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GEOLOGY BETWEEN PINE (BULLION) CREEK AND TENMILE CREEK EASTERN TUSHAR RANGE, PIUTE COUNTY, UTAH

by

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A Thesis

Submitted to

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Master of Science

by

Richard R. Kennedy

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LIST OF ILLUSTRATIONS AND TABLES

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ABSTRACT

The mapped area is located immediately south of Marysvale, Piute County, Utah. The area comprises a region that ranges in altitude from 5,825 feet to 11,000 feet. The area contains four principal physical divisions. It is a semi-arid region, and the chief industries are mining and stock raising.

Sedimentary rocks in the area total approximately 6,100 feet in thickness and range from middle Pennsylvanian to Tertiary-Quaternary in age. Paleozoic rocks are predominately carbonate. Mesozoic rocks are predominately sandstone and shale, with a subordinate amount of carbonate and conglomerate. Tertiary-Quaternary sediments are mainly conglomerate and alluvial debris. Some revisions of the local stratigraphic nomenclature is proposed with the introduction, into this part of Utah, of the terms Callville limestone, Oquirrh formation, Toroweap formation, and Winsor formation. A new formation, the Tushar conglomerate, is named.

It is postulated that during late Tertiary time a lake was formed in the vicinity, and south, of Marysvale as a result of a damming action on the Sevier River by volcanic flows and faulting in the Antelope Range.

Volcanic igneous rocks in the area total approximately 3,500 feet in thickness and range from middle Tertiary to Quaternary (?) in age. Four phases of volcanic activity are recognized: 1. Bullion Canyon series, consisting mainly of andesites, latite, tuff, and agglomerate; 2. Transitional series, consisting of tuff and latite; 3. Mount Belknap series, consisting of rhyolite, tuff, and latite; 4. Late Tertiary-Quaternary (?) basalt. The Bullion Canyon series is subdivided into three units, lower, middle, and upper, based on petrologic and petrographic observations.

The area exhibits structural features that are characteristic of the Colorado Plateau province to the east, namely nearly flat-lying sedimentary formations, and the Basin and Range province to the west, namely tilted fault blocks. North-south folds and faults are prominent but also present are less obvious northwest-southeast, and northeast-southwest trends.

Known ore deposits, except the alunite occurrences, are presently of minor importance. In the past, gold, silver, mercury, lead, copper, zinc, and alunite have been economically exploited. Ore deposits consist of vein and replacement types. Localization appears to have been controlled mainly by favorable Paleozoic carbonate beds, fault intersections, fracture patterns, and sedimentary-igneous contacts. Open space filling has been important as a mode of ore deposition.

INTRODUCTION

PURPOSE AND SCOPE

This thesis is the result of a study of the geology of part of Marysvale Valley and the eastern Tushar Range in the area south of Marysvale, Piute County, Utah. The study is primarily concerned with the more general aspects of the stratigraphy, volcanic rocks, structure, and ore deposits. It is the purpose to present a geologic map and report of the area under consideration.

LOCATION AND ACCESSIBILITY

Marysvale is located approximately 200 miles south of Salt Lake City, Utah, in west-central Piute County (Fig. 1). U. S. Highway 89 passes through Marysvale and continues southward through the center of the mapped area. A branch line of the D. & R. G. W. Railroad, now used only for freight purposes, extends south from Thistle, Utah, and terminates at Marysvale.

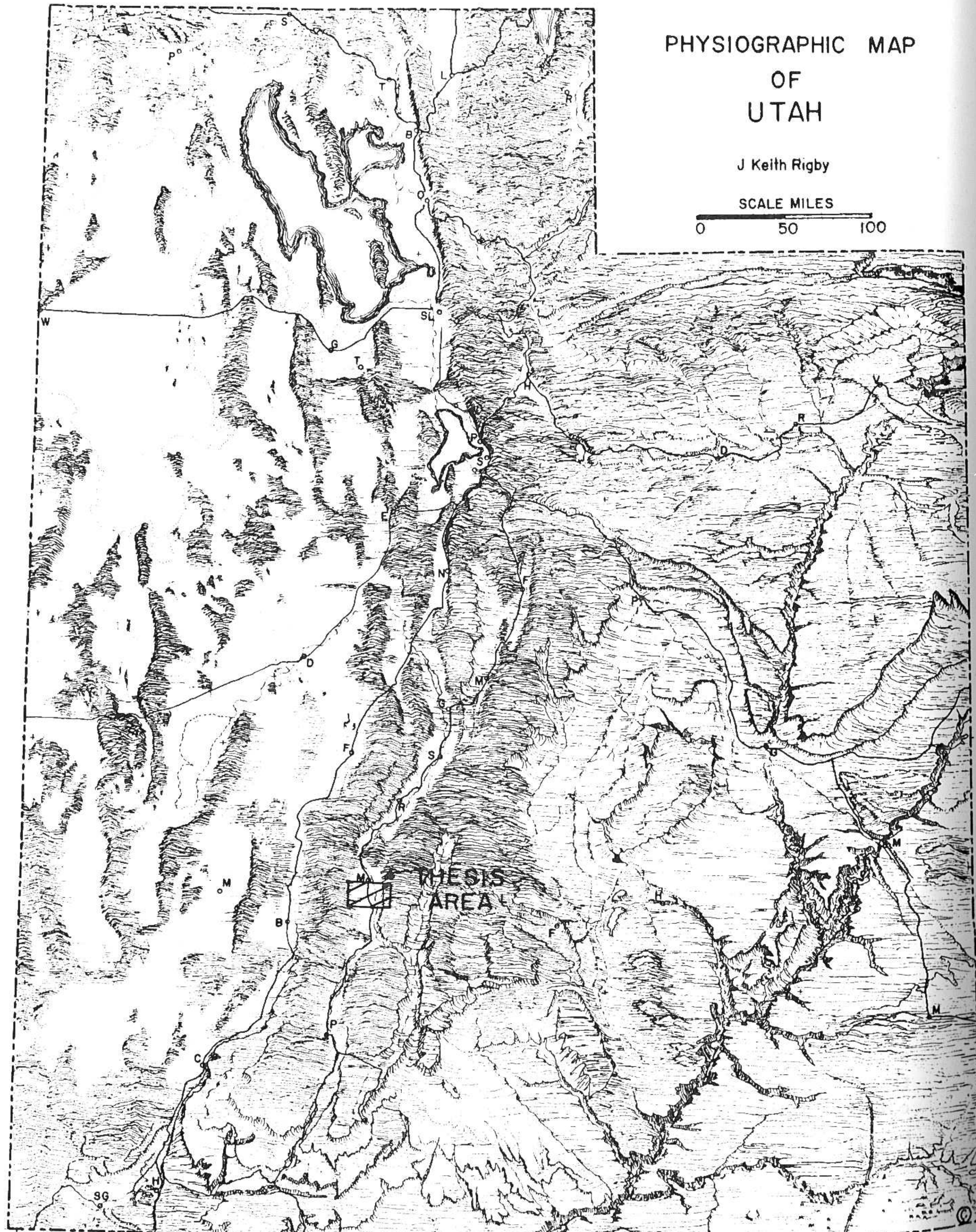
The mapped area is covered by the Marysvale and Delano Peak U. S. G. S. 15 minute quadrangle sheets, and is bounded on the east and west by meridians 112° 10' and 112° 20' respectively, and on the south and north by parallels 38° 20' and 38° 27' respectively. The total area mapped is approximately 50 square miles.

The eastern half of the area is easily accessible, due to low relief, via numerous dirt roads and "jeep trails". The central portion is readily accessible from U. S. Highway 89. The western portion has poor to improved dirt roads penetrating into every major canyon, but owing to the ruggedness of the Tushar Range much of the area is accessible only by foot.

PHYSICAL FEATURES

This region is part of the High Plateaus of Utah and lies within an area that is transitional between the Colorado Plateau province to the east and the Basin and Range province to the west. The region exhibits characteristics of both provinces and probably represents a portion of the Colorado Plateau upon which has been superimposed the effects of later Basin and Range structures.

FIGURE I



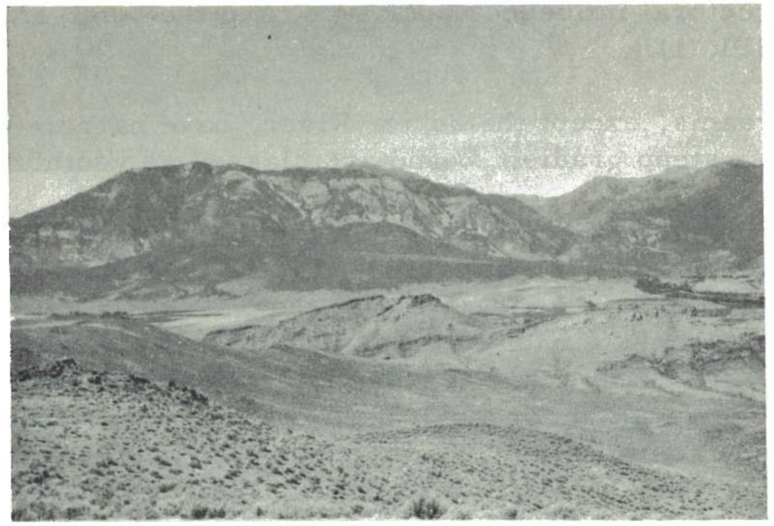
Topography is varied, but is generally recognized as being in late youth or early mature stage of development. Varied topography is a result of structural influence, rock type, and the semi-arid climate of the region (Pl. 1).

All streams, except the Sevier River, have narrow V-shaped cross sections, steep gradients, and are classed as youthful.

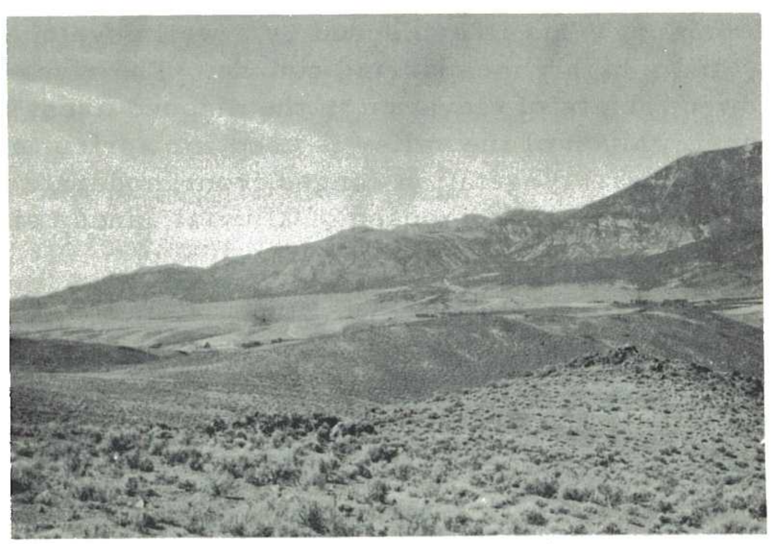
The mapped area contains four principle physical divisions, all having a northwest-southeast trend. On the east side of the area, immediately east of the Sevier River, is the East Hills division. East Hills are a southern extension of the Bullion Hills as discussed by Kerr et al. (1957). They trend approximately north 15° west and average slightly more than one-half mile in width, but tend to broaden at both north and south limits. To the north they merge with the Bullion Hills and the Antelope Range, and to the south they merge with the Elbow and Reservoir Hills. Maximum elevation is 6,300 feet with a maximum relief of 800 feet. They present a rather steep west-facing scarp. Rocks in the East Hills are mainly early and late Tertiary volcanics, Tertiary-Quaternary (?) basalt, and the Tertiary-Quaternary Sevier River formation. Vegetation is sparse.

Immediately west of the East Hills, and parallel to them, is the Sevier River Valley. This feature, as used in this paper, is confined to the present river valley and averages one-half mile in width. Maximum width is one mile and the minimum width is a few hundred feet. The river, in this part of its course, is in the mature stage of development. This is evidenced by a well developed strath, oxbow cutoffs, and a highly meandering course. The river valley contains the lowest points of elevation in the mapped area, approximately 5,820 feet. Much of the valley is used for agricultural and stock raising purposes. Vegetation ranges from moderate to sparse, and the floor of the valley is composed of alluvial sands, silts, and clays.

The third physical feature consists of bench and terrace gravel deposits, remnants of the Sevier River formation, alluvial fans, and landslide debris. This feature lies west of the Sevier River Valley division, and extends westward to the Tushar Fault scarp. The feature averages two miles in width, but is somewhat narrower at the south end. The bench and terrace gravels are essentially flat-topped remnants of a former level of the Sevier River, and Gillin (1941) found archaeological evidence of former habitation by a Basket Maker or Pueblo culture dating back to the 12th century A. D. The alluvial fans are rather large, gently convex features that slope outward from the



Varied Topography.
General view of thesis area, north half (top) and south half (bottom). Foreground is the middle unit of Bullion Canyon volcanic series in the East Hills. In the middle background is Marysvale Valley. Far background is eastern part of the Tushar Range.



mountain front, and are slowly covering the terrace and bench gravels. The landslide debris is confined to minor localities along the Tushar Fault scarp, mainly in the vicinity of the Deer Trail Mine. Maximum elevation of these features is 7,400 feet, and the maximum relief is 1,500 feet. Limited agricultural and stock raising is carried out upon the rocky "bench areas". Vegetation is sparse. The three features discussed above are the western part of a larger graben structure, Marysvale Valley.

