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Plate 1
Utah Geological Survey Open-File Report 454
Interim Geologic Map of the Beaver 30' x 60 ' Quadrangle

Scale 1:100,000

5 4 3 2 1 0 5 10 Miles

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Project manager: Robert F. Biek, Utah Geological Survey
GIS preparation by Southern Utah University:
Luke Ambrose and Tyson Kyhl

Interim Geologic Map of the Beaver 30' x 60' Quadrangle, Beaver, Piute, Iron, and Garfield Counties, Utah

By
Peter D. Rowley, Garrett S. Vice, Robert E. McDonald, John J. Anderson, Michael N. Machette, David J. Maxwell, E. Bart Ekren, Charles G. Cunningham, Thomas A. Steven, and Bruce R. Wardlaw

2005

INTERIM GEOLOGIC MAP OF THE BEAVER 30' x 60' QUADRANGLE, BEAVER, PIUTE, IRON, AND GARFIELD COUNTIES, UTAH

by
Peter D. Rowley[1], Garrett S. Vice[2], Robert E. McDonald[3], John J. Anderson[4], Michael N. Machette[5], David J. Maxwell[2], E. Bart Ekren[6], Charles G. Cunningham[7], Thomas A. Steven[8], and Bruce R. Wardlaw[7]

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[1]Geologic Mapping, Inc., New Harmony, Utah 84757; [2]Dept. of Physical Science, Southern Utah University, Cedar City, Utah 84720; [3]Beaver, Utah 84713; [4]New Harmony, Utah 84757; [5]U.S. Geological Survey, Denver, Colorado 80225; [6]White Sulphur Springs, Montana 59645; [7]U.S. Geological Survey, Reston, Virginia 20192; [8]Lakewood, Colorado 80227

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Utah Geological Survey, 1594 W. North Temple, P.O. Box 146100, Salt Lake City, Utah 84114-6100; ph: 801-537-3300; fax 801-537-3400; www.geology.utah.gov

NO CROSS SECTIONS ARE AVAILABLE WITH THIS PUBLICATION

DESCRIPTION OF GEOLOGIC UNITS

Qf Artificial-fill deposits—Man-made deposits of artificial fill, for dams.

Qal_1, Qal_2 Alluvium—Sand, gravel, silt, and clay in channels, floodplains, and adjacent low river terraces of rivers and major streams; subscript denotes relative age, with Qal_1 younger and Qal_2 older; maximum thickness about 30 feet (10 m).

Qat_1 Younger stream-terrace deposits—Sand and gravel that form dissected surfaces as much as 15 feet (5 m) above the level of adjacent modern streams; maximum thickness about10 feet (3 m).

Qat_2 Older stream-terrace deposits—Sand and gravel that form well dissected surfaces 15 to 40 feet (5-13 m) above the level of adjacent modern streams; maximum thickness about 10 feet (3 m).

Qat_3 Oldest stream-terrace deposits—Sand and gravel that form well dissected surfaces 50 to 80 feet (15-25 m) above the level of adjacent modern streams; maximum thickness about 10 feet (3 m).

Qaf_1 Young alluvial-fan deposits—Poorly to moderately sorted silt, sand, and gravel deposited by streams, sheetwash, debris flows, and flash floods on alluvial fans and on coalesced alluvial fans and pediments (piedmont slopes); surface is modern and generally undissected; thickness at least 30 feet (10 m).

Qaf_2, Qaf_3, Qaf_4 Middle alluvial-fan deposits—Poorly to moderately sorted silt, sand, and gravel deposited by streams, sheetwash, debris flows, and flash floods on alluvial fans and on coalesced alluvial fans and pediments (piedmont slopes); surface is moderately dissected by modern streams; subscript denotes relative age, with Qaf_2 youngest and Qaf_4 oldest; unit Qaf_4 is correlated with the gravel of Last Chance Bench in the Beaver basin (Machette and others, 1984); thickness at least 50 feet (15 m).

$QTaf_5$ Old alluvial-fan deposits—Partly consolidated, poorly to moderately sorted silt, sand, and gravel deposited by streams, sheetwash, debris flows, and flash floods on alluvial fans and on coalesced alluvial fans and pediments (piedmont slopes); surface is well dissected by modern streams; mapped only in the Circleville Canyon – Dog Valley area (Anderson, 1987); thickness at least 30 feet (10 m).

Qmtc Talus and colluvium—Poorly sorted, mostly angular gravel, sand, and silt deposited by rockfall, sheetwash, and streams along scarps and hillsides; mostly mapped where conceals underlying bedrock; maximum thickness about 30 feet (10 m).

Qms Landslide deposits—Unsorted, mostly angular, unstratified rock debris moved by gravity from nearby bedrock cliffs; on high scarp of the Tushar Mountains west-northwest of Circleville, includes reworked glacial deposits; maximum thickness about 100 feet (30 m).

Qmr Rock-glacier deposits—Unsorted, angular, unstratified rock debris in lobate masses in cirques east of the crest of the Tushar Mountains; includes reworked glacial deposits (moraine) of mostly Pinedale age (late Pleistocene); maximum thickness about 30 feet (10 m).

Qes Eolian sand deposits—Windblown sand in vegetated sheets that generally lack dune form; mapped in the northwest part of the map area; maximum thickness about 10 feet (3 m).

Qs Spring deposits—Generally resistant deposits of mostly calcareous tufa from Pleistocene, Holocene, and present springs, including a spring mound 8.5 miles (14 km) north-northeast of Beaver and 4 miles (6 km) north of Minersville; includes siliceous sinter at the Opal Mound, which is controlled by the Opal Mound fault in the northwest part of the map area; also includes 5,000-year-old (middle Holocene) marsh deposits 4 miles (6 km) north of Minersville (report by Beta Analytic, Inc. of Miami, Florida, for the Utah Geological Survey, 2004); maximum thickness about 40 feet (13 m).

Qlae Mixed lacustrine, alluvial, and eolian deposits—Mixed and reworked gravelly lacustrine and alluvial deposits on piedmont slopes; grades from pebbly sand and silt to sandy pebble gravel; lacustrine material was deposited in Escalante Bay of Lake Bonneville and perhaps of older Pleistocene lakes; maximum thickness about 20 feet (6 m).

Qlg Lacustrine gravel—Silty, fine-to-coarse-grained sand and gravel deposited by the Beaver River in Lake Bonneville and then distributed by waves and currents and deposited in shore-zone deposits as beaches, spits, and offshore bars; maximum thickness about 30 feet (10 m).

Qll Lacustrine lagoon deposits—Sand, silt, clay, and silty marl that accumulated in lagoons behind (landward from) gravel barrier beaches of Lake Bonneville; present west of Milford, Utah; generally less than 10 feet (3 m) thick.

Rhyolite of Mineral Mountains—High-silica rhyolite made up of three types of deposits erupted from sources in the Mineral Mountains and derived from the vestiges of the same magma chamber that resulted in the Mineral Mountains batholith; rhyolite largely deposited on the eroded surface and canyons cut in that batholith; the buried rhyolite magma chamber supplies the heat for the Roosevelt geothermal area, which supports an electric power plant (Lipman and others, 1978; Nielson and others, 1978, 1980) from wells drilled east of the Opal Mound fault; like other Quaternary and Tertiary rhyolites and basalts in the area, the unit is synchronous with basin-range extension (Christiansen and Lipman, 1972; Rowley and Dixon, 2001).

Qrd Volcanic dome—Resistant, mostly tan, crystal-poor (sparsely porphyritic), perlite-mantled, flow-foliated, high-silica rhyolite lava flows, flow breccia, and minor tuff that form volcanic domes by deposition around central vents; mostly devitrified but contains a basal vitrophyre zone as much as 30 feet thick (10 m); at least 9 domes concentrated along the crest of the north Mineral Mountains; K-Ar age about 0.6 to 0.5 Ma (e.g., Lipman and others, 1978; Sibbett and Nielson, 1980); maximum thickness about 900 feet (300 m).

Qrt Tuff—Poorly consolidated, white, unwelded, pumice-rich, crystal-poor, high-silica rhyolite ash-flow and airfall tuff; best exposed in Ranch Canyon, where mined for pumice; overlain by Qrd in the Mineral Mountains, and deposited also eastward throughout the Beaver basin after drainage integration with Escalante Desert (Nash and Smith, 1977; Machette and others, 1984; Machette, 1985); K-Ar age about 0.8 to 0.6 Ma (Lipman and others, 1978); exposed thickness as much as 600 feet (180 m).

