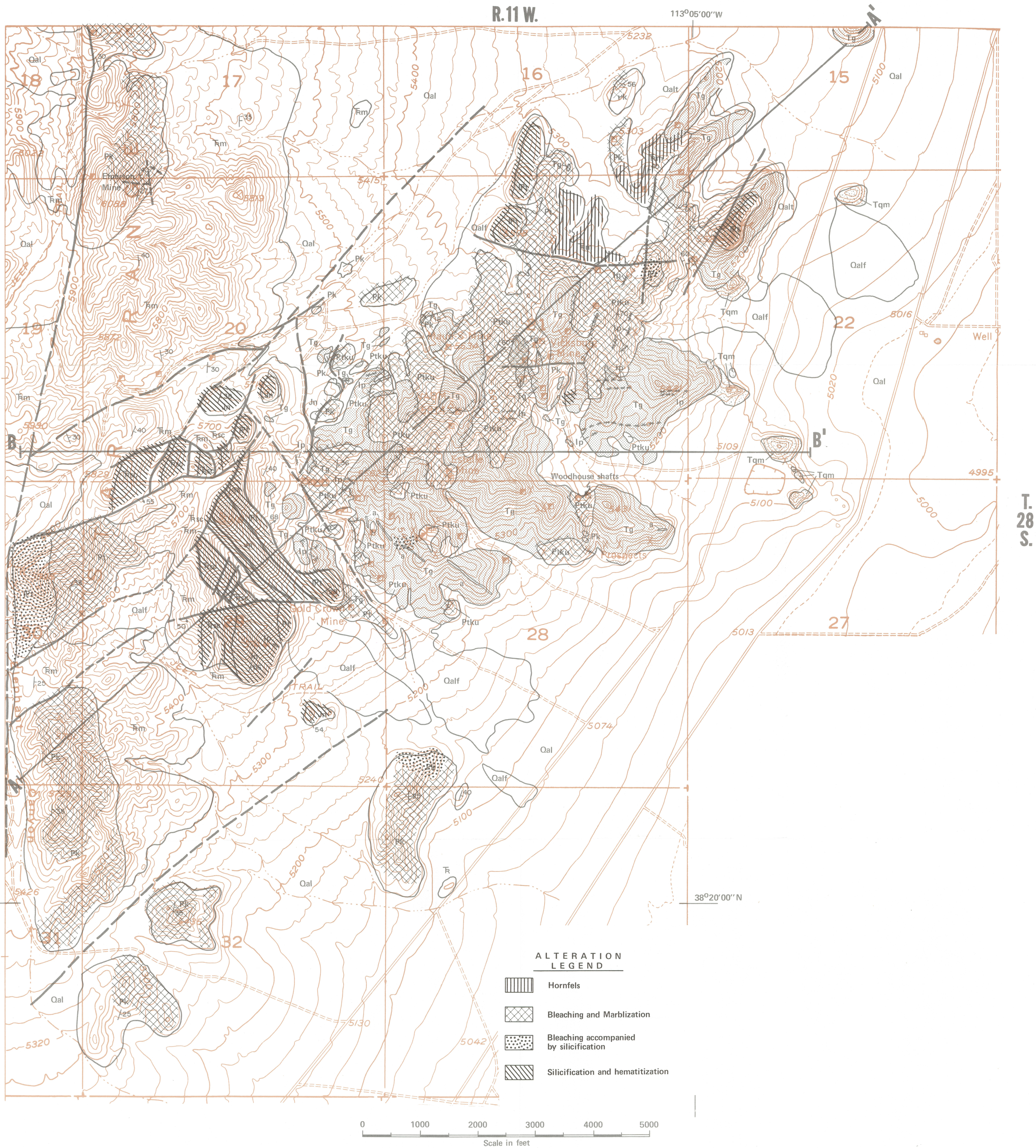
**EXPLANATION**

- SEDIMENTARY ROCKS**
- Qal Alluvium
  - Qalt Alluvial Talus
  - Qalf Alluvial Fan
  - Jn Navajo Sandstone
  - Rsc Shinarump and Chinle formation
  - Rm Moenkopi formation
  - Pk Kaibab formation
  - Ptku Toroweap and Kaibab formation undiff.
  - Pt Toroweap formation
  - Ptq Talisman Quartzite
- IGNEOUS ROCKS**
- Tqm Granodiorite
  - Ip lamprophyre  
a granite aplite
- SYMBOLS**
- Contact
  - Fault, dashed where concealed
  - Strike and dip of beds
- Dikes**
- Ip
  - Tqm

