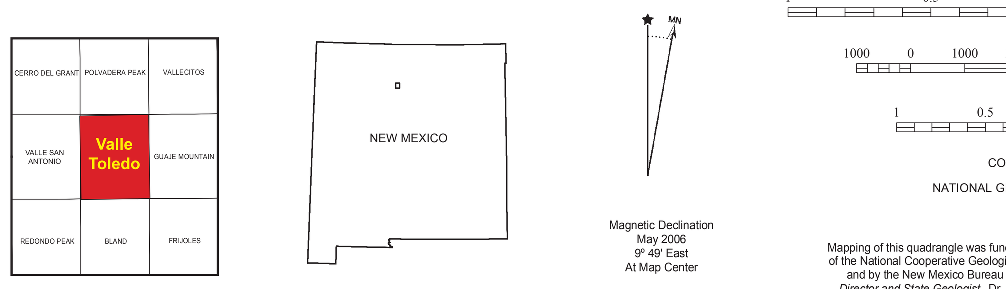
NMBGMR Open-file Geologic Map 133
Last Modified December 2012

Base from U.S. Geological Survey 1964, from photographs taken 1976 and field checked in 1976. Map edited in 1984. Base projected from NAD83 to NAD27. 1927 North American datum, UTM projection -- zone 13. 1000- meter Universal Transverse Mercator grid, zone 13, shown in blue tick



QUADRANGLE LOCATION

Magnetic Declination
May 2006
9º 49' East
At Map Center

1:24,000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the National Cooperative Geologic Mapping Act, administered by the U. S. Geological Survey, and by the New Mexico Bureau of Geology and Mineral Resources, (Dr. Peter A. Scholle, *Director and State Geologist*, Dr. J. Michael Timmons, *Geologic Mapping Program Manager*).

EXPLANATION OF MAP SYMBOLS

- Location of geologic cross section.
- Geologic contact. Solid where exposed or known, dashed where approximately known.
- Exposed gradational geologic contact.
- Normal fault - solid where exposed or known; dashed where approximately located; dotted where concealed; queried where uncertain. Bar and ball on downthrown side, tic showing dip.
- Lacustrine beach ridge.
- Strike and dip of inclined bedding.
- Strike and dip of inclined joints or fractures.
- Strike of vertical volcanic foliation.
- Strike and dip of volcanic foliation.
- Volcanic vent. Queried where uncertain.
- Direction of flow of landslide failure.
- Location of radiometric-dated sample (age in Ma).
- Cold spring.

New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map 133

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http://geoinfo.nmt.edu

Geologic map of the Valle Toledo quadrangle, Sandoval and Los Alamos Counties, New Mexico.

May 2006

by
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DESCRIPTION OF MAP UNITS

Note: Descriptions of map units are listed in approximate order of increasing age. Formal stratigraphic names are described in Griggs (1964) and Bailey, *et al.* (1969) with usage revised in Gardner *et al.* (1986), Goff *et al.* (1990), Goff and Gardner (2004), and Gardner *et al.* (2010). Field names of volcanic rocks are based on hand specimens and petrography, and may differ from names based on chemical classifications (Wolff, *et al.*, 2005). Significant changes in regional stratigraphy and nomenclature have occurred in this area since this map was first compiled and are described in the ***Geologic Map of the Valles caldera, Jemez Mountains, New Mexico*** (Goff *et al.*, 2011).

Quaternary Deposits

Qal — **Alluvium —** Deposits of gravel, sand and silt in canyon bottoms; locally includes stream terraces and canyon wall colluvium; mostly Holocene in age; maximum thickness exceeds 15 m.

Qc — **Colluvium —** Poorly sorted slope wash and talus deposits from local sources; mapped only where extensive or where covering critical relations; unit is commonly gradational into *Qafo*; mostly Holocene and Pleistocene in age; thickness can locally exceed 15 m.

Qaf — **Alluvial fans —** Fan-shaped deposits of coarse to fine gravel, sand, silt, and clay along tributary drainages, at the mouths of valleys and in the Valle Grande; maximum exposed thickness about 15 m.

Qt — **Younger stream terraces —** Deposits of sand, gravel, and silt that underlie young terraces bordering present streams; inferred to be largely Holocene or late Pleistocene in age; maximum thickness uncertain.

Qls — **Landslides** — Unsorted debris, slumps, or block slides partially to completely intact, that have moved down slope; slumps and block slides usually display some rotation relative to their failure plane; thickness varies considerably depending on the size and nature of the landslide.

Qlec, Qlb — **El Cajete lake deposits —** Deposits of reworked El Cajete pumice and coarse sand in Valle Grande; *Qlec* occurs below the upper level of a lake formed when deposits of the El Cajete pumice dammed the East Fork Jemez River (Reneau, *et al.*, 2004; 2007); may include some primary El Cajete fall deposits that were buried by the lake; *Qlb* designates constructional landforms along and near the margin of the lake, including beach ridges and spits; age about 50 to 60 ka; maximum thickness about 4 m.

Qrx — **Boulder fields** — Areas covered with dark grey to dark brown, large (up to 3 m) boulders derived from subjacent rock units; generally devoid of vegetation; many appear to be rock glaciers, exhibiting flowage features such as arcuate pressure ridges (Blagbrough, 1994); thickness unknown.

Qto — **Older stream terraces** — Deposits of gravel, sand, silt, and clay below higher stream terraces along the margins of present streams and basins; overlies *Qdf*, *Ql*, Valles Rhyolite and Cerro Toledo Formation; underlies *Qlec* in Valle Grande; maximum thickness at least 5 m.

Qlso — **Older landslides —** Older slide deposits that are overlain by older terrace gravels (*Qto*); maximum exposed thickness about 25 m.

Qafo — **Older alluvial fans —** Older deposits of coarse to fine gravel and sand derived mostly from the volcanic domes, resurgent dome, and caldera walls; in Valle Grande these fans represent alluvial systems established earlier than the El Cajete pumice and associated lacustrine deposits (*Qlec, Qlb*); in Valle Toledo these fans overlie and interfinger with *Qto* and overlie *Qlso*; portions of fans are still active; contact with *Qc*, particularly around flanks of volcanic domes, is gradational; thickness is unknown.

