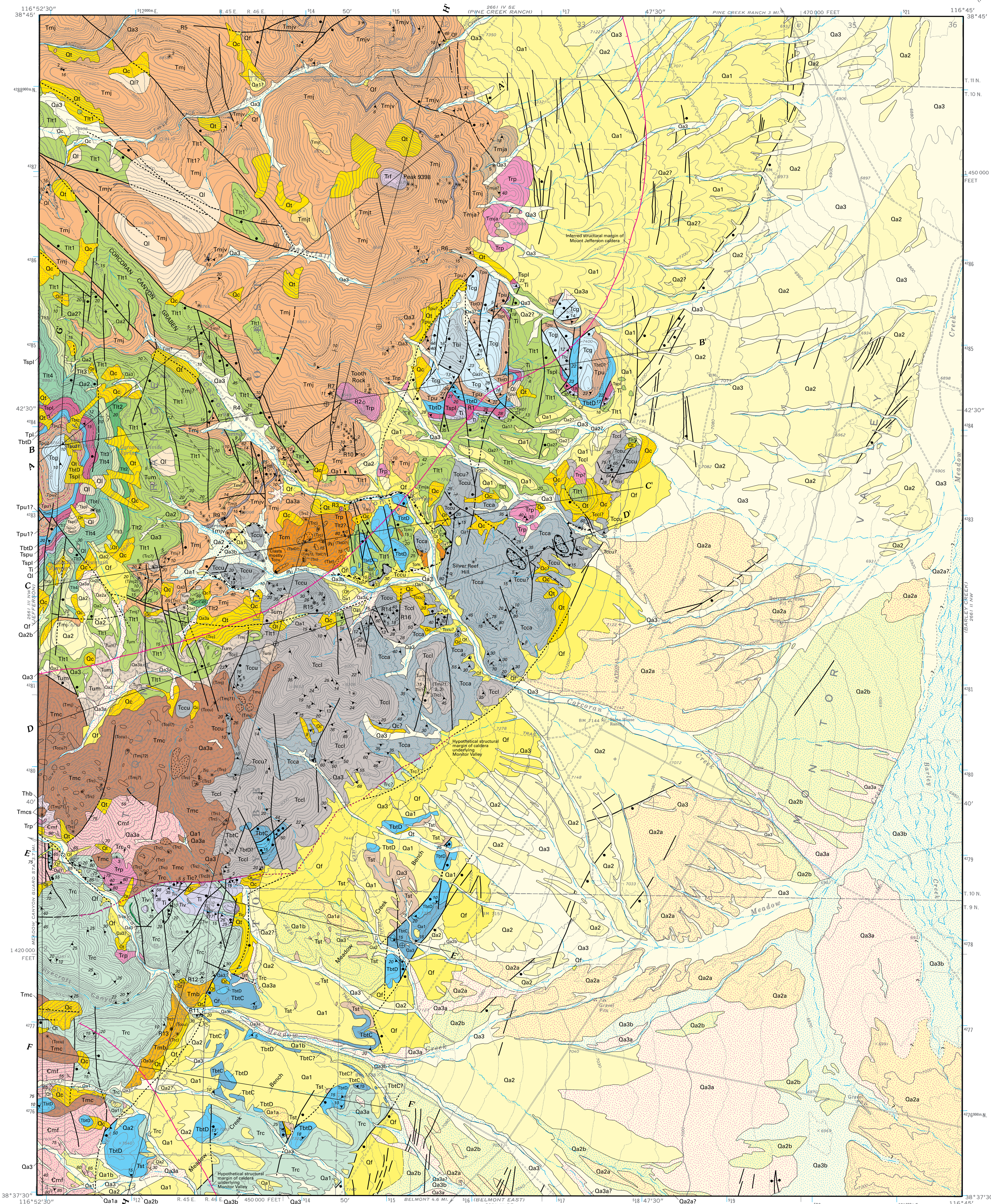
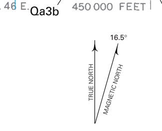
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY



Base from U.S. Geological Survey, 1971
Projection and 10,000-foot grid ticks: Nevada coordinate system, central zone (transverse Mercator)
1,000-meter Universal Transverse Mercator grid ticks, zone 11, shown in blue. 1927 North American datum



1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

1 MILE

1 KILOMETER

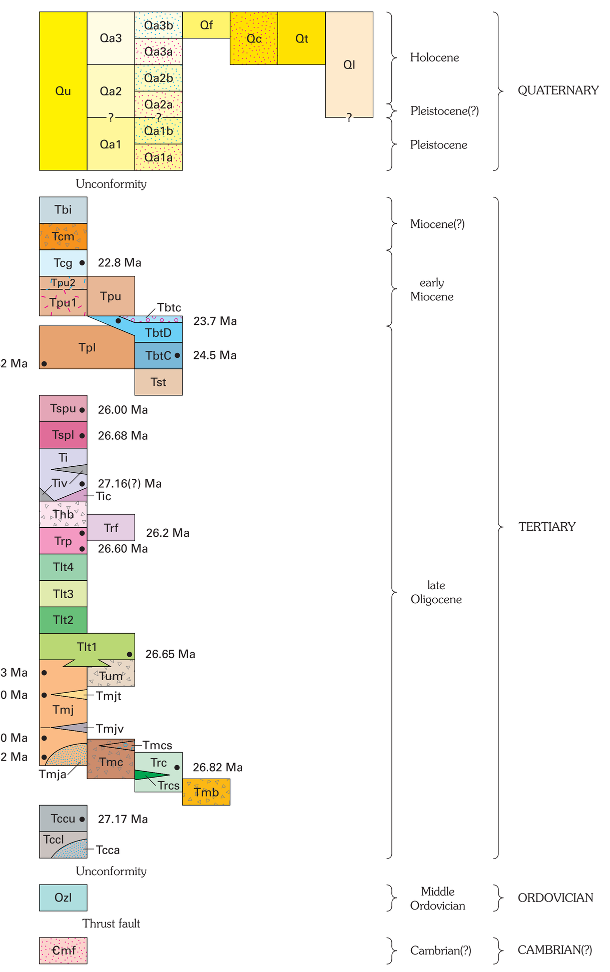
CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS

NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

Geology mapped in May–June 1983, June–July 1984, July–August 1991, July–August 1992 (assisted by Ben Reed), June–July 1993, July 1994, 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 April 27, 1999

CORRELATION OF MAP UNITS



LIST OF MAP UNITS

Qu	**Surficial deposits, undivided (Quaternary)**
	Alluvium (Holocene, Pleistocene?, and Pleistocene)
Qa3	**Youngest alluvium, undivided (Holocene)**
Qa3b	**Youngest alluvium b**
Qa3a	**Youngest alluvium a**
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**
Qa1a	**Oldest alluvium a**
Qf	**Alluvial-fan deposits (Holocene)**
Qc	**Colluvium and slope wash (Holocene)**
Qt	**Talus (Holocene)**
Ql	**Landslide deposits (Holocene and Pleistocene?)**
Tbi	**Biotite-bearing ash-flow tuff (Miocene)**
Tcm	**Megabreccia of Corcoran Creek (Miocene?)**
Tcg	**Tuff of Clipper Gap (lower Miocene)**
	Tuff of Pipe Organ Spring (lower Miocene, upper Oligocene)
Tpu	**Upper member (lower Miocene)**
Tpu2	**Upper unit**
Tpu1	**Lower unit**
Tpl	**Lower member (upper Oligocene)**
	Bates Mountain Tuff (lower Miocene and upper Oligocene)
TbtD	**Unit D (lower Miocene and upper Oligocene)**
Tbtc	**Conglomerate layer**
TbtC	**Unit C (upper Oligocene)**
Tst	**Tuffaceous siltstone (upper Oligocene)**
	Shingle Pass Tuff (upper Oligocene)
Tspu	**Upper member**
Tspl	**Lower member**
	Isom-type ash-flow tuff (upper Oligocene)
Ti	**Welded ash-flow tuff**
Tiv	**Vitrophyre**
Tic	**Conglomerate**
Thb	**Heterolithic breccia (upper Oligocene)**
Trf	**Rhyolite flow rock (upper Oligocene)**
Trp	**Rhyolite plugs (late Oligocene)**
	Volcaniclastic rocks of Little Table Mountain (upper Oligocene)
Tlt4	**Tuffaceous siltstone and sandstone, and tuff**
Tlt3	**Zeolitic tuff**
Tlt2	**Pumiceous ash-flow tuff**
Tlt1	**Tuffaceous claystone, siltstone, sandstone, and conglomerate, and tuff**
Tum	**Unnamed megabreccia unit (upper Oligocene)**
	Tuff of Mount Jefferson (upper Oligocene)
Tmj	**Principal member**
Tmjv	**Vitrophyre**
Tmjt	**Tuffaceous sedimentary rocks**
Tmja	**Altered tuff**
Tmc	**Megabreccia of Meadow Canyon (upper Oligocene)**
Tmcs	**Tuffaceous sandstone**
Trc	**Tuff of Ryecroft Canyon (upper Oligocene)**
Trcs	**Conglomerate lens**
Tmb	**Monolithologic megabreccia (upper Oligocene)**
	Tuff of Corcoran Canyon (upper Oligocene)
Tccu	**Upper member**
Tccl	**Lower member**
Tcca	**Altered ash-flow tuff**
Ozl	**Zanzibar Formation (Middle Ordovician)**
Cmf	**Mayflower Formation (Cambrian?)**

Contact—Dashed where approximately located or gradational; queried where uncertain. Arrow on intrusive contacts in cross sections shows direction of emplacement

Internal contact within map unit—Generally shows bedding plane in sedimentary rocks or flow or cooling unit contact in ash-flow tuffs on map. 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. Arrow shows dip of fault plane; double-barbed arrow shows plunge of lineations on fault surface. On cross sections only, A indicates displacement away; T indicates displacement toward

Thrust fault—Dotted where concealed. Teeth on upper plate

Detachment fault—Dashed where approximately located; dotted where concealed; queried where uncertain. Teeth on upper plate

Caldera structural margin—Approximately located or inferred

Caldera structural margin coincident with high-angle fault in southwest part of map area

Sharp subsurface paleotopographic slope

Strike and dip of inclined bedding in bedded rocks

Strike and dip of foliation—Schistosity in metasedimentary rocks; compaction foliation in ash-flow tuff; flow layering in rhyolite plugs. Absence of value indicates dip not measured

Inclined—Arrow shows plunge of lineations

Vertical

Horizontal compaction foliation in ash-flow tuff

Cleavage in metasedimentary rocks

Inclined

Vertical

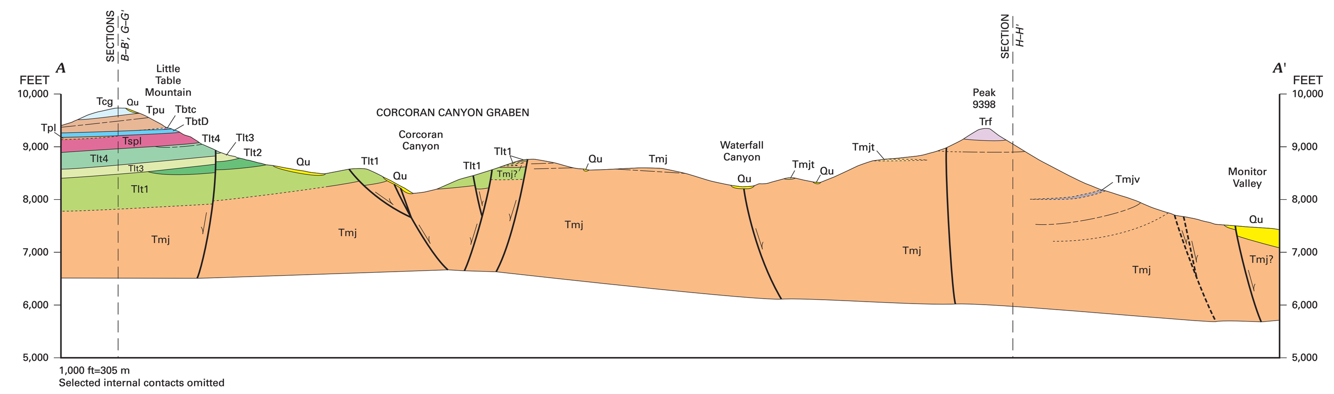
Vein—Arrow shows dip. q, quartz vein; c, calcite vein; f, fissure vein

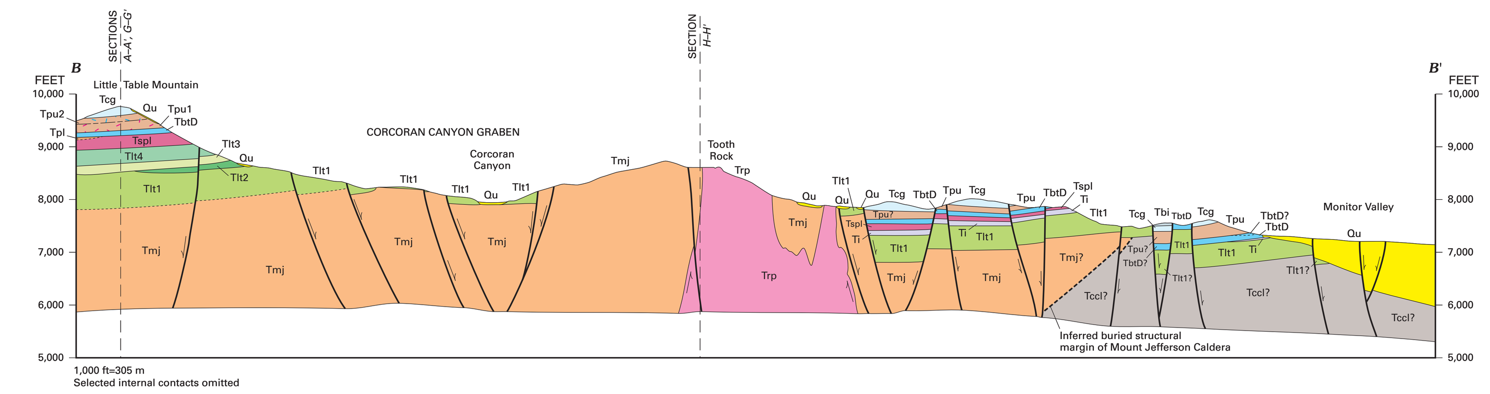
Brecciated rock

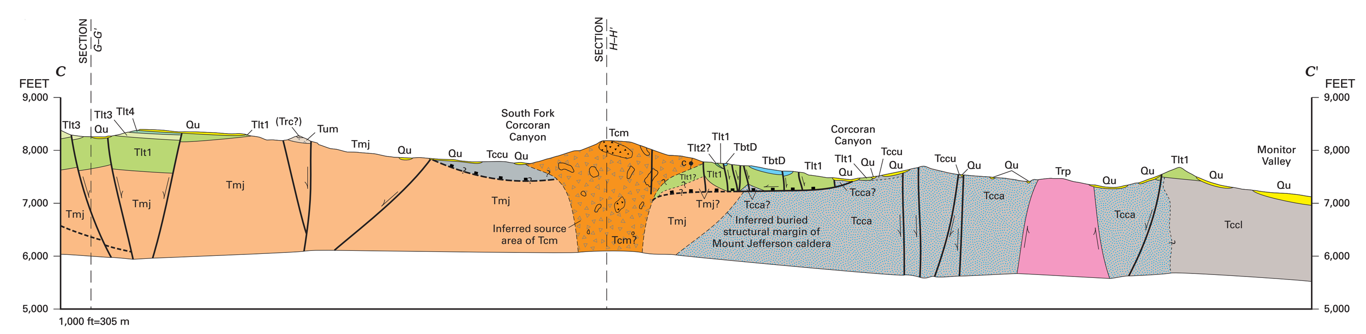
Large block in megabreccia—Label in parentheses indicates specific map unit where recognized; (Pz) indicates Paleozoic rock, undivided; (Tbt) indicates Bates Mountain Tuff, undivided; queried where uncertain

