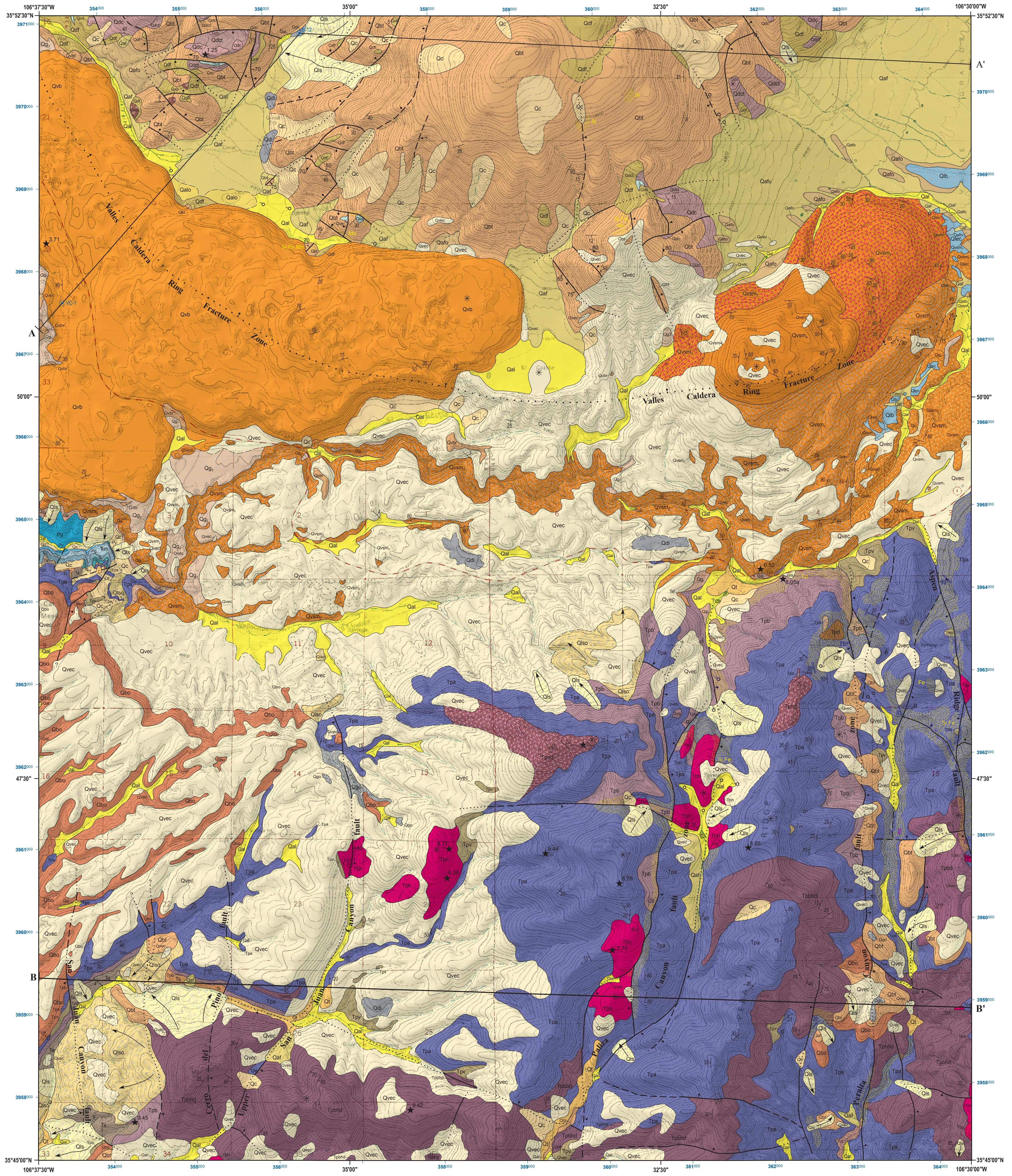
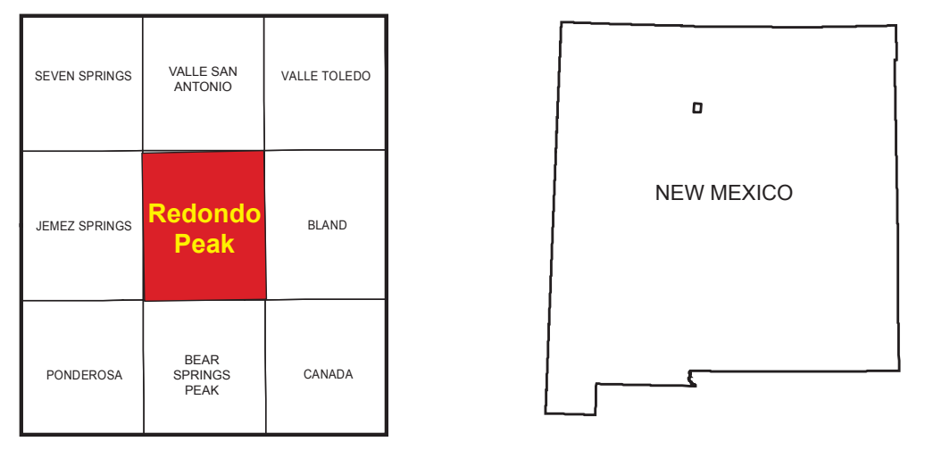
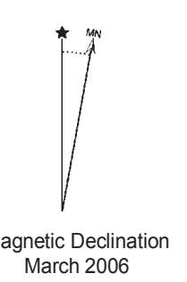


Base from U.S.Geological Survey 1970, from photographs taken 1964-65,
revised from photographs taken 1990, field checked in 1990, edited in 1993.
1927 North American datum, UTM projection -- zone 13N
1000- meter Universal Transverse Mercator grid, zone 13, shown in blue tics.