Qrl Lava flows—Two compound lava flows of resistant, black to light-gray, flow-foliated, aphyric, high-silica rhyolite, most of which is devitrified but much of which is basal vitrophyre (obsidian); overlain by Qrt; the northern flow, the Bailey Ridge flow in Negro Mag Wash, has been mined for perlite, whereas the southern flow, the Wildhorse Canyon flow, is famous for its implement-grade obsidian, artifacts of which have been found in archeological sites throughout the West; K-Ar age about 0.8 Ma (Lipman and others, 1978); maximum thickness of each flow is about 300 feet (100 m).

Qbr Basaltic andesite of Red Knoll—Resistant, dark-gray and black, blocky, vesicular, crystal-rich

basaltic andesite lava flows and red and dark-gray cinder cone of ash and scoria, northwest Beaver basin; synchronous with the latest stage of basin-range extension (Christiansen and Lipman, 1972; Rowley and Dixon, 2001); maximum thickness about 200 feet (60 m).

Qbk Basaltic andesite of Crater Knoll—Resistant, dark-gray and black, blocky, vesicular, crystal-rich basaltic andesite lava flows and red and dark-gray cinder cone of ash and scoria, northwest Beaver basin; has a K-Ar date of 1.0 Ma (Best and others, 1980) but interpreted to overlie Qrt by Machette and others (1984) and more likely is closer to 0.5 Ma, the age of the lithologically similar basaltic andesite of Cove Fort just to the north of the map area (Steven and Morris, 1983; Hintze and others, 2003); maximum thickness about 100 feet (30 m).

Qbc Basalt of Cunningham Hill—Resistant, dark-gray, scoriaceous to massive basalt lava flow that filled the ancestral valley of Cunningham Wash, in the west Beaver basin (Machette and others, 1984); K-Ar age 1.1 Ma (Best and others, 1980); maximum thickness about 30 feet (10 m).

QTs Basin-fill sedimentary rocks—Poorly to moderately consolidated, tan and gray, tuffaceous sandstone and subordinate mudstone, siltstone, and conglomerate deposited in basins of different ages (Pliocene to late Miocene) and origins; basins were formed by normal faults and subordinate oblique and strike-slip faults related to the youngest basin-range extension that is responsible for the present topography (Rowley and Dixon, 2001; Rowley and others, 2002); deposits generally consist of fanglomerate near the present basin margins, piedmont slope deposits farther toward the centers of the basins, and lacustrine deposits near the centers of the basins; includes deposits studied in detail in the Beaver basin (Machette and others, 1984; Machette, 1985), which began to form at about 9 Ma (Evans and Steven, 1982); the main phase of basin-range faulting took place between 7.6 (unit Trf) and 5.4 Ma (rhyolite of Phonolite Hill, Try) in the Kingston Canyon area (Rowley and others, 1981); thickness of QTs at least 2,000 feet (600 m).

Tb Basalt lava flows—Resistant, dark-gray and black, locally vesicular or amygdaloidal, crystal-poor (olivine and pyroxene phenocrysts) olivine basalt lava flows, flow breccia, and cinder cones; synchronous with basin-range extension (Christiansen and Lipman, 1972; Rowley and Dixon, 2001); includes basalt southeast of Otter Creek Reservoir that has a K-Ar date of 5.0 Ma (Best and others, 1980), basalt in the Black Mountains that has a K-Ar date of 6.4 Ma (Best and others, 1980; Anderson and others, 1990b), another north of it near Minersville Reservoir that has a K-Ar date of 7.6 Ma, basalt in Kingston Canyon that has a K-Ar date of 7.8 Ma (Rowley and others, 1981), basalt 2 miles (3 km) west of Piute Reservoir that has a K-Ar date of 10.9 Ma (Rowley and others, 1994), and basalt east of Piute Reservoir that has K-Ar dates of 12.9 Ma (Damon, 1969) and 12.7 Ma (Best and others, 1980); maximum thickness of lava flows about 200 feet (60 m).

Tsr Sevier River Formation—Poorly to moderately indurated, gray, tan, yellow, white, pink, and light-green tuffaceous sandstone, pebbly to bouldery conglomerate, mudstone, and siltstone of fluvial and locally lacustrine origin; deposited in basins that formed generally prior to the main episode of basin-range faulting (Rowley and others, 1981, 1998, 2002; Rowley, 1998); airfall tuff beds and basalt flows within the formation near the town of Sevier north of the mapped area have K-Ar dates between 14 and 5.6 Ma (Best and others, 1980; Steven and others, 1979; Rowley and others, 1994); mapped south of Junction and on the Sevier Plateau; thickness at least 500 feet (150 m).

Trd Rhyodacite of Dry Lake—Resistant light-gray, pink, and tan, flow-foliated, locally spherulitic, moderately crystal-rich rhyodacite volcanic dome and lava flows, locally containing black basal vitrophyre; in the Dry Lake area of the south Sevier Plateau; maximum thickness about 750 feet (230 m).

Try Young rhyolite lava flows—Small, resistant, mostly gray, flow-banded, crystal-poor, high-silica rhyolite volcanic domes and subordinate pyroclastic material, most of which help define an east-trending structural belt known as the Blue Ribbon transverse zone (Rowley and others, 1978; Rowley, 1998), including the rhyolite of Phonolite Hill in Kingston Canyon, which consists of several domes with K-Ar dates of 5.4 and 4.8 Ma (Rowley and others, 1981); a dome at Blue Ribbon Summit in the Black Mountains that has a K-Ar date of 7.6 Ma (Mehnert and others, 1978; Rowley and others, 1978); a dome at Teddys Valley in the Black Mountains that has a K-Ar date of 7.9 Ma (Anderson and others, 1990b); and a dome southwest of Beaver in the Black Mountains that has a K-Ar date of 8.3 Ma (Anderson and others, 1990b); also includes a small dome in Corral Canyon, west of the Mineral Mountains, that has a K-Ar date of 7.9 Ma (Lipman and others, 1978; see also Evans and Steven, 1982); although the dome of Phonolite Hill has relief of more than 1,000 feet (300 m), in most other places the maximum thickness of the rhyolites is less than 200 feet (60 m).

Trf Rhyolite of Forshea Mountain—Resistant light-gray and white, flow-foliated, spherulitic, crystal-poor, high-silica rhyolite lava flows and volcanic dome capping the Sevier Plateau north of Kingston Canyon; locally includes a black basal vitrophyre and soft, poorly exposed airfall and ash-flow tuff, sandstone, and conglomerate at the base of the unit; has K-Ar dates of 7.6 Ma (Rowley and others, 1981); maximum thickness about 1,000 feet (300 m).

Trg Rhyolite of Gillies Hill—Mostly resistant, white and light-gray, flow-foliated, locally vesicular, aphyric to crystal-rich, high-silica rhyolite lava flows and volcanic domes; includes interlayered soft white ash-flow tuff; map unit exposed only at the north end of the Beaver basin; has K-Ar dates that cluster at 9 Ma, probably synchronous with the initiation of basin-range faulting in the Beaver basin (Evans and Steven, 1982); base not exposed but exposed thickness at least 1,200 feet (350 m).

Tir Rhyolite porphyry—Resistant, mostly small, gray, tan, and pink, commonly hydrothermally altered dikes, sills, plugs, a laccolith(?), and masses of other shapes of mostly crystal-poor (phenocrysts of K-feldspar, quartz, plagioclase, and biotite); mostly high-silica rhyolite and fine-grained granite in the Mineral Mountains (Sibbett and Nielson, 1980) that intrudes rocks as young as the main granitic batholith of the Mineral Mountains (Tig) and has K-Ar dates of 9.1 and 9.6 Ma (Nielson and others, 1986), a U-Pb zircon date of 11.0 Ma (Coleman and Walker, 1994), and an $^{40}Ar/^{39}Ar$ date of 11.5 Ma (Coleman and others, 2001); unit also includes several high-silica rhyolite plugs in the Tushar Mountains younger than 19 Ma and shown by Rowley and others (2002) as late rhyolite dikes, stocks, and volcanic domes; map unit also includes lithologically similar low-silica, altered, crystal-poor (phenocrysts of plagioclase and minor sanidine, biotite, and hornblende) rhyolite dikes and plugs in the south Mineral Mountains that have K-Ar dates of 22.5 and 22.3 Ma (Rowley and others, 1994) and may be associated with the calc-alkaline Lincoln Stock (Ticl); most bodies too small to be mapped at this scale but those shown on the map are as much as several hundred feet (100 m) across and more than a mile (1.6 km) long.

