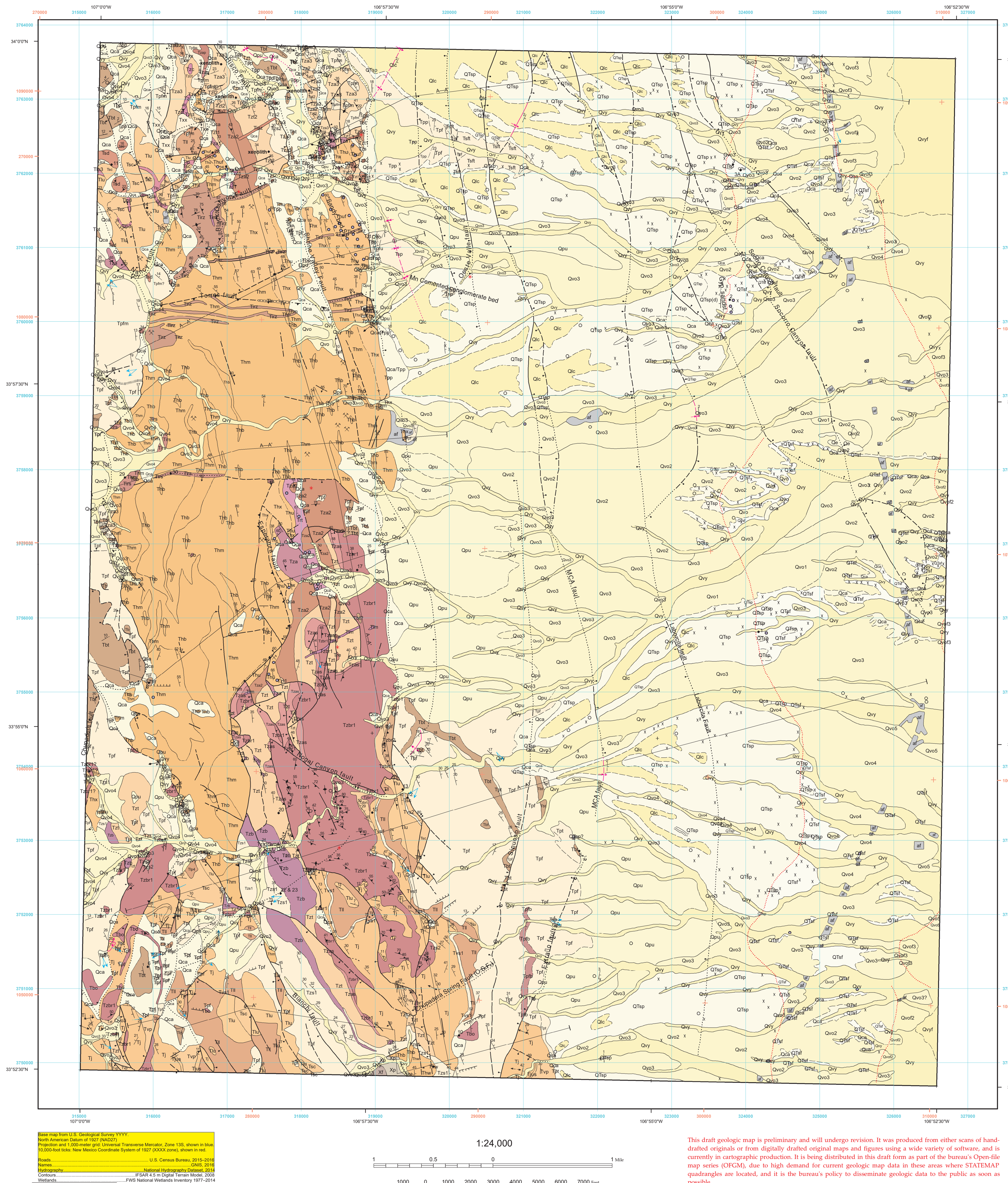
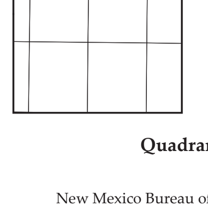
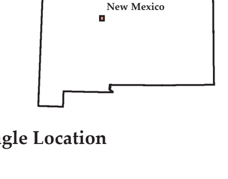
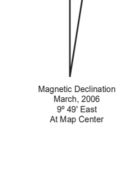


Base map from U.S. Geological Survey YYYY.
North American Datum of 1927 (NAD27)
Projection and 1,000-meter grid: Universal Transverse Mercator, Zone 13S, shown in blue.
10,000-foot ticks: New Mexico Coordinate System of 1927 (XXXX zone), shown in red.
Roads....U.S. Census Bureau, 2015–2016
Names....GNIS, 2016
Hydrography....National Hydrography Dataset, 2014
Contours....IFSAR 4.5 m Digital Terrain Model, 2008
Wetlands....FWS National Wetlands Inventory 1977–2014







Magnetic Declination
March, 2006
9° 49' East
At Map Center

Quadrangle Location

New Mexico Bureau of Geology and Mineral Resources
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

Digital layout and cartography by the NMBGMR Map Production Group:
Phil L. Miller, Amy L. Dunn, Ann D. Knight, and Justine L. Nicolette

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 1929

New Mexico Bureau of Geology and Mineral Resources
Open-File Geologic Map 053

Mapping of this quadrangle was funded by a matching-funds grant from the STATEMAP program of the National Cooperative Geologic Mapping Act (Fund Number:), administered by the U. S. Geological Survey, and by the New Mexico Bureau of Geology and Mineral Resources, (Dr. Nelia W. Dunbar, *Director and State Geologist*; Dr. J. Michael Timmons, *Assoc. Director for Mapping Programs*).

Geologic Map of the Luis Lopez 7.5-Minute Quadrangle, Socorro County, New Mexico

May 2002

by
Richard Chamberlin[1], Ted Eggleston[2], and William C. McIntosh[1]

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This draft geologic map is preliminary and will undergo revision. It was produced from either scans of hand-drafted originals or from digitally drafted original maps and figures using a wide variety of software, and is currently in cartographic production. It is being distributed in this draft form as part of the bureau's Open-file map series (OFGM), due to high demand for current geologic map data in these areas where STATEMAP quadrangles are located, and it is the bureau's policy to disseminate geologic data to the public as soon as possible.

After this map has undergone review, editing, and final cartographic production adhering to bureau map standards, it will be released in our Geologic Map (GM) series. This final version will receive a new GM number and will supercede this preliminary open-file geologic map.

DRAFT

Comments to Map Users

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

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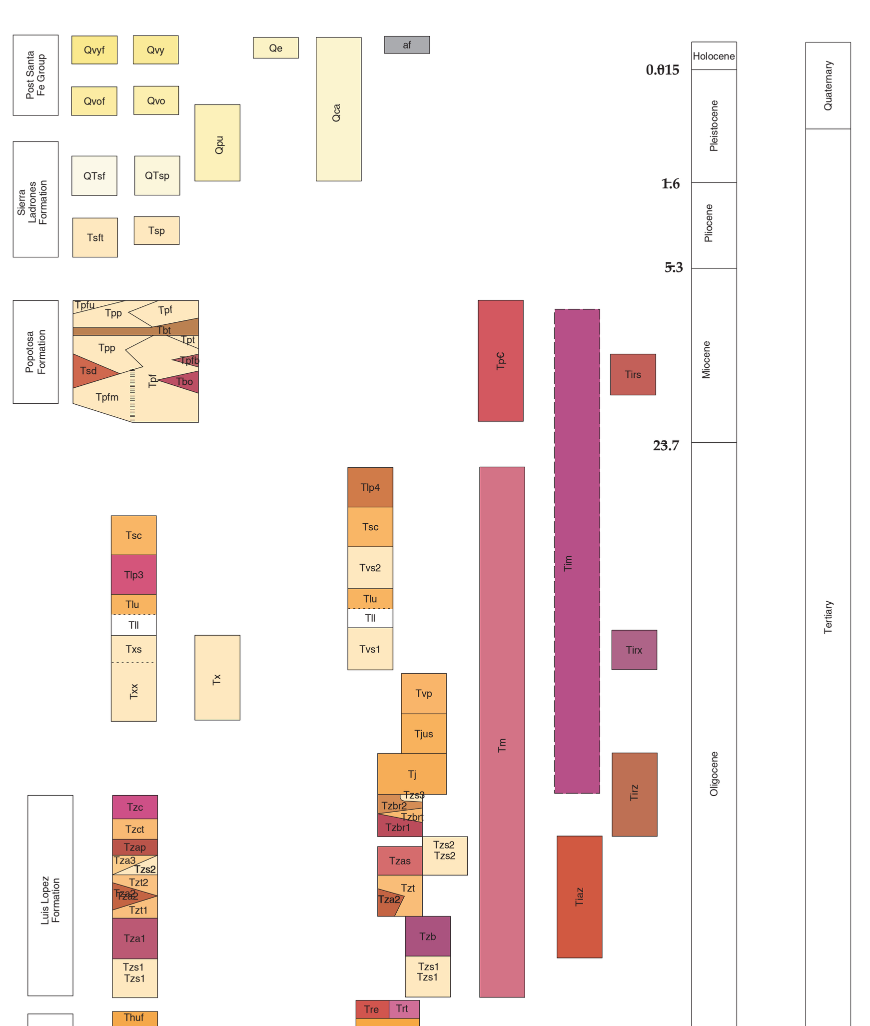


