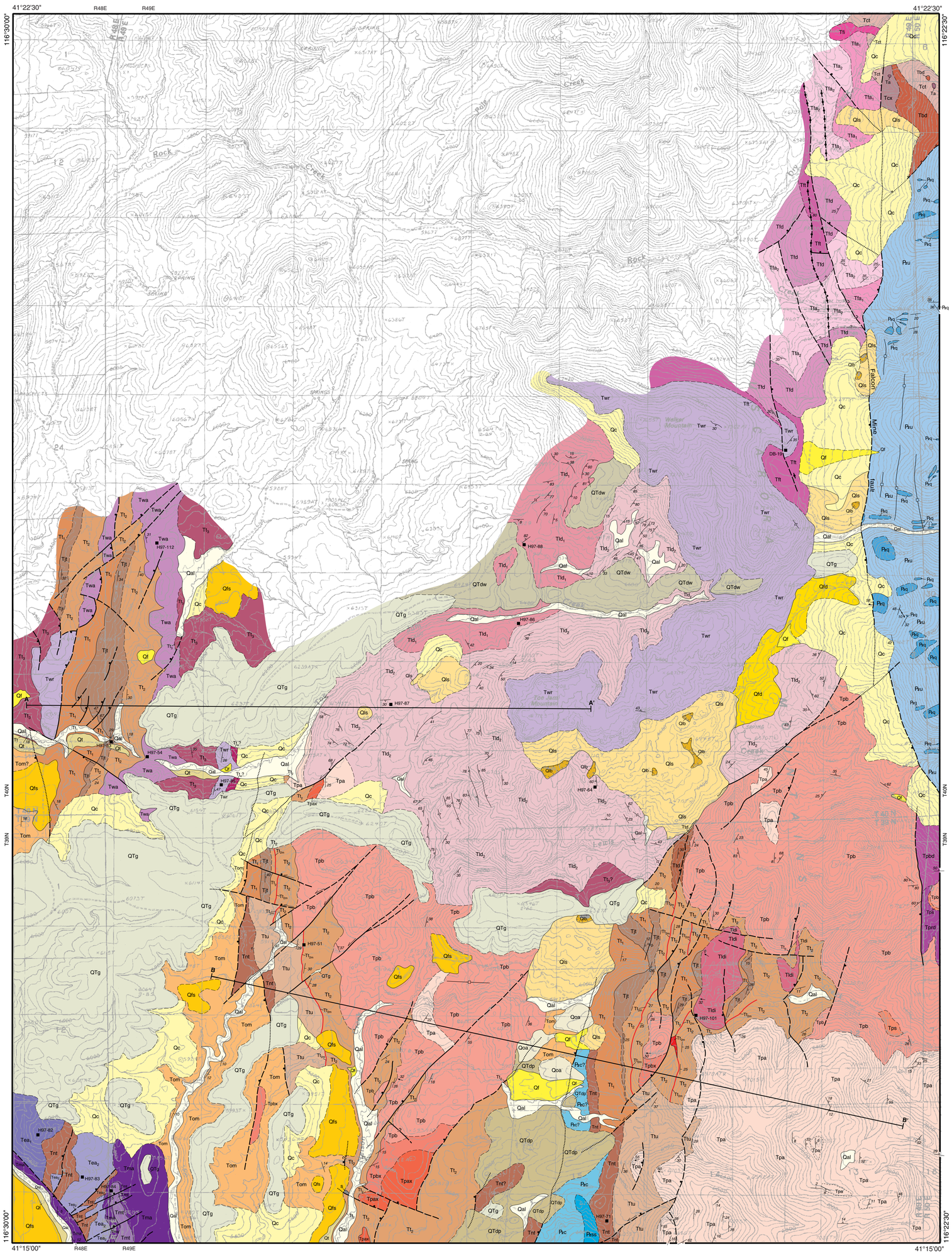


Scale 1:24,000

0 0.5 1 kilometer

0 0.5 1 mile

0 1000 2000 3000 4000 5000 feet

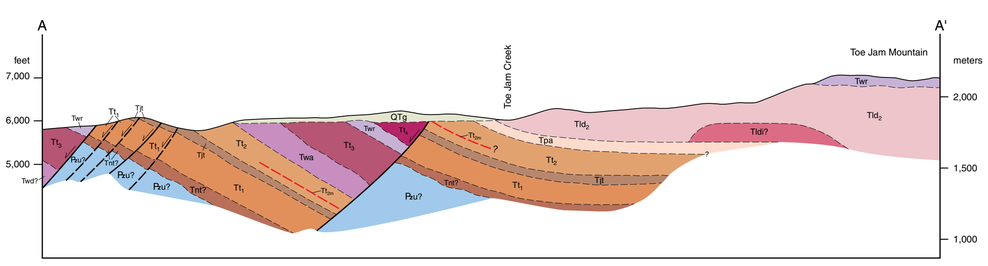
CONTOUR INTERVAL 40 FEET

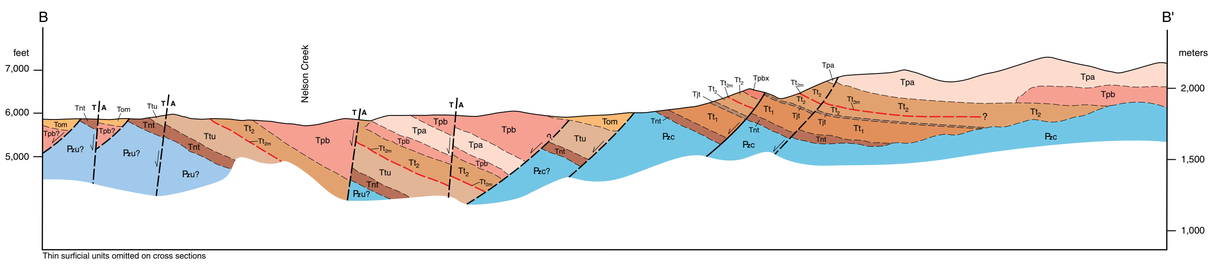
Base map: U.S. Geological Survey Toe Jam Mountain 7.5' Quadrangle, 1987
Digital Raster Graphic (DRG)

