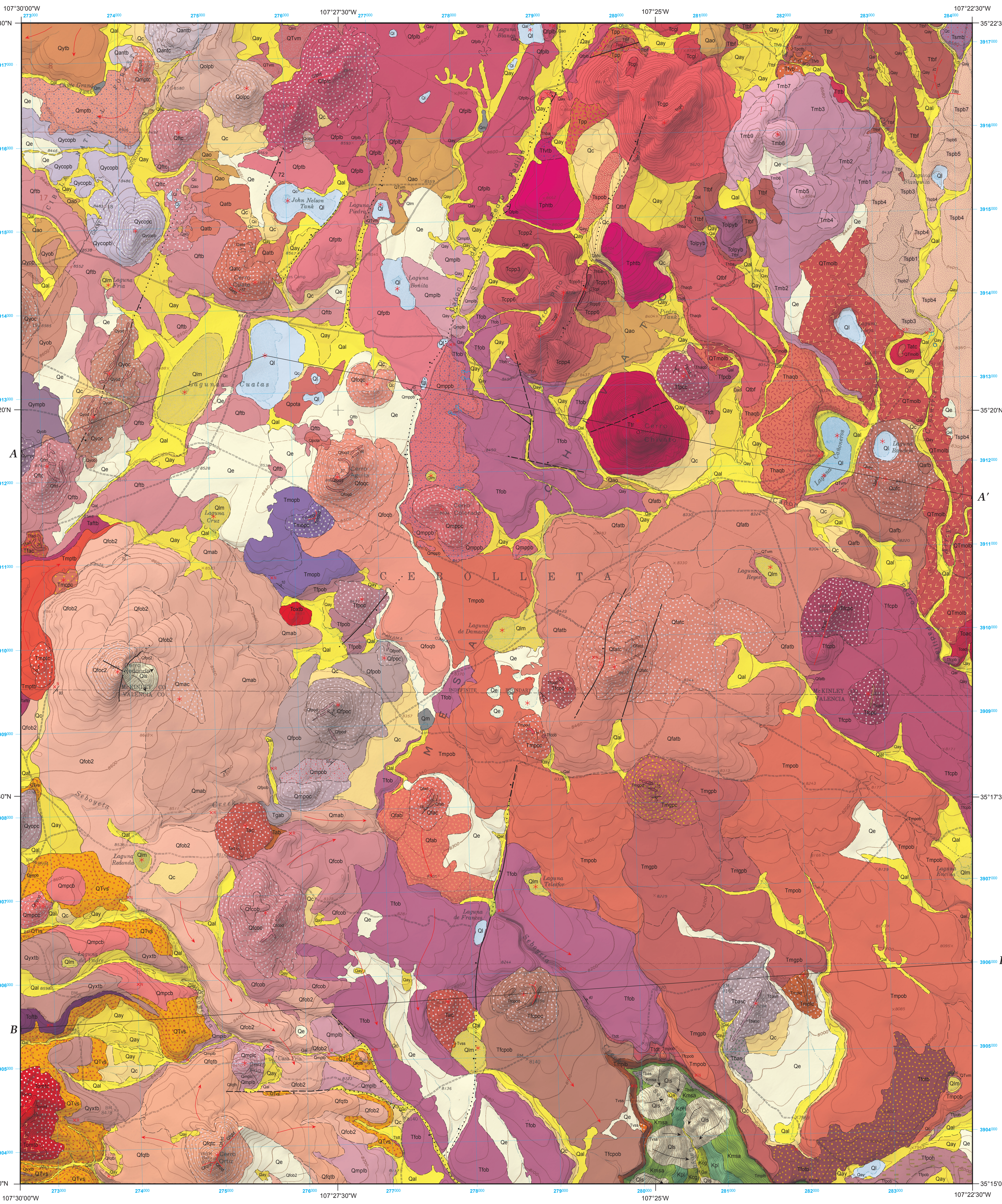
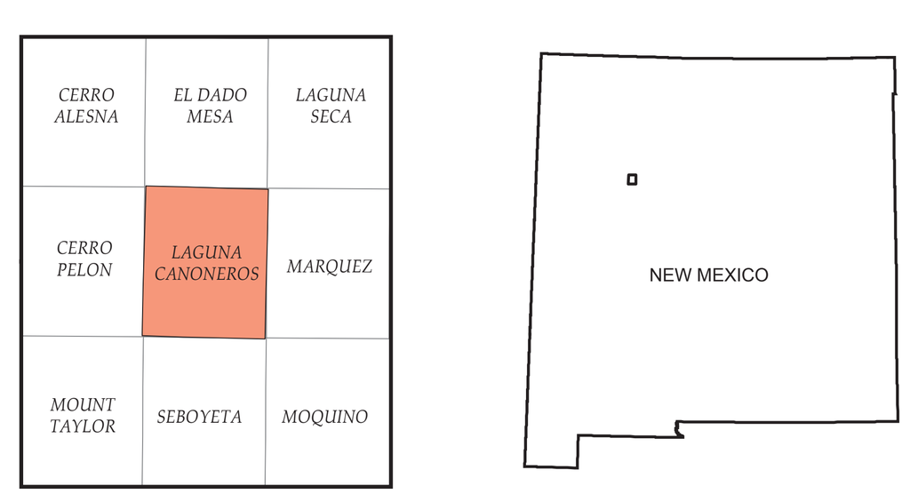
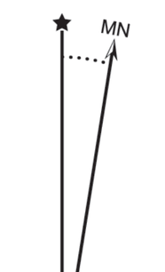
NMBGMR Open-file Geologic Map 244
Last Modified June 2014



Base map from U.S. Geological Survey 1961, from photographs taken 1958, field checked in 1961. 1927 North American Datum, Polyconic projection. Reprojected to UTM projection -- NAD 27 zone 13. 1000-meter Universal Transverse Mercator grid, Zone 13, shown in blue.



QUADRANGLE LOCATION



Magnetic Declination
July, 2012
9.45555° East
At Map Center

1:24,000

1 0.5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

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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 244

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Geologic map of the Laguna Cañoneros 7.5-minute quadrangle, McKinley and Cibola Counties, New Mexico

June, 2014

by
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DRAFT

Explanation of Map Symbols

- A—A′ Location of geologic cross section
- Geologic contact - certain, location accurate
- Geologic contact - certain, location approximate. *Note: intraunit contacts differentiate between flows, lobes, or surfaces.*
- Fault - certain, location approximate
- Fault - certain, location concealed
- Normal fault - certain, location accurate
- Normal fault - certain, location approximate, tick shows dip (72)
- Normal fault - certain, location concealed
- Qfqtd — Dike, location accurate, showing unit name
- Qfqtd — Dike, location approximate, showing unit name
- Flow lines on lava
- Direction of downslope movement of landslide
- 50 — Inclined flow banding, lamination, layering, or foliation in igneous rock — showing strike and dip
- 46 — Inclined dike, showing dip
- Small volcanic cone, vent, cinder cone, or spatter cone
- Volcanic cone, vent, cinder cone, or spatter cone
- Drill hole for mineral exploration
- Spring
- Water well for livestock
- Geophysical data collection locality - N = normal polarity; R = reversed polarity

Map Unit Descriptions

(Partial description of units; complete descriptions are found in the accompanying report)

Quaternary

Qm — **Modern excavations and dams (Historic)** — Compacted silt, clay, and very fine to very coarse sand (with minor pebbles) around stock tanks and associated dams.