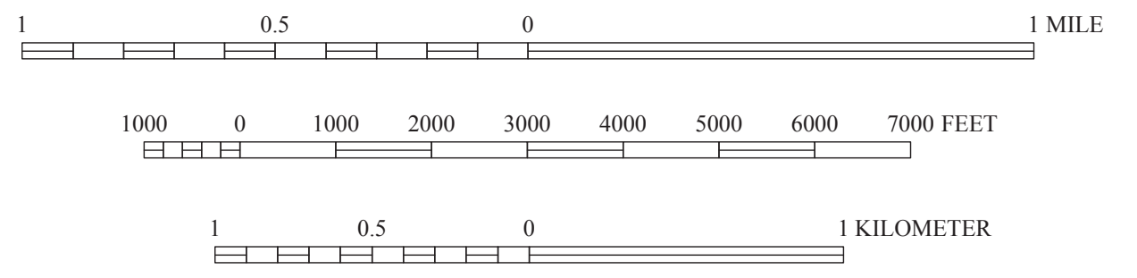


QUADRANGLE LOCATION



Magnetic Declination
March 2006
9º 53' 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*).

New Mexico Bureau of Geology and Mineral Resources
Open-file Geologic Map 111

New Mexico Bureau of Geology and Mineral Resources
New Mexico Tech
801 Leroy Place
Socorro, New Mexico
87801-4796

[575] 835-5490

Geologic map of the Redondo Peak quadrangle, Sandoval County, New Mexico.

January 2006

by
Fraser Goff [1], Jamie N. Gardner[2], Steven L. Reneau[3], and Cathy J. Goff [4].

[1] *Dept. of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131*
[2] *14170 NM-4, Jemez Springs, NM 87025*
[3] *Earth and Environmental Sciences Division, EES-9, Los Alamos National Laboratory, Los Alamos, NM 87545*
[4] *Independent Consultant, 5515 Quemazon, Los Alamos, NM 87544*

MAP SYMBOLS

A ⊢⊣ A'	Geologic cross section.
	Contact - Solid where exposed or known; dashed where approximately located; dotted where concealed.
70	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.
40	Strike and dip of inclined bedding.
75	Strike and dip of magmatic foliation.
70	Strike and dip of inclined joints.
↙ ↘	Direction of flow of landslide failure.
★ 1.25	Location of radiometric-dated sample (age in Ma; "a" indicates altered rock sample).
	Breccia zones along faults.
✳	Volcanic vent (queried if uncertain).
	Cold spring.
⊙ B-12	Geothermal well.
∿∿	Alteration associated with fault shear.
	Localized geochemical alteration.

Alteration Products:

Ep	Vug/vein epidote	Z	Fiberous zeolite
Fe	Iron oxidation	Mn	Abundant pyrolusite
Si	Quartz/chalcedony		

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), Goff *et al.* (2007), Gardner *et al.* (2010), and Goff *et al.* (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; consists of underlying rock units at each area; unit mapped only where extensive at pumice mines and well pads; not shown in correlation chart; maximum thickness more than 10 m but usually less than 3 m.

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 contacts or fault relations; mostly Holocene and Pleistocene in age; thickness can locally exceed 10 m.

Qt **Terrace gravel** — Slightly older alluvium that lies along the margins of present streams and basins; now undergoing erosion; mapped in only a few locations; maximum thickness as much as 15 m.

Qaf **Alluvial fans —** Fan-shaped deposits of coarse to fine gravel and sand at the mouths of valleys and in the Valle Grande; some fan deposits (*Qafu*) may be difficult to distinguish from older alluvial fans (described below); maximum exposed thickness about 15 m.

Qls **Landslides** — Unsorted debris that has moved chaotically down steep slopes, or 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.

Qalo **Older alluvium —** Deposits of gravel, sand and silt that are overlain by alluvial fans; includes bog deposits north of Banco Bonito rhyolite near area where Redondo Creek emerges from the resurgent dome; age varies; estimated thickness unknown.

Qlec, Qlb **El Cajete lake deposits —** Deposits of reworked El Cajete pumice and coarse sand in the 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); 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 exposed thickness about 4 m.

Qafo **Older alluvial fans —** Fan deposits of coarse to fine gravel and sand in the Valle Grande and elsewhere that are older than the El Cajete pumice or contemporaneous lacustrine units; maximum exposed thickness is unknown.

Qlso **Older landslides —** Older slide deposits that are overlain by El Cajete pumice or (rarely) by the Tshirege Member of the Bandelier Tuff; latter examples occur in San Juan Canyon in southwest part of the map; maximum exposed thickness about 25 m.

Qlsm **South Mountain lake deposits** — Laminated to bedded, diatomaceous silty clay and mudstone; minor siltstone and sandstone; found in Valle Grande (Conover *et al.*, 1963; Griggs, 1964; Reneau *et al.*, 2004; Fawcett *et al.*, 2004); lake formed when South Mountain rhyolite dammed drainage of the East Fork Jemez River (Reneau *et al.*, 2004); possibly interbedded with older alluvial fan deposits (*Qafo*); overlies sedimentary deposits time equivalent to Qg_1; age ≤520 ka; maximum drilled thickness in Valle Grande is about 95 m (Conover *et al.*, 1963; Fawcett *et al.*, 2011); drilled thickness in VC-3 core hole east of Redondo Peak quadrangle is 76 m.

