U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE CENTRAL MARYSVALE VOLCANIC FIELD, SOUTHWESTERN UTAH

By

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Geologic Investigations Series I–2645–A

ABSTRACT

The geologic map of the central Marysvale volcanic field, southwestern Utah, shows the geology at 1:100,000 scale of the heart of one of the largest Cenozoic volcanic fields in the Western United States. The map shows the area of 38 degrees 15' to 38 degrees 42'30" N., and 112 degrees to 112 degrees 37'30" W. The Marysvale field occurs mostly in the High Plateaus, a subprovince of the Colorado Plateau and structurally a transition zone between the complexly deformed Great Basin to the west and the stable, little-deformed main part of the Colorado Plateau to the east. The western part of the field is in the Great Basin proper. The volcanic rocks and their source intrusions in the volcanic field range in age from about 31 Ma (Oligocene) to about 0.5 Ma (Pleistocene). These rocks overlie sedimentary rocks exposed in the mapped area that range in age from Ordovician to early Cenozoic. The area has been deformed by thrust faults and folds formed during the late Mesozoic to early Cenozoic Sevier deformational event, and later by mostly normal faults and folds of the Miocene to Quaternary basin-range episode. The map revises and updates knowledge gained during a long-term U.S. Geological Survey investigation of the volcanic field, done in part because of its extensive history of mining. The investigation also was done to provide framework geologic knowledge suitable for defining geologic and hydrologic hazards, for locating hydrologic and mineral resources, and for an understanding of geologic processes in the area. A previous geologic map (Cunningham and others, 1983, U.S. Geological Survey Miscellaneous Investigations Series I-1430-A) covered the same area as this map but was published at 1:50,000 scale and is obsolete due to new data. This new geologic map of the central Marysvale field, here published as U.S. Geological Survey Geologic Investigations Series I-2645-A, is accompanied by gravity and aeromagnetic maps of the same area and the same scale (Campbell and others, 1999, U.S. Geological Survey Geologic Investigations Series I-2645-B).

This database was developed to improve upon previous mapping in the central Marysvale volcanic field and compile older mapping at a consistent scale. This area is an important mining district, and a regional understanding of the geology and mineral deposits will assist in understanding genesis of deposits and in exploration for new deposits. The area is also an important part of the transition zone between the Colorado Plateau to the east and the Great Basin to the west. This tectonically significant province may hold keys to the style and mechanisms of continent-scale deformation in the Western United States.

In addition to the description of map units reproduced in this document, the map sheet itself comprises the principal map, a diagram showing stratigraphic correlation of map units, a west-to-east cross section of major geologic structures, and in index map showing major features in the map area.

DESCRIPTION OF MAP UNITS

[This map is intended to update the geologic map of the same area, but at 1:50,000 scale, by Cunningham and others (1983) as well as to provide digital coverage of the geology. The map is accompanied by the geophysical maps of the same area and at the same scale by Campbell and others (1999). The geologic and geophysical maps will provide the geologic framework of the heart of the Marysvale volcanic field, one of the largest volcanic fields in the Western United States and an area of significant mineral potential (Cunningham and others, 1997; Cunningham, Rowley, and others, 1999). Classifications of volcanic and plutonic rocks are those of the IUGS (Le Bas and others, 1986, and Streckeisen, 1976, respectively). Where necessary, isotopic dates given here have been recalculated using the IUGS decay constants (Steiger and Jager, 1977). Age assignments for surficial deposits are estimated chiefly on the basis of their height above present streams, degree of post-depositional modification of original surface morphology, and degree of soil development—especially the morphology and thickness of calcium-carbonate-enriched horizons. Older deposits thus are typically higher in the landscape, are more eroded, and contain more secondary calcium carbonate than younger deposits. We have not mapped man-made deposits.]

SURFICIAL DEPOSITS

Qac **Alluvium and colluvium (Holocene and late Pleistocene)—**Silt, sand, and minor gravel deposited in modern channels and flood plains. Chiefly flood-plain and channel alluvium of the Sevier River as well as flood-plain and channel alluvium of perennial and intermittent streams. Includes some local fan and sheetwash alluvium and hillslope colluvium. Maximum thickness about 10 m

Qpy **Young piedmont-slope alluvium (Holocene and late Pleistocene)**—Poorly to moderately sorted deposits of sand, gravel, and silt forming modern coalesced alluvial fans and pediments. Includes some alluvium of small streams and in some places colluvium, sheetwash alluvium, and talus. Thickness at least 30 m

Ql **Landslide deposits (Holocene and Pleistocene)**—Mostly angular, unsorted, and unstratified rock debris moved by gravity from nearby bedrock cliffs. Abundant in the mapped area, as is to be expected in such a tectonically active area, where basin-range faulting is continuing (Rowley, Steven, and Mehnert, 1981). May include Pliocene landslide material. Includes minor talus and colluvium. Maximum thickness about 75 m

Qh **Hot-spring deposits (Holocene and late Pleistocene)**—Resistant, tan travertine and tufa mounds at the sites of active and former hot springs. Includes active mounds at Monroe Hot Springs and along the Dry Wash fault southeast of Joseph. Maximum thickness about 20 m

Qt **Stream-terrace alluvium (late and middle Pleistocene)—**Sand and pebbly to bouldery gravel that form dissected surfaces as much as 15 m above the level of current streams. Unit mapped mostly near the town of Beaver, in the southwestern part of the mapped area, where the unit partly includes glacial outwash deposits of the Pinedale glaciation, which is the most recent glacial episode and ended about 12,000-15,000 years ago; of the Bull Lake glaciation, which ended about 140,000 years ago; and of glaciations that preceded the Bull Lake and ended at about 250,000 years ago (Machette and others, 1984). Maximum thickness about 15 m

Qpo **Old piedmont-slope alluvium (late and middle Pleistocene)**—Dissected, poorly to moderately sorted deposits of sand, gravel, and silt forming coalesced alluvial fans and pediments that are not graded to present streams. Thickness at least 30 m

Qg **Glacial deposits (late and middle Pleistocene)—**Mostly angular, unsorted, unstratified, sand and pebble- to boulder-gravel deposited by glaciers of mostly Pinedale age, but may include deposits of Bull Lake or older age. Includes prominent lateral moraines along streams below cirques on the western side of the northern Sevier Plateau and the southern and eastern sides of the high Tushar Mountains. Includes some ground moraine and terminal moraines. Maximum thickness about 35 m

BIMODAL IGNEOUS SUITE AND SYNCHRONOUS SEDIMENTARY ROCKS

[The bimodal suite is the product of the younger of two Cenozoic magmatic episodes in the Marysvale volcanic field (Cunningham and others, 1983; Steven and others, 1990; Cunningham and others, 1997, 1999; Cunningham, Unruh, and others, 1998; Rowley, 1998; Rowley and others, 1998). "Bimodal" refers to the two compositional types of volcanic rocks (basalt and high-silica rhyolite) of the suite, present throughout the Western United States (Christiansen and Lipman, 1972)]