Mount Belknap Volcanics—Large masses of high-silica rhyolite derived from several caldera and volcano eruptive centers in the Tushar Mountains and Marysvale mining district (Callaghan, 1939; Rowley and others, 1979; Cunningham and Steven, 1979a; Cunningham and others, 1983; Steven and others, 1984b; Rowley and others, 2002); map units and their source plutons (Tig) have considerable mineral potential, primarily uranium, molybdenum, and alunite (Kerr and others, 1957; Callaghan, 1973; Steven and others, 1981, 1984a; Podwysocki and Segal, 1983; Beatty and others, 1986; Steven and Morris, 1987; Cunningham and others, 1982, 1984a, b, 1994, 1998a, 1999, 2005); isotopic ages from many types of analyses range from 21 to 12 Ma (Cunningham and others, 1998b).

Tmg Upper gray tuff member, Gray Hills Rhyolite Member, upper red tuff member, and porphyritic lava flows—From youngest to oldest, these local resistant units were deposited in an east-

trending paleocanyon that is east of, and formerly drained, the Mount Belknap caldera: (1) the upper gray tuff member, a crystal-poor rhyolite ash-flow tuff that was derived from the caldera and has a K-Ar date of 18 Ma (Steven and others, 1979) and is at least 425 feet (130 m) thick; (2) the Gray Hills Rhyolite Member, a crystal-poor dome and related rocks from a local vent that has K-Ar dates of 20.5 to 19.5 Ma (Bassett and others, 1963) and is about 1,600 feet (500 m) thick; (3) the upper red tuff member, a densely welded, crystal-poor rhyolite ash-flow tuff derived from the caldera and about 60 feet (20 m) thick; and (4) porphyritic lava flows of coeval, poorly to moderately crystal-rich rhyolite flows and ash-flow tuff as much as 250 (75 m) thick.

Tmc Crystal-rich tuff member—Resistant, dark-reddish-brown, gray, and pink, moderately to densely welded, crystal-rich rhyolite ash-flow tuff that fills channels that radiate outward from its source, the Mount Belknap caldera; K-Ar age about 19 Ma (Steven and others, 1979); thickness about 200 feet (60 m).

Tmr Red Hills Tuff Member—Moderately resistant, reddish-brown, tan, and light-gray, crystal-poor, densely welded rhyolite ash-flow tuff derived from the Red Hills caldera north of Marysvale (Cunningham and Steven, 1979a); about 19 Ma based on K-Ar dates on overlying and underlying units; maximum thickness about 600 feet (180 m).

Tmj Joe Lott Tuff Member—Moderately resistant, light-gray and tan, partly welded, crystal-poor rhyolite ash-flow tuff, with a black basal vitrophyre; the main outflow unit derived from the Mount Belknap caldera (Budding and others, 1987); K-Ar dates on overlying and underlying units indicate an age of 19 Ma (Steven and others, 1979); maximum thickness about 400 feet (120 m).

Tmb Mount Baldy Rhyolite Member—Resistant, light-gray, crystal-poor intracaldera rhyolite lava flows and dikes derived from, and deposited mostly within, the Mount Belknap caldera; thickness about 2,600 feet (800 m).

Tmv Volcaniclastic rocks—Soft to moderately resistant, light-gray and white, mostly intracaldera volcanic mudflow breccia derived from, and deposited within, the Mount Belknap caldera; includes landslide debris and fluvial sandstone and conglomerate; thickness about 800 feet (240 m).

Tmm Middle tuff member—Soft, light-gray and tan, poorly welded, crystal-poor intracaldera rhyolite ash-flow tuff that is lithologically similar to Tmj, with which it is locally continuous across the margin of the Mount Belknap caldera; thickness about 1,600 feet (500 m).

Tmbl Blue Lake Rhyolite Member and lower tuff member—Lower parts of the intracaldera fill of the Mount Belknap caldera, consisting of: (1) the Blue Lake Member, a moderately resistant, gray, flow-foliated, crystal-poor lava flow about 1,100 feet (340 m) thick; and (2) the underlying lower tuff member, lithologically similar to Tmm and Tmj and at least 1,500 feet (460 m) thick, with its base not exposed.

Tmh Lower heterogeneous member—Mostly soft, gray rhyolite volcanic domes, lava flows, and subordinate ash-flow tuff and fluvial sandstone; derived from a volcano source northwest of Marysvale; thickness about 230 feet (70 m).

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; crops out northeast of Marysvale; age about 21 Ma based on dates on overlying and underlying units (Steven and others, 1979; Cunningham and others, 1982); maximum thickness of domes about 800 feet (250

m).

Tig Granitic intrusive rocks—Mostly resistant, mostly gray, high-alkali and mostly high-silica (bimodal igneous episode that is synchronous with basin-range extension) granite and related rocks; includes small, fine-grained intracaldera stocks within the Mount Belknap caldera in the Tushar Mountains (Rowley and others, 2002); to the west, in the Mineral Mountains, includes the main mass of the Mineral Mountains batholith, the largest exposed batholith in Utah, which is made up of individual stocks and sheeted dike-like masses of fine- to coarse-grained or porphyritic, nonfoliated, mostly granite (classification of intrusive rocks from International Union of Geological Sciences) but locally monzonite and syenite (Sibbett and Nielson, 1980; Nielson and others, 1978, 1986; Coleman, 1991; Meschter McDowell and others, 2004) because the batholith was likely formed by partial melting (anatexis) of an older, more mafic, calc-alkaline phase (Coleman and Walker, 1992) that is mapped separately as Tic; isotopic (mostly K-Ar) dating of the plutonic rocks of the Mineral Mountains has been problematic because of almost continuous emplacement of intrusive rocks, and consequent resetting of isotopic clocks, since at least about 25 Ma (Nielson and others, 1986; Aleinikoff and others, 1986; Coleman and others, 2001), but Coleman and others (2001) interpreted on the basis of U-Pb zircon and $^{40}Ar/^{39}Ar$ dates that the main granitic batholith in the Mineral Mountains has an age of about 18 to 17 Ma.

Tml Potassium-rich mafic lava flows—Resistant, black and dark-gray, locally vesicular and amygdaloidal, crystal-poor lava flows and scoria that resemble basalt but chemical analyses show to be high in K_20 (Best and others, 1980; Cunningham and others, 1983; Rowley and others, 1994, 2002); formerly referred to as "older basalt" (Anderson and Rowley, 1975); Mattox and Walker (1989, 1990), Walker and Mattox (1989), and Mattox (1991, 1992) considered Tml to represent the termination of eruption of the Mount Dutton Formation (Tdv, Tda), but we consider the rocks to represent the initial product of bimodal (extension-related) volcanism (Cunningham and others, 1998b), with K-Ar dates of 25 to 21 Ma; maximum thickness about 500 feet (150 m).

Tmgg Mafic gravels of Gunsight Flat—Moderately resistant, black and dark-gray fluvial conglomerate made up of clasts of Tml, locally intercalated with Tml and interpreted to represent fanglomerate shed northward from Miocene fault scarps (Anderson and others, 1990a); exposed only in the south Tushar Mountains; maximum thickness 1,000 feet (300 m).

Thv Horse Valley Formation—Mostly soft, gray and pink, crystal-poor, dacitic lava flows and volcanic mudflow breccia of a probable stratovolcano complex that erupted in the west to central Black Mountains, most vents of which are just west of the map area (Anderson and Rowley, 1975; Rowley, 1978); dated at 22-19 Ma (Fleck and others, 1975) but is calc-alkaline and unlikely to be much younger than 22 Ma; the significance of calc-alkaline igneous rocks, which make up all Tertiary igneous rocks listed below, is that they precede basin-range extension and are the youngest part of the subduction regime that affected North America (Lipman and others, 1972; Rowley and Dixon, 2001); maximum thickness about 1,000 feet (300 m), thickening westward.

Rocks of the Monroe Peak caldera—Includes the Osiris Tuff, whose eruption caused the subsidence of the caldera (Cunningham and others, 1983; Steven and others, 1984b; Rowley and others, 1986a, b, 1988a, b), as well as calc-alkaline intracaldera volcanic, sedimentary, and intrusive rocks of 23 to 22 Ma; north edge of caldera (Rowley and others, 2002; Hintze and others, 2003), like several other calderas and igneous and structural features of the north Marysvale volcanic field, is controlled by the east-striking Cove Fort transverse zone (Rowley, 1998; Rowley and others, 1998; Campbell and others, 1999; Rowley and Dixon, 2001).

Tmpu Late intracaldera deposits of the Monroe Peak caldera, undivided—Moderately resistant lava flows, airfall tuff, and fluvial and lacustrine sedimentary rocks that were deposited in the Monroe

Peak caldera after subsidence; the volcanic rocks represent the effusive products of intracaldera intrusions; unit mapped only where rocks are intensely hydrothermally altered.