Explanation of Map

1.1.1 Contact—Identity and existence certain, location accurate
1.1.17 Gradational contact—Identity and existence certain, location accurate
1.1.2 Contact—Identity or existence questionable, location accurate
1.1.3 Contact—Identity and existence certain, location approximate
1.1.7 Contact—Identity and existence certain, location concealed
1.2.1 Key bed—Identity and existence certain, location accurate
19.01.23 Sedimentary facies boundary—Showing approxiamte boundary between boundary between diagnostic sediment assemblages
2.1.1 Fault (generic; vertical, subvertical, or high-angle; or unknown or unspecified orientation or sense of slip)—Identity and existence certain, location accurate
2.1.3 Fault (generic; vertical, subvertical, or high-angle; or unknown or unspecified orientation or sense of slip)—Identity and existence certain, location approximate
2.1.7 Fault (generic; vertical, subvertical, or high-angle; or unknown or unspecified orientation or sense of slip)—Identity and existence certain, location concealed
2.2.1 Normal fault—Identity and existence certain, location accurate
2.2.3 Normal fault—Identity and existence certain, location approximate
2.2.4 Normal fault—Identity or existence questionable, location approximate
2.2.7 Normal fault—Identity and existence certain, location concealed
2.2.8 Normal fault—Identity or existence questionable, location concealed
2.8.1 Thrust fault (1st option)—Identity and existence certain, location accurate
2.8.3 Thrust fault (1st option)—Identity and existence certain, location approximate
2.8.7 Thrust fault (1st option)—Identity and existence certain, location concealed
2.8.8 Thrust fault (1st option)—Identity or existence questionable, location concealed
31.08 Map Boundary
17.12 Head scarp of landslide-Active, sharp, distinct, and accurately located
5.1.1 Anticline (1st option)—Identity and existence certain, location accurate
5.5.3 Syncline (1st option)—Identity and existence certain, location approximate
5.5.7 Syncline (1st option)—Identity and existence certain, location concealed
5.9.17 Monocline, anticlinal bend (1st option)—Identity and existence certain, location accurate
5.9.19 Monocline, anticlinal bend (1st option)—Identity and existence certain, location approximate
12.5 Fluvial transport direction
2.11.9 Inclined fault (2nd
6.1 Horizontal bedding
6.2 Inclined bedding
8.2.3 Inclined flow banding, lamination, layering, or foliation in igneous rock
8.3.2 Inclined metamorphic foliation
8.3.3 Vertical metamorphic foliation
9.17 Inclined slickline, groove, or striation on fault surface (1st option)
9.5 Horizontal generic (origin or type not known or not specified) lineation or linear structure (1st option)
<Null>
18.55 Small cone, vent, cinder cone, or spatter
19.03.01 Prospect (pit or small open
19.03.04 Open pit, quarry, or glory
26.01.01 Water well, type unspecified
31.21 Sample locality—Showing sample
31.21 Sample locality—Showing sample
31.10 Cross section

01-01-00-00-00–Unit–Qvy–Younger valley alluvium, piedmont facies –Active channel, low terrace and alluvial-fan deposits of tributary arroyos. Consists of poorly sorted, nonindurated, volcanic-rich gravel, sand, silt, and clay. Associated with low graded surfaces formed during last major episode of valley

01-02-00-00-00–Unit–Qvyf–Younger valley fill, axial-fluvial facies –Floodplain deposits of Rio Grande; consists mostly of clay to sand. Grades to well sorted gravel at basal scour surface as much as 30 m below floodplain (McGrath and Hawley, 1987).

01-03-00-00-00–Unit–Qe–Eolian depsits–Light gray, fine grained, well sorted sand; locally buries late Pleistocene scarp of the

01-04-00-00-00–Unit–Qca–Colluvium and alluvium, undifferentiated–Talus and colluvium on steep to moderate slopes in the Chupadera Mountains. Also, gravelly slope wash on erosion surfaces cut in poorly consolidated upper Cenozoic deposits in Socorro Basin. Gravelly colluvium is typically shown where it masks ancestral Rio Grande deposits (QTsf). Includes small upper Pleistocene debris flow on south wall of Blue Canyon. Widespread colluvial veneers on dissected piedmont slopes in the Socorro Basin are generally not delineated. Usually

01-05-00-00-00–Unit–af–Artificial fill and mine waste –– Mostly represents compacted fill, as roadway subgrades along Interstate 25 and adjacent flood control levees. Includes waste-rock piles east of abandoned MCA mines and a 10 m-high tailings pile east

01-06-00-00-00–Unit–Qvo–Older valley alluvium, piedmont facies–Inset terrace and alluvial-fan deposits of tributary arroyos associated with five episodes of valley entrenchment and backfilling. From oldest to youngest, graded surfaces associated with these alluvial deposits project: 64–70 m (Qvo1), 43–52 m (Qvo2), 30–40 m (Qvo3), 15–21 m (Qvo4) and 6–9 m (Qvo5) above the Rio Grande floodplain. Correlation of Qvo units into western third of quadrangle is tentative. Consists of poorly to moderately sorted, bouldery to cobbly, volcanic-rich gravel, gravelly sand and muddy silts. Generally reddish orange to reddish brown, locally light brown to tan in color. Mostly nonindurated, however, uppermost beds beneath graded surfaces are variably cemented by pedogenic carbonate horizons (c) approximately 0.6 m to 0.1 m thick. Distal alluvial-fan deposits contain siliceous sand and rare quartzite pebbles recycled from the underlying Sierra Ladrones fluvial facies (QTsf). Tentative correlation with Quaternary alluvial units in the San Acacia and Las Cruces areas (based on projected height above Rio Grande) suggest these deposits range in age from about 250,000 years to 25,000 years old (Machette, 1978, 1985).

01-07-00-00-00–Unit–Qvof–Older valley fill, fluvial facies and minor piedmont facies–Complexly intertonguing axial-river deposits (older Rio Grande) and distal alluvial-fan deposits of tributary arroyos. Locally divided into older (Qvof2) and younger (Qvof3) units based on lateral continuity with older piedmont deposits (Qvo2 and Qvo3). Consists of light gray to light yellowish brown, well sorted, fluvial sands and gravels (transport to south), interbedded with reddish orange, poorly sorted, sandy to cobbly, volcanic-rich gravels (transport to east), and red-silty mudstones. Well rounded to subrounded quartzite, granite and metamorphic rock pebbles are typical of the axial-river deposits. However, lenses of locally derived volcanic cobbles (reworked piedmont facies) are also present in axial-river deposits. Facies boundary with Qvo placed at approximate western limit (crosses on map) of axial river beds that commonly overlie volcanic-rich piedmont-facies gravels. As much as 24 m

01-08-00-00-00–Unit–Qpu–Piedmont deposits undifferentiated–Coarse debris flows and poorly sorted volcanic-rich gravels, sand and muds, deposited on small alluvial fans derived from small catchment areas on the east flank of the Chupadera Mountains. Contains buried soils similar to those in QTsp; not demonstrated to intertongue with QTsf. Probably represents locally continuous aggradation, equivalent to QTsp and older Qvo deposits. Base not exposed, minimum thickness 30–60 m. Includes remnants of high-level terraces and alluvial fans, as much as 9 m thick, within the Chupadera

02-03-00-00-00–Unit–QTsp–Sierra Ladrones Formation, upper piedmont facies –Alluvial fan deposits below Las Cañas surface (Qlc) of McGrath and Hawley, 1987. From north to south, large, low-gradient alluvial fans (paleoslopes of 120–140 ft/mi) emanate from Socorro Canyon, Red Canyon, Nogal Canyon (Walnut Creek) and "South Chupadera Spring Canyon." Distinctive volcanic clasts demonstrate that all but the latter were fed by large canyons in the eastern Magdalena Mountains, namely Sixmile Canyon, Molino Canyon and Caronita Canyon. Abundant metamorphic clasts and large basalt boulders in the "South Chupadera Spring" alluvial fan indicate that it was derived from a large ampitheatre between Table Mountain and Chupadera Mountain. Consists of reddish orange to reddish brown, poorly consolidated, volcanic-rich, boulder to cobble conglomerates, conglomeratic sandstones, muddy sandstones, and silty mudstones; generally fining to the east. A muddy transitional distal-fan facies (subscript "d") is locally delineated where well exposed in the area north of lower Red Canyon. The distal facies consists mostly of reddish orange silty mudstones and fine-grained sandstones, with a few pebbly conglomerates. Exposures of the distal facies average about 500 m in width and lie just west of the QTsp–QTsf facies boundary. A fine-grained, gypsum cemented sandstone within the distal facies (SE¼ Sec. 11, T4S, R1W) probably represents an overbank splay deposit of the ancestral Rio Grande. Buried calcic soil horizons (bc) are common within the piedmont facies. The gently east tilted base of the upper piedmont facies (QTsp), is locally exposed in the walls of "South Blue Canyon" where it appears to conformably overly poorly exposed fluvial fan deposits (well-sorted sands) of the lower Sierra Ladrones Formation (Tsft). Maximum thickness of upper piedmont facies, estimated from cross section (sheet 2, A A´) is 140 m. West of the MCA fault, on a structurally higher

02-04-00-00-00–Unit–QTsf–Sierra Ladrones Formation, axial-fluvial facies–Axial river deposits of the ancestral Rio Grande, and minor intertonguing distal piedmont-slope deposits (see reference outcrops on sheet 1 for examples of intertonguing localities). QTsf–QTsp facies boundary is placed at western (mountainward) limit of well sorted, light-gray to pale yellowish brown, quartz-rich river sands or pebbly gravels (crosses on map). Piedmont facies gravels that locally cap the fluvial facies (east of the facies boundary) are delineated as QTsp on the map. Axial river sands are mostly non indurated, however, a few lenses of friable calcite-cemented sandstone are locally present (NE¼ sec. 30, T4S, R1E). Pebbly gravel lenses typically contain well-rounded to subrounded clasts of quartzite, chert, granite, metamorphic rocks, and various volcanic rocks (a few recycled from local piedmont facies). Lenses of rhyolitic pumice (r) are also locally present. River sands often fine upwards into red or greenish gray, poorly indurated, mudstones that probably represent floodplain deposits or abandoned channel fills. Water-laid rhyolitic ash beds (a), apparently derived from eruptions in the Jemez Mountains (Dunbar et.al., 1996), commonly overlie floodplain mudstones near the western limit of the axial-river facies. Ash beds are 0.1–0.6 m thick and occur at three stratigraphic levels approximately 18, 27 and 33 m below the projected top of QTsf. The stratigraphically highest ash found near Walnut Creek, was deposited at 1.22 Ma or slightly later (Table 1, no. 1); and the middle ash (Table 1, no. 3A) is geochemically equivalent to pumice dated at 1.6 Ma (Table 1, no. 2 and 3). The oldest ash is widely exposed in the area southwest of Luis Lopez. This undated ash may be equivalent to the 1.78 Ma San Diego Canyon ignimbrite of Spell et.al., 1990, (N. Dunbar, pers. commun. 1996). Base of axial-river facies is not exposed in the Luis Lopez quadrangle. Minimum thickness, based on water well north of Walnut Creek, is 72.5 m. Possibly

