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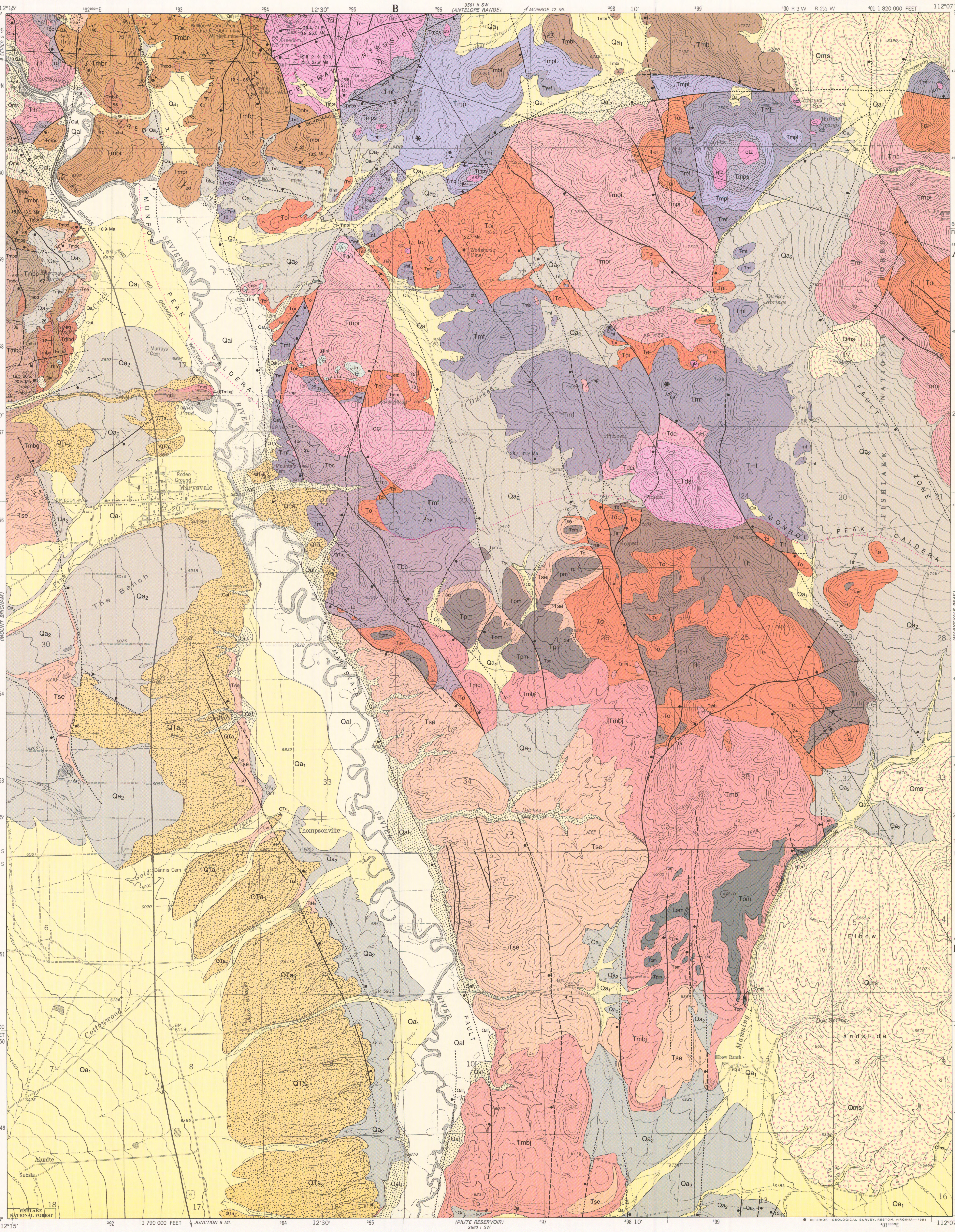
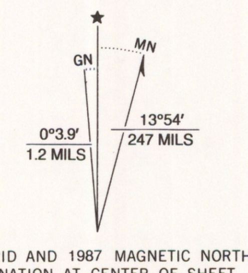


Base map from U.S. Geological Survey, Marysvale Quadrangle, 1981

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Mapped by authors in 1977-79 and 1982-83
J.W. Parker, Cartographer

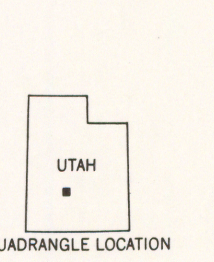


UTM GRID AND 1987 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

GEOLOGIC MAP OF THE MARYSVALE QUADRANGLE, PIUTE COUNTY, UTAH

by
Peter D. Rowley, Charles G. Cunningham, Thomas A. Steven, Harald H. Mehnert, and Charles W. Naeser

1988



QUADRANGLE LOCATION

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CORRELATION OF MAP UNITS

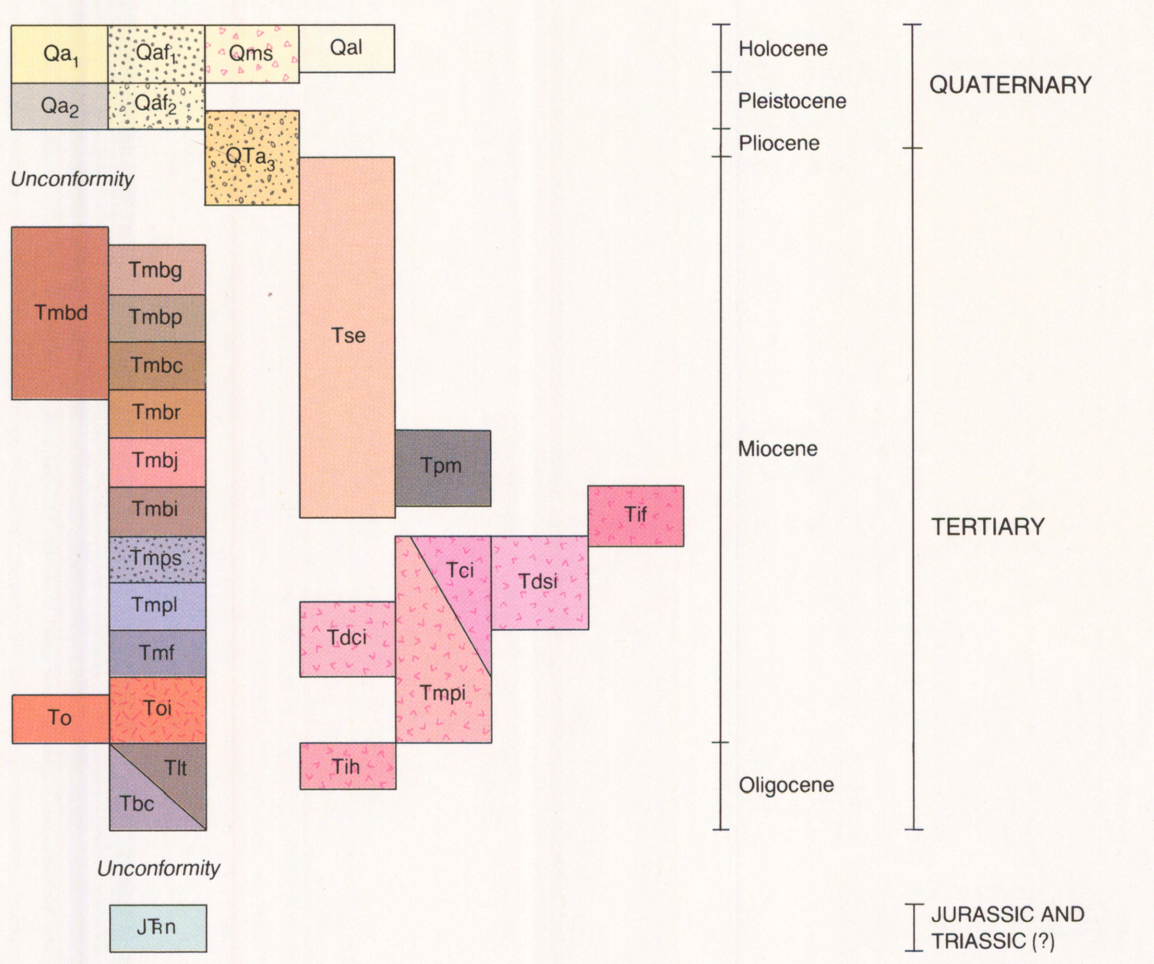


Table 1. Data for K-Ar ages of rocks and alteration minerals in the Marysvale quadrangle, Utah

Sample no.		[1]Rock unit; [2]mineral analyzed	[3]K_2O (%)	*Ar^{40} (10^{-10}moles/g)	*Ar^{40} (%)	[4]T	[5]Reference
1.	KA2	Tci; B	7.78	——	43	22.9	BA
	do	do	——	——	36	27.9	do
	do	do	7.30	——	73	21.9	do
2.	KA7	Tmf; Sa	5.60	——	90	31.9	do
	do	do	——	——	64	28.7	do
3.	KA11	Tci; B	7.45	——	40	27.7	do
	do	do	7.10	——	69	25.8	do
4.	KA14	Tmbd; G	3.90	——	64	18.9	do
	do	do	——	——	58	17.7	do
5.	KA17	Tci; B	5.65	——	40	23.9	do
	do	do	——	——	38	26.0	do
6.	KA28	Tmbg; G	4.16	——	32	20.5	do
	do	do	——	——	56	19.5	do
	KA29	do	4.24	——	80	20.5	do
7.	M29b	Tci; B	8.53, 8.58	2.678	59.6	21.6 ±0.9	ST
8.	M30	A; A	6.94, 6.93	2.284	52.0	22.7 ±1.1	do
9.	M75	Tmbc; Sa	7.38, 7.32	1.977	75.6	18.5 ±0.8	do
10.	M502	Tmbr; Sa	6.58, 6.60	1.799	72.9	18.9 ±0.7	CL
11.	M600	Tif; Se	8.24	2.520	81.8	21.1 ±0.6	do
12.	M704	Tif; Se	7.50	2.229	55.7	20.5 ±0.7	do

Constants for samples 7-12: K^{40} $\lambda_\xi = 0.581 \times 10^{-10}$/yr; $\lambda_\beta = 4.962 \times 10^{-10}$/yr; $K^{40}/K = 1.167 \times 10^{-4}$; samples 1-6 recalculated by using new decay constants of Steiger and Jäger (1977)

*Radiogenic argon

—— Not determined or not published

[1]Rock unit symbols are those shown on the map; A, replacement alunite

[2]A, alunite; B, biotite; G, glass; Sa, sanidine; Se, sericite

[3]Samples 7, 8, 11, 12 determined by isotope dilution; samples 9, 10 determined by atomic absorption; samples 1-6, method of determination not known

[4]Age (Ma) ± 2σ; error figures not given by Bassett and others (1963)

[5]BA, Bassett and others (1963); CL, Cunningham, Ludwig and others (1982); ST, Steven and others (1979)

SAMPLE DESCRIPTIONS

1. Quartz monzonite porphyry from Prospector mine; lat 38°29′45″, long 112°12′47″.
2. Dacitic lava flow from 2.7 miles east of Marysvale; lat 38°27′14″, long 112°10′47″.
3. Quartz monzonite porphyry from south margin of Central intrusion; lat 38°29′30″, long 112°12′48″.
4. Black basal vitrophyre of lava flow just west of highway U.S. 89, 2.1 miles north of Marysvale; lat 38°28′38″, long 112°14′29″.
5. Quartz monzonite porphyry from VCA mine; lat 38°29′55″, long 112°12′48″.
6. Black basal vitrophyre of lava flow from north side of Beaver Creek, 1.2 miles northwest of Marysvale; lat 38°27′48″, long 112°14′40″.
7. Altered quartz monzonite porphyry cut by dike of the fine-grained silicic pluton; samples from dump of VCA mine; lat 38°29′55″, long 112°12′48″. Cunningham, Ludwig and others (1982) noted that this age represents resetting by the fine-grained silicic pluton.
8. Replacement alunite from Whitehorse mine; lat 38°28′25″, long 112°11′27″.
9. Crystal-rich tuff member of Mount Belknap Volcanics. Collected 0.9 mile west of the junction of Beaver Creek with the Sevier River; lat 38°28′37″, long 112°14′57″.
10. Basal vitrophyre of Red Hills Tuff Member, Royston mine; lat 38°29′03″, long 112°12′38″.
11. Altered fine-grained silicic pluton from a lower level in Plumbic mine; lat 38°29′33″, long 112°13′02″. Age represents time of uranium mineralization, which postdates the fine-grained silicic pluton. Age not plotted on map.
12. Altered fine-grained silicic pluton from the 900-foot level of Freedom No. 1 mine; lat 38°29′50″, long 112°12′51″. Age represents time of uranium mineralization, which postdates the fine-grained silicic pluton. Age not plotted on map.