Qb **Basalt lava flows (Pleistocene)**—Resistant, dark-gray, black, and red, locally vesicular and amygdaloidal olivine basalt and basaltic andesite lava flows and cinder cones in the Cove Fort area (Clark, 1977; Steven and Morris, 1983). Includes basaltic scoria and ash deposits. K-Ar whole-rock age is 0.5 Ma (Best and others, 1980). Maximum thickness about 100 m

QTs **Sedimentary basin-fill deposits (lower Pleistocene to upper Miocene)**—Soft to moderately indurated, mostly tan and gray sand and pebbly to bouldery gravel and sand. Consists generally of laterally gradational fanglomerate deposits near current basin margins, piedmont-slope deposits farther toward the center of the basins, and lacustrine deposits near the centers of the basins. Includes minor white airfall tuff beds. Deposited in basins formed by basin-range faults that largely control the present topography and are generally synchronous with the deposits. Deposits subhorizontal in most places. Includes deposits mapped and studied in detail in the Beaver basin, in the southwestern part of the mapped area (Machette and others, 1984; Machette, 1985), where Evans and Steven (1982) dated rhyolites of about 9 Ma that are synchronous with and postdated the beginning of faulting that formed the basin. The main phase of basin-range faulting (Zoback and others, 1981, Anderson and others, 1983; Anderson, 1989) took place between 7.6 and 5.4 Ma in the Kingston Canyon area of the southern Sevier Plateau (Rowley, Steven, and Mehnert, 1981), about 5 km south of the mapped area, where a conformable sequence of volcanic rocks as young as 7.6 Ma was offset vertically at least 2,000 m by basin-range faults to form the plateau. With subsequent integration of drainage that formed the present topography (Anderson, 1987; Rowley and others, 1988a,b), the deep antecedent Kingston Canyon was cut through the plateau, and a 5-Ma rhyolite dome was emplaced in the bottom of the canyon. Only the upper part of the sedimentary basin-fill deposits is exposed, but the entire unit is inferred to be several hundred meters thick, and in the Beaver basin it is probably much thicker than this

Tse **Sevier River Formation (upper Miocene)—**Mostly moderately indurated, gray, tan, yellow, white, pink, and light-green sandstone, pebbly to bouldery conglomerate, mudstone, and siltstone (Callaghan, 1938) of fluvial and locally lacustrine origin. Includes local white airfall tuff beds. Basalt clasts generally common. Probably deposited in basins that formed generally prior to the main episode of basin-range faulting (Rowley, Steven, and Mehnert, 1981; Rowley and others, 1998; Rowley, 1998), and thus the distribution and coarseness of the deposits is not necessarily related to the present topography. As mapped, includes deposits in the southern part of the Monroe Peak caldera (Rowley, Williams, and others, 1981; Rowley and others, 1986a) that may be older and better placed in lithologically similar upper moat sediments of Rowley and others (1986a). Airfall tuff beds within the formation near the town of Sevier have fission-track ages of 14 and 7 Ma (Steven and others, 1979); basalt flows (Tb) that intertongue within the formation west of Sevier have K-Ar dates of 9 and 7 Ma (Best and others, 1980). The Sevier River Formation and the basalt are cut by many faults of the basin-range episode, including strike-slip faults (Anderson and Barnhard, 1992) that act as transfer faults for extensional strain, as well as the dominant normal faults. A K-Ar date from an airfall tuff in the formation, collected about 11 km south-southeast of Marysvale, has a date of 13.6 Ma (Rowley and others, 1994). An airfall tuff within the unit east of Annabella has a K-Ar age of 5.6 Ma (Rowley and others, 1994). Exposed thickness at least 100 m, but total thickness may be as much as several hundred meters

Tb **Basalt lava flows (Pliocene? and Miocene)**—Resistant, dark-gray, black, and red, locally vesicular and amygdaloidal olivine basalt and basaltic andesite lava flows, flow breccia, and cinder cones. Includes basaltic scoria and ash deposits. East of Piute Reservoir and 4 km south of the collection site of the underlying 13.6-Ma tuff in the Sevier River Formation (Tse), the map unit has K-Ar dates of 12.9 Ma (Damon, 1969) and 12.7 Ma (Best and others, 1980). About 3 km west of Piute Reservoir, unit has a K-Ar date of 10.9 Ma (Rowley and others, 1994). Basalt flows interbedded at other places within the Sevier River Formation (Tse) have K-Ar dates of 9.2 and 7.4 Ma (Best and others, 1980). Maximum thickness about 130 m

Trf **Rhyolite of Forshea Mountain (Miocene)—**Mostly resistant, light-gray, white, and black, flow-foliated, spherulitic, locally vesicular, crystal-poor rhyolite lava flows and volcanic domes. Flows locally contain black basal vitrophyre. Includes soft, poorly exposed, white airfall and ash-flow tuff and locally derived sandstone and conglomerate at the base of the unit. Has K-Ar age of about 8 Ma (Rowley, Steven, and Mehnert, 1981). Exposed in the southern Sevier Plateau (Rowley, 1979). Maximum thickness 300 m

Trd **Rhyodacite of Dry Lake (Miocene)**—Resistant, light-gray, pink, tan, and black, flow-foliated, locally spherulitic, moderately crystal-rich rhyodacite volcanic domes and lava flows. Flows locally contain black basal vitrophyre. Exposed only in the Dry Lake area of the southern Sevier Plateau, in the southeastern part of the mapped area (Rowley, 1979). Maximum thickness 230 m

Trg **Rhyolite of Gillies Hill (Miocene)**—Mostly resistant, white and light-gray, flow-foliated, locally vesicular, aphanitic to crystal-rich rhyolite lava flows and volcanic domes. Includes interlayered soft, white ash-flow tuff. Exposed on the western edge of the mapped area and areas to the west (Evans and Steven, 1982; Machette and others, 1984). K-Ar ages cluster at 9 Ma, probably synchronous with the initiation of basin-range faulting in the Beaver basin (Evans and Steven, 1982). Base not exposed; thickness at least 350 m

Mount Belknap Volcanics (**Miocene**)—Originally defined by Callaghan (1939) and mapped by Callaghan and Parker (1961a,b; 1962a,b) and Williard and Callaghan (1962). Rocks derived from several caldera and volcano eruptive centers. Stratigraphy revised by Cunningham and Steven (1979a) and mapped by Cunningham and others (1983) and Steven and others (1990). Source of considerable mineral potential, primarily uranium, molybdenum, and alunite (Steven and others, 1981; Steven and Morris, 1987; Cunningham and others, 1994; Cunningham, Rasmussen, and others, 1998, 1999). Isotopic dates 21-12 Ma (Cunningham, Unruh, and others, 1998)

