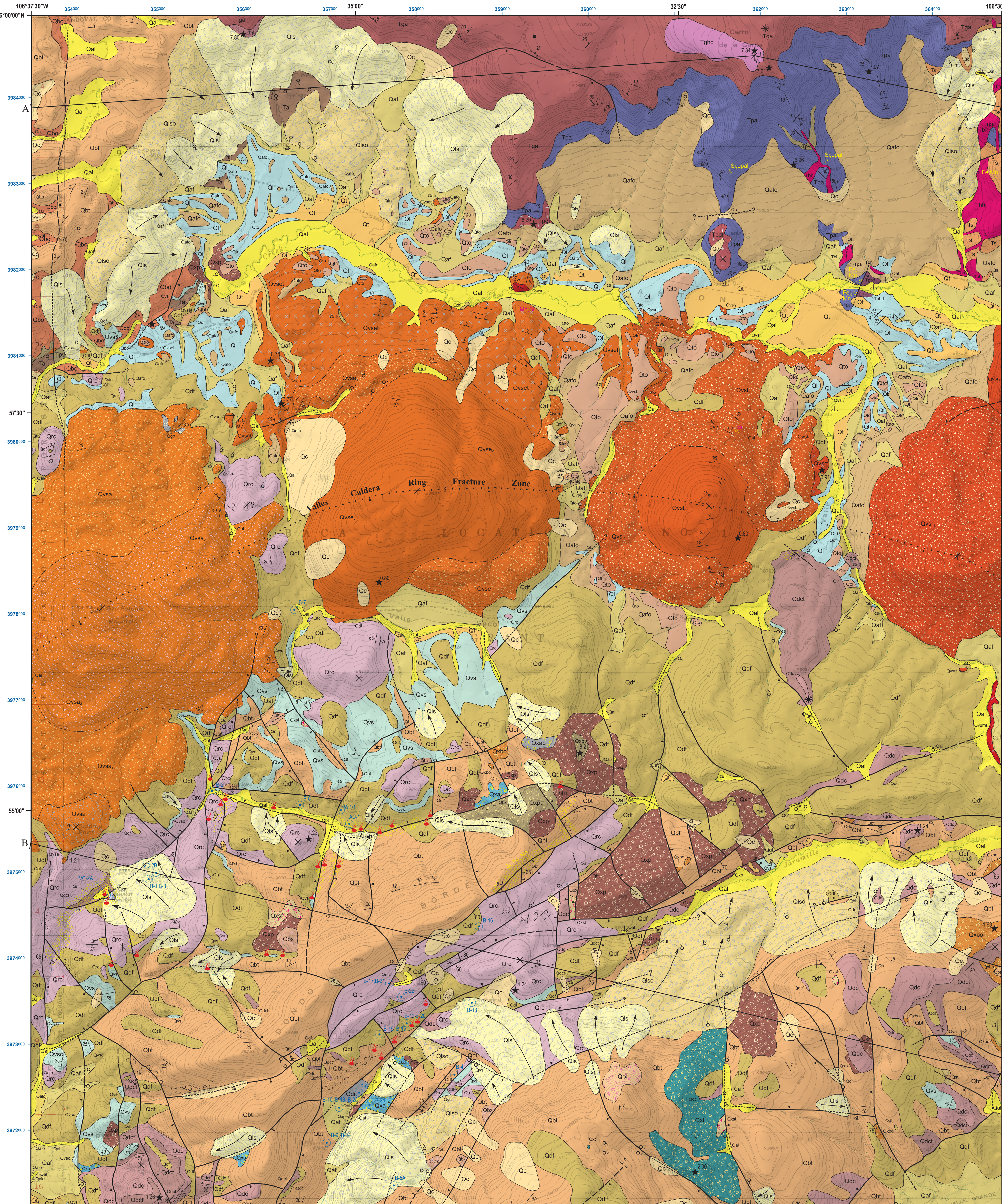


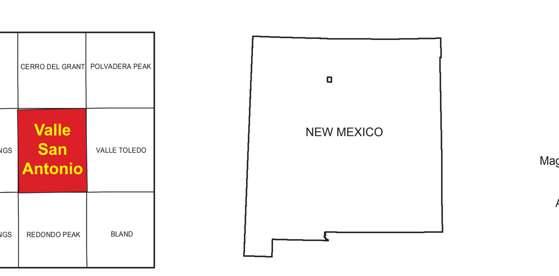
Base from U.S. Geological Survey 1984, from photographs taken 1976 and field checked in 1976. Map edited in 1984. Base projected from NAD83 to NAD27. 1927 North American datum, UTM projection -- zone 13. 1000-meter Universal Transverse Mercator grid, ticks shown in blue

1:24,000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Magnetic Declination May 2006 At Map Center

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).



QUADRANGLE LOCATION

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New Mexico Tech
801 Leroy Place
Socorro, New Mexico
87801-4796

[575] 835-5490

This and other STATEMAP quadrangles are available for free download in both PDF and ArcGIS formats at:

http://geoinfo.nmt.edu

New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map 132

Geologic map of the Valle San Antonio quadrangle, Sandoval and Rio Arriba Counties, New Mexico.