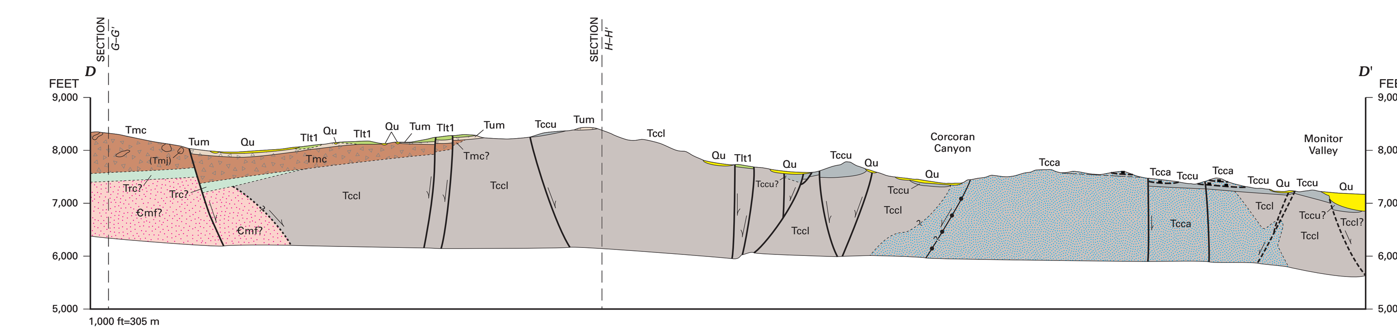
Radiometrically dated rock sample locality

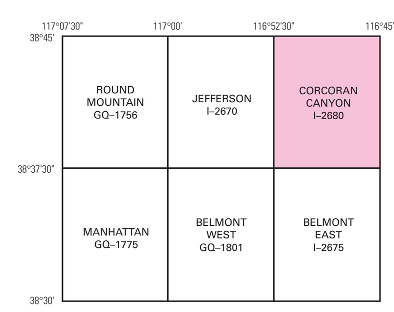
Location of rock sample with modal analysis—Not all shown. Number indicates category assignment based on phenocryst index (PI). Where known, label in parentheses indicates identity of sample in megabreccia (some modal data are from megabreccia blocks too small to show at map scale); queried where uncertain; number indicates PI. *Trc* indicates megabreccia matrix sample. Position may coincide with radiometrically dated rock sample locality symbol to yield ✻



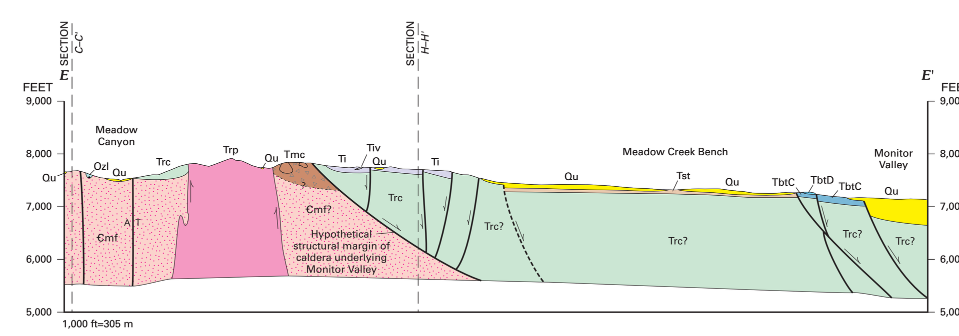


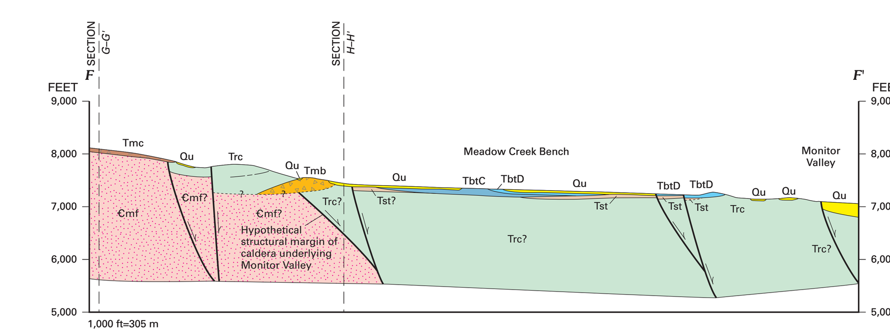


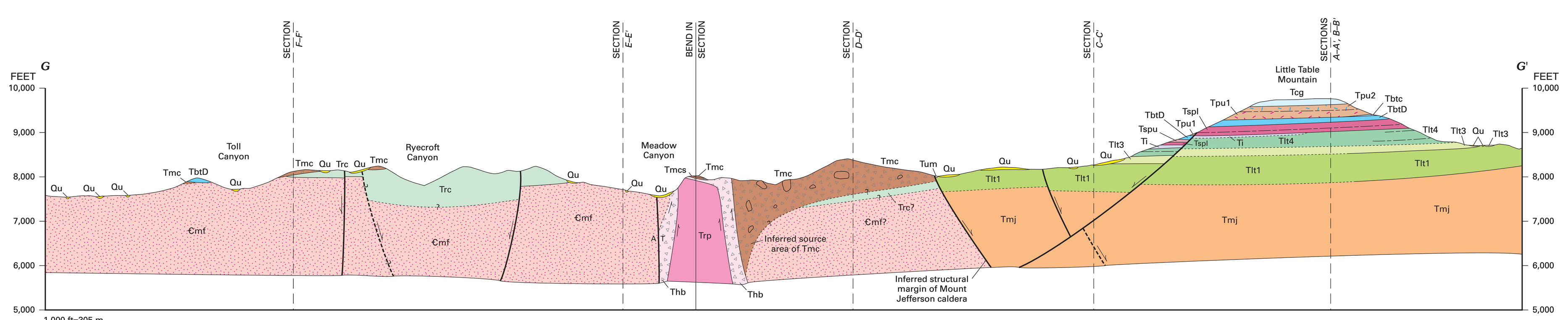


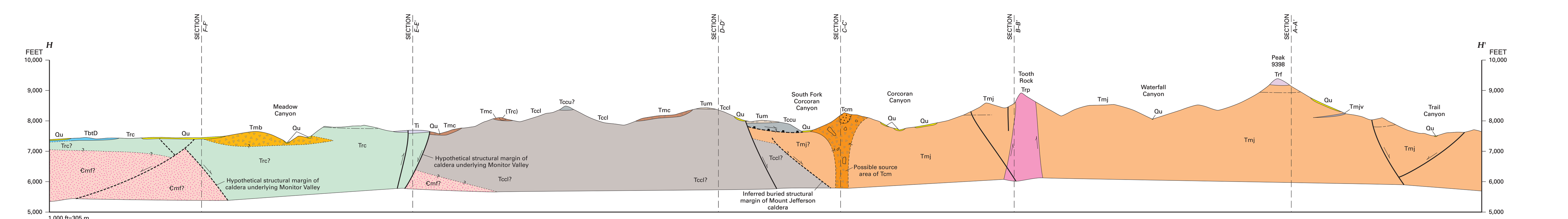


INDEX MAP









GEOLOGIC MAP OF THE CORCORAN CANYON QUADRANGLE, NYE COUNTY, NEVADA

By
Daniel R. Shawe, Richard F. Hardyman, and Frank M. Byers, Jr.

2000

This map was produced on request, directly from digital files, on an electronic plotter

For sale by U.S. Geological Survey Information Services
Box 25286, Federal Center, Denver, CO 80225
1-888-ASK-USGS

This map is also available as a PDF at http://greenwood.cr.usgs.gov/greenwood-pubs.html

Geologic map of the Corcoran Canyon quadrangle, Nye County, Nevada

By Daniel R. Shawe, Richard F. Hardyman, and Frank M. Byers, Jr.

Geologic Investigations Series I–2680

Caption is on the back of this page

2000

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

View northwest from the northeast side of Corcoran Canyon, 1 km north of canyon mouth. Little Table Mountain to the left; Tooth Rock to the right; Mount Jefferson in the distance, center. Ben Reed (lower left) is standing on altered tuff of Corcoran Canyon (Tcca); roadcut in middle distance marks Silver Reef Hill (informal name); flat-lying layers underlying Little Table Mountain are volcaniclastic rocks of Little Table Mountain (Tlt units); Tooth Rock is a rhyolite plug (Trp); tuff of Mount Jefferson (Tmj) surrounds Tooth Rock and underlies Mount Jefferson; knobby hills this side of Little Table Mountain are made up of megabreccia of Corcoran Creek (Tcm) and disrupted volcaniclastic rocks of Little Table Mountain; Corcoran Canyon graben extends northwestward up canyon toward Mount Jefferson. Photograph by the first author, July 1992.

DESCRIPTION OF MAP UNITS

[Geologic mapping was done by Shawe and Hardyman; map compilation of the quadrangle and text preparation were by Shawe; phenocryst contents of most of the ash-flow tuffs and other volcanic rocks described here were determined by modal analyses of thin sections by Byers. Between 2,000 and 4,000 points per thin section of crystal-rich rocks (20 percent or more phenocrysts) generally were counted; points counted per thin section ranged to more than 10,000 for some crystal-poor rocks. A few modal analyses were made by Shawe, Hardyman, and D.A. John of the U.S. Geological Survey (generally 1,000–2,000 points counted). Phenocryst contents are given as volume percent of the total rock, and phenocryst minerals are given as volume percent of total phenocrysts; Q, quartz; K, alkali feldspar (sanidine unless otherwise noted); P, plagioclase; B, biotite; H, hornblende; C, clinopyroxene; O, opaque-oxide minerals; M, unspecified mafic minerals, commonly altered. Other specific mineral names are spelled out in places. Accessory minerals (zircon, apatite, allanite, monazite, sphene) 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.

The modal data allowed assignment of samples into various categories according to phenocryst percentages, for purposes of comparison and correlation of some of the volcanic units described. For the tuff of Mount Jefferson (Tmj) and the tuff of Corcoran Canyon (Tcc units), the category assignments are based on generally increasing plagioclase and mafic mineral contents, and decreasing quartz and alkali feldspar contents, more felsic to more mafic from category 1 through 5, as described by Shawe (1999b). 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 into the 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. The category of modally analyzed samples of tuff is indicated on the geologic map, where appropriate, by number. A PI of greater than 1.00 is also used to categorize the tuff of Ryecroft Canyon (Trc).

Chemical analyses 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 generally equivalent to 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]

Qu **Surficial 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. Specific units could not be correlated by age everywhere in the quadrangle; thus sediment mapped as one unit (for example, Qa3a) may be the same age as sediment mapped as a different unit (for example, Qa2b) elsewhere. Studies of soil characteristics of the different alluvium units, not attempted here, might clarify age relations. Alluvium units are not subdivided in 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, undivided (Holocene)**—Active alluvium in drainage courses. Characterized by braided strands of recently deposited gravel, sand, and silt. Forms broad alluvial flats in Monitor Valley in east part of quadrangle, and fills feeder courses that extend from the interior of the Toquima Range and lead into the broader flats. Maximum thickness a few meters

Qa3b **Youngest alluvium b**—Abundant strands of recently deposited sediment. May grade into alluvial-fan deposits (Qf) or colluvium and slope wash (Qc)

Qa3a **Youngest alluvium a**—Slightly older than Qa3b. Qa3a commonly at higher elevation (a meter or so) than Qa3b along sides of drainage courses. Qa3a may grade into alluvial-fan deposits (Qf) or colluvium and slope wash (Qc)

Qa2 **Older alluvium, undivided (Holocene and Pleistocene?)**—Stabilized alluvium in stream terraces and courses, and flat valley-fill alluvial fans, mostly in Monitor Valley, topographically higher (a meter or more) than youngest alluvium (Qa3 units); presently being eroded. Clasts generally are only slightly weathered and may be moderately sorted. Maximum thickness several tens of meters

Qa2b **Older alluvium b (Holocene)**—Forms stabilized alluvium in some stream courses, and stabilized alluvial flats in Monitor Valley

Qa2a **Older alluvium a (Holocene and Pleistocene?)**—Appreciably eroded alluvial deposits, notably alluvial flats in Monitor Valley, laced with strands of actively forming alluvium too small to map. Older parts of Qa2a may be as old as Pleistocene

Qa1 **Oldest alluvium, undivided (Pleistocene)**—Stabilized alluvium that underlies stream terraces as much as 20–40 m above present stream courses, and extensive valley flats on raised (up-faulted) benches as much as 20 m higher than adjacent younger alluvium, along west side of Monitor Valley. Larger clasts (cobbles and small boulders), especially those of volcanic rocks, may be significantly weathered. Maximum thickness, including subsurface below younger alluvium in Monitor Valley, probably several hundred meters

Qa1b **Oldest alluvium b**—Distinguished only in southwest corner of quadrangle as a small erosional remnant, and in an area of about a square kilometer, about 1 km north of Meadow Creek and along south side of Meadow Creek in southwest part of quadrangle

Qa1a **Oldest alluvium a**—Forms two small erosional remnants, one in southwest corner of quadrangle, and a second on Meadow Creek Bench about 1 km north of Meadow Creek in southwest part of quadrangle

Qf **Alluvial-fan deposits (Holocene)**—Commonly formed at the foot of short drainages where they enter deeply incised stream courses, and fronting the steeper parts of the Toquima Range along west side of Monitor Valley. Maximum thickness several tens of meters

Qc **Colluvium and slope wash (Holocene)**—Gently sloping accumulations of disintegrated rock more or less in place, or deposited by slope wash. May grade up into talus (Qt) or down into alluvium (Qa3 or Qa2 units). 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. May grade downslope into colluvium and slope wash (Qc) and alluvial-fan deposits (Qf). Maximum thickness several meters

Ql **Landslide deposits (Holocene and Pleistocene?)**—Generally heterogeneous mixture of rock fragments and soil derived by slope failure from nearby higher bedrock and surficial materials [locally indicated by map unit symbol in parentheses (Tbt)]. Formed commonly on poorly consolidated tuffaceous sedimentary rocks, as on the slopes of Little Table Mountain in northwest part of quadrangle, and on partially to moderately welded ash-flow tuff (Tmj) in northwest part of quadrangle where collapse of the deposits may have been in part by solifluction. Maximum thickness a few tens of meters

Tbi **Biotite-bearing ash-flow tuff (Miocene?)**—Light-gray; moderately crystal rich, partially to moderately welded rhyodacitic ash-flow tuff; weathers light brownish gray. Contains black-glass shards and fragments in its lower part; minor small lithic fragments locally. Phenocrysts (1–3 mm in diameter) comprise 7–23 percent of five samples of tuff, and consist of: Q, 1–2; K, 13–25; P, 57–68; B, 9–15; O, 2–7; and H, 0–4. Zircon and apatite are accessory minerals. A chemical analysis of one sample of the biotite-bearing tuff shows the following percentages of components: SiO_2, 71.0; Al_2O_3, 15.0; K_2O, 4.28; Na_2O, 4.30; CaO, 1.78; Fe_2O_3, 1.78; FeO, 0.64; MgO, 0.55; TiO_2, 0.41; P_2O_5, 0.12; and MnO, 0.08 (rhyolite). A chemical analysis of a second sample shows the following composition: SiO_2, 71.2; Al_2O_3, 14.8; K_2O, 5.20; Na_2O, 3.43; CaO, 2.31; Fe_2O_3, 1.79; FeO, less than 0.01; MgO, 0.75; TiO_2, 0.30; P_2O_5, 0.06; and MnO, 0.10 (rhyolite). The second sample probably is altered; loss on ignition is 6.89 percent (compare composition of Tbi cited in Shawe, 1999b). Unit is exposed in two small areas, one just east of hill 8013 and one just northwest of hill 7672 in north-central part of quadrangle. Relation to underlying rocks uncertain; possibly disconformable on the tuff of Clipper Gap (Tcg); upper part eroded; maximum remnant thickness about 50 m

Megabreccia of Corcoran Creek (Miocene?)—Character of this complex megabreccia is unusual in that the megabreccia (1) appears to be gradational with, and locally younger than, a large deformed slab of the lowest member of volcaniclastic rocks of Little Table Mountain (Tlt1) which in turn incorporates foundered blocks of volcanic units, such as unit D of the Bates Mountain Tuff (TbtD) and upper member of the Shingle Pass Tuff (Tspu), that are younger than Tlt1; (2) contains matrix that is extensively pulverized and altered; (3) is laced with abundant irregular veinlets of quartz and calcite and microbreccia-like dikelets of pulverized tuff; and (4) shows evidence of multiple episodes of brecciation. Association with a younger assemblage of rocks suggests a relatively young age for the megabreccia.

Petrographic data presented below are intended to clarify the complex interrelations of brecciated blocks, megabreccia matrix, fragments—brecciated and unbrecciated—in brecciated blocks, and matrix in brecciated blocks.

