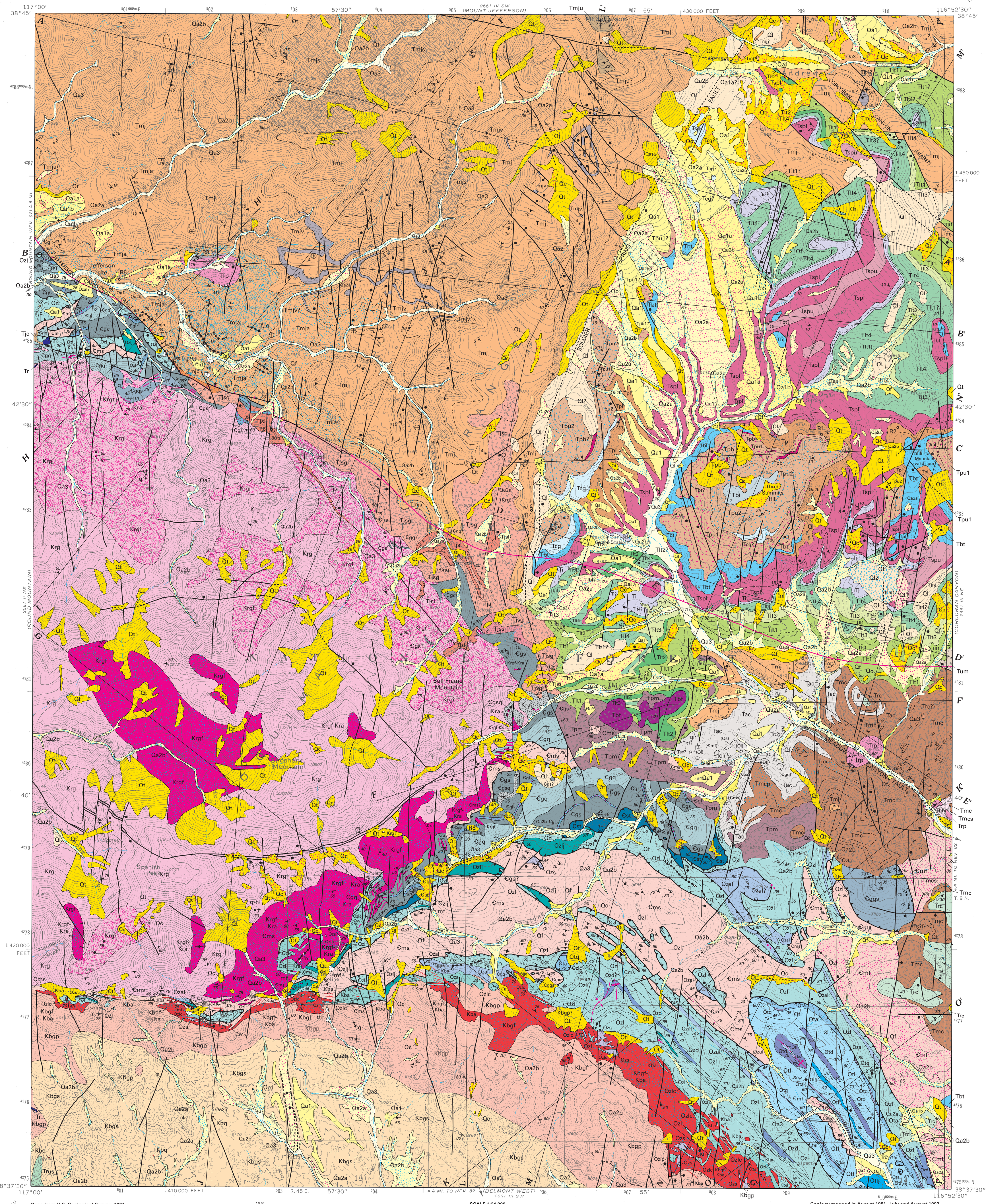
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGIC INVESTIGATIONS SERIES
I-2670
Pamphlet accompanies map



Base from U.S. Geological Survey, 1971
Projection and 10,000-foot grid ticks: Nevada coordinate system, central zone (transverse Mercator)
1927 North American datum

1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

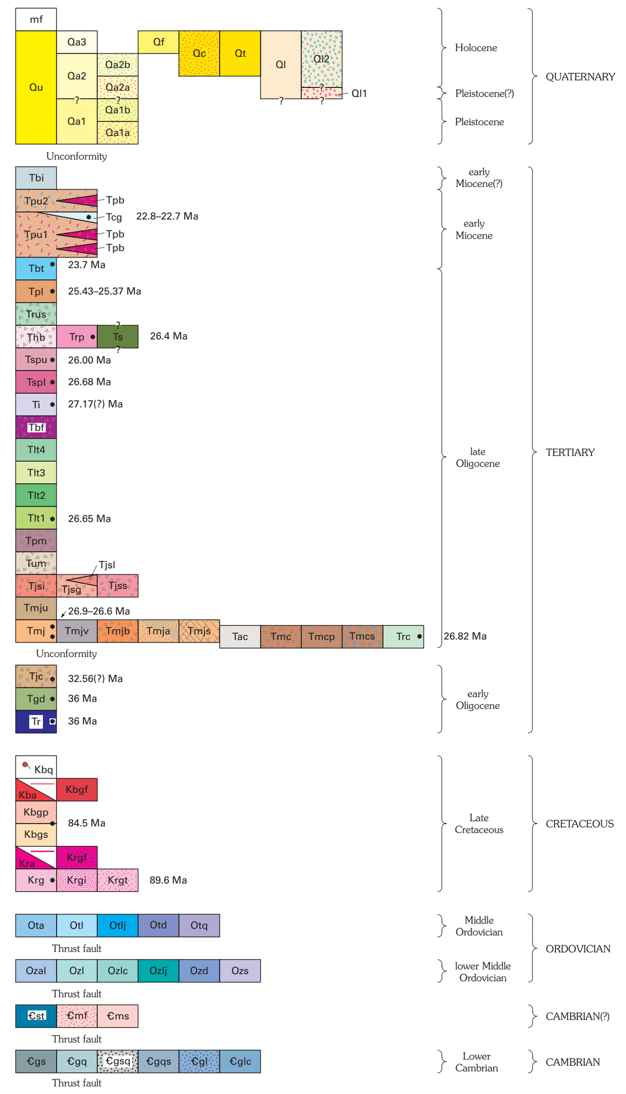
SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

Geology mapped in August 1981, July and August 1982, June–August 1984, June–August 1985, and September 1995
Editing and digital cartography by Alessandro J. Donatich
Geology digitized by Geologic Data Systems, Inc.
Cross sections drafted by Springfield and Springfield
Manuscript approved for publication November 3, 1998

CORRELATION OF MAP UNITS



Contact—Dashed where approximately located or gradational; dotted where concealed; queried where uncertain. Arrow shows dip

Internal contact within map unit—Generally shows bedding plane on map; shows form line in cross section. Dashed and (or) queried where uncertain

High-angle fault—Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side where relative movement is known. Opposed arrows show strike-slip movement; opposed arrows on fault symbol show horizontal grooves. Arrow shows dip of fault plane; where number is missing, dip could not be measured; cross indicates vertical dip. On cross section only, A indicates displacement away, T indicates displacement toward; U indicates displacement up; D indicates displacement down

Thrust fault—Dashed where approximately located; dotted where concealed; queried where uncertain. Arrow shows dip. Teeth on upper plate

Overturned thrust fault—Dotted where concealed. Teeth point to overturned lower plate

Caldera structural margin—Approximately located. Coincides with Jefferson Canyon fault in northwest part of quadrangle

Margin of megabreccia pipe—Dotted where concealed. Hachures inside pipe. Arrow shows dip of pipe margin

Anticline—Showing trace of axial plane

Syncline—Showing trace of axial plane

Drag-fold axis—Showing trend and plunge

Strike and dip of layered rocks—Structural complexity prevents determination of original orientation of most layers

- Inclined
- Inclined—Showing horizontal lineations
- Vertical
- Overturned—Original orientation known
- Overturned—Original orientation inferred

Strike and dip of foliation—Schistosity in metasedimentary rocks; foliation in granite; flow layering in rhyolite plug; compaction foliation in ash-flow tuff. Arrow shows trend and plunge of lineation or minor fold axis

- Inclined—Showing horizontal lineations, or plunge of lineations. *s* indicates attitude of schlieren
- Vertical
- Shear foliation in granite and ash-flow tuff (Tmjs)
- Vertical shear foliation in granite
- Horizontal compaction foliation in ash-flow tuff

Foliation in granite—In cross sections only. Density of lines suggests relative intensity of foliation

Cleavage

- Inclined—Showing trend and plunge of lineations
- Vertical—Showing plunge of lineations

Vein—Arrow shows dip; cross indicates vertical vein. q, quartz vein (h indicates heubnerite); c, calcite vein; f, fissure vein

Brecciated rock

Mylonite layer—Uncertain projection based on geometry of mylonite layer exposed to the south in adjacent Belmont West quadrangle. Open teeth on upper side of mylonite layer

Large block in megabreccia—Colored as megabreccia; label in parentheses indicates specific map unit where recognized. In unit Tac, parentheses around Trc?, Ol, Ols, Os, Єgq, and Єmf indicate large isolated blocks in ash-flow tuff

Amazonite locality

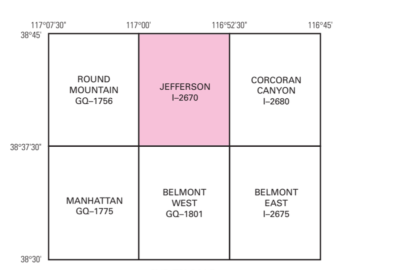
Quartz-feldspar pipe locality

Radiometrically dated rock sample locality

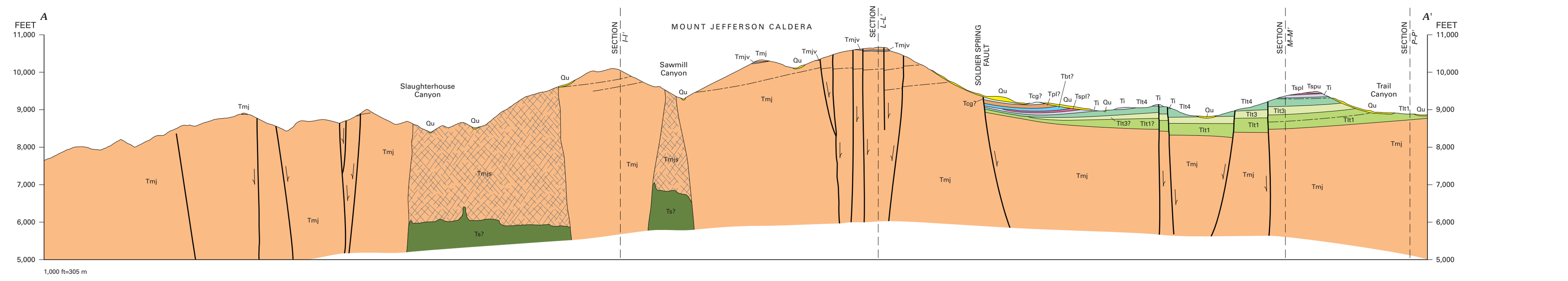
Location of rock sample with modal analysis—Number indicates category assignment. Position may coincide with horizontal foliation symbol to yield ⊛

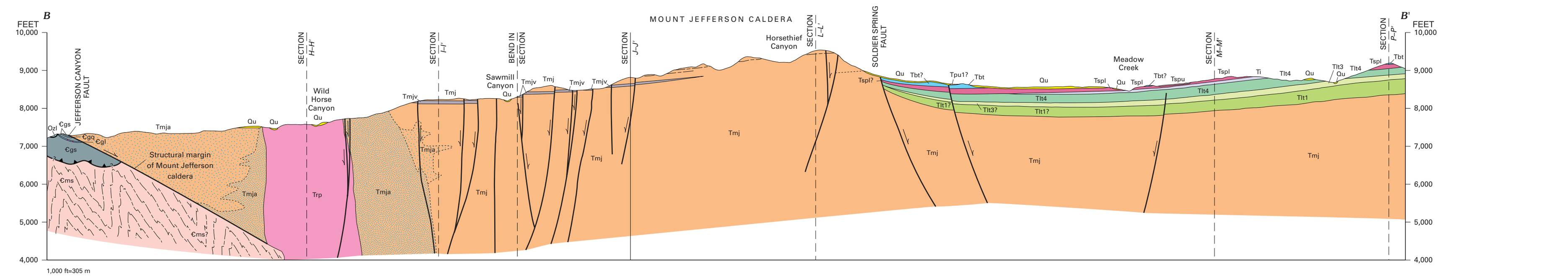
LIST OF MAP UNITS

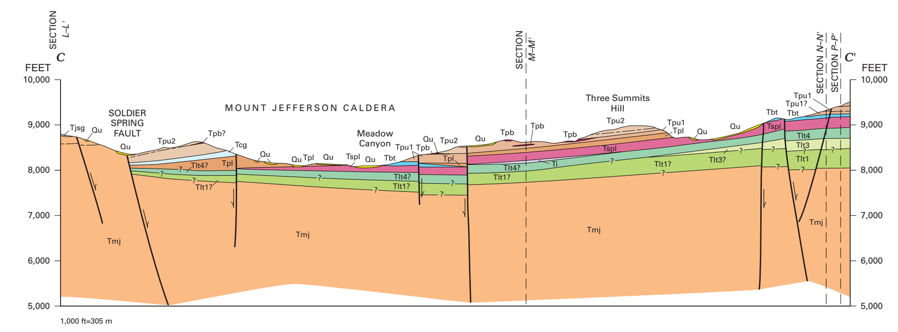
Symbol	Unit
mf	Manmade fill (modern)
Qu	Surficial alluvial deposits, undivided (Quaternary)
	Alluvium (Holocene, Pleistocene?, and Pleistocene)
Qa3	Youngest alluvium (Holocene)
Qa2	Older alluvium, undivided (Holocene and Pleistocene?)
Qa2b	Older alluvium b (Holocene)
Qa2a	Older alluvium a (Holocene and Pleistocene?)
Qa1	Oldest alluvium, undivided (Pleistocene)
Qa1b	Oldest alluvium b (Pleistocene)
Qa1a	Oldest alluvium a (Pleistocene)
Qf	Alluvial-fan deposits (Holocene)
Qc	Colluvium and slope wash (Holocene)
Qt	Talus (Holocene)
Ql	Landslide deposits, undivided (Holocene and Pleistocene?)
Ql2	Younger landslide deposit (Holocene)
Ql1	Older landslide deposit (Pleistocene?)
Tbi	Biotite-bearing ash-flow tuff (lower Miocene?)
	Tuff of Pipe Organ Spring (lower Miocene, upper Oligocene)
	Upper member (lower Miocene)
Tpu2	Unit 2
Tpu1	Unit 1
Tpl	Lower member (upper Oligocene)
Tpb	Mesobreccia lenses (lower Miocene)
Tcg	Tuff of Clipper Gap (lower Miocene)
Tbt	Bates Mountain Tuff, unit D (lower Miocene and upper Oligocene)
	Round Rock Formation (upper Oligocene)
Trus	Eruptive megabreccia of Silver Creek
Thb	Heterolithic breccia (upper Oligocene)
Trp	Rhyolite plugs (upper Oligocene)
Ts	Unexposed stocks (upper Oligocene?)
	Shingle Pass Tuff (upper Oligocene)
Tspu	Upper member
Tspl	Lower member
Ti	Isom-type welded ash-flow tuff formation (upper Oligocene)
Tbf	Megabreccia of Bull Frame Canyon (upper Oligocene)
	Volcaniclastic rocks of Little Table Mountain (upper Oligocene)
Tlt4	Tuffaceous siltstone, sandstone, and conglomerate, and tuff
Tlt3	Zeolitic tuff
Tlt2	Ash-flow tuff
Tlt1	Tuffaceous siltstone, sandstone, and conglomerate, and tuff
Tpm	Mesobreccia with abundant fragments of Paleozoic rocks (upper Oligocene)
Tum	Unnamed megabreccia unit (upper Oligocene)
	Megabreccia of Jefferson Summit (upper Oligocene)
Tjsi	Intrusive phase of vent megabreccia
Tjsg	Eruptive phase of megabreccia containing mostly granitic clasts
Tjsl	Siltstone, sandstone, and conglomerate (lacustrine)
Tjss	Eruptive phase of megabreccia with dominant schist and quartzite clasts
	Tuff of Mount Jefferson (upper Oligocene)
Tmju	Upper member
Tmj	Principal member
Tmjv	Vitrophyre
Tmjb	Tuff breccia
Tmja	Altered ash-flow tuff
Tmjs	Intensely sheared ash-flow tuff
Tac	Tuff of Antone Canyon (upper Oligocene)
Tmc	Megabreccia of Meadow Canyon (upper Oligocene)
Tmcp	Megabreccia with abundant Paleozoic rock clasts
Tmcs	Tuffaceous sandstone
Trc	Tuff of Ryecroft Canyon (upper Oligocene)
Tjc	Megabreccia of Jefferson Canyon (lower? Oligocene)
Tgd	Granodiorite of Dry Canyon (lower Oligocene)
Tr	Rhyolite dikes and plug (early Oligocene)
	Granite of Shoshone Mountain (Late Cretaceous)
	Belmont pluton
Kbq	Quartz-feldspar pipes
Kba	Aplite
Kbgf	Fine-grained granite
Kbgp	Porphyritic granite
Kbgs	Sparsely porphyritic granite
	Round Mountain pluton
Kra	Aplite
Krgf	Fine-grained granite
Krg	Coarse-grained granite
Krgi	Altered and iron-mineralized granite
Krgt	Tourmaline-mineralized granite
	Toquima Formation (Middle Ordovician)
Ota	Argillite
Otl	Limestone
Otlj	Jasperized limestone (jasperoid)
Otd	Dolostone
Otq	Quartzite
	Zanzibar Formation (lower Middle Ordovician)
Ozal	Argillite and subordinate limestone
Ozl	Limestone
Ozlc	Calc-silicate-mineralized limestone
Ozlj	Jasperized limestone
Ozd	Dolostone
Ozs	Schist
Єst	Siltstone formation (Cambrian?)
	Mayflower Formation (Cambrian?)
Єmf	Phyllitic argillite
Єms	Knotted schist
	Gold Hill Formation (Lower Cambrian)
Єgs	Phyllitic schist
Єgq	Quartzite
Єgsq	Schist and subordinate quartzite
Єgqs	Quartzite and subordinate schist
Єgl	Limestone
Єglc	Calc-silicate-mineralized limestone

