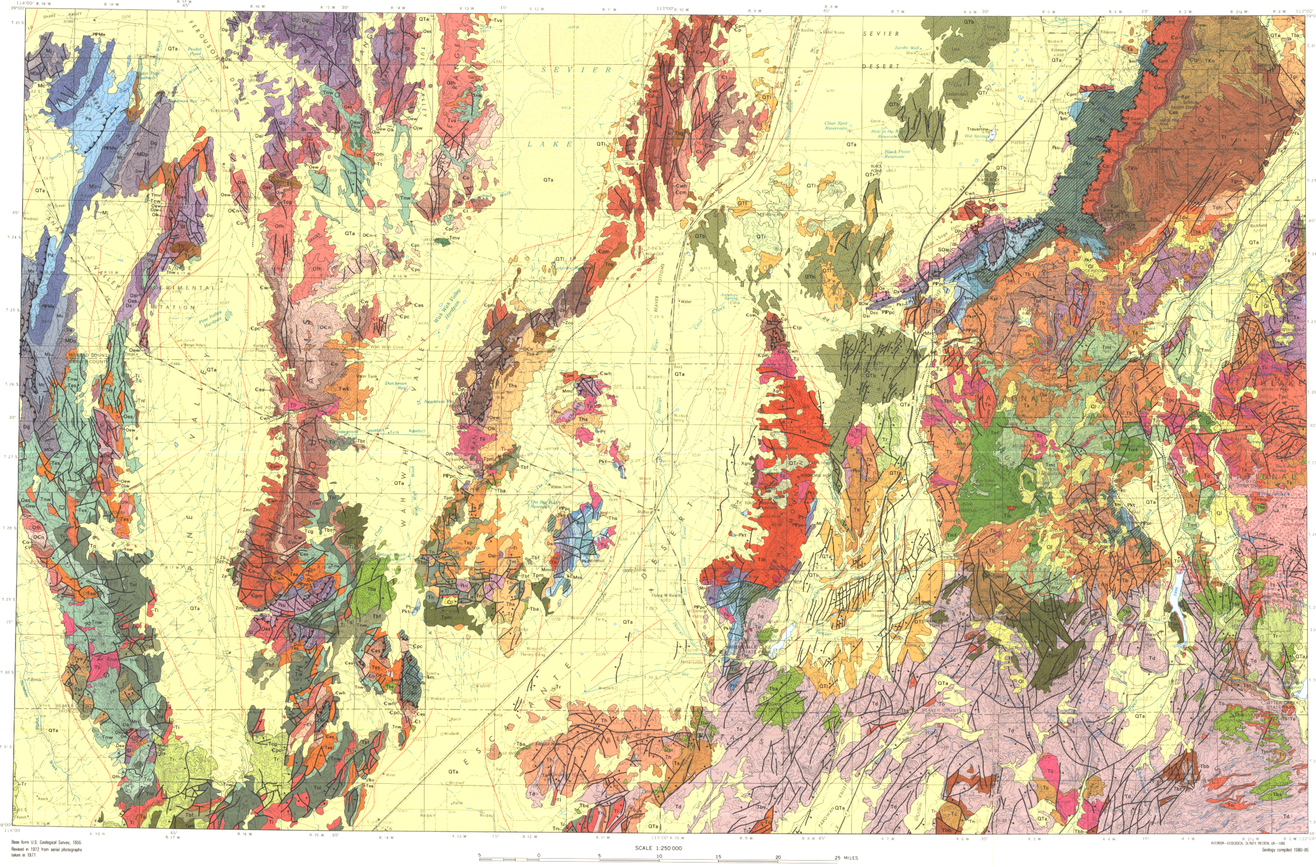

Base from U.S. Geological Survey, 1966
Revised in 1972 from aerial photographs taken in 1971

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1986
Setting compiled 1980–85

NOTE

This map is part of a folio of maps of the Richfield 1° × 2° quadrangle, Utah, prepared under the Conterminous United States Mineral Assessment Program. Background information about this folio is published in U.S. Geological Survey Circular 916 (Steven and Morris, 1982).

