113°22'55"
38°30'
113°00'
38°30'

SCALE 1:50,000

1 0.5 0 1 2 3 4 MILES

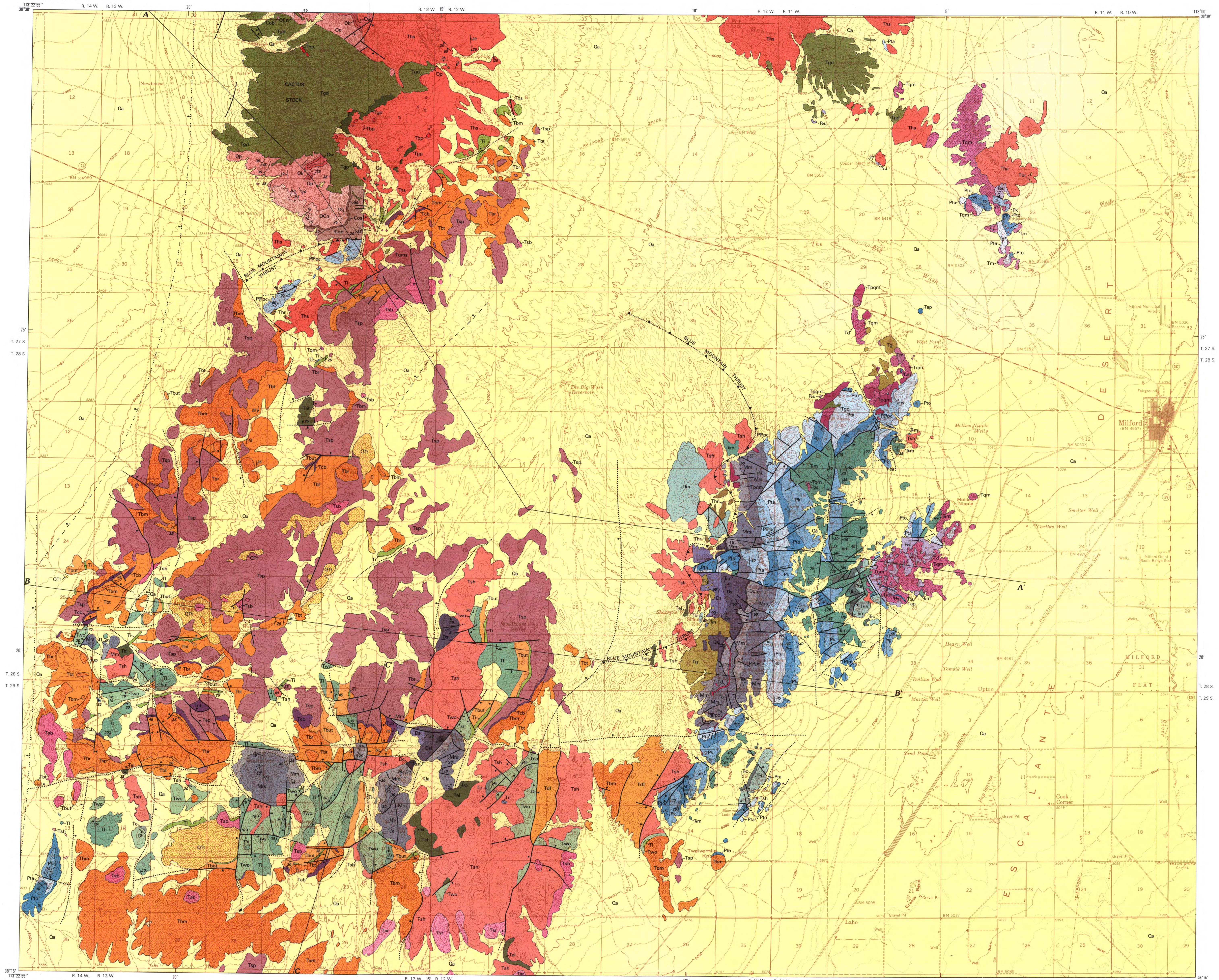
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

1 0.5 0 1 2 3 4 5 KILOMETERS

Utah Geological Survey Open-File Report 674DM

Geologic map of the Milford quadrangle and east half of the Frisco quadrangle,
Beaver County, Utah (GIS reproduction of USGS Map I-1904 [1989])
M.G. Best, D.M. Lemmon, and H.T. Morris

38°15'
113°22'55"
113°00'
38°15'



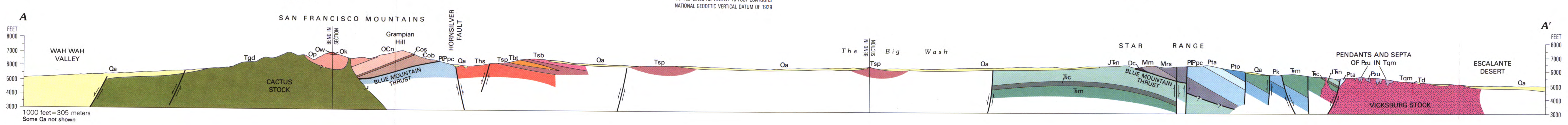
Base from U.S. Geological Survey, 1:62,500
Milford, 1958; Frisco, 1959

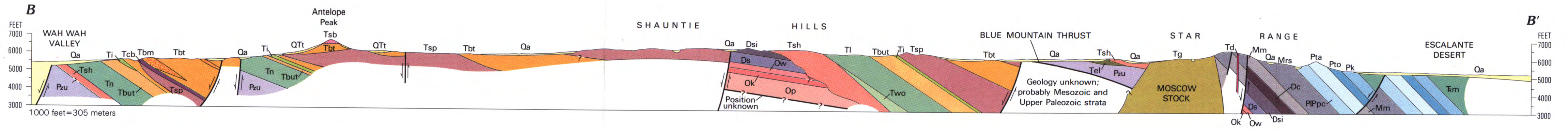
APPROXIMATE MEAN DECLINATION, 1989

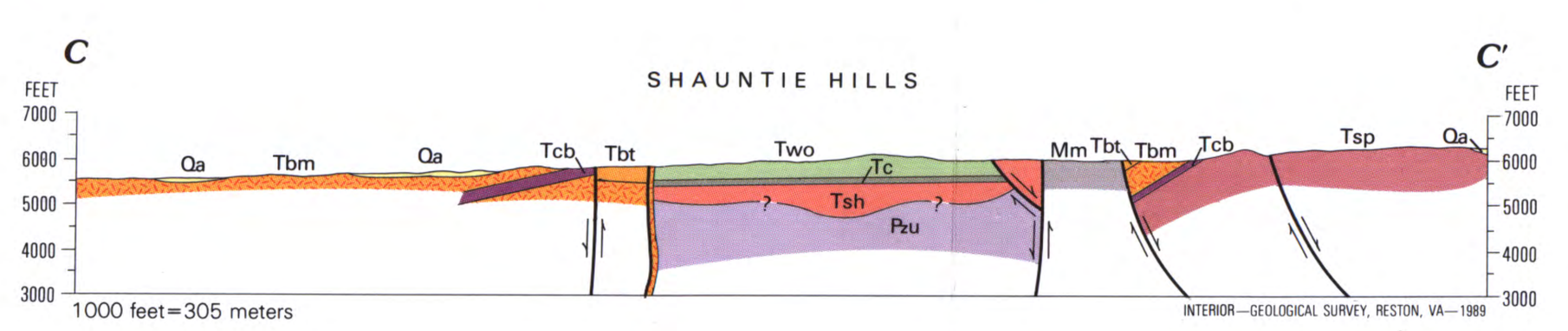
SCALE 1:50 000

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Mapping of eruptive rocks by M. G. Best, 1984–85, in part adapted from D. M. Lemmon; mapping of sedimentary and intrusive rocks by D. M. Lemmon, 1958–72, partly updated and revised by H. T. Morris, 1978–85