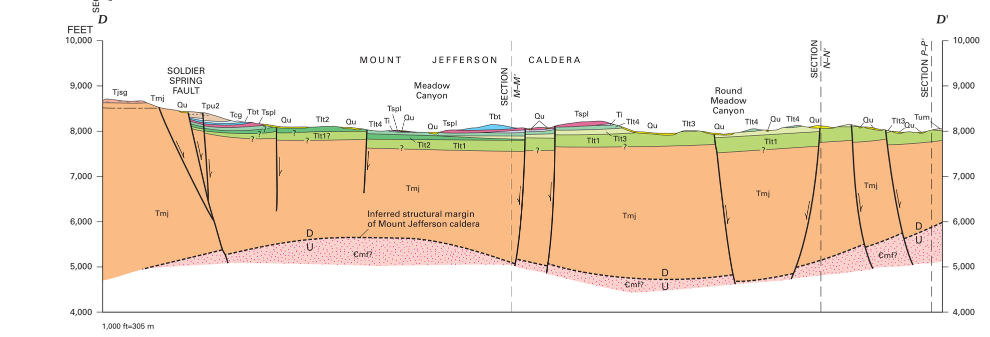


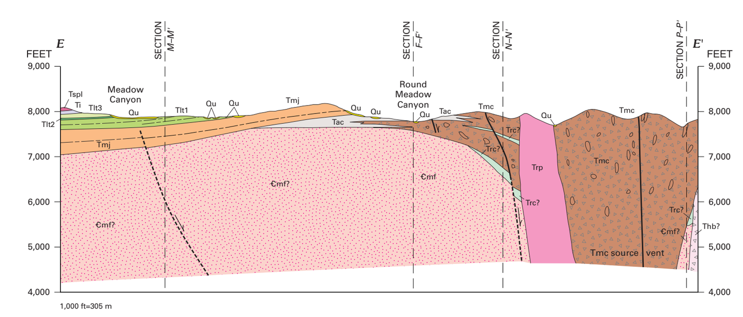
INDEX MAP

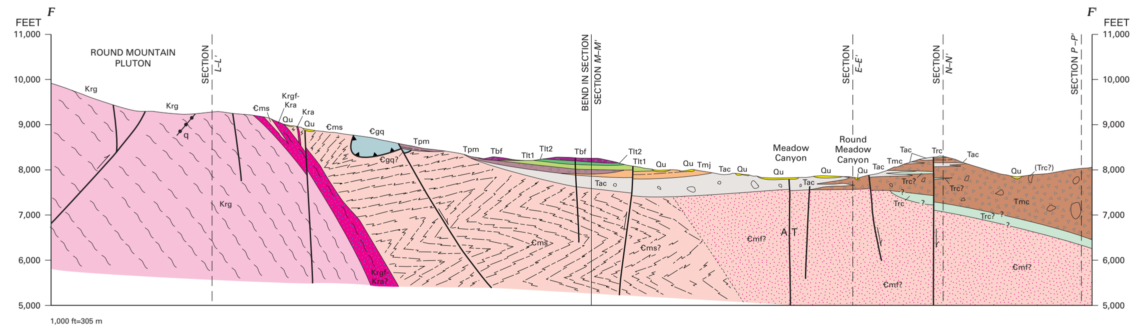


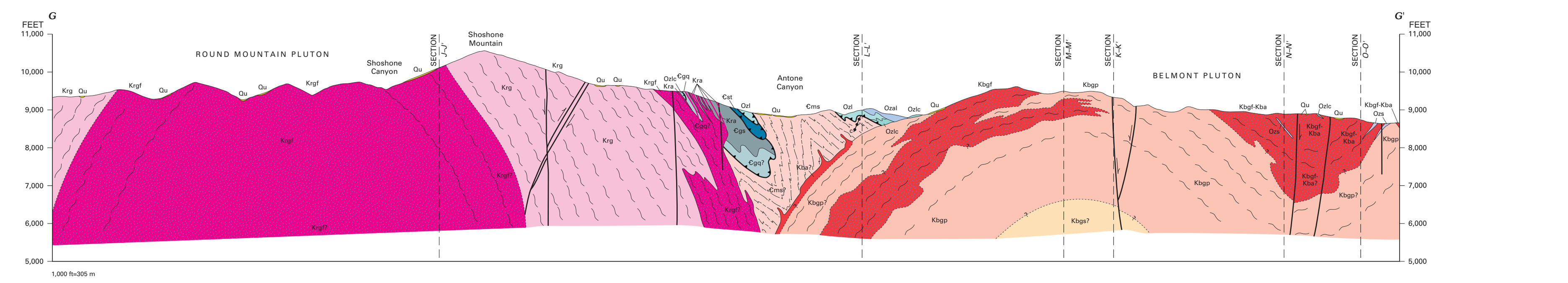


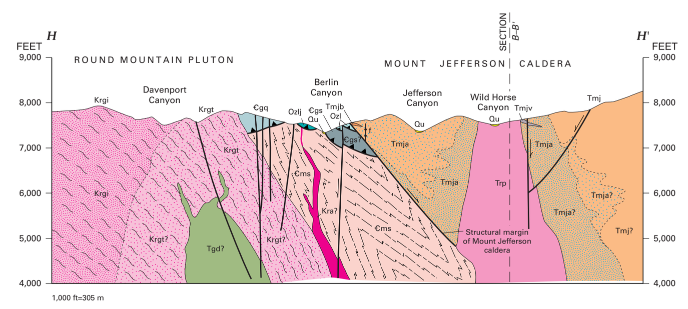


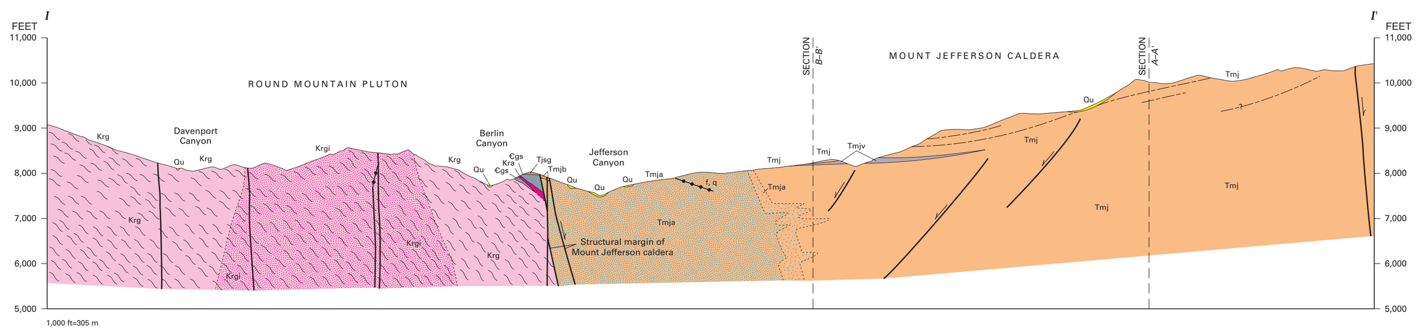


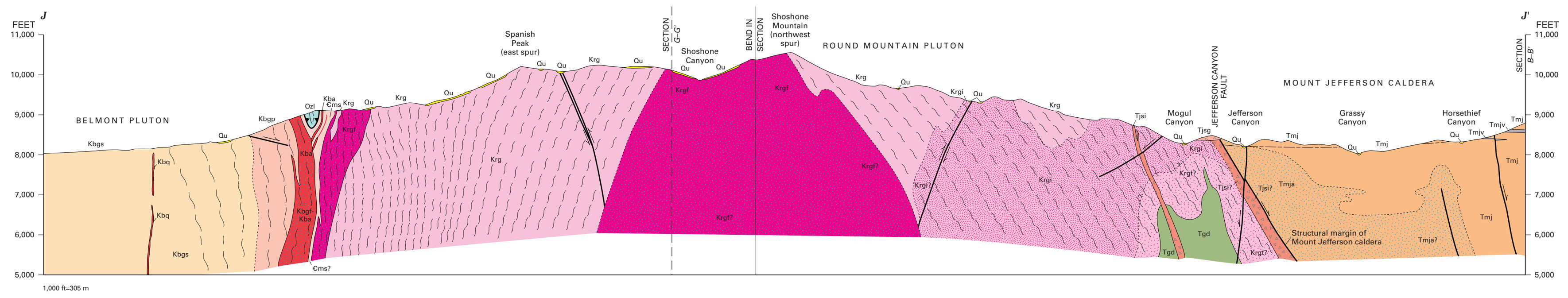


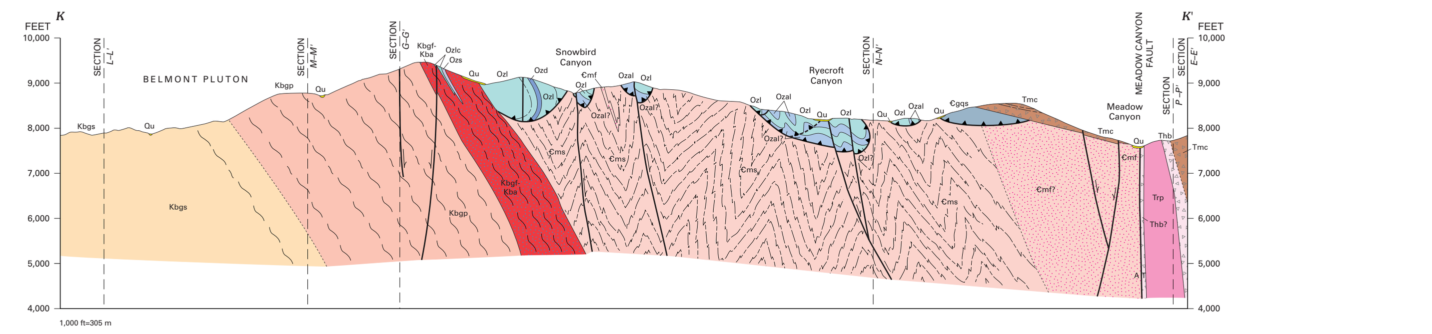


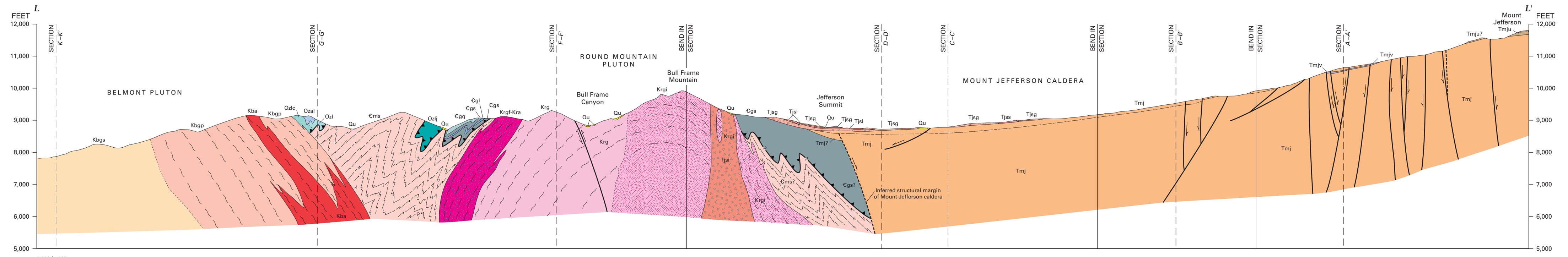


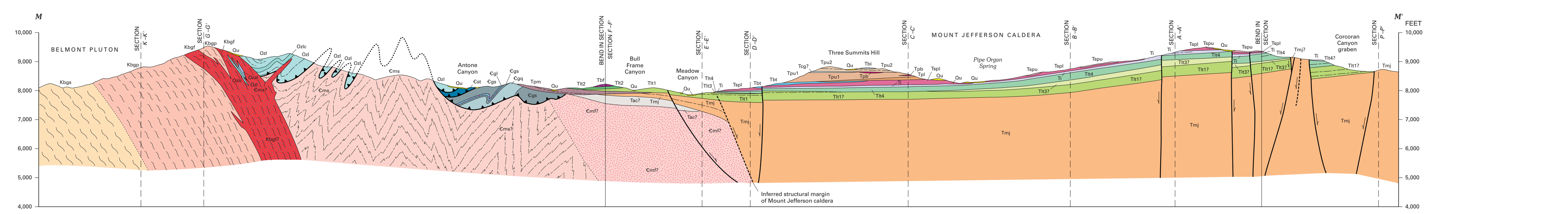


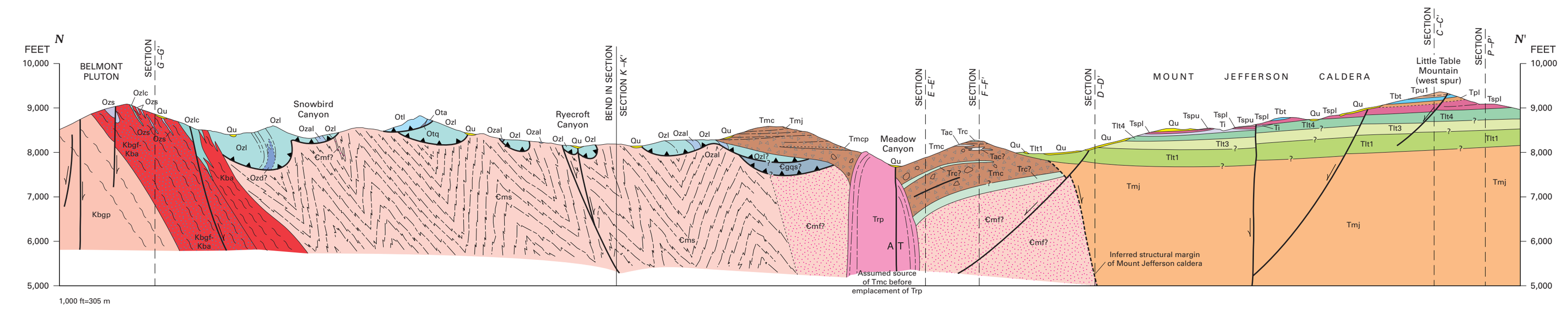


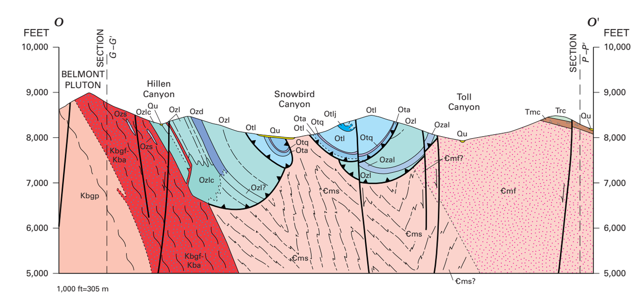


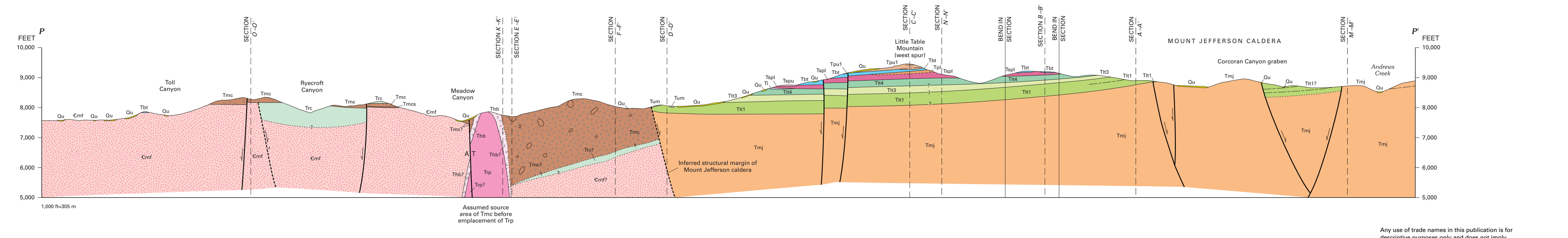












GEOLOGIC MAP OF THE JEFFERSON QUADRANGLE, NYE COUNTY, NEVADA

By
Daniel R. Shawe

1999

Geologic map of the Jefferson quadrangle, Nye County, Nevada

By Daniel R. Shawe

Geologic Investigations Series I–2670

Ruin at Jefferson site: a miner's cabin, relic of early mining in Jefferson Canyon. Walls of the structure are of blocks and slabs of tuff of Mount Jefferson. Photograph by the author, 1985.

1999

U.S. Department of the Interior
U.S. Geological Survey

DESCRIPTION OF MAP UNITS

[Phenocryst contents of most of the ash-flow tuffs and a few other volcanic rocks described here were determined by modal analyses of thin sections by F.M. Byers, Jr. (U.S. Geological Survey). Between 2,000 and 4,000 points per thin section of crystal-rich rocks (20 percent or more phenocrysts) generally were counted; points per thin section counted ranged to more than 10,000 points for some crystal-poor rocks. Phenocryst contents are given as volume percent of total rock, and phenocryst minerals are given as volume percent of total phenocrysts; Q, quartz; K, alkali feldspar (generally sanidine); P, plagioclase; B, biotite; H, hornblende; C, clinopyroxene; O, opaque-oxide minerals; M, unspecified mafic minerals. Other specific mineral names are spelled. Accessory minerals occur in trace amounts; their relative amounts are described as common or moderate, sparse, and rare. In some exposures of the volcanic rocks described here, hydrothermal alteration resulted in partial or complete replacement of feldspars and mafic minerals by secondary minerals. Chemical analyses (major oxides determined by X-ray fluorescence; FeO by potentiometric titration; CO_2 by coulometric titration) are recalculated on a volatile-free basis; analyses by D.F. Siems, J.S. Mee, and J.E. Taggart, Jr. (U.S. Geological Survey), and by Actlabs, Inc., Wheat Ridge, Colo. Volcanic rock names are based on the modal data showing phenocryst content; they are mostly the same as the field terms used during mapping. Rock names based on the IUGS chemical classification (Le Bas and others, 1986) are shown in parentheses following the listed chemical data. Cited K-Ar dates that were determined before 1977 have been converted using new constants given in table 2 of Dalrymple (1979). Queries on map-unit symbols indicate uncertain assignment]

mf **Manmade fill (modern)**—Mostly mine dumps and mill tailings

Qu **Surficial alluvial deposits, undivided (Quaternary)**—Shown only on cross sections

Alluvium (Holocene, Pleistocene?, and Pleistocene)—Sand, silt, and gravel. Subdivisions of alluvium described below are based on relative age in local areas mostly determined by relative height above current stream levels. I was unable to correlate specific units by age everywhere in the quadrangle; thus sediment mapped as one unit (for example, Qa3) may be the same age as sediment mapped elsewhere as a different unit (for example, Qa2b). Studies of soil characteristics that are a function of deposit age were not attempted here. Qa3, Qa2, and Qa1 are not subdivided on cross sections (shown as Qu).

Colors of all alluvium units described here are varied, ranging from yellowish brown, light yellowish brown and light brown, to light brownish gray and light gray. All alluvium units are unconsolidated unless otherwise noted. Poorly to moderately sorted and comprised of poorly rounded to well-rounded clasts

Qa3 **Youngest alluvium (Holocene)**—Active alluvium in drainage channels. Characterized by braided strands of recently deposited gravel, sand, and silt. Locally grades into alluvial fan deposits (Qf). Maximum thickness a few meters

Qa2 **Older alluvium, undivided (Holocene and Pleistocene?)**—Stabilized alluvium in stream channels, stream terraces, and flat valley-fill alluvial fans topographically higher (a few meters) than youngest alluvium (Qa3); map unit commonly is being eroded. Clasts generally are only slightly weathered and commonly are moderately sorted. Some layers contain pebble-size or smaller clasts whereas other layers contain clasts of cobble or boulder size. Maximum thickness about 10 m

Qa2b **Older alluvium b (Holocene)**—Forms narrow to broad stream courses of mostly inactive alluvium, or remnant patches of inactive alluvium marginal to and standing 1 m to a few meters higher than Qa3

Qa2a **Older alluvium a (Holocene and Pleistocene?)**—Extensively eroded deposits laced with strands of active alluvium too small to map; older parts may be as old as Pleistocene

Qa1 **Oldest alluvium, undivided (Pleistocene)**—Stabilized alluvium that underlies stream terraces higher than older alluvium (Qa2) and commonly 20–40 m above adjacent drainage bottoms; locally contains boulders. Large clasts (cobbles and small boulders), especially of volcanic rocks, may be significantly weathered. Presently being eroded. Maximum thickness about 35 m underlying flats northwest of Pipe Organ Spring; oldest alluvium possibly in part resting on a pedimented surface

Qa1b **Oldest alluvium b (Pleistocene)**—Forms small erosional remnants within a few hundred meters of drainage courses

Qa1a **Oldest alluvium a (Pleistocene)**—Alluvial deposits standing several meters higher than Qa1b; most extensive northwest of Pipe Organ Spring

Qf **Alluvial-fan deposits (Holocene)**—Active fans commonly formed at foot of short drainages that enter canyon bottoms. Locally grade into youngest alluvium (Qa3). Maximum thickness a few meters

Qc **Colluvium and slope wash (Holocene)**—Gently sloping accumulations of disintegrated rock nearly in place, or deposited by slope wash. Locally grades upslope into talus (Qt) or downslope into alluvium (Qa3 or Qa2b). Maximum thickness a few meters

Qt **Talus (Holocene)**—Steeply sloping accumulations of angular rock, deposited below cliffs and steep slopes; mapped where accumulations are well defined or where they obscure geologic contacts. Contains blocks several tens of meters long beneath a cliff of rhyolite (Trp) on north side of Meadow Canyon at east margin of the quadrangle. Locally grades downslope into colluvium and slope wash (Qc). Maximum thickness a few tens of meters

Ql **Landslide deposits, undivided (Holocene and Pleistocene?)**—Generally heterogeneous mixture of rock fragments and soil derived by slope failure from nearby higher bedrock and surficial materials. Formed mostly of nonwelded and poorly consolidated tuffs and tuffaceous sedimentary rocks in northeast part of the quadrangle. In places derived almost wholly from single bedrock units (such units indicated in parentheses). Maximum thickness several meters

Ql2 **Younger landslide deposit (Holocene)**—Rejuvenated landslide on west slope of hill about 3 km east of Meadow Canyon Guard Station; upper margin marked by a scarp in higher and older landslide deposit (Ql1)

Ql1 **Older landslide deposit (Pleistocene?)**—Remnant of older landslide deposit near top of hill above younger landslide deposit (Ql2)

Tbi **Biotite-bearing ash-flow tuff (lower Miocene?)**—Light-gray, crystal-poor, partially to moderately welded rhyodacitic ash-flow tuff. Contains flattened pumice lapilli as long as about 2 cm. Phenocrysts (1–2 mm in diameter) comprise 10 percent each of two samples of tuff, and consist of: Q, less than 1 each; K, 14 and 17; P, 72 and 69; B, 10 and 9; O, 2 and 3; and H plus C, 1–2. Zircon and apatite are accessory minerals. Chemical analyses of the same two samples show the following percentages of components: SiO_2, 73.0 and 73.2; Al_2O_3, 14.4 and 14.2; K_2O, 4.56 and 4.62; Na_2O, 4.41 each; CaO, 1.03 and 1.00; Fe_2O_3, 1.45 and 1.26; FeO, 0.36 and 0.49; MgO, 0.37 and 0.33; $Ti0_2$, 0.30 and 0.31; P_2O_5, 0.10 and 0.09; and MnO, 0.08 and 0.09 (rhyolite). Map unit caps summit of Three Summits Hill; slightly unconformable on (appears to channel into) underlying tuff of Pipe Organ Spring (Tpu2), as an erosional remnant no more than about 15 m thick

Tuff of Pipe Organ Spring (lower Miocene, upper Oligocene)—Nonwelded to densely welded, crystal-poor rhyolitic ash-flow tuffs. An upper member of two mappable units (Tpu2 and Tpu1) overlies a lower member (Tpl), each considered to be a separate ash flow or cooling unit. Units of upper member as well as lower member each pinch out locally within the quadrangle. A few thin lenses of mesobreccia occur within or between the various units. Mesobreccia is here considered to contain clasts no more than about 1–2 mm in diameter. Source of tuff of Pipe Organ Spring is unknown. Lower member (Tpl) appears to be equivalent to Boden's (1986; 1992) member 2 of tuffs and sedimentary rocks of Road Canyon; Boden referred to his member 2 as "tuff of Pipe Organ Spring." The name is derived from the vertically fluted cliff, which consists of lower member (Tpl), just south of Pipe Organ Spring. Interlayered in tuff of Pipe Organ Spring are two units that are correlated to widely exposed dated units in central and east-central Nevada: tuff of Clipper Gap (Tcg) and unit D of Bates Mountain Tuff (Tbt)

Upper member (lower Miocene)

Tpu2 **Unit 2**—Upper part is light-gray to light-brownish-gray, moderately to densely welded, crystal-poor rhyolitic ash-flow tuff; weathers light brown. Contains locally abundant dark-gray flattened pumice lapilli as much as 1 cm long. Weathered rock has a mottled appearance. Modal analyses of six thin sections of upper part of unit

2 indicate 4–9 percent phenocrysts (1–3 mm in diameter) that consist of the following phases (in percent): Q, 15–33; K, 43–76; P, 3–30; B, 0–3.5; O, 0.2–2; and H and C, 0–3. Zircon and rare apatite are accessory minerals. A chemical analysis of a sample of upper part of unit 2 indicates (in percent): SiO_2, 76.0; Al_2O_3, 13.1; K_2O, 4.75; Na_2O, 3.95; CaO, 0.61; Fe_2O_3, 1.04; FeO, 0.16; MgO, 0.13; TiO_2, 0.12; P_2O_5, 0.08; and MnO, 0.05 (rhyolite). Upper part of unit 2 is conformable upon lower part of unit 2. Occurs on or near ridge and hill tops east, north, and west of Meadow Canyon Guard Station, where its maximum thickness is about 35 m.