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

QTa **Surficial and basin-fill deposits, undivided (Quaternary and Tertiary)**—Primarily basin-fill alluvium, as well as colluvium, landpowder, and terrace gravels that range in age from late Miocene to Holocene. A transitional sedimentary unit that includes the Sevier Desert Marker Bed (Oviatt, 1988) in the subsurface of Sevier Desert, western part of the quadrangle, deformed Miocene and locally lower Pliocene basin-fill sediments are included in unit **QTa**, whereas in High Plateaus Subprovince, east of the western bases of Pahvant Range, Mineral Mountains, and Black Mountains, equivalent rocks are shown separately as the Sevier River Formation (unit Ts). Many extensive areas largely covered by thin alluvial deposits are shown as bedrock for cartographic purposes.

Qe **Lacustrine deposits (Quaternary)**—Clayey silt to sand, largely in subsurface, eastern part of the quadrangle. Includes lacustrine deposits of Sevier Plateau and Tushar Mountains. Many extensive areas covered by landslide debris are shown as bedrock for cartographic purposes.

VOLCANIC AND ASSOCIATED SEDIMENTARY ROCKS

Qb **Rhyolite in southern Sevier Desert and Mineral Mountains (Pleistocene and Pliocene)**—Rhyolite volcanic domes, lava flows, flow-margin breccia, and local pyroclastic deposits. Phenocrysts (0–35 percent of quartz, sanidine, plagioclase, and biotite are set in glassy to microcrystalline matrices. Glassy rocks are commonly perlite containing abundant "apache tears" (black obsidian). Rhyolite of Mineral Mountains (Rowley, 1978) is exposed in areas of south end of Sevier Desert (rock ages 2.7–2.4 Ma (Michael and others, 1978; Cheatham and others, 1981) and in Mineral Mountains area (0.8–0.3 Ma (Lipman and others, 1978). Silica contents range from 71 to 77 percent and total alkalies 8–10 percent. The Roosevelt Hot Spring area of Sevier Desert and west of the Mineral Mountains probably is related to the nearby rhyolites (Mehnert and others, 1978; Lipman and others, 1978; Nielson and others, 1978), and molten rock may still exist under parts of the area.

Qbt **Mafic lava flows in the Cove Fort-Sevier Desert area (Pleistocene and Pliocene)**—Basalt and basaltic andesite, which occur in widespread lava flows, shield volcanoes, and cinder cones. Cinders locally oxidized to red and black. Most flows are olivine basalt and olivine tholeiite; some are even nepheline to dense and fine-grained basalt, which apparently is compositionally quite variable, ranging from nearly aphyric to prominently porphyritic containing 40–45 percent phenocrysts of labradorite, pyroxene, Fe-Ti oxides, and sparse olivine. Matrices glassy to microcrystalline. Some olivine tholeiite is present but much of the rock is olivine-normative basaltic andesite (Lipman and others, 1978). Silica contents range from 51 to 57 percent; about 1% to about 5.5 Ma (Lipman and others, 1978; Best and others, 1980).

Qtt **Lake beds of pre-Bonneville age (Pleistocene and Pliocene)**—Tuffaceous basin, unit consists of light- to medium-gray silty clay and silt, and gray to brown sand deposited in a broad lake in center of basin, and laterally equivalent piedmont sand and gravel deposits and some lenticulated near margins of basin (Machette and others, 1984). Contains at least five tuffs ranging in age from 1.6 to 0.8 Ma. Tuffs are from Yellowstone Yellowstone National Park area (Christiansen and Wilcox, 1982). Maximum fossils suggest a Blancan 5 age of 2.5–2.0 Ma (C. A. Repenning, written commun., U. S. A. Sant, 1980) for beds underlying Hackenberry Ridge and Sand Ridge.