Qal — **Modern Alluvium (Uppermost Pleistocene to Holocene)** —Deposits of sand, gravel and silt in main valley bottoms, locally includes stream terraces, alluvial fans, and canyon wall colluvium. Valley floor alluvium is typically finer-grained, silt and sand dominated deposits with interbedded gravel beds, whereas low terrace deposits are predominantly sand and gravel. Thickness uncertain but may exceed 15 m.

Qc — **Colluvium (Upper Pleistocene to Holocene)** — Poorly sorted slope wash and mass wasting deposits from local sources; mapped only where extensive or where covering critical relations; thickness can locally exceed 15 m.

Qe — **Eolian deposits (Upper Pleistocene to Holocene)** — Windblown deposits of silt and fine sand 0.2 to greater than 1 m thick, and sheet wash composed of pebbly sand on various surfaces; mapped primarily in low relief locations.

Ql — **Shallow lake deposits (Upper Pleistocene to Holocene)** — Fine-grained,poorly exposed deposits of clay, silt, and sand filling shallow, small basins on lava flow surfaces and sag ponds along fault traces; thickness probably less than 5 m.

Qay — **Younger alluvium (Upper Pleistocene)** — Alluvium that lies above modern drainages, underlying surfaces adjacent to modern drainages that are located approximately 5 to 15 m above local base level. Generally pebble to boulder gravel, pebbly sand, and silt capped by eolian sand. Maximum thickness ~15 m.

Qao — **Older alluvium (Pleistocene)** — Alluvium that lies above modern drainages and **Qay** deposits, forming higher surfaces between the volcanic vents. Generally pebble to boulder gravel, pebbly sand, and silt capped by eolian sand. Maximum thickness ~15 m.

Qls — **Landslides (Middle Pleistocene to Holocene)** — Poorly sorted debris, slumps, and partially intact block slides that have moved chaotically down steep slopes. Thicknesses vary considerably.

Qlm — **Maar crater-fill deposits (Upper Pleistocene to Holocene)** — Poorly exposed, organic-rich, eolian-derived clay and silt filling the eroded tuff ring and circular vent. Margins of deposits near lava flows may contain larger blocks of eroded basalt. Probable thickness is = ≤50 m.

Volcanic Rocks of Southwest Mesa Chivato (northeast and east of Mount Taylor)

Northwest Area

Qytb — **Younger trachybasalt (Pleistocene?)** — Consists of black to dark gray lavas of relatively aphyric basalt with rare, very tiny phenocrysts of plagioclase ± olivine. Various units are not dated and flows are = ≤60 m thick.

Qantb, Qantc — **Gabbro-bearing olivine trachybasalt (lower Pleistocene?)** — Dark gray, porphyritic olivine trachybasalt flows and red to black scoria deposits (**Qantc**) containing enclaves of gabbro, anorthosite and minor peridotite; phenocrysts consist of conspicuous olivine and scattered augite and plagioclase.Unit is not dated; MPB (1 site) = normal suggesting an age of 1.77 - 1.95 Ma (Gee and Kent, 2007); maximum exposed thickness ~45 m.

Qolpb, Qolpc — **Olivine-rich plagioclase basalt (lower Pleistocene?)** — Dark gray to black flows and black to red scoria deposits (**Qolpc**) of olivine-rich, porphyritic basalt with scattered large phenocrysts of augite and plagioclase (see Figure 9 in the accompanying report). Unit is not dated; maximum exposed thickness ~100 m.

Qfplb, Qfplc — **Fine- to medium-grained, plagioclase-phyric trachybasalt (lower Pleistocene)** — Gray flows and red to black scoria deposits (**Qfplc**) of fine- to medium-grained trachybasalt with trachytic texture caused by aligned plagioclase micro- phenocrysts; contains sparse small phenocrysts of plagioclase, augite and olivine. Cone contains a thin, NE-trending dike (**Qfpld**); flows lap into two maar volcanoes (Lagunas Blanca and Chute) along northwest quadrangle boundary. $^{40}Ar/^{39}Ar$ age is 2.13 ± 0.01 Ma; MPB (1 site) = reverse (correlated). Maximum exposed thickness ~75 m.

Qfptb — **Fine-grained plagioclase phyric trachybasalt (lower Pleistocene?)** — Gray flows and red to black scoria deposits (**Qfptc**) of fine-grained trachybasalt with trachytic texture of small plagioclase microlites; contains rare small phenocrysts of augite and olivine. Eroded flows partially fill maar volcanoes John Nelson Tank, Laguna Piedra, and Laguna Blanca. Maximum observed thickness ~65 m.

Qyob, Qyoc, Qyod — **Younger olivine trachybasalt (lower Pleistocene)** — Gray to black flows and red to black scoria deposits (**Qyoc**) of fine-grained basalt containing 2-4% resorbed, translucent green olivine phenocrysts.The olivine is commonly iddingsitized. Felted groundmass contains abundant plagioclase and olivine microphenocrysts. There are three cones of this composition, several contain NNE-trending dikes (**Qyod**), some of which are faulted. Sample of flow from western cone in Cerro Pelon quadrangle has $^{40}Ar/^{39}Ar$ age of 2.18 ± 0.06 Ma. Maximum observed thickness ~70 m.

Qatb, Qatc, Qatd — **Fine-grained aphyric trachybasalt of Cerro Cuate (lower Pleistocene)** — Gray to black flows and red to black cinder deposits (**Qatc**) of fine-grained, aphyric trachybasalt with no visible phenocrysts; scoria cone contains several dikes (**Qatd**). $^{40}Ar/^{39}Ar$ age is 2.18 ± 0.02 Ma. Maximum observed thickness ~35 m.

Qfoqb, Qfoqc, Qfoqd — **Fine-grained quartz-bearing olivine trachybasalt of Cerro Aguila (lower Pleistocene)** — Gray to black flows and red to black scoria deposits (**Qfoqc**) of fine-grained basalt having small phenocrysts of olivine and sparse small xenocrysts of quartz, some with green clinopyroxene reaction rims. Scoria cone has several arcuate and linear dikes (**Qfoqd**). $^{40}Ar/^{39}Ar$ age of lava SE of cone is 2.25 ± 0.01 Ma; Ar-Ar age of dike in cone is 2.27 ± 0.01 Ma. Maximum exposed thickness ~85 m.

Qmptb, Qmptc — **Medium-grained plagioclase phyric trachybasalt (lower Pleistocene?)** — Gray flows and small scoria cone of black to red cinders of medium-grained plagioclase phyric trachybasalt with microphenocrysts of augite and olivine. Maximum observed thickness 40 m.

Qftb, Qftc, Qftd — **Younger fine-grained plagioclase trachybasalt (Lower Pleistocene)** — Light gray flows and red to black scoria deposits (Qftc) of aphyric, aphanitic trachybasalt containing a felted groundmass of very fine-grained plagioclase, clinopyroxene, and minor olivine. Flows originate from a scoria cone (hill 8761) which contains several dikes (Qftd) on the west margin of quadrangle; some flows may originate from cone Qatc. Flows are cut by or are adjacent to the following maars: Laguna Fria, Lagunas Cuatas, and Laguna Cruz. Sample of flow from adjacent Cerro Pelon quadrangle has $^{40}Ar/^{39}Ar$ age of 2.28 ± 0.07 Ma (Goff et al., 2010). Maximum observed thickness is ~50 m.