Lower part is light-grayish-brown to light-yellowish-brown, poorly to moderately welded, crystal-poor rhyolitic ash-flow tuff. Weathers to rubbly rock debris. Lower part of unit 2 is characterized by light-gray, flattened pumice lapilli (2–4 cm long); locally contains abundant lithic fragments 1 cm or less long. Three modal analyses indicate 6–8 percent phenocrysts (1–2.5 mm in diameter) composed of: Q, 16–22; K, 48 each; P, 25–30; B, 3–5; O, 0.3–2; and M, 0–2. Zircon and rare allanite and apatite are accessory minerals. Appears conformable on underlying unit 1 (Tpu1) and on tuff of Clipper Gap (Tcg). Lower part of unit 2 occurs near ridge and hill tops east, north, and west of Meadow Canyon Guard Station; 25–75 m thick

Tpu1 **Unit 1**—Light-yellowish-brown to light-yellowish-gray, poorly to moderately welded, crystal-poor rhyolitic ash-flow tuff. Tuff contains abundant black glass shards and small (about 1 cm long) dark-gray glassy fiamme, and small (about 1–2 cm long) lithic and light-colored pumice fragments in places. Modal analyses of six samples of unit 1 indicate 3–11 percent phenocrysts (1–3 mm in diameter) that consist of: Q, 18–30; K, 49–55; P, 16–28; B, trace–3.5; O, trace–3.5; and M, 0–2. Minor anorthoclase is evident in some thin sections. Zircon and rare allanite and apatite are accessory minerals. Two chemical analyses show: SiO_2, 74.6 and 75.5; Al_2O_3, 14.0 and 13.8; K_2O, 5.67 and 4.88; Na_2O, 2.66 and 3.56; CaO, 0.91 and 0.60; Fe_2O_3, 1.23 and 1.06; FeO, 0.32 and 0.23; MgO, 0.31 and 0.12; TiO_2, 0.15 and 0.13; P_2O_5, 0.08 and 0.07; and MnO, 0.05 and 0.06 (rhyolite). Appears conformable on underlying lower member (Tpl) and on Bates Mountain Tuff (Tbt). Widely exposed on lower slopes of Three Summits Hill. Thickness 0–100 m

Tpl **Lower member (upper Oligocene)**—Light-yellowish-brown, nonwelded to poorly welded, moderately crystal-rich rhyolitic ash-flow tuff. Contains abundant slightly flattened pale-yellowish-brown pumice fragments mostly less than 1 cm in size in a groundmass of uncompacted glass shards. Modal analyses of five samples of lower member show 10–21 percent phenocrysts (1–3 mm in diameter) that consist of: Q, 5–25; K, 17–40; P, 30–46; B, 5–13; O, 1–3; and M, 0–4. Zircon and minor allanite and apatite are accessory minerals. A chemical analysis indicates: SiO_2, 74.3; Al_2O_3, 14.3; K_2O, 5.40; Na_2O, 2.34; CaO, 1.42; Fe_2O_3, 1.17; FeO, 0.23; MgO, 0.46; TiO_2, 0.21; P_2O_5, 0.10; and MnO, 0.06 (rhyolite). L.W. Snee (written commun., 1997) reported sanidine $^{40}Ar/^{39}Ar$ dates of 25.37±0.05 Ma (rock sample locality R1) and 25.43±0.05 Ma (locality R2) for samples of lower member collected south and southeast of Pipe Organ Spring. Tuff forms impressive fluted cliffs near Pipe Organ Spring on both north and east slopes of Three Summits Hill. Map unit pinches out southwestward on Three Summits Hill, but reappears farther west on lower slopes just west of Meadow Creek. Tuff is disconformable on underlying upper member of Shingle Pass Tuff (Tspu), as indicated by local absence of Tspu below lower member. Thickness 0–95 m

Tpb **Mesobreccia lenses (lower Miocene)**—Light-yellowish-brown ash-flow tuff containing abundant rounded fragments of welded tuff that consist mostly of Bates Mountain Tuff (Tbt) and possibly also other older welded tuffs, as large as large-boulder size (1 m). Map unit occurs as lenses at various horizons within unit 2 (Tpu2) and unit 1 (Tpu1) of upper member of tuff of Pipe Organ Spring. Mesobreccia lenses in Tpu2 contain fragments that may be from tuff of Clipper Gap (Tcg). Thickness of unit ranges from 0 m to a few meters. Smaller lenses were not mapped

Tcg **Tuff of Clipper Gap (lower Miocene)**—Pale-lavender-gray, partially to moderately welded, crystal-poor rhyolitic ash-flow tuff; weathers light pinkish gray. In places contains abundant greatly flattened pale-gray pumice lapilli as long as 5 cm. Modal analyses of three thin sections indicate 4–6 percent phenocrysts (1–2.5 mm in diameter) consisting of the following phases: Q, 31–49; K, 37–56; P, 12–25; B, 0–0.4; O, 0.4–1; and M, 0–1. Zircon is an accessory mineral. A chemical analysis of a sample of tuff of Clipper Gap indicates: SiO_2, 76.3; Al_2O_3, 12.8; K_2O, 4.92; Na_2O, 3.57; CaO, 0.64; Fe_2O_3, 1.20; FeO, 0.09; MgO, 0.12; TiO_2, 0.11; P_2O_5, 0.09; and MnO, 0.10 (rhyolite). A sanidine K-Ar date for the Clipper Gap in the northern Toquima Range is 22.8±2–3 percent Ma (McKee, 1976); another sanidine K-Ar date for the unit near Eureka 100 km northeast of the quadrangle is 22.7±0.6 Ma (Grommé and others, 1972). Unit forms relatively thin isolated lenses (0–30 m thick) interlayered in tuff of Pipe Organ Spring on south slope of Three Summits Hill, and farther west on slope west of Meadow Creek; small exposures west of Windy Pass near north margin of map area are possibly of tuff of Clipper Gap.

Tuff of Clipper Gap in the Jefferson quadrangle is correlated with the unit elsewhere on the basis of stratigraphic position, phenocryst content, and lithologic character (Page and Dixon, 1994). It occurs in the quadrangle as erosional remnants, sandwiched between overlying unit 2 of upper member of tuff of Pipe Organ Spring (Tpu2) and underlying rocks. These underlying rocks are unit 1 of upper member (Tpu1) and lower member (Tpl) of tuff of Pipe Organ Spring, and unit D of Bates Mountain Tuff (Tbt). The tuff was deposited during a hiatus in emplacement of tuff of Pipe Organ Spring

Tbt **Bates Mountain Tuff, unit D (lower Miocene and upper Oligocene)**—Pinkish-gray to lavender-gray to gray, moderately to densely welded, crystal-poor, somewhat peralkaline (high potassium-feldspar content) rhyolitic ash-flow tuff; weathers light orangish brown to reddish brown. Characterized by greatly flattened gray to brown pumice lapilli (1–3 cm) that impart a strong foliation to the rock. Weathered surfaces commonly contain numerous holes 1–5 cm long, giving the rock a "swiss cheese" appearance (for example, McKee, 1976, fig. 34). Modal analyses of six thin sections of samples of unit D indicate 2–4 percent phenocrysts (0.5–2 mm in diameter) composed of the following phases: Q, 0–12; K (both anorthoclase and sanidine), 72–89; P, 0–11; B, trace; O, 1–5; C, 1–9; and H, trace. Zircon and rare allanite and apatite are accessory minerals. Chemical analyses of two samples of unit D indicate the following compositions: SiO_2, 76.2 and 74.2; Al_2O_3, 12.0 and 13.5; K_2O, 4.63 and 5.23; Na_2O, 3.65 and 4.24; CaO, 0.78 and 0.33; Fe_2O_3, 1.99 and 2.02; FeO, 0.01(?) and 0.22; MgO, 0.29 and 0.05(?); TiO_2, 0.22 each; P_2O_5, 0.10 and 0.08; and MnO, 0.08 and 0.04 (rhyolite). Unit D of Bates Mountain Tuff extends around west and south slopes of Three Summits Hill, and occurs as scattered patches east, north, and west of hill. According to Grommé and others (1972), unit D has a sanidine K-Ar age of 23.7±0.6 Ma (Miocene-Oligocene boundary). Unit forms relatively thin lenses 0–30 m thick. The tuff was deposited during an erosional hiatus that followed deposition of lower and upper members of Shingle Pass Tuff (Tspl and Tspu) and lower member of tuff of Pipe Organ Spring (Tpl), and before depositon of tuff of Clipper Gap (Tcg)

Round Rock Formation (upper Oligocene)—The Round Rock Formation consists chiefly of caldera fill of the Manhattan caldera and it is widely exposed in adjacent Round Mountain quadrangle (Shawe, 1995), Manhattan quadrangle (Shawe, 1999), and Belmont West quadrangle (Shawe, 1998). The formation is largely absent from the Jefferson quadrangle. Only eruptive megabreccia of Silver Creek (Trus), part of upper member of Round Rock Formation, is present

Trus **Eruptive megabreccia of Silver Creek**—See Shawe (1995) for a more complete description. In the Jefferson quadrangle megabreccia consists of granite boulders (as much as 1 m in size) in tuff matrix. Unit occurs on a low ridge in southwest corner of the quadrangle where it is only a few meters thick

Thb **Heterolithic breccia (upper Oligocene)**—Breccia of mixed rock types including rhyolite (Trp), tuff of Ryecroft Canyon (Trc), pumice, and several varieties of Paleozoic rocks, in a pulverized matrix of the several rock types and tuff matrix of megabreccia of Meadow Canyon (Tmc). Breccia fragments are as much as about 1 m in size. Unit forms a shell that surrounds, and extends outward as much as 200 m from, two closely spaced plugs (Trp) in Meadow Canyon at east margin of the quadrangle. Breccia is related to emplacement of the plugs: within a few meters of plugs, slablike breccia fragments are crudely oriented parallel to nearly vertical walls of plugs, and in places blocks form vertical trains, suggesting laminar flow of material resulting from drag that accompanied emplacement of plugs. A rind of comminuted rock a few centimeters thick is plastered against plug walls. As seen in thin section, rind consists of crudely aligned, mostly sharply angular fragments of volcanic and Paleozoic rocks mostly less than 2 mm long in a fine-grained glassy(?) matrix

Trp **Rhyolite plugs (upper Oligocene)**—Unit consists of four rhyolite plugs. One plug occurs about 0.5 km from mouth of Wild Horse Canyon. Plug is light-gray, flow-layered, nearly aphanitic rhyolite that intrudes hydrothermally altered tuff of Mount Jefferson (Tmja); weathers light yellowish brown. Surface dimensions are about 0.35 km × 0.7 km. Locally near margin of plug, rhyolite is strongly brecciated, and rock is extensively hydrothermally altered (silicified and iron mineralized). Phenocrysts (1 mm and smaller) constitute about 1 percent of rock and consist of mostly quartz and lesser amounts of plagioclase and sanidine. Groundmass is devitrified and in places mostly replaced by silica; vugs and fractures in brecciated rhyolite are lined with quartz and chalcedony, and commonly contain oxidized pyrite crystals.

Three plugs intrude megabreccia of Meadow Canyon (Tmc) in Meadow Canyon. These plugs are light-yellowish-brown to light-orangish-brown, flow-layered, moderately crystal-rich rhyolite; weather brown. Two plugs (each somewhat more than 100 m in diameter) are at east margin of the quadrangle, and a third plug (300–400 m in diameter) is about 1 km farther up canyon. A modal analysis of a sample of rhyolite indicates 16 percent phenocrysts (3–5 mm in diameter) that consist of: Q, 43; K, 34; P, 19; B, 3.5; and O, 0.4. Sparse zircon and allanite constitute accessory minerals. A chemical analysis of the same sample shows the following percentages of components: SiO_2, 73.9; Al_2O_3, 14.2; K_2O, 4.85; Na_2O, 3.59; CaO, 1.45; Fe_2O_3, 0.88; FeO, 0.27; MgO, 0.37; TiO_2, 0.28; P_2O_5, 0.13; and MnO, 0.03 (rhyolite). Biotite K-Ar date of plug exposed 1 km west of east margin of the quadrangle is 26.4±0.8 Ma (McKee and John, 1987)

Ts **Unexposed stocks (upper Oligocene?)**—Subsurface stocks inferred to underlie intensely sheared tuff of Mount Jefferson (Tmjs). Inferred stocks may reflect emplacement of resurgent magmas within Mount Jefferson caldera that caused a pistonlike upward movement of overlying tuff, and partial arching of the core of the caldera. Shown only on cross section *A–A'*

Shingle Pass Tuff (upper Oligocene)—Consists of two distinctive members, an upper member (Tspu) and a lower member (Tspl), that underlie Bates Mountain Tuff (Tbt) and lower member of tuff of Pipe Organ Spring (Tpl). Members appear to be conformable below younger ash-flow tuffs; however, the two members are themselves separated by an erosional unconformity. Shingle Pass members in the Jefferson quadrangle are correlated with their equivalents 60–200 km farther east in Nevada (Page and Dixon, 1994) on the basis of stratigraphic position, phenocryst contents, and lithologic characteristics

Tspu **Upper member**—Light-gray to light-brownish-gray, nonwelded to moderately welded, moderately crystal-rich latitic ash-flow tuff; weathers light brown to light reddish brown. Contains sparse moderately compacted light-yellowish-brown pumice lapilli (as much as 2 cm long). Groundmass is characterized by minute (about 1 mm in diameter) devitrification(?) crenulations. Modal analyses of thin sections of five samples of upper member indicate 8–14 percent phenocrysts (1–4 mm) that consist of: Q, 0–1; K, 33–42; P, 52–57; B, 3–9; O, 1.5–3, and H and C, 0.5–2. A modal analysis of one thin section indicates: Q, 2; K (sanidine), 42; anorthoclase, 9; P, 38; B, 8;, O, 0.4; and H, 0.4. Zircon and rare apatite and allanite are accessory minerals. Chemical analyses of two samples of upper member indicate the following percentages of components: SiO_2, 76.0 and 78.1; Al_2O_3, 12.9 and 11.4; K_2O, 5.02 and 4.76; Na_2O, 3.18 and 2.48; CaO, 0.96 and 1.13; Fe_2O_3, 1.14 and 1.28; FeO, 0.22 and 0.09; MgO, 0.23 and 0.31; TiO_2, 0.21 and 0.19; P_2O_5, 0.08 and 0.10; and MnO, 0.04 and 0.06 (rhyolite). A $^{40}Ar/^{39}Ar$ sanidine date for upper member is

26.00±0.03 Ma (Best and others, 1989). Upper member of Shingle Pass Tuff is exposed in relatively small patches east of Three Summits Hill and north of Pipe Organ Spring. It lies unconformably on underlying lower member of Shingle Pass (**Tspl**). North of Pipe Organ Spring, upper member crops out in a narrow, sinuous band that extends for about 2.5 km northeastward upon underlying lower member and fills an old stream channel cut as much as 15 m into lower member. Elsewhere erosional remnants of upper member are as much as 15 m thick

Tspl **Lower member**—Light-gray, moderately crystal-rich, partially to densely welded quartz latitic ash-flow tuff; weathers light yellowish brown to light yellowish gray. Characterized throughout by black glass shards. Contains numerous nearly white moderately compacted pumice lapilli and some lithic fragments (about 1 cm long) near base; a horizon of larger less compacted whitish pumice fragments (as long as 10 cm) occurs higher in member on southeast flank of Three Summits Hill. Modal analyses of thin sections of seven samples of lower member indicate 7–28 percent phenocrysts (1–3 mm) that consist of: Q, 0–17; K, 18–35; P, 49–64; B, 5–10; O, 1–2; H, 0–4; and C, 0.2–2. Accessory minerals are common zircon and rare apatite and allanite. Chemical analyses of two samples of lower member indicate: SiO_2, 72.9 and 73.3; Al_2O_3, 14.5 each; K_2O, 5.51 and 5.40; Na_2O, 3.24 and 3.30; CaO, 1.34 and 1.36; Fe_2O_3, 1.43 and 1.35; FeO, 0.32 and 0.37; MgO, 0.41 and 0.34; TiO_2, 0.24 each; P_2O_5, 0.10 each; and MnO, 0.06 and 0.07 (rhyolite). Best and others (1989) reported a $^{40}Ar/^{39}Ar$ date of 28.68±0.03 Ma for the unit. Lower member is widely exposed in northeast part of map area, where it is about 20–100 m thick

Ti **Isom-type welded ash-flow tuff formation (upper Oligocene)**—Crystal-poor rhyodacitic ash-flow tuff: dark-gray, moderately to densely welded lower part that weathers brownish gray, and light-brownish-gray to light-gray, moderately to densely welded upper part that weathers orangish-brown. The term “Isom compositional type” or “Isom type” was used by Page and Dixon (1994) to include a number of ash-flow tuff units in eastern Nevada and western Utah that are similar in phenocryst composition to the distinctive Isom Formation of eastern Nevada and western Utah, which is about 27 Ma (Best and others, 1989). Upper part is missing in places. Lower part is characterized by abundant black glass shards and flattened black glass pumice lapilli as long as 15 cm. Lower part is altered (chloritized and (or) zeolitized?) locally where dark grayish green. Upper part characterized by flattened light-yellowish-brown to brown pumice lapilli as long as 4 cm. Small lithic fragments are common throughout. Modal analyses of four samples of Isom-type tuff indicate 8–11 percent phenocrysts (1–2 mm in diameter) made up of the following phases: Q, 4–7; K, 4–19; P, 63–72; B, trace–4; O, 2–5; C, 6–25; and H, tr–1. Apatite and rare allanite are accessory minerals. Chemical analyses of three samples of Isom-type tuff indicate the following ranges of composition: SiO_2, 65.5–66.9; Al_2O_3, 15.6–15.7; K_2O, 3.91–5.04; Na_2O, 2.84–3.29; CaO, 2.72–3.97; Fe_2O_3, 2.85–4.56; FeO, 0.46–2.49; MgO, 1.23–1.67; TiO_2, 0.65–0.81; P_2O_5, 0.23–0.30; and MnO, 0.06–0.09 (trachydacite). Unit is exposed in northeast part of the quadrangle where it crops out locally, mostly as narrow bands. It lies nearly conformably on underlying upper unit of volcaniclastic rocks of Little Table Mountain (**Tlt4**), commonly on a thin chert-rich conglomerate layer. Similar in modal composition and age (sanidine $^{40}Ar/^{39}Ar$ date of 27.17±0.04 Ma for a sample collected in adjacent Corcoran Canyon quadrangle; L.W. Snee, written commun., 1996) to Isom-type welded ash-flow tuffs in southeastern Nevada and southwestern Utah (Page and Dixon, 1994; Best and others, 1989). Thickness 0–35 m

Tbf **Megabreccia of Bull Frame Canyon (upper Oligocene)**—Ash-flow tuff containing small to large fragments (1–30 m in diameter) of a variety of rock types. Apparent matrix of unit at east end of exposures consists of light-yellowish-brown, light-greenish-brown, and light-orangish-brown, nonwelded, crystal-rich rhyolitic ash-flow tuff similar in composition to tuff of Ryecroft Canyon (**Trc**). A modal analysis of one sample of tuff matrix shows about 38 percent phenocrysts (3–4 mm) that consist of the following components: Q, 38; K, 31; P, 26; B, 1; and M, 1. Common accessory minerals are zircon and allanite. In west part of outcrop area, fragments in tuff consist of blocks of dense rhyolitic welded ash-flow tuff and minor amounts of granite, aplite, and Paleozoic silicic and schistose rocks as much as 2 m in diameter. In east part of outcrop area, large rounded blocks as much as 30 m in diameter of light-gray dense rhyolitic welded ash-flow tuff characterize unit. Rhyolitic tuff blocks appear similar in composition to rhyolitic ash-flow tuff matrix. Lenses of fluvial gravel are interlayered locally in megabreccia; this gravel may indicate that unit consists of reworked megabreccia of Meadow Canyon (Tmc)

Volcaniclastic rocks of Little Table Mountain (upper Oligocene)—A thick sequence of volcaniclastic rocks underlies, beneath a low-angle unconformity, Isom-type and younger welded ash-flow tuffs in northeast part of the Jefferson quadrangle, northwest and southwest of Little Table Mountain which lies just outside the quadrangle in adjacent Corcoran Canyon quadrangle to the east. Squence appears to be unconformable on underlying rocks. The volcaniclastic rocks are divided into four units, from base upward: tuffaceous sedimentary rocks (siltstone, sandstone, and conglomerate) and tuff (Tlt1); ash-flow tuff (Tlt2); zeolitic tuff (Tlt3); and a second unit of tuffaceous sedimentary rocks (siltstone, sandstone, conglomerate) and tuff (Tlt4). Some units are locally absent. Units locally contain minor lenses or layers of different lithology, and in places units intertongue (not mapped)