In the Sevier Desert area, in north-central part of quadrangle, the unit consists largely of clayey marl where deposited in deep parts of an extensive lake and of soft marl to hard limestone where deposited on local shallow platforms of basalts and rhyolite lava flows (QTb and QTd) near margins of lake. In southern Sevier Desert area, the unit intercalates with lava flows dated between 3 Ma and 2 Ma (Mehnert and others, 1978; Crecraft and others, 1981) and contains the 2 Ma Hackleberry Ridge ash bed. Total thickness approximately 1 km (Crecraft and others, 1981). It is about 0.5 Ma at Crystal Peak (Crecraft and others, 1981).

Tsd **Sevier River Formation and equivalent rocks (Pliocene and Miocene)**—Poorly to moderately consolidated, gray and salmon pink fluviatile and lacustrine conglomerate, sandstone, and siltstone containing local layers of artifal tuff and basaltic lava flows (Tbs). Shown only in High Plateaus Subprovince, in eastern part of quadrangle east of western bases of the Pahvant Range, Mineral Mountains, and Black Mountains. Unit is in Sevier River Formation and equivalent strata have been deformed by basin-range tectonism, in contrast to nearly undeformed or only slightly deformed younger alluvial deposits (QTa).

In Clear Creek drainage basin, a tuff layer near bottom of Sevier River Formation is dated at 3.4 Ma (Hamblin and others, 1981) and another one is dated at 2 Ma (Steven and others, 1979). In Beaver Canyon flanking the East Fork of the Sevier River east of the banner of Kingston, most of unit is older than a 5 Ma rhyolite center at Pinchute Hill 9 km east of Kingston (Rowley and others, 1981). In Beaver basin and vicinity, unit is more Pliocene than Miocene. Most age-equivalent deposits west of Escalante and Sevier Desert are included in unit QTa.

Tbs **Basalt lava flows (Pliocene and Miocene)**—Black to dark-gray, dense to vesicular (locally amygdaloidal) lava flows of olivine basalt. Aphyric to prominently porphyritic, but generally poorly porphyritic, containing sparse phenocrysts of calcic plagioclase, pyroxene, olivine, and Fe-Ti oxides. Groundmass glassy to microcrystalline. Most flows are olivine-normative and olivine tholeiites. Approximate age range from about 15 Ma to about 4 Ma (Best and others, 1980). Many of the lava flows are interlayered with basalt flows of Sevier River Formation.

Ts **Rhyolite lava flows and pyroclastic rocks (late Miocene)**—Includes Steamboat Mountain Rhyolite (Rowley, 1978) and rhyolite of Kanosh (Steven and Bert, 1980). Best and others, 1987), rhyolites of Dead Horse Reservoir, Thermal Springs, and Sugarloaf Mountain (Rowley and others, 1981). Rhyolite in central part (Evans and Nielson, 1982; Rowley and others, 1978), and rhyolite of Forshea Mountain, rhyolite of Dry Lake, and rhyolite of Kanosh NE (R. S. Mehl in unpublished part (Rowley and others, 1981). Range from nearly aphyric to moderately porphyritic massive to flow-banded rhyolite containing 5–15 percent phenocrysts of plagioclase and biotite. Rhyolite in Steamboat Mountain Formation locally contains prominent crystals of topaz; largely in vesicles and lithophysae.

MIDDLE TERTIARY (OLIGOCENE) VOLCANIC ROCKS

Tmt **Mount Belknap Volcanics (Oligocene)**

Porphyritic rocks—Predominantly slightly to densely welded ash-flow tuff and minor rhyolite lava flows and domes. Most of the tuff is in Mount Belknap caldera source area, including the upper part of the Joe Lott Tuff Member and lower tuffs of the Mount Belknap Volcanics. Most of the tuff is rich in phenocrysts (10–35 percent) of sanidine, biotite, and quartz, and contains trace amounts of fayalite and equivalent intrusives tuff units consist of light-gray, crystal-poor alkali rhyolite ash-flow tuff containing 1–2 percent phenocrysts of quartz, sanidine, plagioclase, sanidine, and traces of biotite (Budding and others, 1987). Tuff of Tushar Mountains (Steven and others, 1979) contains about 7–9 percent phenocrysts of some minerals, and one minor crystal-rich unit contains as much as 30 percent of these phenocrysts. Radiometric ages are 31–28 Ma (Steven and others, 1979).