Ql — **Lacustrine deposits of Valle Toledo and upper Valle Grande** — Finely laminated to thickly bedded deposits of clay, silt, and very fine sand, derived by erosion of surrounding rock units, and deposited in lakes; locally includes coarser sand and gravel near shoreline; deposits commonly tuffaceous, and diatomaceous facies occur; overlies older alluvial fans (*Qafo*) and older landslides (*Qlso*); underlies older terrace gravels (*Qto*); maximum exposed thickness about 6 m.

Qmso — **Older sedimentary deposits of northern caldera** — Debris flow, landslide, and minor fluvial deposits that resemble early caldera fill sediments (*Qdf*, described below) but which also contain fragments of lava and pumice from Cerro del Medio rhyolites; age about 1.2 to 0.9 Ma; maximum exposed thickness about 25 m.

Qalo — **Older alluvium** — Gravel, sand, and silt generally overlying the Tshirege Member, Bandelier Tuff on the rim and flanks of Valles caldera; largely pre-date incision of canyons in surrounding plateaus and highlands; gravels consist primarily of volcanic fragments from sources near the deposits and possibly from within the caldera; 20-m-thick lobe of Qalo overlying Tgbhd and Qcnr consists primarily of white to pale gray debris flows containing mostly fragments of rhyodacite and rhyolite in a poorly exposed sandy matrix. Roughly contemporaneous in age to north caldera sediments (Qmso) and early caldera debris flows (Qdf).; maximum exposed thickness about 15 m.

Tewa Group (Pleistocene)
Valles Caldera

Qvsr2, Qvsr1, Qvsrt — **Cerro Santa Rosa Member (Valles Rhyolite)** — (***Note on terminology***: this entire dome complex was originally referred to as Cerro Santa Rosa [for example, Doell, *et al.*, 1968; Smith, *et al.*, 1970] and this terminology remains entrenched in the literature [for example, Spell and Harrison, 1993; Singer and Brown, 2002]. We retain this usage, but, unfortunately, recently revised topographic maps restrict the name Cerro Santa Rosa to what we map as $Qvsr_2$, and label the entire chain of domes including the Santa Rosa complex and Trasquilar dome [*Qctq*] "Cerros de Trasquilar.") Two domes and flows of petrographically and chemically similar, but temporally and magnetically dissimilar, rhyolite. $Qvsr_2$: Dome of white, porphyritic rhyolite with 15 to 20 % phenocrysts (up to 4 mm) of abundant pink quartz, subordinate sanidine, and trace biotite euhedra; groundmass glassy and pumiceous; outcrops massive to flow banded; dated by $^{40}Ar/^{39}Ar$ at 0.787 ± 0.015 Ma (one sigma error, Spell and Harrison, 1993); maximum thickness about 150 m. $Qvsr_1$: White to grey dome and flows of porphyritic rhyolite with 10 to 15 % fine (1 to 2 mm) to coarse (4mm) phenocrysts of abundant quartz, subordinate sanidine, and sparse, small biotite; groundmass glassy and pumiceous; dome exhibits a breccia apron around summit; west flank of unit, on the Valle San Antonio quadrangle, includes petrographically similar flows, with chatoyant sanidine, that may be of different age; dated by $^{40}Ar/^{39}Ar$ at 0.914 ± 0.004 Ma (one sigma error, Spell and Harrison, 1993) and 0.936 ± 0.008 Ma (two sigma error, Singer and Brown, 2002); maximum thickness over 240 m on the Valle San Antonio quadrangle. *Qvsrt*: Poorly exposed deposit of gray lithic-rich pumice forming rounded hill east of $Qvsr_1$; may be equivalent in age to Santa Rosa ignimbrite exposed to west of dome (0.91 Ma; Goff *et al*., 2006; 2011); maximum thickness about 75 m.

Qvda4, Qvda3, Qvda2, Qvda1 — **Cerro del Abrigo Member (Valles Rhyolite)** — Complex of four dome and flow sequences of finely porphyritic rhyolite with subtle petrographic variations. Spell and Harrison (1993) give a composite $^{40}Ar/^{39}Ar$ date of 0.973 ± 0.010 Ma for the entire complex. $Qvda_4$: white to grey devitrified rhyolite with 10% felsic phenocrysts (about 1 mm) of dominantly sanidine with subordinate amounts of quartz and plagioclase; quartz occurs as both euhedral and embayed forms; trace biotite and hornblende and sparse glomerocrysts of felsic phases, biotite, and magnetite; maximum exposed thickness about 255 m. $Qvda_3$: white to grey devitrified rhyolite with 15% relatively large (2-4 mm) phenocrysts of dominantly sanidine and lesser amounts of plagioclase; pale pink quartz is sparse, large (3-4 mm), and embayed; sparse 2 mm biotite and extremely rare hornblende; sparse opaque phases; maximum exposed thickness about 245 m. $Qvda_2$: white perlitic rhyolite with 10% felsic phenocrysts (1-2 mm) of dominantly sanidine with subordinate plagioclase; biotite and embayed, pale pink quartz are sparse and relatively large (about 1 mm); sparse opaques; trace tiny (0.1 mm) hornblende; maximum exposed thickness about 405 m. $Qvda_1$: apron of white perlitic rhyolite exposed on erosional platforms on south side of dome complex; porphyritic with 20% felsic phenocrysts (2 mm) of dominantly sanidine and subordinate plagioclase and embayed, pale pink quartz; sparse partial bipyrimidal forms of quartz; biotite up to 1%; trace hornblende; glomerocrysts of sanidine ± plagioclase ± biotite ± quartz; maximum exposed thickness about 65 m.