Matrix of the megabreccia consists of a variety of materials that exhibit varied stages of brecciation. Much of the matrix, as seen in thin section, consists of a microbreccia of rhyolitic fragments ranging in size from a few centimeters down to cryptocrystalline. Most rhyolitic fragments have a cryptocrystalline matrix that appears to be devitrified glass; flow layering is evident in some fragments; and a few fragments have the appearance of pumice. In most of the matrix, shard forms are not evident. However, one sample of matrix as seen under the microscope contains 22 percent phenocrysts (2–3 mm) in a groundmass of pulverized crystals in devitrified glass in which shard forms are faintly visible. Phenocrysts consist of: Q, 22; K, 16; P, 43; B, 1; and O, 18 (mostly limonite that replaces cubic pyrite throughout phenocrysts and groundmass). This sample is similar in composition to PI category 2 rhyolite of the tuff of Mount Jefferson (Tmj) or the tuff of Corcoran Canyon (Tcc units) (PI category defined at beginning of "Description of Map Units"). A modal analysis of a thin section of altered matrix collected on the north side of south fork of Corcoran Canyon indicates 21 percent phenocrysts (0.5–3.5 mm) that consist of: Q, 23; K (including much anorthoclase), 56; P, 1; 0, 3; and M (altered), 16. Abundance of anorthoclase suggests affinity to young volcanic units such as the tuff of Clipper Gap (Tcg), Bates Mountain Tuff (Tbt units), or tuff of Pipe Organ Spring (Tp units).

Some of the larger matrix fragments have themselves been brecciated. In addition to rhyolitic fragments, Paleozoic argillite and schist fragments are abundant locally; volcanic rock fragments of intermediate composition are rare.

The matrix characteristically is altered. Iron-oxide replacement of mafic minerals and feldspars is common, and iron oxide is pervasive in groundmass or forms irregular veinlets locally. Irregular quartz and calcite veinlets, some as wide as 10 cm, are common in the megabreccia matrix. Also present in places are thin dikelets of microbreccia that contain abundant fragments of rhyolitic rocks or dark-gray Paleozoic argillite, chert, and schist. Calcite replaces feldspars and mafic minerals, and forms irregular patches throughout the groundmass. Calcite is especially abundant in a small area of megabreccia that lies on the deformed slab of tuffaceous sedimentary rocks of the lowest member of the volcaniclastic rocks of Little Table Mountain (Tlt1) between Corcoran Canyon and south fork of Corcoran Canyon in central part of quadrangle.

Clasts in the megabreccia are small (meter size) to huge (200 m long) blocks and slabs of a variety of materials, mostly brecciated and in part showing more than one stage of brecciation.

Most of the larger blocks in the megabreccia are of rhyolitic welded tuff. Modal analyses of thin sections of three samples of welded tuff fragments in megabreccia blocks indicate 16–41 percent phenocrysts (1–4 mm) that consist of: Q, 17–35; K, 27–52; P, 11–42; B, 0–7; O, 0–1.3; and M, 0–5. Phenocryst composition and chemical composition suggest correlation with the Oligocene tuff of Ryecroft Canyon (Trc), described in a later section. The tuff has been strongly altered such that feldspars and mafic minerals have been extensively replaced by sericite, calcite, silica, and iron oxide. Modal analysis of one thin section of another tuff fragment indicates 29 percent phenocrysts (1–3 mm) that consist of: Q, 49; K, 47; and P, 5. This composition also is similar to that of quartz-rich tuff of Ryecroft Canyon (Trc), as described in a later section. Groundmass of this sample, cryptocrystalline and devitrified, contains some plumose glass fragments as well as abundant small fragmental crystals. Modal analysis of one thin section of a fragment in one large brecciated block indicates 37 percent phenocrysts (2–3 mm) that consist of: Q, 20; K, 23; P, 50; B, 6; O, 0.5; and M, 0.5. Plagioclase has been sericitized, silicified, and iron mineralized. This sample is similar in composition to PI category 2 rhyolite of the tuff of Mount Jefferson (Tmj), or of the tuff of Corcoran Canyon (Tcc units).

Modal analysis of a sample of a large (80 m long) block of microbrecciated volcanic rock indicated 25 percent phenocrysts (1–3.5 mm) in the breccia fragments that consist of: Q, 26; K, 56; and P, 18. Mafic minerals have been destroyed by alteration, and limonite is abundant in the rock.

A large (200 m long) block that contains fragments mostly similar in composition to the tuff of Ryecroft Canyon (Trc) has a pulverized tuff groundmass. A modal analysis of the groundmass indicated 29 percent phenocrysts (1.5–2 mm) that consist of: Q, 29; K, 33; and P, 38. Mafic minerals have been destroyed by alteration, and plagioclase phenocrysts are much altered. Shard forms are evident only in larger tuff fragments.

An isolated tuff fragment in a large brecciated block that contains fragments mostly similar to the tuff of Ryecroft Canyon is similar to either the Miocene tuff of Clipper Gap (Tcg) or unit D of the Bates Mountain Tuff (TbtD). Modal analysis indicated about 27 percent phenocrysts (2–3.5 mm; larger and more abundant than in Tcg or TbtD) that consist of: Q, 25; K, 72; P, 2; and O, 0.7.

Modal analysis of a small (a few meters long?) block of tuff in the megabreccia contains 16 percent phenocrysts (1–3 mm) that consist of: Q, 17; K, 40; P, 36; and B, 7. The composition is similar to that of unit C of the Bates Mountain Tuff (TbtC), described in a later section. The tuff is hydrothermally altered; biotite and plagioclase have been sericitized; and groundmass is extensively silicified.

An area about 200 m across at the west edge of the outcrop of megabreccia of Corcoran Creek contains numerous small blocks (as large as 1 m) of the upper member of the Oligocene tuff of Corcoran Canyon (Tccu). Other megabreccia blocks elsewhere in the megabreccia of Corcoran Creek consist of layered epiclastic tuff (of unknown source) and extremely brecciated Paleozoic rocks. One large (10x30 m) block of Paleozoic rocks (Pz) consists of subrounded fragments of dark-gray argillite, chert, and limestone, and light-brown to gray quartzite (eastern occurrence); minor fragments of coarse-grained porphyritic granite are present, similar to such in the Belmont pluton about 9 km to the southwest (Shawe, 1998, 1999b). Another large block of Paleozoic rock (Pz) appears to consist entirely of strongly brecciated dark-gray silicified argillite and chert (southwestern occurrence). Other smaller blocks are brecciated gray limestone. Small blocks of Paleozoic rocks about 1 m in diameter are scattered sparsely throughout the megabreccia.

The evidence that the megabreccia of Corcoran Creek is younger than foundered blocks of units such as unit D of the Bates Mountain Tuff (TbtD) in the lowest member of the volcaniclastic rocks of Little Table Mountain (Tlt1) indicates that it cannot have been related to calderas that produced the Oligocene ash-flow tuff formations, the tuff of Mount Jefferson (Tmj), the tuff of Ryecroft Canyon (Trc), and the tuff of Corcoran Canyon (Tcc units). However, the megabreccia lies on the apparent structural margin of the Mount Jefferson caldera, suggesting that its position was structurally controlled. The extreme brecciation of the formation, together with evidence of multiple episodes of brecciation, indicate that the formation is a product of several violent, probably explosive events. We infer that the megabreccia is a breccia pipe or diatreme that underwent several phases of emplacement, possibly involving both eruption and subsidence, and incorporating materials from several levels beneath the surface (for a description of the inferred origin of a similar pipe, see Gilluly and Gates, 1965, p. 71–75).

During emplacement of the megabreccia pipe, an event of sudden subsidence may have allowed lateral collapse of the large slab of the lowest member of the volcaniclastic rocks of Little Table Mountain (Tlt1) and younger volcanics that overlie Tlt1 east of the megabreccia pipe, accounting for its deformed character. Collapse of the slab because of withdrawal of megabreccia could also account for apparent intermixing of materials at the indefinite boundary between the two units

Tcg **Tuff of Clipper Gap (lower Miocene)**—Pale-lavender-gray, partially to moderately welded, crystal-poor rhyolitic ash-flow tuff; weathers light pinkish gray. Commonly contains abundant greatly flattened, pale-gray pumice lapilli as long as 5 cm. Modal analyses of four thin sections indicate 5–6 percent phenocrysts (1–2 mm) that consist of: Q, 4–22; K, 68–89; P, 1–4; O, 1–4; and M, 0–3. Alkali feldspar (K) in some samples is in part anorthoclase. Zircon is generally common; apatite and allanite are sparse or rare. A chemical analysis of one sample of the tuff indicates the following percentages of components: SiO_2, 76.7; Al_2O_3, 12.4; K_2O, 4.90; Na_2O, 3.83; CaO, 0.36; Fe_2O_3, 1.48; FeO, 0.08; MgO, less than 0.10; TiO_2, 0.13; P_2O_5, less than 0.05; and MnO, 0.04 (rhyolite). Analysis of a second sample of tuff shows: SiO_2, 72.2; Al_2O_3, 14.7; K_2O, 4.50; Na_2O, 4.17; CaO, 1.44; Fe_2O_3, 1.60; FeO, 0.52; MgO, 0.43; TiO_2, 0.35; P_2O_5, 0.08; and MnO, 0.07 (rhyolite). The marked difference in composition between the two samples may indicate that they were collected from stratigraphically different positions in the unit. The unit is exposed at the top of Little Table Mountain and on low foothills of the Toquima Range in north-central part of quadrangle. Age of the tuff of Clipper Gap was stated by Best and others (1989, p. 110) as 22.8 Ma. Sargent and McKee (1969) reported a date of 22.8±0.9 Ma for the unit. Boden (1992) correlated the unit in the Toquima Range (his member 6 of the tuffs and sedimentary rocks of Road Canyon, Trt6) with the tuff of Clipper Gap, and he reported a sanidine K/Ar age of his member 6 as 22.1±0.3 Ma, but Boden earlier (1986) identified the unit as unit D of the Bates Mountain Tuff. As discussed below, unit D of the Bates Mountain Tuff has been dated variously as 23.4±0.9, 23.7±0.6, and 23.9±0.9 Ma. Because the tuff of Clipper Gap and the Bates Mountain Tuff are petrographically similar, distinction between the two is difficult; the ages of the two units indicated above also point to a problem in correlating the units. The tuff of Clipper Gap in the Corcoran Canyon quadrangle has a thickness of 0–50 m

Tuff of Pipe Organ Spring (lower Miocene, upper Oligocene)—Formation mapped as two members in the quadrangle; an upper member (Tpu; mapped locally as two units, as it was in the adjacent Jefferson quadrangle to the west, Tpu2 and Tpu1; Shawe, 1999b) and a lower member (Tpl). The lower member appears to be equivalent to member 2 (Trt2) of Boden's (1986, 1992) 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 consisting of the lower member (Tpl) just south of Pipe Organ Spring in the Jefferson quadrangle. The upper member (Tpu) is separated from the lower member by unit D of the Bates Mountain Tuff (TbtD) near west-central edge of quadrangle

Tpu **Upper member (lower Miocene)**—Light-gray to light-brownish-gray, partially to densely welded, crystal-poor rhyolitic ash-flow tuff; weathers light brown to light yellowish brown. Locally mapped as two units (Tpu2, Tpu1). Appears conformable on the underlying unit D of the Bates Mountain Tuff (TbtD). Exposed near the top of Little Table Mountain at west edge of quadrangle (Tpu2, Tpu1), and on foothills of the Toquima Range in north-central part of quadrangle (Tpu). Thickness 90–100 m on Little Table Mountain where upper and lower units are mapped, and 30–80 m in foothills in north-central part of quadrangle where member is undivided. Equivalent to member 5 (Trt5) of Boden's (1992) tuffs and sedimentary rocks of Road Canyon

Tpu2 **Upper unit**—Characterized by mottled appearance due to small weathered pumice lapilli; separated by an indefinite contact from the lower unit (Tpu1). Modal analyses of three samples of the upper unit indicate 6–9 percent phenocrysts (1–3 mm) of a rather wide range in composition: Q, 1–34; K, 46–67; P, 7–33; B, 0–9; O, 1–2; and H, 0–2. Alkali feldspar (K) in some samples is in part anorthoclase. Zircon, apatite, and allanite are sparse accessory minerals

Tpu1 **Lower unit**—Contains black-glass shards, and, locally, flattened black-glass pumice lapilli, mostly less than 4 cm long and rarely as much as 30 cm long. Modal analyses of three thin sections of the lower unit indicate 8–9 percent phenocrysts (1–3 mm) that consist of: Q, 2–20; K, 46–72; P, 21–28; B, 1–2; O, 1 each; and H and C, 1–4. Zircon and allanite are accessory minerals. A chemical analysis of a sample of the lower unit indicates the following percentages of components: SiO_2, 74.5; Al_2O_3, 13.7; K_2O, 5.34; Na_2O, 3.97; CaO, 0.70; Fe_2O_3, 1.35; FeO, 0.13; MgO, 0.20; TiO_2, 0.16; P_2O_5, less than 0.05; and MnO, 0.06 (rhyolite)

Tpl **Lower member (upper Oligocene)**—Light-yellowish-brown; nonwelded to poorly welded, moderately crystal-rich rhyolitic ash-flow tuff. A detailed description is given for the unit in the adjacent Jefferson quadrangle (Shawe, 1999b). Present only on the northwest flank of Little Table Mountain at west boundary of quadrangle where a thin wedge (0 to a few meters thick) conformably underlies unit D of the Bates Mountain Tuff (TbtD) and disconformably overlies the lower member of the Shingle Pass Tuff (Tspl). A sanidine $^{40}Ar/^{39}Ar$ date of 25.42±0.05 (1σ) Ma (L.W. Snee, written commun., 1997) was obtained on a sample collected by Shawe from Boden's member Trt2, the apparent equivalent of Tpl, in Road Canyon 12 km north of the Corcoran Canyon quadrangle

Bates Mountain Tuff (lower Miocene and upper Oligocene)—The Bates Mountain Tuff is mapped in north part of quadrangle as unit D (TbtD), whereas it is mapped in southwest part of quadrangle as both unit D (TbtD) and underlying unit C (TbtC). Equivalent to member Trt3 of Boden's (1992) tuffs and sedimentary rocks of Road Canyon. A thin conglomerate layer (Tbtc) lies at the top of unit TbtD on the north slope of Little Table Mountain

TbtD **Unit D (lower Miocene and upper Oligocene)**—Pinkish-gray and light-brownish-gray to lavender-gray and gray, crystal-poor, partially to moderately welded rhyolitic ash-flow tuff; weathers light orangish brown to reddish brown. Characterized in some horizons by abundant oval gas cavities or weathered pumice holes as much as 15 cm long, imparting a "swiss cheese" appearance to the rock (see also McKee, 1976, fig. 34), and flattened pumice fragments 1–2 cm long. Modal analyses of two thin sections of samples collected in north part of quadrangle show 6 and 3 percent phenocrysts (1–2.5 mm) that consist of: Q, 3 and 18; K, 79 and 67; P, 4 and 10; O, 7 and 4; and M, 7 and 4. Zircon is a sparse accessory mineral. Modal analyses of seven thin sections of samples collected in southwest part of quadrangle indicate 4–7 percent phenocrysts (1–2.5 mm) that consist of: Q, 17–42; K, 54–78; P, 1–15; B, 0–1; O, 0–2.5; and H, 0–3. Alkali feldspar (K) in some samples is in part anorthoclase. Sparse zircon and allanite, and rare monazite, are accessory minerals. A chemical analysis of one sample of tuff from unit D consists of the following percentages of components: SiO_2, 76.6; Al_2O_3, 12.5; K_2O, 4.88; Na_20, 3.83; CaO, 0.30; Fe_2O_3, 1.48; FeO, 0.13; MgO, less than 0.10; TiO_2, 0.11; P_2O_5, less than 0.05; and MnO, 0.04 (rhyolite). McKee and Stewart (1971) reported a sanidine K-Ar date of 23.9±0.9 Ma for the unit; according to Grommé and others (1972), unit D has a sanidine K-Ar age of 23.7±0.6 Ma; Sargent and McKee (1969) reported a sanidine K-Ar date of 23.4±0.9 Ma for unit 4 (unit D) of the Bates Mountain Tuff. The unit is exposed on the slopes of Little Table Mountain, in the foothills in north-central part of quadrangle, and on and near Meadow Creek Bench in southwest part of quadrangle. Thickness 0–40 m. The tuff was deposited during an erosional hiatus following deposition of the lower member (Tpl) of the tuff of Pipe Organ Spring, and before deposition of the upper member of the tuff of Pipe Organ Spring (Tpu)