Lava flows and associated volcaniclastic rocks—Thick lava flows and associated volcaniclastic rocks of Mount Belknap Volcanics and Bullion Canyon Volcanics. Most of alkali rhyolite but accumulated and near local vents within Mount Belknap caldera and in an eastern extension of Tushar Mountain. Most rocks are crystal-poor alkali feldspar containing sparse phenocrysts of quartz, sanidine, sodic plagioclase, and biotite in a finely granular, commonly spherulitic matrix. Contorted flow layers are common. Some older lava flows and volcanic domes in eastern source area are more mafic and contain phenocrysts of calcic plagioclase, pyroxene, and Fe-Ti oxides. Approximate age range from 23 to 18 Ma (Bassett and others, 1963; Steven and others, 1979).

Tpmb **Potassium-rich mafic lava flows, volcaniclastic breccia, and conglomerate (Miocene)**—Dark-gray to black, dense to vesicular locally amygdaloidal lava flows of olivine basalt containing small phenocrysts of olivine, pyroxene, Fe-Ti oxides, and plagioclase. Generally contain 2 weight percent or more K2O. The rocks are associated with potassic volcaniclastic rocks called "traffic flow member of Bullion Canyon" (Best and Keith, 1979). Radiometric ages range from 25 to 21 Ma (Best and others, 1980).

Tbf **Felsic rocks of the Bullion Canyon Volcanics (Miocene)**—Light-colorized rhyolite lava flows, ash-flow and air-fall tuffs, and minor sedimentary rocks. Locally altered to argillic assemblages. Most rocks are crystal-poor (commonly less than 10–15 percent) and consist of quartz, sanidine, plagioclase, and biotite, set in a glassy to microgranular matrix. Flow layers are locally prominent. Tuffs range from very densely welded, black ash-flow tuff rhyolite to widespread loosely consolidated, light-colored ash-flow and air fall tuff. A basal ash-flow tuff unit is characterized by trace amounts of dark red garnet (Keith, 1978, 1980). Rocks range in age from about 23 to 18 Ma (Best and others, 1980).

WESTERN FACIES CALC-ALKALINE VOLCANIC AND ASSOCIATED SEDIMENTARY ROCKS

[Those units exposed mostly west of 112°45' longitude]

Tvs **Sedimentary units interlayered with volcanic rocks, undivided (Miocene and Oligocene)**—Generally rarely to conglomeratic sedimentary rock units interlayered at various stratigraphic positions in the volcanic succession in western part of quadrangle. Clasts range from predominantly volcanic in west-central part of quadrangle to predominantly sedimentary in northeast part of quadrangle. Most rocks are poorly to moderately consolidated; only units are exposed over significant areas.

Tvh **Horse Valley Formation (Miocene)**—Light-varicolored rhyolitic and dacite lava flows, volcanic mudflow breccia, plugs, and minor ash-flow tuff. Rhyolitic flow rocks contain phenocrysts of plagioclase and subordinate to sanidine, quartz, and biotite (Rowley, 1978). Dacite flows are as old as 26 Ma (Anderson and Rowley, 1975; Rowley, 1978) from clustered stratovolcanoes in south-central part of quadrangle. Accumulated in part contemporaneously with andesitic rocks of Mount Dutton Formation (Td) and intertongues marginally with ash-flow tuff units of Quichapa Group (Tq).