Table 2. Data for fission-track ages of rocks in the Marysvale quadrangle, Utah

Sample no.		[1]Rock unit; [2]Mineral analyzed	[3]ps	[4]pi	[5]ϕx10^{15}	[6]T	U (ppm)	[7]Reference
1.	M27A	Tci; A	.206(429)	.468(976)	.888	23.3±2.6	17	ST
	do	Tci; Z	8.32 (1464)	10.95 (963)	.418	19.0±0.8	840	do
2.	M29B	Tmpi; Z	6.44 (865)	20.38 (1368)	1.08	20.4±0.9	610	do
3.	M75	Tmbc; Z	4.44 (534)	14.51 (873)	.835	15.3±0.8	560	do
4.	M406	Tif; A	.223(464)	.650(1355)	1.08	22.1±4.4	17	CL
5.	M408	Tmbd; Z	6.58 (609)	12.87 (596)	.594	18.1±0.8	620	do
	do	Tmbd; A	.187(393)	.523(1090)	1.08	23.3±4.7	14	do

Constants: $\lambda_F = 7.03 \times 10^{-17}$/yr; K^{40} $\lambda_\xi = 0.581 \times 10^{10}$/yr; $\lambda_\beta = 4.962 \times 10^{10}$/yr; atomic abundance, $K^{40} = 1.167 \times 10^{-4}$

[1]Rock unit symbols are those shown on the map

[2]A, apatite; Z, zircon

[3]Tracks/cm^2, fossil, x 10^6; (number of tracks counted)

[4]Tracks/cm^2, induced, x 10^6; (number of tracks counted)

[5]Neutrons/cm^2

[6]age (Ma) ± 2σ

[7]CL, Cunningham, Ludwig and others (1982); ST, Steven and others (1979)

SAMPLE DESCRIPTIONS

1. Quartz monzonite porphyry from dump of Prospector mine; lat 38°29′45″, long 112°12′47″.
2. Altered quartz monzonite porphyry cut by dike of the fine-grained silicic pluton; samples from dump of VCA mine; lat 38°29′55″, long 112°12′48″. Cunningham, Ludwig and others (1982) noted that this age represents resetting by the fine-grained silicic pluton.
3. Crystal-rich tuff member of Mount Belknap Volcanics. Collected 0.9 mile west of the junction of Beaver Creek with the Sevier River; lat 38°28′37″, long 112°14′57″.
4. Fine-grained silicic pluton from 700-foot level of Freedom No. 1 mine; lat 38°29′50″, long 112°12′51″. Age not plotted on map.
5. Glassy rhyolite dike from 700-foot level of Freedom No. 1 mine; lat 38°29′50″, long 112°12′51″. Age not plotted on map.

SYMBOLS

CONTACT

66

FAULT—*Most are high-angle normal faults. Dashed where approximately located; queried where probable; dotted where concealed. Direction and angle of dip shown, where observed. Bar and ball on downthrown side, where known.*

CALDERA—*Topographic or structural wall of caldera. Dashed where approximately located, dotted where concealed.*

d(Tif)

DIKE—*Lithology indicated by symbol of equivalent rock unit, in parentheses.*

qtz

QUARTZ MASS—*White, fine- to coarse-grained, locally brecciated quartz. Formed as hot-spring sinter and as replacement masses during wallrock alteration by intrusions.*

ALTERED ROCK—*White, red, and yellow, hydrothermally altered, silicified, and locally mineralized rock. Chiefly argillic alteration to kaolinite and alunite. Propylitically altered rock not shown.*

*

VENT—*Inferred central vent area of volcano.*

CENTRAL MINING AREA—*Approximate outline of principal uranium mines.*

STRIKE AND DIP OF BEDDING

12

Inclined

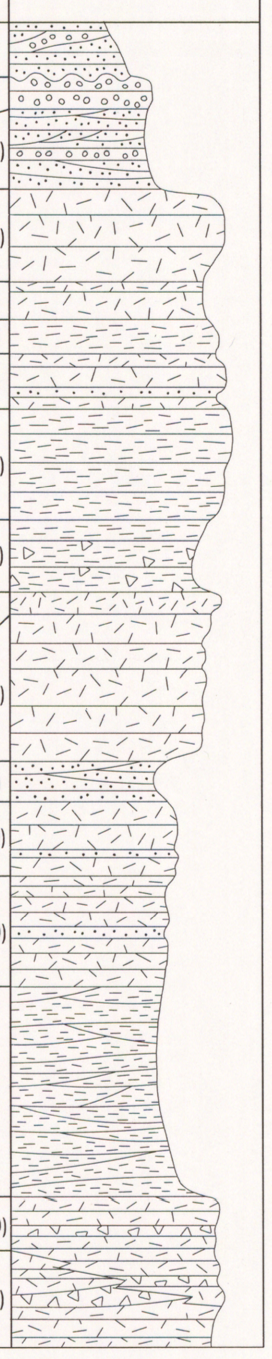
⊕ Horizontal

15

STRIKE AND DIP OF FLOW FOLIATION

▪ **15.3**, 18.5 Ma **SAMPLE LOCALITY**—*Fission-track (bold) or K-Ar dated (see tables 1 and 2).*

	MAP UNIT	SYMBOL	THICKNESS Feet (Meters)	LITHOLOGY
	Surficial deposits	Qa_1, Qaf_1, Qms, Qal, Qa_2, Qaf_2	300 (90)	
	Coarse-grained sedimentary rocks	QTa_3	150(45)	
	Sevier River Formation	Tse	450 (135)	
Mount Belknap Volcanics	Gray Hills Rhyolite Member	Tmbg	500 (150)	
	Porphyritic lava flows	Tmbp	200 (60)	
	Crystal-rich tuff member	Tmbc	200 (60)	
	Dikes, lava flows, and plugs	Tmbd	300 (90)	
	Red Hills Tuff Member	Tmbr	600 (180)	
	Joe Lott Tuff Member	Tmbj	400 (120)	
	Potassium-rich mafic volcanic rocks	Tpm	100 (30)	
Mount Belknap Volcanics	Crystal-rich volcanic domes and plugs	Tmbi	800 (245)	
Intracaldera rocks, Monroe Peak caldera	Sedimentary rocks	Tmps	200 (60)	
	Lava flows of Monroe Peak	Tmpl	400 (120)	
	Lava flows of Monkey Flat Ridge	Tmf	600 (180)	
	Osiris Tuff	Toi	1100 (335)	
	Volcanic rocks of Little Table	Tlt	600 (180)	
	Bullion Canyon Volcanics	Tbc	500 (150)	



DESCRIPTION OF MAP UNITS

Qa_1 Piedmont-slope deposits—*Silt, sand, and gravel on piedmont slopes.*

Qaf_1 Alluvial-fan deposits—*Silt, sand, and gravel in alluvial fans and along streams that feed fans.*

Qms Landslide debris—*Angular, unsorted material emplaced by mass movement.*

Qal Alluvial flood-plain deposits—*Silt, sand, and gravel in the flood plain of the Sevier River.*

Qa_2 Older piedmont-slope deposits—*Dissected remnants of older piedmont-slope deposits*

Qaf_2 Older alluvial-fan deposits—*Dissected remnants of older alluvial fans.*

QTa_3 Coarse-grained sedimentary rocks—*Poorly to moderately consolidated conglomerate and pebbly sandstone.*

Tse Sevier River Formation, undivided—*Gray and tan, poorly to moderately consolidated sandstone, conglomerate, siltstone, and claystone, chiefly deposited in a fluvial environment.*

Tmbg Gray Hills Rhyolite Member of the Mount Belknap Volcanics—*Gray, pink, and red, flow-foliated rhyolite lava flows and dikes.*

Tmbp Porphyritic lava flows of the Mount Belknap Volcanics—*Red, pink, and gray, porphyritic rhyodacitic lava flows and ash-flow tuff.*

Tmbc Crystal-rich tuff member of the Mount Belknap Volcanics—*Red, gray, and pink, crystal-rich rhyodacitic ash-flow tuff.*

Tmbd Dikes, lava flows, and plugs of the Mount Belknap Volcanics—*Gray and pink, flow-foliated rhyolite dikes, lava flows, and plugs.*

Tmbr Red Hills Tuff Member of the Mount Belknap Volcanics—*Red, densely welded, crystal-poor rhyolite ash-flow tuff.*

Tmbj Joe Lott Tuff Member of the Mount Belknap Volcanics—*Tan and gray, poorly welded, crystal-poor rhyolite ash-flow tuff.*

Tpm Potassium-rich mafic volcanic rocks—*Black mafic lava flows and scoria.*

Tmbi Crystal-rich volcanic domes and plugs of Mount Belknap Volcanics—*Tan, pink, gray, and purple, crystal-rich rhyolite volcanic domes, lava flows, and intrusive feeders.*

Tif Fine-grained silicic pluton—*Gray and greenish-gray, fine-grained, granodioritic to granitic intracaldera pluton.*

Tmps Monroe Peak intracaldera sedimentary rocks—*Tan, gray, and yellow, soft to moderately resistant sandstone, airfall tuff, and minor lava flows, siltstone, and conglomerate.*

Tmpl Lava flows of Monroe Peak—*Gray, pink, and khaki, intracaldera, crystal-rich, rhyodacitic lava flows.*

Tmf Lava flows of Monkey Flat Ridge—*Gray, red, tan, and brown, intracaldera, crystal-poor rhyodacitic to dacitic lava flows.*

Tdsi Durkee Springs pluton—*Gray and light-green, intracaldera quartz monzonite and quartz monzonite porphyry.*

Tci Central intrusion—*Gray and green, porphyritic or equigranular, intracaldera quartz monzonite or monzonite.*

Tdci Durkee Creek pluton—*Light-green and gray, intracaldera monzonite porphyry.*

Tmpi Undivided intrusive rocks related to the Monroe Peak caldera—*Tan and gray, intracaldera monzonite porphyry and quartz monzonite porphyry.*