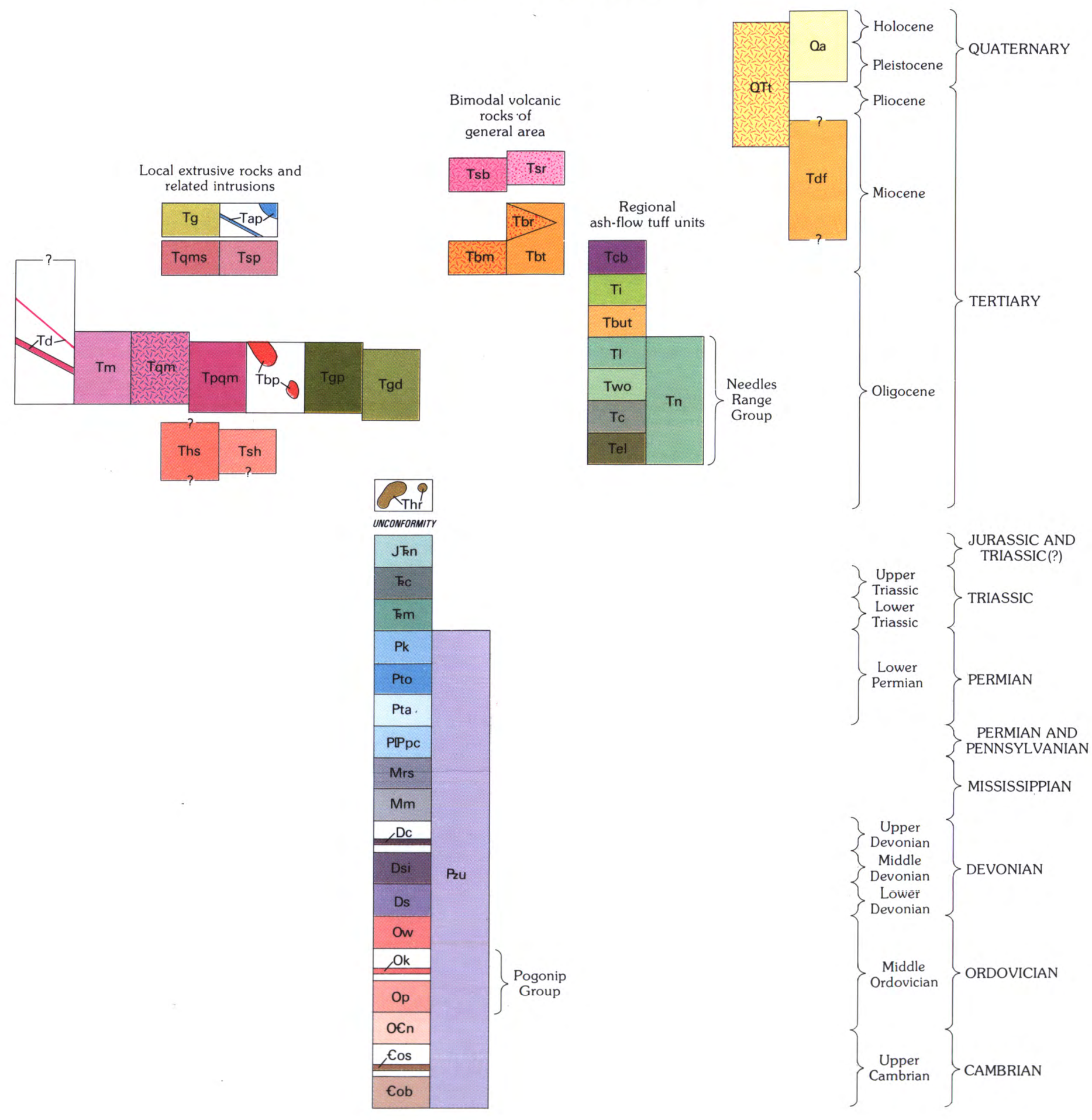


INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1989

GEOLOGIC MAP OF THE MILFORD QUADRANGLE AND EAST HALF OF THE FRISCO QUADRANGLE, BEAVER COUNTY, UTAH

By
M. G. Best, D. M. Lemmon, and H. T. Morris
1989

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qa **Alluvium and other surficial deposits (Holocene and Pleistocene)**—Unconsolidated talus, stream, and floodplain deposits in mountains, and Lake Bonneville deposits and semi-consolidated pediment gravel, fanglomerate, and other basin-fill deposits in valleys. Total thickness locally may exceed 1,000 m

QTt **Talus of basalt lava flow member of Steamboat Mountain Formation (Holocene to Miocene?)**—Talus accumulations and erosional bouldery remnants of basalt flow member (Tsb) that cover less resistant older units, particularly tuff member of the Blawn Formation (Tbt) and quartz latite of Squaw Peak (Tsp). Occurs in southwest quarter of map area where talus may be as much as 10 m thick

Tdf **Volcanic debris-flow deposits (Miocene?)**—Angular to somewhat rounded, boulder- to cobble-size clasts of intermediate-composition flow rock together with fragments of rhyolite lava flow member of Blawn Formation (Tbr), Isom Formation (Ti), and Bauers Tuff Member of Condor Canyon Formation (Tcb) that form loose rubble on hill slopes. No matrix is exposed. Probably volcanic debris-flow deposits and (or) fluvial deposits. Exposed in south-central part of map area where deposits may be as much as 100 m thick

Steamboat Mountain Formation (Miocene)—Younger of two Miocene bimodal associations of basaltic rock and rhyolite that are widespread in areas southwest of map area; has an isotopic age range of 13 to 12 Ma (Best and others, 1987)

Tsr **Rhyolite lava flow member**—Small dikes, shallow plugs, and volcanic domes composed of white to pink, flow-layered, locally vesicular, porphyritic rhyolite. Phenocrysts consist of sparse to abundant quartz, sanidine, sodic plagioclase, and minor biotite and opaque minerals. Sanidine from a rhyolite body about 1 km south of border of map area in adjacent Thermo quadrangle has a K-Ar age of 11.6±0.5 Ma (Rowley and others, 1978). This rhyolite is referred to as rhyolite of Dead Horse Reservoir (Rowley, 1978)