Tmps Sedimentary rocks—Mostly soft, tan, gray, brown, pink, and green, thin- to medium-bedded, fine- to coarse-grained tuffaceous sandstone and airfall tuff deposited in the caldera basin, with minor intertongued lava flows, siltstone, and conglomerate; commonly hydrothermally altered and silicified; maximum thickness about 200 feet (60 m).

Tmpn Lava flows of Indian Flat—Resistant, compositionally heterogeneous sequence of lava flows in east part of caldera; mostly purplish-gray and light-gray, crystal-poor, rhyodacitic lava flows; about 150 feet (50 m) thick, but east of map area, unit thickens to 600 feet (200 m) against the caldera wall and includes andesite and dacite flows.

Tmpl Lava flows of Monroe Peak—Mostly resistant, gray, pink, greenish-brown, and dark-green, vesicular, generally crystal-rich rhyodacitic lava flows, flow breccia, volcanic mudflow breccia, fluvial sandstone, and airfall tuff; K-Ar age of 21.3 (Rowley and others, 1988b); maximum thickness 500 feet (150 m).

Tmpf Lava flows of Monkey Flat Ridge—Moderately resistant, reddish-brown, gray, and greenish-brown, vesicular, crystal-poor dacitic to rhyodacitic lava flows, minor fluvial sandstone and conglomerate, and minor crystal-rich lava flows; maximum exposed thickness 500 feet (150 m).

Osiris Tuff—Ash-flow tuff derived from the Monroe Peak caldera, the largest in the Marysvale volcanic field (Steven and others, 1984b); K-Ar age is about 23 Ma (Fleck and others, 1975; L.W. Snee, U.S. Geological Survey, written commun., 1998).

Toi Intracaldera facies—Soft to resistant, orange and tan, densely welded ash-flow tuff that is petrologically the same as outflow facies but is generally partly hydrothermally altered to clay by emplacement of Ticm and Ticmc; facies confined to its source, the Monroe Peak caldera; includes interbedded intracaldera-collapse breccia (“caldera megabreccia”) derived from landslides from the caldera walls into the caldera; thickness at least 1,000 feet (350 m) but base not exposed.

To Outflow facies—Resistant, light-gray (upper vapor phase zone) and brown (lower part), densely welded, moderately crystal-rich, rhyodacitic ash-flow tuff (Williams and Hackman, 1971); one or two cooling units with black basal vitrophyres; contains drawn-out pumaceous 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 200 feet (60 m).

Ticm Intracaldera intrusions of the Monroe Peak caldera, undivided—Resistant, tan, light-gray, and light-green, locally flow-foliated monzonite porphyry (calc-alkaline) intrusive masses that were the source for, and are intruded into, intracaldera volcanic deposits of the Monroe Peak caldera; fine-grained chilled margin locally resembles Toi, into which they intrude, except that they are fresh rather than altered; commonly called “resurgent intrusions” in other calderas (Smith and Bailey, 1968) because they dome up the cover (intracaldera) tuffs above them in the caldera, but the Monroe Peak caldera exhibits no such structural dome; K-Ar dates suggest an age of 22 to 21 Ma (Rowley and others, 1988a, b).

Ticmc Intracaldera intrusions of the Monroe Peak caldera, Central intrusion—Resistant, gray and green, porphyritic to equigranular monzonite (calc-alkaline) stock that exhibits a fine-grained chilled margin as wide as 200 feet (60 m); isotopic age about 22 Ma (Rowley and others, 1988a, b); pluton was eroded and unroofed by about 19 Ma, when it was unconformably overlain by Tmr.

Ticc Concordant intrusions—Resistant, gray, monzonite (calc-alkaline) intrusions in the Markagunt Plateau (Anderson and Rowley, 1975; Anderson and others, 1990a, b); probably laccoliths that intrude into Tc; one, the Spry Intrusion in Circleville Canyon, is of batholith size in outcrop (Grant and Anderson, 1979) and extends well to the south in the subsurface (Blank and Kucks, 1989; Bankey and others, 1998); the Spry intrusion has an age of 25 Ma (Anderson and others, 1990a), and erupted Tbb and Tbr.

Tvl Local volcanic rocks of the Lincoln Stock—Soft, mostly reddish-brown, hydrothermally altered, dacitic to andesitic lava flows and volcanic mudflow breccia located just west of, and adjacent to, Ticl; about 300 feet (100 m) thick, but its base is not exposed; possibly vented products of the Lincoln Stock.

Ticl Lincoln Stock—Resistant, light-gray, monzonite and granodiorite porphyry stock in the south Mineral Mountains (Earll, 1957; Corbett, 1984; Price, 1998), resulting in contact metamorphic lead-zinc-gold ore deposits of the Lincoln and Bradshaw mining districts; interpreted here to represent a calc-alkaline phase of the Mineral Mountains batholith; has a K-Ar date of 21.9 Ma (Bowers, 1978) and a preliminary U-Pb zircon date of about 23 Ma (Coleman and others, 1997, 2001).

Mount Dutton Formation—Mostly soft, brown, tan, pink, and gray, volcanic mudflow breccia made up of angular clasts of crystal-poor andesitic rock, subordinate resistant lava flows and flow breccia of the same lithology, and minor fluvial and eolian sandstone and conglomerate whose clasts are the same lithology (Anderson and Rowley, 1975); deposited from clustered stratovolcanoes that form most of the south Marysvale volcanic field (e.g., Callaghan, 1939; Anderson and Rowley, 1975; Rowley and others, 1979, 1998, 2002; Steven and others, 1979, 1990; Cunningham and others, 1983; Campbell and others, 1999); dated at 26 to 21 Ma (Fleck and others, 1975); the most voluminous unit in the Marysvale volcanic field; thickness in the area at least 6,000 feet (2,000 m).

Tdv Vent facies—Volcanic mudflow breccia, flow breccia, and lava flows interpreted to represent near-source eruptions (Anderson and Rowley, 1975); many of the source stratovolcanoes are aligned east-west along the east-striking Blue Ribbon transverse zone (Rowley and others, 1978, 1998; Rowley, 1998), which passes west from Kingston Canyon along the break in slope between the Tushar Mountains and Markagunt Plateau, then along the north side of the Black Mountains and on across the entire Great Basin.

Tda Alluvial facies—Primarily volcanic mudflow breccia in which lithologies are more heterogeneous than in the vent facies, representing deposits interpreted to have traveled farther from the source, down the flank of individual stratovolcanoes (Anderson and Rowley, 1975), passing into conglomerate still farther from the source; the unit is by far the most voluminous component of the formation.

Tdp Plugs and dikes—Small source calc-alkaline magma bodies (vents) of the formation (e.g., Blackman, 1985); the crystal-poor (poorly differentiated) nature of the rock, coupled with the low volume of its source plutons, indicate that the intrusive sources of the volcanic rocks of the formation are deep.

Tdan Antimony Tuff Member—Resistant, mostly red, densely welded, crystal-poor, trachytic ash-flow tuff intertongued within the upper part of the formation (Anderson and Rowley, 1975); source vent may underlie Sevier Valley near the town of Sevier; K-Ar age is 25 Ma (Rowley and others, 1994); exposed mostly in the Sevier Plateau; maximum thickness 50 feet (15 m).

Tdb Beaver Member—Resistant, gray, pink, tan, green, and reddish-brown, dense, thick-bedded,

crystal-rich, andesite porphyry lava flows and flow breccia of several volcanic domes, and local tuffaceous sandstone, volcanic mudflow breccia, and tuff (Anderson and Rowley, 1975); K-Ar dates of 26.2 and 25.0 Ma (Fleck and others, 1975); exposed only south of Beaver; maximum thickness about 600 feet (200 m).

Tdl Local tuff—Several, mostly resistant, reddish-brown and tan, densely welded, crystal-poor, trachytic ash-flow tuffs intertongued within the formation; maximum thickness of any one unit is about 200 feet (60 m).

Tdk Kingston Canyon Tuff Member—Resistant, mostly purple, densely welded, crystal-poor, trachytic ash-flow tuff intertongued within the lower part of the formation (Anderson and Rowley, 1975); perhaps derived from the same source area as Tdan; K-Ar date of 26 Ma (Fleck and others, 1975); exposed mostly in the Sevier Plateau; maximum thickness about 50 feet (15 m).

Toa Antimony Tuff Member of the Mount Dutton Formation and Osiris Tuff, undivided.