Tlt4 **Tuffaceous siltstone, sandstone, and conglomerate, and tuff**—Pale-greenish- to yellowish-brown and light-greenish- to yellowish-brown, in part nearly white, interlayered tuffaceous siltstone, sandstone, granule sandstone, pebble sandstone, and conglomerate. Granules and pebbles (angular to subrounded and as large as 2 cm) are mostly chert (black, varied shades of green, reddish brown, and yellowish brown); in one place dark-gray fragments (as long as 5 cm) of graptolitic shale from Ordovician Toquima Formation (Ota) were observed in platy siltstone. Siltstone and sandstone are evenly bedded lacustrine strata; coarser beds are probably both lacustrine and fluvial. Subordinate layers a few centimeters to about 1 m thick of thin-bedded pumice- and biotite-bearing tuff are interbedded locally. Some beds near top of unit contain abundant small (less than 1 mm in diameter) grains of black pyroxene. Most finer grained rocks of unit consist largely of devitrified volcanic glass, lesser amounts of granule-size lithic fragments (mostly devitrified rhyolite), and crystals of plagioclase, alkali feldspar, quartz, and mafic minerals. Uncommon thin (as thick as 1 m) beds of light-greenish- to yellowish-brown lacustrine limestone, in part algal limestone, occur near top of unit. Unit crops out around south base of Three Summits Hill, and more widely northeast of hill. Thickness 0–100 m

Tlt3 **Zeolitic tuff**—Pale-greenish- to yellowish-brown and light-greenish- to yellowish-brown tuff, probably deposited in a lake. In places light yellowish brown to pale brown. Tuff weathers to flaky to platy fragments or to rubble; beds about 10 cm thick display conchoidal fractures. An X-ray-diffraction analysis of a sample of zeolitic tuff by R.A. Sheppard (U.S. Geological Survey) indicated the presence of about 60 percent clinoptilolite (possibly with minor mordenite), 20 percent smectite, 20 percent glass, and traces of quartz and biotite. A modal analysis of this sample indicates a zeolitic-smectitic groundmass that contains about 6 percent crystals (0.5 mm in diameter) made up of the following components: Q, 5; K, 2; P, 79; B, 12; O, 0.6; and M, 2. Zircon and rare sphene and apatite are accessory minerals. Locally zeolitic tuff contains silty and sandy layers. Unit is exposed in an east-trending strip south of Three Summits Hill and mostly northeast of Meadow Canyon, and in scattered strips northeast of Three Summits Hill. Thickness 0–65 m

Tlt2 **Ash-flow tuff**—Light-greenish-brown to light-yellowish-brown, pumiceous, crystal-poor, nonwelded to partially welded quartz latitic ash-flow tuff. Locally light lavender gray in upper part. Characterized by abundant nearly white uncompacted pumice fragments and sparse but conspicuous devitrified rhyolite lithic fragments less than 1 cm in size. Abundant dark-gray flattened pumice fragments as long as 3 cm occur just south of Meadow Canyon Guard Station. A modal analysis of a sample of ash-flow tuff indicates 10 percent phenocrysts (1.5 mm in diameter) made up of the following phases: Q, 23; K, 21; P, 48; B, 7; H, 2; and M (O and C), 0.4. Apatite is an accessory mineral. Minor rhyodacitic tuff layers in unit contain numerous conspicuous black pyroxene crystals. A modal analysis of a sample of this rock shows about 20 percent phenocrysts (0.5–2 mm in diameter) that consist of: Q, 3; K, 9; P, 59; B, trace; O, 4; C (and minor orthopyroxene), 23; and H, 1. Apatite is an accessory mineral. Chemical analyses of two samples of quartz latitic tuff show the presence of: SiO_2, 71.0 and 72.6; Al_2O_3, 15.3 and 15.0; K_2O, 4.44 and 4.68; Na_2O, 2.45 and 2.06; CaO, 2.89 and 2.24; Fe_2O_3, 1.75 and 1.55; FeO, 0.53 and 0.36; MgO, 1.16 and 1.04; TiO_2, 0.31 and 0.30; P_2O_5, 0.16 and 0.09; and MnO, 0.05 and 0.07 (rhyolite). Unit is not everywhere well defined, particularly where poorly exposed; in places it contains thin-platy light-yellowish-brown tuffaceous siltstone layers, and in west part of its exposure it contains tuff layers charged with granite boulders as large as 1.5 m. The boulders typically are stained green, a common characteristic of large granite fragments in these Tertiary tuffs. Unit is exposed south and southwest of Three Summits Hill, but it is present only locally north of hill. Thickness 0–35 m

Tlt1 **Tuffaceous siltstone, sandstone, and conglomerate, and tuff**—Light-yellowish-brown, pale-greenish- to pale-yellowish-brown, and nearly white tuffaceous siltstone, sandstone, and conglomerate, and tuff. In a few places rocks weather with an orangish-brown to brown surface. Unit is dominantly lacustrine thin-bedded and evenly bedded, interlayered siltstone, sandstone, and tuff. Locally, thin-bedded siltstone shows small-scale crumpled folds suggestive of soft-sediment slumps. Rare mud cracks and "worm tracks" appear in places. Siltstone breaks into flaky to platy fragments; tuff layers and ash-rich siltstone and sandstone tend to show conchoidal fractures and to weather to rubbly to hackly fragments. Tuffaceous rocks are locally zeolitized. Some layers of granule conglomerate and small-pebble conglomerate appear in upper part of unit in northeast corner of the quadrangle. A few siltstone beds are limy. Unit lies unconformably on older rocks. Unconformity is most evident on north slope of hill 8262 just east of Round Meadow where it slopes north about 25°, cutting down through nearly flat layers of interlayered megabreccia of Meadow Canyon (Tmc) and tuff of Antone Canyon (Tac). Unit Tlt1 is exposed in an east-trending belt south of Three Summits Hill, and in patches in northeast corner of the quadrangle. Thickness 0–120 m

Tpm **Mesobreccia with abundant fragments of Paleozoic rocks (upper Oligocene)**—Fragments of Paleozoic rocks commonly 1–20 cm long, less commonly as large as 1.5 m, and rarely as large as 10 m are mixed together; matrix is generally not evident. Some larger blocks are brecciated. Rock types include quartzite and schist of Cambrian Gold Hill Formation (Ꞓgq, Ꞓgs); knotted schist and phyllitic argillite of Cambrian Mayflower Formation (Ꞓms, Ꞓmf); shale, limestone, and silicified shale and limestone of Ordovician Zanzibar (Oz units) and Toquima (Ot units) Formations, and minor Cretaceous granite and aplite, and volcanic rocks. Gold Hill quartzite clasts dominate in southwest part of exposed mesobreccia, Ordovician limestone clasts dominate in south-central part, and shale, silicified shale and limestone, and schist clasts dominate elsewhere. Sparse granite and aplite fragments occur in west part of unit, and minor volcanic fragments are found in east part of unit. Angular fragments occur in a pale-greenish- to yellowish-brown tuff matrix on steep south slope of Antone Canyon 1.4 km southwest of Meadow Canyon. Almost everywhere else matrix is not evident, apparently because its soft character allows ready erosion. Unit is exposed in a strip as much as 700 m wide south of Meadow Canyon, extending east-southeastward from Bull Frame Canyon to beyond Antone Canyon. Because unit appears to be interlayered locally with older rocks toward the east, it may in fact consist in part of rocks that are older than most of the rest of unit. In western two-thirds of outcrop area, mesobreccia unit lies unconformably upon units of Gold Hill Formation (Ꞓg units), tuff of Antone Canyon (Tac), and units of volcaniclastic rocks of Little Table Mountain (Tlt units), and it is overlain unconformably by megabreccia of Bull Frame Canyon (Tbf). It lies unconformably upon limestone of Zanzibar Formation (Ozl) and tuff of Antone Canyon (Tac) in eastern one-third of the outcrop area. It also may tongue into megabreccia of Meadow Canyon (Tmc) at east end of its exposure. In exposures near confluence of Meadow and Bull Frame Canyons it appears to form layers within or at base of volcaniclastic rocks of Little Table Mountain; however, these exposures may be incorrectly mapped as interlayers in volcaniclastic rocks, and they may instead represent unconformable remnants on underlying rocks. Thickness of unit is 0–60 m

Tum **Unnamed megabreccia unit (upper Oligocene)**—Megabreccia characterized by common and distinctive well-rounded and polished boulders of light-gray densely welded rhyolitic ash-flow tuff 1–3 m in size, as well as larger blocks as long as 5 m of other volcanic rock types. Unit is generally a light-brown aggregate of poorly sorted materials ranging in size to as little as about 1 cm; fine-grained ash matrix is not evident. The one small exposure lies along east-central margin of the quadrangle. Unit is more widely distributed farther east in the Corcoran Canyon quadrangle

Megabreccia of Jefferson Summit (upper Oligocene)—Unit consists of two eruptive megabreccia phases (Tjsg and Tjss) and one intrusive phase (Tjsi). Intrusive phase is exposed in three pipelike bodies and a dike, presumed vents from which other phases were erupted. The proposed vents are filled with varied rock types. The most widespread eruptive phase (Tjsg), forming a tilted to nearly flat-lying outflow apron, consists mostly of clasts of granite of the Round Mountain pluton (Krg and related rocks) and minor amounts of other rocks. Within unit Tjsg locally are thin layers of sedimentary rocks (Tjsl). The other extrusive phase (Tjss), also a tilted layer, consists mostly of clasts of schist and quartzite of Gold Hill Formation (Ꞓgs and Ꞓgq)

Tjsi **Intrusive phase of vent megabreccia**—Three inferred pipes and a dike are filled with vent megabreccia. The largest pipe, crudely oval shaped and about 600 m long east-west and 300 m wide north-south, occupies an amphitheater-shaped enlargement of Grassy Canyon just west of Jefferson Summit. An intermediate pipe, 500 m long and 60–120 m wide, is exposed farther south on a spur on north slope of Bull Frame Mountain. The smallest pipe (about 220 m long and 60 m wide) crops out on another spur about 700 m to the northwest. The dike, still farther northwest, is 20–30 m wide through most of its length of about 1.5 km, is as much as 300 m wide at its northwest end, and tapers to a pinchout at its southeast end.

The largest pipe is filled with a mixture of extremely brecciated quartzite of Gold Hill Formation (Ꞓgq), in part consisting of blocks and slabs as long as 500 m along periphery of pipe, and blocks of strongly brecciated granite (Krg) as large as about 100 m elsewhere. A thin section of matrix of brecciated quartzite shows only pulverized quartzite. A thin section of matrix of brecciated granite shows about 50 percent granite fragments (less than 1 cm in size) in a groundmass of angular crystal fragments (1–2 mm long) that consist of: Q, 72; perthite, 4; P, 22; B, 0.6; O, 0.6; and muscovite, 0.6. Virtually all crystals are derived from granite; however, rare pumice-like fragments are present. Where exposed in Grassy Canyon, pipe appears to have a nearly vertical north wall against tuff of Mount Jefferson (Tmj) and altered tuff (Tmja). This pipe wall is about 100 m in vertical dimension, extending downward below overlying outflow apron of megabreccia (Tjsg).

The second pipe, on north spur of Bull Frame Mountain, is exposed on a relatively smooth slope unbroken by outcrops of unbrecciated granite that conspicuously surround pipe. Northeast end of pipe extends into schist of Gold Hill Formation (Ꞓgs) that forms wall of Round Mountain granite pluton. Strongly sheared and brecciated schist a meter or two wide lies adjacent and parallel to margin of pipe at its northeast end. Clusters of rounded to subrounded blocks 1–10 m in size of mostly coarse-grained granite, lesser amounts of aplite and fine-grained granite, and minor pegmatite occur locally across surface of pipe. Only rare individual blocks are themselves brecciated. In places mixed in with granite blocks are fragments of schist and quartzite of Gold Hill Formation (Ꞓgs and Ꞓgq), some of them brecciated. Matrix of megabreccia is nowhere evident. Two zones of chalcedony breccia (brecciated chalcedony in chalcedony matrix) 30–50 m in diameter within megabreccia pipe are interpreted as mineralized pipes. One zone occupies northeast end of megabreccia pipe and the other lies about 150 m south, near east margin of pipe. Both zones show multiple generations of chalcedony, and both zones contain thin (as wide as 30 cm) irregular veins of fluorite. Both zones also contain local anomalous amounts of gold, antimony, and mercury (Shawe, unpub. data, 1988).

The third and smallest pipe, exposed on a spur northwest of second pipe, is filled mostly with granite blocks 1–2 m in size. Some blocks are brecciated and iron mineralized. Rare fragments of schist of Gold Hill Formation (**Ꞓgs**) as large as 2 m are present.

The dike of megabreccia intrudes granite of Round Mountain pluton through most of its length; at its northwest end limestone and schist of Gold Hill Formation (**Ꞓgl** and **Ꞓgs**) form its wall rocks. The dike contains mostly rounded blocks 3–4 m in size that consist of various phases of granite (coarse and fine grained, and aplite) through intervals of 200–300 m along dike. Matrix of granite megabreccia, as seen in thin section, consists of pulverized granite minerals, angular crystal fragments, and granite fragments about a centimeter in size. In places, clasts of schist of Gold Hill Formation (**Ꞓgs**), of schist intruded by granite, and of greenish-gray andesite porphyry as long as 10 m, are common. Near northwest end of megabreccia dike, just west of Mogul Canyon where dike is about 200 m wide, a 50-m-long block of granite is surrounded by fragments of schist and andesite porphyry. A modal analysis of a sample of andesite porphyry shows 51 percent phenocrysts (1–7 mm in diameter) made up of the following phases: Q, 7; K, 2; P, 69; B, 10; O, 1.4; and C, 11. A chemical analysis of a clast of andesite porphyry from the dike shows the following percentages of components (recalculated without CaO attributable to calcite—based on CO_2 content of 3.84 percent—and other volatiles): SiO_2, 62.9; Al_2O_3, 15.4; K_2O, 2.49; Na_2O, 2.41; CaO, 2.42; Fe_2O_3, 3.20; FeO, 3.63; MgO, 6.59; TiO_2, 0.61; P_2O_5, 0.23; and MnO, 0.11 (andesite). Composition is quite similar to 36-Ma andesite (**Ta**) and granodiorite (**Tgd**) mapped in the Round Mountain quadrangle about 4 km farther west (Shawe, 1995). L.W. Snee (written commun., 1997) reported a biotite $^{40}Ar/^{39}Ar$ date of 33.18±0.06 Ma for an andesite fragment collected from dike (rock sample locality R6). Possibly a thermal event associated with emplacement of megabreccia dike (at approximately 26 Ma?) reset the date somewhat. I infer that an intrusion or intrusions of 36-Ma andesite porphyry underlie the megabreccia dike. About 400 m northwest of 50-m-long block of granite, an exposure of dike shows rounded fragments of andesite porphyry, granite, and aplite in a matrix of biotite-rich tuff. A rare fragment of light-yellowish-brown flow-layered rhyolite found near northwest end of megabreccia dike is quite similar to 36-Ma rhyolite (**Tr**) found in dikes and a plug about 3 km and farther west in the Round Mountain quadrangle (Shawe, 1995). As seen in thin section, rhyolite is nearly aphyric, containing rare crystals of quartz and biotite less than 0.5 mm long. Again, the megabreccia dike likely tapped a subsurface rhyolite dike during eruption

Tjsg **Eruptive phase of megabreccia containing mostly granitic clasts**—Blocks of granite in outflow megabreccia are mostly rounded to subrounded, 1–10 m in diameter; a 25-m-long brecciated granite block occurs 0.8 km north-northeast of Jefferson Summit. Blocks of schist and quartzite (**Ꞓgs** and **Ꞓgq**, respectively) are locally present, and they are abundant about 1.7 km north of Jefferson Summit. Only rare fragments of andesite porphyry were observed. Most of matrix of granite megabreccia as seen in thin section appears to be pulverized granite. A modal analysis of one sample shows about 57 percent granite fragments (to 1.5 cm in size) in a groundmass of broken crystals made up of: Q, 62; orthoclase, 1; P, 32; B, 5; and muscovite, 0.6. In cliffs exposed 200 m south of Jefferson Summit, matrix of megabreccia consists of layers of material having grain size about 0.1 mm, to layers having grain size of several millimeters, disposed as graded layers molded around adjacent clasts. As seen in thin section, most of the material is pulverized granite; however, sparse biotite microlites and sanidine, and rare shard forms, suggest a minor volcanic component. A chemical analysis of a portion of this matrix indicates the following percentages of components: SiO_2, 89.2; Al_2O_3, 7.19; K_2O, 1.75; Na_2O, O.43; CaO, 0.45; Fe_2O_3, 0.55; FeO, 0.04; MgO, 0.23; TiO_2, 0.15; P_2O_5, 0.06; and MnO, less than 0.01. High silica content suggests that mineral components other than quartz were winnowed from matrix prior to deposition. Two kilometers north of Jefferson Summit a layer of tuff that contains abundant granite fragments as large as about 15 cm long is exposed at base of megabreccia layer. A modal analysis of matrix of the tuff indicates lithic fragments as large as 8 mm composed of granite (21 percent of matrix), metasedimentary rocks (3 percent), and minor pumice. Phenocrysts 1–2 mm in diameter constitute about 10 percent of rock and consist of: Q, 47 (including abundant broken crystals likely derived from granite); K, 12 (one-fourth of which is sanidine); P, 36; B, 2.5; O, 1; and muscovite, 1. Monazite, apatite, and zircon are accessory minerals. Near southeast end of granite megabreccia outflow apron, matrix is light-greenish-brown to light-yellowish-brown tuff.

The granite megabreccia outflow apron, which spreads northwestward 4 km and northward 2 km from Jefferson Summit, forms a relatively flat unit, as indicated on cross sections *C–C'*, *D–D'*, *I–I'*, *J–J'*, and *L–L'*. It is warped upward at about 5°, north of Jefferson Summit, possibly as a result of resurgence of the Mount Jefferson caldera following emplacement of megabreccia. Unit dips 15° northward south of Jefferson Summit (section *L–L'*), and about the same amount eastward southeast of Jefferson Summit, perhaps in part reflecting ground slope at time of emplacement, or uplift of granite of Round Mountain pluton following emplacement. Unit appears conformable on underlying tuff of Mount Jefferson, and unconformable on underlying granite. Thickness 0–50 m

Tjsl **Siltstone, sandstone, and conglomerate (lacustrine)**—Thin evenly bedded layers of platy siltstone, slabby sandstone, and conglomerate are interlayered in granite megabreccia (Tjsg) near Jefferson Summit. Lacustrine siltstone also is exposed in one place at base of granite megabreccia 2 km north of Jefferson Summit. Individual beds of unit mostly are no more than about 10 cm thick. Buff siltstone in places displays oscillatory ripple marks characteristic of lacustrine sediments. Light-brown sandstone and conglomerate appear to consist chiefly of granite fragments; some conglomerate layers contain angular aplite fragments about 25 cm long. Aggregate thickness of layers, less than 10 m

Tjss **Eruptive phase of megabreccia with dominant schist and quartzite clasts**—Forms a layer conformably underlying eruptive phase of megabreccia containing mostly granite clasts (Tjsg), and unconformably overlying schist of Gold Hill Formation (Єgs), southeast of Jefferson Summit. Most fragments are schist and quartzite of Gold Hill Formation (Єgs and Єgq), are less than about 2–3 m in length, and commonly are brecciated. Fragments are rarely as long as about 10 m. Matrix was not observed. Granite fragments in small amounts occur in places, and a fragment of greenish-gray and gray laminated calc-silicate-mineralized limestone of Gold Hill Formation (Єglc) was observed in one place. Thickness about 25 m

Tuff of Mount Jefferson (upper Oligocene)—The tuff of Mount Jefferson constitutes a great thickness of intracaldera welded ash-flow tuff units, individual ash flows, and simple and compound cooling units, within the Mount Jefferson caldera, the south part of which occupies the north one-third of the Jefferson quadrangle. The intracaldera tuff of Mount Jefferson is at least about 2,000 m thick, judged from relief on exposed tuffs between Big Smoky Valley northwest of the quadrangle, and summit of Mount Jefferson just north of the quadrangle. In the Jefferson quadrangle I made sporadic unsuccesful attempts to map individual flows or cooling units, but these efforts were overcome by time limitations and rugged terrain of Mount Jefferson. I nevertheless show some mappable units, as detailed below, as well as some contacts between internal units, to better depict attitudes and configurations of units.

That part of the tuff of Mount Jefferson in the northeast corner of the map area, east of Soldier Spring fault, was previously designated tuff of Trail Canyon by Boden (1986; 1992), and considered by him to represent infill of a caldera (Trail Canyon) younger than the Mount Jefferson caldera. Data (petrographic, chemical, and radiometric) presented here show that the tuff of Trail Canyon is essentially identical to the tuff of Mount Jefferson; this conclusion is confirmed also by microprobe analyses of phenocrysts of the two units (Boden, 1994; F.M. Byers, Jr., written commun., 1995). A small amount of outflow facies of the tuff of Mount Jefferson, considered part of the principal member (Tmj), lies just south of the caldera margin.

Tuff of Mount Jefferson, as defined here, is composed of a thin upper member (Tmju), and a thick lower, principal, member (Tmj). The upper member is equivalent to the lower unit of a capping member of Boden (1992); the principal member is equivalent to Boden's (1992) upper member. Boden (1986, 1992) attributed an age of 25.8±0.5 Ma to 26.6±0.6 Ma to his upper member based on sanidine and biotite K/Ar dates; Boden's (1992) lower member, exposed in north part of the Mount Jefferson caldera, does not crop out but presumably underlies the principal member in the Jefferson quadrangle. Within the principal member, the following units are defined: vitrophyre (Tmjv), tuff breccia (Tmjb), altered welded ash-flow tuff (Tmja), and intensely sheared welded ash-flow tuff (Tmjs).