Tmd **Late rhyolite dikes, stocks, and volcanic domes**—Moderately resistant, gray and pink, flow-foliated, small, crystal-poor, glassy to aphanitic rhyolite dikes, stocks, volcanic domes, and lava flows from scattered vents. A series of glassy rhyolite dikes, too small to be shown at map scale, cuts the Central intrusion (Tci), fine-grained granite (Tmf), and Red Hills Tuff Member (Tmr) and has potential economic significance. These dikes contain genetically related uranium- and molybdenum-bearing veins and are interpreted to be derived from a hidden stock that formed the uranium deposits of the Central mining area (Kerr and others, 1957; Cunningham and others, 1982; Cunningham, Rasmussen, and others, 1998). The stock is shown on the cross section as well as cross section A–A' of Rowley and others (1988a). The apex of this stock may contain a porphyry-type molybdenum deposit (Cunningham and Steven, 1979b). Local vein natroalunite of 18-13 Ma appears to have resulted from heat supplied by hidden stocks of the map unit (Podwysocki and Segal, 1983; Cunningham and others, 1984a). Includes the dikes and small stocks (Tmd) and the rhyolite of Big Star (Tmbs) of Cunningham and others (1983) and the dikes, lava flows, and plugs of Mount Belknap Volcanics (Tmbd) of Rowley and others (1988a, b). An unexposed 14-Ma stock, postulated to dome up the Deer Trail Mountain–Alunite Ridge area, formed alunite and gold and base-metal deposits (Cunningham and Steven, 1979c; Cunningham and others, 1984a, b; Beaty and others, 1986; Steven, 1988). Most rocks of the map unit are younger than the Red Hills Tuff Member (Tmr) and have isotopic ages that range from about 19-14 Ma (Rowley and others, 1988a,b; Rowley and others, 1994). The rhyolite of Big Star is a 16- to 12-Ma volcanic dome as much as 100 m thick (Rowley and others, 1988b)

Tmg **Upper gray tuff member, Gray Hills Rhyolite Member, upper red tuff member, and porphyritic lava flows**—Four local units deposited in an east-trending paleocanyon that is east of, and formerly drained, the Mount Belknap caldera. The youngest is the upper gray tuff member (18 Ma; Steven and others, 1979), a light-gray, partially welded, crystal-poor, rhyolite ash-flow tuff unit at least 130 m thick derived from the Mount Belknap caldera. The underlying Gray Hills Rhyolite Member is a light-gray, pink, and red, spherulitic, flow-foliated, crystal-poor rhyolite that forms a volcanic dome, lava flows, dikes, and a basal thin, light-gray, crystal-poor, unwelded tuff confined to a local vent east of the Mount Belknap caldera. Samples from vitrophyres of flows have concordant K-Ar dates of 20.5, 20.5, and 19.5 Ma (Bassett and others, 1963). At its dome source, the unit is about 500 m thick. The lowest part of the unit consists of the upper red tuff member, derived from the Mount Belknap caldera and consisting of a red, densely welded, crystal-poor rhyolite ash-flow tuff, about 20 m thick, characterized by black fiamme; and of coeval porphyritic lava flows, as much as 75 m thick, consisting of dark-gray, red, and pink, poorly to moderately crystal-rich rhyodacite lava flows interbedded with some ash-flow tuff

Tmic **Intracaldera intrusive rocks**—Moderately resistant, mostly gray, small, crystal-poor rhyolite to dacite stocks within the Mount Belknap caldera

Tmc **Crystal-rich tuff member—**Dark-reddish-brown, red, gray, and pink, resistant, moderately to densely welded, crystal-rich rhyolite ash-flow tuff. Fills paleochannels that radiate outward from its source in the Mount Belknap caldera (Cunningham and Steven, 1979a). Locally includes a black basal vitrophyre and abundant lithic clasts. Exposed west of Marysvale. K-Ar age is about 19 Ma (Steven and others, 1979). Thickness about 60 m

Tmr **Red Hills Tuff Member**—Reddish-brown, reddish-tan, and light-gray, moderately resistant, crystal-poor, densely welded rhyolite ash-flow tuff derived from the Red Hills caldera north of Marysvale (Cunningham and Steven, 1979a). Locally contains a black basal vitrophyre. Location of caldera is beneath this subhorizontal tuff based on steep flow foliation suggestive of post-eruptive flow of the tuff back into its source vent. Unconformably overlies the Central intrusion (Tci). About 19 Ma, based on a K-Ar date of 18.9 Ma (Cunningham and others, 1982) and on ages of overlying and underlying units. Maximum thickness about 180 m

Tmj **Joe Lott Tuff Member—**Light-gray, tan, reddish-brown, and light-green, moderately resistant, partially welded, crystal-poor rhyolite ash-flow tuff (Budding and others, 1987). Contains abundant lithic clasts of darker, flow-foliated cogenetic rhyolite flow rock. Locally contains brown and black basal vitrophyre. This is the main outflow unit derived from the Mount Belknap caldera (Cunningham and Steven, 1979a). Stratigraphic position relative to isotopically dated units indicates an age of about 19 Ma (Steven and others, 1979). Maximum exposed thickness about 120 m

Tmb **Mount Baldy Rhyolite Member**—Resistant, light-gray, flow-foliated, crystal-poor intracaldera rhyolite lava flows and dikes derived from, and deposited mostly within, the Mount Belknap caldera. Maximum exposed thickness about 800 m

Tmv **Volcaniclastic rocks**—Soft to moderately resistant, light-gray and white intracaldera volcanic mudflow breccia that is slightly older than, and derived from, lava flows of the Mount Baldy Rhyolite Member (Tmb). Derived from and deposited within the Mount Belknap caldera. Clasts lithologically similar to the Mount Baldy Rhyolite Member. Includes landslide debris and fluvial sandstone and conglomerate. Maximum thickness about 240 m

Tmm **Middle tuff member—**Soft, light-gray and tan, poorly welded, crystal-poor intracaldera rhyolite ash-flow tuff. Lithologically similar to, and locally continuous across the margin of, the Mount Belknap caldera into the upper part of the Joe Lott Tuff Member (Tmj). Thickness about 500 m

Tmbl **Blue Lake Rhyolite Member and lower tuff member—**Lower parts of the intracaldera fill of the Mount Belknap caldera (Cunningham and others, 1983). The Blue Lake Rhyolite Member consists of moderately resistant, gray, flow-foliated, crystal-poor lava flows about 340 m thick. The underlying lower tuff member, lithologically similar to the middle tuff member (Tmm) and the Joe Lott Tuff Member (Tmj), is about 460 m thick (base not exposed) in the lowest exposed parts of the caldera, so is likely to be much thicker

Tmh **Lower heterogeneous member**—Mostly soft, gray rhyolite volcanic domes, lava flows, and subordinate ash-flow tuff and fluvial sandstone. Derived from a volcanic source northwest of Marysvale. Thickness about 70 m

Tmf **Fine-grained granite—**Resistant, gray and greenish-gray, fine-grained granite and granodiorite stock that cuts the Central intrusion (Tci) in the Central Mining Area and hosts some of the uranium-bearing veins of the district. Exposed northeast of the Red Hills caldera and shown on the cross section. Includes associated dikes as wide as 8 m. Isotopic dates cluster at 21-20 Ma (Cunningham and others, 1982; Rowley and others, 1988a,b). Emplaced within the Monroe Peak caldera and possibly a late intrusive phase of this caldera, but included within the Mount Belknap Volcanics on the basis of its similarity in composition and age.