Tqs **Quartz latite of Squaw Peak (Miocene)**—Porphyritic quartz latite lava flows and underlying heterogeneous pyroclastic rocks and locally interlayered tuffs. Most lava flows are porphyritic, medium-gray, quartz-phenocryst quartz latite containing phenocrysts of sanidine, quartz, plagioclase, biotite, and hornblende set in a dark-gray glassy to microcrystalline matrix. Outcrops of Squaw Peak Quartz Latite are in a broad belt of lava flows that dip 10–20° to the east and are as thick as 1 km. The pyroclastic rocks range from soft, light-colored, fine-grained tuff to coarse-grained breccia, tongues of tuff belonging to Quichapa Group (Tq) locally extend into these rocks. One of the lava flows has been dated at 22.4 Ma (Lipman and others, 1978).

Tq **Quichapa Group, undivided (Miocene)**—Distal tongues of several ash-flow tuff units in Quichapa Group that wedge out northward into several local assemblages of volcanic rocks along south margin of quadrangle. Some tongues extend from source area in Iron Springs District, in central part of quadrangle, but most are from vents in southern Sevier Plateau (the lava flows belonging to volcanic rocks of Signal Peak). Lava flows are commonly vesicular and have flow layers that are parallel to flow contacts. Flow rocks are locally underlain by flow breccia and pillow breccia. Most rocks are porphyritic, containing 10–35 percent phenocrysts of plagioclase, biotite, and hornblende set in a glassy to microcrystalline matrix. Contorted flow layering is common. Some older lava flows and volcanic domes in eastern source area are more mafic and contain phenocrysts of calcic plagioclase, pyroxene, and Fe-Ti oxides. Approximate age range from 23 to 18 Ma (Bassett and others, 1963; Steven and others, 1979).

Tcs **Escalante Desert Formation of the Needles Range Group and Sawtooth Peak Formation, undivided (Miocene and Oligocene)**—Tuffaceous volcanic rocks of Escalante Desert and vicinity. Most of the tuff is rich in phenocrysts (10–35 percent) of quartz, sanidine, plagioclase, and biotite, set in a glassy to microgranular matrix. Most rocks are crystal-poor alkali rhyolite containing 1–2 percent phenocrysts of quartz, sanidine, plagioclase, and traces of biotite (Budding and others, 1987). Tuffs are from Yellowstone Yellowstone National Park area (Christiansen and Wilcox, 1982). Maximum fossils suggest a Blancan 5 age of 2.5–2.0 Ma (C. A. Repenning, written commun., U. S. A. Sant, 1980) for beds underlying Hackenberry Ridge and Sand Ridge.

In the Sevier Desert area, in north-central part of quadrangle, the unit consists largely of clayey marl where deposited in deep parts of an extensive lake and of soft marl to hard limestone where deposited on local shallow platforms of basalts and rhyolite lava flows (QTb and QTd) near margins of lake. In southern Sevier Desert area, the unit intercalates with lava flows dated between 3 Ma and 2 Ma (Mehnert and others, 1978; Crecraft and others, 1981) and contains the 2 Ma Hackleberry Ridge ash bed. Total thickness approximately 1 km (Crecraft and others, 1981). It is about 0.5 Ma at Crystal Peak (Crecraft and others, 1981).

Tbs **Basalt lava flows (Pliocene and Miocene)**—Black to dark-gray, dense to vesicular (locally amygdaloidal) lava flows of olivine basalt. Aphyric to prominently porphyritic, but generally poorly porphyritic, containing sparse phenocrysts of calcic plagioclase, pyroxene, olivine, and Fe-Ti oxides. Groundmass glassy to microcrystalline. Most flows are olivine-normative and olivine tholeiites. Approximate age range from about 15 Ma to about 4 Ma (Best and others, 1980). Many of the lava flows are interlayered with basalt flows of Sevier River Formation.