Tlf Tuff of Lion Flat—Soft, pink, white, tan, and gray, unwelded, crystal-poor, rhyolite ash-flow tuff and minor airfall and water-laid tuff (Wickstrom, 1982; Lanigan and Anderson, 1987); probably tuff-ring deposits related to eruption of Tlj (Rowley and others, 2002); age between 23 and 22 Ma; exposed only in the east Black Mountains and west Tushar Mountains; maximum thickness about 300 feet (100 m).

Tlj Volcanic rocks of Lousy Jim—Resistant, light- to dark-gray, flow-foliated, crystal-rich trachydacite porphyry lava flows and flow breccia forming a volcanic dome east of Beaver that is about 13 miles (8 km) in diameter (Sigmund, 1979); K-Ar age 22.6 Ma (Fleck and others, 1975); thickness about 1,000 feet (300 m).

Tbc **Bullion Canyon Volcanics—**Moderately resistant, tan, gray, pink, and light-green volcanic mudflow breccia, lava flows, flow breccia, ash-flow tuff, and fluvial conglomerate and sandstone (Callaghan, 1939; Rowley and others, 1979; Steven and others, 1979; Cunningham and others, 1984; Rowley and others, 2002); the product of clustered stratovolcanoes, made up of undivided vent-facies and alluvial-facies rocks; the second-most voluminous stratigraphic unit in the Marysvale volcanic field; mostly crystal-rich dacite, thus more highly evolved than the Mount Dutton Formation, with which it intertongues, and derived from intrusive sources (Tic) that are abundantly exposed and much more shallow than those for the Mount Dutton Formation; isotopic dates and stratigraphic relationships indicate an age of at least 30 to 22 Ma (Steven and others, 1979; Kowallis and Best, 1990; Rowley and others, 1994); rocks of the unit and its source plutons (Tic) have high potential for mineral resources of the chalcophile elements (Callaghan, 1973; Steven and others, 1979; Steven and Morris, 1987; Cunningham and others, 1984b, 1994; Cunningham and others, 1998b); thickness at least 5,000 feet (1,500 m).

Tic Calc-alkaline intrusive rock—Moderately resistant, gray, tan, pink, and brown, crystal-rich monzonite, low-silica granite, granodiorite, and monzodiorite; the calc-alkaline sources of Tbc and several other volcanic units, and the calc-alkaline early products of the Mineral Mountains batholith; plutons of Tic, Tig, and other intrusive units represent cupolas of a large composite batholith that underlies the east-trending Pioche-Marysvale igneous belt (Rowley, 1998), including the central and north part of the Marysvale volcanic field, and extends westward beyond the Nevada border, as indicated by geophysics (Steven and Morris, 1987; Rowley, 1998; Campbell and others, 1999; Rowley and others, 2002) and geologic mapping (Steven and others, 1990); isotopic ages of Tic cluster at about 25 to 23 Ma (Steven and others, 1979; Cunningham and others, 1984a; Nielson and others, 1978, 1986; Aleinikoff and others, 1986; Coleman and others, 2001).

Tbcd Delano Peak Tuff Member—Resistant, dark-reddish-brown, densely welded, crystal-rich, dacitic ash-flow tuff; derived from the Big John caldera in the central Tushar Mountains (Cunningham and others, 1984; Steven and others, 1984a, b); K-Ar age is 23 Ma, and mapping shows that it is older than To; maximum thickness about 600 feet (200 m).

Tbct Three Creeks Tuff Member—Resistant, light-gray and tan, moderately welded, crystal-rich, dacitic ash-flow tuff (Steven and others, 1979); derived from the Three Creeks caldera in the south Pahvant Range (Steven, 1981), whose location was likely controlled by the Cove Fort transverse zone (Rowley, 1998); K-Ar age is 27 Ma; the most voluminous ash-flow tuff in the Marysvale volcanic field and formerly was included within the Needles Range Group; maximum thickness about 700 feet (220 m).

Tkcn Kingston Canyon Tuff Member of the Mount Dutton Formation, Buckskin Breccia, Three Creeks Tuff Member of the Bullion Canyon Volcanics, and Needles Range Group, undivided.

Ttm Tuff of Minersville—Small-volume, moderately resistant, tan, gray, and pink, poorly welded, crystal-poor (conspicuous sanidine and subordinate plagioclase and biotite), rhyolite ash-flow tuff and apparent source dikes; most exposures east of Minersville; maximum thickness of tuff about 100 feet (30 m).

Tlt Volcanic rocks of Little Table—Mostly resistant, tan, brown, gray, brownish-red, and green, amygdaloidal, crystal-poor, andesite lava flows and flow breccia and intertongued volcanic mudflow breccia; of vent-facies and alluvial-facies origin (Anderson and Rowley, 1975), separated in detailed mapping (Cunningham and others, 1983); a shield-volcano complex that intertongues with Tda, Tdv, and Tlm; maximum thickness 2,500 feet (750 m).

Tlm Volcanic rocks of Langdon Mountain—Soft to resistant, pink, tan, gray, and red dacitic lava flows, flow breccia, volcanic mudflow breccia, and minor fluvial conglomerate and sandstone; mostly alluvial-facies deposits and some vent-facies deposits derived from clustered stratovolcanoes in the central Sevier Plateau, separated in detailed mapping (Cunningham and others, 1983); deposits extend eastward of the map area (Williams and Hackman, 1971), where an unusual nepheline-syenite breccia pipe of 24.4 Ma was emplaced into it (Agrell and others, 1999); maximum thickness in the map area about 1,300 feet (400 m), thickening northward.

Tql Leach Canyon Formation of the Quichapa Group—Moderately resistant, tan and gray, crystal-poor, poorly welded, low-silica rhyolite ash-flow tuff; part of a series of regional ash-flow tuffs (Quichapa Group; Mackin, 1960; Williams, 1967) derived from the Great Basin; source probably the Caliente caldera complex of eastern Nevada, as suggested by isopachs (Williams, 1967; Rowley and others, 1995); $^{40}Ar/^{39}Ar$ age about 23.8 Ma (Best and others, 1993); exposed only west of Parowan Valley; maximum thickness about 150 feet (50 m), thickening southwestward.

Tws Volcanic rocks of Willow Spring—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; primarily alluvial-facies rocks of a stratovolcano in the Sevier Plateau; maximum exposed thickness about 1,600 feet (500 m).

Tbv Bear Valley Formation—Generally soft, characteristically light-green but locally gray and yellow, moderately to well sorted, commonly cross bedded, fine- to medium-grained, tuffaceous sandstone of mostly eolian but locally fluvial origin, interbedded volcanic mudflow breccia, airfall tuff, and poorly and highly welded ash-flow tuff (Anderson, 1971); has K-Ar dates of about 25 Ma (Fleck and others, 1975); maximum thickness about 1,000 feet (300 m).

Tbr Volcanic rocks of Bull Rush Creek—Soft to moderately resistant, tan, gray, pink, and greenish-yellow, dacitic volcanic mudflow breccia, conglomerate, sandstone, lava flows, poorly welded ash-flow tuff, dikes, and flow breccia (Anderson and others, 1990a); lava flows and clasts have an identical, distinctive lithology of crystal-rich quartz monzonite porphyry identical to the Spry Intrusion (Ticc); stratovolcano deposits on the roof of, and derived from the Spry Intrusion, which subsequently domed up Tbr; K-Ar date of 26.4 Ma; base not exposed but about 800 feet thick (250 m).

Tbb Buckskin Breccia—Moderately resistant, gray and pink, poorly to moderately welded, crystal-poor, dacitic ash-flow tuff, flow breccia, volcanic mudflow breccia, conglomerate, and sandstone (Anderson and Rowley, 1975; Yannacci, 1986); characterized by as much as 50 percent rock volume of crystal-rich lithic clasts identical to Tbr and the Spry Intrusion (Ticc), from which it was derived; intertongues with the Isom Formation (Tin) and considered about 26 Ma; exposed between Buckskin Valley and Circleville Canyon (Markagunt Plateau); maximum thickness about 250 feet (80 m).

Tin Isom Formation and the Needles Range Group, undivided

Isom Formation—Resistant, brown and reddish-brown, crystal-poor, densely welded, trachydacitic ash-flow tuff (Mackin, 1960; Fryman, 1987) derived perhaps from the Indian Peak caldera complex at the Utah-Nevada border (Best and others, 1989a, b); age about 27-26 Ma on the basis of many $^{40}Ar/^{39}Ar$ and K-Ar dates (Best and others, 1989b; Rowley and others, 1994); maximum thickness about 30 feet (10 m).