Qg3, Qg2, Qg1 **Sedimentary deposits of southern caldera moat** — Various deposits of alluvium, colluvium, debris flows and minor lacustrine beds interbedded with lavas and pyroclastic rocks in the southern moat of Valles caldera; formed during at least three episodes of incision and blockage of the ancestral East Fork of the Jemez River and tributaries; generally poorly exposed; identified mostly by stratigraphic position; Qg_1 underlies the South Mountain rhyolite (*Qsm*) and is primarily gravels containing Bandelier Tuff, aphyric rhyolite, precaldera volcanics and rare Permian fragments; contains diatomaceous lacustrine beds just downstream of Jemez Falls; Qg_2 overlies *Qsm* but underlies *Qvec* and *Qvbr*; Qg_2 contains fragments of Bandelier Tuff and precaldera volcanics near southeast edge of South Mountain; also contains fragments of *Qsm* further to west; displays extensive low-temperature hydrothermal alteration in VC-1 corehole; Qg_3 underlies *Qvb* but overlies *Qvec* and *Qvbr*; contains fragments of Bandelier Tuff, precaldera volcanics, Permian redbeds, Pennsylvanian limestone and Precambrian crystalline rocks in western exposures; also contains large blocks of glassy rhyolite in area south of El Cajete vent but north of Jemez Falls campground; maximum exposed thickness about 40 m.

Qvs **Early caldera fill - lacustrine and alluvial 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 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.

Qdf **Early caldera fill - debris flow, landslide, and colluvial deposits** — Dark gray to buff, matrix-supported beds containing fine silt to boulders of various early caldera rhyolites, Bandelier Tuff, precaldera volcanics, Miocene to Permian sandstone, Pennsylvanian limestone and Precambrian crystalline rocks; unit contains minor fluvial deposits; older lithologies are more abundant in the lower beds; upper beds generally contain more precaldera volcanics; rare beds contain mostly Bandelier Tuff; formed during rapid slumping and erosion of caldera walls, erosion of exposed megabreccia blocks (*Qx*), 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 observe; interbedded with and overlies all other units on resurgent dome; maximum exposed thickness in map area is 50 m.

Qgo **Older gravels** — Dark gray to buff gravel and debris flow deposits interbedded with the Tshirege Member of the Bandelier Tuff south of the caldera margin; consists primarily of precaldera volcanic rocks and Bandelier Tuff; exposures are small and usually poor; without stratigraphic control, unit is difficult to distinguish from Tpy if no Bandelier Tuff clasts are present; maximum exposed thickness is 25 m.

Tewa Group (Pleistocene)
Valles Rhyolite
East Fork Member

Qvb **Banco Bonito Flow —** Thick viscous lava flows that contain phenocrysts of plagioclase, quartz, biotite, hornblende, clinopyroxene and rare sanidine in a black glassy to gray devitrified groundmass; contains some quartz with clinopyroxene reaction rims; top of unit is pumiceous; erupted from vent at east end of Banco Bonito ridge in north central map area; fills three deep, west- to northwest-trending paleocanyons cut into the Battleship Rock ignimbrite in southwestern moat of Valles caldera; consists of at least two thick flow units (Manley and Fink, 1987; Gardner *et al.*, 1987); upper surface of unit preserves pressure ridges and valleys with up to 10 m of relief; overlies discontinuous sedimentary and pyroclastic deposits; unit dated at 37 to 45 ka (Ogoh *et al.*, 1993; Phillips *et al.*, 1997) but age still has uncertainties (Lepper and Goff, 2007); maximum exposed thickness roughly 140 m.

Qvcr **VC-1 rhyolite (only on cross section A-A')** — Black flow banded lava containing sparse phenocrysts of plagioclase, quartz, biotite, clinopyroxene, hornblende and rare sanidine in very glassy to perlitic matrix; has unusual prismatic fracturing; found only in VC-1 corehole where it is 19 m thick (Gardner *et al.*, 1987; Goff and Gardner, 1994); underlies 14 m of pumice, fragmented ignimbrite and sediments now correlated with unit Qg_3 sedimentary rocks of southwest moat; separated from underlying *Qvbr* by 0.1 m of sediment baked orange by VC-1 rhyolite; apparently filling shallow paleovalley in southern moat; vent area not known but probably near Banco Bonito and El Cajete vents; may be equivalent to large glassy rhyolite blocks found in uppermost beds of El Cajete pyroclastic beds (Wolff *et al*. 1996); age not resolved but probably around 50 ka.

Qvbr **Battleship Rock ignimbrite** — Ash flow tuff sheets (ignimbrites) consisting of rhyolitic pumice, lithic clasts, crystal fragments, glass shards, and volcanic ash; pumice contains phenocrysts of plagioclase, quartz, biotite, hornblende, clinopyroxene, and rare sanidine; may be densely welded and have conspicuous fiamme; erupted from E1 Cajete crater in north central map area; consists of at least three flow units in VC-1 corehole; consists of many smaller ignimbrites interbedded with the upper part of the El Cajete pyroclastic beds; mostly filled paleocanyons in southwestern moat of Valles caldera; underlies Banco Bonito Flow and various sedimentary deposits; overlies South Mountain rhyolite and various sedimentary deposits; estimated age is 50 to 60 ka (Toyoda *et al.*, 1995; Reneau *et al.*, 1996); maximum exposed thickness about 30 m.