A fourth physical division is the Tushar Range, of which only the eastern part is included in the mapped area. This division forms some of the most notable features of the area, rising very abruptly, in places, up to 3,000 feet in less than a mile. The Tushar Range is bounded on the east by the Tushar Fault and thus presents a very steep east-facing scarp. In the vicinity of the Deer Trail Mine, fault displacement has exposed Paleozoic and Mesozoic sediments capped by Tertiary volcanics. The sedimentary strata generally dip 12°-25° to the west. The Tushar Range is a tilted fault block cut by several deep, rugged canyons that divide the range into several smaller segments. The major canyons all trend northeast-southwest. Maximum elevation in the mapped area is 11,000 feet, and is just above timberline in the west part of the area. Vegetation is scattered, but locally may be abundant.

PREVIOUS WORK

The earliest geologic literature of importance on the Tushar Range and vicinity was written by C. E. Dutton (1880) as a part of the report on the Geology of the High Plateaus of Utah. The report is classic and provides the groundwork for later studies of the area. Butler and Gale (1912), described the alunite deposits near Marysvale. Butler, Loughlin, and Heikes (1920), described the general geology and ore occurrences as a part of the classic U. S. Geological Survey Professional Paper 111. Eardley and Beutner (1934), discussed the geomorphology of Marysvale Canyon and vicinity. Callaghan (1937), made a preliminary report on the alunite occurrences near Marysvale, and in 1939, published a report on the volcanic geology of the Marysvale region. Callaghan recognized the various volcanic and intrusive phases within the area and described their occurrences in some detail. He applied specifc names to the more important units. Proctor (1943), completed a Master's thesis study of the Bulley Boy Mine. Renewed interest in the alunite deposits, as a result of war-time activity produced work by Willard and Proctor (1946).

With the uranium discoveries of 1949-54 there came an abundance of reports on the area, mainly confined to the uranium occurrences in the Antelope Range to the north of the present thesis area. Callaghan and Parker (1951), placed on open file a map of Marysvale and vicinity. Parker (1954), completed a Ph. D. study of the alunitic alteration near Marysvale. Bethke (1957), completed a Ph. D. study of the mercury selenides in the Lucky Boy Mine. The most detailed work thus far undertaken on the volcanic rocks of the area was completed by Kerr et al. (1957). This work was published by the Geological Society of America as Special Paper 64.

The most recent work in the area was undertaken by Molloy (1958-59), as a part of a Ph. D. study from Columbia University. Molloy describes, in some detail, the Mount Belknap volcanic series northwest of Marysvale. The U. S. Geological Survey (1959) placed on open file the Delano Peak quadrangle and the south one-half of the Marysvale quadrangle.

FIELD AND LABORATORY STUDIES

Field work, upon which this report and accompanying map are based, commenced during June of 1958 and required approximately 90 field days to complete. Mapping of the area was accomplished by use of vertical aerial photographs having an approximate scale of 1:20,000. Geologic information was plotted directly on the photographs. Tilt, in the photographs, was effectively eliminated by utilizing a series of acetate overlays using flight lines and wing points as controls. The geologic information was then transferred to the Marysvale and Delano Peak topographic control sheets.

A brunton compass and a 100 foot steel tape were used in measuring stratigraphic sections.

A petrographic microscope and mechanical stage were used in determining the mineralogical composition and percentage of each mineral present in the thin sections.

Photomicrographs were made of the microscopic features, and "acetate peels" were made to show the structure and texture features on a megascopic scale.

STRATIGRAPHY

GENERAL STATEMENT

The stratigraphic sequence of the mapped area is composed of rock strata of the upper Paleozoic, Mesozoic, and Cenozoic eras. Approximately 6,100 feet of sedimentary rocks are exposed in the eatern part of the Tushar Range in an irregular area of about 15 square miles. The Paleozoic rocks are predominately carbonates. The Mesozoic rocks are predominately sandstones and shales with subordinate amounts of carbonate. Consolidated to partially consolidated sands, silts, and gravels of the Sevier River formation represent the Tertiary-Quaternary system, and recent sediments and alluvium represent the Quaternary system.

PENNSYLVANIAN SYSTEM

Deposition of Pennsylvanian sediments occurred near the eastern margin of the Paleozoic miogeosyncline. These are the oldest exposed rocks, and are found in the PTH Mine tunnel.

Callville Limestone

Callville limestone is composed of 692 feet of dark gray to light tan sandstone, limestone, dolomite, minor quartzites, and some gypsum near the base of the exposed section. The formation ranges from massive to thin-bedded, and locally contains nodules of dark gray chert and thin shale partings. The Callville is exposed only in the PTH Mine tunnel where the upper contact is observed but the base has not been exposed.

SECTION OF CALLVILLE LIMESTONE MEASURED IN THE PTH MINE TUNNEL FOUR MILES SOUTHWEST OF MARYSVALE, UTAH
(Sec. 11, T. 28 S., R. 4 W.)

PENNSYLVANIAN
Callville Limestone

Unit No.		Thickness (Feet)
12	Sandstone and shale: Dark brown, reddish-brown, to greenish-white. Brecciated and highly fractured. The beds have been slightly folded. Minor siltstone and limestone is present . . .	210'

11 Limestone: Light to dark gray, medium-grained, and arenaceous to dolomitic. Often contains $\frac{1}{4}$'' veinlets of pink to white calcite. Locally silicified, and contains disseminated and altered pyrite in addition to dendrites of iron and manganese oxides . . . . 272'

10 Limestone: Light gray to spotty yellowish-brown. Medium-grained and slightly arenaceous. Silicified, and contains disseminated and altered pyrite . . . . 8'

9 Limestone: Black, dark gray to greenish-gray, fine-grained and silicified. Often contains blebs and veinlets of white calcite and disseminated pyrite. Talc is a minor constituent, and locally there are abundant dendrites of iron and manganese oxides . . . . 99'

8 Limestone: Light gray to yellowish-brown. Arenaceous to dolomitic. Contains numerous veinlets of clear to milky white calcite and minor disseminated pyrite . . . . 39'

7 Limestone: Light gray to yellowish-brown, fine-grained, and arenaceous to argillaceous. Contains minor quartz inclusions and fine-grained pyrite . . . . 6'

6 Sandstone: Light gray to brown, medium-grained, slightly calcareous, roughly banded, and slightly cross-bedded. Fractures contain clear calcite . . . . 9'

5 Sandstone: Red to yellowish-brown, medium-grained and slightly banded . . . . 8'

4 Limestone: Yellowish-brown, medium-grained, and slightly banded . . . . 17'

3 Sandstone: Maroon to light green, and fine-grained. Slightly argillaceous and calcareous, with $\frac{1}{4}$'' veinlets of calcite . . . . 3'

2 Limestone and Quartzite: Gray to tan, and ranging from fine-grained to conglomeratic . . . . . 4'

1 Sandstone: Dark brown, fine-grained, and slightly calcareous. Contains numerous small veinlets of clear to milky white calcite. Becomes reddish-brown toward the lowest exposed part . 8'

Total thickness of measured Callville . . 692'

Unconformable

Age and Correlation

No fossils were found in the measured section; limited exposure makes the problem of correlation difficult. Correlation (Fig. 2) is based on stratigraphic position and lithology. The above measured section is therefore correlated with Callville to the south and southwest, and with the Hermosa and Supai formations to the southeast. The lower gypsiferous portion may, in part, be correlative with the Paradox member of the Hermosa in southeast Utah. The Callville at Marysvale may be representative of Morrowan to Desmoinesian age.

Oquirrh Formation

Strata immediately overlying the Callville are referred to the Oquirrh formation (Pl. 2), consisting of 580 feet of cross-bedded, fine-grained, tan, white, and flesh-colored orthoquartzite. In the PTH Mine tunnel, the base of the formation is exposed, and the upper contact is exposed in the vicinity of the Deer Trail Mine and southward toward Cottonwood Canyon where it is down-faulted and covered by overburden. Eolian processes appear to have been instrumental in deposition of some beds, and part of the formation may have accumulated on the shelf and in the proximal part of the miogeosyncline, representing the southward extension of the Oquirrh Basin of Utah.

The unconformity at the base of the Oquirrh formation probably represents a time when the seas were withdrawn, or at least were receding, from the area. In part, the Oquirrh formation was deposited in an eolian environment on the stable shelf or part of the craton. The unconformity at the top of the Oquirrh formation represents a considerable period of time during which the transition was again made from essentially eolian conditions to a marine environment.

SECTION OF OQUIRRH FORMATION, LOWER PART MEASURED IN PTH TUNNEL, UPPER PART MEASURED ON EAST FACE OF DEER TRAIL MOUNTAIN, FOUR MILES SOUTHWEST OF MARYSVALE, UTAH
(Sec. 11, T. 28 S., R. 4 W.)

PENNSYLVANIAN
Oquirrh Formation

Unit No.		Thickness (Feet)
2	Quartzite: White, brown, tan, flesh-colored, and medium grained. Fractured throughout and often recemented. Exposed in the PTH tunnel. Locally contains minor pyrite and galena mineralization. Also may locally contain large open vugs and fractures	220'
1	Quartzite: White, tan, and flesh-colored. Clean, medium-grained and cross-bedded throughout. A persistent cliff former with well developed talus slopes obscuring the lower part of the formation. Highly fractured and recemented.	360'
	Total thickness of measured Oquirrh . .	580'

Unconformable

Age and Correlation

No fossils were found in the measured section and correlation (Fig. 2), is based on lithology and stratigraphic position.

Previous workers have considered this formation to be Coconino sandstone. There are, however, certain difficulties in correlating this quartzite unit with the Coconino of Arizona, and the problem has been recognized by other writers. Concerning this problem, McKee (1952) states "Thus it seems likely that the original margin of deposition was in proximity to the area under discussion and that sandstones farther north, some of which have been correlated with the Coconino, probably are not a part of this unit despite lithologic similarities. Among deposits in this category is an un-named cross-stratified quartzite underlying the Toroweap formation at Minersville, Utah." The preceeding statement also will apply to the section at Marysvale, Utah. Bissell (personal communication*) suggested that the quartzite unit in question is Desmoinesian Oquirrh.

*Field Conference

The term Oquirrh is preferred for the Marysvale unit and as such is correlated with Desmoinesian Oquirrh at Milford, Utah, (Bissell 1959), and at Kanosh, Utah (Crosby 1959). The Marysvale unit might also be correlated with part of the Weber quartzite and part of the Oquirrh formation of north-central Utah.

Further work might show that the term Coconino is not appropriate in south-central Utah. If such proves to be the case, correlation can also be made with the so-called Coconino sandstone of the San Rafael Swell and vicinity, and perhaps the Circle Cliffs region.

PERMIAN SYSTEM

Toroweap Formation

The Toroweap formation consists of 306 feet of interbedded tan to light yellowish-gray limestone, dolomite, and quartzite. The Toroweap disconformably overlies the Oquirrh formation and in general follows the same outcrop pattern as the Oquirrh. Toroweap forms steep cliffs that contrast sharply with the underlying dark tan to flesh-colored Oquirrh beds (Pl. 2).

The lower portion of the Toroweap formation is a rather porous limestone, and contains abundant lenses of massive quartzite. The principle ore bodies of the Deer Trail and Lucky Boy Mines were mainly confined to the lower 100 feet, or so, of the formation.

The term Pakoon Limestone might have equally well been applied to this formation, if physical lithology alone is considered. However, because of the relative closeness to previously described sections at Minersville and Milford where the term Toroweap is used, the term Toroweap is used at Marysvale also.

SECTION OF TOROWEAP FORMATION MEASURED ON EAST FACE OF DEER TRAIL MOUNTAIN, FOUR MILES SOUTHWEST OF MARYSVALE, UTAH
(Sec. 11, T. 28 S., R. 4 W.)

PERMIAN
Toroweap Formation

Unit No.		Thickness (Feet)
4	Limestone and sandstone: Light tan to yellowish-gray, medium-grained, vuggy and porous. The weathered surface is often light brown	58'

3	Limestone, quartzite, and dolomite: Limestone is light gray, porous, and arenaceous. Quartzite is light tan and fine to medium-grained, and forms lenses that are interbedded with limestone and dolomite. The dolomite is similar in appearance and weathering characteristics to the limestone. Dendrites of iron and manganese oxides are abundant as are veinlets of milky white calcite. The entire formation appears, from a distance, to weather a light gray	224'
2	Limestone: Dark gray to black with some included brown chert. Locally silicified and contains some stringers of white calcite. Weathers light gray	23'
1	Limestone: Buff to light brown, with minor tan quartzite, and arenaceous. Weathers light gray	11'
	Total thickness of measured Toroweap	306'

Conformable (?)

Age and Correlation

No fossils were found in the measured section and correlation (Fig. 2), is based on stratigraphic position and lithology. The Toroweap formation is correlated with the Toroweap formation of surrounding areas, such as the Frisco district (Bissell 1959) and Pavant region (Crosby 1959). The age of the Toroweap formation is probably Leonardian.