Toi Osiris Tuff, intracaldera facies—*Orange and tan, densely welded rhyodacitic intracaldera ash-flow tuff.*

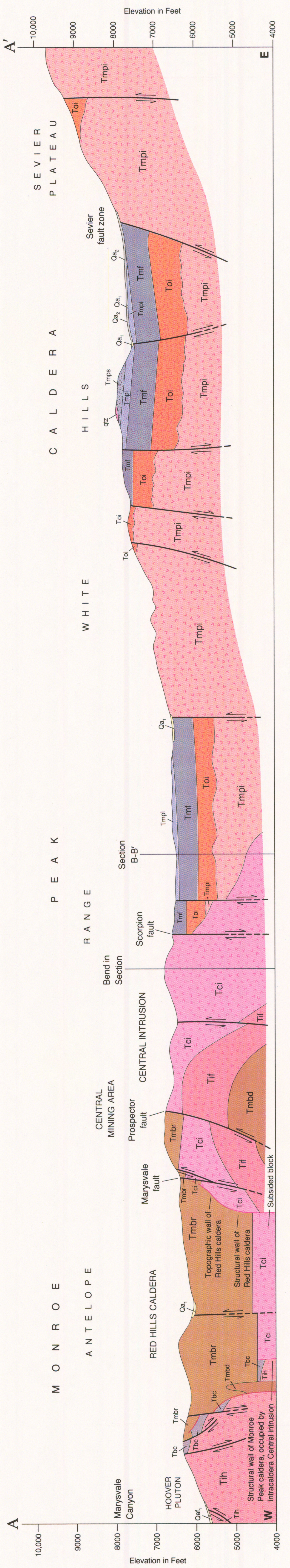
To Osiris Tuff, outflow facies—*Brown and light-gray, densely welded rhyodacitic ash-flow tuff.*

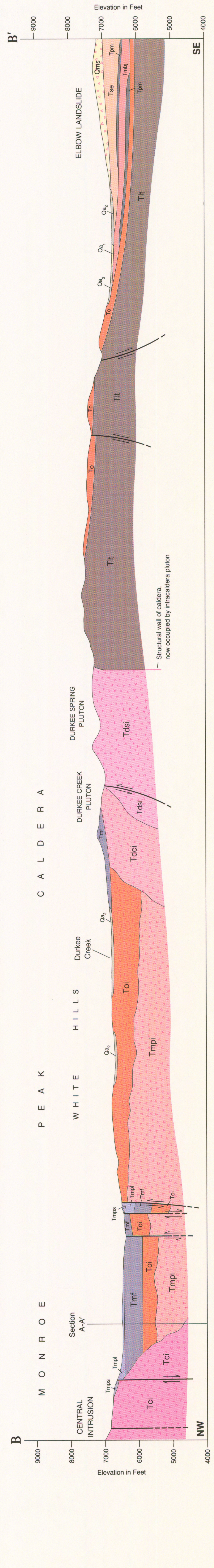
Tlt Volcanic rocks of Little Table—*Green, gray, and red, andesitic lava flows and subordinate flow breccia and volcanic mudflow breccia.*

Tih Hoover pluton—*Green and gray, holocrystalline, porphyritic quartz monzonite.*

Tbc Bullion Canyon Volcanics—*Gray, green, and brown, heterogeneous, dacitic lava flows and subordinate volcanic mudflow breccia and flow breccia.*

JTRn Navajo Sandstone—*Light-gray and buff, resistant, crossbedded sandstone.*





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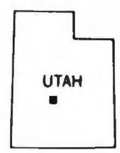
GEOLOGIC MAP OF THE MARYSVALE QUADRANGLE, PIUTE COUNTY, UTAH

By Peter D. Rowley, Charles G. Cunningham, Thomas A. Steven, Harald H. Mehnert, and Charles W. Naeser



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GEOLOGIC MAP OF THE MARYSVALE QUADRANGLE, PIUTE COUNTY, UTAH

By Peter D. Rowley[1], Charles G. Cunningham[2], Thomas A. Steven[1], Harald H. Mehnert[1], and Charles W. Naeser[1]

INTRODUCTION

The Marysvale quadrangle is in the central part of the High Plateaus subprovince of the Colorado Plateaus physiographic province. The subprovince is structurally transitional between the block-faulted Basin and Range province to the west and the stable Colorado Plateaus to the east. The quadrangle contains a series of low hills and structural basins between the fault-bounded Tushar Mountains on the western edge of the quadrangle and the fault-bounded Sevier Plateau on the eastern edge.

The Marysvale quadrangle is near the heart of the Marysvale volcanic field, one of the largest Tertiary eruptive piles in the western United States. Rocks of the Marysvale field were erupted from several volcanic centers within and adjacent to the quadrangle. An older and more voluminous sequence of intermediate-composition, calc-alkaline rocks is overlain by a bimodal (rhyolite and basalt) alkaline sequence that is roughly coeval with extensional tectonism in this part of Utah. Most of the calc-alkaline rocks in the Marysvale field are lava flows, flow breccia, and volcanic mudflow breccia that formed stratovolcanos of dacitic to rhyodacitic composition ranging in age from about 32 to 22 Ma. Some rocks, however, are ash-flow tuffs whose eruption led to subsidence of calderas. The southwestern part of the Monroe Peak caldera, the largest in the Marysvale field, is in the quadrangle. The caldera formed as a result of the eruption of the 23 Ma Osiris Tuff, the most voluminous and widespread ash-flow sheet derived from the Marysvale field. Caldera subsidence took place about 23 to 22 Ma, near the end of the deposition of the calc-alkaline sequence. Thick intracaldera deposits of Osiris Tuff and of post-Osiris lava flows were erupted from local centers within the caldera that are now covered by younger rocks or obscured by the effects of pervasive hydrothermal alteration. The underlying source of these rocks and the alteration was a shallow magma chamber that evolved into a composite intracaldera batholith emplaced into the roots of the caldera.

Bimodal volcanic rocks of the Marysvale field consist mostly of rhyolitic lava flows, domes, and ash-flow tuff of the Mount Belknap Volcanics, and minor basaltic lava flows. Most Mount Belknap rocks in the quadrangle were derived from local centers along the northern margin of the quadrangle (the eastern source area of Cunningham and Steven, 1979d), but ash-flow tuff of the Joe Lott Tuff Member was derived from the Mount Belknap caldera in the Tushar Mountains (western source area; Budding and others, 1987).

The Marysvale quadrangle is within the Marysvale mining district which contains deposits of base and precious metals, uranium, and alunite. Callaghan (1973) described in detail the geologic setting and production history of individual mines in the district. Within the quadrangle, most deposits are of alunite, mined chiefly during World Wars I and II, and uranium, mined principally in the 1950s and 1960s. Most alunite deposits are related to emplacement of plutons that are part of the intracaldera batholith of the Monroe Peak caldera. The earliest comprehensive discussion of the alunite deposits was by Callaghan (1938). Most uranium deposits are in the Central Mining Area, the southern part of which is outlined in the northern part of the quadrangle. Although most uranium is hosted by rocks related to the Monroe Peak caldera, the origin of the uranium is genetically related to emplacement of rhyolite of the Mount Belknap Volcanics. The earliest comprehensive reports on the Central Mining Area were those of Kerr and others (1957) and Kerr (1963, 1968).

In 1975, T.A. Steven and C.G. Cunningham began detailed mapping and studies of specific deposits as part of a reappraisal of the mineral potential of the Marysvale district. They were joined by other geologists, geophysicists, and geo-

[1] *Geologist, U.S. Geological Survey, Denver, CO*
[2] *Geologist, U.S. Geological Survey, Reston, VA*

chemists from the U.S. Geological Survey and other organizations, and the study was expanded to include geologic mapping, Bouguer gravity and aeromagnetic surveys, and geochemical and isotopic investigations of the entire Richfield 2° quadrangle. Resultant publications are too numerous to list here (over 200 of them to date), but some of the reports most relevant to the economic geology of the Marysvale quadrangle are: Cunningham and Steven (1979a) and Rasmussen and others (1985) on the Central Mining Area; Cunningham and Steven (1979b) and Beaty and others (1986) on the Deer Trail Mountain-Alunite Ridge area; Cunningham and Steven (1979c) and Budding and others (1987) on the Mount Belknap caldera; Steven and others (1981) on uranium throughout the Marysvale volcanic field; Cunningham, Ludwig and others (1982) on the geochronology of the Central Mining Area; Cunningham, Steven and others (1984) on the western and southern Tushar Mountains; Cunningham, Rye and others (1984) on Marysvale alunite deposits; Podwysocki and others (1983) and Cunningham, Steven and others (1984) on altered and silicified rocks in the Marysvale area; Miller and others (1984a, b, c) on trace-element distributions in the Marysvale area; Cook and others (1984) on the Bouguer gravity of the Marysvale area; and Campbell and others (1984) on the aeromagnetic data of the Marysvale area.

General discussions of the geology and geophysics in and near the Marysvale quadrangle include Callaghan (1938, 1939); Callaghan and Parker (1961, 1962a); Willard and Callaghan (1962); Shawe and Rowley (1978); Cunningham and Steven (1979e); Steven and others (1979, 1988); Rowley, Steven and others (1979); Steven and Morris (1983, 1984); Cook and others (1984); and Campbell and others (1984). Geologic maps have been published for the areas north of the mapped areas by Callaghan and Parker (1961); Cunningham and Steven (1979f); and Rowley and others (1988); to the west by Callaghan and Parker (1962a) and Cunningham and Steven (1979b, g); to the east by Willard and Callaghan (1962) and Rowley, Williams and others (1981); and to the south by Willard and Callaghan (1962) and Rowley, Cunningham and others (1979). Data available in 1981 were compiled by Cunningham and others (1983).

Before discovery of the Monroe Peak caldera, geologic maps of the Marysvale quadrangle were published by Kerr and others (1957), Willard and Callaghan (1962), and Cunningham and Steven (1979a, e). The geology of the central Marysvale field (Cunningham and others, 1983) was compiled before we realized that the western edge of the Monroe Peak caldera partly underlay the area of the Marysvale quadrangle (Rowley, Cunningham and Kaplan, 1981; Rowley, Williams and others, 1981; Rowley and others, 1986a, b). Subsequent research described in this report has shown that the western part of the caldera extends across the Marysvale quadrangle and the adjoining Antelope Range quadrangle (Rowley and others, 1988). The geology and mineral deposits of the Antelope Range-Marysvale area are thus herein described in the contex of this interpretation. A preliminary discussion of the Monroe Peak caldera was presented by Steven and others (1984).