Tbtc **Conglomerate layer**—Contains abundant subangular clasts as large as 15 cm long of crystal-poor tuff, and minor smaller clasts of chert. Thickness less than 1 m

TbtC **Unit C (upper Oligocene)**—Light-orangish-brown to light-gray and light-lavender-gray, crystal-poor, moderately welded rhyolitic ash-flow tuff; weathers light yellowish brown to light brown and lavender gray. Characterized by abundant flattened, pale-gray and light-brownish-gray pumice lapilli 1–2 cm long. In places pumice has weathered out, leaving oblong holes. In one area at east margin of Meadow Creek Bench about 2 km north of Meadow Creek, a lower part of the unit contains only sparse pumice. Modal analyses of five thin sections of samples of unit C indicate 2–11 percent phenocrysts (1–3 mm) with the following composition: Q, 12–30; K, 33–55; P, 25–48; B, 0–5; O, 0.2–4; H, 0–2; and M, 0–1.5. Zircon is common to sparse, allanite is sparse, and apatite is rare. A chemical analysis of a sample of the tuff shows the following percentages of components: SiO_2, 76.4; Al_2O_3, 12.8; K_2O, 5.08; Na_2O, 3.54; CaO, 0.60; Fe_2O_3, 1.17; FeO, 0.13; MgO, 0.20; TiO_2, 0.09; P_2O_5, 0.07; and MnO, 0.02 (rhyolite). Unit C pinches out locally but appears to lie conformably beneath unit D, and above a volcanic siltstone (Tst). A unit in the northern Toquima Range apparently equivalent to Unit C in the Corcoran Canyon quadrangle was dated by McKee and Stewart (1971, table 1, sample 3) as 24.5±1.0 Ma. The unit is exposed on Meadow Creek Bench where it is 0–30 m thick

Tst **Tuffaceous siltstone (upper Oligocene)**—Light-yellowish-brown to light-brown tuffaceous siltstone and minor interlayered light-brown tuffaceous sandstone and light-yellowish-brown to whitish platy claystone. A layer of ash-fall tuff in tuffaceous siltstone, as seen in thin section, consists of about 98 percent uncompacted glass shards and 2 percent crystals (0.1–0.5 mm) made up of subequal amounts of plagioclase and biotite, and lesser amounts of hornblende, quartz, and sanidine, as well as trace amounts of opaque mineral and zircon. In one locality a layer of pebbles of Paleozoic rocks a few centimeters thick occurs in sandstone. One layer of hackly-weathering, light-greenish-gray silicified siltstone-sandstone 2–3 m thick was observed. As seen in thin section, the rock consists of about 98 percent poorly sorted, rounded clay(?) pellets 0.01–1 mm in diameter, in part closely packed with virtually no pore space surrounding pellets, and in part with voids interstitial to pellets. Some larger pellets are aggregates of smaller pellets. Irregular vugs as long as 3 mm are lined with chalcedony, and chalcedony fills interstices around pellets locally. About 2 percent subhedral crystals (mostly 0.1–0.5 mm long) consist of subequal amounts of plagioclase, hornblende, and biotite. Minor to trace amounts of quartz, opaque mineral, allanite, and epidote(?) also are present. The varied crystal compositions of different parts of the tuffaceous siltstone unit suggest different sources of reworked ash-fall material. The unit probably was laid down in a lacustrine environment. The tuffaceous siltstone unit is exposed on Meadow Creek Bench in southwest part of quadrangle, where it appears conformable beneath units C and D of the Bates Mountain Tuff (TbtC and TbtD). The unit appears also to unconformably overlie the tuff of Ryecroft Canyon (Trc) locally in southwest part of quadrangle. Thickness 0–25(?) m

Shingle Pass Tuff (upper Oligocene)—Two members of the Shingle Pass Tuff crop out in the Corcoran Canyon quadrangle. A thin wedge of the upper member (Tspu) on the south slope of Little Table Mountain extends into the quadrangle from the adjacent Jefferson quadrangle, and the lower member (Tspl) crops out around the slopes of Little Table Mountain and in the foothills of the Toquima Range in the north-central part of the Corcoran Canyon quadrangle. Despite the considerable difference in age of the two units (see below), they are quite similar in composition

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. Modal analyses of two thin sections of samples of the tuff indicate 10–17 percent phenocrysts (1–3.5 mm) that consist of: K, 43 and 40; P, 40 and 50; B, 14 and 6; O, 1 and 2; and M (H and C), 3 and 2. Zircon is an accessory mineral. A more detailed description of the unit in the adjacent Jefferson quadrangle is given in Shawe (1999b). A $^{40}Ar/^{39}Ar$ sanidine date for the upper member is 26.00±0.03 Ma (Best and others, 1989). The unit is present in the quadrangle only as a thin wedge (0 to a few meters thick) on the south slope of Little Table Mountain. It appears conformable beneath unit D of the Bates Mountain Tuff (TbtD) and disconformable upon the lower member of the Shingle Pass Tuff (Tspl)

Tspl **Lower member**—Light-gray, moderately crystal-rich, moderately to densely welded latitic ash-flow tuff; weathers light yellowish brown to light yellowish gray. Characterized throughout by abundant black-glass shards. Contains numerous nearly white, moderately compacted pumice lapilli and some lithic fragments (about 1 cm long) locally near the base. Modal analyses of two thin sections of the lower member indicate 12 and 15 percent phenocrysts (1.5–2.5 mm) that consist of: Q, 3 and 1; K, 37 and 32; P, 48 and 58; B, 9 and 7; O, 2 and 0.5; H, trace and 0.5; and C, 2 each. Accessory minerals are common zircon and sparse apatite. Chemical analyses of two samples of the lower member indicate the following percentages of components: SiO_2, 72.8 and 72.7; Al_2O_3, 14.5 and 14.3; K_2O, 5.71 and 4.69; Na_2O, 3.02 and 3.10; CaO, 1.49 and 2.12; Fe_2O_3, 1.36 and 1.42; FeO, 0.35 and 0.68; MgO, 0.42 and 0.58; TiO_2, 0.24 and 0.28; P_2O_5, 0.07 and 0.10; and MnO, 0.07 and 0.06 (rhyolite). Best and others (1989) reported a $^{40}Ar/^{39}Ar$ sanidine date of 26.68±0.03 Ma for the lower member of the Shingle Pass Tuff. The member is 80–90 m thick where it is exposed on Little Table Mountain, and it is 20–30 m thick where it is exposed in the low hills in north-central part of quadrangle

Isom-type ash-flow tuff (upper Oligocene)—Mainly moderately to densely welded ash-flow tuff (Ti). Thin lenses of vitrophyre (Tiv) within and at base of formation, and a thin layer of conglomerate (Tic) locally at base of formation, occur in southwest part of quadrangle. 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 tuffs of the distinctive Isom Formation of eastern Nevada and western Utah, which is about 27 Ma (Best and others, 1989). A sanidine $^{40}Ar/^{39}Ar$ date of 27.16±0.04 (1σ) Ma (L.S. Snee, written commun., 1997) was obtained on a rock sample of Isom-type tuff collected in the north part of the Corcoran Canyon quadrangle (rock sample locality R1). This date is too old for the unit in the quadrangle, however, as the unit overlies the dated lower unit of volcaniclastic rocks of Little Table Mountain [Tlt1, 26.65±0.07 (1σ) Ma; see below] and the dated tuff of Ryecroft Canyon [Trc, 26.82±0.04 (1σ) Ma and 26.83±0.05 (1σ) Ma; see below]. These relations require that the age of the Isom-type tuff in the quadrangle be no older than about 26.6–26.7 Ma

Ti **Welded ash-flow tuff**—Crytal-poor to moderately crystal-rich 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. 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. Upper part is characterized by flattened light-yellowish-brown to brown pumice lapilli as long as 4 cm. Small lithic fragments are common throughout. Modal analyses of seven samples of the tuff indicate 5–17 percent phenocrysts (1–3 mm) that consist of: Q, 0–12; K, 1–14; P, 65–76; O, 2–6; and C, 7–22 (pyroxene in some samples consists of about half C and half orthopyroxene). Apatite is a common accessory mineral; zircon is rare or absent. A chemical analysis of one sample of tuff indicates the following percentages of components: SiO_2, 66.6; Al_2O_3, 15.9; K_2O, 4.23; Na_2O, 3.33; CaO, 3.16; Fe_2O_3, 3.13; FeO, 1.78; MgO, 0.96; TiO_2, 0.65; P_2O_5, 0.20; and MnO, 0.08 (dacite-trachydacite). In addition to a thin wedge of Isom-type tuff on the south slope of Little Table Mountain, the unit also crops out on the low hills in north-central part of quadrangle where it appears conformable on volcaniclastic rocks of Little Table Mountain (Tlt1). It occurs as erosional remnants that lie unconformably upon the tuff of Ryecroft Canyon (Trc) about 0.5–1.5 km northeast of the lower reach of Meadow Canyon in southwest part of quadrangle. Thickness 0–30 m

Tiv **Vitrophyre**—Dark-gray, crystal-poor vitrophyre occurs as thin (a few meters thick) lenses at base of formation, and locally within it, in the area northeast of Meadow Canyon in southwest part of quadrangle

Tic **Conglomerate**—Poorly consolidated stream gravel containing well-rounded pebbles and small cobbles of volcanic rocks, quartzite, and chert. Forms a thin layer a meter or so thick, locally underlying tuff of the Isom-type formation (Ti) in the area northeast of Meadow Canyon in southwest part of quadrangle

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 the megabreccia of Meadow Canyon (Tmc). Breccia fragments range to about 1 m in size. The unit forms a shell that surrounds, and extends outward as much as 300 m from, the rhyolite plug (Trp) in Meadow Canyon at west margin of quadrangle. The breccia is related to emplacement of the plug. Within a few meters of the plug, slablike breccia fragments are crudely oriented parallel to the nearly vertical walls of the plug, and in places blocks form vertical trains, suggesting laminar flow of material resulting from drag that accompanied emplacement of the plug. A few-centimeters-thick rind of comminuted rock is plastered against the plug walls. As seen in thin section, the rind consists of crudely aligned, mostly sharply angular, fragments of volcanic and Paleozoic rocks chiefly less than 2 mm long in a fine-grained glassy(?) matrix

Trf **Rhyolite flow rock (upper Oligocene)**—Medium-purplish-gray, porphyritic rhyolite flow; weathers brown. Characterized by occasional phenocrysts as large as 1 cm. Modal analysis of a thin section indicates 32 percent phenocrysts (2–5 mm) that consist of: Q, 24; K, 8; P, 58; B, 9; O, 1; and H, trace. Accessory minerals are common zircon, sparse apatite, and rare allanite(?). The flow caps peak 9398 in north-central part of quadrangle. Similarity of the mode to that of the rhyolite (Trp) in the Tooth Rock plug that lies 2.5 km south of peak 9398 suggests that plug as a possible source of the flow. Maximum remnant thickness 35 m

Trp **Rhyolite plugs (late Oligocene)**—Light-gray to light-yellowish-gray, coarsely porphyritic, generally crystal-rich intrusive rhyolite porphyry; weathers light yellowish brown to light brownish gray and grayish brown. Strongly iron stained and argillicaly altered in places. Steeply flow layered near contacts; 2- to 3-m-wide vitrophyre locally rims a large intrusive at Tooth Rock. A small rhyolite plug on the south side of Corcoran Canyon 1.3 km from the mouth of the canyon contains only sparse small phenocrysts of quartz, alkali feldspar, and plagioclase in an aphanitic matrix. The rhyolite in this plug is hydrothermally altered and is injected along fractures with siliceous fine-grained breccia (“hydrobreccia”).

Phenocryst compositions of the porphyritic rhyolite plugs are varied. A modal analysis of a thin section of a plug (350x500 m) about 2 km from the mouth of Meadow Canyon indicates 29 percent phenocrysts (3–5 mm) that consist of: Q, 44; K, 26; P, 28; and B, 2. Zircon is an accessory mineral. A modal analysis of a thin section of a rhyolite plug (diameter about 400 m) exposed 1 km from the mouth of the first canyon northeast of Corcoran Canyon indicates 25 percent phenocrysts (2–4.5 mm) that consist of: Q, 27; K, 31; P, 41; B, 1; and O, 0.3. Zircon is an accessory mineral. The plug has been hydrothermally altered; thin-section examination shows irregular patches of mosaic quartz and sericite throughout the groundmass. The porphyry plug at Tooth Rock (300x600 m) in north-central part of quadrangle, by modal analysis, contains 20 percent phenocrysts (3–5 mm) that consist of: Q, 19; K, 12; P, 53; B, 12; O, 2; and altered mafic minerals, 1.3. Apatite and zircon are accessory minerals. A modal analysis of a thin section of a sample of a large plug (550x1150 m) 1.5 km east of peak 9398 in north-central part of quadrangle indicates phenocrysts (2–4 mm) that consist of: Q, 3; K, 29; P, 55; B, 13; and H plus altered mafic minerals, 1. Apatite, zircon, and allanite are accessory minerals. Rock in this intrusion has been hydorthermally altered; as seen in thin section, the aphanitic matrix is microbrecciated and traversed by irregular, diffuse veinlets of mosaic quartz, sericite, and iron oxide. A modal analysis of a sample of the brecciated margin of the rhyolite plug in Meadow Canyon at west margin of quadrangle indicates 15 percent phenocrysts (1–2.5 mm) that consist of: Q, 33; K, 27; P, 36; B, 3; O, 0.5; and H, 1. Zircon is a common accessory mineral and apatite is a sparse accessory mineral. A chemical analysis of a sample of this rock shows the following percentages of components: SiO_2, 77.2; Al_2O_3, 12.7; K_2O, 4.62; Na_2O, 2.70; CaO, 1.02; Fe_2O_3, 0.98; FeO, 0.09; MgO, 0.31; TiO_2, 0.23; P_2O_5, 0.12; and MnO, 0.01 (rhyolite). Chemical analyses of two samples of rhyolite from the plug exposed 1 km from the mouth of the first canyon northeast of Corcoran Canyon indicate the following percentages of components: SiO_2, 75.0 and 75.4; Al_2O_3, 13.9 each; K_2O, 9.02 and 8.10; Na_2O, 0.99 and 1.57; CaO, 0.21 and 0.29; Fe_2O_3, 0.32 and 0.18; FeO, 0.04 each; MgO, 0.18 and 0.12; TiO_2, 0.20 and 0.27; P_2O_5, 0.05 and 0.07; and MnO, less than 0.01 each (rhyolite). The relatively high contents of K_2O and relatively low contents of Na_2O indicate that the analyzed samples are from hydrothermally altered parts of the plug.