02-05-00-00-00–Unit–Tsp–Sierra Ladrones Formation, lower member, piedmont facies–Easterly transported piedmont-slope deposits (SE¼, NE¼, Sec. 8, T4S, R1W). Consists of poor to moderately indurated, light brown to pale reddish brown, conglomeratic sandstones with abundant locally derived volcanic clasts and rare dark red clasts of jasperoidal cemented (potassium metasomatized) lower Popotosa Formation (Tpfm). Lies in angular unconformity on upper Popotosa Formation (Tpf) and is disconformably overlain by upper Sierra Ladrones piedmont facies (QTsp). Locally contains an unusually well indurated conglomerate bed, which is cemented by manganese oxides and silica (SW¼ sec. 9, T4S, R1W). Lithologically similar to easterly transported piedmont-slope conglomerates that underlie 3.7 Ma basalt flow at Socorro Canyon (sec. 27, T3S, R1W; Chamberlin, 1980; 1999). An intertonguing relationship with lower Sierra Ladrones fluvial-tributary facies (Tsft) is indicated by exposures on the northeast flank of Socorro Peak

02-06-00-00-00–Unit–Tsft–Sierra Ladrones Formation, lower member, fluvial-fan transition facies–Light gray to yellowish brown, well sorted, fine to medium-grained, moderately quartz-rich sand and sandstone, with a few thin beds of volcanic-pebble conglomerate and red or pale green mudstone. Black heavy-mineral laminations are common in the well sorted, sand beds. Calcite cemented conglomerate and sandstones more common toward base. Well sorted fine-grained sands contain about 60 percent monocrystalline quartz, 20 percent feldspar (microcline and non volcanic plagioclase), and 20 percent volcanic lithic fragments. Considering their location, these relatively arkosic and volcanic-poor sandstones may represent the distal portion of a large fluvial fan emanating from the Water Canyon area of the Magdalena Mountains. Transition unit is poorly exposed in walls of "South Blue Canyon." Similar well-sorted quartz-rich sands and volcanic-rich conglomeratic sandstones locally underlie ancestral Socorro Canyon alluvial conglomerates (Tsp) and the 3.7 Ma basalt of Socorro Canyon (Chamberlin, 1999) at Socorro Canyon. The same unit is also found on the upper northeast flank of Socorro Peak, where it contains numerous well sorted crossbedded conglomerates and sandstones of fluvial character (Chamberlin, 1999). Easterly paleocurrents and rare cobbles of well indurated (K-metasomatized) lower Popotosa Formation (Tpfm) in the Socorro Peak exposures indicate this fluvial unit is partly recycled from uplifted lower Popotosa beds in the Magdalena Mountains. Unit probably represents a fluvial-fan tributary facies to the ancestral Rio Grande and marks a transition from closed basin to axial river deposition, possibly in response to a wetter climate. Transition unit was probably inset against Popotosa playa beds and Miocene lavas on flanks of Socorro Peak. Thickness estimated from cross section A-A' is 90–120 m; it maybe as much as 300 m thick north of Socorro Peak and it is probably absent due east of Socorro Peak.

02-07-00-00-00–Unit–Tp_–Popotosa Formation, undivided–Intermontane bolson fill deposits of early Rio Grande rift half grabens; as presently used and mapped by most workers, the Popotosa Formation was probably not deposited in a single broad structural basin (e.g. "Popotosa basin" of Bruning, 1973). Originally defined by Denny, 1940; and redefined by Bruning, 1973; followed by Machette, 1978. Locally divided into a conglomeratic piedmont facies, aka. fanglomerate facies (Tpf, Tpfm), a claystone dominated playa (lacustrine) facies (Tpp), a transitional mudstone-sandstone facies (Tpt), an upper fanglomerate facies (Tpfu), and a basaltic boulder bed (Tpfb). Contains interbedded ashes and lava flows of Miocene age (Osburn and Chapin, 1983b; Cather et.al., 1994a). Undivided

02-08-00-00-00–Unit–Tpfu–Popotosa Formation, upper "fanglomerate" (piedmont) facies–Light brown sandstone and volcanic-rich conglomeratic sandstone locally overlying thick playa facies near "South" Blue Canyon. One exposure of conglomerate that contains abundant mud clasts (NE¼, SW¼ sec. 4 T42 R1W) suggests reworking of underlying playa facies at erosional unconformity(?). If unconformity can be demonstrated, then this unit could be reassigned to the basal Sierra Ladrones

02-09-00-00-00–Unit–Tpp–Popotosa Formation, playa facies–Mostly red or maroon claystone with minor greenish claystones and thin bedded, yellowish brown sandstones. Gypsum, as selenitic veinlets, occurs near north boundary of quadrangle. Claystones are poorly indurated and commonly masked by colluvium (Qca). Appears to conformably or paraconformably overlie metsomatized piedmont-facies conglomerates (Tpfm) in northern Chupadera Mountains; grades laterally to buff-colored distal- piedmont congolmeratic sandstones northeast of Socorro Peak. Thickness at "South Blue Canyon" is 460 m; northeast of Strawberry Peak (Socorro 7.5´

02-10-00-00-00–Unit–Tpf–Popotosa Formation, "fanglomerate" (piedmont) facies–Heterolithic volcanic-rich conglomerates and sandstones derived from stream-erosion of early rift, tilted fault blocks. Generally described as "fanglomerates" (Bruning, 1973) although alluvial fan geometries have not been delineated. Consists of poorly to moderately well indurated, tan, buff and pale red, conglomerates, conglomeratic sandstones, sandstones and minor mudstones. Conglomeratic sandstones are dominant, and range from moderately well sorted stream deposits with well developed pebble imbrications, to poorly sorted, matrix supported debris flow deposits. Pebble imbrications indicate that westerly paleo- transport directions are dominant in the lower half of the piedmont facies at Walnut Creek,"South Chupadera Spring Canyon," and Table Mountain. Sequence adjacent to Walnut Creek fines upwards from boulder conglomerate at base to pebble conglomerate below the intercalated basalt of Broken Tank (Tbt). Above the basalt flows, the sequence generally coarsens upwards. Basal contact is a slight angular unconformity or disconformity associated with as much as 100 m of erosional relief. Colluvial breccias derived from the immediately underlying volcanic unit are common at the basal contact.

02-11-00-00-00–Unit–Tpfb–Popotosa Formation, basaltic boulder bed–Poorly exposed bouldery bed in hanging wall of Extraño fault, primarily expressed as a narrow (30-60 m wide) north-trending belt of loose basaltic boulders and subangular to subrounded boulders. In situ basaltic boulder bed is locally exposed within light gray rhyolite-dominated conglomerates near the north end of the belt (unit dips 15° east here). Basaltic boulders consist of two types: dense dark gray to black diabase and vesicular, medium gray, moderately porphyritic basalt; they are texturally similar to zones in the basalt of Olney Ranch (Tbo). Basalt boulders are as much as 1–2 m across near the south end of the belt and generally become smaller toward the north end (30–50 cm). This unique boulder bed, within the Popotosa piedmont facies (Tpf), was probably derived from erosion and mass wasting of a faulted cuesta of the basalt of Olney Ranch located on the uplifted footwall of the Extraño fault in late Miocene time. Estimated maximum thickness of boulder bed is 6–12 m; unit grades northward into typical heterolithic

02-12-00-00-00–Unit–Tpfm–Popotosa Formation, silicified and potassium metasomatized "fanglomerate" facies–Silicified and potassium metasomatized lateral equivalent of Tpf in northern Chupadera Mountains; characterized by dark red to brick red color and extreme induration in association with jasperoidal silica cement. Silicification boundary (hachure line) locally cuts across fanglomerate beds southwest of the Torres Mine (SE¼, sec. 13, T4S, R2W). Fanglomerates here were derived from the footwall of the low-angle Chupadera fault and contain a mixture of Hells Mesa Tuff clasts and crystal poor rhyolite clasts similar to Tzc or Tirz. Chemical analyses of Hells Mesa clasts collected across this color and induration boundary demonstrates the red, well indurated exposures to the north are potassium metosomatized and poorly indurated exposures to the south are not metasomatized (Ennis, 1996). Overall, the silicification and potassium metasomatism boundary, as defined by well indurated (jasperized) Popotosa outcrops, trends ENE across the northern Chupadera Mountains, subparallel to the Black Canyon fault zone (Chamberlin and Eggleston, 1996). Jasperoidal silica also cements fault breccias and zones of presumed high initial permeability in the underlying volcanic units (heavy stipple pattern) in the northern Chupadera Mountains. 40Ar/39Ar ages of metasomatic adularia from the Socorro Canyon (Box Canyon) area indicate the K-metasomatism system was active from about 10.4 to 7.4 Ma (Dunbar et.al., 1994; Dunbar and Miggins, 1996). Silicified and metasomatized fanglomerates west

02-13-00-00-00–Unit–Tpt–Popotosa Formation, transitional facies–Consists of red non-gypsiferous mudstones and volcanic-rich lithic arenites, may be transitional to a playa facies or an axial-fluvial facies. Occurs near middle of piedmont facies at