Tmi **Crystal-rich volcanic domes and plugs—**Resistant, tan, pink, and gray, flow-foliated, crystal-rich rhyolite volcanic domes and intrusive feeders for domes since eroded away. Unit crops out northeast of Marysvale. Age about 21 Ma (Steven and others, 1979; Cunningham and others, 1982). Maximum thickness of domes about 250 m

Tpm **Potassium-rich mafic volcanic rocks (Miocene)**—Resistant, black and dark-gray, locally vesicular and amygdaloidal, crystal-poor lava flows and scoria. Rock resembles basalt, but chemical analyses show the rocks to be high in K_2O and thus they may be classified as asbsarokite (Wender and Nash, 1979) or shoshonite (Best and others, 1980). Referred to as "older basalt" by Anderson and Rowley (1975). We retain the name "potassium-rich mafic volcanic rocks" (Cunningham and others, 1983) except where mapped as informally named rock units (mafic lava flows of Birch Creek Mountain, Tbi; mafic gravels of Gunsight Flat, Tgf) in the southwestern part of the mapped area. Mattox and Walker (1989, 1990), Walker and Mattox (1989), and Mattox (1991a, 1992) considered the rocks to represent the termination of volcanism of the Mount Dutton Formation (Td), but we considered them to be the oldest product of bimodal volcanism (Cunningham, Unruh, and others, 1998). K-Ar ages are 25-21 Ma (Rowley and others, 1994). Maximum thickness about 50 m

Tbi **Mafic lava flows of Birch Creek Mountain**—Resistant, black and dark-gray, vesicular and amygdaloidal, crystal-poor, potassium-rich mafic lava flows (Anderson and Rowley, 1975; Wickstrom, 1982; Anderson and others, 1990a, b). Isotopic dates are 23-22 Ma (Rowley and others, 1994). Mapped only in one place in the southwestern part of the mapped area, where it is about 15 m thick, but south of the mapped area unit is as much as 150 m thick

Tgf **Mafic gravels of Gunsight Flat**—Moderately resistant, black and dark-gray fluvial conglomerate made up of clasts of potassium-rich mafic lava flows (Anderson and others, 1990b). Locally intercalated with the mafic lava flows of Birch Creek Mountain (Tbi). Interpreted to represent fanglomerates shed northward from Miocene fault scarps (Anderson and others, 1990b). Maximum thickness about 300 m

CALC-ALKALINE IGNEOUS SUITE AND SYNCHRONOUS SEDIMENTARY ROCKS

[The calc-alkaline suite is the product of the older of two Cenozoic magmatic episodes in the Marysvale volcanic field, and it makes up 95 percent of the total volume of igneous rocks in the Marysvale field (Cunningham and others, 1983; Steven and others, 1990; Cunningham and others, 1997; Cunningham, Rowley, and others, 1999; Cunningham, Unruh, and others, 1998; Rowley, 1998; Rowley and others, 1998). "Calc-alkaline" refers to the composition of the volcanic rocks, which ranges from andesite to low-silica rhyolite, as occurs throughout the Western United States (Lipman and others, 1972).]

Tmpu **Late intracaldera deposits of the Monroe Peak caldera, undivided (Miocene)**—Lava flows of varied compositions, intracaldera intrusions, airfall tuff, and fluvial and lacustrine sedimentary rocks that were deposited in the Monroe Peak caldera after subsidence. The lava flows represent the effusive products of intracaldera intrusions (commonly called "resurgent intrusions" in other calderas; Smith and Bailey, 1968) that were emplaced into the caldera and that altered and deformed the intracaldera Osiris Tuff. Although most of these rocks are fresh, huge masses of white bull quartz locally formed as hot-spring sinter and as replacement masses during wallrock alteration by intracaldera intrusions that were emplaced within the volcanic and sedimentary units (Rowley and others, 1988a,b). This lumped rock unit (Tmpu) is mapped only in the northwestern and central part of the caldera, where rocks are so intensely hydrothermally altered that mapping individual lithologic units is not possible. The Monroe Peak caldera was initially formed during the eruption of the Osiris Tuff (To, Toi). The northern part of the caldera, like the southern margin of the Three Creeks caldera and other features (Rowley, 1998; Rowley and others, 1998; Campbell and others, 1999), seems to be controlled by the Cove Fort transverse zone (see index map). This and the Blue Ribbon transverse zone (which passes just south of the mapped area) are east-striking shear zones that have accommodated extensional deformation in the Marysvale volcanic field (Rowley, 1998)

Tmps **Sedimentary rocks**—Mostly soft, tan, gray, yellow, brown, pink, and green, thin- to medium-bedded, mostly planar-bedded, fine- to coarse-grained tuffaceous sandstone and airfall tuff, and minor intertongued crystal-poor and crystal-rich lava flows, siltstone, and conglomerate.

Primarily fluvial but locally lacustrine in origin. Commonly hydrothermally altered and silicified. Maximum thickness about 60 m

Tmpn **Lava flows of Indian Flat—**Resistant, compositionally heterogeneous sequence of lava flows exposed in the eastern part of the Monroe Peak caldera. In the map area, they consist of purplish-gray and light-gray, crystal-poor, rhyodacitic lava flows that are about 50 m thick and were formerly called rhyodacite of Burnt Flat (Rowley and others, 1981b). East of the mapped area, they thicken to 200 m against the caldera wall and include andesite and dacite flows (Rowley and others, 1986a, b)

Tmpl **Lava flows of Monroe Peak**—Mostly resistant, gray, pink, khaki, and dark-green, vesicular and amygdaloidal, generally crystal-rich rhyodacitic lava flows and minor crystal-poor lava flows, flow breccia, volcanic mudflow breccia, fluvial sandstone, and airfall tuff. K-Ar age is 21.3 Ma (Rowley and others, 1988b). Maximum exposed thickness 150 m. Includes the dacite of Big Flat, a lithologically similar volcanic dome as much as 130 m thick that was mapped in the southern part of the Monroe Peak caldera (Rowley, Williams, and others, 1981). An area 2 km east-northeast of Manning Meadow includes a local lens of soft conglomerate about 100 m thick (base not exposed) that was formerly interpreted to represent pre-caldera rocks (Rowley, Williams, and others, 1981; Cunningham and others, 1983) but is now considered to represent intracaldera deposits