A biotite K-Ar date determined for a sample from the plug at Tooth Rock (rock sample locality R2) is 26.2±0.8 Ma (Mckee and John, 1987). A potassium-feldspar $^{40}Ar/^{39}Ar$ date for material from a sample of the small hydrothermally altered plug 1.3 km from the mouth of Corcoran Canyon (rock sample locality R3) is 26.60±0.05 (1σ) Ma (L.W. Snee, written commun., 1996)

Volcaniclastic rocks of Little Table Mountain (upper Oligocene)—A thick sequence of volcaniclastic rocks unconformably underlies the Isom-type (Ti) and some younger welded ash-flow tuffs in the northwest part of the Corcoran Canyon quadrangle. The sequence is in part unconformable on underlying rocks, although it appears to be conformable and transitional to the underlying tuff of Mount Jefferson (Tmj). In south part of outcrop area, the volcaniclastic rocks are underlain by and interbedded with an unnamed megabreccia unit (Tum). The volcaniclastic rocks are divided into four units, from base upward: tuffaceous sedimentary rocks (claystone, siltstone, sandstone, and conglomerate) and tuff (Tlt1); ash-flow tuff (Tlt2); zeolitic ash-fall tuff (Tlt3); and a second unit of tuffaceous sedimentary rocks (siltstone and sandstone) and tuff (Tlt4). The three upper units are present only on the slopes of Little Table Mountain. The units locally contain minor lenses or layers of different lithology, and in places the units intertongue (not mapped)

Tlt4 **Tuffaceous siltstone and sandstone, and tuff**—Light-yellowish-brown to light-greenish-brown, interlayered, evenly bedded tuffaceous siltstone and sandstone, and tuff. Probably mostly lacustrine. Thin bedded (beds a few centimeters to a meter or so thick). Tuff layers are commonly biotite bearing and rubbly weathering. A modal analysis of one thin section of a sample of nonwelded shards (probably ash-fall tuff) interlayered in sedimentary rocks indicates about 8 percent phenocrysts (1–1.5 mm) that consist of: Q, 4; K, 21; P, 55; B, 14; O, 2; H, 1; and C, 3. Accessory minerals are common zircon and apatite, and sparse allanite. A layer of conglomerate a meter or so thick at the top of the unit on the northeast slope of Little Table Mountain contains abundant black chert pebbles, and minor yellowish-brown and light-yellowish-brown chert and white quartz pebbles, mostly 1–3 cm in diameter. Matrix of the conglomerate is predominantly sand-size quartz, feldspar, and chert, and minor biotite. Thickness of unit Tlt4 is 75–100 m

Tlt3 **Zeolitic tuff**—Light-greenish-gray, pale-greenish-gray, pale-yellowish-brown, and very pale-pinkish-brown to whitish, platy to massive zeolitic tuff. Massive intervals commonly biotite bearing. Eight samples collected from a 40-m-thick stratigraphic section of the zeolitic tuff 450 m north-northwest of Corcoran Divide Spring on the northeast slope of Little Table Mountain were analysed by X-ray powder diffraction by Richard A. Sheppard (U.S. Geological Survey). Sheppard's analyses (written commun., 1994) indicate that the lower 30 m (five samples) of the section average about 80 percent clinoptilolite, about 20 percent opal-CT plus smectite, and traces of biotite, plagioclase, and quartz. One of the samples contains about 10 percent plagioclase. A sample collected 7.5 m from the top of the section contains about 60 percent clinoptilolite, 20 percent each of smectite and glass, and traces of quartz and biotite. Two samples collected within about a meter of the top of the section contain about 20 percent clinoptilolite, 40 percent opal-CT, about 40 percent authigenic(?) potassium-feldspar, and traces of smectite and biotite. A modal analysis of a biotite-bearing sample of zeolitic tuff indicates about 11 percent phenocrysts (0.5–1 mm) that consist of: Q, 14; K, 19; P, 57; B, 10; and O, 0.3. Accessory minerals are common zircon, apatite, and allanite, and sparse sphene. Groundmass is well-sorted, fine- to medium-grained, nonwelded zeolitic-smectitic shard tuff. A chemical analysis of the same biotite-bearing zeolitic tuff indicates the following (volatile-free) percentages of components: SiO_2, 73.8; Al_2O_3, 14.5; K_2O, 4.11; Na_2O, 2.42; CaO 2.50; Fe_2O_3, 1.30; FeO, 0.39; MgO, 0.51; TiO_2, 0.33; P_2O_5, 0.09; and MnO, 0.01 (rhyolite). The unit, on the lower slopes of Little Table Mountain, is 30–50 m thick

Tlt2 **Pumiceous ash-flow tuff**—Light-greenish-gray to light-gray, nonwelded to partially welded, moderately crystal-rich rhyodacitic ash-flow tuff; weathers light greenish brown to light grayish brown. Characterized by abundant pale-greenish-gray only slightly flattened pumice lapilli mostly less than 1 cm long. Small (1 cm long) angular fragments of Paleozoic rocks are present locally. A modal analysis of one sample of the tuff indicates 10 percent phenocrysts (0.5–1.5 mm) that consist of: Q, 7; K, 10; P, 71; B, 11; O, 0.3; and M, 1.3. Zircon is a common accessory mineral and apatite is a sparse accessory mineral. A 2-km-wide lens of pumiceous ash-flow tuff as much as 60 m thick is exposed on the east slope of Little Table Mountain

Tlt1 **Tuffaceous claystone, siltstone, sandstone, and conglomerate, and tuff**—Pale-greenish-brown and light-yellowish-brown, to whitish, in places iron stained, interlayered tuffaceous claystone, siltstone, sandstone, and conglomerate, and tuff. The tuffaceous sedimentary layers probably are mostly lacustrine; in a few places low-angle crossbeds in sandstone suggest fluvial deposition. Mostly thin bedded; locally massive; silty-sandy layers tend to show thin-platy bedding. One well-bedded, brownish-green silicified sandstone layer 1 m thick forms a conspicuous ledge. In places, thin irregular veinlets of opaline silica are present in sandstone. Pebbles in conglomerate layers consist of Tertiary volcanic rocks and Paleozoic sedimentary rocks, mostly shale and silicified shale. A layer of megabreccia (rounded ash-flow tuff blocks as large as 5 m), several meters thick, is present locally at the base of the unit in Corcoran Canyon.

A tuffaceous interval in the lower unit is exposed high on the northeast side of Corcoran Canyon, where the sedimentary section is faulted down against the tuff of Mount Jefferson (Tmj). The interval consists of interlayers of tuff and tuffaceous sedimentary rocks that in part contain abundant small, subrounded fragments, mostly of volcanic rocks; parts are bedded and conglomeratic. A modal analysis of a sample of a layer of crystal-rich rhyolitic ash-fall tuff in the interval indicates about 24 percent phenocrysts (1–2 mm), mostly fragmental and angular, that consist of: Q, 26; K, 21; P, 44; B, 7; and O, 3. Apatite and zircon are accessory minerals. An ash-flow tuff fragment within the ash-fall tuff is exceptionally crystal rich (46 percent phenocrysts, 2–3 mm) and has the following modal composition: Q, 13; K, 32; P, 46; B, 9; and O, 0.2. Apatite and zircon are accessory minerals. The modal data for the ash-fall tuff and included fragment of ash-flow tuff indicate that the tuffs have a close affinity to tuffs of PI category 1 of the underlying tuff of Mount Jefferson (Tmj). Thin-section examination of a fine-grained (0.1 mm and finer) ash-fall(?) tuff indicates about 3 percent crystals that include subequal amounts of quartz, alkali feldspar, and biotite, and a minor amount of plagioclase and opaque mineral. Hornblende, muscovite, and apatite are rare. The ash-fall tuff beds appear to occur as tongues that extend laterally from the top of the tuff of Mount Jefferson into the volcaniclastic rocks of Little Table Mountain.

Interlayered tuff and coarse-grained tuffaceous sedimentary layers at the base of unit Tlt1 and at the top of the tuff of Mount Jefferson, in Corcoran Canyon 2.5 km east of the summit of Little Table Mountain, also indicate a gradual transition from deposition of the tuff of Mount Jefferson to deposition of the overlying tuffaceous sedimentary rocks. Modal analysis of a fine-grained, light-yellowish-brown to pale-greenish-brown tuffaceous silty sandstone near the base of the unit indicates 23 percent crystals (1 mm) that consist of: Q, 22; K, 27; P, 43; B, 8; and O, 0.5. Apatite and zircon are accessory minerals. Numerous cavities (5 mm and less) represent leached pumice sites now lined with tridymite or crystobalite. A sanidine $^{40}Ar/^{39}Ar$ date for this sample (rock sample locality R4) is 26.65±0.07 (1σ) Ma (L.W. Snee, written commun., 1997).

A thin tuffaceous sandstone a few meters thick that contains thin (a few centimeters) layers of siliceous sinter lies at the top of the unnamed megabreccia unit (Tum) on a low hill south of the mouth of Corcoran Canyon. As seen in thin section, the sandstone contains subrounded pumice fragments as large as 1.5 mm in diameter, and smaller angular to subangular grains of which about half are sanidine, and about a quarter each are quartz and plagioclase. The rock contains a small amount of biotite, and trace amounts of leucoxene and muscovite.

The tuffaceous sedimentary rock and tuff unit is exposed widely on the lower slopes of Little Table Mountain and in the low hills in north-central part of quadrangle. Maximum thickness about 160 m.

In an area of almost 1 km^2 between Corcoran Canyon and the south fork of Corcoran Canyon just above their fork, the lowest member (Tlt1) is considerably disrupted, probably by slumping of a large slab of the member as a result of removal of lateral support during formation of a diatreme consisting of the megabreccia of Corcoran Creek (Tcm) as described above (see also, cross section *C–C'*). In the east part of this area, individual beds within layered tuffaceous sedimentary rocks have been broken and disoriented whereas adjacent beds remain intact. Farther west, and approaching the area of megabreccia of Corcoran Creek, slabs and blocks of the volcanic units above member Tlt1, as young as the tuff of Clipper Gap, have been jostled and disrupted; some large blocks of younger volcanics are embedded in deformed tuffaceous sedimentary rocks, as though they had foundered into a less coherent medium because of severe agitation. Modal analysis of one thin section of a sample of a large block (100 m long) of unit D of the Bates Mountain Tuff (TbtD) indicates 3 percent phenocrysts (1–2.5 mm) that consist of: Q, 3; K (sanidine), 60; anorthoclase, 27; O, 1.5; and M, 7. Common zircon and sparse apatite are accessory minerals. A modal analysis of a sample from a second large block (30x60 m) of unit D indicates 2 percent phenocrysts (0.5–2.5 mm) that consist of: Q, 2; K (sanidine), 82; anorthoclase, 4; P, 8; O, 2.5; and M, 1.5. Zircon is common. A modal analysis of a thin section of a sample of a large block (30 m in diameter) of the upper member of the Shingle Pass Tuff (Tspu) indicates 10 percent phenocrysts (1–2 mm) that consist of: Q, 1; K, 28; P, 50; B, 6; O, 2; and C, 3. Zircon is a common accessory mineral. The contact between the disrupted lower member and megabreccia of Corcoran Creek seems to be gradational, possibly because of mixing of the units during collapse of the slab of tuffaceous sedimentary rock

Tum **Unnamed megabreccia unit (upper Oligocene)**—Characterized by generally well-rounded boulders or blocks 1–10 m in diameter, mostly of welded ash-flow tuff; conspicuous are common light-gray, well-rounded blocks of rhyolitic crystal-rich welded ash-flow tuff 1–3 m in diameter, some of which exhibit an almost polished surface. Present also are blocks of sandstone and conglomerate 2–3 m long, small-boulder to cobble-size pieces of granite, and pebbles of a variety of Paleozoic sedimentary rocks. Matrix of the megabreccia is not evident; the unit appears to comprise a mixture of fragments ranging from large blocks down to millimeter-size particles. Modal analyses of thin sections of two light-gray, well-rounded blocks indicate 31 and 37 percent phenocrysts (2–4 mm) that consist of: Q, 28 and 34; K, 27 and 24; P, 39 and 34; B, 5 and 6; O, 0.8 and 0.5; and M, 0.5 and 1. These rocks are similar in composition to the tuff of Ryecroft Canyon (Trc). Modal analyses of thin sections of three other less common types of welded ash-flow tuff clasts in the megabreccia indicate 16–32 percent phenocrysts (1.5–3 mm) that consist of: Q, 10–21; K, 20–29; P, 45–60; B, 6–10; O, 1 each; and M, 0.5–1.5. Accessory minerals are common zircon and apatite, and sparse allanite. These rocks are similar in phenocryst content to PI category 1 and PI category 2 rocks of either the tuff of Mount Jefferson (Tmj) or the tuff of Corcoran Canyon (Tcc units). The megabreccia unit, Tum, conformably underlies and appears to intertongue with the lower unit of volcaniclastic rocks of Little Table Mountain (Tlt1). Locally it overlies, apparently unconformably, the megabreccia of Meadow Canyon (Tmc) and the upper and lower members of the tuff of Corcoran Canyon (Tccu and Tccl). The unit is exposed in small areas in west-central part of quadrangle, where its maximum thickness is about 15 m.

The unnamed megabreccia is exposed near the inferred structural margin of the Mount Jefferson caldera. It may have formed as a result of collapse along that margin during or shortly following eruption from the caldera of the tuff of Mount Jefferson (Tmj), described below

Tuff of Mount Jefferson (upper Oligocene)—The tuff of Mount Jefferson constitutes a great thickness of welded ash-flow tuff units, both individual ash flows as well as simple and compound cooling units, within the Mount Jefferson caldera, the southeast part of which occupies the northwest part of the quadrangle. Minor amounts of the unit may constitute outflow near the inferred structural margin of the Mount Jefferson caldera. The intracaldera tuff of Mount Jefferson is at least 2,000 m thick, judged from relief on the exposed tuffs between Big Smoky Valley and the summit of Mount Jefferson northwest of the quadrangle. Individual units in the Corcoran Canyon quadrangle generally were not mapped, but we nevertheless show some mappable units (Tmjv, Tmjt) as well as contacts between internal units, to better depict the attitudes and distributions of the units.

The tuff of Mount Jefferson within the quadrangle was previously designated the 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, and by Shawe (1999b) for the adjacent Jefferson quadrangle, 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).

Modal analyses of a large number of samples of the tuff of Mount Jefferson allowed assignment of the samples into five PI categories on the basis of phenocryst percentages, as described at the beginning of the "Description of Map Units." The data are used primarily to corroborate correlation of the tuff of Mount Jefferson with the unit in nearby areas (for example, Jefferson quadrangle, Shawe, 1999b), and for comparison with the petrographically similar but older tuff of Corcoran Canyon (Tcc units). Inconsistent distributions of the PI categories and chemical data for samples within the Mount Jefferson caldera suggest no discernible stratigraphic significance to both sets of data

Tmj **Principal member**—Rhyolitic, quartz latitic, and rhyodacitic welded ash-flow tuff (PI categories 1–5). Within the member are thin units of vitrophyre (Tmjv) and tuffaceous sedimentary rocks (Tmjt), described separately below, that reflect cooling breaks in the sequence of ash-flow tuffs that make up the member. Altered tuff (Tmja) was mapped near a plug of rhyolite (Trp) in north-central part of quadrangle.

Thin layers of tuff with PI of greater than 1.00 occur at the top of the tuff of Mount Jefferson 1.4 km east and 1.1 km southeast of Little Table Mountain Spring near west-central margin of quadrangle. These layers are modally similar to the rhyolitic tuff of Ryecroft Canyon (Trc), but because of their position they are included as part of the tuff of Mount Jefferson. However, because the determined ages of the tuff of Mount Jefferson and the tuff of Ryecroft Canyon overlap, the thin layers possibly are part of the Ryecroft Canyon.

Category 1 rocks—Pale- to medium-gray, and light-yellowish- to light-greenish-gray, partially to densely welded, crystal-rich rhyolitic to quartz-latitic ash-flow tuff; weathers light pinkish brown, light orangish brown, and light brown. Modal analyses of six samples indicate 22–46 percent phenocrysts (1.5–4.5 mm) that consist of: Q, 18–26; K, 20–32; P, 38–45; B, 6–11; O, 0.5–2; and H, 0–6. Accessory minerals are abundant zircon and apatite and rare allanite. Chemical analyses of two samples of category 1 tuff indicate the following percentages of components: SiO_2, 69.6 and 72.9; Al_2O_3, 15.9 and 14.2; K_2O, 5.28 and 4.83; Na_2O, 2.08 and 3.43; CaO, 3.05 and 1.65; Fe_2O_3, 1.73 and 1.71; FeO, 0.80 and 0.47; MgO, 0.95 and 0.44; TiO_2, 0.37 and 0.29; P_2O_5, 0.15 and 0.10; and MnO, 0.06 and 0.04 (rhyolite). Modal analyses of two crystal-poor tuffs indicate 11 and 12 percent phenocrysts (1–3.5 mm) that consist of: Q, 16 and 24; K, 30 and 22; P, 46 each; B, 3 and 8; and O, 6 and 0. Zircon and apatite are accessory minerals.