03-01-00-00-00–Unit–Tbt–Basalt of Broken Tank–Moderately widespread trachybasalt flows interbedded within Popotosa Formation on southeastern; western and northern flanks of the Chupadera Mountains. Singular to multiple stacked flows range from dark gray to grayish black, slightly pophyritic to fine-grained diabasic, dense to microvesicular and amygdaloidal, trachybasalt (47–50% SiO_2). Slightly porphyritic basal zones locally contain sparse fine-grained (<1.5 mm) phenocrysts of plagioclase, clinopyroxene and olivene, the latter commonly altered to red-brown iddingsite. Amygdaloidal calcite and calcite veinlets are fairly common. Dense cores of flows typically exhibit fine grained diabasic textures, which range from ophitic to subophitic. Flows north of Walnut Creek are greenish gray, propylitically altered and locally contain minor manganese mineralization. New 40Ar/39Ar ages (Table 1, no. 4-8) and petrographic studies (Chamberlin, unpub. data) indicate that the basalt of Bear Canyon (Osburn and Chapin, 1983b, Chamberlin, 1980), is temporally and compositionally equivalent to the basalt of Broken Tank. The "basalt of Bear Canyon" (Osburn and Chapin, 1983b) is here subsumed into the basalt of Broken Tank. Outcrop distribution, thickness variations, and paleocurrent observations in underlying Popotosa conglomerates (Tpf) are consistent with a concealed source area near San Antonio. Flows at Walnut Creek apparently flowed westward down a piedmont slope and paleovalleys toward Table Mountain and Broken Tank. From Broken Tank these lavas flowed northward down a basin axis and then spread out as a thin flow on playa deposits near Bear Canyon. Correlation of basaltic lavas 1 km SW of MCA mine is tentative. Average of 9 40Ar/39Ar age dates on this unit is 8.42 ±0.3 Ma (McIntosh and Chamberlin, unpublished data). Stacked flows at Walnut Creek and near Broken Tank are as much as 30 m thick; singular flow near Bear Canyon is 3–6 m thick. Unit locally wedges out against Miocene paleovalley wall about 2 km SE of Broken Tank (NW1/4 Sec. 31, T4S, R1W).

03-02-00-00-00–Unit–Tbo–Basalt of Olney Ranch, new name–The new name "basalt of Olney Ranch" is here proposed for exposures of a porphyritic tabular basalt flow on the north flank of Table Mountain (SW1/4 Sec. 7, T5S, R1W), which lies on the southwest portion of Olney Ranch (formerly Nogal Ranch, sec. 6, T5S R1W) located in the east-central Chupadera Mountains. Correlative outcrops of this unit are found in the east-central Chupadera Mountains about 4.5 km ESE of Table Mountain. The basalt of Olney Ranch consists of medium to dark gray, slightly porphyritic trachybasalt (49% SiO_2) with about 1–4 percent fine to medium grained (1–4.5 mm) phenocrysts of tabular plagioclase and subhedral greenish olivine. Distinctly porphyritic basal zones are 3–6 m thick and typically grade upwards into a dense core zone of fine-grained diabase with rare medium-grained phenocrysts of plagioclase. Samples from northeast Table Mountain and eastern Chupadera Mountains yield 40Ar/39Ar ages of 9.64 ±0.12 and 9.71 ± 0.14 Ma, respectively (Table 1, no. 9 &10). Outcrops in the east central Chupadera Mountains dip about 20° east, in sharp contrast with the nearly flat lying outcrop on Table Mountain. Similar attitude differences are observed in the younger basalt of Broken Tank (Tbt, sheet 1). Basalt of Olney Ranch is interbedded with poor to moderately indurated conglomerates and sandstones of the Popotosa Formation that locally show westerly paleocurrent directions and inset paleovalley geometries with respect to underlying Oligocene volcanic rocks. The basalt of Olney Ranch apparently flowed westward down a Miocene paleovalley from a now concealed source area between San Antonio and the Bosque del Apache. Thickness 0–10 m; locally wedges out against older rhyolite (Tzbr1) at paleovalley wall on south side of

03-03-00-00-00–Unit–Tsd–Socorro Peak Rhyolite, lower rhyodacite member–Light gray to pale red, flow banded, porphyritic rhyodacite lava flow containing 20–30 percent phenocrysts (1–3 mm) of plagioclase (locally replaced by adularia), hornblende and biotite. Outcrops north and west of Tower Mine contain secondary adularia in close proximity to numerous chalcedony and minor jasperoid veinlets of hydrothermal origin; this suggests adularia is also hydrothermal (Chamberlin and Eggleston, 1996). Unaltered dark gray vitrophyre is locally associated with the chilled base of flow approximately 700 m northwest of Tower Mine. Biotite from unaltered basal vitrophyre yields an 40Ar/39Ar age of 12.23 ± 0.04 Ma (Table 1, no.11); however biotite ages are commonly 10-20% older than comagmatic sanidine ages from the same rock sample (Newell, 1997). A similar rhyodacite in the Pound Ranch area overlies rhyolites that yield a mean sanidine age of 11.31 ± 0.07 Ma (Newell, 1997). Source area uncertain, possibly erupted from Pound Ranch volcanic center; alternatively the silicified round knob immediately NW of Tower mine might represent an eroded neck. Maximum exposed thickness on

04-01-00-00-00–Unit–Tm–Mogollon Group undivided, shown in cross section only.–Mogollon Group undivided, shown in cross section only. The Mogollon Group includes all volcanic formations in the upper part of the Mogollon-Datil volcanic pile, which range in age from approximately 29 to 24 Ma (Cather et.al., 1994b). The Spears Group (not present in Luis Lopez quadrangle) includes all volcaniclastic sedimentary formations throughout the Mogollon-Datil volcanic pile, except volcaniclastic sedimentary units associated with calderas (Cather et.al., 1994b). As delineated here, the Mogollon Group includes 5 regional ignimbrites, plus locally erupted volcanic units and volcaniclastic-sedimentary fill within the Socorro caldera (Luis Lopez Formation), volcaniclastic sedimentary fill of the Sawmill Canyon caldera, and thin tongues of regional basaltic andesite lavas (La Jara Peak Basaltic Andesite). Minor unnamed rhyolitic sandstones and conglomerates (Tvs1 and Tvs2) that occur locally between ignimbrite outflow sheets are not assigned to the Spears Group because they are more likely related to caldera paleotopography or possibly early-rift block faulting, rather than constructional volcanic highlands. Formation nomenclature is

04-02-00-00-00–Unit–Tlp4–La Jara Peak Basaltic Andesite, uppermost tongue of four regional tongues–Medium to dark gray basaltic andesite lava flows, with sparse fine-grained phenocrysts of olivine altered to reddish brown iddingsite. Locally fills paleovalley cut in South Canyon Tuff on south side of Nogal Canyon (SW1/4, Sec. 6, T5S, R1W). Undated flow is tentatively correlated with the "basalt of Madera Canyon" as mapped by Osburn et.al. (1981), on the basis of similar lithology and stratigraphic position. The "basalt of Madera Canyon" has recently been dated at 26.95±0.2 Ma (McIntosh and Chamberlin,

04-03-00-00-00–Unit–Tsc–South Canyon Tuff–Partially to densely welded, light gray to pale grayish red, phenocryst-poor to moderately phenocryst-rich, pumiceous, high-silica rhyolite ignimbrite. Medium grained (1–3 mm) phenocrysts of subequal quartz and sanidine, with traces of biotite and plagioclase, progressively increase upwards from about 5% near partly welded base to as much as 25% near densely welded top (where preserved). Generally lithic poor except near base; light gray pumice (1–5 cm) is moderately abundant (5–15%). Moderately crystal rich upper zone only locally preserved below Miocene erosion surface. Represents remnants of thin outflow sheet erupted from the Mount Withington caldera in the northern San Mateo Mountains (Ferguson, 1991). Mean 40Ar/39Ar age is 27.37 ± 0.07 Ma; magnetic polarity is reverse (McIntosh et.al., 1991). Correlation here is based on lithology and relative stratigraphic

04-04-00-00-00–Unit–Tlp3–La Jara Peak Basaltic Andesite, upper medial tongue of four regional tongues–Reddish brown to dark gray, massive to vesicular, fine-grained, basaltic andesite lava flows characterized by small (1–2 mm) moderately abundant (10–15%) Fe-Mg phenocrysts altered to hematite or iddingsite. The latter presumably represent altered olivine. Repesents thin

04-05-00-00-00–Unit–Tvs2–Unnamed volcaniclastic sedimentary unit, upper of 2 units–Light gray to white, tuffaceous sandstone, siltstone, ash beds and minor pebble conglomerate in area south of Nogal Canyon. Occupies same stratigraphic interval as the upper-medial La Jara Peak Basaltic Andesite at Tower mine.

04-06-00-00-00–Unit–Tlu/Tll–Lemitar Tuff; upper and lower members–Compositionally zoned (77–65 wt% SiO_2), silicic ignimbrite subdivided into a lower member (Tll) of partially to densely welded, light gray, phenocryst-poor (5–15%), high-silica rhyolite, and an upper member (Tlu) of densely welded, dark red, phenocryst-rich (30–45%), rhyodacite to rhyolite. Contains sparse to abundant, medium-grained (1–4 mm) phenocrysts of quartz, sanidine, plagioclase, and biotite with traces of augite and sphene. Lower third of upper member is relatively quartz poor (<5%) compared to upper two thirds, which is quartz rich (10–15%). Small (1–3 cm) phenocryst-poor pumice is moderately abundant (3–5%) in lower member. Sparse, phenocryst-rich pumice and small (<2 cm) grayish red "magma blobs" of andesitic porphyry are typical in outflow of the upper member. Distribution and thickness trends suggest that the Lemitar Tuff was erupted from the Hardy Ridge caldera on the west flank of the Magdalena Mountains (Fig. 2; G. R. Osburn oral commun. 1999; see McIntosh et.al., 1991, fig. 29). Lemitar ignimbrite locally appears to pinchout against eastern wall of the older Sawmill Canyon caldera in the Tower Mine area. Exposures in southern Chupadera Mountains fill broad troughs and paleovalleys. Mean 40Ar/39Ar age is 28.00 ± 0.08 Ma; paleomagnetic polarity is normal (McIntosh et.al., 1991). Correlation based on distinctive zonation of intercept in drillhole at Tower Mine (MC-1), a slightly younger 40Ar/39Ar sanidine age of 27.75 ± 0.16 Ma (Table 1, no. 14), and determination of normal polarity for the lower Lemitar Tuff exposure northeast of the Tower Mine (W. C.