Needles Range Group—Resistant, gray, tan, pink, and light-purple, crystal-rich, moderately welded, dacite ash-flow tuff (Mackin, 1960) derived from the Indian Peak caldera complex (Best and others, 1989a, b); near Minersville, consists of both the Lund Formation (27.9 Ma; Best and others, 1989a) and the Wah Wah Springs Formation (30.5 Ma; Best and others, 1989a) of the Needles Range Group; in the Markagunt Plateau, consists of the Wah Wah Springs Formation; maximum thickness about 100 feet (30 m).

Tvs Local volcanic and sedimentary rocks—Heterogeneous assemblage of mostly resistant lava flows, ash-flow tuff, flow breccia, volcanic mudflow breccia, and tuffaceous sandstone (Anderson and Rowley, 1975); a K-Ar date of 31.9 Ma was determined on an ash-flow tuff (Fleck and others, 1975); exposed only between Buckskin Valley and Circleville Canyon; maximum thickness about 450 feet (140 m).

Tcg Conglomerate—Moderately resistant, white, tan, and light-gray, fluvial conglomerate and sandstone characterized by pebbles of quartzite and carbonates as much as 3 feet (1 m) in diameter, resting unconformably on Mesozoic sedimentary rocks; where exposed in the south Mineral Mountains and Minersville area, its maximum thickness is about 120 feet (40 m); exposed also as a patch that includes tuffaceous sandstone as much as 30 feet thick (10 m) in the central Tushar Mountains.

Tc Claron Formation—Soft to resistant, mostly white and gray (upper part) and red (lower part), lacustrine and fluvial limestone, calcrete, sandstone, siltstone, mudstone, and conglomerate; maximum thickness about 1,000 feet (300 m).

Ja Arapien Shale—Soft to moderately resistant, multicolored but generally light-gray, marine siltstone, shale, mudstone, limestone, sandstone, and minor conglomerate; contains evaporite beds north of the map area; exposed in the central Tushar Mountains, in the southwest part of the Arapien basin of central Utah (Hintze, 1993); thickness more than 1,150 feet (350 m), with its top not exposed.

Jc Carmel Formation—Soft to resistant, light-gray, reddish-brown, and tan thin-bedded limestone and shale underlain by resistant, light-gray, thin- to medium-bedded, locally fossiliferous limestone (Earll, 1957); exposed in the Mineral Mountains; maximum thickness about 600 feet (200 m).

Jn Navajo Sandstone—Resistant, red, yellow, and gray, locally spectacularly cross bedded, fine- to medium-grained, eolian sandstone (Earll, 1957; Price, 1998); exposed northeast of Minersville and in the central Tushar Mountains; maximum exposed thickness about 1,500 feet (450 m) northeast of Minersville and 2,000 feet (600 m) in the central Tushar Mountains.

TRc Chinle Formation—Fluvial and lacustrine rocks of the upper Petrified Forest Member and the underlying Shinarump Conglomerate Member; the Petrified Forest Member is of soft to moderately resistant, red, maroon, brown, tan, and white mudstone, and a basal bed of purple, coarse-grained sandstone; the Shinarump Conglomerate Member is moderately resistant, red to brownish-red, fine- to medium-grained conglomerate; exposed only in the central Tushar Mountains, where the combined thickness is about 600 feet (200 m).

TRm Moenkopi Formation—Soft and locally resistant, red, brown, pink, light- and dark-gray, and greenish-gray, marine and continental, thin-bedded siltstone, shale, and subordinate locally fossiliferous limestone (Earll, 1957; Price, 1998); exposed east and northeast of Minersville and in the central Tushar Mountains; thickness about 1,300 feet (400 m) to 1,700 feet (500 m).

Ppt Plympton, Kaibab, and Toroweap Formations, undivided—Mapped only north of Minersville.

Ppk Plympton and Kaibab Formations, undivided—Mapped only east and north of Minersville. Plympton Formation—Moderately resistant, gray and tan, thin bedded, ledgy, chert-bearing, marine dolomite and limestone (J.E. Welsh and B.R. Wardlaw, unpublished data, 1978); maximum thickness about 200 feet (60 m).

Pkt Kaibab and Toroweap Formations, undivided—Mapped only in the central Tushar Mountains, where their combined thickness is 500 to 800 feet (150 to 250 m).

Pk Kaibab Formation—Resistant, light- to dark-gray, medium-grained, thin- to thick-bedded, fossiliferous marine limestone characterized by cliffs and ledges and by abundant dark-brown chert concretions and beds (Earll, 1957; J.E. Welsh and B.R. Wardlaw, unpublished data, 1978; Corbett, 1984; Price, 1998); maximum thickness about 550 feet (170 m) in the northwest part of the map area.

Pt Toroweap Formation—Generally resistant, light- to dark-gray, black, and tan, fine-grained, mostly thin-bedded, ledgy, locally cherty and fossiliferous, marine limestone and subordinate sandstone (J.E. Welsh and B.R. Wardlaw, unpublished data, 1978; Corbett, 1984); mapped in the northwest part of the map area, where the maximum thickness is about 300 feet (100 m).

PIPqc Queantoweap Sandstone, Pakoon Dolomite, and Callville Limestone, undivided—Mapped only in the central Tushar Mountains, where their combined thickness is about 300 feet (100 m) although the base is not exposed.

Pq Queantoweap Sandstone—Resistant, tan and pink, thin-bedded, ledgy, fine-grained sandstone and quartzite (J.E. Welsh and B.R. Wardlaw, unpublished data, 1978); mapped in the northwest part of the map area; maximum thickness about 500 feet (150 m).

Pzc Paleozoic carbonate rocks—Mapped only in the Gillies Hill area (Machette and others, 1984) and Mineral Mountains where intensely metamorphosed.

Pp Pakoon Dolomite—Alternating soft and resistant, light- to dark-gray and pink, ledgy and cliffy, medium-grained, thick-bedded, locally chert-bearing, marine dolomite and subordinate to minor sandstone (J.E. Welsh and B.R. Wardlaw, unpublished data, 1978; Corbett, 1984; Price, 1998); mapped in the northwest part of the map area; thickness about 800 feet (240 m).

IPc Callville Limestone—Soft to moderately resistant, white and light-gray, fine-grained, thin- to medium-bedded, ledgy, locally fossiliferous, rarely cherty, marine limestone and minor gray, purple, and brown siltstone and fine-grained sandstone capped by an upper limestone cliff in the Bradshaw district (J.E. Welsh and B.R. Wardlaw, unpublished data, 1978; Wardlaw, 1980; Corbett, 1984; Price, 1998); mapped in the northwest part of the map area; thickness about 400 feet (120 m).

Mr Redwall Limestone—Resistant, light-gray to black, medium-grained, thick-bedded, highly fossiliferous, rarely cherty, spar-rich, marine limestone and, in the lower part, dolomite (J.E. Welsh and B.R. Wardlaw, unpublished data, 1978); forms massive cliffs; mapped in the northwest part of the map area; thickness about 1,250 feet (380 m).

Dcs Crystal Pass Formation, Simonson Dolomite, and Sevy Dolomite, undivided—Mapped only in the northwest part of the map area along the west fault scarp of the south Mineral Mountains.
Crystal Pass Formation—Mostly soft, light-gray, thin- to medium-bedded, interbedded marine dolomite and sandstone (J.E. Welsh and B.R. Wardlaw, unpublished data, 1978); thickness about 160 feet (50 m).
Simonson Dolomite—Resistant, light- to medium-gray, mostly thick-bedded, marine dolomite (J.E. Welsh and B.R. Wardlaw, unpublished data, 1978); thickness at least 500 feet (150 m) but no complete section is exposed.
Sevy Dolomite—Mostly resistant, light-gray siltstone and cross-bedded sandstone at the top, underlain by light-gray marine dolomite; thickness less than 100 feet (30 m) but only the top of a complexly faulted section in the Bradshaw mining district is exposed.

pCg Banded gneiss—Resistant, light- to dark-gray biotite, quartz, K-feldspar, hornblende, and plagioclase gneiss and local schist exposed along the west frontal fault of the Mineral Mountains; as mapped, unit includes local dikes and apophyses of Tertiary intrusive rocks of the Mineral Mountains batholith (Nielson and others, 1986); Rb-Sr and U-Pb dating shows that the unit was last metamorphosed at about 1,750 Ma (Aleinikoff and others, 1986).