Qycopb, Qycopc — **Younger porphyritic pyroxene olivine basalt (lower Pleistocene)** — Gray to black flows of very distinctive, speckled, medium to course-grained porphyritic basalt containing abundant phenocrysts of anhedral to resorbed black clinopyroxene, green anhedral olivine, and clear to white, zoned subhedral plagioclase. Flows originate from scoria cone (**Tycopb**) near NW edge of quadrangle. Sample of flow from adjacent Cerro Pelon quadrangle has $^{40}Ar/^{39}Ar$ age of 2.31 ± 0.06 Ma. Maximum observed thickness ~30 m.

Qympb, Qympc — **Younger fine-grained plagioclase trachybasalt (lower Pleistocene)** — Light gray flows and red to black scoria deposits (**Qftc**) of aphyric, aphanitic trachybasalt containing a felted groundmass of very fine-grained plagioclase, clino- pyroxene, and minor olivine. Flows originate from scoria cone containing several dikes (**Qftd**) on west quadrangle margin. Maximum observed thickness ~50 m.

Qmppb, Qmppc — **Medium-grained plagioclase phyric trachybasalt of Cerro Colorado (lower Pleistocene?)** — Gray to black flows and red to black scoria deposits (**Qmppc**) of medium-grained trachybasalt; fresh surfaces display shimmery reflection of aligned plagioclase microlites; contains rare phenocrysts of plagioclase = 0.25 cm in length. Flow surrounds a small, circular, unnamed maar (**Qlm**) north of scoria cone. Maximum observed thickness ~45 m.

Qpota — **Porphyritic olivine trachyandesite (lower Pleistocene?)** — Gray, sugary flow of porphyritic trachyandesite containing large phenocrysts of plagioclase and smaller phenocrysts of augite and olivine; unit underlies quartz basalt of Cerro Aguila. Maximum observed thickness ~20 m.

Southwest Area

Qfqtb, Qfqtc, Qfqth — **Fine-grained quartz-bearing olivine trachybasalt of Cerro Ortiz (lower to middle(?) Pleistocene)** — Flows of dark gray, fine-grained trachybasalt and red to black scoria deposits (**Qfqtc**) containing sparse, small xenocrysts of quartz, and small sparse phenocrysts of olivine and black augite in groundmass of tiny plagioclase, olivine, augite, opaque oxides, and glass. Flows originate from Cerro Ortiz that contains NE-trending dikes (**Qfqtd**); relatively thin beds of hydromagmatic surge are exposed at base of flows on south side of Cerro Frio (**Qfqth**). K-Ar date is 1.56 ± 0.17 Ma (whole rock; Lipman and Mehnert, 1979); MPB (1 site) = reverse (correlated). Maximum observed thickness ~55 m.

Qmpcb, Qmpcc — **Medium-grained plagioclase and augite phyric trachybasalt (lower Pleistocene?)** — Gray flows and red to black scoria deposits (Qmpcc) of olivine and plagioclase phyric trachybasalt; cone contains an eroded dike (**Qmpcd**) trending about N40E. MPB (1 site) = normal suggesting an age between 1.77 and 1.85 Ma. Maximum exposed thickness ~40 m.

Qyxtb — **Young xenocrystal trachybasalt (lower Pleistocene)** — Flows consisting of black to gray, medium- to fine-grained hawaiite having very sparse phenocrysts of olivine, plagioclase, and augite and very rare xenoliths of mantle peridotite and extremely rare fragments of gabbro. Some specimens contain rare quartz xenocrysts. Flows originate from cone in adjacent Cerro Pelon quad (Goff et al., 2010) and have $^{40}Ar/^{39}Ar$ age of 1.85 ± 0.06 Ma. MPB (1 site) is reversed (lightning?); should be normal. Maximum thickness of flows is =60 m.

Qfob2, Qfoc2 — **Fine-grained porphyritic olivine basalt of Cerro Redondo (lower Pleistocene)** — Flows of dark gray to black, fine-grained basalt and red to black scoria deposits (**Qfoc2**) having small, abundant phenocrysts of olivine in groundmass of plagioclase, olivine, augite, opaque oxides and glass. Contains small quartz xenocrysts. Upper (later) flows near vent are extremely porphyritic and contain xenocrysts of peridotite. Flows primarily fill and follow a paleocanyon south of Cerro Redondo and surround an eroded, circular maar (Laguna Redonda, **Qvl**). East margin of cone is faulted and has small landslide. $^{40}Ar/^{39}Ar$ age is 1.90 ± 0.03 Ma on dike in summit area (**Qfob2d**); MPB (3 sites) = all normal (correlated). Maximum observed thickness of flows ~15 m.

Qmab, Qmac — **Medium-grained aphyric basalt (lower Pleistocene)** — Flows of light to dark gray trachybasalt and red to gray scoria deposits (**Qmac**) underlying east side of Cerro Redondo. Flows have trachytic texture caused by aligned plagioclase microphenocrysts; groundmass also contains microphenocrysts of augite and olivine. MPB (1 site) = reverse suggesting an age greater than1.95 Ma (Gee and Kent, 2007). Maximum exposed thickness ~60 m.

Qmpob, Qmpoc — **Medium-grained sparsely porphyritic olivine basalt (lower Pleistocene?)** — Gray to black flows and red to black scoria deposits (**Qmpoc**) of medium to fine-grained trachybasalt with small sparse phenocrysts of olivine and very sparse small phenocrysts of plagioclase and augite. Cone contains NE-trending dike (**Qmpod**). Maximum observed thickness ~35 m.

Qfpob, Qfpoc, Qfpod — **Fine-grained plagioclase and augite phyric olivine basalt (lower Pleistocene)** — Gray to black flows and red to black scoria deposits (**Qfpoc**) of basalt containing conspicuous phenocrysts of plagioclase, augite and olivine in fine-grained groundmass. Cone contains several eroded dikes (**Qfpod**). MPB (1 site) = reverse suggesting an age greater than 1.95 Ma (Gee and Kent, 2007). Maximum exposed thickness~65 m.

Qyopb, Qyopc — **Fine-grained to aphyric olivine plagioclase trachybasalt (lower Pleistocene)** — Gray to black flows and red to black scoria deposits (**Qyopc**) straddling the west central margin of the quadrangle. Specimens are slightly porphyritic with relatively aphyric groundmass containing tiny phenocrysts of olivine ± clinopyroxene, and sparse small phenocrysts of plagioclase. Maximum observed thickness is ~60 m.

Qfcob, Qfcoc, Qfcod — **Fine-grained augite-bearing olivine basalt (lower Pleistocene)** — Gray to black flows and black to red scoria deposits (Qfcoc) of fine-grained olivine basalt containing sparse, large phenocrysts of augite. Cone contains a pond of basalt on the western summit and eroded, NE-trending dikes (**Qfcod**) on the east side of the summit. MPB (1 site) = reverse suggesting an age >1.95 Ma (Gee and Kent, 2007). Maximum observed thickness ~80 m.

Qmplb, Qmplc — **Medium-grained plagioclase-phyric olivine trachybasalt of Cerro Frio (lower Pleistocene)** — Gray, medium-grained, porphyritic trachybasalt flows and red to black scoria deposits (**Qmplc**) containing plagioclase phenocrysts = ≤3 cm long in a groundmass of plagioclase, olivine, augite, opaque oxides and glass. Olivine shows very minor high-temperature iddingsite alteration. Flows, dated at 2.44 ± 0.01 Ma (Skotnicki et al., 2011), originate from Cerro Frio. MPB (2 sites) = both reverse (correlated). Maximum observed thickness ~5 m.