05-01-00-00-00–Unit–Tx–Sawmill Canyon Formation, undivided–Shown in cross section only. Volcaniclastic sedimentary deposits derived from the eastern wall of the Sawmill Canyon caldera (Osburn and Chapin, 1983a; Chamberlin et.al., in press). Fining upward sequence of breccia, conglomerate and sandstone, locally exposed northeast of the

05-02-00-00-00–Unit–Txs–Sawmill Canyon Formation, lower sedimentary member, upper sandstone beds–pale red to grayish red, well sorted, fine-grained rhyolitic sandstone with minor conglomerates near the base; sandstones may be partly eolian. Grades downward into conglomerate/breccia unit (Txx). About 20-25m thick in surface outcrops; Tower Mine drill hole (MC-1) intercepted 25.6m of sandstones below Lemitar Tuff

05-03-00-00-00–Unit–Txx–Sawmill Canyon Formation, lower sedimentary member, basal breccia and conglomerate beds–basal rhyolitic breccias (ancient colluvial deposits derived from flow-banded Tzc) grade upward into crudely bedded debris flows with abundant locally derived clasts of Tzc, Tza3 and Thu. Surface exposures of the basal breccias and conglomerates are well indurated by red jasperoidal silica, which is commonly associated with potassium metasomatism (Dunbar et.al, 1994: Chamberlin and Eggleston, 1996). Txx in Tower mine drill hole (MC-1) appears to be argillized (clay rich), but it is not cemented by jasperoidal silica. Outcrop is 40-50m thick, intercept

06-01-00-00-00–Unit–Tvs1–Unnamed volcaniclastic sedimentary unit, lower of 2 units–Light gray tuffaceous sandstone and minor pebble conglomerates probably derived from the underlying La Jencia Tuff. These alluvial sandstones may locally represent late-stage erosional enlargement of the southeastern wall of the Sawmill Canyon caldera, since they occupy the same stratigraphic position as the Sawmill Canyon Formation (Txs/Txx). Alternatively Tvs1 may be related to erosion of slightly uplifted fault blocks of the early Rio Grande rift, since Tvs1 also occupies the stratigraphic position of the Vicks Peak

06-02-00-00-00–Unit–Tvp–Vicks Peak Tuff–Light gray to pale red, phenocryst poor, densely welded rhyolite ignimbrite. Distinctive aspects include lithophysal zone near base and large pumice lapilli as much as 30 cm long near the top. Contains 1–5 percent phenocrysts of sanidine and sparse quartz. Thin outflow sheet here was erupted from the Nogal Canyon caldera in the southern San Mateo Mountains (Deal and Rhodes, 1976; Osburn and Chapin, 1983a). Appears to be preferentially preserved on the downthrown (southwestern) side of northwest to north- striking normal faults near southern margin of quadrangle. Mean 40Ar/39Ar age is 28.56 ± 0.06 Ma; paleomagnetic polarity is reverse (McIntosh et.al., 1991). Correlation here based on

07-01-00-00-00–Unit–Tjus–Upper zone of La Jencia Tuff and minor volcaniclastic sedimentary rocks–Brick red, densely welded, phenocryst poor, rhyolite ignimbrite with abundant dark gray to black pumice fiamme. Contains sparse (1–3%) small phenocrysts of sanidine and quartz with traces of plagioclase and biotite. Grades downward into main body of the La Jencia Tuff (Tj). Brick red upper La Jencia Tuff is preserved only where locally overlain by the Vicks Peak Tuff (Tvp). As mapped here, includes a few meters of tuffaceous sandstone and pebble conglomerate that discontinuously overly the brick red zone.

07-02-00-00-00–Unit–Tj–La Jencia Tuff, main body–Light gray, pale red and grayish red, phenocryst poor, rhyolite ignimbrite characterized by a thick medial zone of very densely welded, rheomorphic (flow banded) ignimbrite. Flow-banded medial zone grades upwards and downwards to normal eutaxitic ignimbrite near top and base. Contains sparse (3–5%) phenocrysts of sanidine and quartz with traces of plagioclase and biotite. Orientations of lineated (stretched) pumice are consistent with a source area to the west or northwest (Eggleston,1982). Erupted from the composite Sawmill Canyon-Magdalena caldera in the north central and western Magdalena Mountains (Osburn and Chapin, 1983a). Mean bulk sanidine 40Ar/39Ar age is 28.85 ± 0.04 Ma; paleomagnetic polarity is reverse (McIntosh et.al., 1991). Correlation here based on lithology, relative stratigraphic position and a single-crystal sanidine age of 28.69 ± 0.16 Ma (Table 1, no. 15). Thickness in area south of Nogal Canyon ranges from 45–360 m; locally

08-01-01-00-00–Unit–Tzs3–Upper sedimentary member–Light gray, light brown, or pale red rhyolitic sandstones, conglomerates and minor mudstones. Conglomerates locally fill paleovalley cut in underlying rhyolite lava (Tzbr1) in area south of Nogal Canyon. Assignment to Luis Lopez Formation is

08-01-03-00-00–Unit–Tzbr2–Upper rhyolite flow unit–phenocryst-poor rhyolite lava flow consisting of a basal dark gray vitrophyric flow breccia that grades upwards into a dense flow-banded black vitrophyre and an upper zone of reddish brown spherulitic rhyolite. Contains sparse, small phenocrysts of plagioclase, sanidine and rare biotite. Upper flow unit wedges out to south against crest of underlying lava dome (Tzbr1). Yields 40Ar/39Ar sanidine age of 28.72 ± 0.11 (Table 1,

08-01-04-00-00–Unit–Tzbrt–Medial tuff unit–light gray, phenocryst poor, pumiceous, crossbedded, base-surge deposits and thin, poorly welded, pumiceous ignimbrites; compositonally similar to the overlying rhyolite flow unit (Tzbr2). Fragments of lithoidal rhyolite; vitrophyric rhyolite and andesite are locally abundant. Interpreted as a proximal pyroclastic deposit

08-01-05-00-00–Unit–Tzbr1–Lower rhyolite flow unit–high-silica rhyolite lava dome and flow complex (~75% SiO_2) that appears to be centered (thickest) near the latitude of Nogal Canyon. Dominant lithology is light brown, phenocryst-poor, flow-banded, lithoidal rhyolite with minor vitrophyric and spherulitic zones. Contains sparse phenocrysts of plagioclase, sanidine and biotite with traces of hornblende and sphene. Steep flow foliations and paleotopographic crest of lava dome south of Nogal Canyon (center, sec. 5, T5S, R1W), suggest a primary vent near here. Inferred vent area probably marks a point on the older ring fracture zone of the Socorro caldera. Maximum thickness near Nogal Canyon is 550 m; unit locally terminates near south margin of caldera (Sheet 2, high-silica rhyolite lava dome and flow complex (~75% SiO_2) that appears to be centered (thickest) near the latitude of Nogal Canyon. Dominant lithology is light brown, phenocryst-poor, flow-banded, lithoidal rhyolite with minor vitrophyric and spherulitic zones. Contains sparse phenocrysts of plagioclase, sanidine and biotite with traces of hornblende and sphene. Steep flow foliations and paleotopographic crest of lava dome south of Nogal Canyon (center, sec. 5, T5S, R1W), suggest a primary vent near here. Inferred vent area probably marks a point on the older ring fracture zone of the Socorro caldera. Maximum thickness near Nogal Canyon is 550 m; unit locally terminates near south

08-01-06-00-00–Unit–Tzas–Upper intermediate lava member, medium-grained trachyandesite flow unit and volcaniclastic sediments–Consists of trachyandesite porphyry lava flow intercalated with well indurated, maroon, andesitic conglomerates and sandstones. Andesitic porphyry lava contains 15–20 % phenocrysts of fresh to variably altered medium-grained plagioclase, pyroxene and hornblende; it is correlative with Tza3 in the northeast moat. Andesitic conglomerates also contain sparse rhyolite tuff and lava clasts. Thickness 0-40m.

08-01-07-00-00–Unit–Tzs2–Medial sedimentary member–Light gray tuffaceous sandstones and minor conglomerates near near Nogal Canyon. Locally fills paleovalleys cut in upper part of Tzt.