STRATIGRAPHY

Layered rocks exposed in the Marysvale quadrangle are Oligocene to Holocene in age and are at least 7500 feet thick. These rocks are largely Tertiary volcanic rocks and Quaternary surficial deposits. Also included are scattered blocks of Jurassic and Triassic(?) sandstone brought up along intrusive contacts. Of the igneous rocks, most belong to the calc-alkaline sequence. One of the thickest and oldest calc-alkaline units consists of lava flows and subordinate volcanic mudflow breccia and flow breccia of the Bullion Canyon Volcanics, which belong to one or more stratovolcanos. Intrusive rocks of the Hoover pluton in the northwestern corner of the quadrangle probably represent the crystallized magma source for some flows of the Bullion Canyon Volcanics. The Bullion Canyon Volcanics are overlain by ash-flow tuff, lava flows, and sedimentary rocks and are cut by intrusive rocks related to development of the Monroe Peak caldera; these younger units comprise the uppermost calc-alkaline rocks in the quadrangle. Most volcanic rocks of the bimodal sequence are part of the Mount Belknap Volcanics and are derived from a western source area (Mount Belknap caldera) in the Tushar Mountains and an eastern source area in and north of the mapped area. During bimodal volcanism, regional extension formed broad basins by either warping or faulting. Uplands were eroded and the resultant continental sediments, making up older parts of the Sevier River Formation, were deposited in the basins (Steven and others, 1981). Intense basin-range faulting took place later, from latest Miocene to early Pleistocene time, and the sedimentary and volcanic rocks were broken into large, tilted, north-northwest-trending horsts and grabens. The largest of the downfaulted areas is Marysvale Valley in the western part of the quadrangle. The grabens are largely filled with upper parts of the Sevier River Formation and by unconsolidated Quaternary sediments.

JURASSIC AND TRIASSIC?

Navajo Sandstone

The Navajo Sandstone consists of light-gray and buff, resistant, well-sorted, prominently crossbedded or locally planar-bedded, fine-grained sandstone. Subrounded blocks of the Navajo, up to 500 feet long, occur primarily along intrusive margins of intercaldera plutons and were probably carried up to these positions during emplacement of the plutons.

OLIGOCENE

Bullion Canyon Volcanics

The Bullion Canyon Volcanics have not been studied in detail but appear to consist of a thick, soft to resistant, heterogeneous sequence of mostly dacitic stratovolcano deposits of several lithologies and sources. The main rock types are lava flows and subordinate volcanic mudflow breccia and flow breccia of intermediate composition; these rocks are classified as vent-facies rocks according to the concepts of Parsons (1965, 1969) and Smedes and Prostka (1972). The dominant lithology is a light- to dark-gray, light- to medium-green, reddish-brown, and khaki, porphyritic lava flow that contains sparse to moderately abundant phenocrysts of plagioclase and subordinate, but conspicuous, hornblende, and minor pyroxene and Fe-Ti oxides. Exposures east and southeast of Marysvale include interbedded dacitic flows and breccia of the Mount Dutton Formation which intertongues with the Bullion Canyon Volcanics south of the mapped area (Cunningham and others, 1983). Mount Dutton rocks are aphanitic or contain sparse small phenocrysts of plagioclase, hornblende, pyroxene, and Fe-Ti oxides. The Bullion Canyon Volcanics were defined by Callaghan (1939) and the age of the formation in the quadrangle is Oligocene, but Miocene rocks are included elsewhere (Cunningham and others, 1983). Partial faulted sections in the quadrangle indicate that the volcanic rocks are at least 500 feet thick but exposures elsewhere have thickness of several thousand feet.

Hoover pluton

Rocks comprising the Hoover pluton consist of green, gray, and pinkish-gray, resistant, fine- to coarse-grained, holocrystalline, porphyritic quartz monzonite containing plagioclase and subordinate orthoclase, pyroxene, quartz, biotite, and hornblende and minor Fe-Ti oxides. The intrusion locally contains masses and dikes of gray aplitic rock consisting of plagioclase and subordinate orthoclase, hornblende, quartz, and biotite and minor Fe-Ti oxides. The pluton intrudes the Bullion Canyon Volcanics but is considered to be generally synchronous and a probable source for some Bullion Canyon flows. The intrusion is named after Hoover Peak, the high point of the body, located just northwest of the mapped area. The pluton is exposed only in the northwestern corner of the quadrangle.

MIOCENE? AND OLIGOCENE

Volcanic rocks of Little Table

The volcanic rocks of Little Table is an informal unit made up of lava flows and subordinate flow breccia and volcanic mudflow breccia. The flows and breccia clasts are lithologically similar and are characterized by green, gray, red, and salmon, locally amygdaloidal and vesicular, andesitic rock containing moderately abundant phenocrysts of plagioclase and subordinate to minor pyroxene, Fe-Ti oxides, olivine, and sanidine. The unit is well exposed at Little Table (Rowley, Williams and others, 1981), east of the mapped area, where it consists of a series of mostly flat-lying thin beds resembling deposits of a shield volcano. The source of the unit probably was at or near Little Table. Most rocks of the unit are Oligocene but some may be Miocene. The unit is generally equivalent in age with the Bullion Canyon Volcanics and Mount Dutton Formation (Cunningham and others, 1983). Its maximum exposed thickness in the quadrangle is about 600 feet; it is considerably thicker near Little Table.

MIOCENE

Osiris Tuff, outflow facies

The outflow facies of the Osiris Tuff consists of brown (lower part) and light-gray (upper vapor phase zone), resistant, densely welded, rhyodacitic ash-flow tuff containing moderately abundant phenocrysts of plagioclase, subordinate sanidine, and minor biotite, Fe-Ti oxides, and pyroxene. In most places it weathers to rounded bouldery masses. The tuff contains drawn-out pumice lenticules and, in its upper part, steeply dipping flow foliation caused by secondary flowage. One or, locally, two simple cooling units are present in the quadrangle; the lower one in some places contains a black basal vitrophyre as thick as 5 feet. At one place about 1.5 miles southeast of Marysvale, the formation includes a discontinuous 30-foot-thick, soft, white and pink, crystal-poor, locally crossbedded surge deposit or airfall tuff that underlies the typical welded tuff; this tuff may represent an early pyroclastic eruption of the Osiris eruptive cycle. The source of the outflow facies of the Osiris Tuff is the Monroe Peak caldera of this quadrangle and adjoining areas (Rowley, Cunningham and Kaplan, 1981; Rowley, Williams and others, 1981; Rowley and others, 1986a, b; Rowley and others, 1988). After eruption of the outflow facies, the caldera subsided and was largely filled by intracaldera-facies Osiris Tuff and younger lava flows, volcanic domes, airfall tuff, and clastic sedimentary rocks (Steven and others, 1984). The tuff was first recognized and informally named by Williams and Hackman (1971); it was formally defined by Anderson and Rowley (1975). Its K-Ar age is about 23 Ma (Fleck and others, 1975)*. The maximum thickness of the outflow facies in the quadrangle is about 200 feet.

Osiris Tuff, intracaldera facies

The intracaldera facies of the Osiris Tuff is confined to the Monroe Peak caldera, from where it originated and which it largely filled. The unit consists of orange and tan, argillically altered and soft, densely welded ash-flow tuff and lava flows(?) that are petrographically similar to rocks of the Osiris Tuff outflow facies. In several places, the unit includes sparse, interbedded, crystal-poor beds that probably are lava flows. The original base of the unit is not exposed because it is intruded by cogenetic plutonic rocks. Most rocks overlying these intracaldera intrusions were intensely altered and are now poorly exposed in most places. Exposures of the unit, however, are relatively fresh in the SW¼ sec. 15, T. 27 S., R. 3 W., about 2 miles east-northeast of Marysvale. Here, steeply dipping, flow-foliated rocks of the unit are lithologically similar to, and difficult to distinguish from, undivided intrusive rocks related to the Monroe Peak caldera (unit Tmpi). We interpret the intracaldera facies of the Osiris Tuff and the intrusive rocks here to be gradational; the pluton partly represents the magma source of intracaldera Osiris that invaded the roots of its own pyroclastic debris and possibly was frozen in the act of erupting Osiris Tuff. A minumum thickness for the intracaldera facies, of about 1100 feet, is estimated from partial sections measured in the quadrangle.

Undivided intrusive rocks related to the Monroe Peak caldera

This unit consists of tan, light-gray, and light-green, locally flow-foliated, resistant monzonite porphyry and quartz mon-

*Where necessary, isotopic ages have been converted using the new decay constants of Steiger and Jäger (1977).

zonite porphyry that were the source for, and intruded, extrusive and sedimentary rocks in the Monroe Peak caldera. The unit makes up a composite intracaldera plutonic mass consisting of several discrete bodies and apophyses not mapped separately. The plutonic rocks contain moderately abundant phenocrysts of plagioclase, subordinate to minor orthoclase and pyroxene, and minor biotite, hornblende, and Fe-Ti oxides. The groundmass is mostly orthoclase, plagioclase, and quartz and is very fine grained near intrusive contacts but grades progressively to medium-grained rock inward in the pluton. At some margins of the intrusive mass, the rock lithologically resembles the Osiris Tuff; in these places, the pluton probably represents the unevacuated source magma of the intracaldera Osiris Tuff that either remained in place or rose higher and intruded its own ejecta in the caldera fill. Locally, the intrusive rock lithologically resembles lava flows within the post-Osiris intracladera sequence and thus also probably represents the magma source for those rocks. New fission-track ages of a sample collected from a holocrystalline phase in Dry Canyon north of the mapped area are 21.5 ± 0.8 Ma from zircon and 20.0 ± 3.4 Ma from apatite (Rowley and others, 1988). The zircon age is considered to be closer to the true age. Although not statistically different from the zircon age, the apatite age is numerically younger and has a larger analytical error.

Durkee Creek pluton

The Durkee Creek pluton, about 1 mile in north-south diameter and 3 miles in east-west diameter, is located just east of Marysvale, where it is well exposed in a canyon cut by Durkee Creek. It is one of the intracaldera plutons of the Monroe Peak caldera, mapped separately because of its distinctive lithology. Its emplacement was controlled by the southern margin of the caldera. The rock consists of light-green and light-gray, strongly flow-foliated monzonite porphyry that locally contains miarolitic cavities as well as moderately abundant phenocrysts of plagioclase, subordinate orthoclase and pyroxene, and minor biotite and Fe-Ti oxides. In the western part of the pluton, mostly south of Durkee Creek, the rock is deuterically altered and crumbly in places. The altered rock contains selvages of resistant fresh rock as much as about 3 inches wide lining both sides of primary extension joints; these plutonic selvages resemble those within Miocene plutons in the Iron Springs mining district, 65 miles southwest of the mapped area (Rowley and Barker, 1978). Selvage rocks are fresh probably because deuteric fluids from the crystallizing pluton were tapped by early formed joints, whereas the fluids altered the intrusive rock where they were not tapped off. Intrusive rock grades southward into adjacent overlying lava flows mapped with the lava flows of Monkey Flat Ridge (unit Tmf) that are petrographically similar but are vesicular and contain finer grained groundmass cyrstals. Thus the pluton is considered to have breached the surface and been the magma source for some of the intracaldera volcanic rocks.