Qfab, Qfac, Qfad — **Fine-grained aphyric trachybasalt (lower Pleistocene?)** — Black flows and red to black scoria deposits (**Qfac**) of very fine-grained aphyric trachybasalt containing visible microphenocrysts of plagioclase and olivine. Cone contains a NE-trending dike (**Tfad**) and a sill-like body of basalt. Maximum observed thickness ~35 m.

East-Central Area

Qfatb, Qfatc, Qfatd — **Fine-grained aphyric trachybasalt (lower Pleistocene)** — Dark to light gray flows and red to black scoria deposits (**Qfatc**) of extremely fine-grained, aphyric trachybasalt containing no phenocrysts. Prominent scoria cone contains NE-trending dikes (**Qfatd**) and is cut by two NNE-trending faults forming small horst. Flow surrounds maar deposits at Laguna Reyes. $^{40}Ar/^{39}Ar$ plateau age is 2.10 ± 0.03 Ma; $^{40}Ar/^{39}Ar$ integrated age is 2.14 ± 0.02 Ma. MPB (1 site) = normal suggests the later age is correct (Gee and Kent, 2007). Maximum observed thickness ~100 m.

Qafb, Qafc — **Fine-grained aphyric trachybasalt (lower Pleistocene)** — Gray to black flows and red to black scoria deposits (**Qafc**) of fine-grained aphyric trachybasalt with visible microlites of plagioclase; contains no phenocrysts. Prominent scoria cone contains two dikes (**Qafd**); scoria cone and flows are cut and incised by maar of Laguna Bandeja. MPB (1 site) = reverse suggesting unit is greater than 2.58 Ma (Gee and Kent, 2007). Maximum observed thickness is about 50 m.

Northeastern Area

Qtbf — **Fine-grained trachybasalt (lower Pleistocene?)** — Brown lava with 1 to 3% phenocrysts of olivine, pyroxene and plagioclase in an aphanitic matrix; contains rare quartz xenocrysts. Olivine phenocrysts are 3-5 mm in diameter and pyroxene and plagioclase are less than 2 mm in diameter. Unit is 10 to 15 m thick.

Tertiary (Pliocene)

QTvs — **Volcaniclastic sedimentary rocks (upper Pliocene-lower Pleistocene)** — Gray to tan to white debris flows, fluvial deposits and interbedded tuffs (**Ttdt**) shed from the Mount Taylor stratovolcano during growth. Debris flow component is most abundant near SW margin of quadrangle and consists primarily of boulders and cobbles of angular to subangular trachydacite and trachyandesite in a volcanic sand matrix. Boulders form a lag deposit on surface of debris flows. Fluvial component contains rounded to subrounded cobbles. Tuffs consist mostly of thin beds and lenses of fall deposits with vesiculated pumice having phenocrysts of plagioclase, clinopyroxene ± hornblende ± biotite. Interlayered with some Quaternary mafic flows and cones (**Qyxtb** and **Qmpcb**). Maximum exposed thickness ~75 m.

QTvm — **Hydromagmatic deposits from maar eruptions (upper Pliocene-lower Pleistocene)** — Poorly exposed hydromagmatic deposits derived from explosive interaction of shallow groundwater with magma during eruption, which form around the vent area. Best exposures occur in the drainage on the south end of Laguna Cañoneros maar; deposits here consist primarily of plane-parallel base surge beds containing a mixture of quenched basaltic (hydroclastic) shards and fragments, sideromelane, yellow-brown palagonite, and lithic fragments; these underly **Thaqb** (2.58 Ma) and overly volcaniclastic strata containing trachydacite pumice dated elsewhere at 2.70 Ma (Skotnicki et al., 2012). Other **QTvm** deposits are primarily buried by colluvium and recognized by poorly sorted, rounded gravel lag fragments. Maximum observed thickness ~5 m.

QTmolb — **Medium-grained olivine trachybasalt** — Gray to black flows of medium-grained trachybasalt with small phenocrysts of olivine; groundmass is distinctly trachytic. Source of flows is from the north. MPB (2 sites) = both normal suggesting an age = <2.58 Ma; maximum observed thickness is 15 m.

Ti — **Mafic dikes** — Linear spines and fins identified only on air photos, which cut mapped rocks of basaltic composition in northeast. Width of dikes is = ≤15 m.

Tmptb, Tmptc — **Medium-grained porphyritic trachybasalt** — Gray to black flows and red to black cinder deposits (**Tmptc**) of medium-grained trachybasalt containing sparse but obvious phenocrysts of augite, olivine and plagioclase; also contains rare xenocrysts of quartz with pale green clinopyroxene reaction rims. Maximum observed thickness ~35 m.

Thaqb — **Hackly aphyric quartz basanite** — Gray to black flows of aphyric basanite with distinctive hackly texture; contains abundant visible microlites of olivine and augite; some flows contain sparse xenocrysts of quartz, some with clinopyroxene reaction rims; quartz xenocryst size and abundance in some flows increase to NW toward source. East end of flow borders Laguna Cañoneros maar. Unit has $^{40}Ar/^{39}Ar$ age of 2.58 ± 0.01 Ma. MPB (1 site) = normal (correlated), exactly at a major magnetic polarity boundary (Gee and Kent, 2007). Maximum observed thickness ~15 m.

Tmopb, Tmopc — **Medium-grained plagioclase phyric olivine basalt** — Gray flows and red to black scoria deposits (**Tmopc**) of plagioclase phyric trachybasalt with pronounced trachytic texture; contains minor small olivine phenocrysts. Eroded scoria cone contains a dike (Tmopd). MPB (1 site) = normal suggesting an age = >2.58 Ma (Gee and Kent, 2007). Maximum observed thickness ~45 m.

Tfob, Tfoh — **Fine-grained olivine basalt** — Dark gray to black, fine-grained basalt flows with rare megacrysts of resorbed plagioclase and augite, and phenocrysts of olivine in groundmass of plagioclase, olivine, augite, opaque oxides and glass. Megacrysts are less abundant with distance from source. Superficially resembles flows of unit **Qfob2** and **Qfoqb**; flows apparently originate from source buried by Cerro Pino cinder cone complex and followed a paleocanyon south into Seboyeta quadrangle. Two thin hydromagmatic beds (**Tfoh**) are found on lower south flank of Cerro Pino. MPB (2 sites) = normal suggesting an age =2.58 Ma (Gee and Kent, 2007). Maximum observed thickness ~35 m.

Taftb — **Fine-grained aphyric trachybasalt** — Gray flows of very fine-grained trachybasalt containing no obvious phenocrysts; originates from faulted scoria cone just west of quadrangle boundary. Maximum observed thickness ~10 m.

Tmcpc — **Medium-grained augite and plagioclase phyric trachybasalt scoria cone** — Nearly buried scoria cone containing bombs and cinders of red to black medium-grained vesicular trachybasalt with sparse but conspicuous phenocrysts of black augite and white plagioclase. Maximum observed thickness ~5m.

Tomtb, Tomtc, Tomtd — **Older megacrystal trachybasalt** — Cone and flow complex on SW boundary of the quadrangle that consist of gray to black flows and red to black cinder deposits (**Tomtc**) of fine-grained trachybasalt; contains 2-4% phenocrysts of euhedral olivine, black anhedral clinopyroxene, minor plagioclase, and minor quartz xenocrysts. Eroded cone is cut by NE-trending dike. Maximum observed thickness is = ≤55 m.