08-01-08-00-00–Unit–Tzt–Medial pumiceous tuff member, locally divided into lower and upper cooling units–Light gray to pale red, poorly to densely welded, pumiceous, phenocryst-poor, rhyolite ignimbrites (75-77 % SiO_2); locally lithic rich and generally mapped as a single unit in southern Chupadera Mountains (Eggleston, 1982). Lithic-rich lenses that contain abundant small andesitic fragments (< 20 cm) are common near the base; moderately lithic-rich zones with both Hells Mesa and andesite fragments occur in the uppermost 30m. Small (1–3 cm) aphyric to very crystal poor, white pumice lapilli form 15 to 30 percent of the rock. Pumice is commonly altered to white clay or zeolites; rare phenocrysts of plagioclase, sanidine and quartz indicate the pumice is rhyolitic. Sparse crystals (3–5%) of sanidine, plagioclase, quartz and biotite found in the matrix of the upper lithic-rich zones are most likely xenocrysts derived from fragmentation of the accompanying Hells Mesa clasts. A thin bed of water laid ash and mudstone that contains plant impressions occurs at the base of the medial tuff member about 2 km north of Nogal Canyon. About 1 km north of Nogal Canyon, the pumiceous tuffs are locally divisable into a lower light gray, poorly welded cooling unit about 50m thick (Tzt1) and and upper pale red moderately to densely welded cooling unit about 40m thick. A 2m-thick zone of argillized nonwelded ash at the top of the lower cooling unit is locally well exposed in a ravine wall. Maximum xenolith size in the lower cooling unit is 20cm; in the upper unit it is 5 cm. Sanidine from a densely welded lithic-poor interval of the upper cooling unit yields an 40Ar/39Ar age of 30.05 ±0.17 Ma (table 1, no. 20), which is analytically equivalent to the age of the lower cooling unit (Tzt1) near Black Canyon (30.04 ± 0.15 Ma; table 1, no. 19). Pumiceous tuffs were erupted from the Black Canyon vent area in the northern Chupadera Mountains (see Luis Lopez units in northern Chupadera Mountains; Chamberlin et.al, in press). Thin outflow sheets of pumiceous tuff, stratigraphically between Hells Mesa Tuff and La Jencia Tuff, occur widely in the Socorro-Datil region; they are commonly mapped with the base of the La Jencia Tuff or correlated with tuffs in the lower South Crosby Peak Formation (Osburn et.al., 1993; McIntosh and Chamberlin, 1994). Maximum thickness approximately 120 m, locally wedges out to south near caldera wall, but a lithostratigraphically similar tuff is present in a paleovalley on the south rim of the caldera near

08-01-09-00-00–Unit–Tza2–Medial mafic-rhyolite flow unit, within medial pumiceous tuff member–Dark gray to reddish gray and bluish gray, massive to platy (weakly flow banded), phenocryst-poor (5–10%) low-silica rhyolite lava (69.5 % SiO_2) with anomalous mafic component (72 ppm Cr). Contains fine- to medium-grained phenocrysts of pyroxene and plagioclase with traces of fine-grained biotite and quartz. Some quartz crystals exhibit reaction rims of pyroxene, and a glassy basal zone exposed north of the Esperanza mine contains small inclusions of siliceous schist and fine-grained diorite. Compositional data, age relationships, and magmatic disequilibrium textures support the interpretation that the mafic-rhyolite flow unit represents a hybrid magma, a mixture of magmas equivalent to about one part Tza1 and two parts Tzt1 (Chamberlin et.al., in press). Lies in angular unconformity on Hells Mesa-age dome-derived tuffs (Trt) north of the Esperanza mine, and locally overlaps lower pumiceous tuff unit (Tzt1) southeast of the Esperanza Mine. Undated mafic-rhyolite flow unit is bracketed by lower (Tzt1) and upper (Tzt2) cooling units of the medial pumiceous tuff member, thus it must have been erupted at about 30.0 Ma. As much as 180 m thick northeast of the Esperanza mine and absent at Nogal Canyon; probably erupted from vent area along south flank of central horst block near the Red Canyon fault.

08-01-10-00-00–Unit–Tzb–Lower basaltic member, trachybasalt flow unit–Dark gray to black, massive to vesicular, trachybasalt lava flows (47 % SiO_2, 9.3 % MgO) characterized by sparse (2–7%) small phenocrysts of olivene, often partially altered to iddingsite. Vesicular zones containing amygdaloidal calcite are common in the upper half of the unit. Groundmass separate from sample near Nogal Canyon yields a moderately precise plateau age of 29.2 ± 0.47 Ma (Table 1, no. 20). However, this plateau age must be innaccurate since since the trachybasalt unit is immediately overlain by pumiceous tuffs (Tzt) dated at 30.05 ± 0.17 Ma (Table 1, no. 20). Stratigraphic relationships and bracketing age data suggest the trachybasalt was emplaced at about 30.5 Ma. Unit ponded to maximum thickness of 90m in southeast moat of Socorro caldera; pinches out to south near caldera wall at Chupadera Spring and is absent near central horst block, southeast of the Esperanza mine. Probably erupted from vent area near southeast rim of the Socorro caldera

08-01-11-00-00–Unit–Tzs1–Basal sedimentary member–Volcaniclastic conglomerates, sandstones and mudstones spatially divisable into a southern andesitic facies, a northern rhyolitic facies and a late-stage heterolithic axial facies containing distinctive cobbles of moderately phenocryst-rich spherulitic rhyolite and minor andesite clasts. Southern facies near Chupadera Spring is about 240m thick; it generally fines upward from coarse andesitic debris flows and breccias, to bed-load conglomeratic sandstones and mudstones, all of which are mostly purple to dark red in color. Clast compositions and grain-size trends imply the southern andesitic facies was derived from the southern caldera wall. Northern rhyolitic facies at Nogal Canyon is 200m thick; it consists of 170m of pale red tuffaceous mudstones and thin interbeds of light-gray rhyolite-derived sandstone unconformably overlain by 30m of upward coarsening conglomeratic sandstones dominated by cobbles and small boulders derived from crystal-rich Hells Mesa Tuff. An angular unconformity of about 5° separates the basal mudstone facies from the overlying conglomeratic unit; imbricated pebbles and cobbles indicate southerly paleocurrent directions. Compositional trends and paleocurrent observations imply that the northern rhyolitic facies was initially derived from a slightly positive core area, and then later derived from a rapidly emerging central uplift located a few kilometers north of Nogal Canyon. A late-stage axial conglomeratic facies is exposed in the uppermost 20m of section about 1 km south of Nogal Canyon. It consists of light gray conglomeratic sandstones containing abundant cobbles of moderately phenocryst-rich spherulitic rhyolite, which are often flow banded, and minor andesitic clasts. Clast imbrications indicate westerly paleocurrent directions. Sanidine from the spherulitic rhyolite clasts yield 40Ar/39Ar ages of 33.74 ± 0.10 and 33.68 ± 0.15 Ma (Table 1, no. 22 and 23), which supports the intepretation that they were derived from precaldera rhyolite lavas on the southeast margin of the caldera. Basal sedimentary member conformably overlies Hells Mesa Tuff near Chupadera Spring. Just south of map area, it wedges out against Precambrian rocks that locally define the southern wall of the Socorro caldera, (Eggleston, 1982); it is also absent at the central-horst block near the Esperanza mine. Age is bracketed by the underlying 31.9-Ma Hells Mesa Tuff and the superjacent 30.0-Ma pumiceous tuff member. Maximum

08-02-02-00-00–Unit–Tzc–Upper rhyolite lava flow unit–Light gray to pinkish gray, finely flow banded, phenocryst-poor rhyolite lava. Erosional remnants northeast of Tower Mine are 0–20 m thick. Contains small phenocrysts (2–5%) of plagioclase with traces of quartz, biotite and sanidine. Drill hole at the Tower mine, MC-1, intersected 60 m of intensely brecciated Tzc (previously interpreted as brecciated La Jencia Tuff; Chamberlin, 1980); probably representing an Oligocene slump block on the

08-02-03-00-00–Unit–Tzct–Lower tuff unit–Consists of light gray, bedded ash-fall tuffs and thin zones of fused tuffs mineralogically equivalent to overlying flow unit. An unusally fresh fused zone near Highway 60 (Socorro quadrangle, Chamberlin, 1999) yields a precise 40Ar/39Ar age of 28.77 ± 0.10 Ma from a plagioclase separate (Chamberlin et.al., in press); thus confirming correlation of the rhyolite of Cook Spring with the rhyolite of Bianchi Ranch, as inferred by Obsurn and Chapin,

08-02-05-00-00–Unit–Tzap–Upper coarsely porphyritic flow unit–Consists of medium gray to reddish brown trachydacitic lava with moderately abundant phenocrysts (10–15%) of altered plagioclase, pyroxene and minor fresh biotite. Large subhedral to rounded plagioclase phenocrysts (5–15 mm long) are commonly replaced by pink adularia and less commonly by white clay. Northeast striking, coarsely porphyritic dikes and a circular plug near Socorro Canyon (Chamberlin, 1999) represent

08-02-06-00-00–Unit–Tza3–Lower medium-grained flow unit–Dark purplish gray, gray, and reddish brown, medium grained (1–3 mm) trachyandesite porphyry lavas, flow breccias and finely vesicular, near vent, cinder deposits. Massive to platy and locally vesicular lavas contain moderately abundant (5–10 %) phenocrysts of altered plagioclase and pyroxene. Northeast-striking porphyry dike about 2 km NE of Tower Mine appears to be a feeder dike for Tza3 flows; another vent for Tza3 is well exposed on the west wall of Box Canyon, near Socorro Canyon (Chamberlin et.al., 1987, fig. 14; Chamberlin, 1999). Thickness

08-02-07-00-00–Unit–Tzs2–Medial sedimentary member–Planar bedded tuffaceous sandstones and minor andesitic debris-flow conglomerates. Confomably overlies upper pumiceous tuff unit (Tzt2) in area north of Black Canyon, where tuffaceous sandstones are commonly intensely silicified by red jasper. A purplish gray andesitic debris flow is present at the base of this unit near Socorro Canyon (Chamberlin, 1999). About 7-60m

08-02-09-00-00–Unit–Tzt2–Upper pumiceous tuff unit–Light brownish gray, variably welded, pumiceous, phenocryst-poor, rhyolite ignimbrites (75-77% SiO_2); coarse xenolith-rich zones containing abundant fragments of upper caldera-facies Hells Mesa Tuff are common north of Black Canyon. Very phenocryst-poor rhyolitic pumice (<1% crystals) comprise about 15-30 % of the poorly to moderately welded ignimbrites where they are xenolith poor (1-10% lithics). Rare crystals of sanidine, plagioclase, and quartz occur in the pumice and matrix of lithic-poor zones. Tuff matrix of lithic-rich zones contains moderately abundant xenocrysts of feldspar and quartz derived from abrasion of crystal-rich lithics. Several lenses of clast-supported lithic-tuff breccias (1-3m thick), which look similar to debris-flow deposits, occur in the moderately lithic-rich pumiceous tuffs between Black Canyon and Socorro Canyon. Angular to rounded clasts of densely welded upper Hells Mesa Tuff are dominant in the very-lithic rich lenses (80-90% lithics, 10-20 % light gray rhyolitic tuff matrix). Larger xenoliths, as much as 90cm in diameter, are anomalously well rounded, which suggests that the clast-supported lenses repesent rock-avalanche deposits derived from preexisting Hells-Mesa derived conglomerates (i.e. Tzs1) on the west rim of the infered collapse structure (Black Canyon vent zone). Large subangular to subrounded blocks of densely welded upper Hells Mesa Tuff, commonly over 3m long, are widely distributed in zones of moderately lithic-rich pumiceous tuff north of Black Canyon. One large block near Socorro Canyon is bisected by a narrow fracture filled with pumiceous tuff, which suggests tumbling or impact during emplacement. Meter-sized blocks of Hells Mesa Tuff and rare blocks of coarsely porphyritic "turkey-track" andesite occur in clusters around the larger blocks. Largest lithic blocks (3.4m) are less than 5 km from their source vent (Freundt et.al., 2000, fig.4). Clast-size distributions support the interpretation of a primary vent located a few kilometers northwest of Black Canyon, an area that is now obliterated by the younger Sawmill Canyon caldera (Chamberlin, unpublished mapping; Chamberlin et.al., in press). As much as 270 m thick near Black Canyon, about 50m thick at Socorro Peak and 40m thick near Nogal Canyon.