May 2006

by

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MAP SYMBOLS

- A — A' Geologic cross section.
- Contact - Solid where exposed or known; dashed where approximately located; dotted where concealed.
- 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.
- Strike and dip of inclined bedding.
- Strike and dip of magmatic foliation.
- Direction of flow of landslide failure.
- Location of radiometric-dated sample (age in Ma).
- Alteration associated with fault shear.
- Localized geochemical alteration.

Alteration Products:

- Iron oxidation
- Abundant pyrolusite
- Quartz/chalcedony
- Opal
- Geothermal well.
- Volcanic vent.
- Fumarole.
- Cold spring.
- Bog.
- Sag pond.
- Cabin.
- Ruins.
- Pump.

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), Gardner *et al.* (2010), and Goff *et al.* (2007, 2011). 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). Minor yet significant changes in regional stratigraphy and nomenclature have occurred here 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

Qdi — **Disturbed areas** — Anthropogenically disturbed areas consisting of underlying rock units at each site; unit mapped only where extensive at unused electric power plant site west of Redondo Creek; not shown in correlation chart; maximum thickness less than 5 m.

Qal — **Alluvium** — Deposits of sand, gravel and silt in main valley bottoms; locally includes stream terraces, alluvial fans, canyon wall colluvium, and bog deposits; mostly Holocene in age; ^{14}C age on basal bog deposits in Alamo Canyon is 4,595 ± 105 yrBP (Stearns, 1981); more recent ^{14}C age of 7,940 ± 40 yrBP was obtained from a different site at depth of roughly 490 cm (Brunner, 1999; S. Anderson, *personal communication*, 2006); ^{14}C date of 8,110 ± 40 yrBP was obtained at depth of roughly 175 cm in Santa Rosa bog (S. Anderson, *personal communication*, 2006); maximum thickness of various alluvium deposits is uncertain but may exceed 15 m.

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

Qalo — **Slightly older alluvium** — Deposits of gravel, sand, silt and minor lacustrine beds along the edges of Sulphur Creek in the southwest corner of the quadrangle; Holocene or slightly older in age; maximum thickness probably 15 m.

Qaf — **Alluvial fans —** Typically fan-shaped deposits of coarse to fine gravel and sand, silt, and clay within and at the mouths of valleys and in the Valle San Antonio; associated with present drainages and usually not incised; grades into alluvial deposits along main channels; probable age late Holocene to late Pleistocene; 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** — Poorly sorted debris that has moved chaotically down steep slopes; 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; some landslides in Valle San Antonio involve lacustrine deposits (*Ql*) and post-date incision of the inner valley; thickness varies considerably depending on the size and nature of the landslide.

Boulder fields — Areas covered with boulders as large as 3 m 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 sand, gravel, and silt that underlie higher terraces and generally post-date lake that occupied Valle San Antonio, Valle San Luis, and Valle Santa Rosa; includes multiple Pleistocene-age surfaces that formed during incision of main streams through lake deposits, and locally includes fluvial deposits associated with deltas that filled the upper parts of the lake in Valle San Antonio and Valle Santa Rosa; in Valle San Antonio, terrace remnants occur up to 45 m above present channel; commonly overlies strath surfaces cut into lake deposits, and also overlies older rock units; typical thickness is 1 to 2 m, but may locally exceed 10 m in thickness.

Qlso — **Older landslides —** Older slide deposits that are overlain by several types of younger deposits; maximum exposed thickness about 25 m.

Qafo — **Older alluvial fans —** Older deposits of coarse to fine gravel and sand, silt, and clay derived mostly from the volcanic domes, resurgent dome, and caldera walls; deposits commonly post-date the lake that occupied Valle San Antonio, Valle San Luis, and Valle Santa Rosa, and have been incised; mainly Pleistocene in age although, typically, portions are still active; contacts with Qco, particularly around flanks of volcanic domes, are gradational; thickness is unknown.

Ql — **Lacustrine deposits —** Finely laminated deposits of clay, silt, and very fine sand with subordinate fine to coarse sand and gravel; deposited in lakes formed by blockage of drainages by post-resurgence eruptions from the ring-fracture vents (Reneau, *et al.*, 2004; 2007); deposits sometimes tuffaceous, and diatomaceous facies occur; some deposits north of Cerro Seco contain what appear to be insect impressions, fossil reeds, and other organic materials; interbedded with and overlain by older alluvial fans (*Qafo*); overlies older landslides (*Qlso*) and underlies older terrace deposits (*Qto*); deposits in the upper (east) part of the valley generally overlie the lavas of Cerro San Luis (*Qvsl*); some deposits in the lower (west) part of valley underlie the tuffs and tuffaceous sediments of Cerro Seco (*Qvset*) and lavas of San Antonio Mountain (*Qvsa*); deposits beneath *Qvset* and *Qvsa* may display considerable silicification from low-temperature hydrothermal alteration; maximum exposed thickness about 20 m.