Category 2 rocks—Light-gray, nonwelded to moderately welded, crystal-rich quartz latitic ash-flow tuff; weathers light grayish to light yellowish brown. Pale-yellowish-brown pumice lapilli less than 1 cm long in places. In a small area near the north branch of south fork of Corcoran Canyon the tuff appears baked and hardened such that it weathers as 1- to 2-cm-wide, crudely cube-shaped fragments ("cuboids"). Modal analyses of 12 samples of PI category 2 tuff indicate 21–43 percent phenocrysts (1.5–5 mm) that consist of: Q, 11–24; K, 15–31; P, 42–52; B, 4–14; O, trace–3; H, 1–4; and M, 0–0.5. Zircon and apatite are common accessory minerals and allanite and monazite are rare accessory minerals. Chemical analyses of eight samples of category 2 tuff (probably the most prevalent type in the principal member) indicate the following range in percentages of components: SiO_2, 71.2–74.0; Al_2O_3, 13.6–15.1; K_2O, 4.14–5.63; Na_2O, 2.60–3.50; CaO, 1.26–2.93; Fe_2O_3, 1.22–2.01; FeO, 0.36–0.73; MgO, 0.33–0.94; TiO_2, 0.25–0.33; P_2O_5, 0.08–0.15; and MnO, 0.02–0.07 (rhyolite). Modal analyses of two crystal-poor ash-fall tuffs indicate 12 and 14 percent phenocrysts (1–2 mm) that consist of: Q, 12 and 19; K, 26 and 19; P, 50 and 52; B, 9 and 8; O, 0 and 1.5; and H, 2.5 and 0. Zircon and apatite are accessory minerals. A chemical analysis of one sample of crystal-poor tuff indicates the following percentages of components: SiO_2, 73.6; Al_2O_3, 14.5; K_2O, 4.68; Na_2O, 2.52; CaO, 2.17; Fe_2O_3, 1.36; FeO, 0.28; MgO, 0.54; TiO_2, 0.26; P_2O_5, 0.09; and MnO, 0.04 (rhyolite).

Category 3 rocks—Medium-gray, light-pinkish-gray, light-purplish-gray, and light-brownish-gray, partially to densely welded quartz latitic to rhyodacitic ash-flow tuff; weathers light to medium brown, and reddish brown. Flattened pumice lapilli are sparse to abundant, generally less than 2 cm long; locally as long as 30 cm and 1 cm thick. Pumice generally lighter colored than tuff matrix, in places whitish to pale pinkish gray. Modal analyses of seven samples indicate 23–41 percent phenocrysts (1.5–4.5 mm) that consist of: Q, 10–20; K, 12–25; P, 42–52; B, 5–19; O, 0–2.5; H, 0–13; and M, 0–1. Accessory minerals are common zircon and apatite, and sparse allanite. A chemical analysis of a crystal-rich tuff indicates the following percentages of components: SiO_2, 71.1; Al_2O_3, 14.9; K_2O, 4.57; Na_2O, 3.01; CaO, 2.37; Fe_2O_3, 2.06; FeO, 0.58; MgO, 0.82; TiO_2, 0.34; P_2O_5, 0.12; and MnO, 0.07 (rhyolite). Modal analyses of six crystal-poor to moderately crystal-rich samples of category 3 rocks indicate 9–19 percent phenocrysts (1–3.5 mm) that consist of: Q, 10–16; K, 17–26; P, 45–55; B, 11–22; and O, 0.5–3. Accessory minerals are common zircon and apatite, and rare allanite and monazite(?).

Category 4 rocks—Light- to medium-gray, lavender-gray, and medium-brownish-gray, nonwelded to densely welded rhyodacitic ash-flow tuff; weathers brownish gray and grayish brown to dark brown. Light-yellowish-brown, light-pinkish-gray to whitish pumice lapilli, commonly flattened, are generally abundant; lithic fragments, mostly of gray aphyric to light-purplish-brown porphyritic volcanic rocks, are locally present. Modal analyses of four samples of crystal-rich category 4 tuffs indicate 28–44 percent phenocrysts (2–3 mm) that consist of: Q, 6–11; K, 13–17; P, 55–60; B, 11–16; O, 3–4; H, 0–4; and M, 0–4. Accessory minerals are common zircon and apatite and rare allanite. Modal analyses of three crystal-poor to moderately crystal-rich samples of category 4 rocks indicate 7–18 percent phenocrysts (1–2.5 mm) that consist of: Q, 4–7; K, 11–23; P, 51–63; B, 15–18; O, 1–3; and H, trace–11. Zircon, apatite, and allanite are accessory minerals. Chemical analysis of one sample of crystal-poor tuff indicates the following percentages of components: SiO_2, 71.5; Al_2O_3, 15.1; K_2O, 5.76; Na_2O, 3.12; CaO, 1.76; Fe_2O_3, 1.33; FeO, 0.46; MgO, 0.51; TiO_2, 0.32; P_2O_5, 0.13; and MnO, 0.03 (rhyolite).

Category 5 rocks—Light-brown, moderately to densely welded rhyodacitic ash-flow tuff; weathers brown. Modal analysis of one sample indicates 43 percent phenocrysts (2–2.5 mm) that consist of: Q, 1; K, 15; P, 65; B, 12; O, 3; and H, 4. Accessory minerals are common zircon and apatite and rare allanite.

Because of faulting and difficulty in correlating tuff units laterally, the stratigraphic positions of tuffs of the various categories described above have not been established. In a few areas, for example for a few hundred meters south of Tooth Rock and on the east slope of peak 9598, reversals in the sequence of phenocryst ratios (PI categories) is evident. On the east slope of peak 9598 a lower cooling unit beneath vitrophyre (**Tmjv**) is characterized by tuff more mafic in its lower part and more felsic in its upper part, whereas a second, overlying thick cooling unit above a basal vitrophyre (**Tmjv**) has tuff more felsic in its lower part and more mafic in its upper part. Also, in places relatively thin units of crystal-poor tuffs are interlayered in thick sections of crystal-rich tuffs, possibly indicating winnowed upper parts of pyroclastic flow units in compound cooling units. The magma generation, crystallization, and eruption history of the tuff of Mount Jefferson probably was complex. Also, lack of close correlation between phenocryst ratios and chemical composition of the tuffs suggests complexity in their origin, such as sporadic disequilibrium between crystals and magma, or physical mixing during eruption. Finally, the possibility that hydrothermal alteration modified some compositions, for example of tuffs that contain relatively low Na_2O and high K_2O, has not been fully evaluated.

Several sanidine $^{40}Ar/^{39}Ar$ dates were measured for rocks from the principal member by L.W. Snee (written communs., 1996, 1997). The dates are: 26.63±0.06(1σ) Ma (rock sample locality R5), 26.67±0.04(1σ) Ma (locality R6), 26.68±0.04(1σ) Ma (locality R7), 26.70±0.05(1σ) Ma (locality R8), 26.80±0.03(1σ) Ma (locality R9), and 26.82±0.06(1σ) Ma (localilty R10). Because of the difficulty of making stratigraphic correlations within the tuff of Mount Jefferson throughout the Mount Jefferson caldera, the relative stratigraphic positions of all of the dated samples cannot be determined. However, sample R8 (26.70±0.05 Ma) is slightly higher (about 50 m) stratigraphically than sample R9 (26.80±0.03 Ma), and sample R7 (26.68±0.06 Ma) appears significantly higher (about 250 m) stratigraphically than sample R10 (26.82±0.06 Ma). Tuffs represented by the dated samples were deposited through an interval of about 100,000–200,000 years. Probably the entire section of tuffs within the Mount Jefferson caldera was deposited through a much longer interval. Boden (1986, 1992) reported sanidine K-Ar dates of 25.9±0.5 Ma and 26.5±0.5 Ma for the principal member (his upper member) of the tuff of Mount Jefferson.

The principal member appears to conformably underlie the lower unit of the volcaniclastic rocks of Little Table Mountain (**Tlt1**); in places the contact is gradational and probably intertonguing. In the adjacent Jefferson quadrangle, however, the contact appears unconformable beneath the volcaniclastic rocks (Shawe, 1999b). At least 800 m of the member is exposed in the Corcoran Canyon quadrangle in the vicinity of peak 9598 in north part of quadrangle; the base is not exposed. However, in the upper reaches of south fork of Corcoran Canyon, in west-central part of quadrangle, the member may be only about 200 m thick where it conformably(?) underlies volcaniclastic rocks of Little Table Mountain and is probably unconformable upon the upper member of the tuff of Corcoran Canyon (**Tccu**). Although the member in this area is within the inferred margin of the Mount Jefferson caldera, it may be thinner than most of the caldera infill because of its inferred position upon a thick slab of older tuff of Corcoran Canyon (**Tccl**) that collapsed into the caldera during early stages of caldera development (see cross section *C–C'*). The thinner tuffs of the principal member at the foot of Little Table Mountain southwest of Corcoran Canyon are lighter colored and less welded in general than are most of the tuffs to the north

Tmjv **Vitrophyre**—Layers of vitrophyre about 1–10 m thick within the tuff of Mount Jefferson indicate cooling breaks in the sequence of emplacement of the ash-flow tuffs. Some layers of vitrophyre were mapped, but several others, mostly thin, were not. Phenocryst abundances of modally analyzed vitrophyres are presented below.

Category 3 rocks—Dark-gray, vitrophyric, crystal-poor, densely welded quartz latitic to rhyodacitic ash-flow tuff. A modal analysis of one sample indicates 7 percent phenocrysts (1.5–2.5 mm) that consist of: Q, 18; K, 15; P, 49; B, 16; and H, 3.

Category 4 rocks—Gray to dark-gray, vitrophyric, crystal-rich, moderately to densely welded rhyodacitic ash-flow tuff. Modal analyses of three samples of vitrophyre indicate 20–27 percent phenocrysts (1.5–3 mm) that consist of: Q, 6–9; K, 11–14; P, 58–60; B, 15–18; O, 0–2.5; H, 1–1.5; and C, 1–3. Zircon and apatite are common accessory minerals, allanite is sparse, and monazite(?) is rare. A chemical analysis of one sample of category 4 vitrophyre indicates the following percentages of components: SiO_2, 69.3; Al_2O_3, 15.9; K_2O, 3.19; Na_2O, 4.03; CaO, 2.84; Fe_2O_3, 2.07; FeO, 0.97; MgO, 1.03; TiO_2, 0.41; P_2O_5, 0.18; and MnO, 0.07 (rhyolite-dacite).

Category 5 rocks—Gray, densely welded, vitrophyric, crystal-rich rhyodacitic ash-flow tuff; weathers brownish gray. Modal analysis of one sample indicates 30 percent phenocrysts (2–5 mm) that consist of: Q, 4; K, 9; P, 62; B, 19; O, 2; H, 3; and C, 2. Zircon and apatite are common accessory minerals

Tmjt **Tuffaceous sedimentary rocks**—Light-greenish-gray to light-yellowish-brown and yellowish-brown, thin bedded and evenly bedded tuffaceous siltstone, sandstone, and pebble conglomerate; also, reddish-brown granule sandstone. Some layers exhibit low-angle crossbeds; probably both lacustrine and fluvial beds are represented. Layers of tuffaceous sedimentary rocks a few meters thick on the west flank of peak 9598 mark cooling breaks in deposition of the tuff of Mount Jefferson. Locally at the base of sedimentary rocks 2 km east of the summit of Little Table Mountain rounded to subrounded blocks of tuff a meter or so in size are present in tuffaceous conglomerate. In this area, tongues of tuffaceous sedimentary rocks a few meters to perhaps 30 m thick extend from a steep erosional paleoslope in the tuff of Mount Jefferson, southwestward into flow units of younger tuff of Mount Jefferson

Tmja **Altered tuff**—Partly surrounds the large plug of rhyolite porphyry (Trp) in north-central part of quadrangle. There, the rock is strongly iron stained as a result of hydrothermal alteration related to emplacement of the plug. As seen in thin section, feldspars and mafic minerals locally are replaced by calcite and clay minerals

Tmc **Megabreccia of Meadow Canyon (upper Oligocene)**—Eruptive megabreccia characterized by tuff blocks and slabs of all sizes to as much as 350 m long in an ash-flow tuff matrix similar in phenocryst composition to the tuff of Ryecroft Canyon (Trc). Many of the blocks and slabs are themselves strongly brecciated; some are unbrecciated. Most of the blocks are of the tuff of Ryecroft Canyon, predominantly of "typical" tuff and lesser amounts of "quartz-rich" tuff of Ryecroft Canyon, and some are of either the tuff of Mount Jefferson (Tmj?) or the tuff of Corcoran Canyon (Tcc? units). Only minor amounts of other rocks such as Paleozoic sedimentary rocks and other Tertiary volcanic rocks are present.

The petrographic details given below are meant to provide information useful in establishing the relation of the megabreccia to associated units, and in inferring origin of the megabreccia.

The matrix of the 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. A more detailed description of the matrix of the megabreccia of Meadow Canyon in the adjacent Jefferson quadrangle is given by Shawe (1999b).

Samples of several welded ash-flow tuff blocks in the megabreccia that have compositions similar to both "typical" and "quartz-rich" samples of the tuff of Ryecroft Canyon (Trc; see descriptions in a later section) were studied under the microscope. Modal analyses of seven thin sections of samples of moderately to densely welded crystal-rich typical Ryecroft Canyon rhyolitic ash-flow tuff blocks indicate 24–37 percent phenocrysts (1.5–4 mm) that consist of: Q, 23–34; K, 23–36; P, 24–40; B, 0–7; O, 0–2; and H, 0.2–2. Accessory minerals are sparse to common zircon, sparse apatite and allanite, and rare sphene. Modal analyses of a nonwelded to moderately welded typical crystal-poor and a moderately crystal-rich rhyolitic ash-flow tuff indicate 6 and 15 percent phenocrysts (1.5–2 mm) that consist of: Q, 29 and 23; K, 34 and 36; P, 35 and 34; B, 0 and 6; O, 1 each; and M, 0.2–1. Zircon and allanite are sparse. Modal analyses of one partially welded and one densely welded crystal-rich and quartz-rich rhyolitic ash-flow tuff indicate 25 and 43 percent phenocrysts (1–3 mm) that consist of: Q, 41 and 35; K, 30 and

33; P, 25 and 26; B, 4 each; O, 0.5 each; and H, 0 and 1. Zircon is moderately common in the partially welded tuff; zircon and apatite are common and allanite and sphene are sparse in the densely welded tuff.

A block of brecciated quartz-rich tuff 50 m in diameter contains fragments that have 30 percent phenocrysts (2–4 mm) that consist of: Q, 36; K, 25; P, 32; B, 5; O, 1; and H, 1. Zircon is common and apatite is sparse. A modal analysis of one thin section of partially welded matrix of the brecciated block indicates 19 percent broken phenocrysts (1–3 mm) that consist of: Q, 24; K, 41; P, 30; B, 3; O, 0.5; and M, 0.3. Zircon is common and apatite and allanite are sparse. Modal analysis of one partially to moderately welded quartz-rich rhyolitic ash-flow tuff fragment in another brecciated block indicates 27 percent phenocrysts (1–3 mm) that consist of: Q, 43; K, 32; P, 20; B, 4; and O, 1. Partially welded matrix of this block contains 43 percent phenocrysts (2–4 mm) that consist of: Q, 34; K, 32; P, 29; B, 3; O, 0.3; and H, 1. Apatite is common and zircon, allanite, and sphene are sparse. A chemical analysis of this matrix indicates the following percentages of components: SiO_2, 75.3; Al_2O_3, 13.3; K_2O, 4.31; Na_2O, 2.97; CaO, 1.65; Fe_2O_3, 1.25; FeO, 0.28; MgO, 0.57; TiO_2, 0.23; P_2O_5, 0.08; and MnO, 0.03 (rhyolite). Two narrow (5–30 cm) tuff dikes were found in a large brecciated block of tuff of Ryecroft Canyon; the dikes apparently are confined to the block and thus were emplaced prior to incorporation of the block in the megabreccia matrix. Modal analyses of two thin sections of the tuff from the dikes indicate 21 and 23 percent phenocrysts (1–3 mm) that consist of: Q, 47 and 50; K, 29 and 27; P, 22 and 21; B, 2 and 1; O, 0.5 and 0.2; and H, 0.5 and 0.2. Zircon, apatite, allanite, and sphene are sparse accessory minerals. Groundmass of the tuff is cryptocrystalline to microcrystalline comminuted crystals, lithic fragments, and pumice.

Modal analyses of three thin sections of samples of blocks of moderately crystal-rich to crystal-rich, partially to moderately welded rhyolitic to quartz latitic ash-flow tuff indicate 16–32 percent phenocrysts (1.5–5 mm) that consist of: Q, 19–25; K, 23–28; P, 46–47; B, 1.5–8; O, 0.5–1; and M, 1 each. Accessory minerals are sparse to common zircon and apatite. These samples are similar in phenocryst content to PI categories 1 and 2 tuffs of either the tuff of Mount Jefferson (Tmj) or the tuff of Corcoran Canyon (Tcc units). Modal analyses of two thin sections of samples of crystal-rich, moderately to densely welded rhyodacitic ash-flow tuff indicate 29 and 32 percent phenocrysts (1–2.5 mm) that consist of: Q, 0.5 and 2; K, 1 and 2; P, 75 and 73; B, 9 and 10; O, 4 and 3; H, 6 and 5; and C plus orthopyroxene, 4 and 5. Accessory minerals are sparse to moderate zircon and apatite. These samples are similar in phenocryst content to PI category 5 tuffs of either the tuff of Mount Jefferson or the tuff of Corcoran Canyon.