Tsb **Basalt lava flow member**—Black to medium-gray, commonly vesicular, unaltered lava flows. Two petrographic-chemical types occur but on the map are not shown separately as they were on Pine Grove-Blawn Mountain map (Abbott and others, 1983) to the west. A porphyritic type contains phenocrysts of slender plagioclase and augite, commonly clotted together, and lesser olivine, commonly replaced by "iddingsite," in a microcrystalline matrix. SiO_2 is about 53 weight percent and Na_2O and K_2O are both about 3 weight percent. K-Ar whole-rock ages are 13.3±0.3 and 12.9±0.5 Ma (Best and others, 1987). An aphyric type commonly with stretched vesicles has about 56 weight percent SiO_2 and 3.5 weight percent K_2O and a whole-rock K-Ar age of 12.3±0.5 Ma (Best and others, 1987). A local variant of aphyric type has less than 5 percent minute olivine phenocrysts. Exact thickness of unit difficult to ascertain because of extensive talus (unit QTt), but may be as much as 100 m

Blawn Formation (Miocene)—Older of two Miocene bimodal associations of mafic rock and rhyolite that occur in map area and in areas to southwest; isotopic ages range from 23 to 18 Ma (Best and others, 1987)

Tbr **Rhyolite member**—Small shallow intrusions and lava flow remnants of red, pink, and gray to lavender, flow-layered, sparsely to coarsely porphyritic rhyolite. Locally is a vitrophyre and autobreccia. Where weakly altered, as 2–4 km south of Antelope Peak in southwest quarter of map area, member breaks down to small chips that cover rolling hills. Phenocrysts include combinations of quartz, sanidine, sodic plagioclase, and biotite that range in size from less than 1 mm, where they altogether comprise only a few percent of total rock, to almost 1 cm, where they may comprise 20–30 percent of rock. Not petrographically distinguishable from rhyolite lava flow member of Steamboat Mountain Formation (Tsr), but rhyolite outcrops in north and central part of map area are designated as Tbr because they lie on strike with a well-defined southwest-trending band of extensively dated rhyolite in mountain ranges to the west whose ages lie between 23 and 18 Ma (Best and others, 1987). The only dated Tbr rhyolite body in map area lies just south of highway in northwest corner of Milford quadrangle and has a fission track age on zircon of 18.9±1.0 Ma (Best and others, 1987). However, an age of 22.5±5.7 Ma on alunite (Best and others, 1987) in an area of hydrothermally altered silicic rocks near White Mountain supports the Blawn correlation of these and other nearby rhyolite bodies. Includes small local or altered accumulations of associated tuff member (Tbt)

Tbt **Tuff member**—A heterogeneous sequence of ash-flow tuff, minor thin-bedded air-fall and surge tuff, and some fluvial deposits that is associated with eruption of, and is compositionally similar to, rhyolite lava flow member (Tbr) and quartz latite of Squaw Peak (Tsp). Ash-flow tuffs are white, gray, and pink, contain light-colored pumice lapilli, dark-colored volcanic lithic fragments (chiefly of units Tbr and Tsp), and generally less than 20 percent phenocrysts of sanidine, quartz, sodic plagioclase, and biotite. Where unaltered, tuffs are generally weakly consolidated and underlie slopes, although locally west of Antelope Peak they are densely welded. Also west of Antelope Peak and in a hydrothermally altered zone extending westward from White Mountain this unit has beds as much as 100 m thick of well-sorted, evenly and thinly bedded sandstone. A very poorly exposed, tan, weakly bedded, volcanic conglomerate 3–5 km southwest of Squaw Peak contains abundant clasts, chiefly of quartz latite of Squaw Peak (Tsp), as much as 20 cm in diameter in a sandy matrix. It may be as much as 300 m thick. In places, tuff member of Blawn Formation may include unrecognized tuffs associated with eruption of rhyolite lava flow member of Steamboat Mountain Formation (Tsr). Tuff and sandstone sequence west of Antelope Peak may be as much as 650 m thick

Tbm **Mafic lava flow member**—Porphyritic to aphyric, gray to black, latite and trachyandesite lava flows and, south to southeast of Mertons Spring, dikes that weather red-brown, commonly with liesegang bands. Phenocrysts make up as much as one-quarter of the rock, are generally less than 2–3 mm long, and include plagioclase and augite with or without hypersthene and olivine (commonly replaced by orange "iddingsite") in a microcrystalline felsic matrix. Relatively high K_2O content of these flows (3–5 weight percent in several analyses from mountain ranges to the southwest and west) is manifested by local biotite phenocrysts. From Squaw Peak southwest to Antelope Springs, lava flows are commonly vesicular and glassy, locally scoriaceous, and some contain unusually larger plagioclase phenocrysts. Near Frisco and around White Mountain, flows are aphyric or contain only sparse minute pyroxene phenocrysts. K-Ar ages on samples of this unit and on stratigraphically constraining associated units in mountain ranges to the west are about 23 Ma. Member is apparently several hundred meters thick in places

Tg **Granite (Miocene)**—Mostly pinkish-gray to white, fine- to medium-grained intrusive bodies containing 45–60 percent K-feldspar, 20–40 percent quartz, 15–25 percent oligoclase, and 5 percent, or less biotite or hornblende, or both. In general the granite plutons near Moscow mine contain considerably more quartz but about the same amount of plagioclase as those in northern part of Star Range, and locally contain some greenish-white muscovite and scattered grains of fluorite. The lack of aeromagnetic expression of even the large pluton near Moscow and Hub mines further indicates the relative absence of magnetite and iron-bearing ferromagnesian minerals. All other intrusive bodies in map area show some aeromagnetic expression. Two fission-track ages on zircon from this leucocratic pluton, one by C.W. Naeser of the U.S. Geological Survey and the other by B.J. Kowallis and M.G. Best of Brigham Young University gave 21.6±2.3 and 21.1±2.1 Ma, respectively, indicating that the intrusive magma was associated with emplacement of Blawn Formation

Tap **Aplite (Miocene?)**—Small dikes and plugs of light-gray, saccharoidal granitic rock composed predominantly of quartz and orthoclase, and rare biotite. Exposure in north-central part of sec. 33, T. 27 S., R. 11 W. contains much epidote, inclusions of porphyritic flow rock, and miarolitic cavities containing adularia and purple fluorite crystals. Age assignment is based on compositional kinship to granite (Tg)

Tqms **Quartz monzonite porphyry of Squaw Gulch (Miocene?)**—Medium- to light-gray, medium-grained, quartz monzonite porphyry containing phenocrysts of quartz, K-feldspar, andesine, hornblende, and biotite, and many small cognate inclusions. Most exposures are weakly argillically altered in northwest section of map area