08-02-10-00-00–Unit–Tzt1–Lower pumiceous tuff unit–Light gray, poorly welded, pumiceous, lithic-rich, rhyolitic ignimbrite compositionally and texturally similar to lower part of Tzt in southern Chupadera Mountains. Clasts of medium-grained andesite porphyry clasts are locally abundant and crystal-rich Hells Mesa Tuff clasts are typically rare to absent. Rare crystals of sanidine and quartz in matrix are probably primary phenocrysts. Andesite blocks as much as 2m in diameter indicate the Black Canyon-Socorro Canyon area is a proximal zone for the lower puimceous tuff unit (Chamberlin, unpublished mapping). Sanidine from the lower cooling unit near eastern Black Canyon yields an 40Ar/39Ar age of 30.04 ± 0.15 Ma (table 1, no. 19), thereby demonstrating it is coeval with the upper pumiceous tuff unit at Nogal Canyon (Chamberlin et.al., in press).

08-02-11-00-00–Unit–Tza2–Mafic-rhyolite flow unit–Purplish gray to dark gray, phenocryst-poor, mafic-rhyolite lava flow (~ 68 % SiO_2) with anomalously high Cr content (62 ppm Cr). Contains sparse phenocrysts of plagioclase and pyroxene replaced by metasomatic adularia and Fe oxides, respectively; traces of fine-grained phenocrystic quartz and biotite are also present. Thick hogback former transected by Black Canyon appears to represent a singular massive flow, about 120 m thick; thickness and distribution patterns suggest a source vent near the Black Canyon fault zone. Conformably interbedded within lower and upper cooling units of the medial pumiceous tuff member (Tzt1 and Tzt2). Compositional data, age relationships, and magmatic disequilibrium textures support the interpretation that the mafic-rhyolite flow unit represents a hybrid magma, a mixture of magmas equivalent to about one part Tza1 and two parts Tzt1 (Chamberlin et.al., in press). Maximum thickness is 120 m; absent at Socorro Canyon and at Socorro Peak

08-02-12-00-00–Unit–Tza1–Lower basaltic member, compositionally zoned basaltic andesite to andesite flow unit–Purplish gray, phenocryst-poor to moderately phenocryst rich, basaltic andesite to andesite lava and minor andesitic conglomerates. Lavas at Black Canyon are intensely altered. Basal basaltic-andesite zone contains sparse olivene phenocrysts (six-sided euhedra) replaced by hydrothermal silica and hematite; basaltic andesite composition is indicated by high Cr content (160 ppm Cr) and a relatively high TiO_2 content (1.29 %) Upper andesitic zone contains moderately abundant (~10%) fine-grained plagioclase laths (1-2mm long) and octagonal pyroxene phenocrysts preferentially replaced by metasomatic adularia and hematite, respectively. Later-stage calcite and epidote also partially replace adularia and hematite. Altered plagioclase microlites form 70-80% of groundmass in both zones. Vesicular or amygdaloidal zones are common near top. As mapped, includes 2-3 m of andesitic conglomerates at the base of the unit. Limited extent suggests source vent near Black Canyon. Approximately 30 m thick at Black Canyon, absent in eastern Black Canyon and at Socorro Peak. Basaltic andesite to andesite flow unit at Black Canyon occupies the same stratigraphic position as the trachybasalt flow unit (Tzb) at Nogal Canyon. Lies in angular unconformity on bedded facies of the upper

08-02-13-00-00–Unit–Tzs1–Lower sedimentary member–Light gray, pinkish gray, and purplish gray, medium- to coarse-grained rhyolitic sandstones, and minor andesitic debris flows in upper part. Rhyolitic sandstones most likely derived from underlying caldera-facies Hells Mesa Tuff. Well exposed in eastern Black Canyon; occupies same stratigraphic position as lower basaltic andesite to andesite unit (Tza1) exposed at the Black Canyon box. Lies in angular unconformity on bedded facies of the upper Hells Mesa Tuff. Maximum thickness in eastern Black Canyon is 30 m; less than 3 m thick at Black Canyon box. Presumably derived from moderate uplift of the central horst block area near western Black Canyon; probably correlative to uppermost 30 m of the lower sedimentary member at Nogal

09-01-02-00-00–Unit–Tre–Hells Mesa-age lava dome–Grayish red, flow banded to massive, very phenocryst-rich, spherulitic rhyolite lava dome (~ 68-74 % SiO_2) near Esperanza mine. Contains very abundant (~52% phenocrysts), fine- to coarse-grained crystals of sanidine, argillized plagioclase and quartz with minor biotite and traces of sphene in a spherulitic to cryptocrystalline matrix (Chamberlin, 2001b). Coarse sanidine phenocrysts are 6-9mm long, distinctly larger than in the underlying caldera-facies Hells Mesa Tuff (~3-5mm long). Narrow north-trending exposures east of Esperanza mine represent the faulted crest of a lava dome about 200-300 m high; over 300m of early Luis Lopez strata (Tzs1, Tzb, Tzt1 and Tza2) are missing in the apparent crest of the lava dome (Sheet 2, section G-G'). Probably erupted from an inner ring-fracture zone as expressed by a local NE-trending jog in the overall north-trending Esperanza fault (Chamberlin, 2001a). A single-crystal laser-fusion sanidine 40Ar/39Ar age of 31.89 ± 0.16 Ma (Table 1, no. 24) indicates the small lava dome is equivalent in age to the underlying caldera-facies Hell Mesa Tuff. Maximum thickness is

09-01-03-00-00–Unit–Trt–Dome-derived tuffs–Light gray, poorly to densely welded, crudely bedded, phenocryst-rich, quartz rich, rhyolite ash-flow tuffs (~ 72% SiO_2). Densely welded basal tuff breccias about 0.7 km northwest of the lava dome contain large subangular blocks of reddish gray flow-banded crystal-rich lava texturally equivalent to the lava dome. Comagmatic lithics fragments progressively decrease in size northward along the narrow outcrop belts, from greater than 1m at 0.7 km from the source lava dome to less than 10 cm at about 2 km from the dome (Chamberlin, 2001b). Large compositionally zoned sanidine phenocrysts are also characteristic. Large blocks of sanidine granite (0.3-1 m) are are clustered near the base of the tuff unit about 1.2km north of the dome; they represent ballistic blocks of contact metamophosed Proterozoic granite presumably derived from the walls of the Hells Mesa pluton at depth (Chamberlin, 2001a). Conformably overlies about 30m of upper caldera-facies Hells Mesa Tuff (Thu). A 7m thick nonwelded zone, preserved at the top of the upper Hells Mesa, and significantly greater crystal size of the dome-derived tuffs indicates a moderate hiatus (~10^4 yrs) between upper Hells Mesa eruptions and eruption of the dome-derived tuffs (Chamberlin, 2001b). Tuff unit thins northward from maximum thickness of 120m to about 60m at the Red Canyon fault, where it is abruptly

09-02-02-00-00–Unit–Thuf–Caldera-facies Hells Mesa Tuff, upper member, bedded zone–Mostly densely welded, pale red, crystal-rich ignimbrites with many thin tongues (15-20) of comagmatic-lithic lag breccias that are commonly capped by thin, fine-grained ash-fall beds. Distinctly bedded appearance is mostly derived from resistant ledges of thin (2-30cm thick) densely welded (or fused), upward fining, ash-fall deposits. Comagmatic lag breccias contain angular to moderately flattened clasts of reddish brown, spherulitic, phenocryst-rich rhyolite (~72 % SiO_2) compositionally similar to the surrounding pale red crystal-rich tuff matrix. Lag breccias are coarser and fine-grained fall beds are more common near the top of the bedded zone. Distribution patterns of maximum clast sizes (10-75cm) suggest the presence of a concealed vent area about 3-4 km ESE of the Bursum mine (Chamberlin 2001b). Explosive origin of comagmatic lag breccia is demonstrated by fragmented spherulites in the ignimbrite matrix and microfaults (mm scale offsets) in larger quartz or feldspar phenocrysts within the spherulitic clasts (Chamberlin, 2001a). Conformably overlies a 10m-thick poorly welded zone at the top of the massive zone of upper Hells Mesa Tuff (Thu). Sanidine from upper bedded zone at Black Canyon box yields a 40Ar/39Ar age of 31.94 ± 0.17 Ma (Table 1, no. 25). Maximum thickness is 200 m, absent outside the Socorro caldera and in