Qso — **Older sandstone** — Weakly-indurated to unconsolidated, moderate to well sorted, subrounded, medium grained, reddish-tan quartz lithic sand with scattered pumice clasts up to 2 cm diameter. Locally thinly cross-bedded. Pumice clasts are crystal poor, with rare phenocrysts of quartz and biotite. Volcanic lithics are coarse sand to granule size. Unit overlies northerly portions of Cerro Seco lava dome at high elevations; maximum exposed thickness about 20 m.

Qvs, Qvsc — **Early caldera fill - lacustrine and fluvial deposits** — 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 volcanic rocks; may contain Precambrian crystalline fragments and materials eroded from Miocene to Permian sandstone; some beds contain ripple marks, flute casts and plane laminations and may be deltaic deposits near margins of initial caldera lake; beds generally display zeolitic or less commonly acid sulfate alteration (Chipera *et al.*, 2007; Goff *et al.*, 2007); beds generally deformed by uplift of resurgent dome; beds in Valle San Antonio are nearly horizontal; *Qvs* usually underlies Deer Canyon lavas (*Qdc*) and Deer Canyon tuffs (*Qdct*). Unit *Qvsc* contains abundant biotite and is locally derived by erosion of significant amounts of Redondo Creek Rhyolite (*Qrc*); *Qvsc* overlies Redondo Creek rhyolite; *Qvs* and *Qvsc* are interbedded with early caldera fill sedimentary rocks (*Qdf*) and overlie Bandelier Tuff (*Qbt*); maximum exposed thickness about 30 m; maximum drilled thickness in well Baca-7 on northeast side of resurgent dome is nearly 300 m (Lambert and Epstein, 1980).

Qdf — **Early caldera fill - alluvial, debris flow, landslide, and colluvial deposits** — Dark gray to buff, matrix-supported beds containing clay to boulders of various early post-caldera rhyolites, Bandelier Tuff, precaldera volcanic rocks, Miocene to Permian sandstone, Pennsylvanian limestone and Precambrian crystalline rocks (Goff *et al.*, 2007); 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 megabreccia blocks (*Qx*), and erosion of previously formed beds during uplift of the resurgent dome; finer-grained matrix is generally not exposed; resembles eroded alluvial fans at some locations on lower flanks of resurgent dome and may represent remnants of original alluvial landforms; weathering produces a lag of boulders on landscape; lower part of unit displays extensive, low-grade hydrothermal alteration; extensively faulted but fault relations in this unit are often difficult to determine where deposits are extensive; interbedded with and overlies all other units on resurgent dome; maximum exposed thickness in map area is 70 m; maximum drilled thickness in well Baca-7 on northeast side of resurgent dome is over 400 m (Lambert and Epstein, 1980).

Qst — **Sinter Deposits** — Massive to banded, white to dark gray, silica-rich hot spring deposits from early hydrothermal activity on resurgent dome; may contain Fe-oxides; may contain fossil reeds and other organic remains; exposed only on fault blocks in widely scattered locations on resurgent dome; overlies Redondo Creek Rhyolite (Qrc), Deer Canyon Rhyolite (Qdc), and Bandelier Tuff (Qbt); maximum exposed thickness about 3 m.

Tewa Group
Valles Caldera and Resurgent Dome
Valles Rhyolite

$Qvsa_3$, $Qvsa_2$, $Qvsa_1$ — **San Antonio Mountain Member —** Flow-banded, massive to slightly vesicular rhyolite lava containing phenocrysts of sanidine, plagioclase, quartz, biotite, hornblende, and clinopyroxene in a pale gray, perlitic to white, devitrified groundmass; rarely glassy; contains no identifiable pyroclastic deposits; consists of two main flow units (oldest to youngest - $Qvsa_1$ to $Qvsa_2$) erupted from San Antonio Mountain; a third flow and peripheral vent may also occur at Sulphur Point ($Qvsa_3$); buried ancestral drainage of San Antonio Creek in western Valles caldera; overlies caldera fill deposits (*Qdf*), lacustrine and fluvial deposits (*Qvs*, *Qvsr*, and *Ql*) and Redondo Creek rhyolite (*Qrc*); $^{40}Ar/^{39}Ar$ age is 0.557 ± 0.004 Ma on two samples from $Qvsa_2$ (Spell and Harrison, 1993); maximum exposed thickness at least 510 m.