Tmpa **Volcanic rocks of Sage Flat**—Mostly resistant, reddish-brown, medium- to dark-gray, pink, black, and purplish-brown, locally amygdaloidal and vesicular, mostly crystal-poor andesitic lava flows and minor volcanic mudflow breccia, flow breccia, and fluvial sandstone and conglomerate. In the mapped area exposed only in the northern part of the Monroe Peak caldera, where these rocks are about 60 m thick (Rowley, Cunningham, and Kaplan, 1981); east of the map area they thicken to at least 300 m against the eastern wall of the caldera (Rowley and others, 1986a,b)

Tmpf **Lava flows of Monkey Flat Ridge—**Moderately resistant, reddish-brown, gray, khaki, and green, vesicular and amygdaloidal, crystal-poor dacitic to rhyodacitic lava flows, and minor fluvial sandstone, fluvial conglomerate, and crystal-rich lava flows. Includes lava flows of Greenwich Creek, a lithologically similar unit that was mapped separately at larger scale by Rowley and others (1986a,b). Maximum exposed thickness 150 m

Tmpb **Lava flows of Bagley Meadows**—Local sequence of resistant, light- to medium-gray and pink, vesicular and amygdaloidal, locally flow foliated, crystal-rich dacitic lava flows or a volcanic dome. Confined to the northern margin of the Monroe Peak caldera (Rowley, Cunningham, and Kaplan, 1981). Maximum thickness 200 m

Tmpi **Intracaldera intrusions, undivided**—Resistant, tan, light-gray, and light-green, locally flow-foliated monzonite porphyry and quartz monzonite porphyry intrusive masses that were the source for, and are intruded into, late intracaldera deposits of the Monroe Peak caldera (Tmpu) and the Osiris Tuff (To, Toi). In some caldera complexes (for example, Smith and Bailey, 1968; Lipman, 1997), such intrusions are referred to as resurgent plutons because they dome up the cover (intracaldera) tuffs above them in the caldera, but the Monroe Peak caldera exhibits no such structural dome (Steven, Rowley, and Cunningham, 1984 b). At their margins, the intrusions are finer grained and locally resemble intracaldera Osiris Tuff, into which they intrude. Older phases of the same intrusive complex at depth was the source of the Osiris Tuff. Isotopic dates suggest an age of about 22-21 Ma (Rowley and others, 1988a,b). These intrusions make up the eastern end of the east-trending Pioche-Marysvale igneous belt (Rowley, 1998)

Tci **Central intrusion—**Resistant, gray and green, porphyritic to locally equigranular, quartz monzonite and monzonite stock that exhibits a fine-grained chilled margin as wide as 60 m. Distinctive enough so is mapped separately from other intracaldera intrusions of the Monroe Peak caldera. Unit is a possible source for some lava flows in the late intracaldera deposits of the Monroe Peak caldera (Tmpu). Isotopic age is about 22 Ma (Rowley and others, 1988a,b). The pluton was eroded and unroofed by about 19 Ma, when it was unconformably overlain by the Red Hills Tuff Member (Tmr) of the Mount Belknap Volcanics

Tlj **Volcanics of Lousy Jim (Miocene)**—Resistant, light- to dark-gray, flow-foliated, crystal-rich trachydacite porphyry lava flows and flow breccia forming a volcanic dome that is about 8 km in diameter in the southwestern part of the mapped area (Sigmund, 1979). K-Ar age is 22.6 Ma (Fleck and others, 1975). Thickness about 300 m

Ttl **Tuff of Lion Flat (Miocene)**—Soft, light-gray to pink, crystal-poor, nonwelded rhyolitic ash-flow tuff exposed in the southwestern part of the mapped area (Wickstrom, 1982; Lanigan, 1987). Was suggested to be the product of a small caldera (Steven, Rowley, and Cunningham, 1984) but more likely represents tuff-ring deposits preceding and during initial eruption of the overlying volcanics of Lousy Jim (Tlj) because the tuff contains clasts of the volcanics of Lousy Jim believed to be derived from their common magma chamber (C.G. Cunningham, unpub. data, 1993; Rowley and others, 1994). Thickness about 100 m

Osiris Tuff (Miocene)—Petrologically similar sequences of mostly ash-flow tuff derived from the largest caldera in the Marysvale volcanic field, the Monroe Peak caldera (Steven, Rowley, and Cunningham, 1984 ; Rowley and others, 1986a,b, 1988a,b). This unit is the main product of the Monroe Peak caldera, leading to caldera subsidence. K-Ar age is about 23 Ma (Fleck and others, 1975)

Toi **Intracaldera facies—**Soft to resistant, orange and tan, densely welded ash-flow tuff and lava flows(?) that are petrologically similar to the Osiris Tuff outflow facies (To) but are generally altered to clay. Confined to the source Monroe Peak caldera. Includes intracaldera-collapse breccia derived from landslides from the caldera walls into the caldera. The alteration grade is in most places argillic and is due to emplacement of the intracaldera intrusions, undivided (Tmpi), and the central intrusion (Tci). A local volcano within the caldera (called “volcanic rocks of Upper Box Creek Reservoir” in Rowley and others, 1986a,b) occurs near the top of the unit in the southeastern part of the caldera, where it forms a lens of moderately resistant, red to brown andesitic lava flows and volcanic mudflow breccia as much as 150 m. Thickness of intracaldera facies at least 350 m; base not exposed

To **Outflow facies—**Resistant, brown (lower part) and light-gray (upper vapor phase zone), densely welded, moderately crystal-rich, rhyodacitic ash-flow tuff (Williams and Hackman, 1971). Forms one or two cooling units that commonly contain black basal vitrophyres. Contains drawn-out pumiceous lenticules. Upper part locally contains steeply dipping flow-foliated rock caused by secondary flowage of rock fused in the last few tens of meters of movement. Maximum thickness about 60 m

Td **Mount Dutton Formation (Miocene and Oligocene)**—Soft to moderately resistant, tan, gray, pink, light-green, and light-purple volcanic mudflow breccia and sparse flow breccia, lava flows, ash-flow tuff, and fluvial conglomerate and sandstone. Most of these deposits are the products of clustered stratovolcanoes or the erosion of stratovolcanoes that dominated the southern part of the Marysvale volcanic field during most of its calc-alkaline phase (Anderson and Rowley, 1975). The formation is the most voluminous unit in the volcanic field, and it has been traditionally divided (Anderson and Rowley, 1975) into a near-source vent facies and a more distal alluvial facies, following the concepts of Parsons (1965, 1969) and Smedes and Prostka (1973). In detailed mapping, most rocks are shown to belong to the alluvial facies, although in the southwestern part of the mapped area, vent and alluvial facies intertongue. Vent- and alluvial-facies rocks are combined in this map unit. Many of the source stratovolcanoes formed an east-west string along the south side, and south of, the mapped area (Anderson and Rowley, 1975; Rowley, Steven, and others, 1979; Blackman, 1985; Rowley and others, 1987; Anderson and others, 1990a,b). The string of stratovolcano vents is aligned along the east-striking Blue Ribbon transverse zone, whose axis is just south of the mapped area (Rowley, 1998; Rowley and others, 1998). This transverse zone extends westward across the entire Great Basin (Rowley and others, 1978, 1998; Rowley, 1998). Within the formation, clasts in the mudflow breccia, conglomerate, and sandstone, as well as lava flows, are the same lithologic type . Slight variations represent different source volcanoes. Most rocks consist of crystal-poor to aphanitic andesite or less commonly dacite. The crystal-poor aspect of the rocks, and a general absence of exposed source plutons for the unit in the Marysvale volcanic field, indicates that the intrusive sources of the rocks were deep. K-Ar dates, corrected for new decay constants, and stratigraphic relationships with other dated units indicate a long episode of magmatism, from 30 to 21 Ma (Fleck and others, 1975; Rowley and others, 1994). Many other rock units intertongue with the formation. Thickness about 1,500 m in, and south of, the mapped area