Kaibab Limestone

Kaibab limestone consists of 348 feet of light to dark gray limestone and dolomite. The formation weathers to a light-gray that is distinguishable from the yellowish tint of the underlying Toroweap formation. Locally the Kaibab limestone is fossiliferous and contains remnants of crinoids and spiny shelled brachiopods. The formation outcrops only on the Deer Trail face of the Tushar Range (Pl. 2), and as such is of limited extent for geologic study. Zones of local mineralization are found in various beds within the Kaibab limestone.

The unconformity at the top of the Kaibab limestone marks a withdrawal of the Kaibab sea, probably to the south and southwest, and a change to tidal mudflat conditions of deposition for the early Moenkopi sediments.

SECTION OF KAIBAB LIMESTONE MEASURED ON EAST FACE OF DEER TRAIL MOUNTAIN, FOUR MILES SOUTHWEST OF MARYSVALE, UTAH (Sec. 11, T. 28 S., R. 4 W.)

PERMIAN

Kaibab Limestone Unit No.		Thickness (Feet)
9	Limestone: Brown to light pinkish-gray, fine-grained. Weathers tan to brown	100'
8	Limestone: Light gray to yellowish-brown, with minor quartzite nodules and lenses. Weathers tan	13'
7	Limestone: White to light gray, and slightly arenaceous. Roughly banded and contains numerous small calcite veinlets and crystals. Weathers tan	3'
6	Limestone: Tan to yellowish-gray cliff-former with numerous veinlets of white calcite. Fossiliferous with a dictyclostus zone at the base. Weathers light gray	42'
5	Limestone: Light tan to white, medium-grained, and crystalline. Contains spots and blebs of iron oxide. Weathers gray, white, and brown .	54'
4	Limestone: Light gray to white with veinlets of calcite. Fine-grained to sub-lithographic. Weathers tan to light gray	26'
3	Limestone: Light brown to tan, arenaceous, and contains 6" lenses of quartzite. Locally may be silicified. Weathers with a distinct "knobby relief" surface	60'
2	Limestone: Light brown to tan, and roughly banded. Fine-grained and contains minor amounts of quartzite and dolomite. Fractures are coated with calcite crystals. Weathers tan to white. .	10'

1 Limestone: Dark gray to black, coarse-grained, and arenaceous. Locally brecciated with some inclusions of yellowish-brown calcareous sandstone. Slope former. Weathers dark gray. 20'

Total thickness of measured Kaibab 348'

Unconformable

Age and Correlation

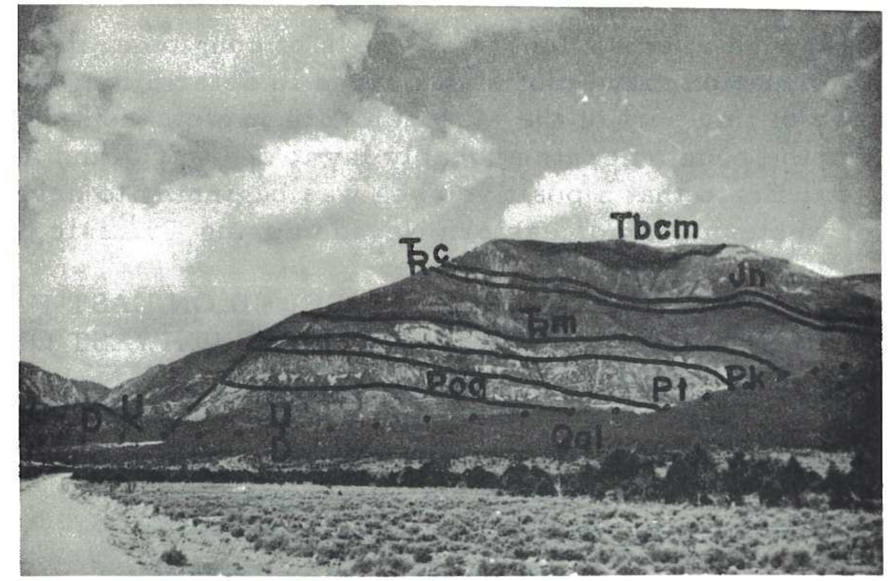
Correlation (Fig. 2), is based primarily on stratigraphic position and lithology, but the presence of a few crinoid remains and spiny brachiopods, particularly Dictyclostus bassi, indicate a Kaibab fauna. The Kaibab limestone is correlated with the Kaibab formation of the Park City group in north-central Utah; with the Cutler formation to the east and southeast, and with the Kaibab of surrounding areas. It is probably Guadalupian age.

TRIASSIC SYSTEM

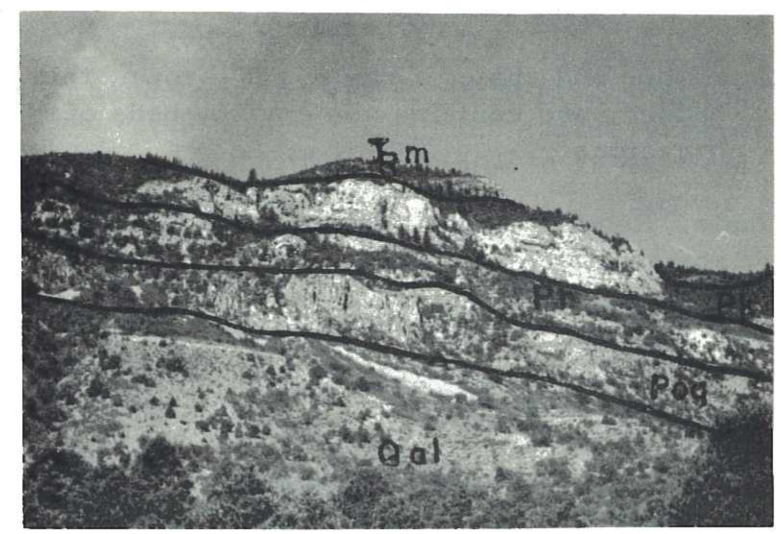
Moenkopi Formation

The Moenkopi formation consists of 1227 feet of varie-colored shales, sandstones, limestones, and local conglomerates. The lower 124 feet consists of red-brown to light green shales and sandstone. Overlying the lower red beds is 278 feet of dark gray, "knobby" weathering limestone that is considered to be the Virgin limestone member. The upper red bed units consist of 825 feet of red, brown, and light green shale, sandstone, and thin limestone conglomerate.

A conspicuous part of the Moenkopi formation is the Virgin limestone member that forms a dark-gray cliff above the lighter gray cliffs of the Kaibab limestone (Pl. 2). In general, the Moenkopi is a slope former and the upper part is mostly covered by overburden, and as such, presents few good outcrops for observation. The upper part contains some intraformational folds (Pl. 3A) of small magnitude, ripple marks, mudcracks, and raindrop impressions. The top of the Moenkopi is an erosion surface from the geologic past. The Moenkopi outcrops to a greater extent than the underlying formations, extending from Cottonwood Canyon to Bullion Canyon.



A. East face of Deer Trail Mountain showing trace of the Tushar fault, outcrop of the Oquirrh formation (Poq), Toroweap formation (Pt), Kaibab limestone (Pk), Moenkopi formation ($T_R m$), Chinle formation ($T_R c$), Navajo formation (Jn), and the middle unit of the Bullion Canyon volcanic series.



B. Closer view of Deer Trail Mountain shows the cliff-forming nature of the Oquirrh formation (Poq), Toroweap formation (Pt), Kaibab limestone (Pk), and the Moenkopi formation ($T_R m$).

The presence of small lenses and beds of conglomerate within the Moenkopi formation may be of significance in determining the tectonic history of this part of the Mesozoic Era in west-central Utah. The source for the conglomerate probably lay to the west, and as such, would seem to indicate that a positive area was beginning to develop in the vicinity of western Utah or eastern Nevada during Triassic time.

SECTION OF MOENKOPI FORMATION MEASURED ON EAST FACE OF DEER TRAIL MOUNTAIN, FOUR MILES SOUTHWEST OF MARYSVALE, UTAH
(Sec. 11, T. 28 S., R. 4 W.)

TRIASSIC
Moenkopi Formation — Thickness (Feet)
Unit No.

16 Sandstone and shale: Brick red to brown, and thin-bedded. Weathers to a subdued slope . . . 124'

15 Limestone: Dark to light gray, fissile, and weathers to a "knobby relief" surface. Forms subdued, rounded cliffs. Locally fossiliferous with remnants of Meekoceras? . . . . . 278'

14 Sandstone and shale: Red to green, thin bedded and contains seams of white calcite up to 4" in width. Slope former . . . . 71'

13 Sandstone and shale: Gray to red-brown, thin bedded, and contains some 4"-6" beds of limestone . . . . 41'

12 Shale: Reddish-brown, thinly bedded, and somewhat arenaceous . . . . 10'

11 Quartzite and limestone: White to light green, medium to coarse grained. Weathers light green. . . . . 15'

10 Sandstone: Brick red to brown, with minor dark, reddish-brown shale partings up to 2" in thickness. Slope former.
This interval subject to error . . . . 60'

9 Sandstone and shale: Tan to greenish-gray, medium grained. The shale generally acts as parting surfaces. Ripple marked. Slope former . . . 40'

8 Limestone: Greenish-gray, fine-grained, and slightly arenaceous . . . . 3'

7 Shale: Dark brown, brick red, and green. Arenaceous and ripple marked. Slope former . 22'

6 Limestone: Tan to light gray, and fine-grained. . 4'

5 Shale and sandstone: White to light green, medium grained and ripple marked. Slope former.
This interval subject to error. . . . . . . 200'

4 Shale and sandstone: Light brick red to brown, and fine-grained. Slope former.
This interval subject to error. . . . . . . 62'

3 Sandstone, shale, and conglomerate: Sandstone is light pink to greenish-white, and medium-grained. Shale occurs mainly as partings. The conglomerate beds are usually less than 6" in thickness. Slope former.
This interval subject to error. . . . . . . 43'

2 Sandstone and shale: Dark red, pink, and brown. Thinly bedded with small 3' intraformational folds and some faults. Steep slope former.
This interval subject to error. . . . . . . 48'

1 Sandstone and shale: Dark green, tan, gray, and light brown. Becomes coarse-grained toward the top. Upper surface is an erosional surface from the geologic past. Cliff former.
This interval subject to error. . . . . . . 150'

Total thickness of measured Moenkopi . 1227'

Unconformable

Age and Correlation

Age of the Moenkopi formation is considered to be early Triassic. Correlation is based on lithology and stratigraphic position. The Moenkopi formation at Marysvale is correlated (Fig. 2), with the Moenkopi formation of surrounding areas, and with the Thaynes and lower Woodside formations of north-central Utah. The Virgin limestone member contains remnants of the fossil cephalopod Meekoceras, and is considered to be correlative with the Sinbad limestone member of eastern Utah, and the Thaynes formation of north-central Utah.

Shinarump Conglomerate

Shinarump conglomerate consists of 94 feet of quartzite pebble conglomerate, coarse sandstone, and associated organic material. The Shinarump has been deposited with marked unconformity upon the underlying Moenkopi formation. The Shinarump is generally a cliff-forming unit.

Outcrop pattern of the Shinarump conglomerate is similar to that of the Moenkopi formation, extending from Cottonwood Canyon to Bullion Canyon (Pl. 2A).

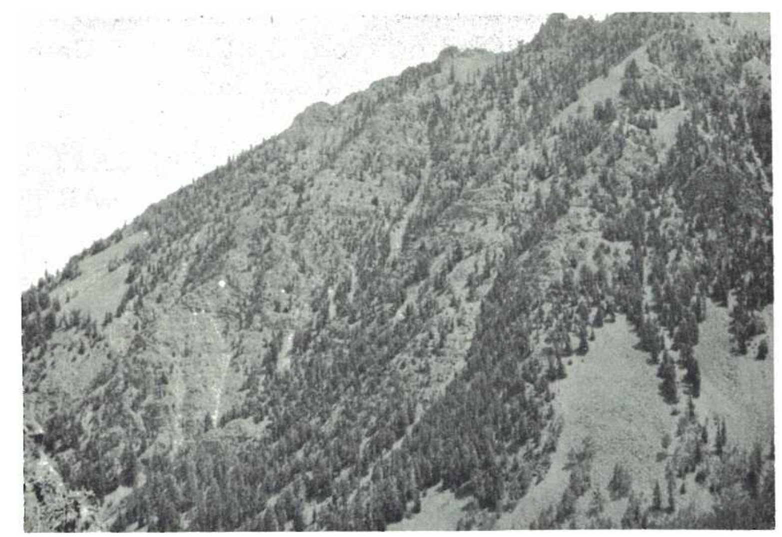
SECTION OF SHINARUMP CONGLOMERATE MEASURED ON EAST FACE OF DEER TRAIL MOUNTAIN, FOUR MILES SOUTHWEST OF MARYSVALE, UTAH
(Sec. 11, T. 28 S., R. 4 W.)

TRIASSIC
Shinarump Conglomerate

Unit No.		Thickness (Feet)
5	Conglomerate and sandstone: White, tan, or dark brown. The conglomerate consists of coarse, rounded quartzite pebbles cemented with quartz sandstone. Sandstone is white, tan, locally cross-bedded, and coarse-grained. Carbonaceous material is present as small logs, twigs, and moldy material. Cliff former	21'
4	Sandstone: Tan to white, coarse-grained. Weathers in slabby masses. Cliff former . .	17'
3	Sandstone: Tan to white, coarse-grained, cross-bedded, and friable. Cliff former . . .	30'
2	Sandstone: Brown to gray, coarse-grained with enclosed greenish-gray clay pellets. Upper part is slabby in character. Cliff former. . .	12'

Plate 3

A. Moenkopi Formation.
Small intraformational folds in the upper part of the Moenkopi formation, on the east face of Deer Trail Mountain.