Toxtb — **Older xenocrystal olivine trachybasalt** — Single knob of gray, fine-grained, olivine trachybasalt and minor agglutinate that is probably an eroded vent; contains abundant small xenocrysts of peridotite consisting of olivine-hypersthene-chrome diopside-spinel; phenocrysts are mostly olivine with minor augite and plagioclase. Maximum observed thickness ~25 m.

Toftb — **Older plagioclase trachybasalt** — Gray flow consisting of aphyric, fine-grained hawaiite exposed along southwest edge of quadrangle; contains trace zoned euhedral plagioclase, tiny interlocking plates of plagioclase and microphenocrysts of olivine and clinopyroxene. Interbedded in **QTvs** and underlies **Qyxtb**. Unit is not dated; MPB (1 site) = normal suggesting an age = ≥2.58 Ma; maximum observed thickness is =20 m.

Tfpob, Tfpoc, Tfpoh — **Fine-grained augite and plagioclase phyric olivine trachybasalt** — Gray to black flows and red to black cinder deposits (**Tfpoc**) of fine-grained trachybasalt with phenocrysts of augite, plagioclase and small olivine. Scoria cone is highly eroded and contains great assortment of spindle bombs and agglutinate. Maximum observed thickness ~20 m.

Northeast Corner and Boundary Areas

Tcgp — **Pyroclastic rocks of the Campo Grande volcanic center** — The Campo Grande volcanic center in the north-central part of the quadrangle is dominated by basaltic pyroclastic rocks (agglomerate, scoria, and spindle-shaped bombs). The pyroclastic material on the eastern ridge contains up to 5% altered to fresh ol-cpx-plag. A NE-striking spine of agglomerate forms the eastern ridge, on line with a thin dike with a hackly weathering texture, an aphanitic matrix, and ol-cpx phenocrysts. The sizes of spatter blocks, scoria, and volcanic bombs increases toward the west. Volcanic bombs on the knob southeast of the highest point of the complex are up to 2 m in length, and bombs that are 1-2 m long are common on the ridge north of the highest point. The scoria, bombs, and blocks of lava are finer grained toward the west, with only trace amounts of ol-cpx-plag phenocrysts. Maximum observed thickness ~120 m.

Tcgl — **Basalt flows of the Campo Grande volcanic center** — The few lava flows exposed in the complex are discontinuously exposed and are varied in composition. A lava breccia on the north end of the eastern ridge of the complex is porphyritic with phenocrysts of olivine, pyroxene, and plagioclase set in a fine-grained matrix. A vesicular lava flow on the north side with a crystalline matrix of plagioclase is porphyritic with elongate ol-cpx-plag phenocrysts, olivine being dominant. Steeply dipping flows on the south side of the western satellite vent have 3 distinct lavas with fine-grained matrices of plagioclase laths. A platy lava that is spotted on its weathered surface located on the south side of the eastern ridge has olivine and a few pyroxene phenocrysts; $^{40}Ar/^{39}Ar$ age is 2.52 ± 0.01 Ma. Maximum observed thickness ~35 m.

Tcpp1-3, Tcpp4-6 — **Pyroclastic rocks of the Cerro Pino volcanic center** — The Cerro Pino volcanic center is dominated by basaltic pyroclastic rocks (agglomerate, scoria, spindle-shaped bombs). At least six deposits were identified (**Tcpp1** [oldest] to **Tcpp6** [youngest]). In general, the pyroclastic blocks are 20 to 30 cm in diameter, although several 1-2 m long bombs were found on the northwest side of the complex. Olivine is the most common phenocryst. Some bombs also contained trace amounts of plagioclase (**Tcpp4**) and pyroxene phenocrysts (**Tcpp6**), quartz xenocrysts (**Tcpp6**), and pyroxene megacrysts (**Tccp6**). Maximum observed thickness ~80 m.

Tcpl — **Basalt flows of the Cerro Pino volcanic center** — The few lava flows exposed in the complex are discontinuously exposed and are characterized by olivine phenocrysts set in an aphanitic matrix. The steeply dipping lava flows associated with **Tccp5** are aphanitic, platy flows with trace of olivine-pyroxene phenocrysts. Maximum exposed thickness ~15 m.

Tmb1-3, Tmb4-6, Tmb7-9 — **Fine-grained megacrystal basalt and pyroclastic deposits** — Multiple flows and pyroclastic deposits (**Tmb1** [oldest] to **Tmb8** [youngest]) from vents just east of the Campo Grande center. Units 7, 8, and 9 are dominated by pyroclastic material and units 1 and 2 are primarily lava flows. The lava, agglomerate, scoria, and bombs contain pyroxene megacrysts. The matrix is aphanitic to fine-grained and the lava is sparsely porphyritic with 1% plagioclase, pyroxene, and olivine phenocrysts, xenocrysts of quartz, and rare "crustal" xenoliths are also present. Maximum observed thickness ~60 m.

Ttbf — **Fine-grained trachybasalt** — A widespread unit composed of trachybasalt lava flows with a crystalline matrix of plagioclase laths, pyroxene, and olivine. Rare phenocrysts of olivine, plagioclase, and pyroxene. On the north side of Campo Grande, some flows in this succession have a spotted texture on weathered surfaces. Some flows southeast of Campo Grande have sparse quartz xenocrysts. Maximum observed thickness ~50 m.

Tspb1-3, Tspb4-7 — **Medium-grained sparsely porphyritic olivine trachybasalt** — Multiple flows (**Tspb1** [oldest] to **Tspb7** [youngest]) of gray to black, medium-grained trachybasalt with abundant small microphenocrysts of plagioclase and visible microphenocrysts of olivine. Flows apparently originate from north of the quadrangle. Various flows are differentiated by topographic breaks on air photos. Most specimens contain plagioclase, pyroxene, and olivine phenocrysts. Maximum observed thickness ~8 m.

Tsmb — **Sparsely megacrystal trachybasalt** — Lava in the northeastern corner of the quadrangle with megacrysts of pyroxene in a crystalline matrix composed of plagioclase laths. Light gray on weathered surfaces. Unit is 6-10 m thick.

Tpctb — **Pyroxene-phyric porphyritic trachybasalt** — Distinctive pink lava with 15% clinopyroxene phenocrysts 2-4 mm in diameter and lesser amounts of plagioclase. Matrix is equigranular. Source of this unit is unknown. Maximum observed thickness ~3 m.

Tttb — **Trachybasalt** — Flow apparently originates north of the quadrangle boundary. Crystalline matrix varies from aligned plagioclase laths to a more equigranular texture. Matrix minerals include olivine and pyroxene. Maximum observed thickness ~10 m.

Tfvb — **Fine-grained vesicular basalt** — Poorly exposed basalt that weathers gray and has sparse large vesicles on the weathered surface. Matrix is black, fine-grained ol-plag-cpx. Maximum observed thickness is =1 m.

Tspob — **Sparsely porphyritic olivine basalt** — Lava flow containing less than 1% olivine and pyroxene less than 4 mm in diameter set in an aphanitic matrix on the southwest flank of Campo Grande. Unit is 10-15 m thick.

Tolpyb — **Porphyritic olivine, pyroxene basalt** — Lava with 1-3% phenocrysts of olivine, pyroxene, and plagioclase that are 3-7 mm in diameter. Matrix is aphanitic to crystalline. Younger flows in this succession have 1-2% pyroxene xenocrysts up to 1 cm across. Unit is 20 to 25 m thick.