GEOLOGIC MAP OF THE SOUTHERN PART OF THE TOE JAM MOUNTAIN QUADRANGLE, NEVADA

Christopher D. Henry and David R. Boden

1999





Thin surficial units omitted on cross sections

Contact Long dashes where approximately located, short dashes between different lava flows within same unit, around magebreccia blocks, or form lines on cross sections, queried where uncertain.

Fault Showing sense of displacement and dip; ball on downthrown side, dashed where approximately located, dotted where concealed, queried where uncertain; arrow shows trend of slickenlines. Arrows show relative direction of movement. **T** (toward) and **A** (away) on cross sections.

Caldera margin Topographic or buried structural margin of Big Cottonwood Canyon caldera, dashed where approximately located, dotted where concealed.

Monocline axial trace Arrows indicate direction of dip.

Vertical joint Showing strike.

Vein coincident with normal fault Showing dip, dashed where approximately located.

Strike and dip of beds

20 Inclined

Strike and dip of compaction foliation in ash-flow tuff

75 Inclined

Strike and dip of flow bands in lava or intrusion

60 Inclined Vertical

Continous curving flowbands

Columnar joints Showing bearing and plunge.

32

Inclined minor fold Showing bearing and plunge of hingeline.

10

Sample location for $^{40}Ar/^{39}Ar$ date or chemical analysis

■ H96-103

Area of silicification Possible sinter.

SURFICIAL DEPOSITS

Quaternary

Qal **Alluvium of active channels** Unconsolidated alluvium up to 4 m thick in active channels of major drainages. Composed of poorly sorted silt- to boulder-sized clasts.

Qf **Alluvial fan deposits** Deposits of active to recently active, alluvial fans along major drainages. Composed of sand- to boulder-sized clasts. At most a few meters thick.

Qc **Colluvium and talus** Coarse talus and finer, commonly deeply weathered material that accumulated along steep to moderate slopes. Includes (1) thin (1 to 2 m) lag of coarse boulders of Paleozoic rocks adjacent to and reworked from Quarternary–late Tertiary gravel (QTg), and (2) thicker (up to 5 m) cover of coarse boulders and finer material reworked from Paleozoic outcrop along major, north-striking normal fault along eastern edge of quadrangle.

Qt **Terrace deposits** Older alluvial deposits adjacent to but above active channels of major drainages. Composed of sand- to boulder-sized clasts and now being dissected. 1 to 4 m thick.

Qfs **Older alluvial fan deposits** Secondary alluvial fans derived from erosion of Quaternary–late Tertiary gravel (QTg). Composed of coarse boulders, mostly of Paleozoic quartzite, in finer matrix. Somewhat gradational to colluvium and talus (Qc) but with distinct fan morphology. Generally 1 to 2 m thick.

Qoa **Older alluvium** Older alluvial deposits away from active channels south of Nelson Creek. Possibly deposited from former course of Nelson Creek. As much as 3 m thick.

Qfd **Dissected alluvial fan deposits** Deeply dissected alluvial fan remnants in upper part of Lewis Creek drainage. Composed of sand- to boulder-sized clasts, mostly of rocks of the Pleasant Valley complex, with lesser rhyolite of Walker Mountain (Twr), other Tertiary rocks, and Paleozoic rocks. Possibly as much as 15 m thick.

Qlb **Landslide basins** Small (up to a few hundred meter across), closed or formerly closed basins developed within recent landslide deposits (Qls). Partly filled with silt and containing standing water during much of the year.

Qls **Landslide deposits** Coarse, unconsolidated debris composed of local bedrock, developed especially where hard, massive rock overlies tuff or other soft rock. Clasts range from silt to large blocks, up to 10 m in diameter. Commonly form hummocky topography with numerous closed basins (Qlb). Probably as much as 50 m thick.

Quaternary–Pliocene

QTg **Quaternary–late Tertiary gravel** Coarse gravel that forms extensive gravel caps as much as 60 m thick in the western part of the quadrangle and a few isolated remnants in the eastern part; probably a more continuous sheet before late Quaternary dissection. Composed mostly of Paleozoic quartzite (Ꝑxq) and lesser andesite and dacite of the Pleasant Valley complex. Maximum clast size ranges from ~3 m in easternmost remnants to ~1 m near the western edge of the quadrangle. Presumably derived from Paleozoic highlands on upthrown side of Falcon Mine fault near eastern edge of the quadrangle. Surfaces at different elevations suggest deposition in several pulses. Dissection suggests at least early Quaternary in age, possibly Pliocene, but flat-lying aspect indicates that it postdates all tilting related to normal faulting.