$Qvse_2$, $Qvse_1$, Qvset — **Cerro Seco Member** — Flow-banded, massive to slightly vesicular rhyolite lava containing phenocrysts of quartz, sanidine, biotite and rare hornblende in a gray to pale pink devitrified groundmass; sanidine is often chatoyant; contains some vitrophyre near summit of Cerro Seco and other locations; consists of two flow units (oldest to youngest - $Qvse_1$ to $Qvse_2$); flows overlie Cerro Seco pyroclastic deposits, caldera fill deposits (*Qdf*), and lacustrine and fluvial deposits (*Qvs*); $^{40}Ar/^{39}Ar$ age is 0.800 ± 0.007 Ma (Spell and Harrison, 1993), probably from flow $Qvse_2$; maximum exposed thickness is 375 m. Various pyroclastic deposits from Cerro Seco (*Qvset*) underlie the dome and flow complex and are combined as one map unit. The deposits consist of ignimbrite and dry surge near the vent, to probable hydromagmatic surge and derivative pumice-rich sediments distally. Where both types of deposits are visible, hydromagmatic surge generally overlies or laps on the ignimbrites; ignimbrites are buff to pale pink containing clasts of pumice (≤20 cm), vitrophyre, and pre-caldera lithologies in massive to rarely layered groundmass of ash, crystals, and fine rock fragments; surge deposits show cross-bedding and undulating dips of winnowed crystals, ash and pumice; hydromagmatic and derivative deposits contain quenched angular to subangular pumiceous rhyolite, crystal fragments and abundant foreign lithic fragments in plane-laminated to cross-bedded layers (see Fisher and Schmincke, 1984); contains rare layers of rhyolitic silt and clay with occasional mud crack features suggesting deposition in a shallow lake; overlies *Qdf*, *Ql*, Cerro San Luis rhyolite lava (*Qvsl*), and portions of Warm Springs dome (*Qcws*); date on sanidine from pumice lump in ignimbrite is 0.77 ± 0.03 Ma; date on sanidine from hydromagmatic deposit is 0.78 ± 0.04 Ma (W. McIntosh, unpub. data); thickness of all pyroclastic deposits is roughly 75 m at edge of Cerro Seco dome complex to <1 m at distal sites; run out distance is roughly 2 km north of edge of dome.

$Qvsl_2$, $Qvsl_1$ — **Cerro San Luis Member** — Flow banded, massive to slightly vesicular porphyritic rhyolite lava containing about 10% phenocrysts of sanidine, quartz and biotite in a gray to pale pink devitrified groundmass; rarely glassy; occasionally spherulitic; eruption produced no identifiable pyroclastic deposits but these may underlie flows on north and east side of dome complex. Contains local zones of opalization on north side of dome. Consists of possibly two eruptive pulses ($Qvsl_1$ and $Qvsl_2$). Fills paleocanyon cut into *Qdf* and *Qvs* on west side of dome. Overlies Santa Rosa ignimbrite and caldera fill deposits on northeast side of dome and underlies *Qvset*. $^{40}Ar/^{39}Ar$ date is 0.800 ± 0.003 Ma (Spell and Harrison, 1993); maximum exposed thickness is 325 m.

$Qvsr_2$, $Qvsr_1$, Qvsrt — **Cerro Santa Rosa Member** — (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 (including this USGS base map) restrict the name Cerro Santa Rosa to what we map as $Qvsr_2$, and label the entire chain of northeast trending domes including the Santa Rosa complex and Trasquilar dome "Cerros de Trasquilar.") Pyroclastic flow (*Qvsrt*) and two dome and flow complexes (*Qvsr*) of petrographically and chemically similar, but temporally and magnetically dissimilar, rhyolite. *Qvsrt* consists of pale gray to pale pink massive ignimbrite having pumice, ash, crystal shards and rare lithic fragments. Pumice lumps may be as much as 20 cm long and contain roughly 10% phenocrysts of quartz, sanidine and biotite in a highly vesicular groundmass; $^{40}Ar/^{39}Ar$ date on sanidine is 0.91 ± 0.03 Ma (W. McIntosh and L. Peters, NMBGMR). Ignimbrite is not exposed beneath Santa Rosa dome complex but is exposed beneath the northeast part of Cerro San Luis west of source, and in small outcrop to south of dome. Maximum thickness is about 15 m. The oldest lava ($Qvsr_1$) consists of white to grey 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 includes petrographically similar flows, with chatoyant sanidine, that may be of different age; dated at 0.914 Ma ± 0.004 (one sigma error, Spell and Harrison, 1993) and 0.936 ± 0.008 (two sigma error, Singer and Brown, 2002); maximum thickness over 240 m. The younger dome ($Qvsr_2$) consists 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 at 0.787 Ma ± 0.015 (one sigma error, Spell and Harrison, 1993); maximum thickness about 150 m.

Qvdmt — **Cerro del Medio Member, ignimbrite** — Massive, white to pale gray rhyolitic ignimbrite containing pumice, ash, crystal fragments, obsidian, and rare lithic fragments; pumice contains tiny, rare quartz and sanidine phenocrysts; some outcrops show reworking by later erosional processes; exposed only along east-central edge of quadrangle underlying colluvium; [illegible] from Cerro del Medio based on [illegible] sparse phenocrysts and presence of obsidian (J. N. Gardner, *unpublished data*); unit as mapped is not dated; maximum exposed thickness is about 3 m.

Qrc — **Redondo Creek Member** — Massive to flow-banded, gray to black to pale pink porphyritic rhyolite to rhyodacite containing plagioclase, conspicuous biotite, clinopyroxene and subordinate sanidine in a perlitic to devitrified groundmass (Goff *et al*., 2007; 2011); occasionally block and glassy to slightly vesicular; commonly spherulitic; contains substantial flow breccia; [illegible]; erupted from multiple sources in central and west resurgent dome; western flows filled paleovalley and/or paleocanyon in western moat [illegible]; shows extensive hydrothermal alteration, particularly in west and northwest; contains no recognizable pyroclastic deposits; $^{40}Ar/^{39}Ar$ ages of different domes and flows range from 1.21 to 1.24 Ma (n=4; Phillips, *et al*., 2007); maximum exposed thickness about 180 m.