Tsp **Quartz latite of Squaw Peak (Miocene)**—Coarsely porphyritic, locally subtly flow-layered lava flows containing autobrecciated margins. Characterized by ledge-and-slope topography. Color is generally red-brown, but also gray, tan, purple, pink, and where a vitrophyre, black or pale green. Phenocrysts make up one-third of rock and include plagioclase, sanidine, and lesser biotite with or without hornblende, augite, orthopyroxene, and quartz in a microcrystalline or glassy matrix. Typically, somewhat anhedral feldspar phenocrysts are visibly zoned in hand sample and are as much as 1.5 cm long; other phenocrysts are less than 2 mm. Some widely scattered outcrops contain rare 1-cm-long hornblende phenocrysts. Large feldspar and sparse mafic phenocrysts distinguish unit from mafic lava flow member of Blawn Formation (Tbm), Horn Silver Andesite (Ths), and andesite of Shauntie Hills (Tsh). According to Lemmon and others (1973), biotite form a sample collected in south-central part of sec. 19, T. 27 S., R. 12 W. has a K-Ar age of 23.0±1.0 Ma (age corrected for new decay constants; Dalrymple, 1979). Thickness may approach 1,000 m near Antelope Peak. Unit locally includes small poorly exposed accumulations of tuff member of Blawn Formation (Tbt)

Tcb **Bauers Tuff Member of Condor Canyon Formation (Miocene)**—Youngest of several regionally extensive ash-flow sheets of Quichapa Group exposed over thousands of square kilometers in southwestern Utah and adjacent Nevada. Source possibly in Caliente cauldron complex, Nevada (Ekren and others, 1977), or in other calderas near Utah-Nevada border. Map area is near distal northeast margin of Bauers eruptive sheet (Williams, 1967), and so unit is discontinuous and generally only a few meters thick; locally, however, such as west of Antelope Peak, it is as much as 18 m thick. Unit is everywhere densely welded, forms resistant ridges, and has distinctive petrography, even where altered, so unit serves as a valuable stratigraphic marker. Gray, tan, pink, or lilac where fresh but orange to red where altered. Phenocrysts are generally less than 2 mm in longest dimension, make up less than 10 percent of rock, and include plagioclase, sanidine, and biotite. Average K-Ar age is 22.3 Ma (Best and others, 1987). West of Long Lick Mountain and northeast of White Mountain, unit includes several meters of older Swett Tuff Member of Condor Canyon Formation. Swett is virtually identical to Bauers in all respects except that it lacks sanidine phenocrysts. South of Mertons Spring, map unit consists only of Swett. Average (corrected) age is 23.7 Ma (Armstrong, 1970)

Ti **Isom Formation (Oligocene)**—Red to brown, densely welded, ash-flow tuff, locally containing a black basal vitrophyre. Vuggy flattened and stretched pumice lapilli are common. Contains less than 10 percent phenocrysts of plagioclase and pyroxene. Average K-Ar age is 26.0 Ma (Best and others, 1987). Eruptive source is probably concealed in Escalante Desert about 50 km to south. In area immediately south and east of Frisco cemetery, a tuff crops out that superficially resembles Isom yet contains as much sanidine as plagioclase. This sanidine-bearing tuff may be a locally derived deposit or may possibly be a distant remnant of the Shingle Pass Tuff of Cook (1965) derived from a source west of Pioche, Nevada. Lemmon and others (1973) reported a K-Ar age (corrected) on sanidine of 22.5±1.0 Ma on "tuff from the Frisco cemetery area." This age is compatible with Bauers Tuff Member of Condor Canyon Formation that is also exposed near the cemetery. Thickness generally only a few meters; locally absent

Tbut **Three Creeks Tuff Member of Bullion Canyon Volcanics (Oligocene)**—Densely to moderately welded, gray to pale-lavender lapilli tuff. About 40 percent of tuff consists of euhedral plagioclase tablets as much as 4 mm long and lesser biotite and hornblende. Lapilli of white pumice locally are evident and fragments of dark reddish-brown volcanic rock as much as 6 cm in diameter constitute as much as 10 percent of rock. Source is Three Creeks caldera in southern Pavant Range about 90 km to east (Steven, 1981). South and east of Mertons Spring several meters of thinly bedded, white, tuffaceous sandstone lies at top of unit. Maximum thickness about 200 m

NEEDLES RANGE GROUP (OLIGOCENE)

[Widely distributed, chiefly reddish-brown, crystal-rich dacitic ash-flow tuff and local minor rhyolite ash-flow tuff. West of Milford and Frisco quadrangles, local rhyolite and andesite lava flows and volcanic sandstone and conglomerate also occur in some of the formations of the group. Many carefully selected samples have been isotopically dated within the range of 32.3±1.1 to 27.9 Ma. Undivided Needles Range Group (Tn) shown on cross section only. In map area the group consists of Lund, Wah Wah Springs, Cottonwood Wash, and Escalante Desert Formations.]

Tl **Lund Formation**—Densely welded, orange, reddish-brown or dark-gray ash-flow tuff containing about 40 percent phenocrysts generally less than 2 mm across; in descending order of abundance they include plagioclase, biotite, quartz, and hornblende. Age is 27.9 Ma and source is White Rock caldera (fig. 1) that straddles Utah-Nevada boundary southwest of map area (Best and Grant, 1987). Complete sections may be as much as 300 m thick

Two **Outflow tuff member of the Wah Wah Springs Formation**—Grades upward from a 2 m thick, speckled-gray, densely welded vitrophyre locally developed at base of deposit, into a reddish-brown, densely welded lapilli tuff containing conspicuous white pumice lapilli, and then to a loosely welded, pink lapilli tuff at top of unit. Phenocrysts of plagioclase, hornblende, biotite, and a trace of augite and quartz make up about 40 percent of tuff. Age is 29.5 Ma and source is Indian Peak caldera (fig. 1) that straddles Utah-Nevada boundary to west (Best and Grant, 1987). As much as 250 m thick

Tc **Cottonwood Wash Tuff**—Reddish-brown, densely welded lapilli tuff containing abundant plagioclase, biotite, and lesser quartz phenocrysts that are as much as 6 mm in diameter. Age is 30.6 Ma (Best and Grant, 1987). Thickness no more than 10 m

Tel **Lamerdorf Tuff Member of Escalante Desert Formation**—Light-gray to lilac, moderately welded ash-flow tuff containing less than 15 percent phenocrysts of plagioclase and lesser biotite and sparse dark-colored volcanic lithic clasts a few cm in diameter. Near Long Lick Mountain and southwest of Antelope Peak, unit includes some altered tuff layers that appear to have more abundant plagioclase as well as hornblende, and in Shauntie Wash in western Star Range contains some heterogeneous lapilli tuff beds. Unit partially filled local paleovalleys and is as much as a few hundred meters thick

Td **Dikes (Miocene? to Oligocene)**—Narrow dikes and small plugs of brownish-gray to white, fine-grained rock containing rare phenocrysts of quartz and biotite. Dikes cut both sedimentary strata and intrusive bodies, mostly in Star Range. Rock mostly a fine-grained intergrowth of K-feldspar and quartz. Unit also includes a few narrow dikes of dark-gray to dark-brownish-gray andesite and lamprophyre that cut quartz monzonite and other intrusive bodies