Ts **Rhyolite lava flows and pyroclastic rocks (late Miocene)**—Includes Steamboat Mountain Rhyolite (Rowley, 1978) and rhyolite of Kanosh (Steven and Bert, 1980). Best and others, 1987), rhyolites of Dead Horse Reservoir, Thermal Springs, and Sugarloaf Mountain (Rowley and others, 1981). Rhyolite in central part (Evans and Nielson, 1982; Rowley and others, 1978), and rhyolite of Forshea Mountain, rhyolite of Dry Lake, and rhyolite of Kanosh NE (R. S. Mehl in unpublished part (Rowley and others, 1981). Range from nearly aphyric to moderately porphyritic massive to flow-banded rhyolite containing 5–15 percent phenocrysts of plagioclase and biotite. Rhyolite in Steamboat Mountain Formation locally contains prominent crystals of topaz; largely in vesicles and lithophysae.

MIDDLE TERTIARY (MIOCENE) VOLCANIC ROCKS

Tmt **Pyroclastic rocks**—Predominantly slightly to densely welded ash-flow tuff and minor air-fall tuff and tuffaceous sedimentary rocks. Most of the tuff in these rocks is rich in phenocrysts (10–35 percent) of quartz, sanidine, and biotite, but also include that Hills Tuff Member and lesser units from an eastern source area of the formation south of Marysvale. Joe Lott Tuff Member and equivalent intrusive tuffs units consist of light-gray, crystal-poor alkali rhyolite ash-flow tuff containing 1–2 percent phenocrysts of quartz, sanidine, plagioclase, sanidine, and traces of biotite (Budding and others, 1987). Tuff of Tushar Mountains (Steven and others, 1979) contains about 7–9 percent phenocrysts of some minerals, and one minor crystal-rich unit contains as much as 30 percent of these phenocrysts. Radiometric ages are 31–28 Ma (Steven and others, 1979).

Lava flows and associated volcaniclastic rocks—Thick lava flows and associated volcaniclastic rocks of Mount Belknap Volcanics and Bullion Canyon Volcanics. Most of alkali rhyolite but accumulated and near local vents within Mount Belknap caldera and in an eastern extension of Tushar Marysvale. Most rocks are crystal-poor alkali feldspar containing sparse phenocrysts of quartz, sanidine, sodic plagioclase, and biotite in a finely granular, commonly spherulitic matrix. Contorted flow layers are common. Some older lava flows and volcanic domes in eastern source area are more mafic and contain phenocrysts of calcic plagioclase, pyroxene, and Fe-Ti oxides. Approximate age range from 23 to 18 Ma (Bassett and others, 1963; Steven and others, 1979).

Tmb **Potassium-rich mafic lava flows, volcaniclastic breccia, and conglomerate (Miocene)**—Dark-gray to black, dense to vesicular (locally amygdaloidal) lava flows of olivine basalt containing small phenocrysts of olivine, pyroxene, Fe-Ti oxides, and plagioclase. Generally contain 2 weight percent or more K2O. The rocks are associated with potassic volcaniclastic rocks called "traffic flow member of Bullion Canyon" (Best and Keith, 1979). Radiometric ages range from 25 to 21 Ma (Best and others, 1980).

Tbf **Felsic rocks of the Bullion Canyon Volcanics (Miocene)**—Light-varicolored rhyolite lava flows, ash-flow and air-fall tuffs, and minor sedimentary rocks. Locally altered to argillic assemblages. Most rocks are crystal-poor (commonly less than 10–15 percent) and consist of quartz, sanidine, plagioclase, and biotite, set in a glassy to microgranular matrix. Flow layers are locally prominent. Tuffs range from very densely welded, black ash-flow tuff rhyolite to widespread loosely consolidated, light-colored ash-flow and air fall tuff. A basal ash-flow tuff unit is characterized by trace amounts of dark red garnet (Keith, 1978, 1980). Rocks range in age from about 23 to 18 Ma (Best and others, 1980).

eine. Formation is local accumulation present largely in paleovalley cut in Paleozoic sedimentary rocks in central Needle Range. It is shown with Escalante Desert Formation for cartographic convenience.