B. Navajo Formation.
Note tendency to form cliffs and general rugged topography. The abundant talus slopes locally develop into small rock glaciers.

1	Sandstone: Tan to buff, and medium-grained. Weathers tan, and is a cliff former	14'
	Total thickness of measured Shinarump . .	94'

Conformable

Age and Correlation

Age of the Shinarump conglomerate is Triassic and correlation is made with Shinarump and Mossback units of surrounding areas. Correlation is based on lithology and stratigraphic position.

Chinle Formation

Chinle formation consists of 240 feet of varie-colored sandstone and shale. The lower part of the Chinle is more arenaceous than the upper part. Contact with the underlying Shinarump is generally rather distinct, but may be gradational. Contact with the overlying Navajo formation is very distinct and definite.

Outcrop pattern of the Chinle is similar to that of the Moenkopi and Shinarump formations, extending from Cottonwood Canyon to Bullion Canyon (Pl. 2A), and is a steep slope former.

SECTION OF CHINLE FORMATION MEASURED ON EAST FACE OF DEER TRAIL MOUNTAIN, FOUR MILES SOUTHWEST OF MARYSVALE, UTAH (Sec. 11, T. 28 S., R. 4 W.)

TRIASSIC
Chinle Formation

Unit No.		Thickness (Feet)
13	Shale: Greenish-brown to tan, massive and arenaceous. Weathers brown. Slope former .	7'
12	Quartzite and shale: Quartzite is yellowish-tan and medium-grained. The shale is dark brown and interbedded with quartzite. Weathers brown. Slope former	4'
11	Shale: Maroon, dark purple, greenish-brown, fissile, and contains minor siltstone. Weathers brown. Slope former	7'

10	Shale: Maroon, dark purple, green, and black. Slightly arenaceous. Slope former	16'
9	Limestone: Greenish-gray pebble conglomerate. Forms a small ledge	3'
8	Shale and siltstone: Shale is maroon. Siltstone is maroon to dark brown. Locally may contain some tan quartzite. Cliff former	23'
7	Shale and siltstone: Maroon, cherty, and locally conglomerate. Weathers to a small, rough surfaced cliff	35'
6	Limestone: Light to dark gray, and conglomeratic with maximum size of fragments approximately 2"	2'
5	Shale and siltstone: Shale is maroon to brick red. Siltstone is dark brown. Weathers brown. Slope former	16'
4	Sandstone and shale: Reddish-purple to white spotted, medium to fine-grained. Locally becomes light orange-red to a darker maroon. Cliff former	67'
3	Sandstone and siltstone: Dark red, maroon, to light purple with gray-white lenses. Thinly bedded. Near the base there are minor 4"-6" beds of limestone conglomerate. Steep slope former	56'
2	Sandstone and shale: Sandstone is maroon to brick red and medium-grained. Shale consists of dark brownish-red "clay balls". The lower 4"-8" contains abundant but irregular calcite replacements. Cross-bedding is well developed. Steep slope former	4'
1	Sandstone: Gray to greenish-gray and coarse-grained. Locally conglomeratic. Fragments are usually subrounded and less than 1/16" in size. Contact with the overlying Navajo formation is very sharp. Steep slope former	5'
	Total thickness of measured Chinle	240'

Conformable

Age and Correlation

Chinle formation is considered to be Triassic in age, and is correlated (Fig. 2), with the Chinle formation of surrounding areas, including the upper part of the Ankareh formation of north-central Utah.

No fossils were found in the measured section and correlation is based on lithology and stratigraphic position.

TRIASSIC-JURASSIC AND JURASSIC SYSTEM

Navajo Formation

The Navajo formation consists of 1722 feet of massive, hard, cross-bedded quartzite. The unit forms steep rugged cliffs as much as 500 feet in height, and forms large, blocky talus slopes (Pl. 2 and 3B). The development of talus slopes and rugged topography is apparently a function of the hardness and joint patterns. Constituent particles are rounded to sub-rounded, medium-grained quartz grains. The entire formation is well indurated and is cemented with silica and carbonate. It is possible that the cementing material may, in part, be reflective of the original depositional environment. Cementing materials could have been added by percolating ground water, or locally, submergence.

The Navajo formation outcrops over a greater area than any other sedimentary unit in the thesis area, and the measured section at Marysvale may also include the Wingate and Kayenta formations.

SECTION OF NAVAJO FORMATION MEASURED ON SOUTH SIDE OF BULLION CANYON, FOUR MILES SOUTHWEST OF MARYSVALE, UTAH
(Sec. 34, T. 27 S., R. 4 W., and
Sec. 3, T. 28 S., R. 4 W.)

TRIASSIC-JURASSIC AND JURASSIC ?

Navajo Formation Unit No.		Thickness (Feet)
12	Sandstone and quartzite: Light reddish-brown, tan and white. Generally massive but locally may be thin-bedded. Disseminated pyrite weathers to give the reddish-brown iron oxide color that may be either random or banded. Cliff former. May be part of the Wingate formation	60'
11	Quartzite: Tan to white, medium-grained, well cemented, and contains abundant reddish-brown specks. Often obscured by upper talus material. Cliff former. May be part of the Wingate formation . . .	460'
10	Sandstone: Greenish-gray to light reddish-brown, well cemented, and contains some argillaceous material. Micaceous on bedding. Locally contains elongate dark spots of iron oxide. Thin bedded. Cliff former. May be part of the Kayenta formation . . .	8'
9	Quartzite: White to tan, medium-grained, and well cemented. May often be banded and spotted brown where pyrite has been altered. Cliff former. May be part of the Kayenta formation . . .	10'
8	Sandstone: Tan, medium-grained, and thin bedded. Poorly cemented and locally argillaceous. Cliff former. May be part of the Kayenta formation . . .	2'
7	Sandstone and quartzite: Tan to white, medium-grained, recemented, and locally contains minor light green, argillaceous material. Cliff former. May be part of the Kayenta formation . . .	16'
6	Quartzite: Tan to white, medium-grained, thin bedded with some argillaceous material. Some secondary quartz in fractures. Micaceous on bedding, with associated iron and manganese oxides. Cliff former. May be the upper part of the Kayenta formation	360'
5	Quartzite: Tan to white, medium-grained with some yellowish-brown banding. Cross bedded. Cliff former. May be the lower part of the Navajo . . .	52'
4	Quartzite: Tan to yellowish-brown, medium-grained. Stained yellow to brown along some zones and fractures. Slightly banded. Cliff former. May be part of the Navajo	180'

3	Quartzite: White to tan, massive, medium-grained, and recemented. Locally contains some light reddish-brown to white banding. Prominent cliff former. Part of the Navajo	260'
2	Sandstone and quartzite: Yellow-brown to white, medium-grained, thin bedded and poorly banded. Cliff former. Part of the Navajo	4'
1	Sandstone and quartzite: Tan, reddish-brown to white, with banding common. Cross bedded. Prominent cliff former. Part of the Navajo	310'
	Total thickness of measured Navajo	1722'

Conformable (?)

Age and Correlation

The Navajo formation as described above, probably includes the Triassic Wingate formation, and Jurassic (?) Kayenta formation, and the Jurassic and Jurassic (?) Navajo sandstone. The term Navajo as used here is correlated (Fig. 2), with the Nugget sandstone of north-central Utah and the Glen Canyon group of surrounding areas.

No fossils were found in the measured section and correlation is based on lithology and stratigraphic position.

JURASSIC SYSTEM

Winsor Formation

Winsor formation of Jurassic age consists of 610 feet of dark gray limestone, tan and red sandstone, and red to light greenish-gray arenaceous and argillaceous fissile limestone. The term Winsor, as applied to the Marysvale region, probably includes the equivalents of the Carmel limestone, Curtis, and Entrada formations.

SECTION OF WINSOR FORMATION MEASURED ON NORTH SIDE OF TENMILE CREEK, SEVEN MILES SOUTHWEST OF MARYSVALE, UTAH (Sec. 36, T. 28 S., R. 4 W.)

JURASSIC

Winsor Formation Unit No.		Thickness (Feet)
3	Limestone: Light to dark gray, fine-grained. Generally massive to thin-bedded. Locally may be argillaceous to arenaceous. 6" beds of dark gray oolitic limestone. Cliff former in thickest part, otherwise forms a subdued slope. Probably equivalent to the Carmel limestone	315'
2	Sandstone and limestone: Sandstone is tan to light brown, medium-grained. Limestone is greenish-gray, fissile to massive, ripple marked, and locally contains gypsiferous partings. Steep slope former. May be equivalent to the Curtis formation. .	185'
1	Sandstone: Brick-red to chocolate-brown, cross bedded, and ripple marked. Locally argillaceous. Weathers in slabby masses. Steep slope former. May be part of Entrada (?) equivalent. This interval subject to error.	110'
	Total thickness of measured Winsor . .	610'

Unconformable

Age and Correlation

Age of the Winsor formation is considered to be Jurassic, and is correlated (Fig. 2), with the Winsor formation of southern Utah, the Twin Creek limestone of northern Utah, and the lower part of the Arapien shale of Sevier and Sanpete Counties, Utah. The unit at Marysvale probably includes equivalents of the Carmel, Curtis, and Entrada formations.

Dutton (1880) and others have recognized the presence of Pentacrinus asteriscus, a characteristic Jurassic fossil.

CRETACEOUS (?) SYSTEM

Tushar Conglomerate (new name)

Overlying the Winsor formation with marked unconformity is a limestone conglomerate. The unit is exposed only as disconnected outcrops, but appears to become more continuous and to increase in thickness toward the south. The Tushar conglomerate is pebble-size to smaller (Pl. 4), well cemented, very resistant to weathering, and forms steep slopes and small step-like cliffs.

SECTION OF TUSHAR CONGLOMERATE MEASURED ON NORTH SIDE OF TENMILE CREEK, SEVEN MILES SOUTHWEST OF MARYSVALE, UTAH (Sec. 36, T. 28 S., R. 4 W.)

CRETACEOUS (?) Tushar Conglomerate Unit No.		Thickness (Feet)
1	Limestone conglomerate: light to dark gray, pebble-size to smaller, and well cemented. Steep slope to cliff former	65'
	Total measured thickness of Tushar Conglomerate	65'

Unconformable

Age and Correlation

The age of the Tushar conglomerate can only be with some certainty determined, for the present at least, as post-Jurassic. The unit may possibly be correlative with the Dakota formation of Cretaceous age.

TERTIARY-QUATERNARY SYSTEM

Sevier River Formation

The youngest formation of significant areal distribution in the mapped area is the Sevier River formation. According to Callaghan (1939), the Sevier River formation probably represents accumulation due to torrential runoff, and is composed of materials that were locally present. The formation ranges from salmon, tan,

Tushar Conglomerate.
Shows the nature of limestone fragments and cementing characteristics. Acetate peel. (actual size).

pink, to white in color, and consists of siltsone, sandstone, and conglomerate. Much of the unit is tuffaceous (Pl. 5-A).

There is evidence that during late Tertiary time the Sevier River was blocked in its northward flow by the Bullion Canyon and Mount Belknap volcanic flows. This resulted in the development of a lake behind (south of) the obstruction (Antelope Range) and subsequent deposition of the lower pinkish to salmon colored silty-clayey beds of the Sevier River formation. The presence of fragments of white or gray banded rhyolite several miles south of present known outcrops may also be indicative of reversed drainage or a damming action. Subsequent erosion has resulted in the cutting of Marysvale Canyon through this obstruction and drainage of the lake by stages as indicated in the several levels developed on the terrace gravels south of Marysvale.

SECTION OF SEVIER RIVER FORMATION MEASURED IN EAST HILLS, THREE MILES SOUTHEAST OF MARYSVALE, UTAH
(Sec. 34, T. 27 S., R. 3 W.)

TERTIARY-QUATERNARY
(Pliocene-Pleistocene)

Sevier River Formation Unit No.		Thickness (Feet)
1	Siltstone, sandstone, and conglomerate: Salmon pink to buff, white or tan. Thin bedded, and often tuffaceous. Highly variable. Locally may form cliffs or steep rounded slopes	300'
	Total measured thickness of Sevier River formation.	300'

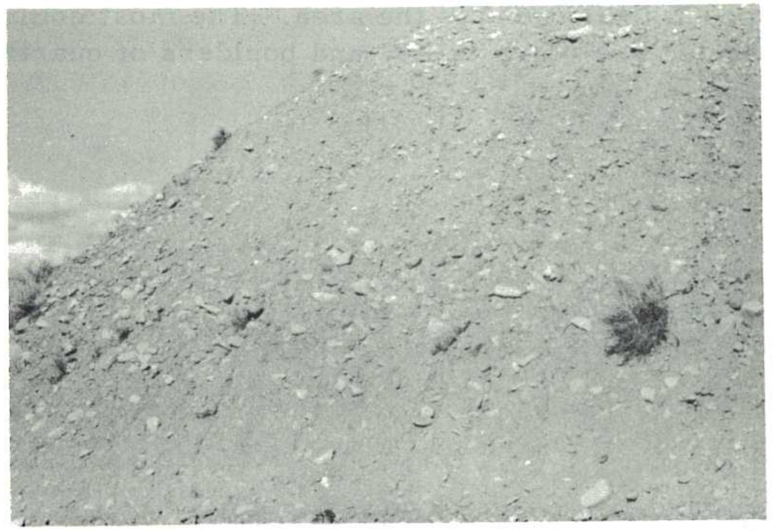
Unconformable

Age and Correlation

The Sevier River formation has been considered by Callaghan (1939), to be late Pliocene or early Pleistocene in age. It is correlated with similar formations to the south near Hatch, Utah and with the Axtell formation of Sevier and Sanpete Counties, Utah.