Central intrusion

The Central intrusion underlies much of the Central Mining Area along the northern margin of the quadrangle. It is made up of gray and green, resistant, porphyritic or less commonly equigranular, quartz monzonite porphyry and monzonite porphyry. Most rocks contain abundant phenocrysts of plagioclase, subordinate hornblende, pyroxene, biotite, and orthoclase, and minor quartz and Fe-Ti oxides in a groundmass of moderately to coarsely crystalline orthoclase, plagioclase, and quartz; accessory minerals are apatite, sphene, and zircon. The pluton generally has a fine-grained chilled margin as much as 200 feet wide. The intrusion is one of the plutons related to the Monroe Peak caldera, and its margins lithologically resemble the main body of undivided intrusive rocks related to the Monroe Peak caldera (unit Tmpi). The Central intrusion is distinguished from the undivided intrusive rocks related to the Monroe Peak caldera by a generally coarse groundmass and a more mafic composition. The pluton was informally named Central "intrusive" by Kerr and others (1957) and was mapped by Kerr and others (1957), Callaghan and Parker (1961), Willard and Callaghan (1962), and Cunningham and Steven (1979f); these geologists recognized that it is a host to many of the uranium deposits in the Central Mining District. Dunkhase (1980) studied the chemistry of the body and reported anomalously high uranium, thorium, and zirconium. The pluton probably is about 22 Ma. Discordant fission-track ages determined on samples collected from the Prospector mine are 23.3 ± 2.6 and 19.0 ± 0.8 Ma (Steven and others, 1979). Ages determined earlier by Bassett and others (1963) are discounted because they are either discordant within the same sample or are unreasonably old. The most consistent isotopic ages for the intrusion were obtained from adjacent contemporaneous replacement alunite bodies (Cunningham, Rye and others, 1984). These K-Ar ages were determined on alunite from the Winkleman mine (21.8 ± 4.3 Ma; Steven and others, 1979) west of the mapped area, from the Whitehorse mine in the quadrangle (22.7 ± 1.1 Ma; Steven and others, 1979), and from mines in the Antelope Range quadrangle. Analytical data of ages from samples from the quadrangle are given in tables 1 and 2. The pluton must have been eroded and unroofed by about 19 Ma because it is unconformably overlain by the Red Hills Tuff Member of the Mount Belknap Volcanics (unit Tmbr).

Durkee Springs pluton

The Durkee Springs pluton, less than 1 mile in diameter, is located about 1.5 miles south-southwest of Durkee Springs. It is one of the intracaldera plutons related to the Monroe Peak caldera, mapped separately because of its distinctive lithology. Its emplacement was controlled by the southern margin of the caldera. The rock consists of gray and light-green, resistant quartz monzonite and quartz monzonite porphyry of plagioclase and subordinate to minor hornblende, pyroxene, biotite, and Fe-Ti oxides. The body contains a discontinuous chilled margin with a fine-grained groundmass 25 feet wide. Groundmass crystals in the interior of the pluton, however, are medium grained and consist of plagioclase, quartz, and orthoclase, and thus this small body resembles the Central intrusion (unit Tci) in that it is a mostly holocrystalline mass that intruded the intracaldera volcanic fill. The pluton cuts rocks of the Durkee Creek pluton (unit Tdci), which here resembles, and probably was the source for, overlying lava flows of Monkey Flat Ridge (unit Tmf). Thus the pluton at the level exposed probably slightly postdates its immediately adjacent wallrocks of this volcanic unit.

Lava flows of Monkey Flat Ridge

This informal intracaldera unit of the Monroe Peak caldera consists of gray, red, tan, brown, purple, khaki, and light-green, moderately resistant, vesicular to amygdaloidal, locally flow-foliated, dacitic to rhyodacitic lava flows and rare flow breccia containing sparse phenocrysts of plagioclase, subordinate to minor sanidine and pyroxene, and minor Fe-Ti oxides, biotite, and olivine. Most flows are tabular but some are more bulbous and appear to form low volcanic domes. The unit locally includes minor fluvial sandstone and conglomerate, crystal-rich lava flows similar to those in the lava flows of Monroe Peak (unit Tmpl), and airfall tuff. The unit was deposited within the Monroe Peak caldera except for some khaki-colored flows just east of Marysvale, which apparently extended out over the caldera margin. The unit is a partial extrusive equivalent of intrusive rocks related to the Monroe Peak caldera. Vent areas and contact relations are generally poorly exposed or obliterated due to pervasive hydrothermal alteration. Near the southern edge of the caldera (S½ sec. 14 and N½ sec. 23, T. 27 S., R. 3 W.), deeply altered (stippled pattern) lava flows of Monkey Flat Ridge are cut by the Durkee Creek pluton (unit Tdci), which breached the surface and produced additional lava flows of Monkey Flat Ridge that are fresh and overlie the altered flows. Fresh flows also overlie altered flows of the same unit to the northwest in the N½ sec. 15. Thus the map unit reflects a complex and rapid intermingling of extrusion, overlapping intrusion, and alteration. The unit is named for fresh flow rocks at Monkey Flat Ridge about 3 miles northeast of the mapped area that were formerly called dacitic lava flows by Rowley, Cunningham and Kaplan (1981). Two K-Ar ages by Bassett and others (1963) determined on a sample collected 2.7 miles east of Marysvale are discounted because they are intruded by units with younger isotopic ages. The maximum exposed thickness of the unit is about 600 feet, although no complete section exists.

Lava flows of Monroe Peak

Intracaldera lava flows of Monroe Peak consist of gray, pink, khaki, tan, and dark-green, generally resistant, vesicular or amygdaloidal, rhyodacitic lava flows containing moderately abundant, locally large (as much as 0.8 inch) phenocrysts of plagioclase and subordinate sanidine, and subordinate to minor pyroxene, hornblende, biotite, oxyhornblende, and Fe-Ti oxides. Some flows locally have thin, black, basal vitrophyres. Most are tabular lava flows but some are more bulbous and appear to form low volcanic domes. This informal unit includes local minor crystal-poor lava flows and dikes similar to those in the lava flows of Monkey Flat Ridge (unit Tmf), fluvial sandstone, flow breccia, volcanic mudflow breccia, and airfall tuff. The unit was deposited only within the Monroe Peak caldera, and it is considered to be a partial extrusive equivalent of intrusive rocks of the Monroe Peak caldera (unit Tmpi). It was named for exposures capping Monroe Peak, about 4 miles northeast of the mapped area (Rowley, Cunningham and Kaplan, 1981). Vent areas and contact relations are generally poorly exposed or obscured by pervasive hydrothermal alteration. New discordant isotopic ages determined on a sample collected from a dome to the north (Rowley and others, 1988) consist of a K-Ar age on sanidine of 21.3 ± 0.7 Ma and a fission-track age on zircon of 15.3 ± 0.7 Ma. The fission-track age indicates resetting probably by heat from an inferred buried pluton; heat from this pluton also appears to have helped to form nearby natroalunite deposits (Cunningham, Rye and othere, 1984). The maximum exposed thickness of the unit is about 400 feet, although no complete section is exposed.

Monroe Peak intracaldera sedimentary rocks

Monroe Peak intracaldera sedimentary rocks are mapped as an informal unit of the Monroe Peak caldera that consists of tan, gray, yellow, dark-brown, bronze, pink, and green, mostly soft, thin- to medium-bedded, mostly planar-bedded but locally crossbedded, fine- to coarse-grained tuffaceous sandstone and airfall tuff, and minor crystal-poor and crystal-rich lava flows, siltstone, and conglomerate. The sedimentary rocks are considered to be primarily of fluvial, but locally of lacustrine origin; they were derived from erosion of highlands at, and outside of, the caldera rim and within the caldera and were deposited in the closed basin of the Monroe Peak caldera. Tuff beds locally are rich in phenocrysts and(or) rounded pumice lapilli; they are either airfall or reworked airfall deposits. Rocks of the map unit are either argillically or advanced-argillically altered or silicified, and contact relations are generally poorly exposed or obliterated. In some places, as along the southern contact of the Central intrusion, the unit is so densely silicified that it resembles Navajo Sandstone. The maximum exposed thickness of the unit is nearly 200 feet, although no complete section is exposed.

Fine-grained silicic pluton

The fine-grained silicic pluton consists of a small patch of gray and greenish-gray, resistant, fine-grained granodioritic to granitic rocks that cut the Central intrusion (unit Tci) in the Central Mining Area. The pluton contains abundant phenocrysts of orthoclase, plagioclase, and quartz, and subordinate to minor biotite, pyroxene, hornblende, and minor Fe-Ti oxides in a groundmass of coarsely to finely crystalline orthoclase, plagioclase, and quartz. The map unit includes several dikes, some of them aplite, as much as 25 feet wide. The pluton was mapped and described by Kerr and others (1957), Callaghan and Parker (1961), and Cunningham and Steven (1979a, f). Cunningham and Steven (1978, 1979a, d, f) interpreted the body to be a fine-grained granite belonging to the bimodal sequence and perhaps a source for some of the rhyolite volcanic rocks in the eastern source area of the Mount Belknap Volcanics. Alternately, the petrographic resemblance of some parts of the pluton to the Central intrusion suggests that it is a late stage, more silicic, differentiated phase of the Central intrusion. The fine-grained silicic pluton is located near the intersection of the eastern source area and the margin of the Monroe Peak caldera. Data from drilling and under-ground mining indicate that the pluton is larger at depth (Kerr, 1968, figure 6). The pluton is a host for many of the uranium ore bodies in the Central Mining Area (Cunningham and Steven, 1978, 1979a). K-Ar and fission-track ages cluster around 21 Ma (Steven and others, 1979; Cunningham, Ludwig and others, 1982), and include K-Ar and fission-track ages of 22.1 ± 4.4 and 20.5 ± 0.7 from lower levels of the Freedom No. 1 mine (Cunningham, Ludwig and others, 1982) (tables 1,2). K-Ar and fission-track ages of 21.6 ± 0.9 and 20.4 ± 0.9 Ma (Steven and others, 1979) determined on altered and reset monozonite porphyry of the Central intrusion adjacent to a dike of fine-grained silicic rock give good ages for the fine-grained silicic pluton itself (Cunningham, Ludwig and others, 1982). All analytical data are given in tables 1 and 2; data on other ages are summarized by Rowley and others (1988).

Crystal-rich volcanic domes and plugs of Mount Belknap Volcanics

This informal unit consists of tan, pink, gray, and purple, resistant, flow-foliated, crystal-rich, rhyolitic volcanic domes and lava flows as well as intrusive feeders for volcanic domes and flows. The unit consists of the oldest products of the eastern source area of the Mount Belknap Volcanics. Black and gray vitrophyres, locally devitrified to crumbly orange rock, mark in some places the bases of flows or the chilled margins of intrusive plugs and domes. The rock contains abundant phenocrysts of sanidine, smoky beta quartz, plagioclase, and minor biotite, hornblende, Fe-Ti oxides, pyroxene, apatite, and sphene. Fission-track and K-Ar ages of the unit cluster about 21 Ma (Steven and others, 1979; Cunningham, Ludwig and others, 1982). The maximum thickness of lava flows in the unit is about 800 feet.

Potassium-rich mafic volcanic rocks

This unit consists of black and dark-gray, resistant, locally vesicular to amygdaloidal, locally glassy lava flows and scoria. The rock contains sparse phenocrysts of pyroxene, plagioclase, olivine, and Fe-Ti oxides, and lithologically and petrographically appears to be basalt. Best and others (1980), however, in a study of basaltic rocks of southwestern Utah, found that mafic rocks about 22-18 Ma are high in K_2O and thus differ chemically from basalt; they called them shoshonites. We designated similar rocks in the quadrangle to the south (Rowley, Cunningham and others, 1979) older basalt(?) lava flows (see also Anderson and Rowley, 1975), but we used the terminology "potassium-rich mafic volcanic rocks" in later compilation (Cunningham and others, 1983). Best and others (1980) determined a K-Ar age of 21.1 Ma on one of these flows, located just west of Piute Reservoir, 8 miles south of the mapped area; Wender and Nash (1979) analyzed the same rock and named it an absarokite. The potassium-rich mafic volcanic rocks mark the inception of the start of bimodal volcanism (basaltic rocks and rhyolite), generally synchronous with extensional tectonism in southwestern Utah (Rowley, Steven and others, 1979). Some flows in the area underlie or are interbedded with the 19 Ma Joe Lott Tuff Member and thus are correlated with potassium-rich mafic volcanic rocks on the basis of their age. Other, lithologically similar flows overlie the Osiris Tuff or Joe Lott Member but are not overlain by younger rocks; they may also be part of the same sequence, which is generally contemporaneous with the Joe Lott Tuff Member (unit Tmbj), so they are also included in the same map unit. Alternatively, these flows could be much younger, perhaps as young as late Tertiary or Quaternary. True basalts of late Cenozoic age are abundant in this part of Utah (Best and others, 1980), including 13 Ma basalts just south of the quadrangle (Rowley, Cunningham and others, 1979; Cunningham and others, 1983). The maximum thickness of the potassuim-rich mafic volcanic rocks is about 100 feet.