Tm **Monzonite (Oligocene?)**—Light-pinkish- to tannish-gray, fine- to medium-grained, moderately porphyritic intrusive bodies containing about 45 percent andesine, 40 percent pink K-feldspar, 5 percent quartz, and 10 percent biotite, augite, and hornblende, with accessory sphene, apatite, and magnetite. Quartz phenocrysts range from 3 to 8 percent in various specimens. For age assignment see unit descriptions for quartz monzonite (Tqm) below. Exposed in northern Star Range and southern Rocky range

Tqm **Quartz monzonite (Oligocene?)**—Gray to pinkish-gray, medium-grained intrusive bodies with hypidiomorphic-granular texture. Rock consists of about 35 percent each K-feldspar and andesine, 10–15 percent quartz, 4 percent each of biotite and augite, 2 percent each of hornblende and hypersthene, and a total of about 3 percent of accesory minerals including apatite, zircon, sphene, rutile, and magnetite. Parts of some plutons are argillized and pyritized, and near contact zones with carbonate rocks also are mineralized with copper sulfides and magnetite. Lemmon and others (1973, p. 23) reported that biotite from pluton near Montreal mine in Rocky Range has a K-Ar age (corrected) of 21.3±0.6 Ma, and hornblende from the same specimen has a K-Ar age (corrected) of 27.7±0.8 Ma. On another sample from dump of Montreal mine, H.H. Mehnert obtained ages of 30.0±1.0 Ma on K-feldspar and 23.8±0.9 Ma on biotite. These discordant ages, and other discordant ages on similar monzonitic and granodioritic rocks that contain greater than 5 percent biotite and hornblende with or without pyroxene (units Tm, Tpqm, Tgd), are interpreted to be Oligocene (about 30 Ma) ages locally and variably reset by an early Miocene thermal event associated with emplacement of the Blawn Formation and deep-seated plutons of similar age and composition

Tpqm **Porphyritic quartz monzonite (Oligocene?)**—Medium-gray to pinkish-gray, coarse-grained, moderately porphyritic plutons containing about 35–40 percent andesine, 30–35 percent K-feldspar, 15 percent quartz, 8 percent biotite, 5 percent hornblende, and 2 percent or less magnetite, zircon, sphene, and apatite. In general, the porphyritic quartz monzonite plutons appear to be cut by the finer, more even-grained quartz monzonite intrusive bodies. Lemon and others (1973, p. 23) reported that biotite from the intrusive body near Copper King shaft in northern part of Star Range has a (corrected) K-Ar age of 21.4±0.6 Ma. In a sample from exposures a short distance west of Wild Bill mine in northern Star Range, K-Ar ages on biotite of 24.6±0.9 Ma and on K-feldspar of 27.6±1.0 Ma have been obtained by H.H. Mehnert; these rocks are interpreted to be Oligocene but having isotopic ages that are apparently younger due to early Miocene heating related to emplacement of deep plutons associated with Blawn Formation

Tbp **Breccia pipes (Oligocene)**—Pipelike bodies of breccia consisting of angular to rounded clasts of adjacent country rock embedded in a matrix of rock fragments and powder. Pipes near Frisco commonly are alunitized and silicified, and pipes near Cactus mine (farther to northwest) commonly are mineralized with copper and iron sulfides and other minerals. Only larger breccia pipes are shown

Tgp **Granodiorite porphyry plugs and dikes (Oligocene)**—Small plutons of greenish- to pinkish-gray granodiorite porphyry in or near contact zone between Cactus stock (Tgd) and Horn Silver Andesite of Stringham (1967) near Frisco. Except for their distinctly porphyritic texture, these plutons are mineralogically similar to granodiorite of Cactus stock, but they are younger bodies because some of them distinctly crosscut parts of that stock

Tgd **Grandiorite (Oligocene)**—Pinkish- or lavender-grey, medium-grained granitic rock, mostly granodiorite but ranging from quartz monzonite to quartz diorite, containing phenocrysts, as much as 5 mm in length, of perthitic K-feldspar, oligoclase-andesine, quartz, hornblende, biotite, and locally, diopsidic augite. Principal exposure is in Cactus stock, a pluton about 2 km in diameter with several apophyses and a few dikes in southern part of San Francisco Mountains. Another large pluton is in southern Beaver Lake Mountains. Under the microscope rock has a distinctive hypidiomorphic-granular texture, and contains accessory apatite, zircon, sphene, rutile, and relatively abundant magnetite in addition to the above-listed major constituents. Biotite from Cactus stock, according to Lemmon and others (1973, p. 24), has a (corrected) K-Ar age of 28.7±0.7 Ma. H.H. Mehnert has obtained K-Ar ages of 31.8±1.1 Ma on K-feldspar and 31.2±1.1 Ma on biotite from a sample collected on dump of lower haulage tunnel of Cactus mine

Ths **Horn Silver Andesite of Stringham (1967) (Oligocene)**—Heterogeneous, medium-gray to reddish-, purplish-, or greenish-gray, medium-grained porphyritic lava flows ranging in composition from andesite to dacite and quartz latite; most of formation consists of medium- to thick-bedded lava flows that have autoclastic margins. Phenocrysts make up about one-third of rock and include plagioclase, hornblende, and lesser biotite and augite in a glassy to very fine grained matrix. In area north of Horn Silver mine, some of these rocks have been propylitized, argillized, and silicified (Stringham, 1967). Thickness is reported by East (1966) to be 572 m, but unit is known to exceed 700 m in some exploration drill holes. Age is uncertain; according to Lemmon and others, (1973), minerals from a sample of porphyritic pyroxene-hornblende-biotite "andesite" vitrophyre, presumed to be Horn Silver Andesite from southwestern corner of Beaver Lake Mountain quadrangle, about 3.2 km north-northeast of Horn Silver mine, yielded (corrected) K-Ar ages of 31.6±1.0 Ma (plagioclase) and 35.0±1.0 Ma (hornblende)

Tsh **Andesite of Shauntie Hills (Oligocene)**—Heterogeneous gray, black, red, purple, and brown lava flows that are rarely vesicular and generally contain less than 20 percent phenocrysts of plagioclase, augite, and lesser orthopyroxene in a fine-grained matrix of the same minerals plus magnetite and locally glass. Appears correlative with andesite flow member of Escalante Desert Formation (Best and Grant, 1987) which is widely exposed in ranges to west, where it has a stratigraphically constrained age of 34–31 Ma. In map area some flows near top of unit additionally contain sparse phenocrysts of hornblende and (or) biotite. Near top of unit east and west of Long Lick Mountain, latitic lava flows contain more than 20 percent phenocrysts of feldspar and biotite and sparse pyroxene. Also east of Long Lick Mountain unit contains local andesitic debris flows and a layer of thin-bedded green sandstone similar to Beers Spring Member of Escalante Desert Formation (Best and Grant, 1987). Typically, andesites of Escalante Desert Formation contain about 58 percent SiO_2. Thickness of andesite of Shauntie Hills locally exceeds 600 m