Qvec **El Cajete pyroclastic beds** — White to tan, moderately sorted, pyroclastic fall deposits of vesicular rhyolite; pumice clasts contain sparse phenocrysts of plagioclase, quartz, and biotite with rare microphenocrysts of hornblende and clinopyroxene; some clasts contain resorbed quartz with pale green, clinopyroxene reaction rims; originated from El Cajete crater (Bailey *et al*., 1969; Smith *et al*., 1970; Gardner *et al.*, 1986; Self *et al.*, 1988; Wolff *et al.*, 1996); maximum diameter of clasts is about 50 cm near vent but clast size diminishes away from source; contains relatively abundant lithic clasts of Bandelier Tuff and precaldera volcanic rocks but rare Paleozoic and Precambrian rocks; also contains blocks of black glassy rhyolite near vent; includes pyroclastic surge deposits in near-vent areas; underlies Banco Bonito Flow and various sedimentary deposits; upper part of unit includes thin ignimbrites of Battleship Rock; overlies South Mountain rhyolite and various sedimentary deposits; unit dated at about 50 to 60 ka (Toyoda *et al.*, 1995; Reneau *et al.*, 1996); unit extensively reworked by erosion, collecting on south and east facing slopes; maximum exposed thickness about 70 m in vent area and as much as 50 m in valleys of the southern map area; thins on mesa tops and hills forming scant exposures too thin or small to map.

$Qvsm_4$, $Qvsm_3$, $Qvsm_2$, $Qvsm_1$ **South 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 very minor pyroclastic deposits at base of flow overlying sedimentary deposit just east of Los Conchas campground on NM highway 4; erupted from South Mountain in eastern map area; consists of four main flow units (oldest to youngest Qsm_1 to Qsm_4); fills paleocanyon in southern moat of Valles caldera; contains low-temperature hydrothermal alteration in the VC-1 corehole (Gardner *et al*., 1987); underlies Battleship Rock ignimbrite, El Cajete pyroclastic beds and various sedimentary deposits; overlies sedimentary deposits and Permian red beds; ^{40}Ar/^{39}Ar age is 0.52 ± 0.01 Ma (Spell and Harrison, 1993); maximum exposed thickness about 100 m west of Jemez Falls; at least 450 m thick in vent area.

Qdc **Deer Canyon Member, lava unit** — Massive, gray to pale pink, porphyritic rhyolite lavas usually containing abundant phenocrysts of sanidine and quartz (Bailey *et al.*, 1969); sanidine is occasionally chatoyant; fresh samples rarely confused with densely welded Bandelier Tuff; lavas display occasional pepperite and pillow breccia; most exposures are highly deformed by uplift and faulting on the resurgent dome of Valles caldera; many exposures show extensive zeolitic alteration and silicification (Chipera *et al.*, 2007); usually overlies Deer Canyon tuffs (*Qdct*) but occasionally interbedded with them; interbedded with *Qdf* and generally overlies *Qvs*; overlies Bandelier Tuff; age of thin flow on southwest shoulder of Redondo Border is 1.25 ± 0.02 Ma (W. McIntosh, NMBGMR); maximum exposed thickness about 40 m.

Qdct **Deer Canyon Member, tuff unit** — 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*; maximum exposed thickness about 30 m.

Qx, Qxp **Caldera collapse breccia** — Caldera-wall landslide breccias (megabreccias) that accumulate synchronously during caldera formation (Lipman, 1976); incorporated in and interbedded with intracaldera Bandelier Tuff (Goff *et al.*, 2007); mapped if more than 30 m across; three megabreccia blocks of Miocene andesitic rocks of the Paliza Canyon Formation (?) (*Qxp*) occur on the southwest shoulder of Redondo Border; other blocks of *Qx* probably 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 tuff are preserved; maximum exposed thickness is highly variable; not shown in cross section A-A' for clarity.

Qbt **Bandelier Tuff, Tshirege Member —** 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 black clinopyroxene and orthopyroxene and extremely rare microphenocrysts of fayalite (Warshaw and Smith, 1988; Warren *et al.*, 2007); sanidine typically displays blue iridescence; consists of multiple flow units in a compound cooling unit (Smith and Bailey, 1966; Gardner *et al.*, 1986; Broxton and Reneau, 1995; Warren *et al.*, 1997). Upper flow units generally more welded than lower ones. Intracaldera flow units are highly welded with well-developed pumice 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 of the caldera; originated from catastrophic eruptions that formed 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.

Qbo **Bandelier Tuff, Otowi Member** — 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 (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; forms broad plateau covered with *Qvec* southwest of the caldera margin; 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 about 60 m.

Tertiary (Pliocene - Oligocene?) Deposits

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

Ttu **Dacite and andesite, undivided, only on cross section A-A' —** Gray to pale pink porphyritic dacite and andesite with phenocrysts of plagioclase, orthopyroxene, clinopyroxene ± hornblende; underlies the Otowi Member of the Bandelier Tuff (*Qbo*); overlies Paliza Canyon andesite (*Tpa*); ages of major domes east of map area roughly 2 to 5 Ma (Goff *et al*., 2002; Kempter and Kelley, 2002); thickness in cross section is speculative; thickness in Sierra de los Valles east of map area exceeds 500 m.