Joe Lott Tuff Member of Mount Belknap Volcanics

The Joe Lott Tuff Member consists of tan, gray, reddish-brown, red, and light-green, moderately resistant, locally glassy, poorly welded, rhyolite ash-flow tuff. It contains about one percent phenocrysts of quartz, sanidine, biotite and accessory minerals but many lithic clasts of darker flow-foliated rocks of the Mount Belknap Volcanics. Basal parts of some cooling units contain basalt boulders. Some cooling units contain brown and black basal vitrophyres. A tan tuff mapped as the Joe Lott Member near Taylor Pond just north of Marysvale may instead be a precursor pyroclastic deposit of the Gray Hills Rhyolite Member (unit Tmbg), which overlies this tuff. A dark-brown or black desert varnish characterizes weathered exposures of the unit. The tuff was defined as a formation by Callaghan (1939). Cunningham and Steven 1979d) recognized its derivation from the Mount Belknap caldera, about 7 miles west of the mapped area, in the western source area of the Mount Belknap Volcanics (Budding and others, 1987), and they made it a member of the Mount Belknap Volcanics. The tuff was erupted in early Miocene time about 19 Ma, based on K-Ar ages of overlying and underlying units. Its maximum exposed thickness in the quadrangle is about 400 feet, although neither the depositional base nor top is exposed.

Red Hills Tuff Member of Mount Belknap Volcanics

The Red Hills Tuff Member consists of red, reddish-tan, reddish-brown, and light-gray, moderately resistant, vesicular, densely welded, rhyolite ash-flow tuff. The tuff displays a notable flow foliation in the Red Hills, and this fabric was interpreted by Cunningham and Steven (1979d) to have formed as the tuff flowed back into the Red Hills caldera after initial eruption. The unit contains sparse small phenocrysts of anorthoclase, quartz, plagioclase, and minor but conspicuous biotite. They also contain abundant light-gray, highly compacted, pumice lenticules and sparse small, dark, lithic clasts. A black basal vitrophyre, about 5 feet thick, is exposed near the Royston mine. The unit was defined by Cunningham and Steven (1979d) and interpreted to have erupted from the buried Red Hills caldera in the northwestern part of the quadrangle (Cunningham and Steven, 1979a, e), in the eastern source area. The tuff is about 19 Ma based on a K-Ar age (table 1) from the basal glass near the Royston mine of 18.9 ± 0.7 Ma (Cunningham, Ludwig and others, 1982) and on ages of underlying and overlying units. The member unconformably overlies the Central intrusion (unit Tci) and Monroe Peak intracaldera lava flows that were altered largely during emplacement of the intrusion. It is exposed only in the northwestern part of the quadrangle, where its maximum thickness here is about 600 feet.

Dikes, lava flows, and plugs of Mount Belknap Volcanics

This informal map unit, made up of rocks of similar lithologies but of several ages in the Miocene, consists of gray, pink, and light-greenish-gray, moderately resistant, flow-foliated rhyolite dikes, lava flows, and hypabyssal plugs. The distribution of these rocks partly defines the eastern source area of the Mount Belknap Volcanics, but ages relative to other members of the formation are poorly known. The bodies contain few phenocrysts and are locally perlitic; most are lithologically similar, and thus, perhaps partly correlative with the Gray Hills Rhyolite Member (unit Tmbg).

The most economically significant element of this unit is a series of glassy rhyolite dikes that cut the Central intrusion (unit Tci) and the fine-grained silicic pluton (unit Tif). Uranium- and molybdenum-bearing veins occur within, and thus are genetically related to, these dikes. Cunningham, Ludwig and others (1982) suggested that the dikes pass downward into a hidden stock (unit Tmbd in section A-A') that provided the uranium metals for mineralization in the Central Mining Area. Cunningham and Steven (1978, 1979a) also proposed that the apex of this stock may contain a porphyry-type molybdenum deposit. Uranium veins cut the Red Hills Tuff Member. Two fission-track ages were determined on glassy dikes in the Antelope Range quadrangle, one of 19.0 Ma (Cunningham, Ludwig and others, 1982) and another of 19.9 Ma (Rowley and others, 1988). Cunningham, Ludwig and others (1982) reported two discordant fission-track ages of 23.3 (apatite) and 18.1 (zircon) Ma on glassy dike samples from the 700-feet level of the Freedom No. 1 mine (table 2); the older of these is rejected. Cunningham, Ludwig and others (1982) favor an age of 19-18 Ma for the glassy rhyolite dikes, which agrees with ages measured on uranium minerals.

A sequence of pink, red, and light-green, resistant, flow-foliated, crystal-poor rhyolite lava flows form the base of the hills about 1 mile northwest of Marysvale. The flows locally contain abundant devitrification spherulites, some of which are as much as 1 foot in diameter. The flows resemble the Gray Hills Rhyolite Member, which caps these hills, but they are lumped in the map unit because of their lower stratigraphic position with respect to the Gray Hills Member. Interbedded with these lava flows are subordinate light-green tuffaceous sandstone and volcanic mudflow breccia, which are included in the map unit. The whole sequence is at least 300 feet thick. A small plug of crystal-poor black vitrophyre exposed just west of U.S. Highway 89 (Kerr and others, 1957, figure 2) 2 miles north of Marysvale has K-Ar ages of 18.9 and 17.7 Ma (Bassett and others, 1963). Several plugs of white, flow-foliated, crystal-poor rhyolite in the northwestern corner of the quadrangle cut the Red Hills Tuff Member near the edge of the Red Hills caldera; their location may be controlled by the caldera structural margin (Cunningham and Steven, 1979a, p. 12).

Crystal-rich tuff member of Mount Belknap Volcanics

The informal crystal-rich tuff member consists of red, brownish-red, gray, and pink, resistant, crystal-rich, densely welded, rhyodacitic ash-flow tuff. The unit, the most crystal-rich extrusive unit of the Mount Belknap Volcanics, contains abundant phenocrysts of anorthoclase, quartz, and plagioclase, and subordinate to minor biotite, hornblende, Fe-Ti oxides, apatite, zircon, and sphene. The unit locally includes vitrophyre and abundant lithic clasts. The member was named by Cunningham and Steven (1979d), who suggested that it was derived from the Mount Belknap caldera because it fills channels that radiate outward from the caldera. The unit occupies two environments in the hills just northwest of Marysvale: 1) a bed overlying the Red Hills Tuff Member in the W½ sec. 7, T. 27 S., R. 3 W.; and 2) either a dike or a deep north-trending channel within the dikes, lava flows, and plugs of the Mount Belknap Volcanics (unit Tmbd) just to the south, in sec. 18. The exposures in sec. 18 are argillically altered and poorly exposed. Discordant K-Ar and fission-track ages of the member were reported by Steven and others (1979) from two locations: 1) a K-Ar age of 18.5 ± 0.8 Ma and a fission-track zircon age of 15.3 ± 0.8 Ma from a sample collected from the bed overlying the Red Hills Tuff Member at the western edge of the quadrangle; and 2) a K-Ar age of 19.4 Ma and a fission-track zircon age of 16.1 Ma from a sample collected 10 miles southwest of the mapped area. The fission-track ages of both samples are too young in comparison with the age of the overlying Gray Hills Rhyolite Member (unit Tmbg) and may represent resetting by later thermal activity. The maximum thickness of the member in the quadrangle is about 200 feet.

Porphyritic lava flows of Mount Belknap Volcanics

The informal porphyritic lava flow member consists of red, pink, and gray, moderately resistant, rhyodacitic lava flows and ash-flow tuff. The rocks contain sparse to moderately abundant phenocrysts of plagioclase and augite and sparse hornblende in a felted groundmass of microlites and hematite. The unit was mapped in the quadrangle as "purple porphyry" by Kerr and others (1957) and proposed as a thin, locally derived, informal unit by Cunningham and Steven (1979d). The maximum thickness of the member in the quadrangle is about 250 feet.

Gray Hills Rhyolite Member of Mount Belknap Volcanics

The Gray Hills Rhyolite Member consists of light-gray, pink, and red, resistant, spectacularly flow-foliated, rhyolite lava flows and dikes. The rock contains almost no phenocrysts other than sparse sanidine, yet small lenticular cavities are commonly lined with drusy crystals of vapor-phase minerals. It is commonly spherulitically devitrified except in a prominent black vitrophyre near the base of the unit. Below this glass, a local, thin, light-gray, crystal-poor, unwelded tuff rich in lithic clasts and pumice, which may mark a precursor pyroclastic eruption of the member, is included in the member. The source of the Gray Hills Member is just west of the mapped unit, where the unit is about 1600 feet thick (Cunningham and Steven, 1979d). The unit was defined as a formation by Molloy and Kerr (1962) and placed within the Mount Belknap Volcanics by Cunningham and Steven (1979d). Samples of black, crystal-poor vitrophyre from the base of the member north of Beaver Creek have concordant K-Ar ages of 20.5, 20.5, and 19.5 Ma (Bassett and others, 1963). The maximum thickness of the unit in the quadrangle is about 500 feet, and it is thicker westward, toward its inferred source.

PLIOCENE? AND MIOCENE

Sevier River Formation, undivided

The Sevier River Formation consists of gray and tan, poorly to moderately consolidated, medium- to thick-bedded sandstone, planar-bedded and gently crossbedded conglomerate, siltstone, and claystone. These clastic rocks were deposited by fluvial and (locally) lacustrine processes, first mostly in broad downwarped basins but later in grabens. The formation was defined by Callaghan (1938) for exposures near the town of Sevier about 8 miles north of the mapped area. Soft, gray, crossbedded, salt-and-pepper sandstone that overlies Osiris Tuff and underlies the potassium-rich mafic volcanic rocks (unit Tpm) in the central part of the quadrangle is about 23 to 19 Ma and is the oldest known part of the formation. The main body of the formation is tan and fine grained, and is best exposed in the western part of the quadrangle. Airfall tuff beds within similar rocks near Clear Creek northwest of the mapped area have fission-track ages of 14 and 7 Ma, middle to late Miocene (Steven and others, 1979). The upper part of the unit, however, may be as young as Pliocene or even Pleistocene. The youngest rocks of the formation are located east of the Sevier River in the southern half of the quadrangle and are largely conglomerate and conglomeratic sandstone containing abundant clasts of basaltic rock. They may be coarse fanglomerates deposited during the main period of block faulting or perhaps after integration of through-flowing drainage through the Marysvale Valley. Numerous high-angle faults of small displacement cut the coarse-grained deposits. Depositional landforms that controlled deposition of the Sevier River Formation are not preserved. The exposed thickness of the rocks is about 450 feet but they are doubtless considerably thicker beneath Marysvale Valley.