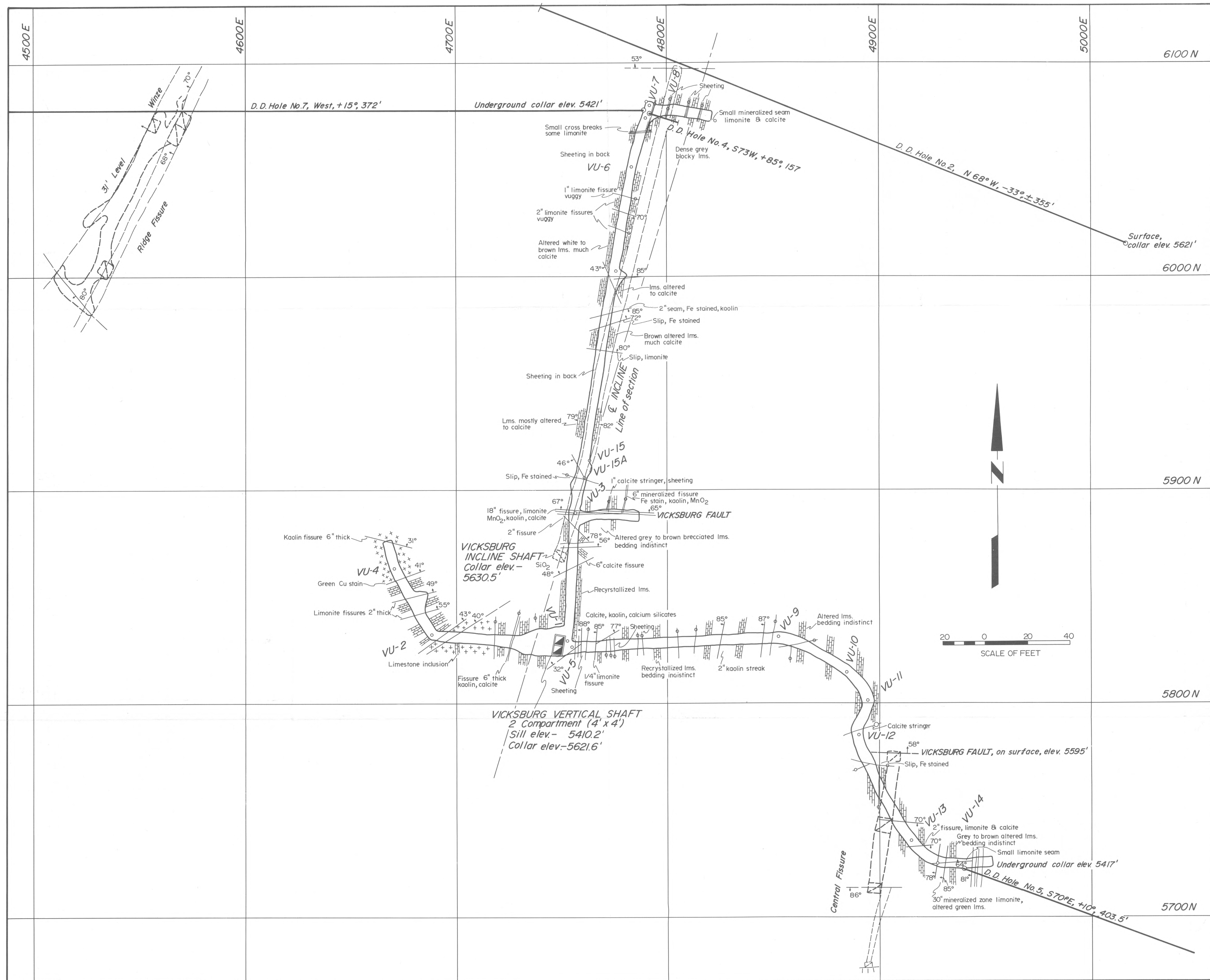
Base after U.S. Geological Survey, Milford Flat Topographic Quadrangle



**GEOLOGY AND SECTIONS OF THE NORTHWESTERN CORNER OF THE MILFORD FLAT QUADRANGLE, BEAVER COUNTY, UTAH**  
 Geology by S. Abou-Zied, 1967



**GEOLOGY AND SECTIONS OF THE NORTHWESTERN CORNER OF THE MILFORD FLAT QUADRANGLE, BEAVER COUNTY, UTAH**  
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**GEOLOGIC PLAN OF UNDERGROUND WORKINGS SHOWING LOCATION OF DIAMOND-DRILL HOLES, VICKSBURG MINE.**

# UTAH GEOLOGICAL AND MINERAL SURVEY

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

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The Survey is instructed to investigate areas of geologic and topographic hazards, to survey the geology and mineral occurrences, and to collect and distribute reliable information concerning the mineral industry and mineral resources, topography and geology of the state so as to contribute to the effective and beneficial development of the state. The *Utah Code, Annotated, 1953 Replacement Volume 5, Chapter 36, 53-36-1 through 12*, describes the Survey's functions.

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#### Directors:

William P. Hewitt, 1961-

Arthur L. Crawford, 1949-1961