Modal analyses of a large number of samples of tuff of Mount Jefferson allowed assigning samples into five petrographic categories on the basis of phenocryst percentages. Assignments are based on generally increasing plagioclase and mafic mineral contents, and decreasing quartz and alkali feldspar contents, from category 1 to category 5. A "phenocryst index" (PI), determined by the sum of quartz plus alkali feldspar contents divided by the sum of plagioclase plus mafic minerals (biotite, hornblende, pyroxene, and opaque minerals) contents, allows assignment of modal data into five categories as follows: category 1, PI 0.81–1.00; category 2, PI 0.61–0.80; category 3, PI 0.41–0.60; category 4, PI 0.21–0.40; and category 5, PI 0.00–0.20. Tuffs of category 1 are generally low in the stratigraphic section, and tuffs with higher PI numbers are progressively higher in the section, although in places samples that do not fit this pattern may indicate local reversals in phenocryst compositions. Locations and category assignments of modally analysed samples are shown on the map

Tmju **Upper member**—Gray, moderately welded, crystal-rich rhyodacitic ash-flow tuff; weathers brown. Modal analyses of two samples of member indicate 29 and 38 percent phenocrysts (2–3 mm in diameter) made up of the following phases: Q, 3 and 5; K, 5 and 9; P, 72 and 67; B, 14 each; O, 3 and 2; H, 3 and 1; and C, 0.2 and 1. Zircon and apatite are common accessory minerals. Samples are included in petrographic category 5 of analyzed rocks of tuff of Mount Jefferson based on this petrography. Chemical analyses of the same two samples indicate the following percentages of components: SiO_2, 67.9 and 66.3; Al_2O_3, 16.1 and 16.6; K_2O, 4.27 and 4.09; Na_2O, 3.95 and 3.89; CaO, 2.78 and 3.20; Fe_2O_3, 2.73 and 3.08; FeO, 0.72 and 1.00; MgO, 0.73 and 1.02; TiO_2, 0.45 and 0.51; P_2O_5, 0.21 and 0.25; and MnO, 0.09 and 0.08 (trachydacite). Upper member is exposed as two small erosional remnants at north margin of the quadrangle, near summit of Mount Jefferson (which is just north of the quadrangle). A small patch of outflow facies of tuff of Mount Jefferson belonging to petrographic category 5 overlies megabreccia of Meadow Canyon (Tmc) south of Meadow Canyon. A modal analysis of a sample of this rock shows 34 percent phenocrysts (1.5–3 mm) that consist of the following phases: Q, 2; K, 9; P, 65; B, 16; O, 4; H, trace; and C, 2. Zircon and apatite are common accessory minerals. Remnant thickness 0–40 m

Tmj **Principal member**—Quartz latitic to rhyodacitic welded ash-flow tuff (petrographic categories 1–5). At north-central edge of the quadrangle, principal member underlies upper member (Tmju) conformably. However, in west-central part of the quadrangle, principal member underlies megabreccia of Jefferson Summit (Tjsg) conformably, and in northeast corner of the quadrangle, principal member unconformably underlies lowest unit of volcaniclastic rocks of Little Table Mountain (Tlt1). Apparently considerable erosion took place before later units (Tjsg and Tlt1) were deposited. L.W. Snee (written commun., 1997) reported sanidine $^{40}Ar/^{39}Ar$ dates of 26.61±0.05 (1σ) Ma (rock sample locality R3), 26.64±0.04 (1σ) Ma (locality R4), and 26.72±0.04 (1σ) Ma (locality R5), and a biotite $^{40}Ar/^{39}Ar$ date of 26.77±0.05 (1σ) Ma (locality R5) for samples of principal member. Rock samples R3 and R5, inferred to be from lower part of exposed principal member, were collected from zone of altered rock (Tmja) associated with plug of rhyolite (Trp) that intrudes principal member 0.7 km northeast of Jefferson Canyon in northwest part of the quadrangle. Rock sample R4 was collected from a stratigraphically higher part of the principal member. Possibly the determined younger date of sample R3, from lower (older) part of member, may have resulted from thermal resetting related to emplacement of a rhyolite plug (Trp). Several biotite and sanidine $^{40}Ar/^{39}Ar$ dates of samples collected in adjacent Corcoran Canyon quadrangle from principal member are about 26.6–26.9 Ma (L.W. Snee, written commun, 1996). About 500 m of principal member is exposed in the Jefferson quadrangle; base is not exposed.

Category 5 rocks—Light-lavender-gray, moderately welded, crystal-rich rhyodacitic ash-flow tuff; weathers brownish gray. Modal analyses of nine samples of this group indicate 24–36 percent phenocrysts (1–3 mm in diameter) consisting of the following phases: Q, 2–11; K, 4–11; P, 61–74; B, 12–16; O, 1–4; H, trace–3; and C, 1.5–5. Accessory minerals are common zircon, moderate apatite, and rare allanite. A chemical analysis of a sample of category 5 tuff indicates the following: SiO_2, 69.7; Al_2O_3, 15.4; K_2O, 4.66; Na_2O, 3.75; CaO, 2.20; Fe_2O_3, 2.24; FeO, 0.63; MgO, 0.77; TiO_2, 0.39; P_2O_5, 0.20; and MnO, 0.05 (rhyolite). Samples in category 5 are from relatively high stratigraphically in principal member.

Category 4 rocks—Very light gray to light-brownish-gray, partially to densely welded, crystal-rich rhyodacitic ash-flow tuff; weathers light brown to light orangish brown. Category 4 tuffs are massive to flaggy; spheroidally weathered in places. Modal analyses of 23 samples of this category indicate 15–44 percent phenocrysts (1.5–3 mm in diameter) consisting of the following phases: Q, 3–16; K, 7–23; P, 53–68; B, 5–20; O, 0.2–5; H, 0–5; and C, trace–7. Accessory minerals are common zircon, moderate apatite, and rare allanite. Tuff is strongly magnetic in a few places. Samples of category 4 occur generally in middle to upper parts of exposed principal member.

Category 3 rocks—Light-gray, light-lavender-gray, and light-olive-gray, partially to densely welded, crystal-poor to crystal-rich rhyodacitic ash-flow tuff; weathers brownish gray, olive gray, and reddish brown. Massive to platy; spheroidally weathered in places. Modal analyses of 13 samples of this category indicate 9–41 percent phenocrysts (2–4 mm in diameter) of the following phases: Q, 7–18; K, 15–25; P, 46–55; B, 6–15; O, 0.5–3; H, 0–6; and C, trace–2. Accessory minerals are common zircon and apatite, and rare allanite. Tuff is strongly magnetic in a few places. Samples in category 3 occur generally in middle to upper parts of exposed principal member. Outflow facies of tuff of Mount Jefferson along Meadow Creek, similar to category 3 samples, is light-yellowish-brown, pumice-rich, nonwelded to partially welded, crystal-rich rhyodacitic ash-flow tuff; weathers light brown. Modal analysis of one sample from upper part of outflow facies indicates 29 percent phenocrysts (2–3 mm in diameter) that consist of the following phases: Q, 10; K, 20; P, 53; B, 13; O, 2; and M, 1.5. Common zircon and sparse apatite are accessory minerals. Chemical analysis of one sample of category 3 tuff indicates the following composition: SiO_2, 70.0; Al_2O_3, 15.2; K_2O, 4.65; Na_2O, 3.87; CaO, 2.14; Fe_2O_3, 2.02; FeO, 0.72; MgO, 0.79; TiO_2, 0.37; P_2O_5, 0.18; and MnO, 0.07 (rhyolite).

Category 2 rocks—Light-gray, light-lavender-gray, and to light-pinkish-gray, partially to densely welded, crystal-rich rhyodacitic to quartz-latitic ash-flow tuff; weathers light brown, light orangish brown, and reddish brown. Modal analyses of five samples of category 2 tuffs indicate 22–39 percent phenocrysts (2–5 mm in diameter) made up of the following phases: Q, 15–24; K, 16–27; P, 46–48; B, 6–10; O, 1–3; H, 0–2; and C, trace–2. Common zircon, sparse to common apatite, and rare allanite are accessory minerals. Modal analysis of a sample from lower part of outflow facies indicates 30 percent phenocrysts (3–5 mm) that consist of the following phases: Q, 11; K, 29; P, 49; B, 8; and O, 2; abundant zircon and sparse sphene are accessory minerals. Chemical analyses of two samples of category 2 tuff show the following compositions: SiO_2, 70.9 and 71.5; Al_2O_3, 15.0 and 15.1; K_2O, 4.96 and 4.36; Na_2O, 3.39 and 3.32; CaO, 1.87 and 1.93; Fe_2O_3, 2.14 and 2.38; FeO, 0.36 and 0.25; MgO, 0.77 and 0.62; TiO_2, 0.33 and 0.36; P_2O_5, 0.17

each; and MnO, 0.06 and 0.02 (rhyolite). Category 2 tuffs occur mostly in middle and lower parts of exposed principal member of tuff of Mount Jefferson.

Category 1 rocks—Light-gray, light-lavender-gray, and light-pinkish-gray, moderately to densely welded, crystal-rich rhyolitic to quartz-latitic ash-flow tuff; weathers light brown, light orangish brown, and reddish brown. Tuff contains abundant flattened pumice lapilli as long as 3 cm in some layers. In places contains abundant lithic fragments of metasedimentary rocks, rhyolite, and intermediate volcanic rocks as much as 2 cm long, and small noncompacted pale-yellowish-brown pumice fragments. Mostly massive and locally spheroidally weathered. Modal analysis of one sample of category 1 tuff shows 34 percent phenocrysts (2.5–4 mm in diameter) that consist of the following phases: Q, 22; K, 28; P, 38; B, 7; O, 2; H, 2.5; and C, trace. Accessory minerals are zircon and apatite. A modal analysis of a crystal-poor sample of a thin (a few meters) ash-fall tuff layer stratigraphically one-third of the way above exposed base of principal member in northwest part of the quadrangle indicates 8 percent phenocrysts (1–1.5 mm) that consist of: Q, 19; K, 27; P, 47; B, 4; O, 1; H, 2; and C(?), 0.5. Chemical analysis of the same sample of category 1 tuff shows the following composition: SiO_2, 74.2; Al_2O_3, 13.7; K_2O, 4.86; Na_2O, 2.66; CaO, 1.47; Fe_2O_3, 2.00; FeO, 0.13; MgO, 0.56; TiO_2, 0.24; P_2O_5, 0.10; and MnO, 0.01 (rhyolite). The two samples identified as category 1 tuff appear to be in lower part of exposed principal member

Tmjv **Vitrophyre**—Dark-gray to black, glassy, partially to densely welded rhyodacitic ash-flow tuff. Lenticular layers of vitrophyre 0–30 m thick occur sporadically throughout principal member (Tmj). They were mapped in zones identified by modal analyses as belonging to categories 1, 3, 4, and 5.

Category 5 rocks—Modal analysis of one sample of crystal-rich vitrophyre indicates 30 percent phenocrysts (1.5–2 mm) that consist of: Q, 4; K, 8; P, 66; B, 14; O, 2; H, 4; and C, 2. Zircon and apatite are accessory minerals. A chemical analysis of the same sample indicates the following composition: SiO_2, 67.1; Al_2O_3, 16.3; K_2O, 3.60; Na_2O, 4.17; CaO, 3.09; Fe_2O_3, 2.78; FeO, 1.02; MgO, 1.15; TiO_2, 0.48; P_2O_5, 0.24; and MnO, 0.09 (trachydacite-dacite).

Category 4 rocks—Modal analyses of four samples of crystal-rich vitrophyre show 25–34 percent phenocrysts (2–3.5 mm in diameter) that consist of the following phases: Q, 6–9; K, 12–16; P, 55–60; B, 12–17; O, 2–3; H, 2–3; and C, 1–3. Zircon and apatite are common accessory minerals, and allanite is a sparse accessory mineral. Chemical analysis of one sample of category 4 vitrophyre indicates the following percentages of components: SiO_2, 68.6; Al_2O_3, 15.8; K_2O, 4.49; Na_2O, 3.76; CaO, 2.63; Fe_2O_3, 2.24; FeO, 0.83; MgO, 0.97; TiO_2, 0.41; P_2O_5, 0.21; and MnO, 0.09 (trachydacite).

Category 3 rocks—A modal analysis of a sample of crystal-poor vitrophyre indicates 9 percent phenocrysts (1–1.5 mm in diameter) made up of the following phases: Q, 18; K, 18; P, 56; B, 6; O, 0.5; H, 0.5; and C, 1. Zircon is a common accessory mineral, and apatite and allanite are sparse. Unusually, a sparse amount of white mica is present. A chemical analysis of the same sample indicates: SiO_2, 77.4; $Al_2 0_3$, 11.7; K_2O, 8.09; Na_2O, 0.75; CaO, 0.46; Fe_2O_3, 0.69; FeO, 0.23; MgO, 0.35; TiO_2, 0.23; P_2O_5, 0.12; and MnO, 0.02 (rhyolite). Presence of white mica and the unusually high silica content of this sample suggest possible contamination of the vitrophyre by granitic material.

Category 1 rocks—A modal analysis of a sample of crystal-rich vitrophyre indicates 35 percent phenocrysts (2–4.5 mm in diameter) that consist of the following phases: Q, 30; K, 18; P, 45; B, 6; and M, 1.5. Zircon and apatite are accessory minerals. A chemical analysis of the same sample indicates: SiO_2, 73.4; Al_2O_3, 14.6; K_2O, 4.45; Na_2O, 3.62; CaO, 1.55; Fe_2O_3, 0.83; FeO, 0.64; MgO, 0.43; TiO_2, 0.28; P_2O_5, 0.12; and MnO, 0.05 (rhyolite)

Tmjb **Tuff breccia**—Welded ash-flow tuff containing abundant fragments chiefly of Paleozoic rocks and granite; fragments are mostly 20 cm and less in size. Occurs as a layer within sequence of tuffs that constitute the Mount Jefferson caldera fill. Exposed for about 700 m along the margin of the caldera south of Jefferson

Canyon and about 2 km from the west boundary of the quadrangle. Thickness is a few meters

Tmja **Altered ash-flow tuff**—Light-yellowish-brown to light-brown, locally iron-stained, strongly altered, welded ash-flow tuff of principal member (close stipple on map), and light-yellowish- to light-greenish-brown and light-greenish-gray, moderately altered, welded ash-flow tuff of principal member (open stipple on map). Strongly altered tuff as seen in thin section is characterized by ramifying veinlets of quartz, chalcedony, and calcite, by sericitized and calcite-replaced feldspars, and by strongly devitrified groundmass, commonly partially silicified and pyritized. Moderately altered tuff as seen in thin section is characterized by sericitized and chloritized biotite, by sericitized and calcite-replaced feldspars, and by partially silicified and chloritized groundmass. Strongly altered tuff forms a halo surrounding rhyolite plug (Trp) in Wild Horse Canyon, a zone about 100 m wide along north margin of rhyolite plug and spreading south a kilometer and more to fault that bounds southwest margin of the Mount Jefferson caldera. Most of the mineralized rock in the Jefferson mining district that lies within the caldera is within strongly altered tuff. Moderately altered tuff forms an irregular zone extending northwest and southeast beyond strongly altered tuff, and lying adjacent to structural margin of caldera

Tmjs **Intensely sheared ash-flow tuff**—Olive-gray, welded ash-flow tuff. Forms two crudely oval-shaped zones marked by intensely sheared tuff in north-central part of the quadrangle. The larger zone, about 1.5 km × 2.5 km within the quadrangle, is bisected by Slaughterhouse Canyon; the smaller zone, about 0.5 km × 1.5 km, is bisected by Sawmill Canyon. Probably the canyons were localized within sheared zones because of greater susceptibility of weakened rock to erosion. Sheared tuff is characterized by numerous steeply dipping anastomosing shear planes, spaced 1–3 cm apart. Sheared zones are interpreted to have resulted from a pistonlike, differential uplift of the zones by emplacement of igneous plugs at depth (see cross section *A–A'*). Shears generally are oriented at a high angle to originally subhorizontal compaction foliation. Therefore, local divergence of shear planes from nearly vertical may indicate tilting of tuff layers because of intrusion of plugs. Unit contacts mapped elsewhere in tuff of Mount Jefferson appear to have been obliterated within sheared zones

Tac **Tuff of Antone Canyon (upper Oligocene)**—Light-greenish-gray to whitish-gray, lithic-, pumice-, and crystal-rich, nonwelded rhyolitic ash-flow tuff; weathers pale yellowish brown to pale yellowish gray. Abundant (about 15 percent) poorly compacted, pale-yellowish-brown pumice lapilli (as much as 1 cm long) are present. Unit contains abundant lithic fragments, mostly of Paleozoic formations, as much as 5 cm long, locally larger; and in places it contains huge isolated blocks and slabs as much as 200 m long of Ordovician limestone (Ol), silicified limestone (Ols), and schist (Os), quartzite of Cambrian Gold Hill Formation (€gq), and Cambrian Mayflower Formation (€mf). A few large fragments of rhyolitic welded ash-flow tuff (Trc?) and rhyolite lava also are present. The large blocks, each monolithologic, commonly are strongly brecciated. Modal analyses of three samples of tuff indicate 19–20 percent phenocrysts (2–3 mm in diameter) composed of the following phases: Q, 28–31; K, 28–32; P, 31–36; B, 6 each; and M, 0.5–1.5. Zircon and allanite are common accessory minerals, and apatite is sparse. The tuff of Antone Canyon is exposed in an area about 1 km × 2 km along Antone and Round Meadow Canyons where they enter Meadow Canyon. Unit unconformably underlies outflow facies of tuff of Mount Jefferson (Tmj), intertongues with megabreccia of Meadow Canyon (Tmc) and tuff of Ryecroft Canyon (Trc) (see cross sections *E–E'* and *F–F'*), and unconformably overlies Paleozoic formations. Tuff that forms tongues into megabreccia is partially welded in places. Maximum thickness of unit about 150 m.

Although tuff of Antone Canyon has a phenocryst content similar to that of tuff of Ryecroft Canyon, and as described below the two units are of comparable age, the units are petrologically dissimilar, inasmuch as the Antone Canyon is generally nonwelded and contains large blocks of foreign materials whereas the Ryecroft Canyon is variously welded and is devoid of large blocks of foreign materials. Possibly tuff of Antone Canyon is an aberrant part of tuff of Ryecroft Canyon

Tmc **Megabreccia of Meadow Canyon (upper Oligocene)**—Eruptive megabreccia consisting of small to huge, either slablike or rounded clasts (1 m to more than 100 m long, commonly brecciated) chiefly of welded ash-flow tuff and other volcanic rocks, in a nonwelded to partially welded ash-flow tuff matrix. [Much of the megabreccia of Meadow Canyon is within the Corcoran Canyon quadrangle east of the Jefferson quadrangle.]

Matrix of megabreccia is pale-greenish- to pale-yellowish-brown and light-greenish- to light-yellowish-brown, nonwelded to partially welded, mostly structureless, crystal-rich rhyolitic ash-flow tuff. Modal analyses of two samples of matrix show 19–28 percent phenocrysts (2–5 mm in diameter) that consist of: Q, 26–33; K, 28–37; P, 31–32; B, 3–6; and M, 1–3. Accessory minerals are common zircon and sparse allanite and apatite. These samples are similar in phenocryst composition to tuff of Ryecroft Canyon (Trc) described below. A third sample of matrix contains 24 percent phenocrysts (2–3 mm in diameter) that consist of: Q, 13; K, 30; P, 49; B, 8; and M, 1. Accessory minerals are common zircon and sparse apatite and allanite. This sample is similar in phenocryst composition to category 2 samples of tuff of Mount Jefferson (Tmj). Inasmuch as ages of tuff of Mount Jefferson and tuff of Ryecroft Canyon are comparable in part, this sample may represent intermixing of tuff of Mount Jefferson during deposition of megabreccia of Meadow Canyon.

Large blocks in central part of megabreccia, in an area about 1 km^2 on northeast side of Meadow Canyon, are mostly slablike, and stand vertically in surrounding ash-flow tuff matrix. Their upright attitudes suggest a significant component of vertical movement in their emplacement, perhaps resulting from eruption through a conduit underlying the area. Presence of rhyolite plugs (Trp) in Meadow Canyon on margins of this area indicates conduits penetrating deep into the crust, and suggests a zone of weakness where eruption of megabreccia was facilitated. Many large blocks elswhere in megabreccia are strongly brecciated and rounded, and some are noticeably smoothed or polished as though abraded during transport in ash flow during emplacement. In places unbrecciated blocks sit side by side with extremely brecciated but indurated blocks, suggesting that the mechanism of brecciation was not by transport in ash flow. Evidently brecciated blocks were brecciated and indurated prior to incorporation into ash flow.

Modal analyses of three samples of clasts of moderately welded rhyolitic ash-flow tuff within megabreccia indicate 21–34 percent phenocrysts (1.5–7 mm in diameter) that consist of the following phases: Q, 23–31; K, 22–34; P, 38–41; B, 4–5; and M (O and H), 1–3. Common zircon and minor apatite are accessory minerals. These modes are quite similar to those of tuff of Ryecroft Canyon (Trc). A chemical analysis of a sample of one of these clasts indicates the following composition: SiO_2, 75.7; Al_2O_3, 13.4; K_2O, 5.69; Na_2O, 2.91; CaO, 0.75; Fe_2O_3, 0.66; FeO, 0.36; MgO, 0.30; TiO_2, 0.13; P_2O_5, 0.08; and MnO, 0.04 (rhyolite). Modal analyses of two samples of clasts of autobrecciated rhyolite show 19 and 25 percent phenocrysts (4–7 mm in diameter) made up of: Q, 29 and 22; K, 30 each; P, 36 and 41; B, 5 each; and 0, 1 each. Zircon is an accessory mineral. These modes also are similar to those of tuff of Ryecroft Canyon. A clast of rhyolitic ash-fall(?) tuff contains about 12 percent phenocrysts (1.5–3 mm in diameter) and has the following modal composition: Q, 39; K, 38;, P, 13; B, 9, and M, 1. Zircon and apatite are accessory minerals. A quartz latite lava clast contains 25 percent phenocrysts (3–10 mm in diameter) that consist of: Q, 11; K, 44; P, 39; B, 5; O, 1; and M, 0.5. Accessory minerals are zircon and apatite. A modal analysis of a sample of a clast of nonwelded rhyodacitic ash-flow(?) tuff indicates 12 percent phenocrysts (2 mm in diameter) consisting of: Q, 9; K, 15; P, 59; B, 11; O, 1.5; and H, 5. Zircon, apatite, and monazite(?) are accessory minerals. A rhyodacitic lava clast contains 19 percent phenocrysts (2–4 mm in diameter) that consist of: Q, 2; K, 7; P, 78; B, 9; O, 1.5; and M, 2. Zircon and sparse apatite are accessory minerals. These last two samples are similar in modal composition to upper member of tuff of Mount Jefferson (Tmju).