QTdw **Debris deposits (Walker Mountain)** Debris apron, probably ancient landslide deposit, as much as 30 m thick along south flank of Walker Mountain and composed entirely of blocks of rhyolite of Walker Mountain (Twr). Consists of boulders up to 4 m in diameter in matrix of cobbles and finer material. Highly dissected and overlain by Quaternary–late Tertiary gravel (QTg).

QTdp **Debris deposits (Pleasant Valley)** Debris apron, probably ancient landslide deposit, as much as 25 m thick along west flank of high area in southeastern corner of quadrangle. Composed mostly of clasts of andesite (Tpa) of Pleasant Valley complex up to 8 m across. Highly dissected and appears to be overlain by Quaternary-late Tertiary gravel (QTg).

TERTIARY ROCKS

Miocene

Tmt **Vitric tuff** Poorly to moderately welded, glassy to slightly axiolitically devitrified, black to dark red-brown, dacitic ash-flow tuff that is approximately 15 m thick. Coarse (to 1 mm) glass shards are prominent and easily identified in hand specimen. Contains sparse pumice to 1 cm and microlitic, flow-banded glass lumps to 5 mm. Commonly columnar jointed. Regional distribution and thickness indicates the tuff was derived from a source west of the quadrangle. Phenocrysts (10–12%): plagioclase (7%, 4 mm), sanidine (3%, <1 to rarely 2 mm), iron-rich pyroxene (1%, 1 mm), and opaques (<1%, 0.5 mm). Age: 5.26±0.05 Ma, sanidine, H97-84; also 15.29±0.06 Ma, sanidine, 96WC24, Willow Creek Reservoir Quadrangle. Reverse polarity.

Tma **Air-fall tuff** Sequence of poorly indurated, well-bedded air-fall tuff and tuffaceous sediment as much as 20 m thick crops out only in the southwestern corner of the quadrangle. Air-fall tuff composed of perlitic glass shards in layers 1 to 10 cm thick, some showing minor normal grading. Sedimentary rocks range from fine sandstone to pebble conglomerate with clasts to 3 cm of glass lumps, rhyolitic pumice, and mafic scoria.

Miocene–Oligocene

Tom **Sandstone and conglomerate** Poorly exposed sequence of poorly indurated, massive, brown, coarse to pebbly sandstone and boulder conglomerate. Crops out rarely along stream cuts; commonly expressed as boulder lag or sandy soil. Clasts are dominantly cobbles to boulders of Pleasant Valley complex up to ~1 m in diameter and, near western edge of quadrangle, minor rhyolite of Walker Mountain (Twr). Thickness uncertain but at least 100 m.

Eocene

Tt **Volcaniclastic rock** Eocene(?) volcaniclastic sedimentary rocks that crop out along south side of Toe Jam Creek at western edge of quadrangle and west of major normal and strike-slip faults. Probably Eocene but stratigraphic position relative to other units is unknown. Includes well-bedded, coarse to fine tuffaceous sandstone, pebble conglomerate with igneous rock fragments to 8 mm, and lignite to carbonaceous shale in lenses 3–10 cm thick. At least 30 m thick.

Tt_4 **Covered tuff** Probably soft tuff similar to upper soft tuff (Tt_3). Shown on map along Toe Jam Creek and on cross sections, but everywhere covered by colluvium.

Twr **Rhyolite of Walker Mountain** An extensive rhyolite lava flow or series of flows caps Walker and Toe Jam Mountains and crops out in fault blocks to the western edge of the quadrangle. The unit is as much as 150 m thick on Walker Mountain and thins slightly to the south and west. Most of the body is massive to locally flow banded and vesicular, stony rhyolite; flow-banded, vitrophyric (perlitic) breccia is common along the base. The flow on the south side of Walker Mountain filled irregular topography developed on the top of the upper Lewis Creek dome (Tld_2). Phenocrysts (25%): quartz (5%, 1–2 mm, smoky, bipyramidal), sanidine (5–7%, 1–3 mm), plagioclase (10–12%, 1–5 mm), and biotite (2–3%, 1 mm). Age: 35.29±0.10 Ma, sanidine, DB-19; 35.15±0.10 Ma, sanidine, H97-85.

Tt_3 **Upper soft tuff** Very poorly exposed, poorly indurated, pumiceous, lithic tuff that makes up stratigraphic interval above western dacite (Twd) and below rhyolite of Walker Mountain (Twr). Includes probable nonwelded ash-flow tuff and tuffaceous sedimentary rock. Massive ash-flow(?) tuff contains rounded pebbles of volcanic rocks to 10 cm, which are coarsest to north. Commonly expressed as lag of rounded pebbles. Sedimentary layers are moderately bedded siltstone, fine sandstone, and pebble conglomerate. As much as 300 m thick in Toe Jam Creek but wedges out over topographic high of Lewis Creek domes (Tld_1 and Tld_2).

Lavas of the Falcon Mine

Andesite and dacite lavas, minor tuff and tuffaceous sedimentary rock, and a dacite intrusion crop out in the northeastern part of the quadrangle and host veins at the Falcon Mine. These rocks are younger than the tuff of Big Cottonwood Canyon (Tct) and older than the rhyolite of Walker Mountain (Twr). They are petrographically similar to and possibly correlative with andesite-dacite lavas (Sixmile Canyon lavas) in the northern part of the Tuscarora Quadrangle (Henry and others, 1998). The Sixmile Canyon lavas are also younger than the tuff of Big Cottonwood Canyon.