Tpp — **Porphyritic basalt with plagioclase phenocrysts** — Several lava flows from an unknown source. The basalt flows contain varying amounts of plagioclase laths with trace amounts of pyroxene and olivine phenocrysts in an aphanitic matrix. No sediment was observed between the flows. Unit is =30 m thick.

Tfvtb — **Fine-grained vesicular trachybasalt** — Vesicular, aphyric to fine-grained basalt with less than 1% of 2-4 mm olivine and trace pyroxene and plagioclase. Source unknown. Maximum observed thickness is less than 3 m.

Tatc — **Old scoria cone by Arroyo Cañoneros** — Red to black scoria deposits exposed along west margin of arroyo near eastern quadrangle boundary. Consists of fine-grained nearly aphyric trachybasalt with very sparse small phenocrysts of olivine and plagioclase, and bombs. Maximum exposed thickness ~12 m.

Toac, Toad — **Old scoria cone in Cañon de Pedro Padilla** — Red to black scoria deposits and black north-trending feeder dike (Toad) exposed in north canyon wall along east margin of quadrangle. Consists of aphyric basalt with no phenocrysts. Maximum observed thickness ~25 m.

Tphtb — **Porphyritic hornblende trachybasalt** — Dark gray lava with black to greenish black hornblende phenocrysts, some striated, in a fine crystalline matrix of plagioclase, pyroxene and devitrified glass. Small olivine phenocrysts occur near the base of the flow. Phenocrysts are rounded near the base of the flow and are more euhedral near the top of the unit. Unit has $^{40}Ar/^{39}Ar$ age of 3.16 ± 0.01 Ma. Maximum exposed thickness ~20 m.

Ttr — **Fine- to medium-grained trachyte of Cerro Chivato** — Light gray, highly foliated trachyte dome containing plagioclase in groundmass of plagioclase and clinopyroxene microlites. Intrusion breccia occurs on southern margin of dome. Some specimens are spotted from deuteric alteration of groundmass. Trachyte has $^{40}Ar/^{39}Ar$ age of 3.16 ± 0.02 Ma. Maximum observed thickness ~120 m.

Thba — **Hackly basanite** — Lava with hackly and spotted textures on weathered surfaces. The lava is generally aphanitic with rare olivine, weathered and altered to iddingsite. Unit is 10 m thick.

Ttbfo — **Older fine-grained trachybasalt** — Foliated lava with pyroxene and olivine phenocrysts. This lava is probably inter-bedded with volcaniclastic sedimentary deposits and are covered with thick colluvium. Unit is 5 m thick.

Southeast and Seboyeta Canyon Areas

Tmgpb, Tmgpc, Tmgpd — **Medium-grained, gabbro bearing, plagioclase phyric trachybasalt** — Gray flows and red to black scoria deposits (**Tmpgc**) of medium-grained trachybasalt with small scattered phenocrysts of plagioclase and xenoliths of gabbro up to 5 cm in diameter that become more obvious close to the cone. Cone contains 2 WNW-trending dikes (Tmpgd). MPF (1 site) = reversed, suggesting an age = ≥2.58 Ma. Maximum observed thickness ~25 m.

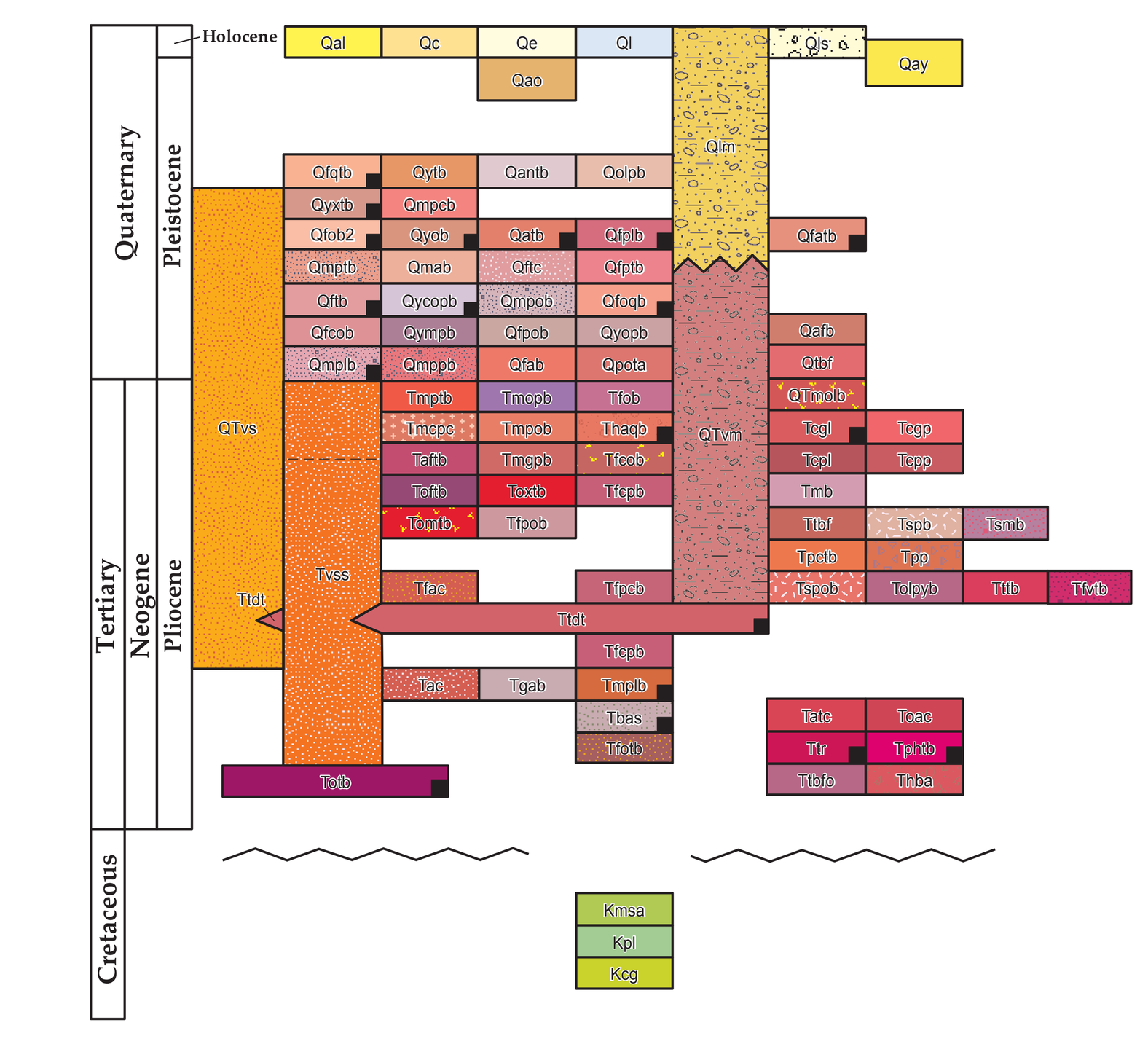
Tfcob, Tfcoc, Tfcod — **Fine-grained augite megacrystal olivine basalt** — Tiny flow remnant and red to black cinder deposits of fine-grained basalt containing abundant black augite megacrysts with resorbed margins up to 1 cm in diameter (see Figure 11 in the accompanying report). Groundmass contains tiny olivine micro- phenocrysts with iddingsite alteration. Unit contains an eroded cone (**Tfcoc**) with a NW-trending dike (**Tfcod**) and much bedded agglutinate; flow remnant is found on east flank of cone Tmpoc. Maximum observed thickness ~25 m.