A crudely layered pale-lavender-gray breccia of rounded ash-flow tuff fragments mostly less than 0.5 m in diameter in pulverized matrix appears to be part of the megabreccia of Meadow Canyon overlying heterolithic breccia (Thb) at the east side of the rhyolite plug in Meadow Canyon, at west margin of quadrangle. A modal analysis of a sample of a tuff fragment indicates 22 percent phenocrysts (2–3.5 mm) that consist of: Q, 8; K, 10; P, 66; B, 10; O, 1; and H(?), 5. Zircon and apatite are common accessory minerals. A chemical analysis of the same sample shows the following composition: SiO_2, 72.4; Al_2O_3, 15.2; K_2O, 4.79; Na_2O, 3.16; CaO, 1.82; Fe_2O_3, 1.58; FeO, 0.04; MgO, 0.49; TiO_2, 0.35; P_2O_5, 0.16; and MnO, 0.02 (rhyolite). This sample is similar in phenocryst composition to PI category 4 tuffs of either the tuff of Mount Jefferson (Tmj) or the tuff of Corcoran Canyon (Tcc units).

Inasmuch as the megabreccia of Meadow Canyon is in part coeval with the tuff of Mount Jefferson (Tmj) [the megabreccia and the tuff of Ryecroft Canyon (Trc) in the adjacent Jefferson quadrangle are interlayered and hence of comparable age, and the younger part of Trc is of similar age to the older part of Tmj; see Shawe, (1999b)] and it is younger than the tuff of Corcoran Canyon (Tcc units), the blocks of PI categories 1, 2, and 5 may have been derived from either Tmj or Tcc, or from both.

A fragment of white vein quartz several centimeters in diameter from the megabreccia, examined in thin section, exhibits a microbrecciated character. Quartz fragments range from about 10 mm in size down to less than 0.1 mm. Matrix is in part opalline and chalcedonic; remaining matrix consists of a cryptocrystalline, shardy volcanic groundmass. The character of the quartz fragment indicates that severe brecciation was accompanied by injection of volcanic ash; silicification followed brecciation and injection of ash.

The character of brecciated blocks in the megabreccia of Meadow Canyon indicates that they were brecciated prior to incorporation in the matrix of the megabreccia. Many brecciated blocks are well rounded and in fact polished as though abraded by transport in erupting ash. Had the brecciation been the result of collapse or transport in an erupting column of ash, fragments would have been disaggregated rather than remaining in a coherent and rigid block. The brecciated block that contains two thin dikes of finely comminuted tuff indicates that following brecciation the block was invaded by tuff and subsequently was incorporated in the megabreccia. Inasmuch as brecciated tuff of the character of the megabreccia blocks is not present in any of the ash-flow tuff formations in the vicinity of the megabreccia, it seems likely that the brecciated blocks were derived from depth where they had previously been broken by some violent action and then indurated before incorporation in the ash-flow tuff of the megabreccia matrix.

Blocks and slabs in the megabreccia of Meadow Canyon lie in a matrix that is mostly similar in composition to the tuff of Ryecroft Canyon, leading to the inference that the megabreccia is related to the volcanic episode that saw eruption of the Ryecroft Canyon. Some brecciated blocks in the megabreccia exhibit fragments that contain a higher percentage of phenocrysts than does the matrix surrounding the fragments in the blocks, and conversely, other blocks contain fragments with lower phenocryst content than in surrounding matrix. Matrix and fragments alike of the brecciated blocks are similar in composition to the tuff of Ryecroft Canyon, again suggesting a genetic tie to the Ryecroft Canyon. In addition, the phenocryst variations within blocks indicate that brecciated tuff formed during a pulse of eruption that preceded eruption of its matrix material.

Other evidence for the eruptive origin of the megabreccia of Meadow Canyon in the adjacent Jefferson quadrangle, such as presence of numerous vertically oriented breccia slabs that indicate vertical transport, was presented by Shawe (1999b).

The megabreccia of Meadow Canyon is exposed in an area of several square kilometers mainly north of Meadow Canyon in southwest part of quadrangle. It lies unconformably upon Cambrian(?) Mayflower Formation (Ꞓmf) and the lower and upper members of the tuff of Corcoran Canyon (Tccl and Tccu). It is overlain unconformably by the unnamed megabreccia unit (Tum), and the lower member of the volcaniclastic rocks of Little Table Mountain (Tlt1). It is in an area of considerable topographic relief that shows it is as much as 200 m thick. The source of the eruptive megabreccia of Meadow Canyon is interpreted to be the area at depth surrounding a rhyolite plug in Meadow Canyon in the Jefferson quadrangle (Shawe, 1999b)

Tmcs **Tuffaceous sandstone**—Light-yellowish-brown tuffaceous sandstone forms a layer 3–10 m thick that lies on top of heterolithic breccia (Thb) which surrounds the rhyolite plug (Trp) in Meadow Canyon at west margin of quadrangle. Where the tuffaceous sandstone is thickest, it fills a deep channel in the underlying heterolithic breccia. The sandstone displays bedding locally that is suggestive of fluvial deposition. The 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 grayish brown, light pinkish brown, light orangish brown, and light brown. The unit contains common flattened pale-yellowish-brown to gray pumice lapilli as long as 5 cm, and in places small lithic fragments of Paleozoic sedimentary and Tertiary volcanic rocks, mostly less than 1 cm in diameter but locally as much as 4 cm long. Where the tuff is vitrophyric, pumice fragments are black glass. Tuff is strongly magnetic in some horizons. A thin lens of sedimentary rock (Trcs, described below) within the formation is exposed on the northeast slope of Meadow Canyon in southwest part of quadrangle.

The tuff of Ryecroft Canyon consists largely of two modally distinct types of ash-flow tuff ("typical" and "quartz-rich"). All samples of both types have PI greater than 1.0. The two types show no consistent pattern of distribution throughout the area of exposure. Modal analyses of 11 samples of typical tuff of Ryecroft Canyon indicate 24–46 percent phenocrysts (1.5–5 mm) that consist of the following phases: Q, 22–33; K, 21–46; P, 17–42; B, 1–8; O, 0.5–1.5; and H, 0–2. Modal analyses of five quartz-rich samples of tuff indicate 34–40 percent phenocrysts (1–4.5 mm) that consist of the following phases: Q, 35–45; K, 29–37; P, 22–26; B, 1–4; O, 0.1–0.5; and H, 0–1. A modal analysis of one quartz-poor (less quartz than typical) sample that contains 25 percent phenocrysts (2.5–5 mm) indicates: Q, 14; K, 33; P, 43; B, 7; O, 1; and H, 2. Zircon is a common accessory mineral in all of the Ryecroft Canyon samples, apatite is less common, and allanite, sphene, and monazite(?) are sparse to rare. A chemical analysis of a typical tuff of Ryecroft Canyon indicates the following percentages of components: SiO_2, 73.3; Al_2O_3, 14.1; K_2O, 4.84; Na_2O, 3.42; CaO, 1.46; Fe_2O_3, 1.68; FeO, 0.34; MgO, 0.45; TiO_2, 0.29; P_2O_5, 0.11; and MnO, 0.06 (rhyolite). Two sanidine $^{40}Ar/^{39}Ar$ dates determined by L.W. Snee (written commun., 1997) on samples of the tuff of Ryecroft Canyon are 26.83±0.05 (1σ) Ma (rock sample locality R11) and 26.82±0.04 (1σ) Ma (rock sample locality R12). The dated samples were collected near the exposed base of the formation; the dates are close to those determined for the older parts of the tuff of Mount Jefferson (Tmj) (see above), indicating that the two formations probably are in part coeval.

The formation is exposed in the southwest part of the quadrangle in the steep slopes of Ryecroft Canyon (name of the unit proposed by Boden, 1986) and Meadow Canyon, and underlying the flats of Meadow Creek Bench. North and south of the mouth of Meadow Canyon the formation appears to lie conformably upon a unit of megabreccia (Tmb). An outcrop of the Ryecroft Canyon just southeast of the mouth of Meadow Canyon may represent older tuff underlying the megabreccia unit (Tmb), as suggested in cross sections *F–F′* and *H–H′*. The tuff of Ryecroft Canyon is overlain unconformably (upper part of the formation has been eroded) by Isom-type tuff (Ti) in the hills north of Meadow Canyon, and by tuffaceous siltstone formation (Tst) and units C and D of the Bates Mountain Tuff (TbtC, TbtD) on Meadow Creek Bench. A thin layer of the tuff of Ryecroft Canyon may lie at the top of the tuff of Mount Jefferson (Tmj) 1.2 km east of Little Table Mountain Spring (as discussed in the section describing Tmj, above), and thin layers of tuff and tuff breccia of Ryecroft Canyon (not mapped) may be interlayered in the tuff of Mount Jefferson in Corcoran Canyon about 2.5 km east of the top of Little Table Mountain, in west-central part of quadrangle. Maximum exposed thickness in southwest part of quadrangle about 200 m; thickness uncertain because varied attitudes of layering and compaction foliation that possibly resulted from collapse along a caldera margin, and numerous faults of uncertain displacement (many not shown on the map), preclude recognition of a continuous section of tuff.

The source of the tuff of Ryecroft Canyon has been interpreted as a caldera mostly underlying alluvium in the south part of Monitor Valley (Shawe and Byers, 1999), and largely within the Belmont East quadrangle south of the Corcoran Canyon quadrangle. Based on that interpretation, we consider that the tuff of Ryecroft Canyon exposed on Meadow Creek Bench is intracaldera facies, and tuff exposed in the walls of Ryecroft and Meadow Canyons may be either caldera fill or outflow, within, on, or near the margin of the caldera. Possibly the thick section of Ryecroft Canyon in southwest part of quadrangle was emplaced in a northwest-striking graben (suggested in the adjacent Jefferson quadrangle by Shawe, 1999b) that stems from the inferred caldera underlying Monitor Valley. As speculated upon by Shawe and Byers (1999), the similarity, both in phenocryst composition and in age, of the tuff of Ryecroft Canyon and the tuff of Moores Creek, mapped by Boden (1986, 1992) 2–20 km north and northwest of the Corcoran Canyon quadrangle, suggests that the two units may be parts of the same formation. If so, they would appear to have been derived from an exceptionally large caldera (see Shawe and Byers, 1999)

Trcs **Conglomerate lens**—Poorly exposed lens about 5 m thick of well-rounded pebbles and small cobbles of volcanic rocks, chert, quartzite, and aplite represents a partial(?) cooling break in deposition of the tuff of Ryecroft Canyon. The lens is exposed about 30 m above the floor of Meadow Canyon, on the northeast slope of the canyon about 1.5 km from the mouth of the canyon. The southeast part of Trcs consists of brecciated tuff; poor exposures preclude assurance that it is in fact a continuation of the conglomerate lens

Tmb **Monolithologic megabreccia (upper Oligocene)**—Gray megabreccia (weathers brown) of generally rounded blocks and slabs as long as 15 m, ranging in size down to a pulverized groundmass of apparently the same material. Most blocks appear to consist of tuff of Ryecroft Canyon (Trc). Modal analyses of two thin sections of samples of partially welded crystal-rich rhyolitic tuff from blocks 8 and 13 m long indicate respectively 26 and 20 percent phenocrysts (1.5–5 mm) that consist of: Q, 16 and 20; K, 38 and 35; P, 40 and 34; B, 5 and 8; O, 1 and 2; and H, 0.3 and 0.5. Accessory minerals are sparse to moderate zircon and apatite. A few blocks in the megabreccia are of the tuff of Corcoran Canyon (Tccu). A modal analysis of a thin section of one sample of moderately to densely welded crystal-rich rhyodacitic tuff from a block 2x3 m in size indicates 35 percent phenocrysts (1.5–5 mm) that consist of: Q, 2; K, 5; P, 69; B, 11; O, 3; H, 4; and C, 5. Zircon and apatite are common accessory minerals. A sanidine $^{40}Ar/^{39}Ar$ date of 27.05±0.06 (1σ) Ma was determined (L.W. Snee, written commun., 1996) for this sample (rock sample locality R13) of the tuff of Corcoran Canyon. The monolithologic megabreccia forms a unit underlying, on a moderately steep (about 20°) contact, the exposed tuff of Ryecroft Canyon for about 1.7 km along the range front north and south of Meadow Canyon. Its position suggests that it formed as a collapse megabreccia along the wall of the inferred caldera underlying Monitor Valley. The unit forms impressive cliffs and knobs flanking the mouth of Meadow Canyon. Maximum exposed thickness about 200 m; base not exposed

Tuff of Corcoran Canyon (upper Oligocene)—Welded ash-flow tuff formation petrographically similar to the tuff of Mount Jefferson, but distinctly older. The formation is divided into upper and lower members (Tccu and Tccl) based on petrographic differences; altered tuff (Tcca) was mapped in wide areas within the lower member

Tccu **Upper member**—Gray, partially to densely welded, biotite-rich and crystal-rich rhyodacitic ash-flow tuff; weathers brownish gray. Characterized by flattened, light-grayish-brown pumice lapilli mostly 1–6 cm long, locally as much as 15 cm long. Parts of the unit are tuff breccia. Modal analyses of nine thin sections of samples of the unit indicate 31–44 percent phenocrysts (2–6 mm) that consist of: Q, 1–11; K, 6–25; P, 52–74; B, 10–17; O, 1–8; and M, 1–4. Zircon and apatite are common accessory minerals; allanite is rare. These modes fall within PI categories 4 and 5 and thus are indistinguishable from modes in these categories in the tuff of Mount Jefferson. A modal analysis of a common rhyolitic welded ash-flow tuff clast in tuff of the upper member indicates 29 percent phenocrysts (3 mm) that consist of: Q, 25; K, 34; P, 37; B, 3; O, 1; and M, 0.4. Common zircon and apatite are accessory minerals. The composition is similar to that of part of the lower member of the tuff of Corcoran Canyon (Tccl), it being the likely source of the clasts. A chemical analysis of a sample of the upper member shows the following percentages of components: SiO_2, 67.1; Al_2O_3, 18.0; K_2O, 4.70; Na_2O, 3.59; CaO, 2.91; Fe_2O_3, 1.42; FeO, 0.56; MgO, 0.93; TiO_2, 0.61; P_2O_5, 0.21; and MnO, 0.02 (trachydacite). A chemical analysis of fiammi separated from this sample indicates the following percentages of components: SiO_2, 66.9; Al_2O_3, 17.9; K_2O, 5.19; Na_2O, 3.74; CaO, 2.67; Fe_2O_3, 1.31; FeO, 0.63; MgO, 0.88; TiO_2, 0.55; P_2O_5, 0.21; and MnO, 0.03 (trachydacite). The close similarity of the two analyses indicates a single magma source for the tuff and included pumice. A sanidine $^{40}Ar/^{39}Ar$ date of 27.17±0.05 (1σ) Ma was determined for a sample of the upper member (rock sample locality R 14; L.W. Snee, written commun., 1997). A biotite K-Ar date of

27.1±0.7 Ma was reported by McKee and John (1987) for another sample of the member (rock sample locality R 15). A third rock sample (rock sample locality R 16) provided a sanidine K-Ar date of 27.7±0.7 Ma (Boden, 1986, 1992). The upper member is present in central to west-central part of quadrangle where it overlies, apparently conformably, the lower member of the tuff of Corcoran Canyon (Tccl), and is overlain unconformably by the megabreccia of Meadow Canyon (Tmc), the unnamed megabreccia (Tum), and the lowest member of volcaniclastic rocks of Little Table Mountain (Tlt1). Locally in central part of quadrangle, the lower member lies above the upper member, and in this area we think the lower member was emplaced on the upper member along a detachment fault (see cross section *D–D'*), possibly related to collapse along the margin of the Mount Jefferson caldera. Maximum thickness about 100 m where a slab of the upper member is interpreted to have collapsed into the Mount Jefferson caldera (see cross section *H–H'*)