Qdc — **Deer Canyon Member, lava unit** — Massive, to flow-banded gray to pale pink, porphyritic to aphyric rhyolite lavas usually containing phenocrysts of sanidine and quartz (Bailey, *et al*., 1969); phenocrysts are large and abundant in western flows but are tiny and sparse in eastern flows; some obsidian is present; groundmass is devitrified; flow breccias are often opalized and iron-stained; [illegible] extensive zeolitic alteration (Chipera *et al*., 2007); overlies Deer Canyon tuffs (*Qdct*); interbedded with *Qdf* and generally overlies *Qvs*; overlies Bandelier Tuff (*Qbt*); $^{40}Ar/^{39}Ar$ ages of three different flows range from 1.25 to 1.28 Ma (n=3; Phillips, *et al*., 2007); maximum exposed thickness about 40 m.

Qdct — **Deer Canyon Member, tuff unit** — White to cream to pale buff lithic-rich rhyolitic tuffs; pumice fragments contain phenocrysts of quartz and sanidine; lithic fragments generally consist of Bandelier Tuff and precaldera rocks; 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*; $^{40}Ar/^{39}Ar$ ages of different tuff beds range from 1.23 to 1.27 Ma (n=5, Phillips, *et al*., 2007); maximum exposed thickness about 30 m.

Qbx — **Bandelier Tuff vent and/or hydrothermal breccia** — Widely scattered, lenticular to nearly circular outcrops of mosaic breccia, usually located along faults or within faults; usually less than 300 m in diameter; composed primarily of subangular to angular fragments of Tshirege Member Bandelier Tuff (*Qbt*) in matrix of fine-grained tuff; may also contain fragments of precaldera lithologies; may be hydrothermally altered; breccias of this type do not display gouge and shear typical of fault breccia; thickness unknown; origins of such breccias are probably variable.

Qbt — **Bandelier Tuff, 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, 2007); in more welded portions, sanidine typically chatoyant (blue iridescence); upper flow units generally more welded than lower ones; [illegible] 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 eruption; [illegible] erupted during formation of the Valles caldera; most recent $^{40}Ar/^{39}Ar$ age is 1.25 ± 0.01 Ma (Phillips, *et al*., 2007); maximum observed thickness within caldera over 900 m.

Qx, Qxbo, Qxt, Qxpt, Qxp, Qxsf, Qxab, Qxa, Qxm — **Caldera collapse breccia** — Caldera-wall landslide breccias (megabreccias) that accumulated synchronously during caldera formation (Lipman, 1976); incorporated in and interbedded with intracaldera Tshirege Member of the Bandelier Tuff (Goff, *et al*., 2007); individual blocks mapped if more than 30 m across; within Valle San Antonio quadrangle, this unit consists of: 1) Silicified and brecciated, brownish-red, Otowi Member of the Bandelier Tuff (*Qxbo*) with phenocrysts of quartz and sanidine; most of the brecciated texture in this unit is not obvious; 2) Tschicoma Formation rhyodacite, dacite and coarse volcaniclastic materials (*Qxt*); 3) Paliza Canyon Formation porphyritic dacite tuff (*Qxpt*); 4) Paliza Canyon Formation andesite and volcaniclastic materials (*Qxp*); 5) Santa Fe Group to white well-sorted sandstone (*Qxsf*); 6) Abiquiu Formation white, non-indurated sandstone and conglomerate rich in Precambrian cobbles and pebbles (*Qxab*); 7) Permian Abo and Yeso Formation brick red to orange sandstone, siltstone, and shale (*Qxa*); 8) Pennsylvanian Madera Formation gray limestone, micrite and shale (*Qxm*); [illegible] maximum exposed thickness is highly variable; not shown in cross sections for clarity.

Toledo Caldera

Qcws — **Warm Springs rhyolite (Cerro Toledo Rhyolite)** — Massive to flow banded, gray to pale pink porphyritic rhyolite lava containing phenocrysts of quartz, sanidine and biotite; groundmass is devitrified; exposed only in small bluff at Warm Springs in Valle San Antonio; overlain by hydromagmatic pyroclastic deposits from Cerro Seco (*Qvset*); $^{40}Ar/^{39}Ar$ age is 1.26 ± 0.01 Ma (Spell, *et al*., 1996); maximum exposed thickness is 25 m.

Qbo — **Bandelier Tuff, Otowi Member** — White to pale pink to orange, generally moderately welded rhyolitic ash-flow tuff; pumice and matrix contains abundant phenocrysts of sanidine and quartz, and sparse mafic microphenocrysts; sanidine may be chatoyant (blue iridescence); contains abundant accidental lithic fragments (Eichelberger and Koch, 1979); consists of multiple flow units in a compound cooling unit; contains a stratified pumice fall and surge deposit at its base (Guaje Pumice; Griggs, 1964); may form tent rocks; *Qbo* discontinuously fills in rugged topography on a volcanic surface of pre-Toledo caldera age; very difficult to distinguish from upper 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 about 60 m.