Qvdmt, Qvdmn, Qvdmw, Qvdms, Qvdm6, Qvdm5, Qvdm4 — **Cerro del Medio Member (Valles Rhyolite)** — Dome and flow complex of at least six distinctive phases of rhyolitic activity; includes pyroclastic fall deposits (*Qvdmt*) on north flank of Cerro del Medio and pyroclastic flows on the Valle San Antonio quadrangle. Stratigraphic relations and dates among the three oldest flow lobes do not permit discrimination of their sequence; thus, they are designated north, west, and south (*Qvdmn*, *Qvdmw*, and *Qvdms*, respectively). The sequence of eruption of the three youngest phases is clear from field relations, and, thus these units are designated from oldest to youngest $Qvdm_4$, $Qvdm_5$, and $Qvdm_6$. Spell and Harrison (1993) gave a composite $^{40}Ar/^{39}Ar$ date of 1.133 ± 0.011 Ma (one sigma error) for the entire Cerro del Medio complex. However, detailed work by Phillips (2004, unpub.) has yielded very high precision dates on *Qvdms* and $Qvdm_4$, that indicate the Cerro del Medio eruptions up through $Qvdm_4$, spanned at least 40,000 to 80,000 years, and that more dating of the complex could be fruitful. *Qvdmt*: white to grey, crudely bedded pumice fall deposit with cognate pyroclasts up to 20 cm; unit commonly has strong pedogenic overprint and is extensively colluviated; pumice pyroclasts are sparsely phyric with sanidine laths and glomerocrysts of sanidine plus opaques; sanidines are weakly zoned and inclusion-free; unit is likely associated with eruption of $Qvdm_6$, based on petrographic similarities; thickness uncertain due to blanketing nature of deposit, but is at least 4 meters maximum thickness. $Qvdm_6$: massive, devitrified, grey, pumiceous rhyolite flow with about 5% small (<2mm) phenocrysts of sanidine laths and glomerocrysts of sanidine plus opaques; sanidines are weakly zoned and largely inclusion-free; vent and associated breccia are near the topographically highest point on Cerro del Medio; maximum exposed thickness about 45 m. $Qvdm_5$: upheaved dome of vitrophyric to devitrified rhyolite; locally flowbanded; sparsely phyric with 1-3% sanidine phenocrysts in blocky and lath-shaped forms; phenocrysts are moderately zoned and some exhibit cores and zones riddled with inclusions (mostly glass); sparse opaque phases; extremely rare clinopyroxene and zircon; margins of unit near contacts with older units, where well-exposed, are vertically foliated breccia with elongate clasts, oriented parallel to the contact, set in a very fine grained matrix; maximum exposed thickness about 215 m. $Qvdm_4$: massive, brown to black, aphyric obsidian flow; flowbanded and devitrified around unit margins; obsidian from this unit is so clean and free of inclusions and crystals that it was a highly desired material for tool and point making for ancient peoples; ancient quarry sites are common within the unit and lithic scatters include exotic rocks, such as rounded quartzite cobbles from axial river deposits near the Rio Grande, that were used as hammerstones; ancient peoples quarried the obsidian from this unit for so many millennia that there are very few true outcrops left; maximum exposed thickness about 260 m. Phillips (unpub.) has $^{40}Ar/^{39}Ar$ data that suggest 1.169 ± 0.005 Ma (two sigma error) is a good age estimate for $Qvdm_4$, consistent with a previous $^{40}Ar/^{39}Ar$ date of 1.161 ± 0.010 Ma on this unit (Izett and Obradovich, 1994). *Qvdmn*: grey to light brown, pumiceous, flowbanded, glassy to devitrified rhyolite; sparsely phyric with about 5% phenocrysts of sanidine and glomerocrysts of sanidine plus opaques; some sanidine phenocrysts are strongly zoned; rare clinopyroxene; maximum exposed thickness about 30 m. *Qvdmw*: light brown to black, obsidian flow; locally devitrified and flowbanded; nearly apyric with <1% small (<0.3 mm) sanidine and very sparse magnetite; maximum exposed thickness about 120 m. Izett and Obradovich (1994) dated this unit at 1.207 ± 0.017 Ma. *Qvdms*: grey to light brown, flowbanded, sparsely porphyritic, devitrified rhyolite; approximately 5% phenocrysts of sanidine and glomerocrysts of sanidine; sparse hornblende and embayed quartz; rare plagioclase; maximum exposed thickness about 75 m. Phillips (2004) dated *Qvdms* by $^{40}Ar/^{39}Ar$ at 1.229 ± 0.017 Ma.

Valles Caldera Resurgent Dome

Qdf — **Early caldera fill; alluvial, debris flow, landslide, and colluvial deposits** — Dark gray to buff, matrix-supported beds containing fine silt to boulders of various early post-caldera rhyolites, Bandelier Tuff, precaldera volcanic rocks, Miocene to Permian sandstone, Pennsylvanian limestone and Precambrian crystalline rocks; unit contains fluvial sand and gravel deposits; cobbles of older lithologies are more abundant in the lower beds; upper beds generally contain more precaldera volcanic rocks; rare beds contain mostly Bandelier Tuff; formed during rapid slumping and erosion of caldera walls, erosion of exposed megabreccia blocks (e.g., *Qxbo*), and erosion of previously formed beds during uplift of the resurgent dome; finer-grained matrix is generally not exposed; weathering produces a lag of boulders on landscape; lower part of unit displays extensive, low-grade hydrothermal alteration; fault relations in this unit are often difficult to determine; interbedded with and overlies all other units on resurgent dome; maximum exposed thickness in map area is 50 m.

Qdc — **Deer Canyon Member, lava unit (Valles Rhyolite)** — Massive, gray to pale pink, aphyric rhyolite lavas usually containing tiny phenocrysts of sanidine and quartz (Bailey, *et al.*, 1969); some sanidine is chatoyant; groundmass is generally silicified; flow breccias are often opalized and iron-stained; most exposures are highly deformed by uplift and faulting on the resurgent dome of Valles caldera; many exposures show extensive zeolitic alteration; overlies Deer Canyon tuffs (*Qdct*); interbedded with *Qdf* and generally overlies *Qvs*; overlies Bandelier Tuff; ages of three flows range from 1.28 to 1.25 Ma (Phillips *et al.*, 2007); maximum exposed thickness about 40 m.

Qdct — **Deer Canyon Member, tuff unit (Valles Rhyolite)** — White to cream to pale buff lithic-rich rhyolitic tuffs; pumice fragments usually contain phenocrysts of quartz and sanidine; lithic fragments generally consist of Bandelier Tuff and precaldera volcanics; tuff beds usually deformed by faulting; beds often extensively altered to zeolites, silica, Fe-oxides, and clay (Chipera *et al.*, 2007); beds occasionally graded; beds occasionally contain accretionary lapilli and hydromagmatic surge; interbedded with *Qdc*, *Qdf*, and *Qvs*; overlies *Qbt*; ages of five tuffs range from 1.27 to 1.23 Ma (Phillips *et al.*, 2007); maximum exposed thickness about 30 m.