Plate 5

A. Sevier River Formation.
East Hills outcrop. Note the bedding and included zones of coarse material. The unit is highly tuffaceous.



B. Terrace Gravel.
Typical cross-section. Material consists of rounded to sub-rounded quartzite and volcanic rocks. The exposure is in roadcut on U. S. Highway 89, just south of the Marysvale Post Office.

QUATERNARY SYSTEM

The Quaternary system is represented by valley alluvium, terrace gravels (Pl. 5B), stream deposits, talus materials, landslide debris, and glacial deposits.

Stream deposits and valley alluvium are confined to stream channels or valley areas. They consist of clay and boulder deposits that are poorly sorted and stratified. The talus deposits are found mainly at the base of the massive weathering rock units, usually quartzite, and less commonly igneous flows. Locally, in the vicinity of fault zones, there has been landslide activity. The largest landslide in the thesis area has occurred in about the vicinity of the Deer Trail Mine. At this location the mountain front is largely composed of weak shale beds of Moenkopi and Chinle formations. Large segments of these formations have slumped and slid downward over the Tushar Fault scarp. A relatively large mass has been involved, and preserved, somewhat imperfectly, the original bedding. Other smaller slides have occurred in the Cottonwood and Bullion Canyon areas.

Most of these deposits consist of unconsolidated debris of all of the exposed formations in the area. The most common rock types represented are clays, silts, and boulders of quartzite and volcanic debris.

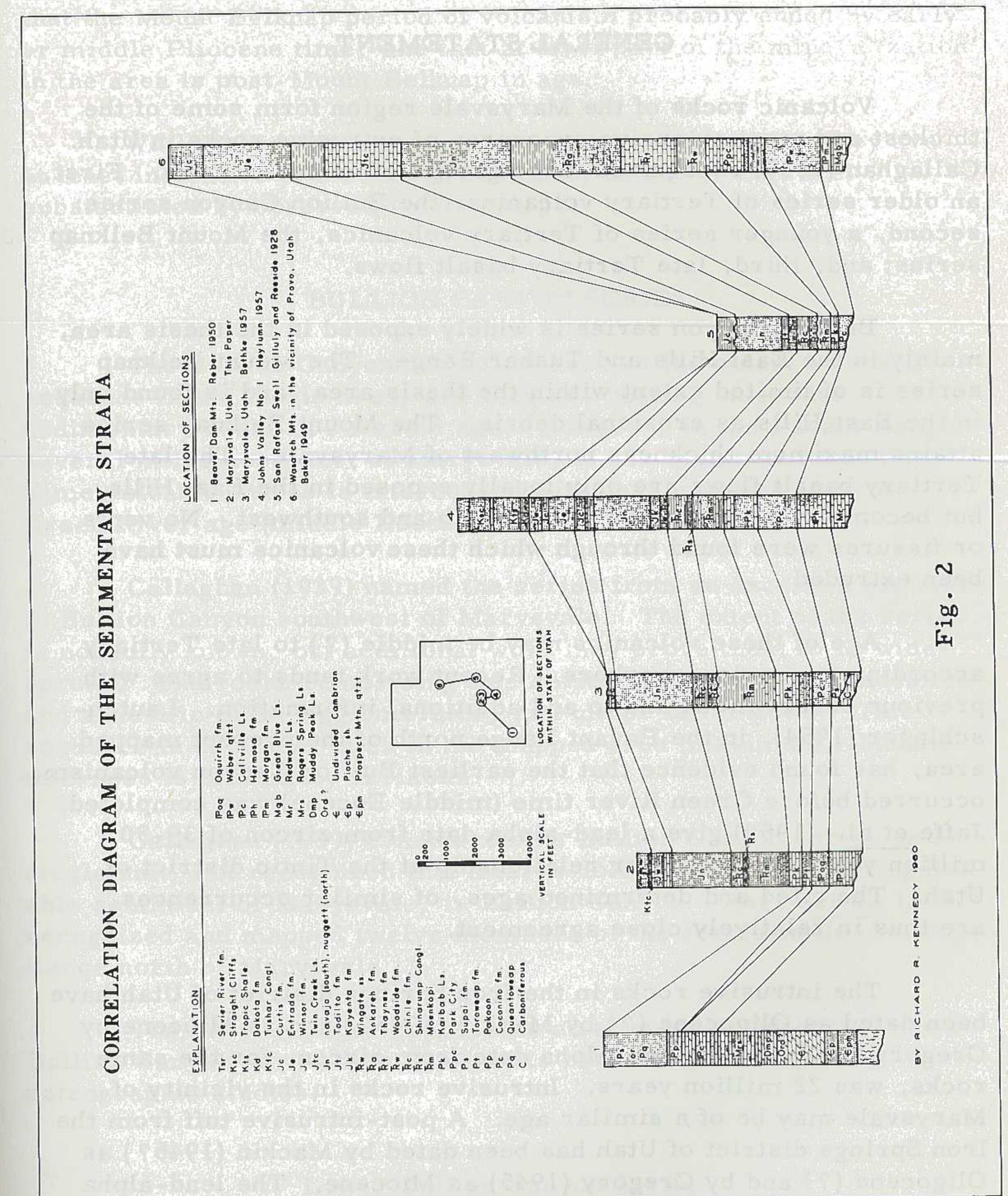


Fig. 2

IGNEOUS ROCKS

GENERAL STATEMENT

Volcanic rocks of the Marysvale region form some of the thickest and most extensive exposures of extrusive rocks in Utah. Callaghan (1939) recognized three groups of volcanic rocks. First, an older series of Tertiary volcanics, the Bullion Canyon series; second, a younger series of Tertiary volcanics, the Mount Belknap series; and, third, late Tertiary basalt flows.

Bullion Canyon series is widely exposed in the thesis area, mainly in the East Hills and Tushar Range. The Mount Belknap series is of limited extent within the thesis area, and is found only in the East Hills as erosional debris. The Mount Belknap series attains maximum thickness northwest of Marysvale. The late Tertiary basalt flows are only locally exposed in the East Hills, but become more extensive to the south and southwest. No vents or fissures were found through which these volcanics must have been extruded.

Age of these volcanics may be middle (?) to late Tertiary according to previous workers. Recent work tends to agree with previous observations and to add additional information. Lautenschlager (1954), in the Pavant Range north of the present mapped area, has found evidence that the earliest Bullion Canyon volcanism occurred before Green River time (middle Eocene) was completed. Jaffe et al. (1959) give a lead-alpha date from zircon of 39-50 million years for a similar relationship at the Tintic district of Utah. The cited and determined ages, of similar occurrences, are thus in relatively close agreement.

The intrusive rocks in the Iron Springs district of Utah have been dated as Oligocene (?) by Mackin (1945?) and as Miocene by Gregory (1945). The lead-alpha date from zircon, for the same rocks, was 22 million years. Intrusive rocks in the vicinity of Marysvale may be of a similar age. A post-intrusive tuff from the Iron Springs district of Utah has been dated by Mackin (1945?) as Oligocene (?) and by Gregory (1945) as Miocene. The lead-alpha date from zircon, on these same rocks, was 19 million years. Mount Belknap series of the Marysvale region may be of a similar

age. It thus appears that the cited and determined ages are relatively similar. In addition, Kerr, et al. (1957) indicate a Pb:U age of 10 million years for a pitchblende sample taken from a vein in quartz monzonite associated with Mount Belknap dikes. This age indicates that the Mount Belknap period of volcanism probably ended by early or middle Pliocene time, and that at least part of the mineralization in the area is post-Mount Belknap in age.

While these dates are not to be taken as absolute, they are at least indicative of a relative continuity of events that are substantiated by observed relationships.

BULLION CANYON SERIES

The Bullion Canyon series represents the oldest volcanic sequence in the thesis area, and they are resting on eroded sedimentary rocks of Jurassic age. However, in the Pavant Range, several miles northwest of Marysvale, it has been noted that this same volcanic series is interbedded with, and overlies beds of Green River age (middle Eocene).

Callaghan (1939) named the series from an excellent exposure in Bullion Canyon southwest of Marysvale. The extent of the series is not fully known, but additional work may prove them to be widespread. The rocks comprising this series are principally andesites and andesitic tuffs, agglomerates, and minor latite flows. This sequence is 2800 feet thick in the mapped area (maximum), but the thickness is extremely variable.

Callaghan (1939) considered the Bullion Canyon series as a single unit, but recognized that a three-fold division was distinguishable southwest of Marysvale, in Bullion Canyon. Kerr, et al. (1957) recognized and mapped twelve members of the series in the Antelope Range north of Marysvale.

The present paper represents an attempt to sub-divide the Bullion Canyon series into three units based on petrologic and petrographic studies.

Lower Bullion Canyon Series

The lower unit of the Bullion Canyon series rests with marked unconformity upon the eroded underlying sedimentary rocks. In the thesis area, the sedimentary rocks in contact with the oldest volcanic rocks are the Jurassic Winsor, and Jurassic and Jurassic (?) Navajo sandstone. At the contact is a relatively thin bed of conglomerate composed chiefly of limestone and quartzite fragments. The composition of the conglomerate varies with the underlying rock type, and locally may be absent. The conglomerate may be indicative of orogeny that was post-Winsor, possibly early Laramide.

The lower series or unit has a maximum thickness of 2800 feet and consists almost exclusively of andesitic tuffs and agglomerates that range from coarse flow breccias to fine-grained welded tuffs, massive bedded tuffs, and some thin-bedded tuffaceous flows. Callaghan (1939) reported less than ten per cent flows.

The most characteristic feature about the lower unit is the dark bluish-gray to black and somewhat banded or bedded appearance. Near the base is a distinct greenish-purple welded flow breccia (Pl. 6). Above this basal part the tuffs and agglomerates are generally finer grained, as are the flows. Locally, the unit may become coarser or finer, and may thicken or thin rapidly. There is enough continuity for correlation over much of the mapped area.

A petrographic analysis has been made of two samples of pyroclastics taken from the lower Bullion Canyon series. Much of the lower series is seen to have a hemicrystalline or a breccia texture. Sample BC-L (Table 1, column 1) was taken from Bullion Canyon southwest of Marysvale, and sample 10M-L (Table 1, column 2) was taken from Tenmile Canyon in the extreme south part of the mapped area.

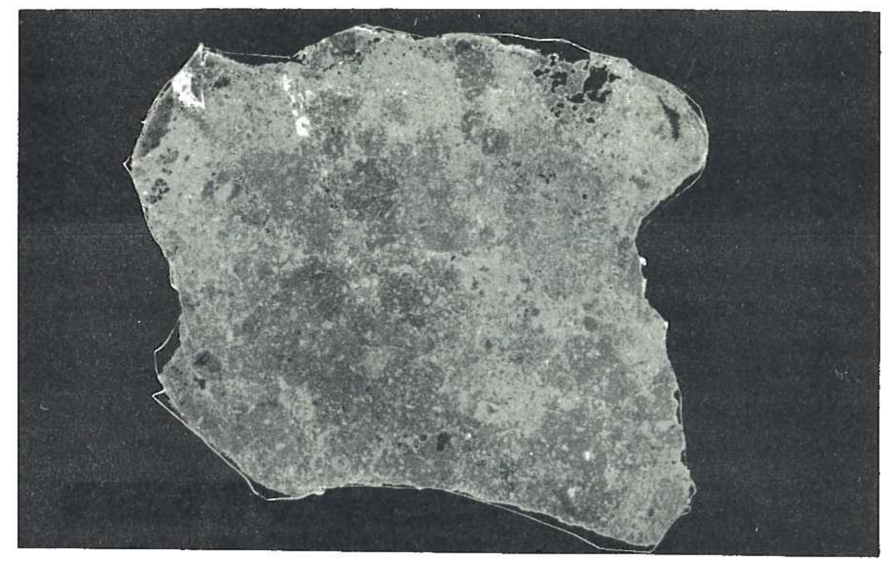
The plagioclase feldspars are most commonly oligoclase or andesine. Accessory minerals common to both samples are calcite, pennine, clinochlore, sericite, hematite, magnetite, sphene, and apatite. The rock is an andesite.

Alteration is widespread and common to the lower series. The most common alteration is chloritization and calcitization, with subordinate amounts of sericitization and silicification (Pl. 7).

Many of the ore deposits of the area are associated with the lower Bullion Canyon series, particularly near the contact with underlying sedimentary rocks. Ore deposits found in these localities consist of metalliferous veins and alunitic alteration.