QUATERNARY

Coarse-grained sedimentary rocks

This informal unit consists of remnants of alluvial fan and pediment deposits. The deposits consist mostly of gray or locally tan, poorly to moderately consolidated conglomerate and pebbly sandstone and minor siltstone and fine sandstone. Clasts commonly are coated with caliche. The deposits are lithologically similar to, but less consolidated than, deposits east of the Sevier River that are mapped as Sevier River Formation; the latter appear to have been uplifted along the Marysvale fault and may be older products of the same depositional sequence. The subhorizontal surface atop these deposits west of the Sevier River may represent a Pleistocene river terrace. The unit is probably early Pleistocene and Pliocene but may include Miocene rocks. The maximum thickness of the unit is at least 150 feet, but it probably is thicker under the surficial cover.

Older piedmont-slope deposits

Dissected remnants of older piedmont-slope deposits consist of gray, unconsolidated to poorly consolidated silt, sand, and gravel. Clasts commonly are coated with caliche. The unit is mostly Pleistocene but may include some Pliocene deposits. The unit's maximum exposed thickness is at least 300 feet.

Older alluvial-fan deposits

Dissected remnants of older alluvial fans consist of gray, unconsolidated to poorly consolidated silt, sand, and gravel. Clasts commonly are coated with caliche. Maximum exposed thickness of this Pleistocene unit is about 200 feet.

Piedmont-slope deposits

Piedmont-slope deposits consist of unconsolidated, poorly sorted silt, sand, and gravel on broad, sweeping surfaces (piedmont slopes) formed by erosion (as pediments) and deposition (as alluvial fans). The unit includes alluvium of small drainages; locally it also includes colluvium, alluvial slope wash, and talus. The maximum exposed thickness is about 200 feet for this Holocene and Pleistocene unit.

Alluvial-fan deposits

Alluvial-fan deposits consist of unconsolidated, poorly sorted silt, sand, and gravel deposited at the bases of some slopes. The unit includes alluvium from streams that fed fans and local colluvium, alluvial slope wash, and talus. The maximum exposed thickness is about 100 feet for this Holocene and Pleistocene unit.

Landslide debris

Landslide debris consists of unconsolidated, angular, unsorted material that moved downslope, mostly off the Sevier Plateau fault scarp, to form lobate deposits. The unit includes some talus and colluvium. The large Elbow landslide, derived from the high Sevier Plateau to the east, contains numerous fresh features suggesting relative recent emplacement, probably in late Pleistocene; parts may still move, particularly during wet periods. The maximum thickness of the unit is at least 400 feet.

Alluvial flood-plain deposits

Unconsolidated silt, sand, and gravel form a flood plain flanking the Sevier River. The unit includes overbank deposits as well as islands and bars exposed in the stream channel during low-water stages. Maximum thickness is about 30 feet for this Holocene unit.

MONROE PEAK CALDERA

The Monroe Peak caldera is the largest caldera in the Marysvale volcanic field, with an east-west diameter of 16 miles and a north-south diameter of 11 miles. The caldera was inset into an upland of clustered volcanos, which erupted rocks such as the Bullion Canyon Volcanics near the central part of the Marysvale field and the volcanic rocks of Little Table to the southeast. The caldera formed during final stages of calc-alkaline volcanic activity when cupolas rose above a huge composite batholith complex that is inferred to underlie most of the volcanic field (Steven and others, 1984). The southwestern part of the caldera is exposed in the Marysvale quadrangle; the rest of the caldera was mapped by Rowley, Cunningham and Kaplan (1981); Rowley, Williams and others (1981); Rowley and others (1986a, b); and Rowley and others (1988). A summary of the geology of the caldera is provided by Steven and others (1984). The Monroe Peak caldera coincides with an aeromagnetic high and a gravity low, apparent at both regional (Zietz and others, 1976; Mabey and Virgin, 1980; Cook and others, 1975, 1981) and detailed scales (Campbell and others, 1984; Cook and others, 1984).

The Monroe Peak caldera was the source of the Osiris Tuff, the most widespread volcanic unit in the Marysvale volcanic field. The Osiris Tuff is a densely welded rhyodacitic ash-flow tuff that consists of a thin outflow facies deposited outside the caldera and a thick intracaldera facies. The outflow facies presently is exposed over an area of at least 1500 square miles mostly in the central High Plateaus; it formerly covered most of the Marysvale field. Outflow rocks are rarely more than 50 feet thick within the main part of the Marysvale field, but as much as 300 feet are preserved north and east of the field where the tuff apparently drained down off the field and pooled in lowlands. In contrast, the thickness of the intracaldera facies is at least 1800 feet. The total volume of both facies is at least 50 $miles^3$.

Most of the caldera formed by rapid subsidence when the outflow facies of the Osiris Tuff was erupted about 23 Ma. Tuff from subsequent eruptions probably was largely confined to the caldera, although some outflow material probably also was produced. The caldera continued to subside in response to the continued evacuation of the magma chamber. Emplacement of the Osiris Tuff was followed by eruption of lava flows and volcanic domes at several sites within the caldera. The younger lava flows have isotopic ages of about 22 Ma. All these rocks are in turn overlain by airfall tuff and by fluvial and lacustrine sedimentary rocks deposited in the remaining parts of the topographic basin of the caldera. The post-Osiris intracaldera units complexly intertongue in parts of the caldera. The volcanic rocks represent tapping of a composite cupola that underlay the caldera and rose to shallow levels as the caldera developed. The various plutonic units have isotopic ages of about 22 Ma.

The intracaldera cupola rose to such shallow levels that it intruded the intracaldera facies of the Osiris Tuff and most other intracaldera rocks. In some places, intrusive bodies extending upward from the source batholith pass gradationally into volcanic rocks, demonstrating that they breached the surface. The complex pattern of younger faults that characterize the quadrangle has obscured the answer to the question as to whether the intracaldera batholith produced minor resurgent uplift within the caldera. The presence of intracaldera sedimentary rocks concentrated near the southeastern edge of the caldera (Rowley, Williams and others, 1981; Rowley and others, 1986a) suggests that they filled a moat within the caldera on the outer flank of a resurgent uplift. However, less faulted parts of the caldera in the Sevier Plateau to the east are saucer shaped, suggesting that any resurgent uplift was minor. Our interpretation is that the intracaldera rocks that formed the roof of the intracaldera batholith did not have the strength to support a structural dome owing to the shallow depth of the batholith, which was probably only several thousand feet or less below the surface.

RED HILLS CALDERA

The Red Hills caldera is not exposed but has been inferred to underlie rocks of the Red Hills Tuff Member in the northwestern part of the quadrangle (Cunningham and Steven, 1979d). It was suggested to be the source of the Red Hills Tuff Member. The evidence for these interpretations is chiefly steep inward-dipping flow foliation in the Red Hills Member that describes a circular pattern in the area where the tuff is thickest and most densely welded; outside the inferred caldera, the tuff is flat lying and moderately welded (Steven and others, 1981). Cunningham and Steven (1979d) hypothesized that after eruption, but before consolidation, some of the highly welded but still plastic reconstituted magma flowed back into a small caldera as it subsided around the vent. Evidence of actual subsidence is sketchy, and the flow-back may have been caused by magma withdrawal down the throat of a vent. The feature is marked by a gravity low and magnetic high. The location of the feature along the margin of the Monroe Peak caldera suggests control by the older, larger caldera.

HIGH-ANGLE FAULTS

The rocks in the Marysvale quadrangle are cut by numerous high-angle basin-range faults formed during regional extension of the Basin and Range province and High Plateaus. Most faults strike north-northeast or north-northwest, creating a rhombic fault pattern. Some fault planes in the area exhibit subhorizontal slickensides (R.E. Anderson, oral communication, 1984), but known relative displacement for most faults in the area indicates that dip-slip displacement dominated along most faults.

The greatest vertical displacement known in the quadrangle is that along the Sevier fault zone, along which uplift of the Sevier Plateau took place. Topographic relief between the summit of the plateau and Marysvale Valley is more than 5000 feet, thereby giving a minimum amount for vertical displacement along the fault zone. The Tushar fault zone just west of the mapped area is of comparable or greater displacement. The low hills in the quadrangle represent a complexly faulted graben between these two great fault zones. The Marysvale fault within the graben may be of large displacement, as suggested by the significant low-gravity anomaly west of the fault (Cook and others, 1984).

Ages of faulting are poorly known, but most offset seems to have taken place during latest Miocene through early Pleistocene time. In the Kingston Canyon area of the Sevier Plateau, about 13 miles south-southeast of the mapped area, the ages of rhyolites bracket the age of canyon cutting, and therefore major faulting, at between 8 and 5 Ma (Rowley, Steven and Mehnert, 1981). Faulting may have begun much earlier, however, inasmuch as regional extension in Utah seems to be generally associated with compositionally bimodal (alkali basalt and alkali rhyolite) volcanism, which began about 22 Ma in this and neighboring quadrangles (Anderson and Rowley, 1975; Rowley, Cunningham and others, 1979; Steven and others, 1979; Best and others, 1980). Sedimentary rocks of the Sevier River Formation below the potassium-rich mafic volcanic rocks and the 19 Ma Joe Lott Member may mark the start of the extensional downwarping or downfaulting in the quadrangle. Faulting locally continued into late Quaternary time, as indicated by scarps that cut surficial sediments in some nearby areas (e.g., Rowley, Cummingham and others, 1979).

ECONOMIC GEOLOGY

The northern part of the Marysvale quadrangle contains mineralized and hydrothermally altered rocks of several ages (Steven and others, 1979; Cunningham and others, 1983), and propylitic, argillic, and advanced-argillic alteration products are common and conspicuous (Cunningham, Steven and others, 1984). Numerous mines and prospects have been dug in the quadrangle, and uranium and alunite have been the main commodities produced. Most uranium mines are confined to a small area, 0.7 mile north-south by 0.3 mile east-west, called the Central Mining Area (Cunningham and Steven, 1978, 1979a), which extends across the border of the Marysvale quadrangle into the Antelope Range quadrangle to the north (Rowley and others, 1988). The Central intrusion, the fine-grained silicic pluton, and the Red Hills Tuff Member are the main hosts for uranium veins in the Central Mining Area.

The oldest period of alteration and mineralization in the Marysvale area was coeval with emplacement of 27-23 Ma plutons associated with the Bullion Canyon Volcanics (Steven and others, 1979; Steven and Morris, 1984). In the Tushar Mountains, sparse pyrite-bearing quartz-carbonate veins that locally contain some gold and silver formed during this time generally near the carapace of plutons, but no such productive veins are yet known in the Marysvale quadrangle. One pluton of this age that might have associated veins of this type is the Hoover pluton; the Trinity mine just northwest of the mapped area is in contact-metamorphosed sedimentary rocks at the pluton margin but only thin streaks of pyrite and chalcopyrite are exposed (Callaghan, 1973). Alternatively, some of the mineralized rocks at the Trinity mine may be related to a small rhyolite stock that cuts the metamorphosed rocks near the mine.