Tertiary (Pliocene - Oligocene?) Deposits

Keres Group (Pliocene-Miocene)

Ttd — **Dacite and rhyodacite, undivided (only on cross section B-B') —** Gray to pale pink to pale blue, massive to sheeted, flows of dacite and rhyodacite exposed in the Sierra de los Valles east of quadrangle; flows are generally highly porphyritic containing phenocrysts of plagioclase, orthopyroxene, clinopyroxene, opaque oxides ± quartz ± sanidine ± hornblende ± biotite in a trachytic groundmass; underlies lower Bandelier Tuff (*Qbo*); overlies Paliza Canyon Formation andesite (*Tpa*) and Santa Fe Group (*Ts*); sources of various flows unknown; may be equivalent to dacitic flows vented near Tschicoma Peak northeast of quadrangle (5.34 to 3.21 Ma; WoldeGabriel *et al.*, 2006), to dacitic flows exposed in the walls of Santa Clara Canyon (3.91 to 3.79 Ma; WoldeGabriel, *et al*., 2006), and to domes vented east of map area near Cerro Rubio and Sierra de los Valles (roughly 2 to 5 Ma; Goff and Gardner, 2004); thickness in cross section is speculative; thickness in Sierra de los Valles east of map area exceeds 500 m.

Tghd — **Hornblende dacite of Cerro de la Garita (La Grulla Formation)** — Dark gray, massive to sheeted, sparsely porphyritic dacite with phenocrysts of plagioclase, conspicuous hornblende, sanidine, biotite, and minor clinopyroxene in a devitrified groundmass containing tiny microlites of plagioclase, hornblende, and pyroxene; vent caps southern part of Cerro de la Garita and flows spread west of vent; overlies biotite andesite (*Tga*); date on biotite is 7.34 ± 0.07 Ma (W. McIntosh, *unpublished data*); maximum exposed thickness is 30 m.

Tga — **Biotite andesite of Cerro de la Garita (La Grulla Formation)** — Gray to pale pink, massive to sheeted, porphyritic andesite lavas with phenocrysts of plagioclase, biotite, clinopyroxene, orthopyroxene, opaque oxides, sparse hornblende and rare resorbed quartz in a groundmass containing microlites of plagioclase, pyroxene, and opaque oxides; hornblende and biotite are commonly oxidized; contains plagioclase-pyroxene-biotite clots; groundmass is trachytic; most samples are devitrified; contains substantial amounts of flow breccia; distinguishable from other volcanic rocks on north caldera rim by abundant, equant feldspar crystals and conspicuous biotite; overlies sandstone (*Ts*) and Paliza Canyon andesite (*Tpa*) and overlain by hornblende dacite (*Tghd*); intruded by altered rhyolite dike (*Tbh*) in northeast corner of quadrangle and displays weak hydrothermal alteration to silica, clay and Fe-oxides near intrusive contacts; vent area believed to be at Cerro de la Garita; flows apparently filled paleo-depression or paleocanyon south of Cerro de la Garita that predated formation of Toledo caldera; date on biotite is 7.61 ± 0.07 Ma (W. McIntosh, *unpublished data*); maximum exposed thickness is about 330 m.

Tgb — **Olivine basalt (La Grulla Formation)** — Black to gray lava flow exposed at base of slope in northwestern portion of caldera wall; contains abundant phenocrysts of olivine, clinopyroxene and plagioclase in glassy, intersertal groundmass of plagioclase, pyroxene and opaque oxides. Olivine is altered to complex mixture of Fe-oxides, silica and clay (iddingsite). Flow contains abundant vesicles near top; underlies biotite andesite of La Grulla Formation (*Tga*); base of unit not exposed; age is 7.80 ± 0.13 Ma; maximum exposed thickness is about 30 m.

Tpv — **Volcaniclastic deposits —** Black to gray to pale pink volcaniclastic unit consisting predominately of gravelly fluvial deposits, lahars, block and ash flows, and other debris flows; mostly formed contemporaneously with with Paliza Canyon (and La Grulla?) Formations but may extend into Pliocene; locally contains hyper-concentrated flow and fluvial deposits, scoria and cinder deposits, and pyroclastic fall deposits; contains andesite flow-breccias too small or thin to map; unit accumulated in small basins, topographic lows, and canyons cut into Paliza Canyon volcanoes; most of unit mapped according to the definition of Cochiti Formation described by Bailey, *et al*., (1969) and Gardner, *et al*.(1986) with stratigraphic interpretation extended to Pliocene (Lavine, *et al*., 1996; Smith and Lavine, 1996); overlies Abiquiu Formation (*Ta*) and underlies Otowi Member Bandelier Tuff (*Qbo*) along San Antonio Creek in west edge of map; age bracketed between roughly 3 and about 13 Ma; maximum exposed thickness about 70 m.