Tda **Antimony Tuff Member (Oligocene)**—Resistant, mostly red, densely welded, crystal-poor trachytic ash-flow tuff intertongued within the Mount Dutton Formation (Td), mostly in the Sevier Plateau (Anderson and Rowley, 1975). Generally includes a black basal vitrophyre as much as 3 m thick. Source has not been found but may underlie Sevier Valley in the vicinity of the towns of Sevier or Joseph (Rowley and others, 1988b). Vents for such densely welded, high-temperature ash-flow tuffs have rarely been described in the literature because they are rarely exposed. This is probably because their magma chambers were deep in the crust and vent areas were never expressed by typical collapse calderas (Ekren and others, 1984). K-Ar age is 25 Ma (Rowley and others, 1994). Maximum thickness 15 m

Tdk **Kingston Canyon Tuff Member (Oligocene)**—Resistant, mostly purple, densely welded, crystal-poor trachytic ash-flow tuff intertongued within the Mount Dutton Formation (Td) mostly in the Sevier Plateau (Anderson and Rowley, 1975). Generally includes a black basal vitrophyre as much as 1 m thick. Probably derived from the same source as the Antimony Tuff Member (Tda). Exposed south of the Monroe Peak caldera and in the southern Sevier Plateau, especially south of the mapped area. K-Ar age is 26 Ma (Fleck and others, 1975). Maximum thickness 15 m

Taa **Basaltic andesite lava flows, Antimony Tuff Member of the Mount Dutton Formation, and tuff of Albinus Canyon, undivided (Miocene and Oligocene)**

Ta **Basaltic andesite lava flows—**Resistant, dark-gray and black, locally vesicular and amygdaloidal, crystal-poor, basaltic andesite lava flows that make up a relatively thin sequence in the southeastern Pavant Range. Intertongued with the Antimony Tuff Member of the Mount Dutton Formation (Tda) and tuff of Albinus Canyon (Tal). Probably represent flows of one or more shield volcanoes, which may underlie valley-fill deposits in Sevier Valley or occur in the northern Sevier Plateau; if so, they may correlate with the volcanic rocks of Signal Peak (Tsp). Maximum thickness about 150 m

Tal **Tuff of Albinus Canyon (Oligocene)**—Resistant, light-purplish-gray, pink, tan, reddish-brown, red, and gray, vesicular, crystal-poor, densely welded trachytic ash-flow tuff. Several thin cooling units, locally separated by thin beds of volcanic mudflow breccia, conglomerate, and sandstone, are exposed in the southern Pavant Range, Antelope Range, and Annabella area. Lithologically similar to the Antimony Tuff Member, which overlies it, and the Kingston Canyon Tuff Member, which in part underlies it. Probably all were derived from the same deep-seated source, perhaps buried beneath the Sevier Valley basin in the Joseph area. Has a K-Ar age of 25.3 Ma (Rowley and others, 1994). Maximum thickness about 100 m

Tbc **Bullion Canyon Volcanics (Miocene and Oligocene)**—Moderately resistant, tan, gray, brown, pink, light-green, and light-purple volcanic mudflow breccia, lava flows, flow breccia, ash-flow tuff, and fluvial conglomerate and sandstone. Unit originally proposed by Callaghan (1939) and mapped by Callaghan and Parker (1961a,b; 1962a, b) and Willard and Callaghan (1962). Stratigraphy revised by Steven and others (1979), discussed by Rowley, Steven, and others (1979) and Cunningham and others (1984c), and mapped by Cunningham and others (1983) and Steven and others (1990). Most of these deposits, which make up the second most voluminous unit in the Marysvale volcanic field, are the products of clustered stratovolcanoes or the erosion of stratovolcanoes (Steven and others, 1979). Unit consists of undivided vent-facies and alluvial-facies rocks. Clasts in mudflow breccia, conglomerate, and sandstone are lithologically the same as lava flows in the unit. These flow rocks are of several similar rock types , commonly representing different source volcanoes that consist mostly of crystal-rich dacitic rock, but also include local accumulations of fine-grained, crystal-poor, black andesitic rock. The crystal-rich, more highly evolved aspect of the rocks, and a general abundance of exposed source plutons for the unit in the Marysvale volcanic field, indicate that the intrusive sources of the rocks were shallow at the time of magmatism. Isotopic dates and stratigraphic relationships indicate an age of at least 30-22 Ma (Steven and others, 1979; Kowallis and Best, 1990; Rowley and others, 1994). Former metal production of the chalcophile elements, shallow intrusive sources, and abundant altered areas indicate that the mineral potential is high for these rocks and their associated intrusive sources (Steven and Morris, 1987; Cunningham, Unruh, and others, 1998). Thickness at least 1,500 m in the mapped area

Tbci **Intermediate-composition intrusive rock—**Moderately resistant, gray, tan, and brown, crystal-rich monzonite and quartz monzonite. These plutons are the solidified magma sources of some of the younger deposits of the Bullion Canyon Volcanics. Plutons represent cupolas of a large composite batholith that underlies the central and northern part of the Marysvale volcanic field (Campbell and others, 1984; Cook and others, 1984; Steven, Rowley, and Cunningham, 1984; Steven and Morris, 1987). K-Ar ages cluster at about 23 Ma (Steven and others, 1979; Cunningham and others, 1984a)

Tbcd **Delano Peak Tuff Member (Miocene)—**Resistant, dark-reddish-brown, densely welded, crystal-rich dacitic ash-flow tuff. Source is the Big John caldera in the central Tushar Mountains (Cunningham and others, 1984c; Steven, Cunningham, and others, 1984; Steven, Rowley, and Cunningham, 1984). K-Ar age is about 23 Ma (Steven and others, 1979). Earlier interpretations suggesting that the unit is younger than the Osiris Tuff (Cunningham and others, 1983) have been revised, and the unit now is interpreted to be older than the Osiris (Rowley and others, 1994). Maximum thickness about 200 m