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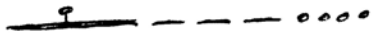
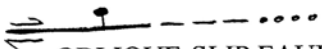
GEOLOGIC SYMBOLS

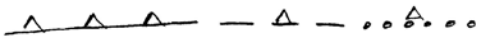
CONTACT



NORMAL FAULT
Dashed where location inferred; dotted where concealed; bar and ball on downthrown side



OBLIQUE-SLIP FAULT
Dashed where location inferred; dotted where concealed; bar and ball on downthrown side and arrows show relative movement



LOW-ANGLE NORMAL FAULT
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GRAVITY-SLIDE SURFACE
Dashed where location inferred; dotted where concealed; hachures on upper plate; only in southwest corner of map area

CALDERA MARGIN
Dashed where location inferred; dotted where concealed; hachures on downthrown side

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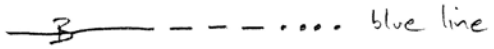
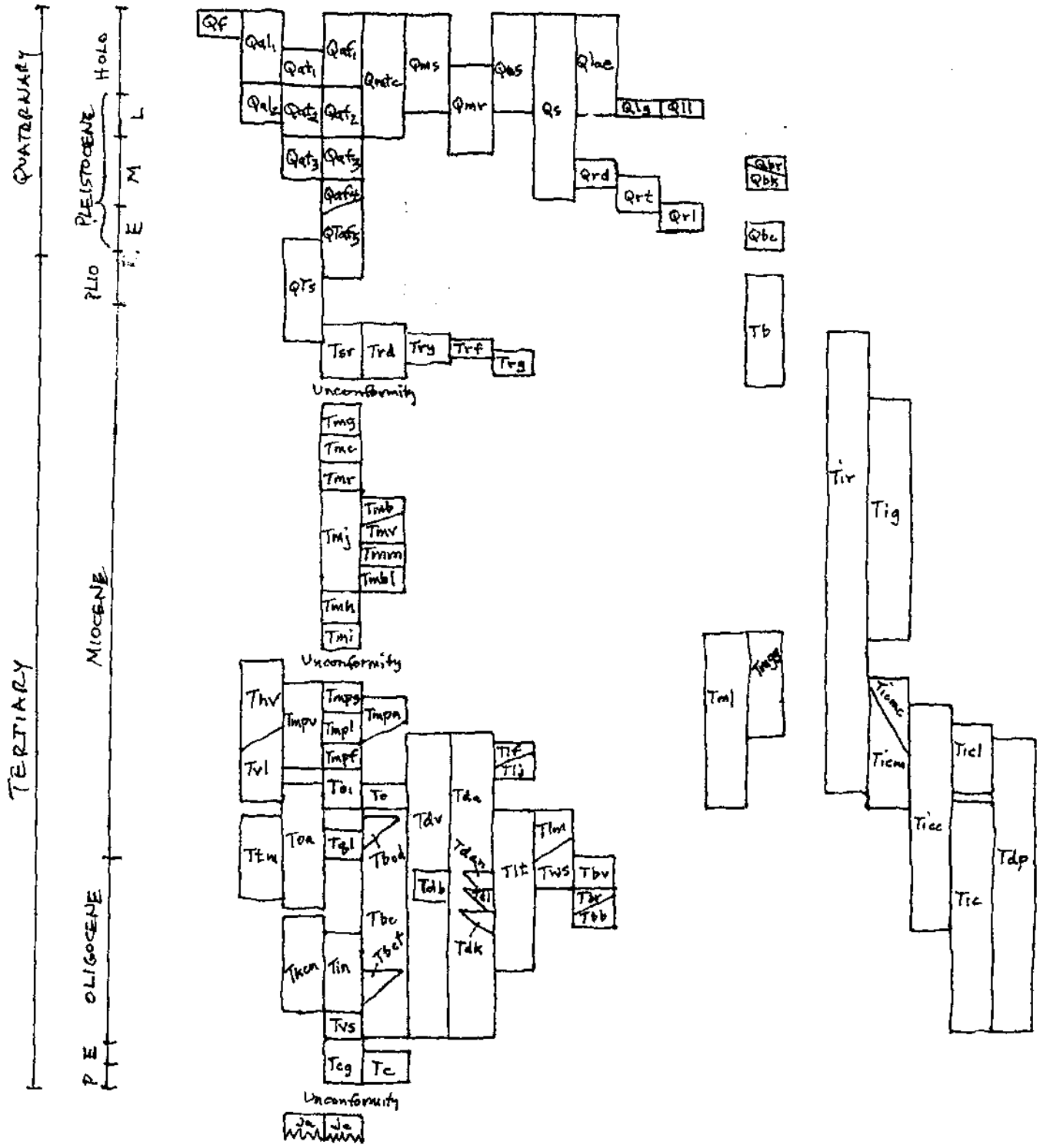
STRIKE AND DIP OF BEDDING

VOLCANIC VENT



LAKE BONNEVILLE SHORELINE
Dashed where location inferred: dotted where concealed

DEEP EXPLORATION WELL
Map symbol on left; cross-section symbol on right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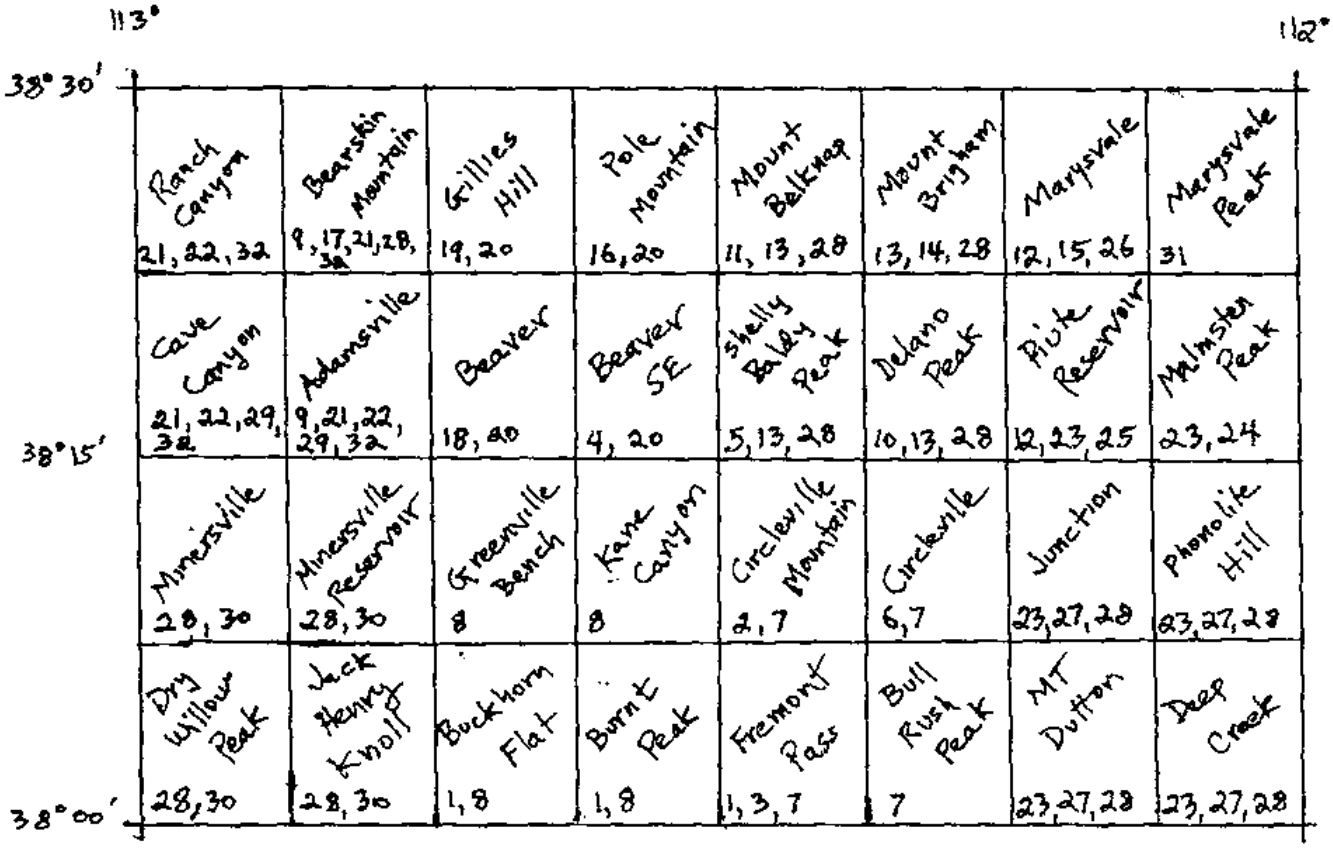
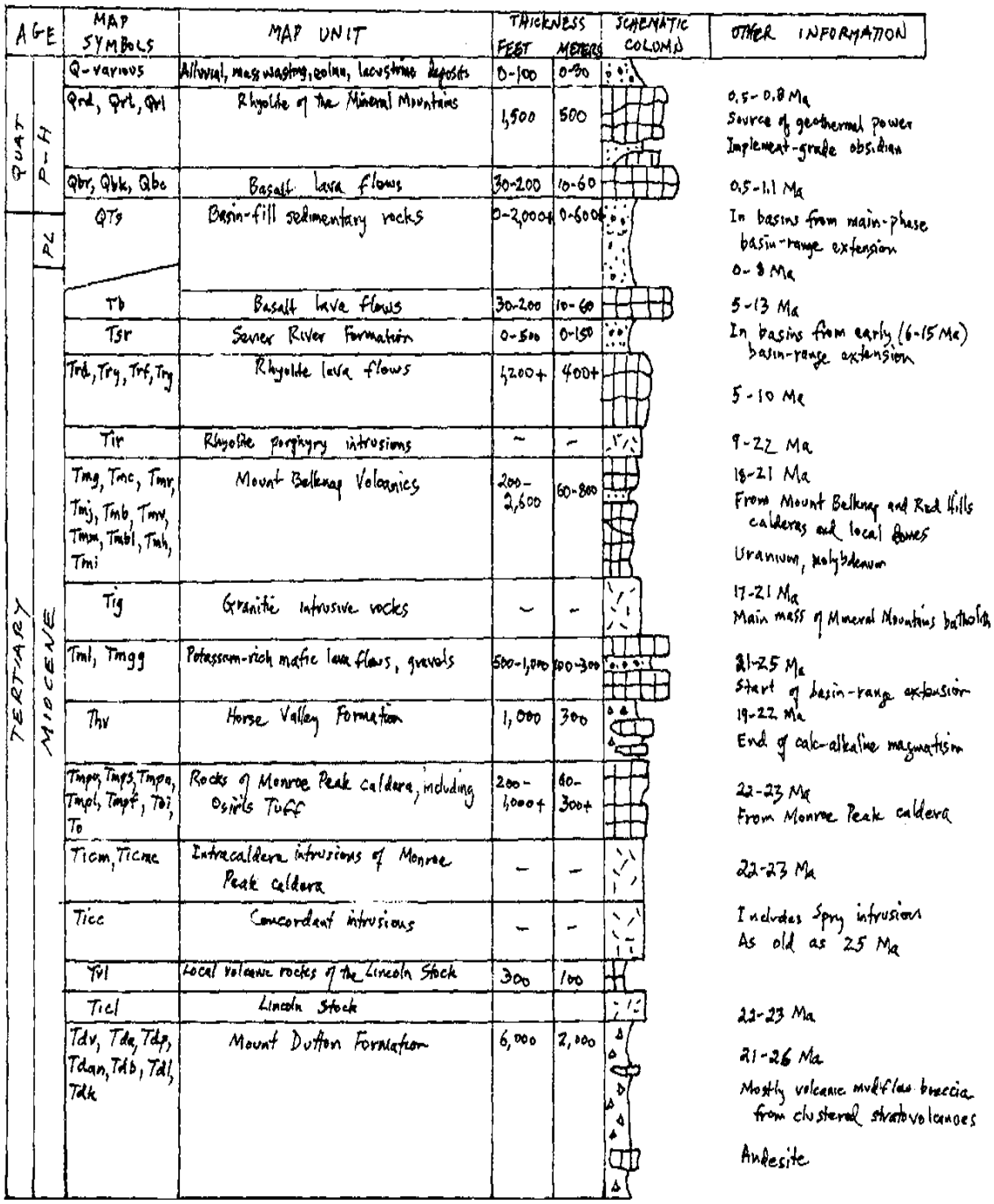