Qvs — **Early caldera fill lacustrine and fluvial deposits (shown on cross-sections only)** — White to buff, laminated to thinly bedded, diatomaceous mudstone and siltstone, and generally white to gray to tan cross bedded to normally graded sandstone and conglomerate; sandstone and conglomerate beds contain mostly fragments of rhyolite pumice, tuff and lava but also contain some grains of precaldera volcanics, Miocene to Permian sandstone, and Precambrian crystalline fragments; some beds contain ripple marks, flute casts and plane laminations and could be deltaic deposits near margins of initial caldera lakes; beds generally display zeolitic or less commonly acid sulfate alteration; beds generally deformed by uplift of resurgent dome; usually underlies *Qdc* and *Qdct*; interbedded with *Qdf*; overlies *Qbt*; maximum exposed thickness about 20 m on the Redondo Peak quadrangle.

Qxbo — **Caldera collapse breccia** — Caldera-wall landslide breccias (megabreccias) that accumulate synchronously during caldera formation (Lipman, 1976); incorporated in and interbedded with intracaldera Tshirege Member of the Bandelier Tuff; individual blocks mapped if more than 30 m across; within Valle Toledo quadrangle, this unit consists primarily of silicified and brecciated, brownish-red, Otowi Member of the Bandelier Tuff (*Qxbo*) with phenocrysts of quartz and sanidine; the origin of the brecciated texture is not obvious; other blocks of megabreccia may occur within the map area but are difficult to distinguish from *Qdf* because of poor exposures; generally show baking and odd disaggregation textures around margins if contacts with enclosing *Qbt* are preserved; maximum exposed thickness is highly variable; not shown in cross sections for clarity.

Qbt — **BandelierTuff, Tshirege Member** — Multiple flows of white to orange to dark gray densely welded to non-welded rhyolitic ash-flow tuff (ignimbrite); pumice and matrix contain abundant phenocrysts of sanidine and quartz, sparse microphenocrysts of clinopyroxene and orthopyroxene and extremely rare microphenocrysts of fayalite (Warshaw and Smith, 1988; Warren, *et al*., 1997); in more welded portions, sanidine typically displays blue iridescence. Upper flow units generally more welded than lower ones. Intracaldera flow units are highly welded with well-developed fiamme and rare vitrophyre. Locally contains a thin (<2 m) laminated, pumice fall and surge deposit at base of unit (Tsankawi Pumice) that contains roughly 1% of hornblende dacite pumice (Bailey, *et al*., 1969). Locally contains accidental lithic fragments of older country rock entrained during venting and pyroclastic flow. *Qbt* is major unit of the Valles caldera resurgent dome; forms inconspicuous canyon-filling outliers on pre-existing volcanic topography south and east of the caldera and in the Toledo embayment; erupted during formation of the Valles caldera. Most recent $^{40}Ar/^{39}Ar$ age is 1.25 ± 0.01 Ma (Phillips, 2004; Phillips *et al*., 2007); maximum observed thickness within caldera over 900 m.

Cerro Toledo Formation (Pleistocene)

Qcpc — **Gravel and sandstone (Pueblo Canyon Member)** — Thin deposit of primarily Tschicoma Formation-derived gravels in lower northeast wall of Valles caldera (Goff *et al.*, 2011); sandy matrix very poorly exposed; underlies *Qbt*; overlies rhyodacite of *Ttrc*; maximum exposed thickness about 15 m.

Toledo Embayment

Qcrt — **Rhyolite tuff (Valle Toledo Member)** — Two areas of white to gray to black, partially to densely welded, nearly aphyric, rhyolitic tuff; many fragments are vesicular and show flow banding and spherulitic texture; other fragments resemble welded fiamme in pyroclastic flows; microphenocrysts consist of sparse quartz, sanidine, biotite and rare clinopyroxene; tuffs apparently fill the vents for the pyroclastic eruptions; east exposure contains core of aphyric rhyolite lava (*Qcr*); intrudes *Qcr* and *Ttcd*; overlain by *Qbt*; K-Ar age of west exposure (Pinnacle Peak) is 1.20 ± 0.02 Ma (Stix, *et al*., 1988); maximum exposed thickness is roughly 200 m.

Qcr — **Aphyric rhyolite (Valle Toledo Member)** — Two dome and flow complexes and two small intrusive bodies of white to gray to black, flow-banded rhyolite; obsidian phases are completely aphyric; devitrified phases contain spherulites and very sparse microphenocrysts of quartz, sanidine, and biotite; locally displays bread crust textures; flow bands are locally oxidized to reddish color; intrudes *Ttcr* and *Qcrt*; overlain by *Qbt*; K-Ar age of dome west of dacite north of Cerro Rubio (*Ttcd*) is 1.33 ± 0.02 Ma (Stix, *et al*., 1988); maximum exposed thickness is 365 m.

Qcs — **Sierra de Toledo rhyolite (Valle Toledo Member)** — White to gray, flow-banded, sparsely porphyritic rhyolite with roughly 5% phenocrysts of quartz, sanidine, biotite, and tiny magnetite; sanidine is often chatoyant blue; most samples are devitrified, platy and spherulitic; commonly exhibits bread crust textures; apparently overlies *Qcr*; overlies *Qcwp*; overlain by *Qbt*; possibly originates from two vents; $^{40}Ar/^{39}Ar$ ages of two samples range from 1.34 to 1.38 Ma (Spell, *et al*., 1996); maximum exposed thickness is 365 m.

Qctr — **Turkey Ridge rhyolite (Valle Toledo Member)** — White to gray, flow-banded, porphyritic rhyolite with roughly 7% phenocrysts of quartz, sanidine, biotite, and magnetite; sanidine is commonly large and chatoyant; most samples are devitrified, platy and spherulitic; commonly exhibits bread crust textures; overlies *Qci*; overlain by *Qcs* and *Qbt*; has one vent along axis of ridge; $^{40}Ar/^{39}Ar$ age is 1.34 ± 0.02 Ma (Spell, *et al*., 1996); maximum exposed thickness is 490 m.