Complex relations of the megabreccia formation to adjacent and internal units are illustrated in cross sections *E–E'*, *F–F'*, *N–N'*, and *P–P'*. Main part of megabreccia formation within the quadrangle along Meadow Canyon is structureless. Stratigraphically higher in formation and to the west, megabreccia is distinctly layered, and to the northwest and southwest it intertongues with tuff of Antone Canyon (Tac). A unit (Tmcp) in west part of megabreccia formation is dominated by large fragments of Paleozoic rocks, and it is described separately below. Thin layers of sedimentary material (Tmcs) are associated with megabreccia formation at east margin of the quadrangle. A unit of bedded tuffaceous siltstone and sandstone overlies heterolithic breccia (Thb) and in turn is overlain by a layer of megabreccia of Meadow Canyon just north of a rhyolite plug (Trp) in Meadow Canyon. A layer of gravel consisting of mostly rounded fragments as large as small boulders (made up of Paleozoic quartzite, chert, limestone, and silicified shale and limestone, as well as Tertiary welded ash-flow tuff and vitrophyre) lies at base of megabreccia of Meadow Canyon 600 m south of Meadow Canyon. Thin lenses of welded ash-flow tuff of Ryecroft Canyon (Trc) lie at or near base of megabreccia formation near mouth of Antone Canyon, and an erosional remnant of tuff of Ryecroft Canyon (Trc) lies on megabreccia formation about 0.8 km northeast of mouth of Antone Canyon. At the margin of the Jefferson quadrangle about 3 km farther south, megabreccia of Meadow Canyon overlies a thick section of tuff of Ryecroft Canyon (Trc), and it is in turn overlain by tuff of Ryecroft Canyon. About 1.3 km south of mouth of Antone Canyon, a remnant of megabreccia overlies mesobreccia with abundant fragments of Paleozoic rocks (Tpm). Where eruptive megabreccia is interpreted to be outflow, it is as much as 100 m thick; in the vicinity of interpreted vent area, formation has a relief of as much as 200 m.

Affinity of megabreccia of Meadow Canyon to tuff of Ryecroft Canyon (Trc) is clear. Because the megabreccia is significantly different petrologically, however, it is described separately. Tuff of Antone Canyon (Tac), tuff of Ryecroft Canyon (Trc), and megabreccia are of comparable age and appear to be related genetically

Tmcp **Megabreccia with abundant Paleozoic rock clasts**—Clasts of a variety of lithologies derived from Paleozoic formations, including shale or slate, phyllitic shale, silicified argillite, limestone, schist, and quartzite, mostly strongly brecciated and indurated. Clasts are as much as 2–3 m in size, as much as tens of meters long locally, and occur in a matrix of pale-greenish- to pale-yellowish-brown, pumiceous, nonwelded or only slightly welded ash-flow tuff. Contains a few well-rounded, densely welded rhyolitic tuff and lava fragments as large as a few meters in diameter. One large phyllitic shale clast about 50 m long, located just below the point of a spur about 400 m south of the confluence of Antone and Meadow Creeks, exhibits thin fingers of tuff penetrating its margins along irregular fractures; block is thoroughly brecciated, but bedding layers have crude continuity through block. These features, not observed in megabreccia blocks elsewhere in the quadrangle, are suggestive of collapse of block into ash-flow tuff during eruption of ash flow, and commensurate partial disaggregation of block. Lack of such features in other megabreccia blocks has led me to doubt a collapse origin of most megabreccias mapped in the Jefferson quadrangle

Tmcs **Tuffaceous sandstone**—Light-yellowish-brown tuffaceous sandstone forms a layer 3–10 m thick that lies on top of heterolithic breccia (Thb) that surrounds rhyolite plug (Trp) in Meadow Canyon at east margin of the quadrangle. Where tuffaceous sandstone is thickest (in adjacent Corcoran Canyon quadrangle) if fills a deep channel in underlying heterolithic breccia. Sandstone displays bedding locally that is suggestive of fluvial deposition. Unit is capped by a thin layer of megabreccia of Meadow Canyon (Tmc)

Trc **Tuff of Ryecroft Canyon (upper Oligocene)**—Light-gray, light-yellowish-brown to light-yellowish-gray, and light-lavender-gray, moderately to densely welded, crystal-rich rhyolitic ash-flow tuff. Weathers light pinkish brown, light grayish brown, light orangish brown, and light brown. Unit contains common flattened pale-yellowish-brown pumice lapilli as long as 5 cm, and in places small lithic fragments of Paleozoic and volcanic rocks. Where tuff is vitrophryic, pumice fragments are black glass. Tuff is strongly magnetic in some places. Modal analyses of 10 samples of tuff of Ryecroft Canyon indicate 22–35 percent phenocrysts (2–4 mm in diameter) made up of the following phases: Q, 21–30; K, 23–35; P, 32–42; B, 4–8; O, 0.5–2; and H, trace–3. Zircon is a common accessory mineral, and allanite, monazite, and apatite are less common. Chemical analyses of three samples of tuff indicate the following ranges in compositions: SiO_2, 73.2–73.4; Al_2O_3, 14.1–14.2; K_2O, 4.68–4.75; Na_2O, 3.46–3.60; CaO, 1.44–1.60; Fe_2O_3, 1.51–1.64; FeO, 0.29–0.36; MgO, 0.37–0.41; TiO_2, 0.28–0.30; P_2O_5, 0.13–0.14; and MnO, 0.04–0.07 (rhyolite). Lower part of tuff of Ryecroft Canyon crops out in roughly 120 m of exposure in Ryecroft Canyon in southeast corner of the quadrangle. There the tuff is overlain nearly conformably by a 30-m-thick layer of megabreccia of Meadow Canyon (Tmc), which in turn is overlain by a nearly conformable 60-m-thick layer of Ryecroft Canyon. Also, a thin lens of Ryecroft Canyon lies at base of megabreccia of Meadow Canyon at confluence of Antone and Meadow Canyons, and a small erosional remnant of Ryecroft Canyon lies on top of megabreccia about 600 m to the northeast.

Tuff of Ryecroft Canyon was named by Boden (1986, 1992) for exposures in the canyon of that name; he considered it to be substantially younger than tuff of Mount Jefferson (Boden, 1986, 1992). A $^{40}Ar/^{39}Ar$ date on sanidine from a sample I collected from tuff of Ryecroft Canyon in adjacent Corcoran Canyon quadrangle, about 2 km from quadrangle boundary, is 26.82±0.04 (1σ) Ma (L.W. Snee, written commun., 1996). This date is within the range of dates determined for tuff of Mount Jefferson by Boden (1992) and as given in this report; the two formations in part are equivalent in age

Tjc **Megabreccia of Jefferson Canyon (lower? Oligocene)**—A small area of megabreccia of Jefferson Canyon extends into the quadrangle from adjacent Round Mountain quadrangle to the west, 600 m south of Jefferson Canyon. Unit was described by Shawe (1995). Boden (1986) assigned a K-Ar date of 32.3±0.7 Ma (biotite) to unit, and L.W. Snee (written commun., 1997) determined a $^{40}Ar/^{39}Ar$ date of 32.56±0.07 Ma (biotite) for a sample of vitrophyre I collected in the Round Mountain quadrangle. However, I have pointed out considerable contamination by granitic material in vitrophyric rocks analyzed, and I have considered unit to be related to tuff of Mount Jefferson (Tmj), and age of unit to be about 27 Ma (Shawe, 1995).

A small (50 × 80 m) pluglike body of breccia that intrudes tuff of Mount Jefferson (Tmj) 300 m southwest of Jefferson Canyon and 1.7 km from west boundary of the quadrangle contains granite fragments as large as 2 m in diameter, and minor small (a few centimeters in diameter) fragments of Paleozoic rocks in tuff matrix. Tuff of Mount Jefferson near the pluglike body is brecciated and quartz veined

Tgd **Granodiorite of Dry Canyon (lower Oligocene)**—Presence of a subsurface stock inferred from abundant andesite porphyry clasts of similar composition in a megabreccia dike (Tjsi), as shown only on cross section *J–J'*. Shawe (1995) described the 36-Ma granodiorite of Dry Canyon as exposed in Round Mountain quadrangle west of Jefferson quadrangle

Tr **Rhyolite dikes and plug (early Oligocene)**—Light-gray, nearly aphyric to sparsely porphyritic, flow-layered rhyolite; weathers light yellowish brown. Two thin dikes a few meters thick occur at west margin of the quadrangle, one near southwest corner of the quadrangle, and a second extending into northwest part of the quadrangle 1 km south of Jefferson Canyon. A modal analysis of a sample of first dike indicates about 1 percent phenocrysts (1 mm in diameter) composed of the following phases: Q, 13; K, 54; P, 24; B, 6, and O, 3. A small plug about 100 m in diameter lies near the quadrangle boundary about 700 m south of Jefferson Canyon. A modal analysis of a sample of the plug, which is hydrothermally altered, shows about 16 percent phenocrysts (2–5 mm in diameter) consisting of 13 percent quartz, 84 percent altered feldspars, 2.5 percent mafic psuedomorphs, and 0.6

percent opaque oxide minerals. Accessory minerals are sparse zircon and rare apatite. Rhyolite dikes and plug are part of a group of rhyolite intrusions in adjacent Round Mountain quadrangle that are about 36 Ma (Shawe, 1995)

Granite of Shoshone Mountain (Late Cretaceous)—Mostly coarse-grained two-mica granite that forms two large oval-shaped plutons, Round Mountain pluton which is half in east part of adjacent Round Mountain quadrangle (Shawe, 1995) and half in west part of the Jefferson quadrangle, and Belmont pluton which is mostly in north part of adjacent Belmont West quadrangle and partly in south part of the Jefferson quadrangle.

The Round Mountain and Belmont plutons appear to have been emplaced as flat-topped intrusions that, several million years following solidification, were domed by rise of granitic magma from a deeper level. The Belmont pluton differentiated into layered phases while its roof was still nearly horizontal. Possibly the plutons were emplaced initially as thick sill-like bodies at a crustal level where magma pressure was sufficient to raise overlying rocks. As mentioned in the description of the megabreccia of Jefferson Summit as well as in a later section, the Round Mountain pluton was intruded by Tertiary megabreccia bodies that brought schist from a deeper level, suggesting that the pluton was bottomed in part on schist

Belmont pluton—The Belmont pluton consists of several intrusive bodies and rock types, including a core of coarse-grained two-mica granite that is not exposed in this quadrangle but is exposed in the Belmont West quadrangle (see Kgb of Shawe, 1998). Coarse-grained granite grades outward into sparsely porphyritic granite (Kbgs) that in turn grades outward into porphyritic granite (Kbgp). These differentiated phases form an oval-shaped, domed pluton whose long axis strikes northwest; pluton is exposed in southwest and south-central parts of the quadrangle. Porphyritic outer shell of pluton (Kbgp) is widely intruded by irregular masses to dikelike bodies of fine-grained granite (Kbgf), and aplite dikes (Kba), some of which penetrate into adjoining wall rocks. Some bodies of intermixed aplite and fine-grained granite are labeled Kbgf-Kba. Thin-section examination shows that plagioclase and potassium feldspars have sharply defined optical properties in places in some rock types, but elsewhere feldspar crystals intergrade in complex ways, as for example where individual crystals are composed of patches of different feldspars, and where feldspars appear indistinct and ragged with only faint evidence of twinning. A few small pipes of quartz and feldspar (Kbq) were recognized in sparsely porphyritic granite near southwest corner of map area. Thin quartz veins are locally abundant in pluton. Emplacement age of Belmont pluton, based on Rb-Sr whole-rock data (John and Robinson, 1989), is 84.5±3.4 Ma (average of two isochrons). As described by Shawe and others (1986, 1987) and by John and Robinson (1989), the seven biotite and muscovite K-Ar ages of 80–82 Ma for the Belmont pluton (see John and Robinson, 1989, for references) reflect an episode of later doming, metamorphism, and mineralization of pluton.

The Belmont pluton is foliated parallel to its contact in the outer shell of porphyritic granite (Kbgp), and otherwise shows only sparse steep, northwest-striking, postmetamorphic shears probably related to strike-slip deformation at the northeast margin of the northwest-striking Walker Lane tectonic zone, a structural "lane" that has been dominated by right-lateral deformation since late Mesozoic time. A thin zone of northeast-dipping mylonite in porphyritic granite is projected into the quadrangle from the northeast corner of the Belmont West quadrangle south of the Jefferson quadrangle (Shawe, 1998)

Kbq **Quartz-feldspar pipes**—Several quartz and quartz-feldspar pipes occur in granite (Kbgs) in southwest corner of map area. A quartz pipe 3 m in diameter is about 200 m from west boundary and 350 m from south boundary of map area. Another pipe about 400 m north of south boundary of the quadrangle consists of a barren, massive, white quartz core about 5 m in diameter surrounded by a shell 1–2 m wide of pale-yellowish-brown myrmekitic feldspar containing local patches of coarse-grained muscovite. Nearby are two smaller similar pipes (not shown). Two other pipes (shown as one location on map), about 800 m northeast of these pipes and about 7 m from each other, each consists of a core of barren white quartz 5 m in diameter surrounded by a shell of pale-yellowish-brown, coarse-grained myrmekitic feldspar. This myrmekite, as observed under the microscope, consists of perthitic microcline that contains abundant subparallel, anastomosing lenses and layers, 1–3 mm wide, of quartz, and scattered small flakes of muscovite. A late 1-mm-wide veinlet of biotite, muscovite, and fluorite cuts quartz lenses and layers. I think the pipes formed as a result of late-stage crystallization of magma at a deeper level, which resulted in upward streaming of volatile components that precipitated quartz, feldspar, muscovite, and minor biotite and fluorite in zoned cylindrical bodies

Kba **Aplite**—Pale-gray to pale-yellowish-brown, leucocratic aplite. Forms dikes intruding granite, and sills and dikes that intrude or form apophyses into Paleozoic metasedimentary wall rocks. Pods of quartz and pegmatite occur locally in aplite. Aplite is varied in composition. A modal analysis of a sample from a zone of intermixed fine-grained granite and aplite (Kbgf-Kba) in southeast corner of the quadrangle indicates about 48 percent quartz, 27 percent potassium feldspar (80 percent orthoclase and 20 percent microcline), 23 percent plagioclase, 2 percent hornblende, and about 0.5 percent opaque mineral and 0.5 percent monazite. Traces of zircon and apatite are present. Aplite has a granophyric texture; grain size is 1.5 mm and less. Monazite appears as tiny pinkish grains in hand specimen. A modal analysis of a second sample of aplite from a similar setting in southwest part of the quadrangle indicates about 34 percent quartz, 34 percent orthoclase (virtually no microcline), 30 percent plagioclase, 1 percent biotite, 1 percent muscovite, and trace amounts of opaque mineral, monazite, and zircon. This rock also has a granophyric texture, grain size 0.1–1 mm.

One pegmatitic zone in aplite in southeast corner of map area contains amazonite and several unidentified minor pegmatite minerals (location labeled “A”)

Kbgf **Fine-grained granite**—Pale-gray to pale-yellowish-brown, fine- to medium-grained granite. Commonly leucocratic or alaskitic (nearly white). Rock has a granophyric texture; crystals are as large as 2–4 mm. One modal analysis indicates: Q, 34; K (virtually all orthoclase and very little microcline), 30; P, 33 (in part myrmekite); B, 2.5; O, 0.2; and muscovite, 0.2. Apatite, zircon, and monazite are trace accessory minerals. Forms irregular masses, dikes, and sills a few meters to a kilometer or more across intruded into porphyritic granite (Kbgp) and Paleozoic wall rocks near pluton margin in south part of the quadrangle. In some areas, unit was mapped as fine-grained granite where remnants of pophyritic granite have been intricately invaded by fine-grained granite. In other places, masses of fine- and medium-grained granite and aplite (Kbgf-Kba) were mapped together. Near mineralized zones at margin of Belmont pluton, these rocks are altered to clay, sericite, and iron minerals, but were not mapped separately

Kbgp **Porphyritic granite**—Light-gray, coarse-grained granite. Contains about 15 percent or more large phenocrysts of orthoclase and (or) microcline 2–10 cm long. Locally phenocrysts form closely spaced masses. In one locality near quartz-feldspar pipes (Kbq) I observed nearly vertical trains of phenocrysts in coarse-grained granite. Rock has a hypidiomorphic-granular texture; locally it shows mortar structure. Orthoclase poikilitically encloses quartz and other feldspars in places. Muscovite commonly partially replaces biotite and plagioclase. Zircon and apatite are common accessory minerals. In several places in north part of Belmont pluton, porphyritic granite is altered to clay, sericite, and iron minerals, but was not mapped separately

Kbgs **Sparsely porphyritic granite**—Pale-gray to pale-yellowish-brown, coarse-grained, two-mica granite. Contains 0 to about 15 percent large phenocrysts 1–8 cm long of orthoclase or microcline. Phenocrysts 1–2 cm long are more abundant than in porphyritic granite (Kbgp), and phenocrysts 8 cm long are less abundant. Rock has a hypidiomorphic-granular texture. Mineral composition of rock in the Belmont West quadrangle just south of the Jefferson quadrangle was described by Shawe (1998). A sample of hydrothermally altered rock collected south of mineralized area near Barcelona Summit, as seen in thin section, is silicified and pyritized. Plagioclase crystals are extensively silicified and partially replaced by sericite, biotite margins are replaced by muscovite, and sparse fluorite blebs are scattered throughout. Sparsely porphyritic granite forms an annular shell 1–2 km wide in outcrop pattern within peripheral porphyritic granite shell (Kbgp) that surrounds pluton

Round Mountain pluton—Pluton consists of a principal mass of coarse-grained granite (Krg), the east half of which occupies west-central part of the quadrangle. It is foliated most prominently near its margins where foliation, defined in part by biotite and muscovite aligned in folia, parallels the intrusive contact of the pluton against contact-metamorphosed Paleozoic wall rocks. Core of pluton west of Shoshone Mountain consists of a large body of fine-grained granite, and southeast margin of pluton is intruded by intermixed masses of fine-grained granite (Krgf) and aplite (Kra). Small poorly defined bodies of fine-grained granite are present elsewhere in pluton. Parts of pluton have been iron mineralized (Krgi) and tourmaline mineralized (Krgt). Emplacement age of Round Mountain pluton, on the basis of Rb-Sr whole-rock and mineral data (John and Robinson, 1989), is 89.6±3.3 Ma. Biotite and muscovite K-Ar ages of about 80–81 Ma are thought to indicate time of doming, metamorphism and mineralization of pluton (Shawe and others, 1986; Shawe, 1995). Foliation, which is defined partly by aligned muscovite and biotite flakes, reflects shearing that accompanied metamorphism rather than laminar flow associated with granite emplacement

Kra **Aplite**—Light-gray, pale-gray, and nearly white aplite bodies containing small zones of pegmatite locally; locally weathers pale yellowish brown. Aplite forms small masses and dikes in granite, and thin (a few meters wide) dikes and sills in Paleozoic metasedimentary wall rocks. Aplite has xenomorphic-granular or granophyric to hypidiomorphic-granular texture; locally aplite shows mortar structure. Typical examples were described by Shawe (1995). An atypical sample of aplite from south part of pluton has the following mode: Q, 23; K (mostly orthoclase and only minor microcline), 63; P, 9; B, 3; and O and muscovite, about 1 each. Zircon and apatite are accessory minerals. This rock is strongly foliated, and its grain size is 0.1–2 mm. A thin quartz veinlet (4–5 mm wide) transgresses foliation; veinlet is lined with a thin selvage of muscovite. As in the Round Mountain quadrangle (Shawe, 1995), some aplite dikes are foliated and some are not, indicating that foliation, likely formed at time of doming and metamorphism of pluton, took place during period of aplite emplacement

Krgf **Fine-grained granite**—Pale-gray, fine- to medium-grained granite; locally weathers pale yellowish brown. Commonly leucocratic or alaskitic (nearly white). Rock has a granophyric texture and crystals are as large as 2–4 mm. Fine-grained granite contains subequal amounts of quartz, potassium feldspar, and plagioclase, and minor biotite and muscovite; a more detailed description of composition was given by Shawe (1998). Rock forms irregular masses several hundred meters to a kilometer or more across, which intruded into coarse-grained granite (Krg); also it forms a large northwest-trending body almost 3 km long and 1 km wide that intruded core of pluton. Core body is flanked by inward-dipping, arcuate faults, north and south, that may have broken as a result of upward thrust of emplacement of fine-grained granite (see cross sections *G–G*' and *J–J*'). Remnant patches of coarse-grained granite are common within areas mapped as fine-grained granite. In places, masses of fine- and medium-grained granite and aplite (Krgf-Kra) were mapped together

Krg **Coarse-grained granite**—Light-gray to pale-gray granite; locally weathers pale yellowish brown. Foliation is pronounced near margin of pluton; it is conformable with the contact and diminishes inward. Texture of granite is hypidiomorphic-granular to xenomorphic-granular. A modal analysis of a sample of coarse-grained granite (1–10 mm in diameter) shows: Q, 16; K (25 orthoclase and 18 microcline), 43; P, including 2.5 myrmekite, 37; B, 3; and muscovite, 1.5. Opaque mineral, zircon, and apatite are accessory minerals. Muscovite replaces biotite and plagioclase. (See chemical data for coarse-grained granite in the Round Mountain quadrangle *in* Shawe, 1995)