Thr **Conglomerate of High Rock Pass area (Oligocene)**—Heterogeneous conglomerate containing pebbles, cobbles, and boulders of limestone, quartzite, and other sedimentary rocks in a red-weathering, fine-grained matrix of sandy siltstone or shale. Unit represents soil and rubble zone that overlay the sedimentary rocks at time of first volcanic eruptions in general area, and it compositionally reflects the varied lithologic characteristics of local source rocks. Named from exposures near High Rock Pass in adjacent Beaver Lake Mountains quadrangle to north where it is locally more than 100 m thick; however, thickness in map area is probably less than 10 m

UNCONFORMITY

JTRn **Navajo Sandstone (Jurassic and Triassic?)**—Light-gray, buff, and white, medium- to fine-grained, thick-bedded to massive, friable sandstone containing some pink to red layers and zones. Distinguished by large curving crossbeds of eolian origin. Locally parts of formation are silicified, forming a dense quartzite that may be confused with Early Cambrian Prospect Mountain quartzite, which is not crossbedded, or with Early Permian Talisman Quartzite, which is crossbedded but which is coarser grained and tends to weather a much darker hue. Maximum thickness in Milford quadrangle is about 300 m but top is eroded; in adjacent areas complete sections are as much as 700 m thick

TRc **Chinle Formation (Upper Triassic)**—Upper part, which is 15–130 m thick and may be equivalent to Petrified Forest Member, is mostly red to brownish-red, thin- to medium-bedded siltstone and shale containing discontinuous beds of red, orange, and buff-colored sandstone and thin layers of red-weathering, chert-pebble conglomerate. Lower part, which is 15–75 m thick and probably equivalent to Shinarump Member, is chiefly pebble conglomerate containing well-rounded clasts of chert and minor quartzite in a sparse, generally silicified matrix of sandstone, siltstone, or shale. Fragments of silicified wood are common in some areas. Sections range from 25–200 m thick

TRm **Moenkopi Formation (Early Triassic)**—Consists of four members that are not differentiated on map: (1) upper red member; (2) Virgin Limestone Member; (3) lower red member; and (4) Timpoweap Member. Upper red member is approximately 400 m thick and consists predominantly of grayish-green and brownish-red, fine-grained, platy, ripple-marked sandstone. Interlayered with sandstone are some thin and massive beds of limestone and a few beds of coarse-grained sandstone. Upper red member is probably equivalent to combined middle red member, Shnabkaib Member, and upper red member of Moenkopi Formation in southernmost Utah and northern Arizona (Stewart and others, 1972), but these members as yet have not been differentiated in Milford area. Virgin Limestone Member is about 30 m thick and is composed of light-gray, medium- to thick-bedded, cherty limestone. Most of chert occurs as medium-sized, dark-brown nodules, and locally limestone is streaked with thin layers of sand grains. In some areas, limestone beds are separated by thin beds of brownish- to greenish-gray siltstone. Lower red member is about 100 m thick and consists of brownish- to grayish-red siltstone and interbeds of ripple-marked, brownish-red shale and sandstone. Timpoweap Member, about 200 m thick, consists of basal chert-pebble conglomerate 1–15 m thick and an overlying heterogeneous unit composed of interlayered dark-gray limestone, red, green, and gray siltstone and shale, yellowish sandstone, and thin lenses of gypsum. Cephalopod *Meekoceras*, a fossil characteristic of Timpoweap Member in type area, occurs about 70 m above base

Pk **Kaibab Limestone (Lower Permian)**—Mostly medium- to dark-gray, medium-bedded, moderately cherty limestone. Upper half or so, which may be equivalent to Plympton Formation of Welsh (1973), also contains some interlayered thin-bedded, dark-gray dolomite and discontinuous thin lenses of phosphatic mudstone, sandstone, quartzite, minor gypsum, and massive chert or jasperoid. Complete sections range in thickness from 100–300 m

Pto **Toroweap Limestone (Lower Permian)**—Medium- to dark-blue gray, medium-bedded, cherty limestone and subordinate dolomite. Upper part contains much silty and sandy limestone, some limy sandstone, and at least one bed of gypsum that is typically leached away at surface. In middle part limestone beds are light gray and commonly phosphatic. In lower part of formation beds are silty, dolomitic, and commonly cherty. Outcrops in Star Range are probably northernmost recognized exposures of Toroweap Limestone. Thickness 115–125 m

Pta **Talisman Quartzite (Lower Permian)**—Massive, crossbedded, gray to pink orthoquartzite that locally weathers dark reddish brown. Commonly highly fractured and develops thick accumulations of talus. Locally contains lenses and beds of limestone and gypsum at base and near middle. Thickness 70–225 m; the considerable variation is probably due to elimination of parts of formation on bedding-plane faults

PPpc **Pakoon(?) Dolomite of Welsh (1973) (Permian) and Callville Limestone (Permian and Pennsylvanian)**—Cyclically bedded limestone, dolomite, and sandstone or orthoquartzite; locally mostly cherty dolomite in upper part. Limestone units are medium to light gray and streaked with silt and sand; dolomite units are darker gray, commonly cherty, and somewhat thinner bedded; arenaceous beds are gray to light brown, fine grained, and commonly crossbedded. Permian fossils have been reported from the cherty dolomite beds in upper part of formation and these beds have been identified as Pakoon Dolomite (Welsh, 1973), but because of hydrothermal alteration and metasomatism, Pakoon is not readily distinguishable from Callville. Relatively complete sections of the two formations are 150–450 m thick

Mrs **Formation of Rose Spring Canyon (Mississippian)**—Largely medium- and dark-gray, thin- to thick-bedded, locally sand-streaked, cherty, fossiliferous limestone and subordinate dolomite. Gray, medium-grained sandstone beds are common in middle of unit. Unit probably equivalent to Deseret, Humbug, and Great Blue Formations of East Tintic Mountains, Utah (Morris and Lovering, 1961). Thickness about 140–360 m

Mm **Monte Cristo Limestone (Mississippian)**—Upper one-third is dark-gray, thin- to thick-bedded cherty limestone. Lower two-thirds is medium- to dark-gray, thick-bedded, medium-grained dolomite and subordinate limestone. Both units locally are bleached and recrystallized. Probably equivalent to Fitchville and Gardison Formations of East Tintic Mountains, Utah (Morris and Lovering, 1961), and Dawn (base), Anchor, and Bullion (top) Members of Monte Cristo Limestone of Goodsprings quadrangle, Nevada (Hewett, 1931). Thickness in Star Range is about 150–200 m

Dc **Crystal Pass Member of Sultan Limestone (Upper Devonian)**—Chiefly medium-gray, thin- to medium-bedded, argillaceous limestone; somewhat darker hued in upper half. Base is locally marked by discontinuous lenses of coarse-grained, buff-colored quartzite probably equivalent to Cove Fort Quartzite of Crosby (1959). Upper half or so also has yielded fossils characteristic of *Cyrtospirifer* sp.-*Paurorhyncha endlichi* faunas of Pinyon Peak Limestone of East Tintic Mountains and thus may be slightly younger than Crystal Pass Limestone Member in its type area in Spring Mountains, Nev. Thickness in Star Range is about 75–125 m