Qct — **Cerro Toledo rhyolite (Valle Toledo Member)** — White to gray, flow-banded, aphyric rhyolite with microlites of quartz, sanidine, biotite; obsidian phase is completely aphyric; rarely contains spherulites and bread crust textures; overlies *Qci* and apparently underlies *Qctr*; underlies *Qbt*; originates from two vents; K-Ar date on Cerro Toledo proper is 1.38 ± 0.05 Ma (Stix, *et al*., 1988); maximum exposed thickness is 520 m.

Qci — **Indian Point rhyolite (Valle Toledo Member)** — White to gray, flow-banded, sparsely porphyritic rhyolite with about 3% phenocrysts of quartz and sanidine; biotite is extremely rare; most samples are devitrified and spherulitic; underlies *Qctr* and *Qct*; originates from single vent; $^{40}Ar/^{39}Ar$ age is 1.46 ± 0.01 Ma (Spell, *et al*., 1996); maximum exposed thickness is 410 m.

Qcnr — **North caldera rim intrusion** — Flow-banded, sparsely porphyritic rhyolitic intrusive body and minor lava having phenocrysts of quartz, sanidine, and biotite; intrudes Tgbhd, Tpbd, and Tscu; overlain by Qalo; $^{40}Ar/^{39}Ar$ age is 1.61 ± 0.03 Ma (Goff et al., 2011); maximum exposed thickness is 50 m.

Toledo Ring-Fracture Zone

Qctq — **Cerro Trasquilar rhyolite (Cerro Toledo Rhyolite)** — White to gray to black, flow-banded to massive, sparsely porphyritic rhyolite with tiny phenocrysts of quartz, sanidine, clinopyroxene, opaque oxides and rare biotite; glassy samples usually show perlitic textures; devitrified samples are often spherulitic; flow-banded samples are commonly oxidized to red and orange colors; overlies and intrudes *Ts* and *Tpa*; underlies *Ql*; erupted from a single vent; $^{40}Ar/^{39}Ar$ age is 1.36 ± 0.01 Ma (Spell, *et al.*, 1996); maximum exposed thickness is 225 m.

Qcep — **East Los Posos rhyolite (Cerro Toledo Rhyolite)** — White to gray, flow-banded to massive porphyritic rhyolite with 5% phenocrysts of quartz, sanidine, biotite, hornblende, opaque oxides; rarely contains black glassy groundmass; most samples are devitrified and spherulitic; flow-banded samples often display red to orange oxidation; erupted from a single vent; $^{40}Ar/^{39}Ar$ age is 1.45 ± 0.01 Ma (Spell, *et al*., 1996); maximum exposed thickness is 165 m.

Qcwp — **West Los Posos rhyolite (Cerro Toledo Rhyolite)** — White to gray to black, flow-banded to massive porphyritic rhyolite with 5% phenocrysts of quartz, sanidine, plagioclase, biotite and opaque oxides; commonly contains relict black glass in a spherulitic, flow-banded groundmass; most samples are devitrified; underlies *Qcs* and *Qbt*; erupted from a single vent; $^{40}Ar/^{39}Ar$ age is 1.54 ± 0.01 Ma (Spell, *et al*., 1996); maximum exposed thickness is 370 m.

Qbo — **Bandelier Tuff, Otowi Member (shown on cross-sections only)** — White to pale pink to orange, generally poorly welded rhyolitic ash-flow tuff; pumice and matrix contains abundant phenocrysts of sanidine and quartz, and sparse mafic microphenocrysts; sanidine may display a blue iridescence; contains abundant accidental lithic fragments; consists of multiple flow units in a compound cooling unit; contains a stratified pyroclastic fall and surge deposits at base (Guaje Pumice); outflow sheets of *Qbo* discontinuously fill rugged topography on a volcanic surface of pre-Toledo caldera age; very difficult to distinguish from the Tshirege Member of the Bandelier Tuff in hand samples and thin sections; best distinguished by poorer degree of welding, greater tendency to form slopes instead of cliffs, more abundant lithic fragments, less abundant iridescent sanidine, and stratigraphic position beneath the Tsankawi pumice; originated from catastrophic eruptions that formed Toledo caldera; $^{40}Ar/^{39}Ar$ ages 1.61±0.01 to 1.62±0.04 Ma (Izett and Obradovich, 1994; Spell et al., 1996); maximum exposed thickness on the Redondo Peak quadrangle about 60 m.

Quaternary - Tertiary Deposits

QTp — **Puye Formation** —Thin deposit of poorly exposed gravel exposed above northeast wall of upper Quemazon Canyon; apparently underlies *Ttqc* but overlies *Ttrc*; sandy matrix poorly preserved; thickness about 6 m.

Tertiary Deposits
Keres Group (Pliocene-Miocene)
Tschicoma Formation (Pliocene)

Ttqc — **Upper Quemazon Canyon dacite** — Bluish-gray to pinkish-gray, flow-banded to massive, porphyritic dacite with 3% phenocrysts of large plagioclase and small resorbed quartz in a trachytic groundmass of plagioclase, orthopyroxene, clinopyroxene, biotite and opaque oxides; overlies *Qmso* and *Ttrc*; erupted on topographic margin of Toledo caldera from now-eroded vent; erupted lava flowed to west; $^{40}Ar/^{39}Ar$ age is 2.92 ± 0.05 Ma; maximum exposed thickness is roughly 65 m.

Ttpm — **Pajarito Mountain dacite** — Dome and flow complex of blue-gray to pale pink, massive to sheeted, porphyritic dacite containing phenocrysts of plagioclase, hypersthene, clinopyroxene, rare oxidized biotite and opaque oxides in a devitrified groundmass; contains clots of complexly zoned plagioclase and sparse clots of two pyroxenes; thick flows contain intervals of flow breccia; unit forms a volcanic center probably consisting of several eruptive events; source is Pajarito Mountain northeast of map area on the Guaje Mountain quadrangle; overlies hornblende dacite of Cerro Grande (*Ttcg*); locally underlies Tshirege Member of the Bandelier Tuff (*Qbt*); $^{40}Ar/^{39}Ar$ ages on widely separated samples range from 3.1 to 2.9 Ma (Broxton *et al.*, 2007); maximum exposed thickness is about 365 m.