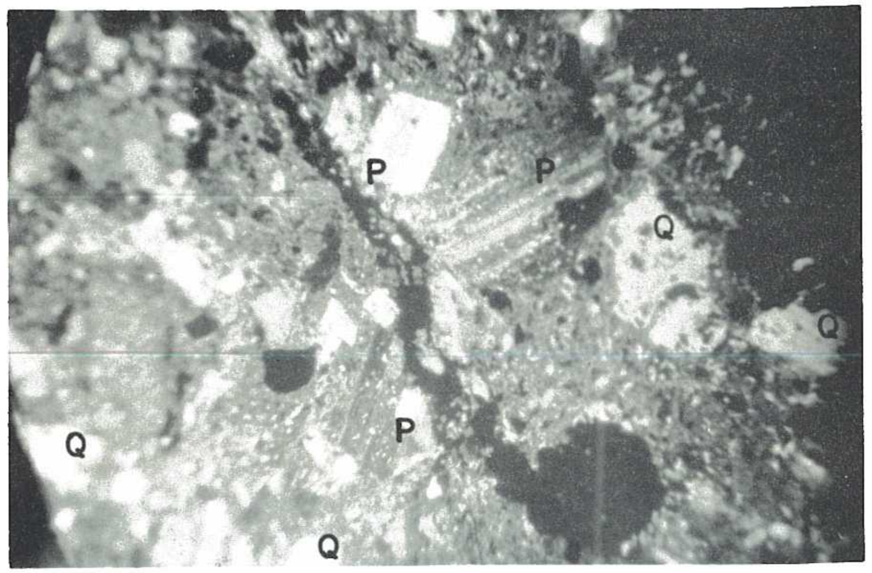
Plate 6

A. Lower Bullion Canyon volcanic rocks. The lower unit is characterized by a coarse agglomerate or flow breccia.



B. Lower Bullion Canyon pyroclastic. Welded tuffaceous agglomerate. Often dense and silicified. Acetate peel (actual size).

Plate 7



Lower Bullion Canyon volcanic rock. Photomicrograph shows highly altered nature of the lower unit. Plagioclase (P) is mostly altered to specks and blebs of calcite. Quartz (Q) is slightly corroded. Black spots are holes in the slide. (100 x).

Middle Bullion Canyon Series

The middle Bullion Canyon series consists of approximately 1800 feet of reddish-purple and greenish-gray andesitic tuffs and agglomerates, and some latite flows. The series is generally massive and weathers to rounded knobs and hills with steep slopes often littered with loose talus material. The series is generally highly fractured and often has the megascopic appearance of being porphyritic (Pl. 8), with phenocrysts of milky-white feldspar. Locally, the material seems to have been extruded as a rather viscous flow in which the feldspars had begun to crystallize before movement ceased. Broken or deformed crystals and flow lineation indicate a protoclastic structure.

Petrographically, the rocks vary from hemicrystalline to hypidomorphic granular. Petrographic analysis has been made of four samples, taken throughout the mapped area. BC-M (Table 1, column 3) is from Bullion Canyon; GH-M (Table 1, column 4) is from Gold Hill; 10M-M (Table 1, column 5) is from Tenmile Canyon; and NEH-PA (Table 1, column 6) is from the north part of East Hills.

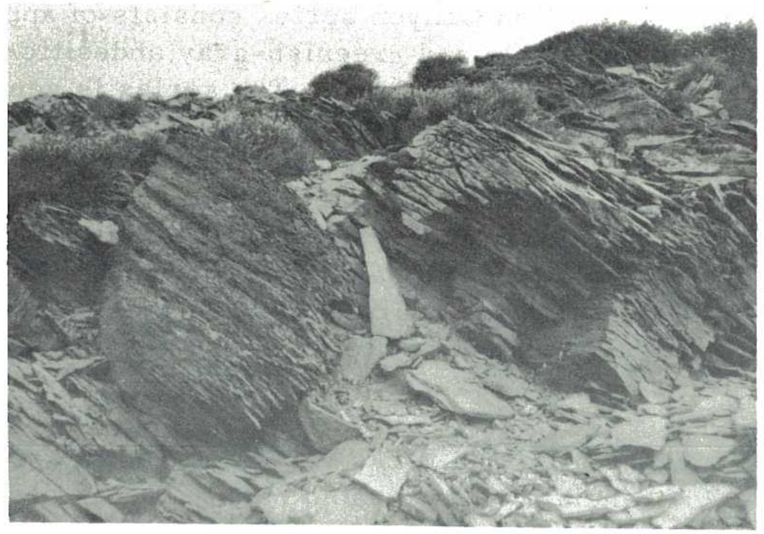
The plagioclase feldspars are most commonly oligoclase and andesine, with minor labradorite. Accessory minerals common to all four samples are sericite, calcite, muscovite, magnetite, apatite, zircon, pennine, and sphene. The rock is andesite.

Alteration is widespread in the middle unit and may consist of chloritization (Pl. 9), sericitization, calcitization, silicification and alunitization. Generally, not all of the above listed types of alteration were found in any one sample.

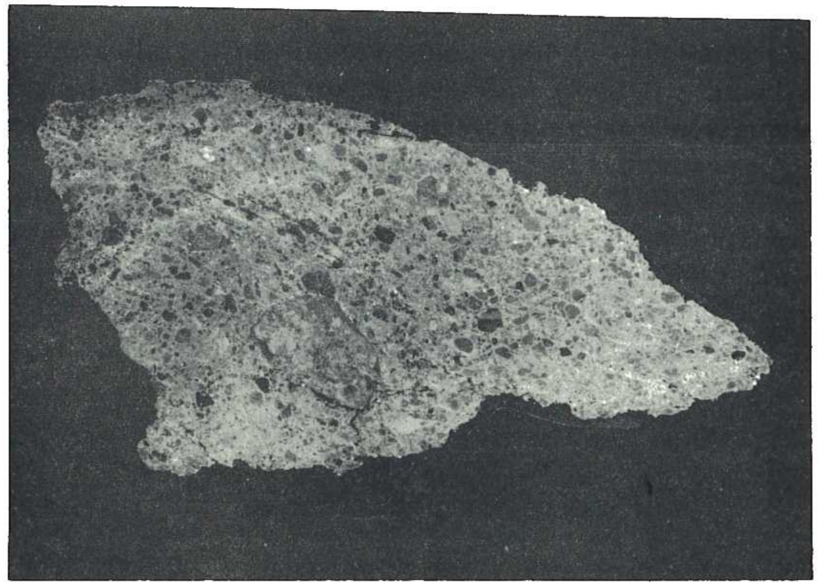
Bonanza type gold and silver deposits found in the area have been mainly confined to the middle Bullion Canyon unit, as have the higher grade alunite deposits. In the East Hills, small calcite veinlets and associated manganese deposits of small size have been observed.

Upper Bullion Canyon Series

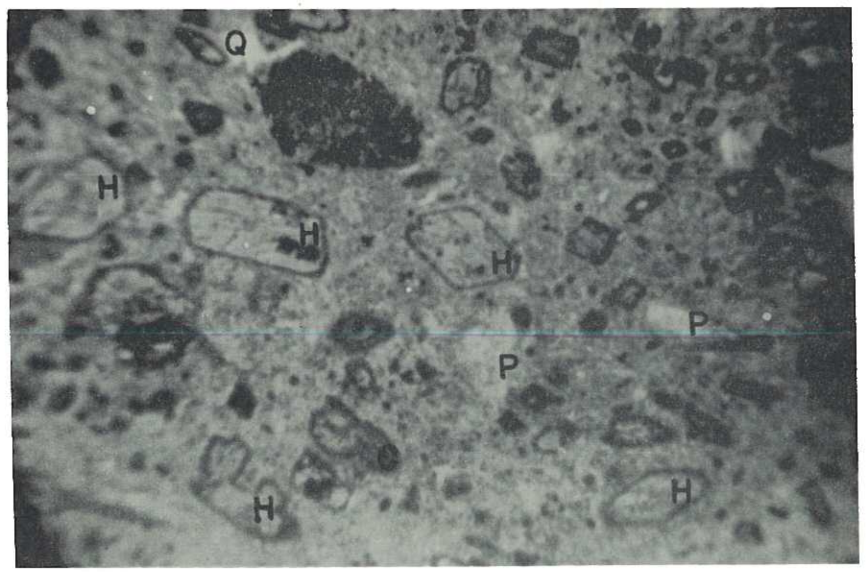
In the mapped area, the upper part of the Bullion Canyon series consists of approximately 500 feet of dense, dark reddish-brown, latite flows, andesite agglomerates and minor flow breccia (Pl. 10-A). The ratio of flows to agglomerate is probably greater than 50 per cent.



A. Middle Bullion Canyon rocks. Note extensive joint and fracture patterns. These features tend to largely control the weathering of outcrops.



B. Middle Bullion Canyon rock. The rock is andesite. Note the tendency to be fragmental. Acetate peel (actual size).



Middle Bullion Canyon rock. Photomicrograph showing relict outlines of former euhedral hornblende (H) now altered to Chlorite (C) and magnetite rich rims (M). Minor quartz (Q) and plagioclase (P) are present. (100 x).

These units are mainly exposed in the East Hills with only minor occurrences near the Tushar fault and in the mapped portion of the Tushar Range.

Near the Tushar fault, and scattered throughout the eastern Tushar Range, is a prominent dark reddish-brown porphyritic flow that Callaghan (1939) named the Delano Peak latite. This unit probably lies very near the top of the Bullion Canyon series, and has been altered mainly by calcitization (Pl. 10-B).

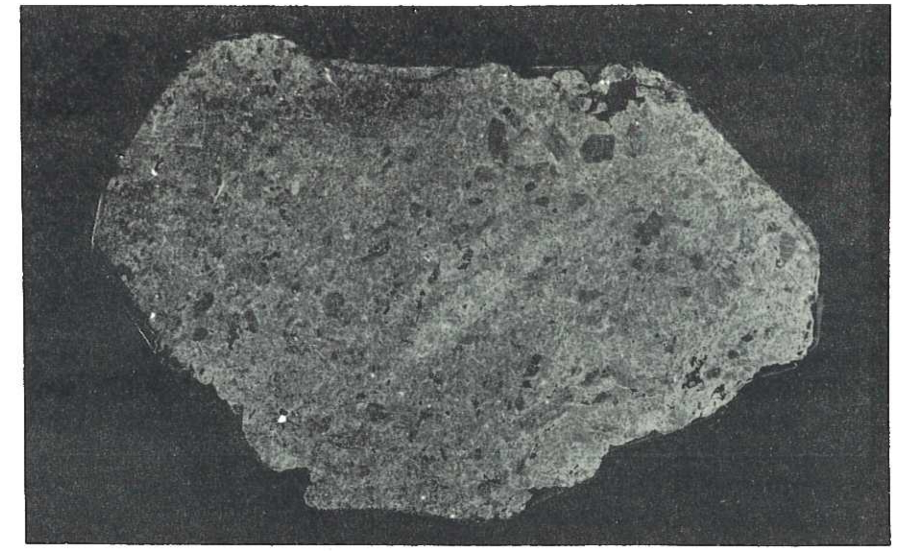
Petrographic studies indicate that the Delano Peak latite is a flow breccia with broken and bent crystals. The texture varies from hemicrystalline to hypidormorphic granular. Petrographic analysis of this latite has been made from three localities. BC-U (Table 1, column 7), is from Bullion Canyon; GG-U (Table 1, column 8), is from Gold Gulch; and 10M-U (Table 1, column 9), is from Tenmile Canyon. The plagioclase feldspars are most commonly andesine and oligoclase. The davitrified to glassy groundmass represents about 35-50 per cent of the rock. Accessory minerals common to all three samples are calcite, magnetite, muscovite, hematite, sericite and minor apatite.

Locally, this unit has been altered rather extensively to alunite (Pl. 11), but no known important metalliferous deposits occur within the unit.

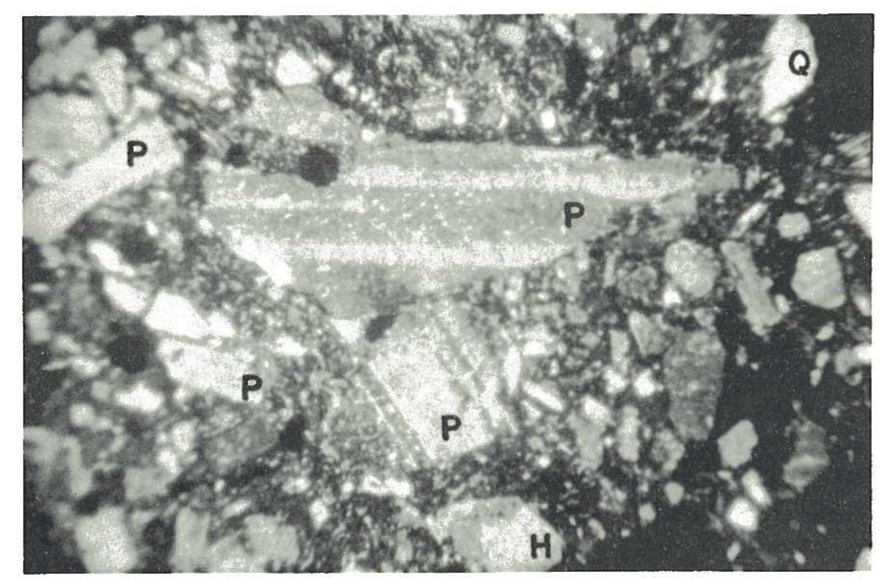
TRANSITIONAL SERIES

Rather complex time relationships exist between the uppermost Bullion Canyon Delano Peak latite member and the overlying (?) Dry Hollow latite; and between the Dry Hollow latite, Joe Lott tuff and the Mount Belknap rhyolitic facies. All of the above units were named by Callaghan (1939).