Bearhead Rhyolite (Pliocene-Miocene)

Thb **Hydrothermal breccia and quartz vein** — Relatively small areas of hydrothermal rocks in north-trending fault zone on Aspen Ridge along southeastern edge of map; probably associated with volcanism of the Bearhead Rhyolite because of close spatial and structural relations but may be related to Keres Group volcanism. *Thb* consists of relatively circular, vertical pipes of mosaic breccia ≤100 m in diameter containing fragments of altered andesite in a fine-grained, silicified matrix and a poorly exposed lens of quartz veins about 300 m long and 50 m wide cutting altered andesite; both have been modified by faulting; probably between 5.6 and 8.5 Ma (WoldeGabriel and Goff, 1989); vertical thickness is unknown.

Tbh, Tbp **Rhyolite intrusive rocks (Bearhead Rhyolite)** — White to gray intrusions, domes, and flows of slightly porphyritic to aphyric devitrified rhyolite containing rare phenocrysts of quartz, potassium feldspar, and fresh to altered biotite ± plagioclase; margins of flows may be slightly pumiceous; contains minor flow breccia; margins of intrusions may display chilled contacts with black to gray to pink obsidian, perlite, and banded spherulitic rock; interiors of units are generally flow-banded; associated lithic-rich tuffs (*Tbp*) occur only in extreme southeast part of map; small, hydrothermally altered plugs and dikes occur along fault zones in southeast map area; intrudes or overlies all other Keres Group rocks; apparently surrounded by *Tpv* in south-central map area; dates on various Bearhead units range from about 6.0 to 7.2 Ma (Gardner et al., 1986; Goff et al., 1990; Justet, 1996); ^{40}Ar/^{39}Ar date on unnamed dome in uppermost San Juan Canyon is 6.38 ± 0.09 Ma (Justet, 1996); maximum observed thickness about 170 m. Two ^{40}Ar/^{39}Ar dates on the faulted rhyolite south of Cerro Pelado range from 7.6 to 7.8 Ma (W. McIntosh and L. Peters, NMBGMR).

Paliza Canyon Formation (Miocene)

Tpv **Volcaniclastic Member —** Black to gray to pale pink volcaniclastic unit consisting predominately of gravels, lahars, block and ash flows, and other debris flows; mostly formed contemporaneously with Keres Group but may extend into Pliocene; locally contains hyper concentrated flow and fluvial deposits, cinder deposits, and pyroclastic fall deposits; contains andesite flow-breccias too small or thin to map; unit has accumulated in small basins, topographic lows, and canyons cut into Keres Group volcanoes; unit generally thickens to south and east toward San Juan and Paliza canyons; 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 (Smith and Lavine, 1996); interbedded with *Tpb* and *Tpa* in lower San Juan Canyon; interbedded with *Tpa* and *Tpbhd* in southern west wall of Peralta Canyon; overlies *Tpa*, *Tphd* and *Tpbhd* on eastern flanks of Cerro Pelado Ridge; apparently surrounds dome of *Tbh* in south-central map area; age of *Tpv* is bracketed between roughly 3 and about 13 Ma; maximum exposed thickness about 70 m.

Tpd **Aphyric dacite** — Greenish gray, flow banded, plug-like body exposed along fault scarp north-northeast of Las Conchas peak; groundmass is very fine grained and trachytic, with sparse microphenocrysts of plagioclase, hornblende, opaque oxides, and possibly potassium feldspar; pervasively altered to chlorite, silica, and clay; margins display intrusion breccia with small blocks and fragments of basalt and andesite in dacite host; maximum exposed thickness about 120 m.

Tpbd **Porphyritic biotite dacite** — Eroded dome and flows of gray to pale pink dacite having ≤5 % phenocrysts of plagioclase, biotite, and pyroxene in a trachytic groundmass of plagioclase, pyroxene, and opaque oxides; contains complexly zoned and fritted plagioclase phenocrysts ≤10 mm in diameter; contains minor clots of plagioclase and pyroxene; most specimens are extensively altered to silica, chlorite, clay, Fe-oxides and minor calcite; intrudes and overlies andesite in fault zone along southeast side of map; maximum exposed thickness is 160 m.

Tphd **Porphyritic hornblende dacite** — Eroded flows capping the summits of Las Conchas and Los Griegos (Smith *et al.*, 1970; Gardner, 1985); the latter includes a remnant of a vent; flows overlie andesite; Las Conchas consists of gray to pale pink flow banded dacite containing about 12% phenocrysts of plagioclase, hornblende, orthopyroxene and clinopyroxene in a trachytic groundmass of plagioclase and pyroxene; hornblende is ≤10 mm long and completely oxidized; contains plagioclase-pyroxene clots ≤15 mm in diameter; unit is pervasively altered; groundmass is moderately silicified and cracks contain opal; phenocrysts contain Fe-oxides, silica, calcite, and chlorite; maximum exposed thickness is 50 m; Los Griegos consists of virtually unaltered, gray, flow banded dacite with complexly zoned and fritted plagioclase (8%; ≤15 mm), conspicuous hornblende (6%; ≤15 mm), and rare ortho- and clinopyroxene phenocrysts in a trachytic groundmass of plagioclase and minor opaques; contains rare clinopyroxene clots ≤2 mm in diameter; ^{40}Ar/^{39}Ar date on hornblende from Los Griegos is 8.71 ± 0.66 Ma (W. McIntosh and L. Peters, NMBGMR); maximum exposed thickness is 75 m.