Ttcb — **Caballo Mountain dacite** — Dome and flow complex of dark gray to purple-red, massive to sheeted, porphyritic dacite containing large phenocrysts of plagioclase in a trachytic groundmass of plagioclase, clinopyroxene, rare rounded quartz, opaque oxides and oxidized biotite; contains plagioclase-clinopyroxene clots; contains minor flow breccia; source is Caballo Mountain just east of map area; may contain multiple eruptive units; overlies *Ttrc* and *Ttd*; $^{40}Ar/^{39}Ar$ age is 3.06 ± 0.15 Ma (Broxton *et al.,* 2007); maximum exposed thickness is about 200 m.

Ttcg — **Cerro Grande dacite** — Extensive dome and flow complex of light to dark gray to pale pink, massive to sheeted porphyritic dacite containing phenocrysts of plagioclase, hypersthene, and conspicuous hornblende; the latter two phases commonly show oxidized rims and may be difficult to see in hand sample; contains microphenocrysts of plagioclase, hypersthene and clinopyroxene, and clots of hornblende, hypersthene, plagioclase, and opaque minerals; thick flows contain intervals of flow breccia; source is Cerro Grande in northeast map area; unit forms a volcanic center apparently consisting of several eruptive events; underlies *Ttpm* and Tshirege Member of the BandelierTuff (*Qbt*); dates on widely separated samples range from 3.8 to 3.1 Ma (Dalrymple, *et al*., 1967; Broxton *et al.,* 2007); maximum exposed thickness is about 750 m.

Ttcr — **Cerro Rubio dacite** — Gray to pink to black, massive to sheeted, fine-grained shallow intrusive dacite with phenocryst assemblage similar to plug *Ttcd* (described above); contains glassy material near top and upper flanks; intruded by *Qcr* and overlain by *Qbt* and *Qcep*; K-Ar age is 3.56 ± 0.36 Ma (Stix, *et al*., 1988); maximum exposed thickness is 440 m.

Ttcd — **Dacite north of Cerro Rubio** — White to gray, massive to sheeted, fine-grained dacite plug with small phenocrysts of plagioclase, hornblende, orthopyroxene, sparse biotite and rare quartz in a devitrified groundmass of containing microlites of plagioclase; contains some columnar jointing around margins and top of unit; appears to be a plug with hypabyssal texture; intruded by *Qcr* and *Qcrt*; overlain by *Qbt*; $^{40}Ar/^{39}Ar$ age is 4.21 ± 0.12 Ma (Goff *et al*., 2011); maximum exposed thickness is 365 m.

Ttsc — **Santa Clara Canyon dacite** — Faulted, plug-like, circular body along south side of Santa Clara Canyon near east edge of map; consists of gray, massive to sheeted, porphyritic dacite containing phenocrysts of plagioclase, sanidine, hornblende, biotite, and sparse resorbed quartz in trachytic, glassy to devitrified groundmass with microlites of plagioclase, sanidine, hornblende, biotite, orthopyroxene and opaque oxides; plagioclase is fritted, resorbed, and complexly zoned; contains clots of plagioclase-hornblende; relations with other Tschicoma units uncertain but resembles *Ttcd* and *Ttcr* in petrography; underlies *Qbt*; unit not dated; maximum exposed thickness is 160 m.

Ttpd — **Tschicoma Peak area dacite and rhyodacite, undivided** — Gray to pale pink to pale blue, massive to sheeted flows of dacite and rhyodacite exposed in the walls of Santa Clara Canyon in northeast sector of map; flows are generally highly porphyritic containing phenocrysts of plagioclase, pyroxene and opaque oxides ± quartz ± sanidine ± biotite ± hornblende in a trachytic groundmass; overlies *Tpa* and underlies *Qbt*; sources of various flows unknown; may be equivalent to dacitic flows vented near Tschicoma Peak just north of map area (5.34 to 3.21 Ma; Goff, unpub.) or to flows exposed in the walls of Santa Clara Canyon just east of map area (3.91 to 3.79 Ma; WoldeGabriel, *et al*., 2006); maximum exposed thickness is about 565 m.

Ttrc — **Rendija Canyon rhyodacite** — Dome and flow complex of gray to pale pink, massive to sheeted, highly porphyritic rhyodacite with phenocrysts of quartz, sanidine, complexly zoned and fritted plagioclase, hornblende and biotite in a trachytic groundmass of plagioclase, hornblende, orthopyroxene, biotite, opaque oxides and apatite; quartz is conspicuous, pale pink and resorbed; hornblende and biotite commonly oxidized; sanidine content varies considerably (Warren, 2005, unpub.); probably represents a volcanic center with several eruptive events; probable vent occurs on northwest-trending ridge south of Quemazon Canyon where frothy, vesicular lava is locally oxidized to orange; possible vent occurs on east edge of map north of Pipeline Road as white, pumiceous, finer-grained rhyodacite; underlies *Ttcb*, *Ttpm*, *Qqc* and *Qbt*; probably underlies *Ttpd* and *Ttcg*; overlies Paliza Canyon Formation andesite (*Tpa*) in Los Alamos Canyon east of map area in the Guaje Mountain quadrangle; dates on widely separated samples range from 5.36 to 3.50 Ma (Goff, *et al*., 1989; Broxton *et al.,* 2007; Goff *et al*., 2011); maximum exposed thickness approximately 500 m.

Pliocene - Miocene Deposits
Bearhead Rhyolite (Miocene)

Tbh — **Bearhead intrusive rocks** — White to gray to pale orange dikes, plugs and flows (?) of slightly porphyritic devitrified to completely silicified rhyolite containing sparse phenocrysts of quartz, sanidine, plagioclase, biotite and opaque oxides in a groundmass containing abundant microlites of feldspar and biotite; rhyolite is rarely flow-banded; dikes may display complicated intrusive relations with country rocks; widths of individual dikes shown on map are commonly exaggerated to be shown at 1:24,000, and may consist of many smaller sub-parallel dikes; pervasive, hydrothermal alteration consists primarily of quartz, chalcedony and/or opal, illite, Fe- and Mn-oxides, pyrite and possibly other sulfides, alunite, jarosite and gypsum; intrudes other Keres Group rocks, Tertiary sedimentary rocks (*Tscu*) and La Grulla Formation rhyodacite (*Tgbhd*); probably equivalent to the early and intermediate rhyolite of Loeffler, *et al*. (1988) dated at 7.5 to 5.8 Ma and located north of the map area; $^{40}Ar/^{39}Ar$ age of dike west of Rito de los Indios is 4.81 ± 0.03 Ma; dates on various Bearhead units in southern Jemez Mountains range from about 6.0 to 7.2 Ma (Gardner, *et al*., 1986; Goff, *et al*., 1990; Justet, 1996); maximum observed thickness about 100 m.