The term transitional volcanic series is introduced in this paper in an effort to help clarify some of the volcanic associations. The term transitional volcanic series as used in this paper includes those volcanic materials that were extruded post-Bullion Canyon series and pre-Mount Belknap red rhyolite. Any intrusive action that might have occurred during this time interval would also be part of the transitional series.

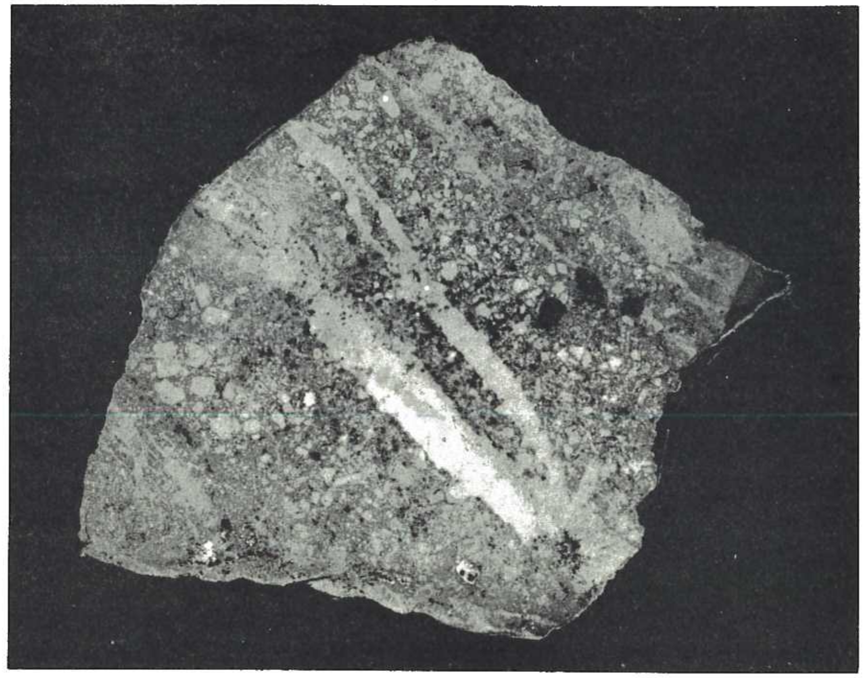


A. Upper Bullion Canyon rock.
The rock is latite. Note the tendency to be somewhat fragmental and porphyritic. Acetate peel (actual size).



B. Upper Bullion Canyon volcanic rock.
Photomicrograph shows rather large crystals of plagioclase (P) in a groundmass of smaller quartz (Q) and hornblende (H) fragments. (100 x).

Plate 11



Alunite Vein.
Alunite veins (light) replacing upper Bullion Canyon latite. Note bleaching and alteration in areas of feldspar. Acetate peel (actual size).

Dry Hollow Latite

The Dry Hollow latite consists of approximately 200 feet of reddish-brown to gray, porphyritic flows that often exhibit protoclastic structure. Petrographically, the flows are porphyritic with a glassy groundmass and have a hemicrystalline texture.

The feldspars are commonly andesine and labradorite; the groundmass is glassy material that ranges from 50-80 per cent of the rock. Accessory minerals commonly present are magnetite, calcite and minor zeolites.

Little alteration other than calcitization has occurred. A petrographic analysis has been made of two samples. One from the north East Hills (NEH-DHL, Table 1, column 10), and the other from the south East Hills (SEH-DHL, Table 1, column 11).

The Dry Hollow latite was named by Callaghan (1939), and has been recognized in the following relationships: 1. lying directly on eroded Bullion Canyon volcanics and perhaps is transitional or a facies of the upper Bullion Canyon Delano Peak latite member; 2. interbedded with Joe Lott tuff; and, 3. lying upon the lower Mount Belknap red rhyolite but underlying the upper Mount Belknap white rhyolite. These relationships seem to be indicative of a post Bullion Canyon pre-to post (?) Mount Belknap age for at least part of the Dry Hollow latite.

Joe Lott Tuff

Closely associated with the Dry Hollow latite flows and Mount Belknap rhyolites is the Joe Lott tuff named by Callaghan (1939). The Joe Lott tuff consists of approximately 300 feet of pink, salmon-colored to white, ashy, conglomeratic tuffaceous materials.

Petrographically, the Joe Lott tuff is seen to consist of 70-90 per cent ash and glassy fragments with only minor biotite grains, calcite, quartz, chalcedony, broken crystals of orthoclase and oligoclase, and breccia structure.

The Joe Lott tuff has been recognized in the following relationships: 1. lying upon eroded Bullion Canyon volcanics; 2. Contains tongues of Mount Belknap red rhyolite; 3. interbedded with, and overlying the Dry Hollow latite flows; 4. lying upon Mount Belknap rhyolites.

These relationships seem to indicate a post Bullion Canyon pre-to post Mount Belknap series age for at least part of the Joe Lott tuff. The Joe Lott tuff is partly contemporaneous with, and partly younger than the Dry Hollow latite.

MOUNT BELKNAP VOLCANIC SERIES

The later Tertiary volcanic activity was predominantly extrusions of rhyolites, tuffs and latites and was named the Mount Belknap series by Callaghan (1939). Principally, the series consists of a lower red rhyolite and agglomerates, and an upper-gray to white rhyolite; a part of which exhibits well-developed flow banding. Molloy (1959) has subdivided the rhyolites into several members. Neither of these rhyolites outcrops in the mapped area, however, there are erosional fragments of gray to white banded rhyolite within parts of the Sevier River formation.

The middle to upper Dry Hollow latite and Joe Lott tuff are locally intercalated with the rhyolites and therefore are, in part, Mount Belknap in age.

BASALT

There are a few exposures of late Tertiary-Quaternary (?) basalt flows in the East Hills. These flows are usually less than 70 feet in thickness and consist of dark-gray to black, isolated erosional remnants. The basalt ranges from dense and fine-grained to scoriaceous, vesicular, or glassy.

Thomas and Taylor (1946) make the following statement concerning basalt found in the southwestern part of Utah. "The flows in eastern Iron County are probably roughly contemporaneous with the basalt flows in the Marysvale region, which Callaghan found to be associated with the late Pliocene and early Pleistocene Sevier River formation, and with those further south in Washington County, which Dobbin suggests are Quaternary in age."

A petrographic analysis of basalt from the East Hills (EH-Tb, Table 1, column 12), indicated that the plagioclase feldspars are most commonly andesine and labradorite. The groundmass is extremely fine-grained with some glassy fragments consisting mainly of microlites of plagioclase feldspar with a microphilitic texture. Accessory minerals are apatite, magnetite, calcite, hornblende, and minor sericite. The flows are little altered.

TABLE I
Petrographic Analysis of Igneous Rocks
(Mineral content given in per cent)

Column No.	1	2	3	4	5	6	7	8	9	10	11	12
Sample No.	BC-L	10M-L	BC-M	GH-M	10M-M	NEH-PA	BC-U	GG-U	10M-U	NEH-DHL	SEH-DHL	EH-TB
Minerals												
Orthoclase	tr.		tr.			tr.	tr.	tr.	tr.	tr.	tr.	
Oligoclase	55	20	20	5	10				10			
Andesine		40	50	60	50	30	45	40	50	25	20	
Labradorite										tr.	tr.	60
Quartz	5	5	2	2	2	2	1	1	tr.	1	1	tr.
Hornblende	20	15	13	10	20		5	10	5			
Biotite		1	2	3	4	3	1	tr.	tr.	1	1	
Chlorite	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	
Olivine												4
Augite						10				1	1	8
Calcite	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.
Glassy Groundmass	20	19	13	20	14	55	48	49	35	72	77	28
Total	100	100	100	100	100	100	100	100	100	100	100	100

1. Andesite, Bullion Canyon
2. Andesite, Tenmile Canyon
3. Andesite, Bullion Canyon
4. Andesite, Gold Hill
5. Andesite, Tenmile Canyon
6. Pyroxene andesite, North-East Hills
7. Latite, Bullion Canyon
8. Latite, Gold Gulch
9. Latite, Tenmile Canyon
10. Latite, North-East Hills
11. Latite, South-East Hills
12. Basalt, East Hills

INTRUSIVE ROCKS

Callaghan (1939) noted the occurrence of an intrusive latite on the eastern part of Gold Hill. The latite forms sills up to 100 feet in thickness, and was intruded at the base of the volcanic sequence. The latite greatly resembles some of the monzonitic intrusive rocks. This is the only observed intrusive action within the thesis area.

Due to the irregularity and unknown extent the intrusive latite was not mapped as a separate unit, but is included with the middle Bullion Canyon sequence on Gold Hill.

METAMORPHIC ROCKS

Despite the extent and thickness of flow, and the abundance of volcanic action in the Marysvale region, metamorphism has been of little consequence.

Locally, some of the flows have caused a slight "baking" effect on the underlying unit. However, these zones are generally not more than a few inches in width, and as noted by Kerr et al. (1957) the contact metamorphic zones around intrusive bodies are not extensive.

STRUCTURE

GENERAL STATEMENT

The tectonic setting of the Marysvale region, as noted by Dutton (1880) and others, is transitional between the Colorado Plateau to the east and the Great Basin (Basin and Range) province to the west. The area is presently considered to be a part of the High Plateaus of Utah.

In general, the major tectonic trends, as indicated on the tectonic map of the United States by King et al. (1955), have a decided north-south direction with additional northwest-southeast directions. The north-south structures appear to be most pronounced. Heylmun (1957), has found the same trends to be characteristic to the south and east of the Marysvale region. These major trends may be representative of early established structures that have been propagated through time.

The region consists of a relatively linear valley and mountain range that are bounded both on the east and west by major faults. Marysvale Valley is a graben and the Tushar Range is a horst. However, the structure of the region is relatively simple in that complex folds and thrusts are generally lacking.

The present physiography is due principally to Pliocene-Pleistocene, and post-Pleistocene faulting with some subsequent modification, at higher elevations, by the Wisconsin (?) stage of glaciation, but of greater importance has been the effect of running water and mass wasting.

FOLDS

Proctor (1943) noted that the Tertiary and pre-Tertiary formations had been warped and locally rather closely folded into a north-south anticline that had been highly faulted. A series of similar structures may be present throughout the area, but are obscured by volcanic materials and are highly faulted making observation difficult. Observations in the Deer Trail and PTH mines indicate that numerous minor flexures exist in the area.

FAULTS

The most noteworthy structure features of the area are the faults. Located from three to five miles east of the mapped area is the prominent Sevier Fault zone with a series of down-dropped blocks to the valley or west side. Located approximately 15-18 miles west of the mapped area is the Hurricane fault zone that forms the western limit of the Tushar Range with the down-dropped blocks also to the west.

The most notable fault within the thesis area is the Tushar fault; this forms the east boundary of the Tushar Range and the west boundary of Marysvale Valley, with down-dropped block to the valley or east side. The amount of displacement is variable, but may reach a maximum of 2, 000 feet south-southwest of Marysvale. This fault was named and described by Dutton (1880). It has a northwest trend of from 15-45 degrees with a dip that varies, but is generally 55-80 degrees to the northeast. Displacement along the Tushar is variable and not precisely known, but locally is in excess of 2, 000 feet and may be nearer to 4, 000 feet.

Many less prominent faults (Pl. 12-B) have been noted in the area both east and west of the Tushar fault, several being parallel to the Tushar fault and others being transverse to it.

Less notable are the northeast trending faults that occupy almost every major canyon cutting into the Tushar Range. Chief among these are the Bullion Canyon, Cottonwood Canyon, Gold Gulch and Tenmile Canyon. Of these, Cottonwood seems to have the greatest displacement, with a south-southeast dip. Displacement along these faults is variable, with greatest displacement in the Cottonwood Canyon area near its intersection with the Tushar Fault.

ECONOMIC GEOLOGY

GENERAL STATEMENT

Since the discovery of gold in 1868 in the gravels of Bullion (formerly Pine) Creek, Marysvale has been the scene of sporadic mining activity. Shortly after the initial discovery, the Tushar Range became a center of active prospecting and mining. Other discoveries were made throughout the late 1800's, but production never came up to expectations and the first "boom" was over. Interest in the area was renewed with discovery of alunite in the early 1900's, and a mill was established in 1915 to recover potash from the alunite ores. Some potash was produced, but shortly thereafter, the plant closed down and has not operated since. Thus the second "boom" in Marysvale's history was over. With the advent of World War II, interest was revived in the alunite as a possible source for aluminum. Production of aluminum from alunite was never realized since other sources of aluminum ore, mainly bauxite, assured the United States of a sufficient source of this metal for the war effort. Presently, the area is active in uranium production, though the future is doubtful. Recently, an effort has been made to utilize the lower grade alunite as the principle component of a commercial fertilizer. The results of this venture are not presently known. Active prospecting for metalliferous deposits is being carried on by the Deer Trail Mining Company through the PTH tunnel at the eastern base of the Tushar Range south of Marysvale.