Tft **Tuff and tuffaceous sedimentary rocks** Poorly welded, crystal-poor, lithic tuff with local interbeds of tuffaceous sandstone and shale locally overlies dacite lava (Tfd). Maximum thickness is 12 m. Rock is recessive and poorly exposed except where locally silicified. Probably stratigraphically equivalent to upper soft tuff (Tt_3).

Tfd **Dacite of the Falcon Mine** One or more lava flows of moderately to coarsely porphyritic dacite that total as much as 75 m thick. Rock is glassy to devitrified. Phenocrysts (25%): plagioclase (20%, 5 mm), hornblende (3–4%, 3 mm, altered), biotite (1%, <1–2 mm), clinopyroxene (1.5%, 3 mm), orthopyroxene (0.75%, 1 mm), and opaques (<1%, 0.1 mm). In hand specimen, hornblende is not particularly evident because it is preferentially altered.

Tfi **Dacite intrusion of the Falcon Mine** An elongate, flow-layered dacite that intrudes the upper and lower andesite of the Falcon Mine (Tfa_2 and Tfa_1) in the northeastern corner of the quadrangle. Presence of 1–2% rounded, embayed quartz and absence of pyroxene distinguishes intrusion from host lava flows. Medium-grained phenocrysts (15–20%): plagioclase (10–12%), quartz (1–2%), and subequal amounts of biotite and hornblende (1.5% each).

Tfa_2 **Upper andesite of the Falcon Mine** Probably a single lava flow of moderately porphyritic andesite as much as 45 m thick that forms variably brecciated outcrops. Similar to lower andesite (Tfa_1) but contains more biotite and less pyroxene. Phenocrysts (20–25%): plagioclase (15–18%), hornblende (3%), biotite (1–2%), and pyroxene (0.5–1.0%).

Tfa_1 **Lower andesite of the Falcon Mine** Two or more flows of moderately porphyritic andesite that total as much as 60 m thick. Unit forms subdued to blocky outcrop along major, north-striking normal fault along eastern edge of quadrangle.

Rocks of the Big Cottonwood Canyon Caldera

The Big Cottonwood Canyon caldera (Berger and others, 1991; Henry and Boden, 1998) is a large (>15 km diameter), rhyolitic ash-flow caldera that formed during eruption of the voluminous tuff of Big Cottonwood Canyon (Tct). The caldera lies mostly within the Mount Blitzen and Big Cottonwood Canyon Quadrangles to the northeast, but its southwesternmost part extends into the northeastern corner of the Toe Jam Mountain Quadrangle. The caldera margin is marked by the juxtaposition of Paleozoic rocks in the caldera wall against thick, intracaldera tuff. The caldera and tuff are dropped beneath rocks of the Falcon Mine by the Falcon Mine fault near the eastern edge of the quadrangle. Outflow tuff of Big Cottonwood Canyon has been found in the Willow Creek Reservoir Quadrangle to the southwest (Wallace, in preparation) and in the southeastern part of the Tuscarora Quadrangle to the east (Henry and others, 1998).

Tct **Tuff of Big Cottonwood Canyon** Compound cooling unit of light-gray, devitrified, lithic, densely welded, rhyolitic ash-flow tuff. Crops out exclusively within and along the topographic margin of the Big Cottonwood Canyon caldera in the northeastern part of the quadrangle. Tuff within the caldera may be several kilometers thick, based on its 15° to 25° westward dip across the caldera in the Mount Blitzen and Tuscaora quadrangles. Phenocrysts (20–25%): quartz (6%, 3 mm), sanidine (6–7%, 2.5 mm), plagioclase (7–10%, 3 mm), biotite (1%, 2 mm), and hornblende (<1%, <1 mm); individual fiamme, which are up to 25 cm long, contain 15% of the same phenocrysts. Commonly weakly propylitically altered. Age: 39.67±0.10 Ma, sanidine, H96-42; 39.67±0.10 Ma, sanidine, H96-80; in Big Cottonwood Canyon Quadrangle (Henry and Boden, 1998). Reverse polarity.

Tcx **Breccia and debris deposits** An irregular body of massive breccia occurs within the tuff of Cottonwood Canyon near the caldera margin. Deposit consists of various older rocks, including dacite of Mount Blitzen (Tbd), early andesite (Ta), and Paleozoic chert, quartzite, and siltstone, up to several meters in diameter (larger blocks are mapped as megabreccia). Matrix consists of finer pieces of the same rocks. Forms poor outcrop, mostly expressed as abundant weathered out clasts littering the surface. Interpreted as landslide debris from the caldera wall during eruption of the tuff and initial caldera collapse.

Tbd **Megabreccia** Large blocks of older rocks within the tuff of Big Cottonwood Canyon (Tct) are mapped as their individual rock type. Blocks are composed of two rock types, neither of which crop out in situ within the Toe Jam Mountain Quadrangle, up to approximately 100 m across. These are dacite of Mount Blitzen (Tbd) and early andesite (Ta). As with the breccia and debris deposits (Tcx), megabreccia blocks are interpreted as landslides from the caldera wall. The large area of Tbd in the northeast corner of the map may be either an exceptionally large megabreccia block or an in-situ dome in the caldera wall. **Tbd dacite of Mount Blitzen** Sparsely to moderately porphyritic, commonly flow laminated dacite makes numerous domes and shallow intrusions within the Mount Blitzen volcanic center (Henry and Boden, 1998). Phenocrysts (8–20%): plagioclase (5–15%, 1–4 mm), biotite (1–4%, 1–2 mm), clino- and orthopyroxene (<0.5%, 0.5 mm), and horn-blende (0.5%, 1 mm); mafic minerals are generally chloritized. **Ta Early andesite** Porphyritic andesite lava flows mostly occurring as blocks within the Mount Blitzen volcanic center. Somewhat similar to andesite lavas of the Pleasant Valley volcanic complex, but relative age and possible relation are uncertain. Phenocrysts (20–25%): plagioclase (19–24%, 3 mm) and clinopyroxene (1–2%, 1.5 mm); commonly as glomerocrysts. Commonly altered, with all mafic minerals converted to chlorite and calcite.