Tha **Hostedler Andesite of Stringham (1963) (Oligocene)**—Heterogeneous gray, dark-gray, and brown lava flows and associated rocks. Most rocks are andesite in composition from andesite to quartz latite. Most of formation consists of medium- to thick-bedded dacite lava flows, but discontinuous layers of volcanic flow breccia, mudflow breccia, and pyroclastic rocks are common. Porphyritic rocks contain phenocrysts of plagioclase, quartz, hornblende, biotite, pyroxene, and magnetite set in microcrystalline to glassy matrices. Hydrothermally altered rocks are locally abundant. Includes lava flows previously called "dacite of Shaunte Hills" and in places lavas previously called "dacite of Shaunte Hills" and in places lavas previously called "conglomerate of High Rock Pass area" (Lemmon and Morris, 1979a, 1979b) that elsewhere are included in unit Tqg. In Shaunte Hills, includes local areas of unit Tsm that are too small to be shown at scale of map. Radiometric age of one of the flow units is about 31 Ma (Lemmon and others, 1973).

Tbp **Rhyolite of Tunnel Spring Mountains (Oligocene)**—Forms local intrusive-extrusive volcanic dome complex in southern Tunnel Spring Mountains, where it is in contact with Tunnel Spring Tuff. Consists of reddish-gray porphyry containing 5–15 percent phenocrysts of sanidine, quartz, plagioclase, and biotite. Most flow layers are parallel to flow contacts. Approximate age is about 26 Ma (K-Ar) and 28 Ma (fission track) for a single sample of this rock. It is believed to have been emplaced slightly later but during the same general period of igneous activity as Tunnel Spring Tuff (Tts) and Tbt.

Tts **Tunnel Spring Tuff (Oligocene)**—Densely welded, black ash-flow tuff. Lower parts of tuff remain in northwestern part of the quadrangle. Mostly massive but includes welded, vitrophyric, and nonwelded zones, and conglomerate units that increase in abundance outward from a caldera at Tunnel Spring Mountains (Steven and others, 1979). Contains inconspicuous phenocrysts of sanidine and quartz crystals, glassy lithophae tubes, and shiny black biotite flakes. Tuff is rich in lithic fragments of Paleozoic and lava fragments are common, especially near source. The property of underlying Paleozoic rocks ranges from 20 percent or more of tuff near the source to only a few percent in the distal facies. Tuff has a volume of more than 600 in. under Crystal Peak to leather edge against irregular topography of Paleozoic rocks. Tuff is about 26 Ma old (Lipman and others, 1978; Steven and others, 1979). Tuff is about 26 Ma old (Lipman and others, 1982).

Tmt **Dacite of Mah Wah Cove and andesite of Kelley Place, undivided (Miocene)**—Intermediate-composition volcanic rocks forming base of Quichapa Group in southern Needle Range and in Mah Wah Cove area. Flow is a medium- to coarse-grained, crudely stratified andesite with prominent brecciation containing blocks as much as 2 m across and several interbed lava flows of dark brown andesite. Tuff is a dark-gray, crystal-poor dacite with extensive equivalents of nearby dacite intrusive bodies (unit Td). One of lava flows has K-Ar age of about 32 Ma (Lemmon and others, 1973).

Dacite of Mah Wah Cove consists of gray porphyritic dacite to rhyodacite containing phenocrysts of plagioclase, biotite, and quartz. Tuff is a dark-gray, crystal-poor dacite containing phenocrysts of quartz and biotite. Tuff is derived from Three Creeks caldera in southwestern Needle Range. Flow rocks are locally underlain by Paleozoic rocks in southern Needle Range, where unit forms part of 66 in Indian Peak caldera.

Td **Mount Dutton Formation (Miocene and Oligocene)**—See description under Tcs

Tcs **Isom Formation (Oligocene)**—Numerous cooling units of brown, tan, gray, and red, densely welded ash-flow tuff that characteristically show evidence of secondary flow, such as flow layering, stretched vesicles, and gently dipping foliation. Most rocks are crystal-poor (10–20 percent) but some of the rock and consist of plagioclase and biotite phenocrysts and Fe-Ti oxides. Locally contains interlayered lava flows, particularly in southern Mah Wah Mountains and Needle Range, where interlayered and overlying andesite lava flows of similar phenocryst content make up a significant part of the section. Tuff is a dark-gray, crystal-poor dacite similar to that in Shaunte Hills, the tuff is shown by a single line bedder pattern. Age is about 26 Ma (Pinch and others, 1975).