Tpbhd **Porphyritic biotite, hornblende dacite** — Extensive dome and flow complex filling east-west trending paleocanyon in southern map area (Smith *et al*., 1970; Gardner, 1985); contains 15% phenocrysts of plagioclase, biotite (≤3 mm), oxyhornblende (≤5 mm), orthopyroxene, and clinopyroxene, in a trachytic groundmass filled with plagioclase and pyroxene microlites; groundmass also contains apatite microphenocrysts up to 0.5 mm long; plagioclase phenocrysts (≤20 mm) are fritted and complexly zoned; contains gray, vesiculated enclaves of plagioclase, pyroxene ± hornblende ± biotite up to 30 cm in diameter; vented from hill east of Cerro del Pino; relatively fresh in west near vent but displays considerable hydrothermal alteration in east, particularly along faults and near canyon bottoms; interbedded with andesite flows (*Tpa*); $^{40Ar/39Ar}$ age of sample from ridge east of vent is 9.42 ± 0.22 Ma (Justet, 2003); exposed thickness at least 275 m north and west of Cerro del Pino.

Tpa **Two-pyroxene andesite, undivided** — Domes, flows, flow breccia, spatter deposits, and scoria of andesite from multiple sources; individual units are slightly porphyritic to very porphyritic; flows dense to highly vesicular; tends to be relatively fresh and sometimes glassy in the west to hydrothermally altered in east; typically contains 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; visible alteration generally consists of silica, calcite, Fe-oxides, clay ± chlorite ± zeolite ± pyrite; underlies *Tpbd* and *Tpbhd*; interbedded with *Tpv*, *Tpbhd* and *Tpb*; Cerro Pelado ridge is probably the vent area for many of the flows; black porphyritic andesite along crests of Cerro Pelado and Peralta Ridge have ^{40}Ar/^{39}Ar dates of 8.78 ± 0.14 and 8.85 ± 0.17 Ma; platy andesite midway down west flank of Cerro Pelado is dated at 9.44 ± 0.21 Ma (Justet, 2003); maximum exposed thickness over 310 m near Cerro Pelado.

Tpb **Olivine basalt and basaltic andesite, undivided (Paliza Canyon Formation)** — Flows, flow breccia, spatter deposits, and scoria of basalt and subordinate basaltic andesite from multiple sources; most units are slightly porphyritic; flows dense to highly vesicular; tends to be relatively fresh in southwest to highly altered in northeast and east; typical basalt contains 5 % phenocrysts of olivine and plagioclase (≤2 mm) in intersertal groundmass of olivine, clinopyroxene, plagioclase, opaque oxides, and glass; olivine occurs rarely in clots ≤3 mm in diameter; most olivine has high-temperature iddingsite; some flows have diktytaxitic texture; some flows have clinopyroxene phenocrysts; visible alteration consists of silica, calcite, Fe-oxides, clay ± zeolite ± chlorite ± epidote ± pyrite; interbedded with and underlies *Tpa*; overlies and possibly interbedded with Santa Fe Group (*Ts*); overlies Abiquiu Formation (*Ta*); ^{40}Ar/^{39}Ar date on basalt east of San Juan Canyon near southwest corner of map is 9.45 ± 0.07 Ma (W. McIntosh and L. Peters, NMBGMR); K-Ar age of hydrothermal clay in altered basalt on NM highway 4 south of Las Conchas is 8.05 ± 0.13 Ma (WoldeGabriel, 1990); maximum exposed thickness about 140 m.

Canovas Canyon Formation (Miocene)

Tcc **Canovas Canyon rhyolite tuff** — Poorly exposed unit in bottom of Peralta Canyon at southern edge of map; consists of bedded aphyric pumice and lithic fragments of sandstone and mafic volcanics in altered matrix of clay-rich rhyolitic ash; underlies *Tpa*; relation to *Tpb* unknown; maximum exposed thickness roughly 35 m.

Santa Fe Group (Miocene)

Ts **Volcaniclastic deposits (Pliocene to Miocene)** — Poorly exposed pale tan to pink sandstone and dark gray conglomerate; sandstone is generally well-sorted and usually non-indurated; grains are usually well-rounded and consist of weathered mafic volcanic rocks, plagioclase, altered olivine, weathered pyroxene and minor quartz; cement if present is calcite, silica, and Fe-oxides; conglomerate contains basalt and andesite pebbles and cobbles in a sandy matrix; beds too thin to map occur with basalt (Tpb) in area around Las Conches; underlies andesite (Tpa) in upper south wall of East Fork Canyon; underlies basalt in San Juan Canyon north of Cerro del Pino; relations with underlying Abiquiu Formation unclear; maximum observed thickness roughly 60 m; K-Ar date on basalt interbedded with upper Santa Fe Group east of map area is 16.5 ± 1.4 Ma (Gardner and Goff, 1984; Goff et al., 1990).

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; well-exposed in San Juan Canyon where it underlies basaltic rocks (Tpb); maximum observed thickness is 120 m; ^{40}Ar/^{39}Ar age on ash bed in upper Abiquiu Formation to southwest is 20.6 ± 0.1 Ma (Osburn et al., 2002).