Tbh — **Rhyolite intrusive rocks (Bearhead Rhyolite)** — 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; rarely flow-banded; dikes not uniformly tabular and 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 Paliza Canyon Formation rocks, Tertiary sedimentary rocks (*Ts*) and Tschicoma andesite (*Tga*) on the north caldera rim; 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; dates on various Bearhead units in southern Jemez Mountains range from about 4.81 to 7.83 Ma (Justet and Spell, 2001; Kempter *et al*., 2007; Goff *et al*., 2011); maximum observed thickness about 100 m.

Tpdt — **Porphyritic dacite tuff (Paliza Canyon Formation)** — Distinctive unit of pale green to gray, massive, lithic-rich tuff with conspicuous crystals of biotite and tiny hornblende, and crystals of plagioclase; contains lithic fragments of andesite, dacite, rhyolite, possible intrusive rocks and sandstone in altered matrix of dense to vesicular dacite; alteration consists of silica, clay, Fe-oxides and probable chlorite; exposed only in lower central caldera wall area; underlies andesite lava (*Tpa*); intrudes andesite in possible vent area located in fault block south of caldera wall; may be correlative with similar looking dacite tuff found as megabreccia block in northern part of resurgent dome (*Qxpt*), K-Ar date of altered tuff is 8.20 ± 0.29 Ma (WoldeGabriel, 1990); maximum exposed thickness about 40 m.

Tpbd — **Porphyritic biotite dacite (Paliza Canyon Formation)** — Eroded flows of gray, glassy to devitrified 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; exposed only along north edge of San Antonio Creek in eastern map area in fault contact with altered andesite (*Tpa*); vent area unknown; unit not dated; maximum exposed thickness is 12 m.

Tpa — **Two-pyroxene andesite, undivided (Paliza Canyon Formation)** — 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 mafic 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 *Ts*; intruded by *Tbh*; vent areas not known; flows in map area not dated; fresh flows of *Tpa* in southern Jemez Mountains range from 8.8 to 9.4 Ma (Gardner, *et al*., 1986; Goff, *et al*., 2005a; 2005b); altered flows in north caldera wall are dated at 6.96 to 7.07 Ma (WoldeGabriel, 1990); stack of flows in northern caldera wall has maximum exposed thickness of about 490 m. *Tpa* shown in cross section B-B' is interpreted from the geothermal well intercepts listed in Nielson and Hulen (1984); thickness in wells is highly variable.

Santa Fe Group (Miocene)

Ts, Tsf — **Volcaniclastic deposits (Pliocene to Miocene)** — Thick sequence of sedimentary deposits, intercalated with Paliza Canyon and Tschicoma formation volcanic and volcaniclastic deposits; exposed in northeast corner of map and best exposed on Valle Toledo quadrangle to west (Gardner, *et al.*, 2006); 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; volcanic fragments originate from sources in the Paliza Canyon Formation; *Ts* is interbedded with andesite lavas (*Tpa*) and is overlain by biotite andesite (*Tga*); intruded by rhyolite dikes and plugs (*Tbh*). Assignment of *Ts* is problematic; may be equivalent to portions of the Santa Fe Group (Chamita Formation), Puye Formation, and volcaniclastic deposits of the Keres Group (*Tpv*, 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, allowing interbeds of arkosic sandstone in volcanic and volcaniclastic material; maximum exposed thickness in map area is roughly 100 m. Unit *Tsf* is recognized in drill holes such as VC-2b, Baca-16, Baca-13, etc. (Nielsen and Hulen, 1984; Goff and Gardner, 1994) and consists of well-sorted, non-indurated quartz-rich sandstone; thickness in well VC-2b is 48 m; thickness in other holes may be as much as 75 m.

Abiquiu Formation (Miocene to Oligocene?)

Ta — **Sandstone and siltstone** — White to buff well-bedded sandstone and siltstone; contains grains of rounded to subangular quartz, plagioclase, potassium feldspar, quartzite, and crystalline rocks; contains rare grains of diopside and possible tremolite; cement is commonly opaline; thus beds are sometimes very indurated; calcite and limonite cement less common; exposures on Valle San Antonio quadrangle look different from typical exposures (e.g., Goff, *et al*., 2005a; Kelley, *et al*., 2004) in that they contain substantial amounts of laminated silt and clay of possible lacustrine origin; maximum observed thickness is 40 m in northeast caldera wall; not recognized in any deep wells drilled around and within resurgent dome or northern moat; $^{40}Ar/^{39}Ar$ age on ash bed in upper Abiquiu Formation to south is 20.6 ± 0.1 Ma (Osburn, *et al*., 2002).

Paleozoic Rocks

Permian

Pu — **Permian rocks, undivided (only on cross sections) —** Sedimentary rocks consisting of (top to bottom) the Glorieta Sandstone, the Yeso Formation, and the Abo Formation; well-exposed to west and southwest in adjacent quadrangles; Glorieta Sandstone consists of white to reddish white, well-sorted, generally plane to cross-bedded quartz arenite with some mica; forms fractured cliffs; Yeso Formation is composed of orange red, well-sorted, medium-grained quartzofeldspathic sandstone and minor siltstone; Abo Formation is made up of brick red to brownish red quartzofeldspathic sandstone, siltstone and mudstone; contains some obvious mica; contains minor conglomerate and limestone; Yeso and Abo are usually indurated in geothermal wells (cross section A-A'), displaying considerable greenish hydrothermal alteration and minor calcite and quartz veining; contact of *Pu* with underlying Madera Formation is sharp to gradational depending on location; thickness is 498 m in VC-2b (Goff and Gardner, 1994); thickness is 501 m in Baca-12 just south of quadrangle boundary (Nielson and Hulen, 1984).