Lavas, Domes, and Sedimentary Rocks of the Pleasant Valley Volcanic Complex

The Pleasant Valley volcanic complex consists of abundant andesite to dacite lava flows and flow breccia, several dacite lava domes and intrusions, and tuff and volcaniclastic sedimentary rock. The complex is named for exposures of the rocks in the Mount Blitzen Quadrangle (Henry and Boden, 1998) and extends to the south into the China Camp and Sugarloaf Butte Quadrangles. Sources for Pleasant Valley rocks in the Toe Jam Mountain Quadrangle include a dacite dome (Tpbd) between Nelson and Lewis Creeks near the eastern edge of the quadrangle, two lava domes (Tld_1 and Tld_2) north of Lewis and Toe Jam Creeks, and several intrusions (Tldi) in Nelson Creek. The lavas are subdivided on the basis of their mafic phenocryst content and probable composition into pyroxene andesite (Tpa) and biotite-bearing dacite lava (Tpb). Additional hornblende-phyric dacite lavas crop out in the Mount Blitzen Quadrangle. Individual flows are 10 to possibly as much as 75 m thick, and the dacite domes are as much as 300 m thick. Composite thickness is at least 370 m in the southeastern part of the quadrangle. Platy flow bands and ramp structures are developed in all rock types but are most prominent in pyroxene andesite and in the Lewis Creek domes. Basal parts of flows have what were initially approximately horizontal flow bands and vertical columnar joints. Where the flows have been tectonically tilted, these structures can be used to indicate presence and approximate amount of tilt. Pleasant Valley volcanic rocks rest upon early Tertiary tuffs in this quadrangle but directly overlie basal Tertiary conglomerate and Paleozoic rocks to the east. Age: 39.86±0.24, hornblende, H96-73; 39.69±0.28, hornblende, H96-86; both on hornblende-phyric dacite lavas in the Mount Blitzen Quadrangle (Henry and Boden, 1998).

Tpb **Tpbx** **Biotite-bearing dacite lava** Biotite-bearing lavas crop out mostly north of Nelson Creek, adjacent to either the biotite-dacite dome (Tpbd) or to the and lignite to carbonaceous shale in lenses younger Lewis Creek dome (Tld_2). In both areas, numerous, resistant flows total more than 300 m thick. Flows are petrographically similar to the adjacent domes and probably in part derived from them. The contact between biotite-bearing lavas and upper Lewis Creek dome is very approximately located. White to mustard-yellow opal coats fractures and fills vesicles in flows near the confluence of Lewis and Nelson Creeks. Phenocrysts (20–35%): plagioclase (15–25%, 5 mm), biotite (1–2%, <1–3 mm), hornblende (<1–2%, <1–2 mm), clinopyroxene (1–3%, 2 mm), orthopyroxene (1–2%, 1 mm), and opaques (<1%, 0.1 mm). **Tpbx** Massive breccia composed of mostly angular blocks of biotite-bearing andesite-dacite lava to 3 m in diameter. Probably mostly lava-flow breccia at margins of thick flows.

Tpa **Tpax** **Pyroxene andesite lava** Andesitic lavas that contain pyroxene as the only or nearly only mafic phenocryst crop out mostly south of Nelson Creek where they are as much as 370 m thick. They continue eastward and are particularly abundant in the Mount Blitzen Quadrangle. Phenocrysts (25–35%): plagioclase (18–25%, 3 mm), clinopyroxene (6-7%, 1.5 mm), orthopyroxene (2-3%, 1 mm); a few flows contain hornblende (trace, 3 mm) or biotite (<1%, 1 mm). **Tpax** Massive to faintly bedded breccia composed of blocks of angular to slightly rounded, glassy to crystalline, flow-banded, and vesicular andesite to 2.5 m in diameter in a matrix of fine, granular andesite. Clast- to matrix-supported. Probably a mix of primary lava-flow breccia and debris deposits reworked from flow margins.

Tld_2 **Upper Lewis Creek dome** A strongly flow-banded dacite lava dome crops out in a 6x5-km area along and north of Lewis Creek and is at least 300 m thick. Petrographic and compositional similarity over this area and continuity of flow bands over distances of as much as 1 km indicate it is a single body. Carapace breccia consisting of flow-banded, vesicular, vitrophyric blocks is preserved along the southern margin south of Lewis Creek and at the top of the dome on the south side of Walker Mountain. The dome made a topographic high that was not covered by upper soft tuff (Tt_4). The spectacular flow bands, blocky plagioclase phenocrysts with thin (~1 mm) resorbed rims, and the presence of common rounded inclusions of porphyritic microdiorite up to 25 cm in diameter are characteristic. Greater abundance of hornblende and biotite relative to pyroxene and more abundant inclusions distinguish this dome from the slightly older dome adjacent to it north of Toe Jam Creek. Phenocrysts (20–25%): plagioclase (10–15%, 2–6 and up to 10 mm), hornblende (2–5%, 1 up to 5 mm), biotite (1–2%, 3 mm), clinopyroxene (1–2%, 1.5 mm), orthopyroxene (1%, 1.5 mm), and opaques (<1%, 0.1–0.5 mm). Inclusions contain ~10% phenocrysts of plagioclase and orthopyroxene in a finely crystalline, interlocking groundmass of plagioclase, hornblende, orthopyroxene, and opaques.