Mesozoic Rocks

Triassic

Ʀu, Ʀc, Ʀm **Triassic rocks, undivided** — Poorly exposed rocks in middle south wall of East Fork Canyon consisting of three units; the youngest (Ʀu) is composed of brick-red to maroon, poorly exposed mudstone and bed of black conglomerate (Salitral shale and Poleo sandstone of the Chinle Group); the middle unit (Ʀcs) is composed of gray to yellow-brown coarse sandstone and conglomerate, the latter with distinctive yellow chert clasts (Shinarump Formation of the Chinle Group); and the oldest unit (Ʀm) consists of reddish brown micaceous siltstone and thinly bedded sandstone (Moenkopi Formation); underlies *Tpa* and *Ts*; overlies Pu; maximum exposed thickness roughly 40 m.

Paleozoic Rocks

Permian

Pu, Pg, Py **Permian rocks, undivided —** Well exposed rocks in lower south wall of East Fork Canyon consists of (top to bottom) the Glorieta sandstone, and the Yeso Formation. 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 (only in wells) 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; underlies Tru; contact of Pu with underlying Madera Formation is sharp to gradational depending on location; thickness is 90 m in VC-1 (Goff and Gardner, 1994); thickness is 501 m in Baca-12 (Nielson and Hulen, 1984); maximum exposed thickness in map area roughly 70 m.

Mississippian - Pennsylvanian

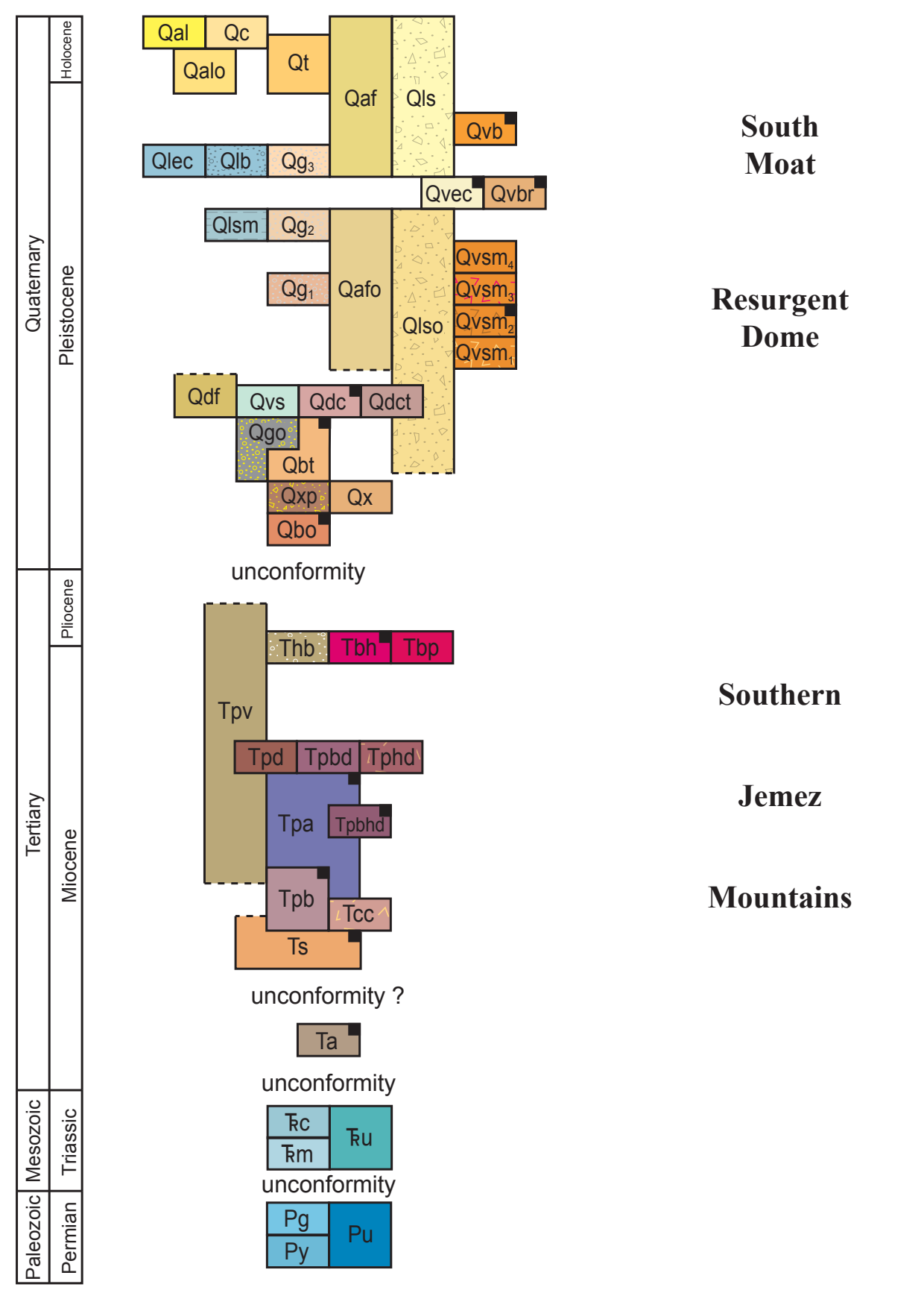
MIPu **Mississippian-Pennsylvanian rocks, undivided (only on cross section A-A') —** Light to dark gray, fossiliferous limestone and micrite with subordinate gray to buff arkose, sandstone, shale and mudstone (Madera Formation); displays considerable hydrothermal alteration, veining, faulting, fracturing and brecciation in geothermal wells (Goff and Gardner, 1994 and references therein); thickness is 390 m in VC-1; thickness is 293 m in Baca-12 (Nielson and Hulen, 1984); the Madera Formation is underlain in VC-1 by 17 m of hydrothermally altered shale, sandstone, conglomerate, and limestone of the Sandia Formation; the Sandia Formation is not identified in Baca-12 but is probably present.