Mississippian - Pennsylvanian

MPu — **Mississippian-Pennsylvanian rocks, undivided (only on cross sections) —** Light to dark gray, fossiliferous limestone and micrite with subordinate gray to buff arkose, sandstone, shale and mudstone (Madera and Sandia Formations); displays considerable hydrothermal alteration, veining, faulting, fracturing and brecciation in geothermal wells (Goff and Gardner, 1994 and references therein); thickness in VC-2b is 262 m; thickness is 293 m in Baca-12 (Nielson and Hulen, 1984); the Sandia Formation is not identified in Baca-12 but is probably present.

Precambrian Rocks

p€u — **Precambrian rocks, undivided (only on cross sections) —** Highly variable unit of crystalline rocks throughout Jemez Mountains region (Goff, *et al*., 1989, Table 2); displays minor to severe hydrothermal alteration; in VC-2b the upper Precambrian consists of roughly 204 m of gray to green to pink, hydrothermally altered, coarse-grained, biotite quartz monzonite; alteration minerals are epidote-illite-phengite-chlorite-quartz-pyrite-calcite (Goff and Gardner, 1994); in Baca-12 consists of 90 m (Nielson and Hulen, 1984) of white to green, altered quartz monzonite containing epidote-chlorite-pyrite-actinolite-quartz-calcite (Hulen and Nielson, 1988); age is 1.62 to 1.44 Ga (Brookins and Laughlin, 1983).

REFERENCES

(See accompanying report).

COMMENTS TO MAP USERS

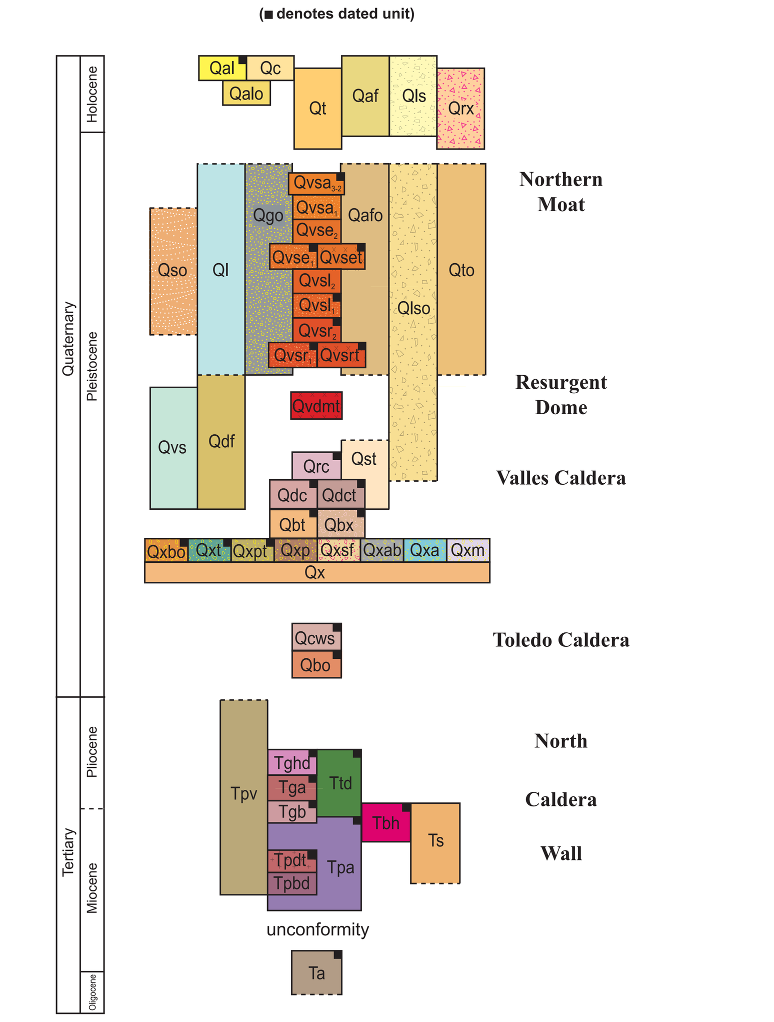
A geologic map displays information on the distribution, nature, orientation, and age relationships of rock and deposits and the occurrence of structural features. Geologic and fault contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic 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.

The map has not been reviewed according to New Mexico Bureau of Geology and Mineral Resources standards. The contents of the report and map should not be considered final and complete until reviewed and published by the New Mexico Bureau of Geology and Mineral Resources. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of New Mexico, or the U.S. Government.

CORRELATION OF MAP UNITS

(■ denotes dated unit)



GEOLOGIC CROSS SECTIONS