Krgi **Altered and iron-mineralized granite**—Light-yellowish-brown to light-brown, coarse-grained granite. Rock has been argillized and (or) sericitized and pyritized; small pyrite cubes are altered to iron oxide that stains rock and lines numerous fractures. Numerous thin, irregular quartz veins that are locally vuggy occur throughout altered granite; a few veins are mineralized with base-metal sulfides, and some veins carry the manganese tungstate huebnerite, and fluorite. Chalcedonic-silica veins occur in places. Extensive, irregular zones of altered and iron-mineralized granite occupy much of north and northeast parts of pluton and a smaller zone is found near south margin of pluton

Krgt **Tourmaline-mineralized granite**—Light-gray, fine- to coarse-grained granite; weathers light yellowish brown to light yellowish gray. Tourmaline-mineralized zone is a continuation of a halo surrounding the stock of 36-Ma granodiorite of Dry Canyon (Tgd) in adjacent Round Mountain quadrangle (Shawe, 1995). A subsurface extension of stock into the Jefferson quadrangle is inferred on the basis of tourmaline-mineralized granite at the surface (cross section *H–H'*). Rock contains sparse to abundant crystals and clusters of black tourmaline, commonly forming sunbursts or aggregates as much as 1 cm in size. As seen in thin section, feldspars are partially to almost wholly replaced by sericite and muscovite; biotite is replaced by muscovite; and tiny cubes or blebs of oxidized pyrite are scattered throughout. Accessory minerals are zircon, apatite, and a high-relief mineral (monazite?) that includes abundant opaque dust. A chemical analysis of rock indicates the following percentages of components: SiO_2, 75.2; Al_2O_3, 16.6; K_2O, 5.43; Na_2O, less than 0.15; CaO, 0.19; Fe_2O_3, 1.28; FeO, 0.28; MgO, 0.45; TiO_2, 0.30; P_2O_5, 0.14; and MnO, 0.02. Spectrographic analysis (by R.T. Hopkins of the U.S. Geological Survey) indicates the presence of about 200 ppm boron. Unit forms a zone about 1 km long at north margin of pluton, at west edge of the quadrangle

Toquima Formation (Middle Ordovician)—Typically thin-bedded, interlayered, marine sedimentary rocks and their jasperized and (or) contact-metamorphosed equivalents. Divided into argillite (Ota), limestone (Otl), dolostone (Otd), and quartzite (Otq); limestone is jasperized in places (Otlj). Lithologies may be transitional from one unit to an adjacent unit; minor amounts of other rock types may be present in some units. Rocks are strongly deformed by folding and thrust faulting, probably in several episodes from late Paleozoic to Late Cretaceous time. Units in the Toquima have undergone extreme deformation and disruption such that some lithologic units are out of stratigraphic sequence and the original sequence cannot be determined. Thus, units are shown in the "Correlation of Map Units" as though they are of correlative age. The Toquima correlates with part of Ordovician Palmetto Formation in southern Nevada (for example, Ferguson, 1924; McKee, 1968) and Middle and Upper Ordovician part of Vinini Formation in northern Toquima Range (McKee, 1976). Formation constitutes a thrust plate overlying Zanzibar Formation; the Toquima locally is internally cut by thrusts. Main part of plate is exposed in southeast corner of the quadrangle, and a small outlier crops out in south-central part of the quadrangle south of Antone Creek. Original thickness is uncertain because of deformation but probably the formation is several hundred meters to more than 1,000 m thick

Ota **Argillite**—Gray argillite; in places weathers light brownish gray, light pinkish gray, or light purplish gray; somewhat phyllitic or fissile; locally silty, limy, or silicified. Platy, laminated, and (or) thin bedded. In thin section, a sample of laminated silty argillite consists of alternating layers that contain either sparse or abundant detrital grains of quartz (0.02–0.1 mm in diameter). Matrix of layers is made up of minute intergrown mosaic quartz crystals, clay(?), and subparallel flakes of chloritoid(?). Quartz grains in some laminae are graded. Cubes and blebs of oxidized pyrite about 0.05 mm in size are scattered throughout rock. Where gray argillite is in contact with quartzite (Otq) graptolites commonly are preserved; graptolites appear to be absent where argillite is light pinkish gray to light purplish gray and in contact with quartzite. Graptolites collected in adjacent Round Mountain quadrangle were identified by R.J. Ross, Jr. (then of the U.S. Geological Survey) as of Mohawkian (Middle Ordovician) age (Shawe, 1995). Argillite units about 30–60 m thick

Otl **Limestone**—Light-gray to dark-gray, thin-bedded and (or) thin-platy to laminated limestone; light brown to light orangish brown from iron stain where weathered. Laminae are due mostly to tectonic shearing related to deformation that resulted in folding and thrust faulting. Laminae generally parallel bedding but locally laminae transgress bedding sharply. Some limestone beds are silty. In part, light-gray limestone and dark-gray limestone form alternating layers a few meters to several tens of meters thick. Color generally reflects abundance of grains and flakes of graphite streaked along laminae; darker-gray limestone contains more abundant graphite. Some dark-gray silty layers are silicified ("case hardened") such that they stand out on weathered surfaces, giving appearance of thin chert layers. Other thin silicified limestone layers consist of mosaic quartz grains ranging from less than 0.01 mm to 0.1 mm, containing wispy patches of graphite grains streaked along layers. Sparse to abundant calcite crystals (as much as 0.1 mm long) are locally present. Larger units of silicified limestone (jasperoid, **Otlj**) are mapped seperately. A few beds of fetid, phosphatic limestone exhibit tiny fragments of phosphatic brachiopods and other shelly fossils (cell structures visible in thin section). Thin-section examination also shows scattered isotropic, oval blebs (as long as 1 mm) of solid organic matter ("dead oil"?) whose walls are lined with an unidentified low-birefringent mineral that is present also as tiny crystals suspended within the organic matter. A few organic blebs show crystals of apatite growing out from walls of blebs. Much limestone is mildly contact-metamorphosed and contains sparse tiny crystals of tremolite. In a few places, especially close to thrust faults, limestone is strongly brecciated or contorted. Much of thrust plate of Toquima Formation in southeast corner of the quadrangle consists of limestone, which is probably about 200 m in maximum thickness

Otlj **Jasperized limestone (jasperoid)**—Dark-gray rock; commonly stained reddish or yellowish brown as a result of oxidation of pyrite during weathering; a siliceous (cherty) rock that replaced limestone. Rock commonly is brecciated. Silicified dark-gray layers, as seen in thin section, consist of mosaic quartz in interlocking grains as much as 0.2 mm in diameter that form streaks a few millimeters wide; in some streaks terminated quartz crystals indicate open-space filling. Some streaks are crowded with wispy, anastomosing trains of graphite grains and flakes that parallel layering in rock. Scattered oxidized pyrite cubes and blebs are common. Jasperoid forms one layer a few tens of meters wide and more than a kilometer in length and a patch several hundred meters across within thrust plate containing Toquima Formation. Scattered patches of jasperoid in limestone (**Otl**) are too small to map

Otd **Dolostone**—Light-gray, laminated to thin-bedded dolostone; weathers light yellowish brown. Nearly white locally. A few laminated beds contain streaks of graphite, and give off a fetid odor when rock is broken. A thin section of one such sample consists of mosaic grains of interlocking dolomite crystals as much as 0.5 mm in diameter; minor mosaic quartz is present. Thin 1-mm-wide veinlets of calcite and quartz traverse the dolostone. Two layers of dolostone 40–50 m thick are interlayered in limestone (**Otl**) in southeast part of the quadrangle. One bed appears to grade laterally into limestone locally, suggesting that dolostone is a replacement of limestone rather than of sedimentary origin

Otq **Quartzite**—Gray to light-gray, fine-grained, massive to laminated quartzite; locally weathers brown to light yellowish brown; locally bleached nearly white to very pale yellowish brown. Some beds are siltstone. Quartz grains are closely packed and mosaic textured, mostly less than 0.5 mm in diameter. In places mortar-structured quartz grains (0.0l–0.05 mm) fill interstices among larger rounded quartz grains. Minor sericite-muscovite clusters are scattered through rock, or form interstitial screens or patches among quartz grains. Some slightly foliated quartzite contains scattered sheaves (as much as 1.5 mm long) of crudely aligned tremolite crystals. Sparse detrital black opaque oxide grains and a trace of zircon grains are present in some quartzite. Euhedral crystals (mostly less than 0.05 mm, rarely as much as 0.1 mm in size) of metamorphic apatite are common in some quartzite. Cubes and pyritohedrons of pyrite (mostly smaller than 1 mm in size) as well as black specks and streaks of graphite are interstitial to quartz grains. Quartzite commonly is veined with white quartz, and in a few places it contains masses of white quartz as much as 5 m long. Quartzite constitutes only a small part of Toquima Formation. It forms beds one to several meters thick that are locally brecciated, contorted, and discontinuous as though boudinaged during extreme deformation. Probably at least two quartzite beds are present in klippen in southeast part of the quadrangle, as some quartzite is associated with graptolitic gray shale and some is associated with nongraptolitic reddish- to pinkish-gray siliceous shale. A small klippe of quartzite of the Toquima about 20 m in diameter lies on schist of Gold Hill Formation (**Ꞓgs**) 300 m south of Jefferson Canyon and about 600 m from west boundary of the quadrangle. Map unit is correlative with Middle Ordovician Eureka Quartzite of eastern and southern Nevada on the basis of comparable graptolite faunas (for example, Nolan and others, 1956)

Zanzibar Formation (lower Middle Ordovician)—Generally thin- to medium-bedded interlayered argillite and subordinate limestone (**Ozal**), limestone (**Ozl**), and dolostone (**Ozd**). Limestone (**Ozl**) is further subdivided into calc-silicate-mineralized limestone (**Ozlc**) and jasperized limestone (**Ozlj**). Some contact-metamorphosed argillite is mapped as schist (**Ozs**). Because deformation has obscured original stratigraphic sequence of units of formation, they are described as lithologic units rather than as stratigraphic units. Formation forms a thrust plate sandwiched between an upper thrust plate of Toquima Formation and lower thrust plates of Cambrian(?) siltstone formation (**Ꞓst**), Cambrian Gold Hill Formation (**Ꞓg** units), and Cambrian Mayflower Formation (**Ꞓm** units). It is intruded by both Belmont and Round Mountain granite plutons, against which limestone and argillite have been contact metamorphosed (to **Ozlj** and **Ozlc**, and to **Ozs**). The Zanzibar is widely exposed in south part of the quadrangle, and in a small area in northwest part of the quadrangle. Age of formation is Whiterockian (early Middle Ordovician, based on fossil identifications by W.B.N. Berry, R.J. Ross, Jr., and J.W. Huddle of samples from the Manhattan quadrangle; Shawe, 1999). Formation is correlative with part of Palmetto Formation in southern Nevada (for example, Ferguson and Cathcart, 1954). It also is in part the same age as Antelope Valley Limestone in eastern Nevada (Ross, 1970), on the basis of comparable faunas

Ozal **Argillite and subordinate limestone**—Medium- to dark-gray, platy, noncalcareous to limy, locally laminated or phyllitic argillite; and subordinate interlayered light- to dark-gray, thin-platy, laminated limestone. Argillite and limestone are in part silicified or silty. Close to sole thrust fault of Zanzibar thrust plate, argillite is reddish gray to light reddish brown or brown. Rock has been mildly metamorphosed regionally. Argillite consists of oriented minute flakes and grains of clay, sericite or chloritoid, and quartz, all of which are commonly intergrown with lenses of calcite; argillite has moderately developed phyllitic cleavage. Graphite dust may be strung out along cleavage planes. Faint traces of graphite that transgress cleavage appear to reflect original bedding. Limy argillite adjacent to or as lenses within granite may be contact metamorphosed to quartz-calcite-chloritoid schist, commonly containing small amounts of sericite, tremolite, and graphite. In places argillite and limestone are contorted and isoclinally folded. Argillite and subordinate limestone form units as much as about 100 m thick interlayered in limestone (**Ozl**) in south part of the quadrangle

Ozl **Limestone**—Light-gray to dark-gray, thin-platy to thin- to medium-bedded, laminated limestone (laminae due mostly to shearing related to thrust faulting probably at time of mild regional metamorphism); in places weathers light brown, light orangish brown, or light brownish gray. Locally, limestone is argillaceous, silty, and (or) silicified. A few layers contain thin zones of nodular chert, and elsewhere thin, dark-gray layers of silicified ("case-hardened") silty limestone. Most beds are a few centimeters to 10–20 cm thick; uncommonly beds are as thick as 70 cm and massive. In places beds are strongly contorted and (or) brecciated. Beds may be isoclinally folded, broken, or boudinaged. Thin-section examination shows laminated limestone to consist chiefly of crude, interlocking lensoids of calcite ranging from less than 0.1 mm to 0.5 mm long, commonly lined with dusty streaks of graphite. Graphite varies from almost absent to very abundant, resulting in limestone coloration that ranges from light gray to almost black. Scattered crystals of tremolite (as long as 2 mm) and clear to seived crystals of diopside (as long as 4 mm) are found in laminated limestone near granite plutons. Tiny cubes and blebs of oxidized pyrite are common; where they are abundant, iron oxide derived from pyrite accounts for brownish stains on weathered rocks. Limestone consititutes bulk of Zanzibar Formation; it is widespread in south part of the quadrangle and is present in lesser amount in northwest part of the quadrangle near Jefferson Canyon. Aggregate thickness of unit is uncertain, but it is at least several hundred meters

Ozlc **Calc-silicate-mineralized limestone**—Light-gray, light-greenish-gray, light-yellowish-gray and light-yellowish-brown, dense calc-silicate-mineralized limestone; weathers light brown. Rock is the result of contact metamorphism near or in contact with both Belmont and Round Mountain plutons in south part of the quadrangle. Thin layers commonly are interlayered with lesser amounts of dark-gray silicified limestone and light-gray to medium-gray limestone. Several types of calc-silicate-mineralized limestone are recognized in the quadrangle. A common type contains abundant ragged and seived, in part interlocking, crystals of diopside (0.5–3 mm long) in a matrix of mosaic quartz (grain size about 0.5 mm); abundant small (as large as 0.5 mm) sphene crystals are scattered throughout. Some samples contain tremolite also, and sparse to abundant graphite may be present. One sample, as seen under the microscope, consists of a fine-grained (0.01–0.1mm) schistose aggregate of mosaic quartz, semi-aligned subhedral andalusite crystals, and abundant tiny blebs of pyrite(?). Ragged crystals and aggregates of andalusite, diopside, and uvarovite garnet, 1–5 mm long, are present in schistose aggregate. In vicinity of Barcelona Summit, coarse-grained (to 1 cm) varieties of calc-silicate-mineralized limestone contain brown grossularite(?) garnet and epidote, as well as sulfide minerals, including molybdenite. Thickness a few meters to several tens of meters

Ozlj **Jasperized limestone**—Dark-gray silicified limestone; commonly stained yellowish brown to reddish brown as a result of weathering and oxidation of pyrite. Commonly brecciated; in places, folded bedding layers are evident. Common veinlets of white to light-yellowish-brown quartz; uncommon thin layers of pale-green fluorite along light-gray bedding layers 0.8 km southeast of Barcelona Summit. Some dark-gray, brown-weathering jasperoid has the fine-grained, dense appearance of hornfels. In a few places gossan is associated with intensely iron-mineralized jasperoid. Forms beds laterally continuous for tens of meters or more, or irregular masses that grade along bedding from unaltered limestone. Jasperized limestone is localized along faults or bedding. Masses of jasperized limestone range from thin layers to as much as hundreds of meters across. Not all thin layers were mapped

Ozd **Dolostone**—Light-gray, laminated dolostone; weathers light yellowish gray to light yellowish brown. In places contains numerous laminated limy chert layers, and nodules (as much as 30 cm long); chert is boundinaged. Chert commonly displays a selvage of white tremolite a few centimeters thick. Dolostone as seen in thin section consists of intergrown oblong grains of dolomite (0.02–0.2 mm long) aligned with laminae, which contain numerous scattered needles, sheaves, and sunbursts of tremolite as long as 3 mm. Dolostone grades laterally into light-gray limestone. Forms part of a single bed about 30 m thick and 3 km long in limestone in southeast corner of the quadrangle. Segments of bed are limestone, suggesting that dolomite is secondary rather than of sedimentary origin

Ozs **Schist**—Dark-gray, foliated and lineated schist; weathers brown. Locally contains varied amounts of tremolite, muscovite, and graphite. A thin section of a dark-gray schist sample indicates abundant films of graphite along folia that are defined by strings of grains of mostly(?) quartz (grain size about 0.01 mm). Scattered sheaves (as much as 2 mm long) of tremolite, and cubes and blebs of oxidized pyrite (0.01–0.05 mm in diameter), appear to postdate foliation. A few andalusite crystals (as much as 0.1 mm long), with hour-glass-shaped concentrations of graphite, are present. Elongate concentrations of graphite oblique to foliation form compositional layering in schist. Schist occurs where thin apophyses of aplite and (or) fine-grained granite of Belmont and Round Mountain plutons invaded argillite, or where thin leaves of argillite were incorporated into margins of plutons, in south part of the quadrangle

€st **Siltstone formation (Cambrian?)**—Medium-gray, laminated, limy arkosic(?) siltstone; weathers medium brownish gray. Thin and evenly bedded. Thin-section examination shows a fine-grained (0.01–0.1 mm) mosaic aggregate of quartz, orthoclase(?), and calcite grains that contains abundant subparallel chloritoid flakes that are commonly ragged and less than 0.1 mm long. Orientation and varied abundance of chloritoid flakes define laminations that may or may not be parallel to bedding. Abundant rounded and corroded detrital grains of zircon are surrounded by pleochroic halos in adjacent chloritoid flakes. Formation forms a thrust plate that underlies plate of Zanzibar Formation (Oz units) and overlies plate of Gold Hill Formation (€g units), in south-central part of the quadrangle. Maximum thickness of thrust plate probably less than 100 m. Siltstone formation correlates with a thrust plate of Cambrian(?) arkosic siltstone in the Manhattan quadrangle that is lithologically similar and that occupies a similar structural position (Shawe, 1999)

Mayflower Formation (Cambrian?)—Phyllitic argillite (€mf) and knotted schist (€ms). Within about 2–3 km of the Cretaceous granite plutons, formation is metamorphosed to knotted schist; farther from plutons, formation consists of phyllitic argillite that generally exhibits well-developed axial-plane(?) cleavage. The transition from argillite to schist is gradational and occurs through an interval of perhaps a kilometer. Schist is considered to be a result of contact metamorphism whereas phyllitic argillite is considered to be a result of regional metamorphism. These strata are extremely deformed by shearing and isoclinal folding. They are widely exposed in south-central and southeast parts of the quadrangle, and in small patches south of Jefferson Canyon in northwest part of the quadrangle. Map unit underlies thrust plates of Gold Hill Formation (€g units), Cambrian siltstone formation (€st), Ordovician Zanzibar Formation (Oz units), and Ordovician Toquima Formation (Ot units). Formation was considered by Ferguson (1921; 1924) to be Ordovician(?); unfossiliferous phyllite referred to Mayflower in Toiyabe Range to the west was considered by Finney and Perry (l991) to be Lower Ordovician; formation is here believed to be Cambrian(?) on the basis of similarity to known Cambrian rocks elsewhere in region. As the entire formation is nowhere exposed, its original thickness is unknown, but it likely was several hundred meters to a kilometer or more; considerably more than this may remain in the subsurface.