Tbl **Bullion Canyon Volcanics (Miocene and Oligocene)**

Three Creeks Tuff Member (Oligocene)—Exposed on eastern flank of Mah Wah Mountains and in Shaunte Hills. Mapped with Needle Range Group in Shaunte Hills. See description under eastern facies

Lava flows and associated volcaniclastic rocks (Oligocene)—Thick lava flows of presumed Oligocene age are scattered through northwestern part of quadrangle. Most are too poorly exposed for their stratigraphic positions to be ascertained, but one flow in southern Needle Range is interlayered between Cottonwood Wash Tuff and Mah Wah Springs Formation of Needles Range Group. Most of the lava flows are dark-gray, dense, dacite flows grey to reddish-brown. Fine-grained rocks containing sparse small phenocrysts of plagioclase, pyroxene, and olivine(?). Only largest areas are shown.

Tc **Three Creeks Tuff Member of the Bullion Canyon Volcanics and the Needles Range Group, undivided (Oligocene)**—Shown only in Shaunte Hills.

Needles Range Group, undivided (Oligocene)—Moderately welded, crystal-rich ash-flow tuff units in the Needles Range Group that were not mapped separately in places in the central Mah Wah Mountains, Shaunte Hills, Black Mountains, and southern Mount Marysvale. Rocks belonging to the Mah Wah Springs and Lund Formations were recognized in the Needles Range, but the Needles Range Formation, but distribution of these units in other areas is not known.

Tq **Lund Formation of the Needles Range Group (Oligocene)**—Slightly to densely welded ash-flow tuff. Most rocks are crystal-poor (10–30 percent) of plagioclase, quartz, hornblende, biotite, minor Fe-Ti oxides, and trace amounts of sanidine and pyroxene. Some secondary sphene is characteristic. Quartz makes up as much as 15 percent of rock and, in contrast to other units in Needles Range Group, sanidine is absent. Lund is widely distributed throughout Needles Range. Mah Wah Mountains and southern Needle Range and is particularly thick (900 m or more) where Cottonwood Wash is exposed and northeast side of the Indian Peak caldera. Had its source in White Rock caldera. Age of Lund Formation is about 28 Ma (Lipman and others, 1978).

Tmz **Mah Wah Springs Formation (Oligocene)**—Tuffaceous sedimentary rocks, a sequence of crystal-poor and locally zeolitic-rich rhyolite to quartz latite ash-flow tuff units, and minor air-fall tuff and tuffaceous sedimentary rocks, and minor interlayered volcanic sandstone and debris-flow deposits. Rhyolitic rocks contain phenocrysts of quartz, sanidine, and biotite 1–2 percent of the tuffs. Crystal-rich to central part of Needle Range within area of Indian Peak caldera.

Tmw **Wah Wah Springs Formation of the northern Needle Range Group (Oligocene)**—These two formations of Needles Range Group are shown together in northwestern part of quadrangle. Wah Wah Springs Formation consists of outflow member that spread widely over paleotopography of Needles Range and of local intracaldera tuffs that appear to organize from Indian Peak caldera in Needles Range. Outflow member rocks near source area consist mostly of a multiple ash-flow simple cooling-unit of densely welded tuff that has a dark-gray, massive member changes to irregularly welded compound cooling unit, and near distal ends into compound cooling unit of moderately welded tuff. Outflow member is crystal-poor (10–20 percent) of plagioclase, quartz, biotite, and hornblende and biotite, minor sanidine, and trace amounts of pyroxene. Intracaldera tuffs are more crystal-rich than outflow member. Intracaldera tuffs are more crystal-rich than outflow member. Intracaldera tuffs are more crystal-rich than outflow member