ORE DEPOSITS

Three genetic types of ore deposits are recognized: 1. base metal-precious metal deposits consisting mainly of galena, sphalerite, copper, mercury, gold and silver; 2. alunite deposits; 3. uranium deposits.

The base metal-precious metal deposits are found in the older sedimentary rocks and the Bullion Canyon volcanic series. Locally, the ratio of base metals to precious metals may vary. In the past, "bonanza" type precious metal deposits have been found in the upper middle part of the Bullion Canyon series.

The alunite deposits are mainly confined to the Bullion Canyon volcanic series, and perhaps principally to the middle unit. However, veins and replacement deposits are known to exist in the lower and upper units.

The uranium deposits are not located in the mapped area, however, the mineralization is associated with an intrusive quartz monzonite stock in the Antelope Range as veins and replacement. Locally, the Bullion Canyon and Mount Belknap volcanics may contain some dessiminated pitchblend in the older carbonate sedimentary rocks in the PTH tunnel.

Ore deposits seem to be localized by the following controls. 1. Structural: features such as faults, fault intersections, fracture systems, and folds. 2. Lithology: the Paleozoic carbonate beds have been favorable to ore deposition by replacement and some discontinuous vein systems. The Bullion Canyon volcanic rocks have locally been extensively replaced by alunite. 3. Open space vein filling: extensive vein systems are present in the area. The veins are abundant and extensive in the Bullion Canyon volcanic rocks and Navajo sandstone. They are less extensive in the underlying red beds, but are apparently continuous with depth. 4. Contacts: the physical-chemical characteristics of contact zones have aided in the localization of some ore deposits. 5. Ore-forming fluids: the nature of the ore-forming fluids always exerts a profound influence on the type and extent of mineral deposits. The nature of the ore-forming fluids varies from one locality to another, and such appears to have been the case in the Marysvale region.

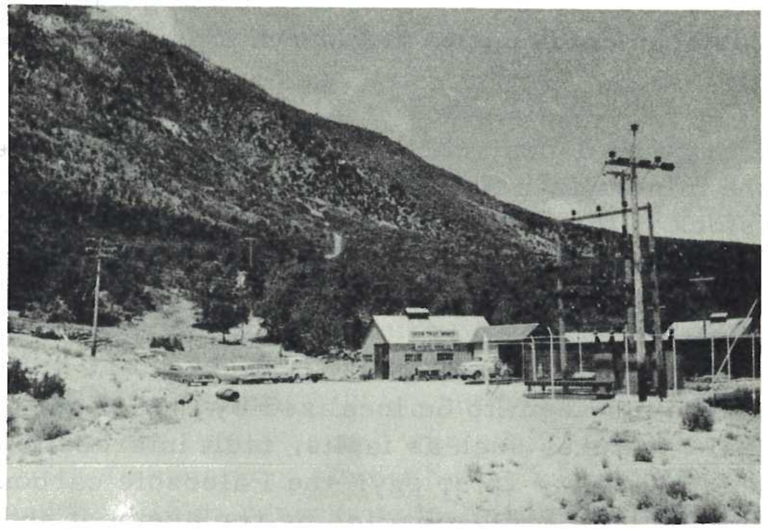
Variable combinations of the above controls have been responsible for most of the ore deposits in the mapped area. However, many of the ore deposits are associated with fissure veins that are principally the result of open space filling as indicated by banding and crustification. Locally, replacement is of major importance, as in the Deer Trail mine, with some alunite deposits.

Proctor (1943) and Evans (1951) suggest that the deposits are probably representative of an epithermal environment of deposition.

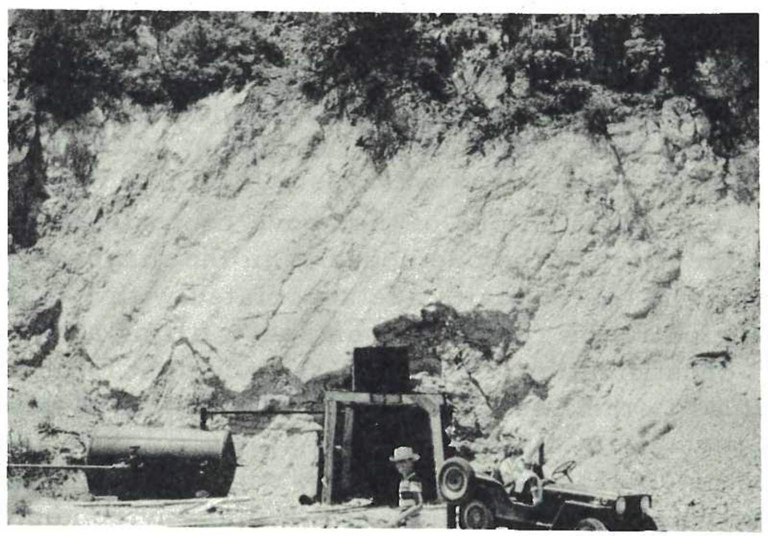
MINES

Few mines in the mapped area are actively being worked. The largest operating mine is the Deer Trail Mines PTH tunnel (Pl. 12-A). An active program of prospecting and development

Plate 12



A. PTH tunnel entrance.
The only operating mine in the thesis area. Prospecting and development work are in progress for base metal-precious metal deposits.



B. Fault Surface.
Note the nature of the fault surface. The fault is located near the top of the Oquirrh formation in a dense, brittle quartzite. South of Deer Trail mine.

work is being forward in the operation and seems to offer possibilities of future production.

A small amount of work is completed yearly in Bullion Canyon, by independent operators, and annual assessment work is done each year in several areas throughout the Tushar Range.

WATER SUPPLY

Water for the town of Marysvale is derived from a spring in Bullion Canyon. Numerous springs are found in the vicinity of Bullion, Cottonwood, Gold Gulch, and Tenmile Canyons. They appear to be fault or fracture controlled. A series of springs are found at the base of the terrace gravel deposits where they merge with the Sevier River valley, and are representative of the ground water intersecting the surface. The extensive development of alluvial fans and the flow of streams across these unconsolidated materials has resulted in a potential ground water source that has not been utilized.

SUMMARY OF GEOLOGIC HISTORY

During Pennsylvanian time, there was deposition of limestone and dolomite, possibly in an embayment of the western miogeosyncline. During middle to late Pennsylvanian time, the sea withdrew from the area and deposition of some of the cross-bedded eolian sands of the Oquirrh formation took place.

In Permian time, deposition of the sandy and dolomitic Toroweap formation occurred indicating that the sea was probably again advancing. In later Permian time, the Kaibab limestone was deposited in the extensive Kaibab sea. By Triassic time, the sea had again withdrawn and the basal red beds of shale and sandstone of the Moenkopi formation were laid down. The encroachment of an arm of the sea resulted in deposition of the Virgin limestone member of the Moenkopi formation. Upper Moenkopi sediments were deposited under shallow water to tidal flat conditions. This is indicated by the presence of shale, sandstone, and mudstone containing ripple marks, raindrop impressions, and mud cracks. A rather extensive period of erosion followed, in which channels were cut into the upper Moenkopi sediments. Flood plain conditions followed, and prevailed, for deposition of the Shinarump conglomerate. Deposition of shale and sandstone of the Chinle formation followed. Eolian conditions developed as indicated by deposition of the massive, cross-bedded Navajo sandstone.

In upper Jurassic time, deposition of basal Winsor (Carmel?) limestone indicates an encroachment of the sea from the west or southwest. Subsequent oscillations of the sea are indicated by the alternating red beds and thin bedded limestone of the upper Winsor formation.

Events that occurred between upper Jurassic time and early to middle Tertiary time are difficult to evaluate. Evidence, in the Pavant Range to the north and also in the region to the south, indicates that deposition was probably continuous up to Paleocene or early Eocene time. Subsequent uplift, folding, faulting, and erosion has removed evidence of any original deposition. An indication of this orogeny is to be found in the arching of pre-Tertiary and Tertiary beds, the development of post-Winsor conglomerate, and sedimentary-volcanic relationships in the Pavant Range.

The Bullion Canyon volcanic series was deposited on the post-Winsor erosional surface. Lautenschlager (1954) found evidence that the earliest volcanism occurred before Green River time (middle Eocene) was completed. Eruption probably continued through late Oligocene or early Miocene time. A period of faulting and intrusion followed. Early ore deposition might have taken place at this time since Callaghan (1939) has noted that nearly all the fissure veins are confined to the older sedimentary rocks and the Bullion Canyon volcanics.

Faulting and intrusion, combined with extensive volcanism, resulted in development of the Antelope Range north of the mapped area. The Antelope Range is transverse to the course of the Sevier River. It thus seems likely that a damming action resulted and a lake backed up behind (south of) the obstruction. Christiansen (1937) expressed a similar opinion. However, lake beds are not evident.

A lengthy period of erosion was followed by extensive volcanism and deposition of the Mount Belknap series and contemporaneous faulting. Volcanism began to decrease in intensity and extent.

In early Pliocene time, major faulting had begun and the present structural units began to develop. By late Pliocene or early Pleistocene time, the Sevier River formation was deposited, with some associated basalt flows, followed by subsequent erosion by the Sevier River and tributary system. Some of the basalt flows are younger than the Sevier River formation. Faulting has continued to the present, and erosion continues to actively reduce the highland areas.

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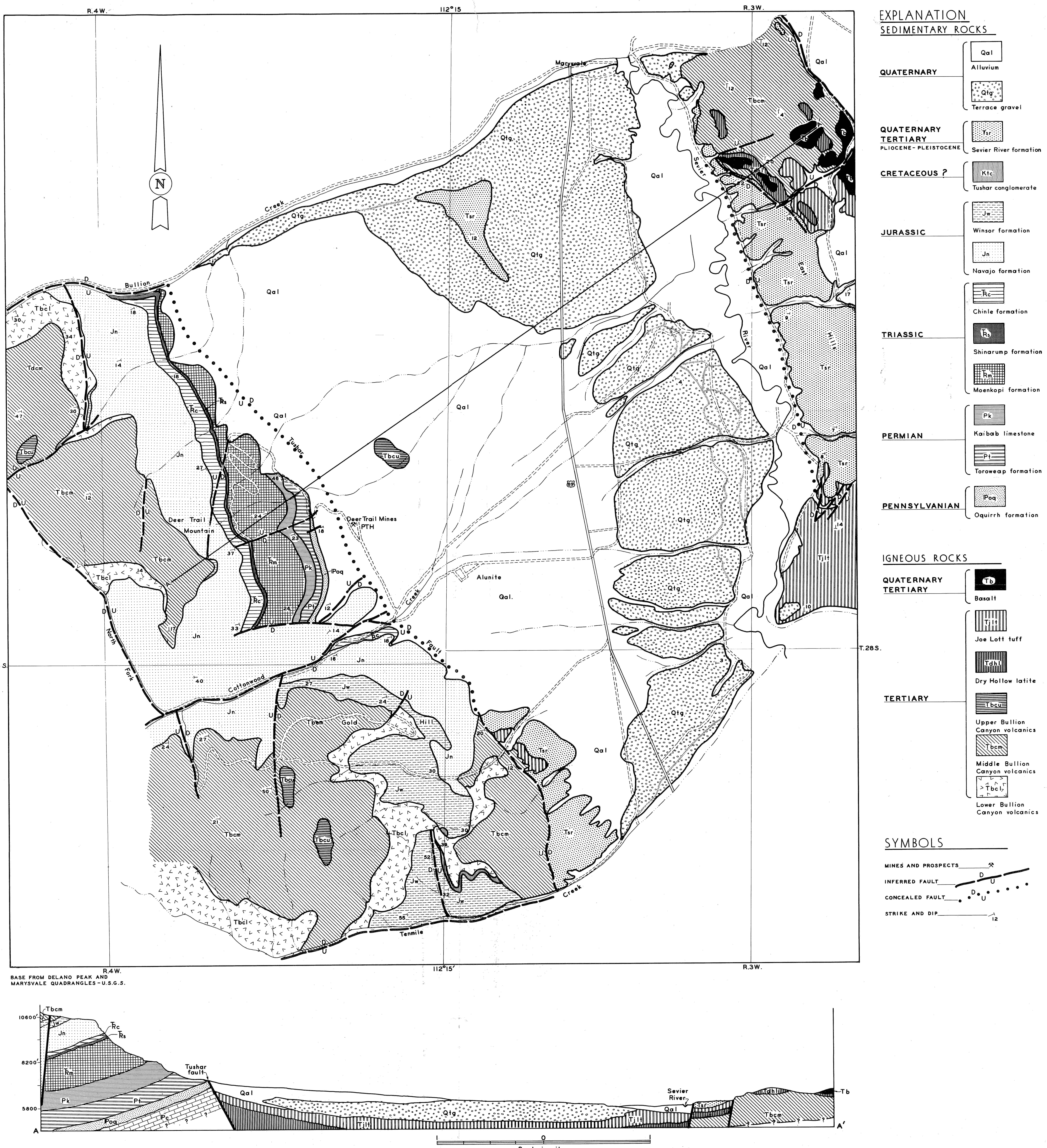

GEOLOGIC MAP AND CROSS SECTION OF BULLION CREEK TO TENMILE CREEK, EASTERN TUSHAR RANGE, PIUTE CO., UTAH

BY RICHARD R. KENNEDY