Ferguson (1924, p. 20–25), as well as Ervine (1972, p. 44), Stewart (1980), and Kleinhampl and Ziony (1984, p. 46–47), following Ferguson, considered the Mayflower and Zanzibar Formations in the southern Toquima Range to be parts of a stratigraphic sequence. Ferguson (1924) and Stewart (1980) included the Toquima Formation as well in the sequence. However, mapping in the Round Mountain (Shawe, 1995) and Manhattan (Shawe, 1999) quadrangles suggests that the Mayflower is separated from the overlying Zanzibar and Toquima by a thrust plate of Gold Hill Formation. The Mayflower appears unrelated to the Zanzibar and Toquima

€mf **Phyllitic argillite**—Medium-gray, mostly phyllitic argillite or shale; weathers olive gray to brownish gray. Grades from platy shale a few kilometers from Cretaceous granite plutons, to phyllitic schist closer to plutons. Thin-section examination of a laminated phyllitic schist sample indicates a mass of strongly oriented clay and sericite flakes parallel to foliation, and quartz grains, mostly less than 0.01 mm in size. Scattered throughout are specks and streaks of iron oxide (probably from oxidized pyrite), and sparse streaks of graphite dust. In places bedding laminae are tightly folded and intersected by generally steep axial-plane(?) cleavage. Rocks are locally brecciated, and are mineralized by quartz and iron. Several hundred meters of the section of the phyllitic argillite is exposed in southeast corner of the quadrangle

€ms **Knotted schist**—Dark-gray, well-foliated knotted schist; weathers dark olive gray to brown. Extremely deformed by shearing and probable isoclinal folding. Rock is locally fractured, brecciated, and iron mineralized. In places it contains irregular veinlets of iron-mineralized quartz. Thin-section examination shows a well-developed foliation manifested by abundant chloritoid and (or) biotite, phlogopite, or sericite flakes. Flakes are commonly less than 0.02 mm long, locally as long as 0.5 mm, and are embedded in a granular mass of quartz grains of similar size. Sparse to moderaterly abundant tiny grains of oxidized pyrite are scattered throughout, and graphite dust and films are streaked along the foliation. Rock is characterized by abundant oval knots, mostly about 5 mm long; knots consist of quartz and chloritoid, generally oriented parallel to the foliation. One thin section shows knots to consist of lensoid forms of andalusite(?), 4 mm–1 cm long, aligned parallel to schistosity. Knots contain abundant flakes of chloritoid and sericite mostly less than 0.01 mm long oriented parallel to schistosity, and contain scattered specks of graphite. Widely exposed near Cretaceous granite plutons in south-central part of the quadrangle, and in smaller patches south of Jefferson Canyon in northwest corner of the quadrangle

Gold Hill Formation (Lower Cambrian)—Phyllitic schist (Ꞓgs), quartzite (Ꞓgq), and limestone (Ꞓgl) deposited as marine shale, sandstone, and limestone, respectively. Units that are schist with subordinate interlayered quartzite beds are mapped as Ꞓgsq, and units that are quartzite with subordinate interlayered schist are mapped as Ꞓgqs. Some limestone is calc-silicate mineralized (Ꞓglc). The Gold Hill Formation is exposed in central part of the quadrangle, and in northwest corner of the quadrangle in and near Jefferson Canyon. Parts of formation are at least several hundred meters thick, but because of thrust faulting and folding, original thickness of formation is not known; it probably was at least a kilometer thick. Forms a thrust plate that underlies plates of Zanzibar Formation (Oz units) and Cambrian(?) siltstone formation (Ꞓst), and that overlies a plate of Mayflower Formation (Ꞓm units). Age in part Early Cambrian, based on the presence of *Olenellus gilberti Meek* in similar rocks in Toiyabe Range about 25 km to the west (Ferguson and Cathcart, 1954). Correlative with upper part of Prospect Mountain Quartzite in eastern Nevada and Zabriskie Quartzite in southern Nevada

Ꞓgs **Phyllitic schist**—Olive-gray, light-olive-brown, and olive-brown phyllitic argillite to mica schist; weathers light yellowish brown to dark brown. Silty in part. Minor thin layers of quartzite and limestone are present in places. Schist is more strongly metamorphosed near granite contacts. A thin section of schist collected near granite shows a mosaic groundmass of quartz grains (0.05–0.1 mm) through which are scattered abundant, crudely aligned, ragged to euhedral flakes (0.1–0.3 mm) of choritoid and muscovite that define foliation of rock. Sericite-flake aggregates (as large as 2 mm) and sparse, ragged oxidized-pyrite patches (as large as 0.5 mm) are scattered through rock. A nearby similar sample shows larger aggregates (as large as 5 mm) of sericite flakes and muscovite crystals (as large as 1 mm). Euhedral crystals of metamorphic apatite, and sparse detrital zircon crystals, are present. L.W. Snee (written commun., 1997) reported a white mica (sericite) $^{40}Ar/^{39}Ar$ date of 79.74±0.12 Ma for sulfide-mineralized rock collected at a prospect in unit within a few meters of granite contact of Round Mountain pluton (rock sample locality R7). The date indicates an episode of mineralization related to the inferred 80- to 82-Ma episode of doming and metamorphism of the 89.6-Ma pluton. Individual units of schist are locally as thick as 200 m

Ꞓgq **Quartzite**—Light-yellowish-brown, mostly fine-grained, thin-bedded to massive quartzite; weathers light brown to dark brown. Beds generally are 0.1–1.5 m thick; in part, unit has low-angle crossbeds, and in part it is massive. Beds commonly separated by schistose-shaly partings. Some quartzite contains extensive worm borings, probably *Skolithos*, as much as 1 cm in diameter and 15 cm long; soft-sediment slump structures are uncommon. As seen in thin section, rock consists chiefly of closely packed, well-rounded, somewhat oblong grains of quartz (0.1–0.3 mm in diameter), partly surrounded by interstitial sericite and very fine grained mosaic quartz. Sparse metamorphic tourmaline, oxidized pyrite blebs and cubes, and detrital zircon are scattered through rock. One deformed worm boring(?) is filled with sericite, iron oxide, and tourmaline. Another quartzite sample contains moderately abundant detrital zircon, oxidized pyrite, and metamorphic tourmaline. Quartz grains form a mosaic texture; metamorphic muscovite occurs as scattered flakes as long as 1 mm. Individual quartzite units are locally as thick as 150 m

€gsq **Schist and subordinate quartzite**—Light-olive-brown to light-yellowish-brown phyllitic schist; sparse to moderate interbeds, a few centimeters to a meter or more thick, of medium-gray to light-yellowish-brown, brown-weathering quartzite. Map unit forms layers a few tens of meters thick in central part of the quadrangle

€gqs **Quartzite and subordinate schist**—Light-yellowish-gray, olive-gray, light-gray, and nearly white quartzite (as beds about 0.2–1.5 m thick) interlayered in places with shaly-silty phyllitic schist intervals (10–30 cm thick); weathers light to dark brown. Quartzite locally contains abundant worm borings, especially in an isolated exposure of Gold Hill Formation (**€gqs**) about 1 km southwest of Meadow Canyon near east edge of the quadrangle. Worm borings, as much as 1 cm in diameter and disposed normal to bedding, are probably *Skolithos*, a characteristic form in quartzite in Wood Canyon Formation, Zabriskie Quartzite, and Harkless Formation, age equivalents of Gold Hill Formation is southeastern California and southern Nevada (J.H. Stewart, written commun., 1997; see also Link and others, 1993, p. 552). This isolated exposure may be incorrectly mapped as Gold Hill Formation. Ervine (1972) described *Skolithos* in quartzite that he mapped as parts of the Zabriskie and Wood Canyon Formations in an area from south of Bull Frame Canyon southwestward to near Barcelona Summit. I have included these rocks also as part of Gold Hill Formation. Low-angle crossbeds and scours that are convex upward indicate that quartzite beds are overturned in places. Map unit is exposed in northwest and southeast parts of the quadrangle and locally is as much as 150 m thick in southeast area

€gl **Limestone**—Light-gray, light-pinkish-gray, and light-yellowish-brown, evenly to irregularly layered, in part laminated limestone; weathers light brownish gray, light orangish brown, and brown. In places, beds about 1 cm thick are lenticular to nodular. Locally, 2- to 30-cm-thick beds of chert and argillite are interlayered. Rock commonly is sheared, brecciated, and iron mineralized. A thin section of fractured limestone shows disoriented fragments of limestone of varied grain size (0.02–0.3 mm), veined with calcite; abundant oxidized pyrite cubes (0.05 mm in size) are scattered throughout. Strongly brecciated limestone shows much pulverized matrix that contains significant iron oxide. Near granite contacts, thin layers in limestone commonly are mineralized by calc-silicate phases. L.W. Snee (written commun., 1997) reported an actinolite $^{40}Ar/^{39}Ar$ date of 84.1±0.3 Ma for material from the metamorphosed base of a limestone layer about 100 m from granite contact of Round Mountain pluton (rock sample locality R8). The date suggests metamorphism associated with emplacement of the 89.6-Ma pluton. The date may have been reset somewhat by a thermal event that followed intrusion, probably the younger (80–82 Ma) episode of doming, metamorphism, and mineralization of the pluton. Limestone units, chiefly interlayered in phyllitic schist (**€gs**) in south-central and northwest parts of the quadrangle, are as much as about 20 m thick

€glc **Calc-silicate-mineralized limestone**—Gray, light-greenish-gray, and green, dense calc-silicate-mineralized limestone; weathers light brown, brownish gray, and brownish green. Locally, bedding characteristics of original limestone are present; in other places rock is structureless. A coarse-grained hand specimen of unit **€glc** contains abundant sheaves of actinolite needles (as much as 2 cm long) intergrown with calcite and phlogopite crystals (about 0.5 cm in size), set in a dense, fine-grained matrix of granular diopside. Unit **€glc** was mapped separately only along Berlin Canyon in northwest part of the quadrangle, where unit is about 20 m thick

SUMMARY OF GEOLOGIC EVENTS

I infer that the Cambrian marine clastic and carbonate rocks of the Mayflower Formation (Ꞓm units), Gold Hill Formation (Ꞓg units), and Cambrian(?) siltstone formation (Ꞓst) in the Jefferson quadrangle were deposited as part of a westward-thickening sedimentary wedge on the continental shelf at what was then the western edge of the North American continent (Stewart, 1980). Ordovician marine rocks of the Zanzibar (Oz units) and Toquima (Ot units) Formations were probably deposited as transitional facies rocks between predominantly carbonate-facies sediments on the continental shelf and siliceous-facies sediments in a deeper western ocean basin. Rocks of the Toquima Formation are more siliceous than those of the Zanzibar Formation, and they may have been deposited west of the Zanzibar.

Although opinions differ as to whether or not the southern Toquima Range lies within the region of late Paleozoic–early Mesozoic compression and thrust faulting (for example, Stewart, 1980, p. 39, 55–59), the structural and lithologic characteristics of the rocks in the southern Toquima Range indicate that it is within that region. No sedimentary rocks of known late Paleozoic and Mesozoic age are present in the Jefferson quadrangle. However, the presence of ophiolite (interlayered serpentinite, greenstone, and chert) 8 km south of the quadrangle (Shawe, 1998, 1999) proves that oceanic rocks were thrust into the region of the quadrangle. The oceanic rocks are interleaved with strongly deformed allochthonous rocks of Ordovician age: the Toquima Formation lies in thrust contact upon ophiolite south of the quadrangle and the Toquima there is part of the same plate of Toquima exposed in the Jefferson quadrangle. Elsewhere in the region such rocks have been interpreted to have been emplaced during the Late Devonian–Early Mississippian Antler and (or) the Late Permian–Early Triassic Sonoma orogenies (Poole and Desborough, 1973). Also, fragments of Permian Diablo Formation in eruptive volcanic megabreccia in the Manhattan quadrangle (Shawe, 1999) 10 km southwest of the Jefferson quadrangle indicate that the Golconda allochthon (emplaced during the Sonoma orogony) extends into the region. These occurrences thus suggest that periodic compressional deformation in the region started in the late Paleozoic and continued into the Mesozoic.

The present configuration of plates of Cambrian and Ordovician rocks reflects such deformation: a lower plate of the Mayflower Formation is overlain on a strongly folded thrust fault by a plate of the Gold Hill Formation, which in turn is overlain successively by plates of the Cambrian(?) siltstone formation, the Zanzibar Formation, and the Toquima Formation. The higher thrust faults generally are less folded than are the lower thrust faults, and in places the higher faults truncate the lower ones, indicating a sequence of thrusting from lower to higher. Some thrust faults appear more tightly folded near granite plutons (Kr and Kb units), and part of the folding may have resulted from intrusion of the plutons.

Because orientation and configuration of structures in the Paleozoic rocks may have resulted in part from the shouldering effect of intrusion of the Cretaceous granite plutons (Kr and Kb units), the structures probably cannot be used to infer direction of thrust faulting. For example, in the south part of the quadrangle, tight folds in the thrust fault that separates the Zanzibar Formation from underlying Mayflower Formation, as well as foliation attitudes in the metamorphosed sedimentary rocks, appear to wrap around the north margin of the Belmont pluton. Thrust faulting probably continued into the Late Cretaceous, as evidenced by sheared granite sills emplaced along thrust faults in the Manhattan quadrangle to the southwest (Shawe, 1999), and by the foliated character of the Cretaceous plutons, which formed millions of years following emplacement of the plutons, and at the time of pluton doming. The foliation thus is suggestive of compressional deformation.

The Late Cretaceous granite plutons were emplaced during the waning stages of compressional deformation. Initially, they may have formed thick lensoid sills intruded along major deep-seated thrust breaks. The Round Mountain pluton (Krg) was emplaced at about 90 Ma and the Belmont pluton (Kbg) was emplaced at about 85 Ma. The Belmont pluton before solidification differentiated into an upper porphyritic granite layer (Kbgp), an underlying sparsely porphyritic granite layer (Kbgs), and a lower coarse-grained granite layer (Kbg of Shawe, 1998). Evidence of graded layering and low-angle crossbeds in the sparsely porphyritic layer in the Belmont West quadrangle (Shawe, 1998) indicates sedimentation from convection currents prior to complete consolidation of the granite magma. Both the Round Mountain and the Belmont plutons were invaded by aplites (Kra and Kba) and fine-grained granite (Krgf and Kbgf) during an episode of doming that saw development of foliation localized near and subparallel to their margins, at about 82–80 Ma. The plutons also were partly metamorphosed and mineralized during this stage of deformation (see Shawe, 1995, 1998, 1999). Some of the details of mineralization were described by Shawe (1988). Emplacement of the Pipe Spring granite pluton (exposed in the Manhattan and Belmont West quadrangles, Shawe, 1998, 1999) took place at about 80 Ma, coincident with the late episode of deformation, intrusion, metamorphism, and mineralization of the Round Mountain and Belmont plutons.

At about 36 Ma, when the presently exposed rocks were still beneath a cover probably more than 1 km thick, a swarm of northeast-trending rhyolite dikes and a rhyolite plug (Tr) were emplaced into and near the Round Mountain pluton west of the quadrangle; immediately thereafter, a granodiorite stock (Tgd) and associated andesite dikes (Ta of Shawe, 1995) were intruded into the northeastern part of the rhyolite dike swarm. The rhyolite intrusion event barely reached into the Jefferson quadrangle, but evidence of the granodiorite event extends about 1 km into the quadrangle in the form of a tourmalinized granite halo adjacent to subsurface intrusion of granodiorite (see cross section *H–H'*). The mineralizing event that introduced tourmaline in the granite also accounted for extensive iron mineralization of granite outward from the tourmaline halo, and localized along the north margin of the pluton. Possibly an early stage of precious-metal mineralization occurred in this area at that time, in what is now the Jefferson mining district.

The tuff of Ryecroft Canyon (Trc) was emplaced in the southeast part of the quadrangle at about 27 Ma. The source of the Ryecroft Canyon may be a caldera in Monitor Valley on the east side of the Toquima Range (Shawe and Byers, 1999). The great thickness of the lower, main part of the formation (at least 300 m; estimated to be as much as 1,000 m by Boden, 1992) just east of the quadrangle, suggests a close source. Possibly the Ryecroft Canyon within the Jefferson quadrangle was erupted from a northwest-trending structure extending 3 km from the west margin of the proposed caldera underlying Monitor Valley. Such a vent might be analogous to vents proposed by Ekren and others (1980) along strike-slip zones elsewhere within the Walker Lane. Cross section *P–P'* presents a possible subsurface configuration of the formation related to the zone of northwesterly strike-slip faulting that coincides with the lower reach of Meadow Canyon. The widely divergent attitudes within the tuff of Ryecroft Canyon, some exceptionally steep, suggest that the formation collapsed somewhat chaotically into its present form following eruption.

Before the final stage of emplacement of an upper relatively thin part of the Ryecroft Canyon (Trc), a layer of the megabreccia of Meadow Canyon (Tmc) 50 m or so thick was deposited on the lower part of the Ryecroft Canyon. Also, thin layers of the tuff were emplaced locally in the lower part of the megabreccia formation. The contemporaniety of the two formations introduces a puzzling aspect of their emplacement, which is discussed further below.

I consider that the megabreccia of Meadow Canyon (Tmc) was erupted through a conduit, evidence for which is the presence of rhyolite plugs (Trp) that attest to a conduit penetrating into the deep crust. Within the inferred vent zone of megabreccia eruption, large slabs of welded ash-flow tuff stand vertically, implying that they were oriented thus by some vertical movement of the enclosing tuff matrix during emplacement. Many large blocks within the megabreccia were thoroughly brecciated before emplacement; inasmuch as such brecciated rock is nowhere in evidence at the surface within ash-flow tuff formations, I conclude that the blocks were derived from depth (see Shawe and Snyder, 1988, for a more complete discussion of eruptive megabreccia). Most of the blocks are of the tuff of Ryecroft Canyon (Trc); a few consist of welded ash-flow tuff of Mount Jefferson (Tmj), autobrecciated rhyolite, rhyolite lava, and rhyodacite lava. The latter three rock types are not known at the surface, suggesting possible derivation from depth. The matrix of the megabreccia has a phenocryst composition similar to that of the Ryecroft Canyon, attesting to the affinity of the two units.

The tuff of Antone Canyon (Tac) intertongues with the megabreccia of Meadow Canyon, and it is similar in phenocryst content to the tuff of Ryecroft Canyon. The three units, of comparable age, appear to be genetically related. Their puzzling intertongueing relation poses a question as to manner of emplacement. Perhaps the megabreccia is akin to a pyroclastic-flow lag deposit, and the Antone Canyon is a distal facies from which much of the clast fraction has been winnowed. The Ryecroft Canyon may have been emplaced intermittently through conduits that tapped the same source magma, but not with the explosive force that entrained the large blocks that characterize the megabreccia.

Although outflow facies of the tuff of Mount Jefferson lies upon the tuff of Antone Canyon, the determined age of the Mount

Jefferson is similar to that of the Ryecroft Canyon (about 27 Ma), and hence also close to the age of the Antone Canyon and of the megabreccia of Meadow Canyon. The surface disposition of the megabreccia of Meadow Canyon relative to the Mount Jefferson caldera (for example, cross section *N–N'*), as well as the intermixing of the tuff of Mount Jefferson as both matrix and clasts in the megabreccia, suggest that the megabreccia may have formed by collapse into the Mount Jefferson caldera. I think, however, that the evidence for eruption of the megabreccia countervails this supposition; intermixing of the formations probably was a result of the more or less contemporaneous activity of two separate sources.

Chemical and phenocryst compositions of tuffs in the tuff of Mount Jefferson within the Jefferson quadrangle suggest episodic eruption from a differentiated magma chamber, such that earlier eruptions tapped higher portions of a chamber that contained rhyolite magma, and later eruptions tapped lower portions that had differentiated to trachydacite composition. However, there are local inconsistencies in this pattern, and faulting has disrupted the volcanic section, such that stratigraphic correlations within the tuff of Mount Jefferson are uncertain. Reversals of compositional trends resulting from long pauses in eruptive activity, or from magma mixing, may have occurred.

Following ash-flow eruption and collapse of the Mount Jefferson caldera, erosion produced an irregular topography that was covered in rather rapid succession by a sequence of unrelated rock units. The megabreccia of Jefferson Summit (Tjs units) was erupted from pipes and a dike, up through the Round Mountain pluton and wallrocks, and was spread as an outflow apron across the middle part of the tuff of Mount Jefferson within the quadrangle. (Presence of schist fragments in the dike and plugs within the Round Mountain pluton indicates that schist exists below the granite, and supports my suggestion that the granite plutons were originally thick sills, and hence bottomed on schist wallrocks.) The megabreccia vents are aligned with the northwest-striking southwest margin of the caldera; the aligned vents and caldera margin probably reflect control by northwest-striking strike-slip structures at the margin of the Walker Lane. A broad zone of altered granite (Krgi) bounds the trend of dike and pipes, suggesting an episode of hydrothermal alteration related to emplacement of the dike and pipes.

A thick sequence of volcaniclastic rocks of Little Table Mountain (Tlt units) was deposited next, in the northeast part of the quadrangle and east of the Soldier Spring fault. Clastic materials may have been derived mostly from erosion of the Mount Jefferson center; the source of the interlayered tuffs may have been late-stage volcanism of the Mount Jefferson caldera.

Mesobreccia with abundant fragments of Paleozoic rocks (Tpm) and the megabreccia of Bull Frame Canyon (Tbf) that overlie the volcaniclastic rocks may be related to the cycle of emplacement of the megabreccia of Meadow Canyon. The mesobreccia, where exposed on the steep slope of Antone Canyon, is seen to have a tuff matrix; the unit may have been emplaced as an eruptive blanket, although no source vent is recognized. Alternatively, it may have formed by dumping of erosional debris, from topographically higher areas to the west, into volcanic ash derived either from the Mount Jefferson caldera or from the source of the tuff of Antone Canyon (Tac).

The Isom-type welded ash-flow tuff formation (Ti) was spread across much of the volcaniclastic rocks of Little Table Mountain (Tlt units) about 27 Ma, and derived from a source probably to the east. It was quickly followed by emplacement of the lower and upper members of the Shingle Pass Tuff (Tspl and Tspu), between about 27 and 26 Ma, from an eastern source. Despite the rather rapid accumulation of these units, their deposition was punctuated by periods of moderate erosion.

A northwest-trending array of rhyolite plugs (Trp) was emplaced into the tuff of Mount Jefferson (Tmj) and the megabreccia of Meadow Canyon (Tmc). The trend of the plugs follows closely the alignment of the southwest margin of the Mount Jefferson caldera and a strike-slip fault in the lower reach of Meadow Canyon. The one dated plug has an age of about 26.4 Ma.

The inferred strike-slip structure that localized the plugs may have been responsible for the formation of a local basin lying east of the Soldier Spring fault. Perhaps sporadic right-lateral movement on the structure caused sagging on its northeast side, and east of the Soldier Spring fault. The volcaniclastic rocks of Little Table Mountain (Tlt units), the Isom-type welded ash-flow tuff formation (Ti), and the lower and upper members of the Shingle Pass Tuff (Tspl and Tspu) were deposited and preserved in the basin east of the Soldier Spring fault.

Following a fairly long interval of erosion, the tuff of Pipe Organ Spring (Tp units) was deposited in the persistent shallow basin just east of the Soldier Spring fault. The source of the Pipe Organ Spring is unknown, but presumably it lies east of the Jefferson quadrangle. Minor offset of the northwest-trending strike-slip fault that intersects the 26.4-Ma rhyolite plug (**Trp**) indicates that the basin may have continued gradual subsidence subsequent to the plug's emplacement. During the interval of Pipe Organ Spring deposition, thin layers of unit D of the Bates Mountain Tuff (**Tbt**), at about 24 Ma, and the tuff of Clipper Gap (**Tcg**), at about 23 Ma, were emplaced. These units also were derived from an eastern source.

A biotite-rich rhyodacitic ash-flow tuff (**Tbi**) from an unknown source marks the last event of volcanic activity manifested in the Jefferson quadrangle.

The oldest Quaternary deposit in the area is Pleistocene alluvium (**Qa1a**). It indicates that 20–40 m of erosion along stream courses has occurred since its deposition. Varied younger alluvial deposits have since been laid down, the youngest being active alluvium in present stream courses (**Qa3**).

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