Tfcpb, Tfcpc, Tfcpd — **Fine-grained augite and plagioclase phyric trachybasalt** — Gray to black flows and red to black cinder deposits (**Tfcpc**) of fine-grained trachybasalt with sparse phenocrysts of augite and plagioclase and rare megacrysts of augite = ≤1 cm in diameter. Flow SW of scoria cone (hill 8487) has much agglutinate and seems to be part of NNE-trending fissure. Maximum observed thickness ~80 m.

Tmpob, Tmpoc, Tmpod — **Medium-grained plagioclase phyric olivine trachybasalt** — Gray widespread flows and red to black cinder deposits (**Tmpoc**) of medium-grained trachybasalt with sparse phenocrysts of plagioclase and olivine in trachytic groundmass of plagioclase, augite and olivine. Texture is occasionally sugary. Eroded cone contains an arcuate dike (**Tmpod**). The east flank of the cone is overlain by thin flow remnant from unit **Tfcob**; flows cut by maar volcanoes Laguna de Damacio and Laguna Telesfor. MPB (2 sites) = both normal suggesting an age = ≥2.58 Ma. Maximum observed thickness ~30 m.

Correlation Of Map Units

(Black squares denote dated units)



Tfpcb, Tfpcc — **Fine-grained augite and plagioclase phyric olivine trachybasalt** — Gray to black flow and red to black cinder deposits (**Tfpcc**) of fine-grained trachybasalt containing phenocrysts of augite, plagioclase and olivine, rare gabbroic xenoliths of orthopyroxene and plagioclase, and rare quartz xenocrysts with clinopyroxene reaction rims. Scoria cone contains dike or vertical rib of agglutinate trending N35W. Maximum observed thickness ~60 m.

Tvss — **Volcaniclastic sandstone** — Gray to tan, fine- to course-grained fluvial sandstone containing small clasts and grains of quartz, plagioclase, olivine, augite, chert, pumice, and various types of basalt and intermediate composition volcanics. Exposed mostly in upper walls of Seboyeta Canyon where it occupies shallow channels cut into earliest lava flow surfaces in the region. Maximum exposed thickness ~35 m, but usually is much less.

Ttdt — **Porphyritic trachydacite tuffs** — White to light gray beds of pumice and pumice-rich sediments interbedded in middle to lower parts of unit **QTvs** and **Tvss**; pumice is highly vesicular containing sparse, small phenocrysts of plagioclase, augite ± sanidine, biotite, hornblende and quartz. Tuffs originate from sources within Mount Taylor; beds are up to 2 m thick. $^{40}Ar/^{39}Ar$ dates on similar deposits to west and southwest range from 2.71 to 2.76 Ma (n=4; Goff et al., 2008, 2010). Date on pumice bed in tuff from Seboyeta quad is 2.700 ± 0.002 Ma (Skotnicki et al., 2011).

Tfcpob, Tfcpoc, Tfcpod — **Fine-grained augite and plagioclase phyric olivine trachybasalt** —Distinctive flows of dark gray to black, fine-grained, porphyritic basalt with conspicuous black megacrysts of resorbed augite and small phenocrysts of plagioclase, olivine and magnetite in a groundmass of plagioclase, olivine, augite, opaque oxides and glass. Olivine is extensively altered to high-temperature iddingsite. Flows originate from scoria cone (**Tfcpoc**) containing NE-trending dike (**Tfcpod**). MPB (1 site on dike) = normal suggesting an age greater than 2.58 Ma; maximum exposed thickness~20 m.

Tmplb, Tmplc, Tmpld — **Medium-grained plagioclase-phyric trachybasalt** — Flows and scoria deposits (**Tmplc**) of distinctive gray, medium-grained porphyritic trachybasalt with phenocrysts of plagioclase and very small phenocrysts of olivine and augite in groundmass of plagioclase, olivine, augite, opaque oxides and glass. Scoria cone contains a NNW-trending dike (**Tmpld**). Unit has $^{40}Ar/^{39}Ar$ age of 2.70 ± 0.02 Ma; MPB (2 sites) = both normal (correlated). Maximum exposed thickness ~15 m.

Tfac, Tfad — **Fine-grained, aphyric trachybasalt scoria cone** — Exhumed scoria cone in bottom of unnamed ravine on the west margin of the quadrangle. Consists of red to black cinder deposits surrounding an eroded, arcuate dike (**Tfad**). Trachybasalt is fine-grained and aphyric with a few tiny but visible microlites of olivine and plagioclase. Maximum observed thickness ~8 m.

Tac, Tab, Tad — **Aphyric trachybasalt scoria cones** — Two isolated cones of red to black scoria deposits consisting of aphyric, vesiculated trachybasalt. The northwest cone contains a well-exposed NW-trending dike (**Tad**) and has a small exposure of lava to east (**Tab**). The southeast cone, containing a variety of bombs, is partially surrounded by **Tfob**, and is cut by the Laguna maar (**Qlm**). Maximum exposed thickness ~50 m.

Tgab — **Medium-grained olivine gabbro** — Tabular body of gray medium-grained, equigranular gabbro consisting of plagioclase, olivine, and augite. May be associated with eroded scoria cone (**Tac**). Maximum observed thickness ~15 m.

Tbas, Tbasc, Tbasd, Tbash — **Aphyric olivine trachybasalt** — Dark gray, fine-grained, nearly aphyric trachybasalt flows with rare tiny phenocrysts of plagioclase and olivine in a groundmass of plagioclase, olivine, opaque oxides and glass. Vugs, vesicles and cracks are commonly filled with opal/chalcedony, calcite and Fe-oxides; weathered surfaces are distinctly to vaguely spotted in outcrop. Source is scoria cone with NE-trending dike (**Tbasc** and **Tbasd**) just east of Seboyeta Canyon; east side of cone also contains a thin layer of hydromagmatic deposits (**Tbash**). $^{40}Ar/^{39}Ar$ age is 2.83 ± 0.02 Ma; MPB (1 site from outcrop in bottom of canyon) = normal (correlated). Maximum exposed thickness ~40 m.

Tfotb — **Fine-grained olivine trachybasalt** — Dark gray, fine-grained trachybasalt flows with sparse phenocrysts of olivine, plagioclase and augite in groundmass of plagioclase, olivine, augite, opaque oxides and glass. Flows originate from eroded hills of cinders and scoria (**Tfotc**) on southeast tip of Mesa Chivato (Red Mesa) in adjacent Seboyeta quadrangle. MPF (1 site) = reverse suggesting an age = >3.04 Ma. Maximum exposed thickness of flows ~15 m.

Totb — **Older basalt and trachybasalt (cross section only)** — Gray to black flows of older basaltic lavas that underlie most other volcanic units and overlie Cretaceous rocks in map area; equivalent to Totb in San Mateo and Cerro Pelon quadrangles (McCraw et al., 2009; Goff et al., 2012). Ages of dated flows to west are around 3.1 to 3.3 Ma. Thickness = ≤45 m.

Cretaceous (adapted from Goff et al., 2012 and Skotnicki et al., 2012)

Mesa Verde Group

Kmf — **Menefee Formation (cross section only)** — Interbedded golden to yellow orange, medium to thin bedded sandstone, black to gray to brown shale and siltstone with carbonized wood fragments, and minor coal. Maximum exposed thickness in other quadrangles = ≥45 m.

Kpl — **Point Lookout Sandstone, Hasta tongue** — Fine-grained quartz sandstone with rare darker lithic grains. Uppermost 5 m shows planar cross-bedding in sets up to 1 m. Below about 5 m bedding is mostly horizontal with low-angle cross-beds, especially in the lowermost 2-3 m. Forms prominent light gray cliffs; maximum exposed thickness ~45 m.