Dsi **Simonson Dolomite (Middle Devonian)**—In areas where it is not pyrometasomatized, mostly medium to dark-brownish-gray, medium bedded, sugary-textured, fetid dolomite containing a few thin beds and at least one thick bed of gray to brown quartzitic sandstone. Baer (1962, p. 32) assigned all or part to the Guilmette Formation, but the brownish color, striped appearance, and abundance of dark-colored dolomite beds containing *Amphipora* serve to identify formation as Simonson and indicate a significant unconformity at top of formation. In exposures near Shauntie site and Moscow and Mowitza mines, large parts of the formation have been bleached and recrystallized to dolomite marble. Total thickness is 120–300 m

Ds **Sevy Dolomite (Lower Devonian)**—In areas where it is not pyrometasomatized, chiefly medium- to light-gray, medium-to thick-bedded, dense to faintly laminated dolomite. Basal part, which is exposed about 1 km west of Hoosier Boy mine, locally contains thick beds of coarse-grained quartzite. In exposures near Shauntie site, virtually entire formation is converted to white marble. Total thickness is uncertain but probably 150–175 m

Ow **Watson Ranch Quartzite (Middle Ordovician)**—Remnant patches of massive, medium-grained white, buff, and light-gray quartzite in southern San Francisco Mountains; may, however, also include some marbleized Crystal Peak Dolomite. Exposures near Loeber Gulch are bleached to brilliant white. About 95 m thick

Ok **Kanosh Shale (Middle Ordovician)**—Dark-brownish-green shale containing rare, thin lenses of gray sandstone and brown, platy limestone. Shale beds commonly contain graptolites. Exposures near Loeber Gulch are all dark-brown hornfels. Complete sections are 30–150 m thick

Op **Pogonip Group, undivided (Middle and Lower Ordovician)**—In the southern San Francisco Mountains, strongly bleached and recrystallized thin-bedded strata lying between Kanosh Shale and Notch Peak Formation are believed to represent the Lower Ordovician House, Fillmore, and Wah Wah Limestones and the Middle Ordovician Juab Limestone. Regionally these are mostly thin- to medium-bedded, gray to blue, silty and argillaceous limestones containing local beds of limy flat-pebble conglomerate. Complete and unaltered sections of these formations in adjacent areas are 650–750 m thick

O€n **Notch Peak Formation (Lower Ordovician and Upper Cambrian)**—Gray to white, massive to thick-bedded, locally cherty marble and recrystallized dolomite underlying central part of Grampian Hill in southern San Francisco Mountains. Strong contact metasomatic alteration precludes recognition of its constituent members. Thickness appears to be approximately 500 m

Orr Formation (Upper Cambrian)—In southern San Francisco Mountains, appears to consist of two members listed below; however, the additional upper or Sneakover Pass Limestone Member may have been included in basal part of marbleized Notch Peak Formation

€os **Steamboat Pass Shale Member**—Dark-brown to gray-green, weakly metamorphosed, thin-bedded to fissile shale; locally contains trilobites. About 33 m thick

€ob **Big Horse Limestone Member**—Incomplete section of medium- to dark-gray, medium-bedded dolomitic limestone, irregularly bleached and streaked within outer fringe of contact zone of Cactus stock. Exposed beds are 335 m thick

Pzu **Paleozoic strata, undivided**—Highly bleached and recrystallized carbonate strata of unknown formational affinities. Strata above thrust fault in southern Rocky Range are considered by Welsh (1973) to be Cambrian(?) dolomite. Intensely marbleized carbonate rocks in general vicinity of Vicksburg mine 8 km southwest of Milford are probably of Permian and Pennsylvanian age

Contact—Dashed where approximately located; some Quaternary contacts shown as solid are approximately located

High-angle fault—Dashed where approximately located; dotted where concealed; groups of three dots where inferred and concealed; bar and ball on downthrown side

Thrust fault—Dotted where concealed; sawteeth on upper plate

Strike and dip of beds
- 35 **Inclined**
- **Horizontal**
- 60 **Overturned**

25 **Strike and dip of compaction foliation in welded tuffs**

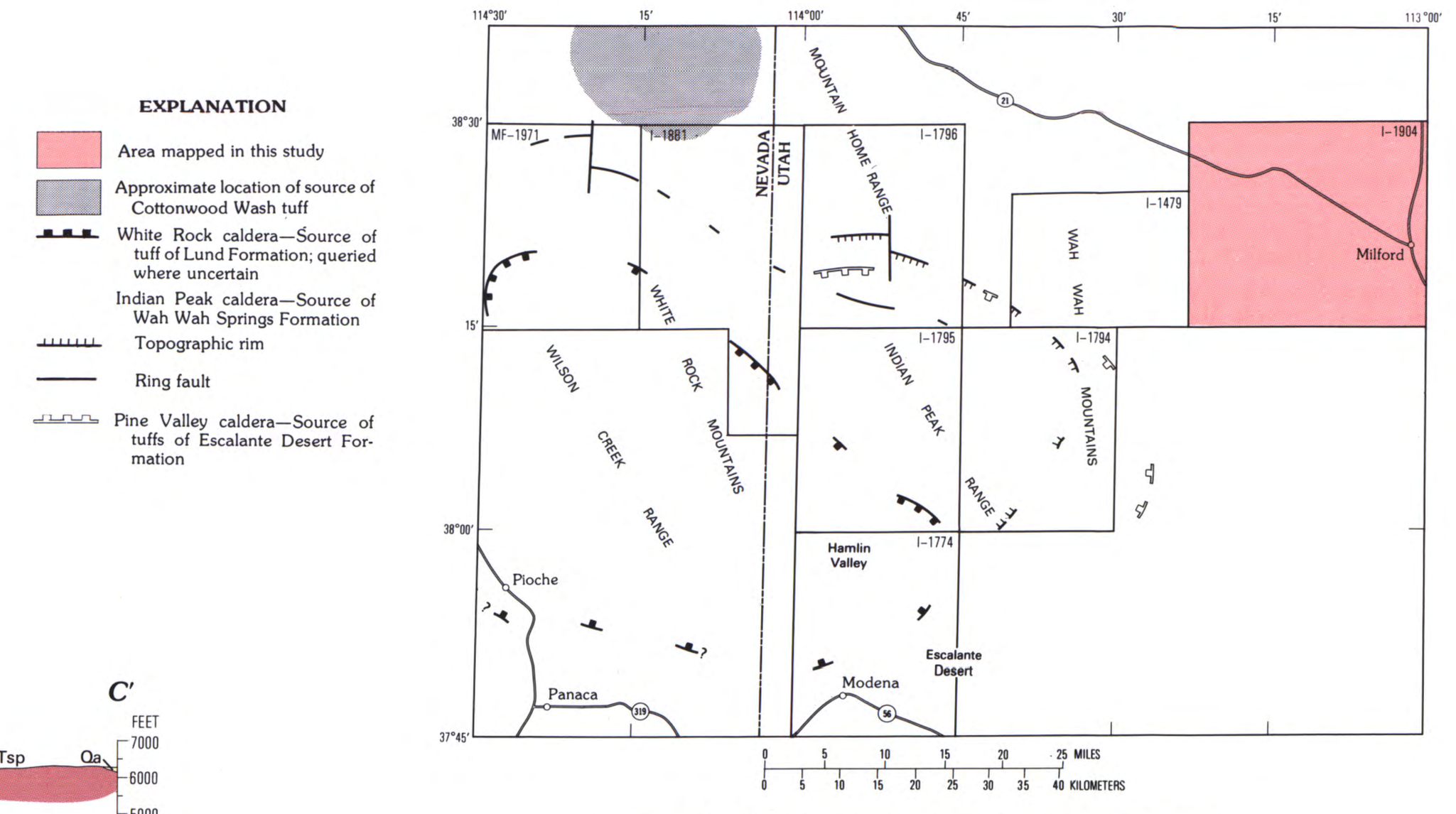


Figure 1.—Map showing location of calderas and recently published geologic maps, Utah and Nevada

REFERENCES CITED

Abbott, J. T., Best, M. G., and Morris, H. T., 1983, Geologic map of the Pine Grove-Blawn Mountain area, Beaver County, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I–1479, scale 1:24,000.