Tld_1 **Lower Lewis Creek dome** An andesitic lava dome crops out along and north of Toe Jam Creek and is at least 3 km in diameter and 240 m thick. Tld_1 is similar to Tld_2 in containing rimmed plagioclase phenocrysts and microdioritic inclusions, but inclusions are less abundant and flow bands are less continuous. Vitrophyric carapace breccia is preserved along the southern margin where it is overlain by the dacite dome. Thin sections of the vitrophyre show swirled bands of more porphyritic (andesite?) and less porphyritic (dacite?) glass, suggesting mixing between the two dome magma types. Phenocrysts (25–30%): plagioclase (15–20%, 1–5 mm), clinopyroxene (3–4%, 1.5 mm), orthopyroxene (1–2%, 1.5 mm), hornblende (1%, 1 mm), biotite (1%, 2 mm), and opaques (<1%, 0.2 mm).

Tldi **Andesite intrusion** Two small stocks and a north-striking dike that extends from the eastern stock cut lavas of the Pleasant Valley complex and older tuffs in Nelson Creek. The intrusions share petrographic characteristics of both Lewis Creek domes, with prominent biotite and rounded microdiorite inclusions but more abundant pyroxene relative to hornblende and biotite, and may have been feeders for other domes or flows. Commonly glassy margins have vertical flow bands that parallel contacts and subhorizontal columnar joints, which suggest near vertical walls. Tuffs adjacent to the intrusions are locally indurated and even welded. Phenocrysts (25–30%): plagioclase (15–20%, 1–5 mm), clinopyroxene (4–6%, 1–2 and up to 4 mm), orthopyroxene (2%, 2 mm), biotite (1–2%, 0.5–3 mm), hornblende (1%, 1 mm), and opaques (1%, 0.1–0.3 mm).

Tprd **Red dacite** Pale-pinkish-red dacite lava. Unit crops out in a small area in the southeastern part of the quadrangle. The unit, which is approximately 10 to 30 m thick, forms poor outcrops and typically occurs as litter on slopes underlain by this unit. Characterized by streaky flow laminae and lithophysae. Phenocrysts (8%): plagioclase (6–7%, 3 mm) and biotite (0.5–1.0%, 2 mm, typically oxidized).

Tps **Volcaniclastic sedimentary rocks and tuff** Poorly indurated, tuffaceous rocks crop out in two small areas as discontinuous lenses interbedded with Pleasant Valley lavas in and north of Nelson Creek. They consist of poorly bedded tuffaceous sedimentary rock and massive, nonwelded, pumice-lithic ash-flow tuff, both similar to soft tuffs that underlie the Pleasant Valley sequence to west. These rocks appear to have been deposited around and between lavas and are generally less than about 10 m thick.

Tpbd **Biotite dacite dome** A biotite dacite lava dome crops out between Nelson Creek and Lewis Creek at the eastern edge of the quadrangle and is more extensive to the east in the Mount Blitzen Quadrangle. The dome varies from glassy to perlitic to devitrified and oxidized. Devitrified parts have a rough hackly texture. The dome had at least 170 m of primary relief, and later flows abutted its flanks at low elevation. Probably a source for surrounding biotite-bearing andesite-dacite lava (Tpb). Phenocrysts (25–30%): plagioclase (20–23%, 5 mm), hornblende (3%, 4 mm), biotite (2%, 2 mm), clinopyroxene (1.5%, 1.5 mm), and orthopyroxene (1.5%, 1.5 mm). Age: 39.3±0.2 Ma, hornblende, DB-31, Mount Blitzen Quadrangle (Henry and Boden, 1998).

Twa **Western andesite** Andesitic to dacitic(?) lava flows, probably contemporaneous with, and distal parts of, lavas of the Pleasant Valley complex. Several black, massive to columnar-jointed flows, locally with basal breccia. Individual flows are 20 to 40 m thick and total as much as 200 m. Different flows are variably finely to coarsely porphyritic and pyroxene- or hornblende+biotite-rich. Mostly glassy to finely crystalline matrix. Phenocrysts (15–25%); plagioclase (10–15%, <1–6mm), hornblende (1–3%, <1–2 mm), biotite (0–2%, to 2mm), clinopyroxene (1–5%, <0.5–2 mm), orthopyroxene (<1–4%, <0.5–2 mm), and opaques (<1%, 0.1–0.3 mm).

Early Tuffs

The early tuffs are a thick (as much as 400 m) sequence of ash-flow tuff, air-fall tuff, and tuffaceous sedimentary rocks that crop out in the southern and western parts of the quadrangle. Several relatively resistant, densely to poorly welded ash-flow tuffs separate less resistant tuffaceous sedimentary rocks and nonwelded ash-flow tuff. From oldest to youngest, the mapped tuffs are the tuff of Nelson Creek (Tnt), the tuff of Toe Jam Creek (Tjt), the marker tuff (Tlt_{2m}), and the dacite ash-flow tuff (Ttd). All are outflow tuffs, erupted from unknown sources that are probably mostly outside this quadrangle. The tuff of Nelson Creek, which is a major unit that crops out from west of Willow Creek Reservoir (Wallace, in preparation) eastward into the southern Independence Mountains, may have been an early eruption from the Big Cottonwood caldera, and the dacite ash-flow tuff probably was an early, pyroclastic eruption of the Pleasant Valley volcanic complex. Distribution and thickness of the tuff of Toe Jam Creek suggests it erupted from a source northwest of the quadrangle. The marker tuff may be locally derived.