Crevasse Canyon Formation

Kcg — **Gibson Coal Member** — Interbedded light orange very fine-grained quartz sandstone in massive to thinly bedded layers up to 4 m thick and dark shale. The shale commonly contains dark brown to black lignite coal in seams up to 2 m thick. Locally contains light gray fragments of fossilized wood; maximum exposed thickness less than 50 m.

Kcda — **Dalton Sandstone Member (cross section only)** — Consists of two prominent sandstone layers: a lower yellowish-orange layer and an upper white layer, with an intervening shale bed. Maximum exposed thickness in the Lobo Springs quadrangle is = ≤25 m (Goff et al., 2008).

Kcs — **Stray Sandstone Member (cross section only)** — Consists of two prominent reddish-orange sandstone layers with an intervening shale bed. It pinches out under the southeastern part of the quadrangle. Maximum exposed thickness in Lobo Springs quadrangle is ≤40 m. (Goff et al., 2008).

Kcdi — **Dilco Coal Member (cross section only)** — Interbedded black to brown siltstone, thin to medium bedded tan, brown, and olive-green sandstone, and black coal. The sandstones are cross-bedded to ripple laminated. The coal beds are under 0.5 m thick and are usually in the lower part of the unit. Maximum exposed thickness in Lobo Springs quadrangle is ≤150 m. (Goff et al., 2008).

Gallup Sandstone

Kg — **Gallup Sandstone (cross section only)** —Yellowish gray, white, or golden yellow, medium to thick-bedded, cross-bedded sandstone with intercalated Mancos Shale. Maximum exposed thickness in Lobo Springs quadrangle is ≤70 m. (Goff et al., 2008).

Mancos Shale

Kmsa — **Satan Tongue** — Interbedded dark shale and less abundant very fine-grained quartz sandstone exposed in Seboyeta Canyon in SE part of the map. Maximum observed thickness is about 65 meters. Pinches out and interlayers with the Point Lookout sandstone going to the northwest (Sears et al., 1941).

Kmm — **Mulato Tongue (cross section only)** — Golden yellow, thin-bedded, tabular to ripple-laminated sandstone and black shale. Maximum exposed thickness in Lobo Springs quadrangle is = ≤50 m (Goff et al., 2008).

Km — **Main body (cross section only)** — Black to dark brown shale and silty shale intercalated with finely laminated to cross-bedded thinly bedded sandstone. Maximum exposed thickness of Main Mancos beneath Gallup Sandstone is =50 m. Maximum drilled thickness including Bridge Creek Limestone (described below) is roughly 145 to 180 m (Goff et al., 2008, Table 2; Skotnicki et al., 2012).

Kmb — **Bridge Creek Limestone (combined with Km in cross section)** — Finely laminated, fossiliferous, light gray limestone interbedded with thin black shale. Correlative with the Greenhorn Limestone. Maximum exposed thickness of Main Mancos beneath Gallup Sandstone is =50 m. Maximum exposed thickness in Lobo Springs quadrangle is = ≤25 m (Goff et al., 2008).

Dakota Formation

Kd — **Dakota Formation, undivided (cross section only)** — Alternating sandstones and shales of Dakota Formation and Mancos Shale; Dakota unit identified in uranium well logs to west near San Mateo (Reise, 1977, 1980) is inferred to be the lower Oak Canyon Sandstone Member (about 25 m thick). Aggregate thickness of Dakota is about 100 m in northwestern map area (Owen and Owen, 2003; see also cross sections in Goff et al., 2008 and McCraw et al., 2009).

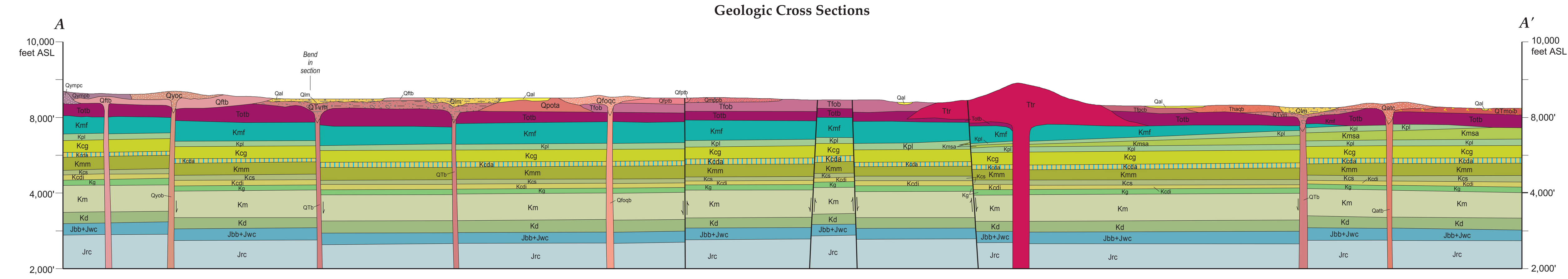
Jurassic

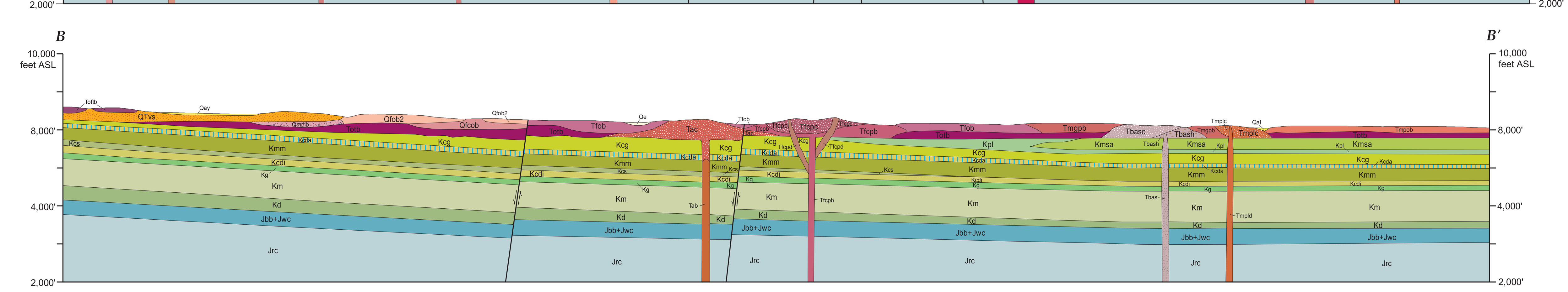
Morrison Formation

Jbb+Jwc — **Brushy Basin and Westwater Canyon Members (cross section only)** — Alternating sandstones and shales identified only in drill holes to the west and southwest (see Reise, 1977; Lucas and Zeigler, 2003). Goff et al., 2012); as defined here probably includes Jackpile Member on top of Brushy Basin beneath east side of quadrangle; may include Salt Wash Member; thickness probably around 80 ± 20 m depending on location.

Jrc — **Recapture Member (cross section only)** — Consists of grayish-red sandy claystone and clayey sandstone with limy nodules, and white, clean, fine- to medium-grained sandstone in beds 1.5 to 15 m thick (Freeman and Hilpert, 1957). In the Laguna Pueblo area, the unit varies tremendously in thickness 20 to 170 ft thick; thickens to north from pueblo area. Thickness in cross section is quite speculative.

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.