Armstrong, R. L., 1970, Geochronology of Tertiary igneous rocks, eastern Basin and Range province, western Utah, eastern Nevada, and vicinity, U.S.A.: Geochimica et Cosmochimica Acta, v. 34, p. 203–233.

Baer, J. L., 1962, Geology of the Star Range, Beaver County, Utah: Brigham Young University Geology Studies, v. 9, pt. 2, p. 29–52.

Best, M. G., and Grant, S. K., 1987, Stratigraphy of the volcanic Oligocene Needles Range Group in southwestern Utah and eastern Nevada: U.S. Geological Survey Professional Paper 1433–A.

Best, M. G., Mehnert, H. H., Keith, J. D., and Naeser, C. W., 1987, Miocene magmatism and tectonism in and near the southern Wah Wah Mountains, southwestern Utah: U.S. Geological Survey Professional Paper 1433–B.

Cook, E. F., 1965, Stratigraphy of Tertiary volcanic rocks in eastern Nevada: Nevada Bureau of Mines Report 11, 61 p.

Crosby, G. W., 1959, Geology of the south Pavant Range, Millard and Sevier Counties, Utah: Brigham Young University Geology Studies, v. 6, 59 p.

Dalrymple, G. B., 1979, Critical tables for conversion of K-Ar ages from old to new constants: Geology, v. 7, p. 558–560.

East, E. H., 1966, Structure and stratigraphy of the San Francisco Mountains, western Utah: American Association of Petroleum Geologists Bulletin, v. 50, p. 901–920.

Ekren, E. B., Orkild, P. P., Sargent, K. A., and Dixon, G. L., 1977, Geologic map of Tertiary rocks, Lincoln County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I–1041, scale 1:250,000.

Hewett, D. F., 1931, Geology and ore deposits of the Goodsprings quadrangle, Nevada: U.S. Geological Survey Professional Paper 162, 172 p.

Lemmon, D. M., Silberman, M. L., and Kistler, R. W., 1973, Some K-Ar ages of extrusive and intrusive rocks of the San Francisco and Wah Wah Mountains, Utah; *in* Geology of the Milford area, 1973: Utah Geological Association Publication 3, p. 23–26.

Morris, H. T., and Lovering, T. S., 1961, Stratigraphy of the East Tintic Mountains, Utah: U.S. Geological Survey Professional Paper 361, 145 p.

Rowley, P. D., 1978, Geologic map of the Thermo 15-minute quadrangle, Beaver and Iron Counties, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ–1493, scale 1:62,500.

Rowley, P. D., Lipman, P. W., Mehnert, H. H., Lindsey, D. A., and Anderson, J. J., 1978, Blue Ribbon lineament, an east-trending structural zone within the Pioche mineral belt of southwestern Utah and eastern Nevada: U.S. Geological Survey Journal of Research, v. 6, no. 2, p. 175–192.

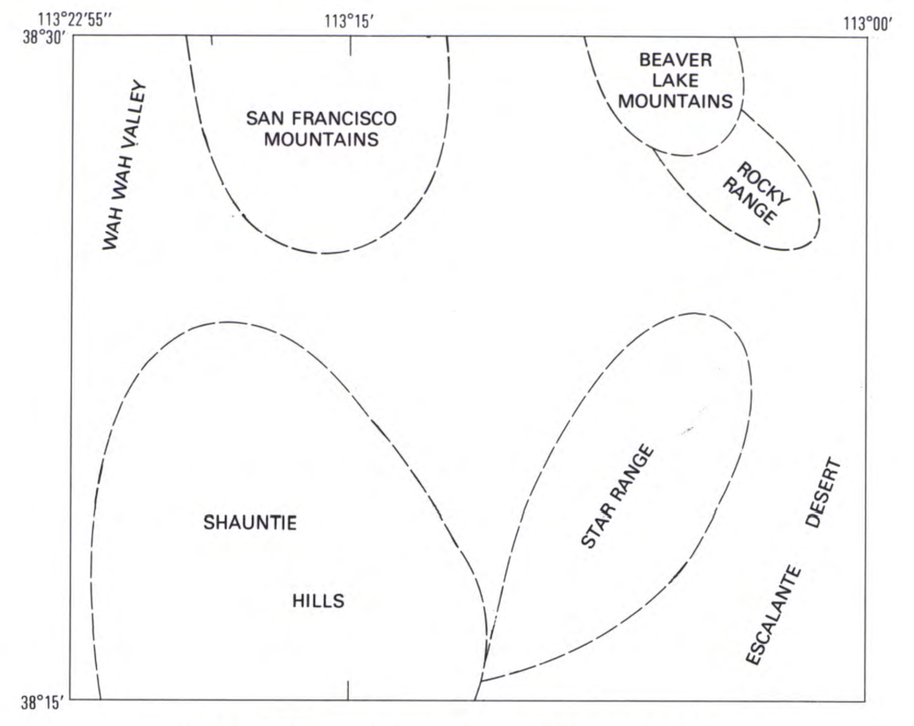
Steven, T. A., 1981, Three Creeks caldera, southern Pavant Range, Utah: Brigham Young University Geology Studies, v. 18, p. 1–7.

Stewart, J. H., Poole, F. G., and Wilson, R. F., 1972, Stratigraphy and origin of the Triassic Moenkopi Formation and related strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 691, 195 p.

Stringham, B. F., 1967, Hydrothermal alteration near the Horn Silver mine, Beaver County, Utah: Utah Geological and Mineral Survey Special Studies 16, 35 p.

Welsh, J. E., 1973, Paleozoic and Mesozoic stratigraphy of the Milford area, Beaver County, Utah; *in* Geology of the Milford area, 1973: Utah Geological Association Publication 3, p. 9–12.

Williams, P. L., 1967, Stratigraphy and petrography of the Quichapa Group, southwestern Utah and southeastern Nevada: Seattle, University of Washington, Ph.D. dissertation, 139 p.



INDEX MAP SHOWING SOME MAJOR GEOGRAPHIC FEATURES IN THE MILFORD-FRISCO AREA, UTAH

For sale by U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225