Tccl **Lower member**—Light-gray to pale-lavender-gray, partially to densely welded rhyolitic and quartz latitic ash-flow tuff; weathers light yellowish brown, light pinkish brown, and light brownish gray. Characterized by pale-gray to almost white, extremely flattened pumice lapilli mostly 3–5 cm long; in some horizons 10–25 cm long. Lithic fragments generally sparse, but abundant small fragments of yellowish-brown and reddish-brown chert were observed in one locality. Modal analyses of five thin sections of tuff indicate 25–34 percent phenocrysts (2–6 mm) that consist of: Q, 17–28; K, 21–25; P, 38–49; B, 3–10; O, 0.3–2; and M, 1–6. Zircon and apatite are common, and allanite is sparse. These modes fall into PI categories 1 and 2, and hence are similar in phenocryst composition to such tuffs in the tuff of Mount Jefferson (Tmj). Modal analysis of one thin section of tuff from the lower member indicates 45 percent phenocrysts (3–4 mm) that consist of: Q, 15; K, 13; P, 43; B, 19; O, 11; and M, 2. This mode is in PI category 4, also similar to such tuff in the tuff of Mount Jefferson. The member is exposed along the range front for about 7 km, north and south of Corcoran Canyon, and extending into the range as much as 2 km. It appears to underlie the upper member conformably; its base is not exposed. Judged from a rather consistent, mostly moderate to steep, southwesterly to southerly dip of compaction foliation in the member, the member's thickness may be as much as 2,000 m. However, numerous faults that cut the member, most not shown on the geologic map, may have repeated section of a thinner member. Nevertheless the member has significant thickness, indicating that it is likely intracaldera facies. The caldera from which the member was erupted has been much disrupted by formation of the inferred caldera underlying Monitor Valley from which the tuff of Ryecroft Canyon (Trc) was erupted, and by the Mount Jefferson caldera which was the source of the tuff of Mount Jefferson

Tcca **Altered ash-flow tuff**—Large areas in the lower member have been altered. In these areas ash-flow tuff is yellowish brown to yellowish gray, argillically altered, sericitized, and (or) iron mineralized. The tuff commonly is weathered to ocherous soil in areas of low relief. In places iron oxide, quartz, calcite, or botryoidal chalcedony fill fractures; iron oxide may be pervasive throughout tuff. Altered tuff is extensive in the northeast half of exposed lower member, where it appears to be centered on a silver-gold mineralized zone at Silver Reef Hill (informal name) about 1.5 km northwest of the mouth of Corcoran Canyon. Altered tuff was mapped only in the lower member; small areas of altered tuff in the upper member were not mapped

Ozl **Zanzibar Formation (Middle Ordovician)**—Only a small klippe of altered limestone (Ozl?) on the south side of Meadow Canyon at west edge of quadrangle represents the formation in the Corcoran Canyon quadrangle. Detailed descriptions of the entire formation, and of limestone where it is much more widely exposed in nearby and adjacent quadrangles, are given by Shawe (1995, 1998, 1999a, b) and Shawe and Byers (1999). Consists of gray, platy limestone. Platy cleavage is coincident with bedding but probably is of tectonic origin. The unit forms a small klippe about 300 m long and less than 100 m wide, lying upon and apparently infolded into platy shale of the Cambrian(?) Mayflower Formation (Ꞓmf). The thrust fault zone separating the two units is brecciated and sheared, and locally iron and quartz mineralized

€mf Mayflower Formation (Cambrian?)—Medium-gray, platy shale or slate; weathers olive gray to brownish gray and yellowish gray. Silty layers in shale are uncommon. Platy cleavage in most outcrops appears to be parallel to bedding, although in one outcrop platy cleavage diverges about 10° from compositional layering. In a few outcrops the unit consists of siliceous argillite or phyllitic shale. Platy cleavage is thought to be the result of regional deformation and metamorphism. Locally, platy cleavage is contorted or crinkled, indicating deformation subsequent to the inferred regional metamorphism. The Mayflower Formation is exposed in an area of about 1 km^2 in southwest corner of quadrangle, and on either side of Meadow Canyon near west margin of quadrangle, where it crops out in an east-trending zone almost 2 km long and about 600 m wide. The exposure near Meadow Canyon is interpreted to consist of intact bedrock lying between the Mount Jefferson caldera to the north and the inferred caldera underlying Monitor Valley to the south and east. Thickness of the Mayflower Formation is unknown; it may be as much as a kilometer or more

SUMMARY OF GEOLOGIC EVENTS

Discussion of an incompletely known Paleozoic and Mesozoic history of events in the southern Toquima Range was given by Shawe (1995, 1998a, 1999a, b), and Shawe and Byers, (1999). The complex history of Tertiary volcanic events in the Corcoran Canyon quadrangle is described here.

Volcanic activity in the Corcoran Canyon quadrangle began in late Oligocene time with emplacement of the rhyolitic to rhyodacitic tuff of Corcoran Canyon. The formation, judged from its evident thickness of as much as 2,000 m, is probably intracaldera facies within a caldera whose extent and configuration is unknown. Following emplacement of the thick lower member (Tccl), a relatively thin upper member (Tccu) was erupted at about 27.17 Ma.

The rhyolitic tuff of Ryecroft Canyon (Trc units), interpreted to have been erupted from an inferred caldera that lies mostly covered by alluvium in the south part of Monitor Valley (Shawe and Byers, 1999), was emplaced at about 26.82 Ma. In the Corcoran Canyon quadrangle the formation appears to be at or near the margin of the caldera inferred to underlie Monitor Valley. A megabreccia unit (Tmb) interlayered in or underlying the formation consists mostly of material of the composition of the tuff of Ryecroft Canyon. A few blocks in the megabreccia were derived from the tuff of Corcoran Canyon; one such dated block is about 27.05 Ma.

A widely exposed megabreccia formation (Tmc; megabreccia of Meadow Canyon) emplaced during later stages of the tuff of Ryecroft Canyon (Shawe, 1999b) consists of a matrix chiefly of Ryecroft Canyon composition that contains small to immense blocks mostly of the tuff of Ryecroft Canyon and of lesser amounts possibly of both the tuff of Corcoran Canyon and the tuff of Mount Jefferson, a formation whose lower part is about the same age as the tuff of Ryecroft Canyon. The megabreccia of Meadow Canyon is interpreted to be of eruptive origin, based mostly on evidence in the adjacent Jefferson quadrangle to the west (Shawe, 1999b).

The rhyolitic to rhyodacitic tuff of Mount Jefferson (Tmj units), erupted from the large Mount Jefferson caldera lying mostly north of the Corcoran Canyon quadrangle, erupted initially during the later stages of deposition of the tuff of Ryecroft Canyon. The tuff of Mount Jefferson within the Corcoran Canyon quadrangle (called here principal member, Tmj, and at least 2,000 m thick) is part of an upper member of the formation that overlies a lower member in the north part of the Mount Jefferson caldera, as described by Boden (1986, 1992). Judged from the radiometric data, the lower part of the principal member was emplaced at about 26.82–26.80 Ma and the upper part of the member was emplaced at about 26.70–26.63 Ma. The age data for the principal member suggest a span of about 100,000–200,000 years for accumulation of the unit.

The close similarity in modal compositions between the rocks of the tuff of Mount Jefferson and those in the older tuff of Corcoran Canyon suggests a possible common magma source of the two formations. If so, the magma that produced the two episodes of volcanic activity, one of the tuff of Mount Jefferson and the other of the tuff of Corcoran Canyon, remained extant for a period of at least 350,000 years. Variations in composition within both tuff formations indicate that magmatic differentiation occurred during both episodes of volcanism. Eruption of the tuff of Ryecroft Canyon occurred largely during the interval between eruption of the tuff of Corcoran Canyon and the tuff of Mount Jefferson. Modal data for the tuff of Ryecroft Canyon indicate a consistent rhyolitic composition, suggesting that it had a magma source different from that of the tuff of Corcoran Canyon and the tuff of Mount Jefferson. However, comparison of chemical data for the three volcanic formations (Shawe, 1999b; Shawe and Byers, 1999; and this report) show that they are chemically similar.

An unnamed megabreccia unit (**Tum**) that contains clasts of the tuff of Ryecroft Canyon and possibly of both the tuff of Mount Jefferson and the tuff of Corcoran Canyon was emplaced following eruption of the megabreccia of Meadow Canyon. The unnamed megabreccia and the tuff of Mount Jefferson both appear, in places, to be transitional into the overlying lowest member of volcaniclastic rocks of Little Table Mountain (**Tlt1**).

Deposition of the lowest member of volcaniclastic rocks of Little Table Mountain consisted of a sequence of interlayered tuffaceous claystones, siltstones, sandstones, and conglomerates, and tuffs. Sanidine from a tuffaceous silty sandstone collected near the base of the member was dated at 26.65 Ma; the source of the dated material was either eroded tuff of Mount Jefferson or reworked ash erupted near the end of volcanism of the Mount Jefferson caldera. The volcaniclastic rocks were deposited mostly in a lacustrine environment.

A 60-m-thick lens of pumiceous rhyodacitic tuff constitutes the next higher member of volcaniclastic rocks of Little Table Mountain (**Tlt2**). It is compositionally similar to parts of the tuff of Mount Jefferson, and likely was erupted from the Mount Jefferson caldera.

Zeolitic tuff (**Tlt3**) exposed on the lower slopes of Little Table Mountain was deposited in a lake. Modal and chemical data indicate that it too may have been erupted from the Mount Jefferson caldera. An interval about 30 m thick in one locality consists of about 80 percent of the zeolite mineral clinoptilolite. The unit, 30–50 m thick, is exposed for a distance of about 5 km around the north, east, and south slopes of Little Table Mountain, as well as for several kilometers in the adjacent Jefferson quadrangle (Shawe, 1999b). The unit consists in large part of an unusually clinoptilolite-rich rock of great volume constituting a significant zeolite resource.

The uppermost member of volcaniclastic rocks of Little Table Mountain (**Tlt4**) is similar in lithologic composition to the lowest member; it also was laid down largely in a lacustrine environment.

Shortly after deposition of the tuff of Mount Jefferson and volcaniclastic rocks of Little Table Mountain, several rhyolite plugs (**Trp**) were intruded widely throughout the Corcoran Canyon quadrangle. Some of them were emplaced along or near the structural margin of the Mount Jefferson caldera, and they too are likely manifestations of the fading igneous actvity of that caldera. One such plug is dated at 26.60 Ma and another at about 26.2 Ma. Three plugs are localized along the trend of a northwest-striking structure in Meadow Canyon that is interpreted to be related to the Walker Lane northwest-striking regional structural element (Shawe, 1999b). A fourth such plug farther to the northwest in the Jefferson quadrangle was dated at 26.4 Ma (McKee and John, 1987; Shawe, 1999b).

The rhyolite plug in Meadow Canyon at the west margin of the Corcoran Canyon quadrangle is surrounded by a zone of heterolithic breccia (**Thb**) that formed as a result of the forceful emplacement of the rhyolite plug. Above the plug, and atop a layer of heterolithic breccia that caps the plug, rests a layer of tuffaceous sandstone (**Tmcs**). The sandstone in turn is overlain by a thin remnant of the megabreccia of Meadow Canyon (**Tmc**).

Several of the rhyolite plugs in the Corcoran Canyon quadrangle are in part hydrothermally altered and (or) surrounded by a zone of hydrothermally altered wall rocks. One zone, centered on the lower reach of Corcoran Canyon, is particularly broad, and it contains a silver-gold prospect at the vein on Silver Reef Hill (informal name) on the east side of the canyon about 2 km from the mouth of the canyon. The episode of mineralization here manifested most likely took place during the period of intrusion of the rhyolite plugs, at about 26.8–26.2 Ma.

Overlying the volcaniclastic rocks of Little Table Mountain is a relatively thin layer, not everywhere present, of Isom-type rhyodacitic welded ash-flow tuff (**Ti** units). This distinctive formation, similar in modal composition to the 27-Ma Isom Formation of eastern Nevada and western Utah (Best and others, 1989), is about 26.6–26.7 Ma based on its stratigraphic position in the quadrangle. Its probable source is to the east in eastern Nevada or western Utah.

The latitic Shingle Pass Tuff, represented by a lower and an upper member (**Tspl** and **Tspu**) in the quadrangle, overlies the Isom-type tuff. The lower member is dated at 26.68 Ma (Best and others, 1989), and the upper member, only a thin wedge present, is dated at 26.00 Ma (Best and others, 1989). The Shingle Pass Tuff probably was erupted from a caldera in eastern Nevada.

The tuff of Pipe Organ Spring in the Corcoran Canyon quadrangle consists of a lower rhyolitic ash-flow tuff member (Tpl) and an upper rhyolitic ash-flow tuff member (Tpu). The lower member, only a thin wedge exposed, and the upper member are separated by unit D of the Bates Mountain Tuff (TbtD). The lower member is dated at 25.42 Ma, and thus was emplaced near the end of the Oligocene epoch. The source of the tuff of Pipe Organ Spring is unknown.

A thin tuffaceous siltstone unit (Tst) locally overlies the tuff of Ryecroft Canyon and underlies units C and D of the Bates Mountain Tuff (TbtC and TbtD) in the southwest part of the quadrangle. Probably lacustrine, it appears to contain reworked ash-fall materials from different unidentified sources.

Unit C of the Bates Mountain Tuff is probably about 24.5 Ma based on correlation with a similar unit in the northern Toquima Range (McKee and Stewart, 1971). Unit D has been dated at 23.9 Ma (McKee and Stewart, 1971), 23.7 Ma (Grommé and others, 1972), and 23.4 Ma (Sargent and McKee, 1969) at different localities in central Nevada.

Overlying the upper member of the tuff of Pipe Organ Spring (Tpu) in the north part of the quadrangle is the tuff of Clipper Gap (Tcg). The tuff of Clipper Gap and unit D of the Bates Mountain Tuff are similar in modal composition, but according to available data, the tuff of Clipper Gap is about 22.8 Ma (Best and others, 1989; Sargent and McKee, 1969) and hence younger than the Bates Mountain Tuff, as is also shown by the stratigraphic position of the tuff of Clipper Gap above the upper member of the tuff of Pipe Organ Spring and the Bates Mountain Tuff.

An unusual megabreccia unit exposed in the central part of the quadrangle, the megabreccia of Corcoran Creek (Tcm), is characterized by a matrix of pulverized material that contains fragments some of which themselves show evidence of several stages of brecciation. Large brecciated blocks of a variety of rock types are randomly distributed in the megabreccia. The east margin of the megabreccia appears to merge transitionally into a deformed slab of the lowest member of volcaniclastic rocks of Little Table Mountain (Tlt1) upon which rest slabs and jumbled blocks of younger volcanic units (tuff of Clipper Gap, Tcg, unit D of the Bates Mountain Tuff, TbtD, and upper member of the Shingle Pass Tuff, Tspu) some of which have foundered in tuffaceous rocks of Tlt1 as a result of severe agitation. We interpret the megabreccia of Corcoran Creek to constitute a pipe or diatreme which in the course of eruption and subsidence caused lateral collapse of the slab of the lowest member of volcaniclastic rocks of Little Table Mountain.

The youngest volcanic activity recorded in the Corcoran Canyon quadrangle was deposition of a biotite-bearing rhyodacitic ash-flow tuff (Tbi). The unit appears to lie disconformably upon the tuff of Clipper Gap (Tcg). Source and age of the unit are unknown; the age of the unit probably is lower Miocene.

A variety of alluvial deposits was laid down in the area of the quadrangle during the Holocene and Pleistocene; alluviation continues with erosion of the high-standing Toquima Range.

Faults that have deformed the alluvial deposits provide some insight into the recent tectonism (Basin-range structure) that has affected the area and that is responsible for the continuing uplift of the Toquima Range. Subparallel sets of faults in alluvium that form zones stepping out from the range front indicate that the range has been raised in a series of steps rather than along a single zone of faulting at the present range front. The surface of Meadow Creek Bench and the surface of the bench just east of the range in the north part of the quadrangle consist of oldest (Pleistocene) alluvium (Qa1), whereas alluvium farther from the range is younger, indicating that faults farther from the range generally are younger than faults along the range front. The range-front fault that extends from about 2 km north of the mouth of Meadow Canyon to about 5 km south of the north boundary of the quadrangle, and faults in alluvium farther to the north, form an arc that is concentric with the arc of the southeast structural margin of the Mount Jefferson caldera. The coincidence in form of the caldera margin and form of the arc of range-front faults suggests a relation, most likely reflecting structural breaks associated with collapse of the caldera during its development. Control of Basin-range faults by structures that predate the development of Basin-range structure merits attention in any attempt to understand mechanisms of Basin-range tectonism.

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