Ttd **Dacite ash-flow tuff** Densely welded, black, glassy to devitrified, dacite ash-flow tuff that grades upward to white, moderately welded tuff. Distinctly streaky appearance from faint, glassy lenses of densely welded pumice or magma lumps. Contains sparse fragments of andesite and Paleozoic(?) sandstone to 5 mm. Crops out only in a small area between Lewis and Nelson Creeks but probably correlative with similar tuff in Sugarloaf Butte Quadrangle to southeast. Phenocrysts (30–35%): plagioclase (25–30%, 1–2 mm), sanidine (trace, 1 mm), biotite (1–2%, 1 mm), hornblende (2%, 1, but up to 3 mm), clinopyroxene (1%, 1 mm), altered pyroxene? (2%, 1 mm), and opaques (0.5%, 0.2 mm). Pumice fragments contain 15–20% of the same phenocryst assemblage. Age: 39.84±0.10 Ma, sanidine, H96-32, Sugarloaf Butte Quadrangle.

Ttu **Tuff undivided** Combined lower and middle soft tuffs (Tt_1 and Tt_2) where tuff of Toe Jam Creek (Tjt) is absent.

Tt_2 **Middle soft tuff** Poorly indurated, white to light-gray, massive to poorly to well-bedded, glassy, pumiceous, lithic tuff makes up the stratigraphic interval above tuff of Toe Jam Creek (Tjt) and below rocks of Pleasant Valley complex, western dacite (Twd), or dacite ash-flow tuff (Ttd). Includes nonwelded ash-flow tuff, air-fall tuff, and tuffaceous sedimentary rock. Sparsely to moderately porphyritic: generally contains phenocrysts of plagioclase (5–15%, 1–4 mm), biotite (1–3%, 1–2 mm), and, locally, minor quartz ± sanidine. Contains as much as 30% pumice up to 10 cm, 5% black glass lumps up to 2 cm, and, locally, petrified wood. Fragments of volcanic rocks are mostly 5 cm in diameter but range up to 20 cm and can comprise as much as 15%. A few lenses of normally graded, coarse sandstone and pebble con-glomerate. As much as 200 m thick.

Tlt_{2m} **Marker tuff** [Marker bed within Tt_2] Thin (1–2 m thick), black, glassy, densely to moderately welded, dacitic ash-flow tuff composed mostly of coarse (1 mm) glass shards. Contains as much as 10% flattened pumice to 2 cm and sparse igneous rock fragments. Moderately resistant unit makes an excellent marker bed in otherwise monotonous soft tuffs. Phenocrysts (10%): plagioclase (8%, 1–5 mm), clinopyroxene (1%, 1 mm), orthopyroxene (1%, 1 mm), hornblende (<1%, 1 mm), biotite (trace, 0.5 mm), and opaques (trace, 0.1–0.3 mm). Age: 39.75±0.49 Ma, plagioclase, H97-51.

Tjt **Tuff of Toe Jam Creek** Sparsely porphyritic, rhyolitic ash-flow tuff as much as 70 m thick makes a resistant marker through the southern and western part of the quadrangle but pinches out approx-imately 2 km north of the southern edge. Typically weathers brick red. Grades from poorly or nonwelded, glassy base, to densely welded, devitrified, red, locally silicified interior, to poorly welded, white to tan, pumiceous top. Contains as much as 15% pumice to 3 cm and sparse to 10% frag-ments of porphyritic andesite and dacite to 1 cm. Phenocrysts (10%); plagioclase (8%, 1–2 mm), biotite (1–2%, 2 mm), and opaques (<1%, 0.1–0.4 mm). Reverse polarity.

Tt_1 **Lower soft tuff** Poorly indurated, massive to poorly bedded, pumice-lithic tuff that makes up the stratigraphic interval above tuff of Nelson Creek (Tnt) and below tuff of Toe Jam Creek (Tjt). Includes non- to poorly welded, pumiceous ash-flow tuff, air-fall tuff, and tuffaceous sedimentary rock. Ash-flow tuffs are 5 to 10 m thick and aphyric to sparsely porphyritic (10% plagioclase to 4 mm and 1% biotite to 2 mm). About 160 m thick.

Tnt **Tuff of Nelson Creek** Crystal-rich, densely to poorly welded, pumiceous, rhyolitic ash-flow tuff. Crops out as a mostly welded and moderately resistant lens overlying Paleozoic rocks in the south-central part of the quadrangle and as a poorly to moderately welded, locally silicified layer interbedded with the upper and lower southwestern dacites (Ted_2 and Ted_1) in the southwestern part. Spherulitically devitrified, flattened to nonwelded pumice up to 3 cm long makes up 10–20%. Contains sparse fragments of porphyritic andesite, tuffaceous sandstone, and felsic igneous rock to 10 cm. Phenocrysts (25–35%): plagioclase (16–25%, 3 mm), quartz (2–3%, 1–2 mm), sanidine (1–2%, 2.5 mm), biotite (3–4%, 2 mm), hornblende (2–3%, to 4 mm), and opaques (trace, 0.2 mm). Age: 39.88±0.11 Ma, sanidine, H97-71; 39.97±0.11 Ma, sanidine, H97-110.