Index map showing 7.5-minute quadrangles and sources of geologic mapping

LITHOLOGIC COLUMN



AGE	MAP SYMBOLS	MAP UNIT	THICKNESS FEET	THICKNESS METERS	OTHER INFORMATION
QUAT P-H	Q-various	Alluvial, mass wasting, eolian, lacustrine deposits	0-100	0-30	
	Qrd, Qrl, Qrl	Rhyolite of the Mineral Mountains	1,500	500	0.5-0.8 Ma Source of geothermal power Implement-grade obsidian
	Qbr, Qbk, Qbc	Basalt lava flows	30-200	10-60	0.5-1.1 Ma
QUAT PL	QTs	Basin-fill sedimentary rocks	0-2,000+	0-600+	In basins from main-phase basin-range extension 0-8 Ma
TERTIARY MIOCENE	Tb	Basalt lava flows	30-200	10-60	5-13 Ma
	Tsr	Sevier River Formation	0-500	0-150	In basins from early (6-15 Ma) basin-range extension
	Trd, Try, Trf, Trg	Rhyolite lava flows	4,200+	400+	5-10 Ma
	Tir	Rhyolite porphyry intrusions	–	–	9-22 Ma
	Tmg, Tmc, Tmr, Tmj, Tmb, Tmv, Tmm, Tmbl, Tmh, Tmi	Mount Belknap Volcanics	200-2,600	60-800	18-21 Ma From Mount Belknap and Red Hills calderas and local domes Uranium, molybdenum
	Tig	Granitic intrusive rocks	–	–	17-21 Ma Main mass of Mineral Mountains batholith
	Tml, Tmgg	Potassium-rich mafic lava flows, gravels	500-1,000	100-300	21-25 Ma Start of basin-range extension
	Thv	Horse Valley Formation	1,000	300	19-22 Ma End of calc-alkaline magmatism
	Tmpo, Tmps, Tmpa, Tmpl, Tmpt, Tdi, To	Rocks of Monroe Peak caldera, including Osiris Tuff	200-1,000+	60-300+	22-23 Ma From Monroe Peak caldera
	Ticm, Ticmc	Intracaldera intrusions of Monroe Peak caldera	–	–	22-23 Ma
	Ticc	Concordant intrusions	–	–	Includes Spry intrusion As old as 25 Ma
	Tvl	Local volcanic rocks of the Lincoln Stock	300	100	
	Ticl	Lincoln Stock			22-23 Ma
	Tdv, Tda, Tdp, Tdan, Tdb, Tdl, Tdk	Mount Dutton Formation	6,000	2,000	21-26 Ma Mostly volcanic mudflow breccia from clustered stratovolcanoes Andesite

TERTIARY	MIOCENE	Tlf	Tuff of Lion Flat	300	100	
		Tlj	Volcanic rocks of Lousy Jim	1,000	300	22.6 Ma
		Tbc, Tbcd, Tbct	Bullion Canyon Volcanics	5,000	1,500	22-30 Ma Lava flows, mudflow breccia, and tuff from clustered stratovolcanoes Dacite
		Tic	Calc-alkaline intrusive rock	—	—	Source of Bullion Canyon Volcanics Chalcopyrite mineral resources
		Tem	Tuff of Minersville	100	30	
		Tlt	Volcanic rocks of Little Table	2,500	800	Shield-volcano complex
		Tlm	Volcanic rocks of Langdon Mountain	1,300	400	Stratovolcano
		Tgl	Leach Canyon Formation	150	50	23.8 Ma
	OLIGOCENE	Tws	Volcanic rocks of Willow Spring	1,600	500	Stratovolcano
		Tbv	Bear Valley Formation	1,000	300	Mostly eolian
		Tbr	Volcanic rocks of Bull Rush Creek	800	250	
		Tbb	Buckskin Breccia	250	80	From Spry intrusion
		Tin	Isom Formation and Needles Range Group	100	30	26-30.5 Ma
		Tvs	Local volcanic and sedimentary rocks	450	140	
	EO	Tcg	Conglomerate	30	10	
	PAL	Tc	Claron Formation	1,000	300	Fluvial and lacustrine
						Unconformity
JURASSIC		Ja	Arapien Shale	1,150+	350+	
		Jc	Carmel Formation	600	200	
		Jn	Navajo Sandstone	1,500-2,000	450-600	Mostly red eolian sandstone
TRIASSIC		TRc	Chinle Formation	600	200	
		TRm	Moenkopi Formation	1,300-1,700	460-500	
PERMIAN		Pzt, Pzpk, Pzkt, Pzk, Pz	Plympton, Kaibab, and Toroweap Formations	500-800	150-250	Cherty marine limestone
		Pq	Queantoweap Sandstone	500	150	
		Pp, Pzc	Pakoon Dolomite	800	240	Marine dolomite
		Pc, Pzc	Callville Limestone	400	120	
MISS		Mr, Pzc	Redwall Limestone	1,250	380	Highly fossiliferous
DEV		Dcs	Crystal Pass Formation, Simonson and Sevy Dolomite	760	230	
PROT		pEg	Banded gneiss	—	—	Unconformity 1,750 Ma