Precambrian Rocks

p€u **Precambrian rocks, undivided (only on cross section A-A')** — Highly variable unit of crystalline rocks throughout Jemez Mountains region (Goff et al., 1989, Table 2); displays minor to severe hydrothermal alteration; in VC-1 consists of roughly 15 m of gray to green hydrothermally altered, molybdenite-bearing gneiss breccia; alteration minerals are illite-phengite-chlorite-quartz-pyrite-calcite (Hulen and Nielson, 1988; Goff and Gardner, 1994); in Baca-12 consists of 90 m (Nielson and Hulen, 1984) of altered quartz monzonite containing epidote-chlorite-pyrite-actinolite-quartz-calcite; age is 1.62 to 1.44 Ga (Brookins and Laughlin, 1983).

CORRELATION OF MAP UNITS

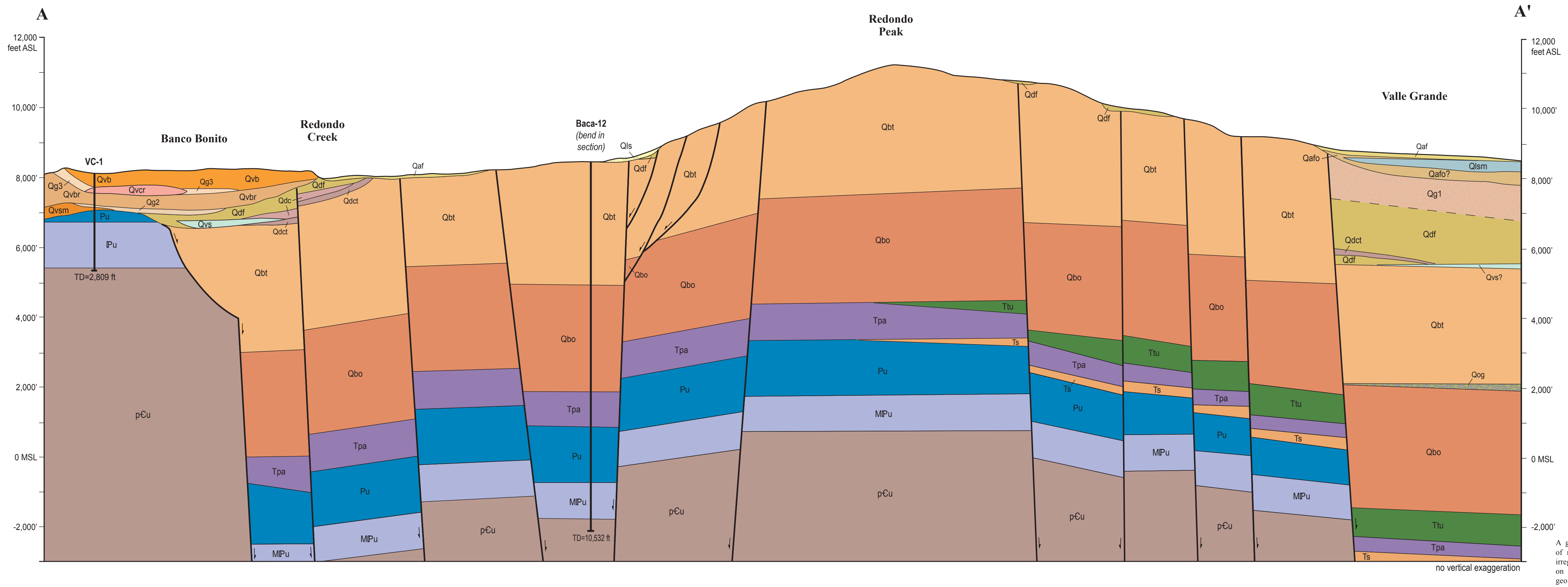
(■ denotes dated unit)

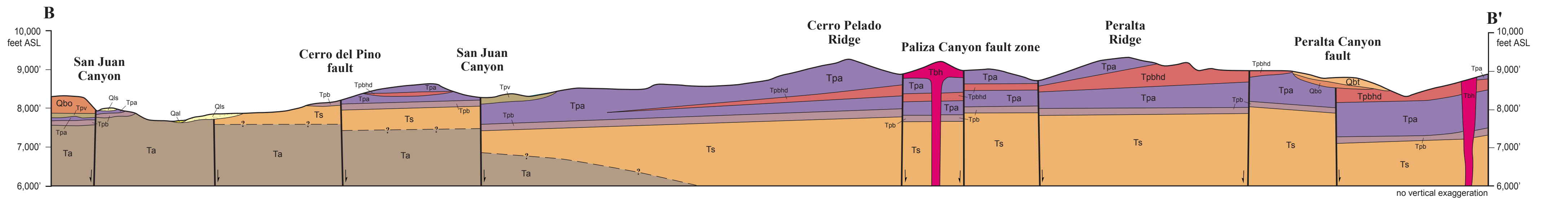


REFERENCES

(See accompanying report).

GEOLOGIC CROSS SECTIONS





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.