Andesite lavas in the southwestern corner of quadrangle

Tea_2 **Upper southwestern andesite** Andesitic lava and breccia that overlies irregular (eroded?) surface on Tnt. Variably massive to vesicular and finely crystalline to glassy matrix. Characterized by scattered, large (3–8 mm), blocky plagioclase phenocrysts, which are accompanied by finer grains down to 0.5 mm. Phenocrysts (10–15%): plagioclase (7–10%, 0.5–8mm), clinopyroxene (2%, <0.5–3 mm), orthopyroxene (1%, <0.5–2 mm), hornblende (1–2%, 0.2–1 mm), biotite (1%, to 2mm), and opaques (<1%, 0.1–0.3 mm). Possibly as much as 100 m thick with eroded top.

Tea_1 **Lower southwestern andesite** Andesitic lava and breccia. More finely and abundantly porphyritic than Ted_2. At least 100 m thick but base not exposed. Phenocrysts (20–25%): plagioclase (20%, to 3mm), hornblende (5%, 2mm), clinopyroxene (3%, 2 mm), orthopyroxene (1%, 2 mm), biotite (<1%, 0.2–2mm), and opaques (<1%, 0.1–0.2 mm).

PALEOZOIC ROCKS

Highly deformed Paleozoic rocks crop out in two settings partly bounded by Tertiary normal faults. (1) An ~1-km-wide belt along the eastern edge of the quadrangle. Rocks there continue extensively into the Mount Blitzen Quadrangle to the east but are cut off by a major normal fault on the west. (2) Two small areas underlying Eocene rocks at the southern edge of the quadrangle.

Based on geologic mapping in the Mount Blitzen Quadrangle (Henry and Boden, 1998), the first area is part of a northern package that contains pods of probably Ordovician quartzite (Ꝑxq) and chert in a matrix composed mostly of siltstone, argillite, and chert (Ꝑxu). The second area is part of a Devonian–Silurian±Ordovician package that consists of chert and siltstone (Ꝑzc) and sandstone (Ꝑsss) but lacks quartzite. The Paleozoic rocks appear to be very thick, but, because these rocks are highly, possibly isoclinally, folded and probably thrust faulted, no accurate estimate of thickness is possible.

The rocks are strongly deformed. Along the eastern edge of the quadrangle and extensively in the Mount Blitzen Quadrangle, beds strike east to northeast and mostly dip moderately to the northwest. Near the Falcon Mine fault, beds have a more northerly strike and westerly dip, probably as a result of drag along the fault. Beds at the southern edge of the quadrangle strike to the east and dip moderately to the north. Subtracting ~30° east tilt resulting from Cenozoic extension restores these to a east-northeast strike and northwest dip. Orientations of small-scale folds and thrust faults in the Mount Blitzen Quadrangle indicate contraction with transport toward the southeast. Henry and Boden (1998) interpreted a major east-northeast-striking, northwest-dipping thrust fault that places the Ordovician quartzite-bearing package over the Devonian–Silurian±Ordovician package. Polished surfaces and slickenlines on quartzite pods in the Toe Jam Mountain Quadrangle are consistent with these interpretations.

Ꝑxu **Undivided siltstone, argillite, and chert** Heterogeneous, generally recessive mix of siltstone, argillite, chert, and minor sandstone. Siltstone is finely laminated, tan to black (carbonaceous?), rarely micaceous, and locally in graded beds with fine sandstone. Argillite is black to dark brown, faintly thick to laminar bedded, and highly indurated. Chert is thick-bedded (10 to 30 cm), commonly nodular, black to reddish brown, variably re-crystallized, and in sets up to about 5 m thick. Some chert forms boudins within highly deformed siltstone-argillite.

Ꝑxq **Quartzite** Massive, resistant, light-tan to medium-gray orthoquartzite makes numerous pods and lenses within undivided siltstone, argillite, and chert (Ꝑxu). Quartzite appears to be composed almost exclusively of well-sorted and well-rounded, 0.25 to 0.5 mm, commonly strained quartz grains that are strongly silica cemented. Quartzite bodies are mostly a few meters to about 300 m long and 1 to 50 m thick; they generally parallel regional and local strike of the host siltstone or argillite. Many bodies are boudins within variably sheared siltstone-argillite matrix and have faulted, commonly slick-enlined surfaces. The discontinuous nature of the beds may reflect both depositional pinch out and tectonic disruption.

Ꝑzc **Chert-siltstone assemblage** Mix of bedded chert and finely laminated siltstone. Chert is thick (10–30 cm) to thin-bedded, commonly nodular, black to reddish-brown to pale-greenish-gray, "glassy" to variably recrystallized, and in sets up to about 5 m thick. Individual chert beds are separated by thin (1 cm) siltstone layers, which were squeezed out during folding in many areas. Intervening siltstone layers are tan to black and locally in graded beds with fine sandstone.

Ꝑsss **Sandstone** Massive, light-colored, silica-cemented, fine to medium sandstone makes a distinct lens within the chert-siltstone assemblage (Ꝑzc). Sandstone "outcrop" consists of abundant fragments in soil.

See accompanying text for references and a discussion of the geology of the Toe Jam Mountain Quadrangle.

Field work done in 1996 and 1997.

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