The next youngest period of alteration and mineralization accompanied emplacement of the intracaldera batholith, especially the Central intrusion. The principal economic commodity formed during this event was replacement alunite. Most production of replacement alunite in the quadrangle came from the Whitehorse and White Hills mines (Callaghan, 1938, 1973; Willard and Callaghan, 1962). Direct isotopic dating confirms that replacement alunite was formed at the same general age (23-22 Ma; table 1) as the Central intrusion (Steven and others, 1979; Cunningham, Rye and others, 1984). The origin of replacement alunite deposits was attributed by Cunningham, Rye and others (1984) to heat from the Central intrusion that produced a series of hydrothermal convection cells of circulating ground water in the country rocks. Evaporite minerals in Mesozoic rocks at depth supplied sedimentary sulfur, which was reduced while passing through the volcanic rocks. The sulfur reacted with atmospheric oxygen near the ground surface to produce acidic solutions that altered the country rocks and developed alunite and related minerals. Alunite deposits, marking the location of the upflowing limbs of the convection cells, surround the Central intrusion (Podwysocki and others, 1983). The main products of the alteration are kaolinite, alunite, jarosite, and hematite; within each cell, the alunite zone passes laterally into kaolinite and upward into jarosite, hematite, and flooded silica zones. Propylitically altered rocks formed below the permanent water table, whereas alunite and kaolinite formed just above the water table, and jarosite, hematite, and silica formed progressively closer to the surface. The zones are best exposed in the Yellow Jacket and Al Kee Mee hydrothermal cells of the Antelope Range quadrangle (Rowley and other, 1988). In places, rock in the hematite zone forms ore-grade concentrations of stalactic and botryoid iron and manganese, although the tonnage of such material is small. Small deposits of magnetite were mined at the Iron Duke mine at the contact of the Central intrusion (Willard and Callaghan, 1962; Callaghan, 1973), but these do not appear to be related to the hematite zone in altered rocks; instead the ore occurs as a dike or lens in the pluton and thus resembles magnetite dikes in porphyry plutons at the Iron Springs mining district (Mackin, 1968). Base and precious metals related to hydrothermal cells or to deeper-level vein, replacement, or skarn deposits may also exist near the Central intrusion (Steven and Morris, 1984).

The upper flooded silica zones form numerous resistant knobs in the quadrangle. They developed when silica released during alteration migrated upward and either replaced rocks near the surface or was deposited on the surface as siliceous sinter from hot springs (Cunningham, Rye and others, 1984). When silica sealed up vents of hot springs and geysers, built-up pressure inside sinter mounds eventually was released explosively, producing hydrothermal breccia (Cunningham, Rye and others, 1984). Repeated sealing of vents and succeeding "blowouts" formed large quartz caps, which are numerous in the quadrangle. In addition, ponds that formed in association with former hot springs were filled with laminated clay, siltstone, and sandstone that were silicified soon after deposition. These sediments exhibit soft-sediment deformation features. The depositional environments then must have resembled the ones we see now in the hot spring areas of Yellowstone National Park (Eaton and others, 1975).

Two younger periods of alteration and mineralization are related to rhyolitic magmas of the Mount Belknap Volcanics. The first deposited uranium and related lithophile elements in the Central Mining Area. Most production (1 million lbs. of U_3O_8) came from nine mines (Callaghan, 1973; Steven and Cunningham, 1979a); of these, the Prospector, Freedom No. 1, Bullion Monarch, Farmer John, Wilhelm, and Sunnyside mines are in the quadrangle. Most of the uranium is in uraninite and coffinite that were precipitated in fracture-filled veins of diverse trends. Low-grade uranium values were also noted during drilling east of the Central Mining Area (Steven and others, 1981; Steven and Morris, 1984). Hydrothermal alteration association with uranium mineralization was relatively slight (Cunningham and Steven, 1978, 1979a; Steven and others, 1981). Fluid-inclusion data indicate that the fluids that deposited uranium were dilute, acidic, reducing solutions with temperatures of about 200°C, and that these fluids were rich in fluorine, suggesting that uranium was carried in uranous fluoride complexes.

The uranium veins are genetically associated with rhyolite dikes of the Mount Belknap Volcanics (unit Tmbd). The veins and dikes cut the Central intrusion, the fine-grained silicic pluton, and the Red Hills Tuff Member. Isotopic ages on the dikes range from 19-18 Ma and are the same as ages measured directly on the ore, including a U-Pb isochron age of 19.0 ± 3.7 Ma on uranium and fluorine vein material and a fission-track age of 16.5 ± 4.3 Ma on quartz adjacent to pitchblende (Cunningham, Ludwig and others, 1982). Molybdenum and fluorite are associated with the uranium, and molybdenum increases in abundance downward in subsurface mine workings. Cunningham and Steven (1978, 1979a) and Steven and others (1981) suggested that the uranium and molybdenum are related to emplacement of, and distention of, overlying rocks by an underlying parent source magma body of the Mount Belknap Volcanics, and that this intrusion (unit Tmbd on cross section A-A') also may contain a porphyry-type disseminated molybdenum deposit. Uranium also is enriched within rocks related to the Monroe Peak caldera and exceeds 50 ppm (parts per million) in fresh silicic, intracaldera lava flows in the eastern part of the caldera (Rowley and others, 1986a,b). Dunkhase (1980) noted the anomalously high values of uranium in fresh rocks of the Central intrusion and postulated that the pluton was the ultimate source of the uranium.

The next youngest known period of alteration and mineralization produced natroalunite that is superimposed on, and whose constituents are derived from, the older replacement alunite (Cunningham, Rye and others, 1984). Heat from plutons or feeders of the Mount Belknap Volcanics probably remobilized the natroalunite about 18-13 Ma (Steven and others, 1979; Cunningham, Steven and others, 1984). Natroalunite has been mined in the Antelope Range quadrangle (Rowley and others, 1988). Rhyolite or granite plutons may underlie the deposits (Cunningham, Rye and others, 1984). The age of natroalunite is similar to the age of mineralization, alteration, and inferred plutonism in the Deer Trail mine and Alunite Ridge area about 4 miles west of the mapped area (Cunningham and Steven, 1979b).

The youngest period of alteration in the area is that associated with hot springs along faults to the north (Rowley and others, 1988). Calcareous tufa occurs at the sites of these springs. The springs have no known association with Quaternary bimodal volcanism and may have originated by deep convection along basin-range faults.

GEOMORPHOLOGY

The present topography in the Marysvale quadrangle is the result of erosion of downwarped basins and fault blocks formed during a long phase of regional extension. One of the first products of this extension was closed basins in which the oldest parts of the Sevier River Formation were deposited. Perhaps the first sediments of this basin are those that predate the 19 Ma Joe Lott Tuff Member. The mountains and valleys took on their present overall size and shape later, probably in late Tertiary time and perhaps in the 8 to 5 million-year interval hypothesized for most faulting in the Kingston Canyon area to the south (Rowley, Steven and Mehnert, 1981). As subsidence and faulting continued, fluvial and lacustrine sediments of the Sevier River Formation probably filled the faulted basins. The present drainage was superposed on the thick fill of younger parts of the Sevier River Formation during destruction of closed basins and integration of drainage throughout much of the High Plateaus and adjacent parts of the Basin and Range. As streams cut down and the base level lowered, the soft rocks of the Sevier River Formation were selectively removed by the ancestral Sevier River. Marysvale Canyon, the southern end of which is in the northwestern part of the quadrangle, for example, is cut more than 1000 feet through the Antelope Range and parts of the northeastern Tushar Mountains. Eardley and Beutner (1934) ascribed the cutting of Marysvale Canyon to stream piracy of a former south-flowing river. We suggest instead that it formed by superposition through a cover of the Sevier River Formation. The flat top of the Antelope Range, with its preserved patches of Sevier River Formation, gives evidence of the minimum level to which the formation filled the basin. This flat top is an erosion surface, perhaps a pediment, cut probably during basin filling. Faulting continued during downcutting in this part of Utah; many streams probably were antecedent across active faults.

The widespread silica masses and related intracaldera volcanic, sedimentary, hydrothermally altered, and mineralized rocks that are known to have formed at or near the surface about 22 Ma are an enigma. One would not expect former erosion surfaces to be preserved for that length of time, especially where uplift and deep erosion were profound after the surfaces were formed. A similar problem was noted in the Kingston Canyon area by Rowley, Steven and Mehnert (1981). At this locality, a rhyolite tuff cone and volcanic dome formed at the bottom of Kingston Canyon about 5 Ma, but there has been no incision below this level in the canyon since then. The most reasonable explanation is that the 22 Ma erosion surface and perhaps the 5 Ma cone were buried by the Sevier River Formation and that they only recently have been exhumed.

GEOLOGIC HAZARDS

This part of Utah is within a seismically active belt and earthquakes have been felt in the Marysvale quadrangle in the historic past. One of Utah's largest earthquakes (magnitude 7) occurred about 15 miles to the northwest during 1967 (Stover and others, 1986). There is no evidence to indicate that any historical earthquakes resulted from local faulting. The only faults in the quadrangle known to have displaced Quaternary deposits are in the western part and the southern edge of the quadrangle; other such faults are south of the mapped area (Rowley, Cunningham and others, 1979). Houses, dams, or major buildings are in danger of being damaged if they are constructed on or near active faults. Buildings on poorly consolidated alluvium or thick, soft soil in valley bottoms are also prone to damage from shaking and subsidence related to earthquake activity.

Two major landslides are mapped in the eastern part of the quadrangle. There are indications of recent movement on the landslides, including fresh ridges, cracks, ponds, and bent trees. It is probable that parts of the landslide will continue to move, especially during wet periods.

Flooding by the Sevier River has taken place in the quadrangle during the last several years, as well as in previous years, and thus flooding can be expected to occur in the future. Flash floods are probable along most other perennial or intermittent streams in the quadrangle, especially those draining the Sevier Plateau or Tushar Mountains. Flood hazards are particularly severe at the mouths of these canyons where flood water might funnel. The town of Marysvale is vulnerable to flooding for it lies on the floodplain of Pine Creek, a stream that drains a large area of the Tushar Mountains. Failure of dams at Otter Creek or Piute Reservoir, along the Sevier River upstream from the Marysvale quadrangle, would cause serious flooding within and downstream from the mapped area.

WATER RESOURCES

The Sevier River provides a perennial source of water for domestic and agricultural uses in the quadrangle. Several small streams and springs issue from the mountain fronts of the Sevier Plateau and Tushar Mountains, but they have been only partly exploited.

SCENIC AND RECREATIONAL AREAS

The Sevier Plateau and Tushar Mountains are rugged, beautiful, heavily wooded mountains, suitable for camping, hiking, and hunting. Other parts of the quadrangle, however, are underlain by sagebrush flats and hills, locally sprinkled with pinyon and juniper trees; these areas are not traditionally considered to be scenic areas, but they are lovely in their own right. In parts of the quadrangle, these hills contain scattered trenches, pits, adits, tunnels, and the remains of a mill and company town (Alunite, in the southwestern part) left from past mining and minerals exploration activity. These features may interest mining and history buffs and rockhounds. In some places, mine workings are not covered or fenced off so that visitors exploring the area on foot should be careful.

ACKNOWLEDGMENTS

We are grateful to many persons for their assistance in the field work and during the evolution of ideas as the long-term study of the Marysvale mining district progressed. These include J.R. Rasmussen, J.J. Anderson, P.L. Williams, D.R. Mabey, K.L. Cook, R.J. Fleck, and R.R. Kennedy. We received encouragement and considerable logistic support from several local residents: Jim and Joan Anderson of Marysvale, Ada Hoover of Marysvale, LaWayne and Marian Hatch of Koosharem, and Dean and Sheren Pierson of Junction and Kanab deserve special mention. The manuscript was much improved by technical reviews by J.C. Cole and B.A. Skipp.

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