La Grulla Formation (Miocene)

Tgbhd — **Porphyritic biotite, hornblende rhyodacite** — Gray to pale pink, massive to sheeted porphyritic rhyodacite with phenocrysts of sanidine, plagioclase, resorbed quartz, biotite, hornblende, clinopyroxene, orthopyroxene and opaque oxides in a groundmass containing microlites of plagioclase, pyroxene, and opaque oxides; hornblende and biotite are commonly oxidized; contains rare iddingsitized olivine crystals; contains plagioclase-pyroxene-biotite clots; groundmass is trachytic; most samples are devitrified; overlies *Tga*, *Tscu*, and *Tpbd*; intruded by *Tbh* and displays hydrothermal alteration to silica, clay, chlorite and Fe-oxides near intrusive contacts; vent area not known but probably originates from north to northwest; $^{40}Ar/^{39}Ar$ age is 7.42 ± 0.05 Ma (Goff *et al.*, 2011); maximum exposed thickness is about 135 m.

Tga — **Porphyritic andesite and dacite, undivided** — Massive to sheeted, porphyritic lavas with phenocrysts of plagioclase, biotite, clinopyroxene, orthopyroxene, and opaque oxides; may contain plagioclase-pyroxene-biotite clots; erupted from multiple vents; found only in extreme northeast corner of quadrangle; overlies *Tscu*; $^{40}Ar/^{39}Ar$ ages on widely separated samples range from 7.43 to 7.81 Ma (Goff *et al.*, 2011); maximum exposed thickness about 60 m.

Paliza Canyon Formation (Miocene)

Tpbd, Tpbdx — **Porphyritic biotite dacite** — Eroded flows of gray, porphyritic dacite with phenocrysts of potassium feldspar, plagioclase, biotite, clinopyroxene, orthopyroxene and rare hornblende in a trachytic groundmass of plagioclase, pyroxene, biotite, and opaque oxides; contains minor clots of plagioclase-pyroxene-biotite; contains thick flow breccia (*Tpbdx*) exposed on north side of fault west of Rito de los Indios; flows are highly variable in thickness suggesting *Tpbd* filled a very irregular paleotopography; many exposures are extensively altered to silica, chlorite, clay and Fe-oxides; underlies *Tgbhd*; interbedded with *Ts*; overlies *Tpa*; intruded by *Tbh*; vent area unknown but probably originates from northwest; $^{40}Ar/^{39}Ar$ ages range from 7.66 to 7.78 Ma (Goff *et al.*, 2011); maximum exposed thickness near north edge of map is 230 m.

Tpa — **Two-pyroxene andesite, undivided** — Flows and flow breccia of andesite from unknown sources; individual units are slightly porphyritic to very porphyritic; flows dense to platy to highly vesicular; fresh units may contain up to 20% phenocrysts of plagioclase, orthopyroxene, and clinopyroxene in an intersertal or slightly trachytic groundmass; groundmass usually contains abundant opaque oxides; plagioclase phenocrysts are commonly fritted and complexly zoned; most specimens contain plagioclase-pyroxene clots ≥ 1 mm in diameter; some units contain enclaves of plagioclase-pyroxene a few centimeters in diameter; some flows contain minor hornblende and/or biotite; visible alteration varies from slight to extremely intense; alteration generally consists of silica, Fe-oxides, clay ± chlorite ± illite ± pyrite; underlies and is interbedded with *Tscu*; intruded by *Tbh*; vents areas not known but probably lie to the west; andesite exposed in bottom of Santa Clara canyon dated at 7.88 ± 0.04 Ma (WoldeGabriel, *et al*., 2006); other flows in map area not dated; fresh flows of *Tpa* in southern Jemez Mountains range from 8.2 to 9.4 Ma (Gardner, *et al*., 1986; Justet, 2003; Goff *et al*., 2011); maximum exposed thickness about 30 m.

Lobato Basalt (Miocene)

Tlb — **Olivine basalt (shown only in cross sections)** — Thin flows of olivine basalt (Smith *et al*., 1970; Aldrich and Dethier, 1990) interbedded in the Santa Fe Group (*Ts*). Occurrences in cross sections is speculative but are correlated with similar flows in Santa Clara Canyon west of map area (WoldeGabriel *et al.*, 2006); thickness of individual flows ≤15 m.

Santa Fe Group (Pliocene-Miocene)