Tbct **Three Creeks Tuff Member (Oligocene)—**Resistant, light-gray and tan, moderately welded, crystal-rich, dacitic ash-flow tuff. Source is the poorly defined, relatively small Three Creeks caldera in the southern Pavant Range (Steven, 1981). The caldera is likely controlled by the Cove Fort transverse zone, which also bounds the northern side of the calderas, volcanoes, and batholith complex of the central Marysvale field (Rowley, 1998; Rowley and others, 1998). K-Ar age is 27 Ma (Steven and others, 1979). Probably the most voluminous ash-flow tuff in the Marysvale field. Unit formerly was included in the Needles Range Group, which is derived from the Indian Peak caldera complex on the Utah-Nevada border (Best and others, 1973; Best and Grant, 1987; Best and others, 1989). Maximum thickness about 220 m

Tlt **Volcanic rocks of Little Table (Miocene and Oligocene)—**Mostly resistant, tan, brown, gray, brownish-red, green, and pink, amygdaloidal, crystal-poor, andesite lava flows and flow breccia and intertongued volcanic mudflow breccia containing clasts of the same lithologic type . Vent-facies and alluvial-facies rocks (Anderson and Rowley, 1975) were separated during more detailed mapping (Cunningham and others, 1983). Probably represents a shield volcano complex that intertongues with the Mount Dutton Formation (Td) and its members as well as lower parts of the volcanic rocks of Langdon Mountain (Tlm) in the central Sevier Plateau. Maximum thickness about 750 m

Tlm **Volcanic rocks of Langdon Mountain (Miocene and Oligocene?)—**Soft to resistant, pink, tan, light-gray, red, and purplish-gray, locally amygdaloidal, moderately crystal-rich dacitic lava flows, flow breccia, and volcanic mudflow breccia, and minor fluvial conglomerate and sandstone. Vent-facies and alluvial-facies rocks were separated during more detailed mapping (Cunningham and others, 1983). Probably represents eruptions of clustered stratovolcanoes in the central Sevier Plateau. Deposits extend into the Awapa Plateau to the east (Williams and Hackman, 1971; Mattox, 1991b). An unusual nepheline syenite breccia pipe, located just east of the mapped area and dated at about 24.4 Ma, was emplaced into both the volcanic rocks of Little Table (Tlt) and Langdon Mountains (Agrell and others, 1986, 1999; Rowley and others, 1994). Alluvial facies about 400 m thick and vent facies about 150 m thick in the Sevier Plateau

Tsp **Volcanic rocks of Signal Peak (Miocene and Oligocene)—**Mostly resistant, gray, black, brown, reddish-brown, and red, locally vesicular and amygdaloidal, mostly crystal-poor, andesitic lava flows and flow breccia and subordinate volcanic mudflow breccia, densely welded ash-flow tuff, and conglomerate. Primarily vent-facies rocks of a clustered, long lived (middle Oligocene to early Miocene) shield volcano complex in the northern Sevier Plateau. Vent-facies and alluvial-facies rocks were separated during more detailed mapping (Cunningham and others, 1983; Rowley and others, 1986b). Thickness as much as 650 m

Tzt **Zeolitic tuff (Miocene)—**Soft, white, partially welded, crystal-poor rhyolitic ash-flow tuff containing about 10 percent lithic clasts (Cunningham and others, 1983). Matrix converted to the zeolite clinoptilolite. May correlate with the 24-Ma Leach Canyon Formation, a widespread ash-flow sheet in the eastern Great Basin (Anderson and Rowley, 1975). Exposed only in the Cove Fort area, where it is intertongued with the Bullion Canyon Volcanics (Tbc). Thickness about 120 m

Tws **Volcanic rocks of Willow Spring (Miocene and Oligocene)**—Soft to moderately resistant, reddish-brown, light-gray, and black, crystal-poor dacitic volcanic mudflow breccia and subordinate lava flows, flow breccia, and fluvial conglomerate and sandstone. The product of primarily alluvial-facies rocks of a stratovolcano in the central Sevier Plateau. Maximum exposed thickness about 500 m

Tql **Quartz latite volcanic dome (Oligocene)**—Resistant, gray, crystal-rich quartz latite lava flows of a large volcanic dome in the southern Pavant Range. Includes a resistant, dark-gray, crystal-poor rhyodacitic lava flow that overlies the dome. Maximum thickness about 200 m

Twd **Volcanic rocks of Wales Canyon and volcanic rocks of Dog Valley, undivided (Oligocene)—** Originally described by Caskey and Shuey (1975) and mapped by Cunningham and others (1983)

Tw **Volcanic rocks of Wales Canyon**—Moderately resistant, red, moderately crystal-rich, intermediate-composition lava flows and densely welded ash-flow tuff exposed in the northwestern part of the mapped area. Locally intertongued within the Three Creeks Tuff Member (Tbct) of the Bullion Canyon Volcanics. Thickness about 135 m

Tdv **Volcanic rocks of Dog Valley—**Soft to moderately resistant, gray, heterogeneous assemblage of intermediate-composition, crystal-poor lava flows, flow breccia, and volcanic mudflow breccia, and minor moderately welded ash-flow tuff. Exposed in the southern Pavant Range. Maximum thickness about 370 m

Tnw **Wah Wah Springs Formation of the Needles Range Group (Oligocene)—**Mostly resistant, gray, tan, and pink, moderately welded, crystal-rich dacite ash-flow tuff. Exposed in scattered places near the base of the volcanic section in the mapped area. One of the world's largest known ash-flow sheets, derived from the Indian Peak caldera complex on the Utah-Nevada border (Best and others, 1973; Best and Grant, 1987; Best and others, 1989). Isotopic age about 30 Ma (Best and Williams, 1997). Maximum thickness in the mapped area about 70 m

SEDIMENTARY ROCKS THAT PREDATE ROCKS OF THE MARYSVALE VOLCANIC FIELD

Tcg **Conglomerate (Oligocene, Eocene, or Paleocene)**—Soft, light-gray and tan, fluvial, pebble conglomerate containing rounded clasts of sandstone and limestone derived from Mesozoic and Paleozoic rocks. Locally includes tuffaceous sandstone, which suggests affinity to nearby Oligocene volcanic rocks. Mapped only in the central Tushar Mountains. Thickness as much as 10 m

Tau **Formation of Aurora of Willis (1980) (Eocene)**—Mostly soft, white and light-gray, lacustrine and fluvial mudstone, shale, siltstone, sandstone, and minor limestone. In the upper and middle parts, contains upwardly increasing amounts of fine-grained rhyolitic volcanic ash and reworked volcanic detritus. Exposed only in the northern part of the mapped area. Informally named by Willis (1988) to generally replace the Bald Knoll Formation of Spieker (1949) and Gilliland (1949, 1951), which Willis abandoned. Biotite in the ash from the upper part yielded a K-Ar date of 40.5 Ma, and pumice near the top of the formation yielded K-Ar dates of 39.6 and 38.4 Ma (Willis, 1985). Thickness about 85 m