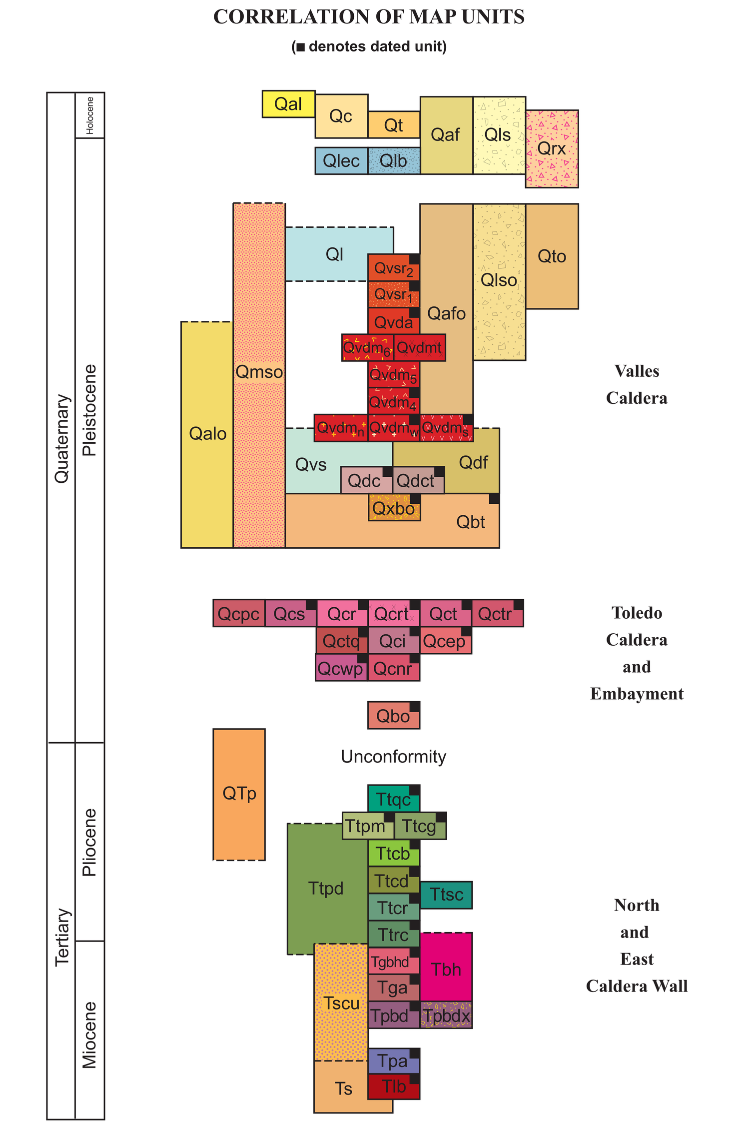
Ts — **Santa Fe Group, undivided (cross sections only)** — Tan to white to gray sandstone, siltstone and conglomerate; age roughly bracketed between 10 and 20 Ma; thickness highly speculative.

Chamita Formation (Miocene)

Tscu — **Hernandez Member (?)** — Thick sequence (>200 m) of sedimentary deposits, intercalated with Paliza Canyon and Tschicoma formation volcanic and volcaniclastic deposits; sequence is dominantly arkosic sandstone, but interbeds of pebbly conglomerate, wacke, subangular gravel of intermediate composition volcanics, debris flows, and angular breccias occur; intense silicification is widespread, and unit deposits are additionally locally altered to iron oxides, clays, and chlorite; 20 m-thick lobe of *Tscu* overlying *Tgbhd* and *Tbh* consists primarily of white to pale gray debris flows containing mostly fragments of rhyodacite and rhyolite in a poorly exposed sandy matrix. *Tscu* overlies *Tpa* and is interbedded with *Tpa*, *Tpbd*, and *Tgbhd*; unit is also overlain by *Tgbhd* and *Tbh* flows, and intruded by Bearhead Rhyolite (*Tbh*) dikes and plugs. Assignment of *Tscu* is problematic; may be equivalent to the Hernandez Member of the Chamita Formation of the Santa Fe Group as implied by temporal constraints (on eastern ends of the cross-sections, Puye Formation, and volcaniclastic deposits of the Keres Group) (Cochiti Formation of Gardner 1985; Gardner, *et al*., 1986; Goff, *et al*., 1990). Gardner and Goff (1996) point out that *Ts* represents basin-fill deposits at the eastern margin of the volcanic field, revealing interbedding of arkosic sandstones with proximal volcanic and volcaniclastic material.

CORRELATION OF MAP UNITS

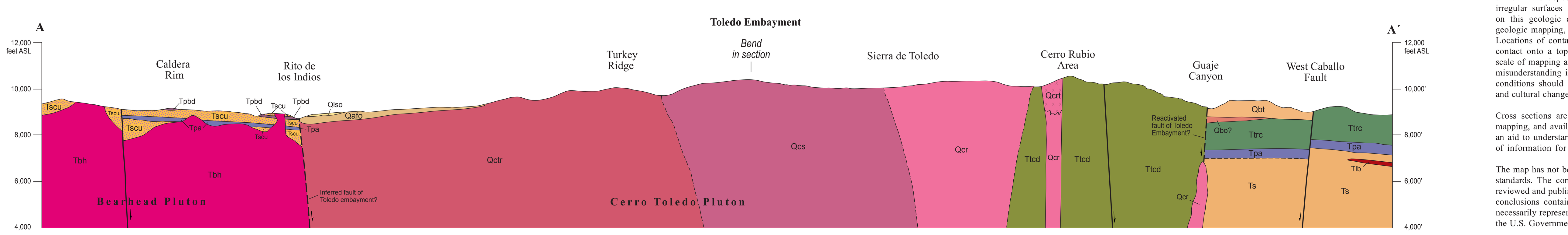
(■ denotes dated unit)

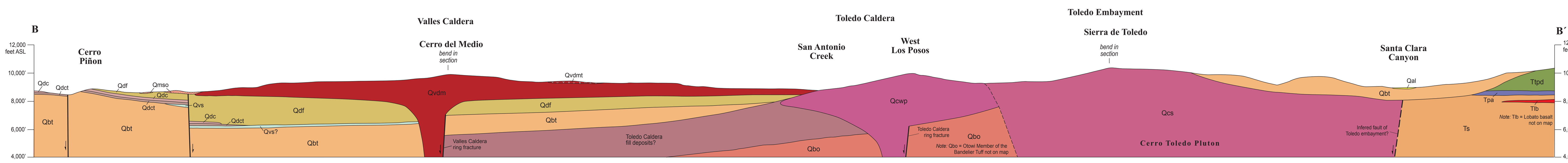


REFERENCES

See accompanying report.

GEOLOGIC CROSS SECTIONS





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A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic quadrangle map may be based on any of the following: reconnaissance field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation. Locations of contacts are not surveyed, but are plotted by interpretation of the position of a given contact onto a topographic base map; therefore, the accuracy of contact locations depends on the scale of mapping and the interpretation of the geologist(s). Any enlargement of this map could cause misunderstanding in the detail of mapping and may result in erroneous interpretations. Site-specific conditions should be verified by detailed surface mapping or subsurface exploration. Topographic and cultural changes associated with recent development may not be shown.

Cross sections are constructed based upon the interpretations of the author made from geologic mapping, and available geophysical, and subsurface (drillhole) data. Cross-sections should be used as an aid to understanding the general geologic framework of the map area, and not be the sole source of information for use in locating or designing wells, buildings, roads, or other man-made structures.

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