Tf **Flagstaff Limestone (Paleocene)—**Mostly moderately resistant, white, tan, reddish-brown, and gray, locally fossiliferous, slightly vuggy lacustrine limestone. Includes minor soft red and gray shale and siltstone in upper part and soft gray shale and limy siltstone near the base. Exposed only at the northern edge of the mapped area. Full thickness not known but probably more than 600 m in and near the mapped area

Kpr **Price River Formation (Upper Cretaceous)**—Moderately resistant, massive, reddish-gray conglomerate and local interlayered beds of sandstone and siltstone. Derived during rapid fluvial deposition from erosion of Sevier thrust sheets, some of which are exposed in the northern part of the mapped area. Exposed only in the northern part of the mapped area. Unconformably overlies the Arapien Formation (Ja). Thickness changes abruptly within short distances and ranges from a few meters to more than 800 m in the western Pavant Range

Ja **Arapien Formation (Middle Jurassic)**—Soft to resistant, multicolored but generally light-gray marine siltstone, shale, mudstone, limestone, sandstone, and minor conglomerate. Evaporite beds are abundant outside the mapped area. Exposed in the central Tushar Mountains. More than 350 m thick, the top not exposed

Jn **Navajo Sandstone (Lower Jurassic)**—Resistant, tan, yellowish-gray, and white, medium- to fine-grained, crossbedded eolian sandstone. Locally altered to resistant quartzite. Unconformably overlies the Petrified Forest Member of the Chinle Formation (TRc). Thins southwestward from more than 600 m to about 500 m

TRc **Chinle Formation (Upper Triassic)**—Fluvial and lacustrine rocks consisting of part of the Petrified Forest Member and the underlying Shinarump Member. The Petrified Forest Member is moderately resistant, red, maroon, chocolate, tan, and white mudstone overlying a basal bed of purple, coarse-grained sandstone; the member is 1-100 m thick. The Shinarump Member is moderately resistant, red to brownish-red, fine- to medium-grained conglomerate; the member is a few meters to 130 m thick. Unconformably overlies the Moenkopi Formation (TRm)

TRm **Moenkopi Formation (Middle? and Lower Triassic)**—Mostly soft to moderately resistant, dark-red to chocolate-brown siltstone and shale. Contains two prominent light-bluish-gray limestone beds. Deposited in alternating marine and continental environments. Thickness is 300-700 m

Pkt **Kaibab Limestone and Toroweap Formation, undivided (Lower Permian)**—Kaibab Limestone is mostly a resistant, medium-gray, thick-bedded, locally cherty marine limestone. Underlying Toroweap Formation is mostly a resistant, medium-gray marine limestone that is interlayered with medium-gray dolomite, tan sandy and silty limestone, and minor shale. It also contains minor beds of gypsum that typically were leached away at the surface. Thickness 150-250 m

PIPpc **Talisman Quartzite and Pakoon Limestone (Lower Permian) and Callville Limestone (Pennsylvanian), undivided**—Marine deposits that are mapped together. Talisman Quartzite, at the top of the map unit, is a resistant, light-tan, well-sorted, crossbedded orthoquartzite about 50-250 m thick. Some prefer the designation Queantoweap Sandstone for the Talisman. Underlying this is a sequence made up mostly of moderately resistant, bluish-gray to gray, fine- to medium-grained, thin-bedded to massive, commonly cherty, moderately fossiliferous marine limestone and dolomite. The upper third of this sequence is commonly dolomitic, includes sparse sandstone and quartzite beds, contains fossils of Permian age, and is believed to represent the Pakoon Limestone of McNair (1951). The lower two-thirds of the sequence consists mostly of limestone and dolomite typical of the Callville Limestone, some beds of which have yielded conodonts of Pennsylvanian age (Wardlaw, 1980). This lower two-thirds also contains moderate amounts of interbedded tan and brown, fine- to coarse-grained quartzite and sandstone, resembling parts of the Oquirrh Group of generally equivalent age, as mapped farther north in Utah. The Pakoon and Callville are as much as 1,500 m thick in and north of the mapped area

Mr **Redwall Limestone (Upper and Lower Mississippian)**—Resistant, dark-gray, medium-bedded to massive, locally cherty, fossiliferous, marine limestone containing sparse beds of tan sandstone in the upper part. Exposed only in the northwestern part of the mapped area. Thickness 400-500 m

Dc **Cove Fort Quartzite (Upper Devonian)**—Defined by Crosby (1959) for a moderately resistant, white to light-gray, somewhat vuggy quartzite and subordinate beds of conglomerate made up of flat pebbles of limestone. Unit apparently overlies an extensive unconformity cut on the Simonson Dolomite (Dsi). Exposed only in the northwestern part of the mapped area. Average thickness 25 m

Dsi **Simonson Dolomite (Middle Devonian)—**Resistant, medium- to dark-brownish-gray, medium- to thick-bedded, medium- to coarse-grained marine dolomite that locally contains minor beds of light-gray dolomite. Exposed only in the northwestern part of the mapped area. Thickness 25-175 m

Ds **Sevy Dolomite (Lower Devonian)—**Moderately resistant, light- to medium-gray, medium- to thick-bedded, dense to faintly laminated, marine dolomite. Exposed only in the northwestern part of the mapped area. Thickness 150-200 m

SOle **Laketown (Silurian) and Ely Springs (Upper Ordovician) Dolomites, undivided** —Laketown Dolomite is a moderately resistant, light- to medium-gray, medium- to thick-bedded, medium- to coarse-grained, sparsely cherty marine dolomite that is 300-400 m thick. The underlying Ely Springs Dolomite is a moderately resistant, mostly black but locally light- to medium-gray, medium-bedded to massive, sparsely fossiliferous, medium- to coarse-grained marine dolomite that is 50-150 m thick. Exposed only in the northwestern part of the mapped area

Oej **Eureka Quartzite, Juab and Wah Wah Limestones, Fillmore Formation, and House Limestone, undivided (Ordovician)**—Marine deposits that are mapped together. The Eureka Quartzite, at the top, is resistant, white, tan, and pinkish-gray, fine- to very-fine-grained, medium-bedded orthoquartzite that is 25-125 m thick. The Juab Limestone is a moderately resistant, medium-gray, thin- to thick-bedded, sparsely fossiliferous, silty limestone or limy siltstone about 50 m thick. The Wah Wah Limestone is a moderately resistant, medium-gray, thin-bedded, abundantly fossiliferous, silty limestone about 80 m thick. The Fillmore Formation is a moderately resistant, medium-gray, thin-bedded silty limestone, much of which is intraformational conglomerate. The Fillmore contains minor interbeds of yellowish-gray shale in its upper part; it is 500-600 m thick. The House Limestone is a moderately resistant, medium-bluish-gray, medium-bedded, sparsely cherty, finely crystalline silty limestone about 150 m thick. Exposed only in the northwestern part of the mapped area

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