09-02-03-00-00–Unit–Thu–Caldera-facies Hells Mesa Tuff, upper member, massive zone–Pale red, mostly densely welded, crystal-rich rhyolite ignimbrite with sparse to rare comagmatic lag breccias that contain small pumice-like clots and angular clasts of dark red spherulitic rhyolite and 2 or 3 fine-grained ash-fall beds. Occurs near Bursum mine and near the Esperanza mine. Gradational basal contact is marked by upward dissapearance of rare small andesitic xenoliths at the top of the densely welded, lower xenolith-poor Hells Mesa Tuff (Thx) and appearance of rare small clasts of red spherulitic rhyolite in the densely welded massive zone (Thu). Both types of clasts can be present in the same rock sample near the gradational contact. Subtle contact zone is locally well exposed along the road to the Bursum mine. A 20 cm thick ash-fall bed, about 10m above the basal contact, is well exposed in a ravine about 100m south of the road. A 7-10m thick poorly welded to non-welded zone occurs at the top of the massive zone. Massive zone is about 200m thick in area east of the Bursum mine; it is over 100m thick south of the Esperanza mine and about 30m thick north of the Esperanza mine (Chamberlin 2001b). Thickness variations near the Esperanza mine suggest at least 70m of local uplift prior to emplacment of

09-02-04-00-00–Unit–Thx–Caldera-facies Hells Mesa Tuff, lower member, xenolith-poor zone–jointed, phenocryst-rich rhyolite ignimbrite. Typically contains sparse to rare small xenoliths of medium gray andesite porphyry. Grades downward into lithic-rich mesobreccia zone (Thm), basal contact approximately located. Maximum thickness south of Black Canyon is 550 m,

09-02-05-00-00–Unit–Thm–Caldera-facies Hells Mesa Tuff, lower member, xenolith-rich mesobreccia zone–Mostly xenolith-rich (5–50%), reddish orange to reddish brown to grayish red, densely welded, phenocryst-rich, rhyolite ignimbrite mesobreccia. Angular to subrounded accidental lithic fragments, mostly 1–50 cm across, consist mostly of dark gray to purplish-gray DatilGroup-type andesite porphyry (containing medium-grained plagioclase phenocrysts) with and crystal-poor rhyolite blocks; also with minor amounts of granite and schist of Precambrian affinity, plus rare limestones and sandstones of Paleozoic affinity. Mesobreccias in lower caldera-facies tuff are intimately interleaved with large coignimbrite landslide blocks of andesite and adjacent zones of very lithic-rich ignimbrite megabreccia (Thb). Thm is interpreted as a relitively finer grained mesobreccia facies laterally equivalent to more proximal caldera-collapse megabreccias (Thb) apparently derived from the southern wall of the Socorro caldera (Eggleston, 1982). As mapped, Thm includes a 100 m thick, xenolith-poor zone in its lower part, south of the Torres mine. Maximum estimated thickness of Thm plus Thb in area south of Red Canyon is 2400

09-02-06-00-00–Unit–Thb–Caldera-facies Hells Mesa Tuff, lower member, xenolith-rich megabreccia zone–Caldera-collapse megabreccia slabs and very xenolith-rich mesobreccias within densely welded to partially welded phenocryst-rich rhyolite ignimbrite. Dominated by large slabs of Datil Group-type andesite porphyry as much as 1 km long and 100 m thick. Rare "dikelets" of quartz-rich Hells Mesa ignimbrite injected into fractures in the andesite slabs locally help distinguish them from Datil Group andesites (Eocene) that could represent caldera floor rocks. A large coherent block of Spears-type conglomerate, as much as 120 m thick, is also present about 1 km north of Olney Ranch (aka. Nogal Ranch). Thb includes very lithic-rich and blocky mesobreccias (>50% clasts) that contain abundant large blocks of andesite, rhyolite, granite, schist and limestone typically 0.5 to 3 m across. These two major lithologies probably represent large landslide blocks and rock-avalanche deposits, respectively. Wedges of Thb thicken to the south, indicating that they were most likely derived by slumping of the south wall of the Socorro caldera, during early stages of eruption of the Hells Mesa Tuff (Eggleston, 1982). Combined maximum thickness of

09-02-07-00-00–Unit–Thw–Caldera-facies Hells Mesa Tuff, lower member, xenolith-bearing caldera-wall facies–Densely to poorly welded, light-gray to pale red, locally xenolith-rich to xenolith-poor, phenocryst-rich, quartz-rich, rhyolite ignimbrite. Locally contains abundant andesite and granitic xenoliths; Spears-type conglomerate megabreccia slabs locally occur at the base. Also contains xenocrysts of microcline derived from Precambrian rocks. Lower half is strongly bleached and "argillized" (milky sanidines) in area near Chupadera Spring. Slightly altered, xenolith-poor, phenocryst-rich ignimbrite from top of xenolith-bearing facies yields a single-crystal laser-fusion 40Ar/39Ar sanidine age of 31.85 ± 0.17 Ma (Table 1, no. 26), thereby confirming correlation with the Hells Mesa Tuff. Unconformably overlies Proterozoic schists and granites. Interpreted as medial Hells Mesa Tuff (laterally equivalent to Thm & Thx) filling a shallow embayment in the southern topographic wall of the Socorro caldera. Previously assigned to lower Luis Lopez Formation ("Tzt1" of Eggleston, 1982; and "Tzt1" of Osburn and Chapin, 1983b). Maximum thickness near Chupadera Spring is 270 m. About 1 km south of the quadrangle, Thw wedges out against Precambrian rocks that locally define the inner

10-01-00-00-00–Unit–Xp–Porphyritic schists–Light to medium gray, quartz-feldspar porphyritic schist and porphyry. Includes

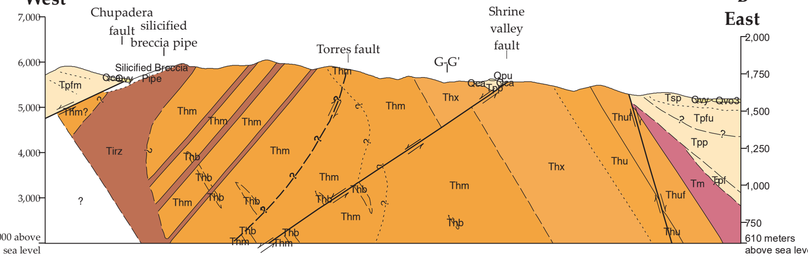
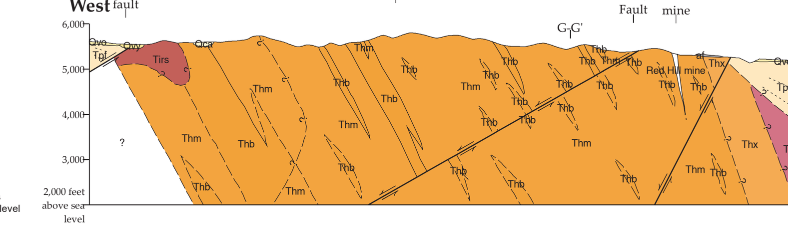
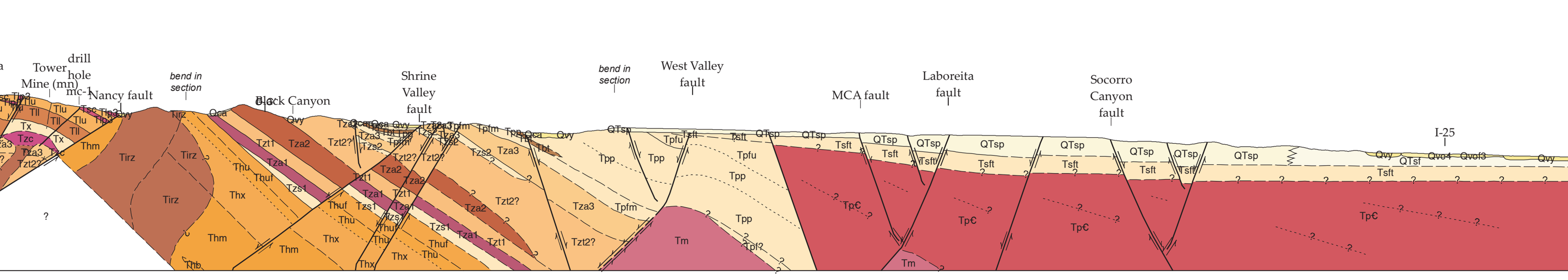
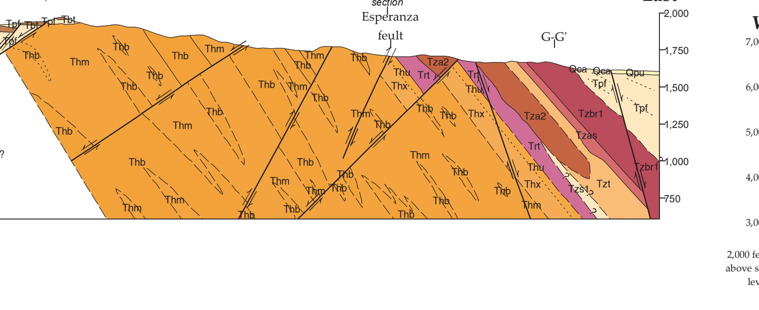
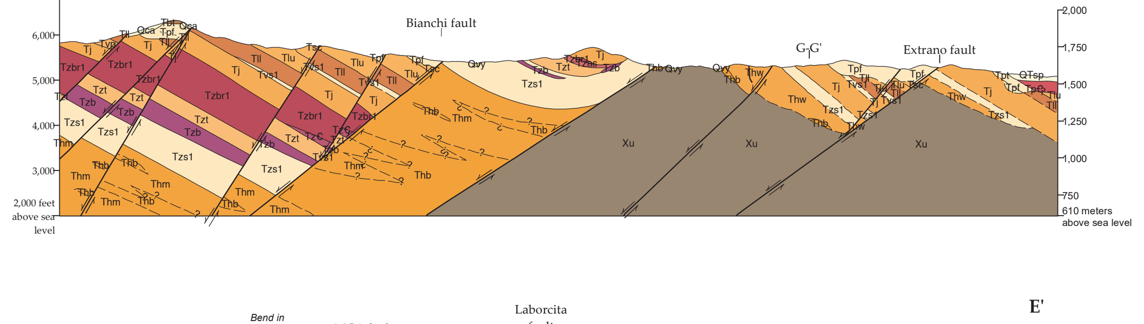
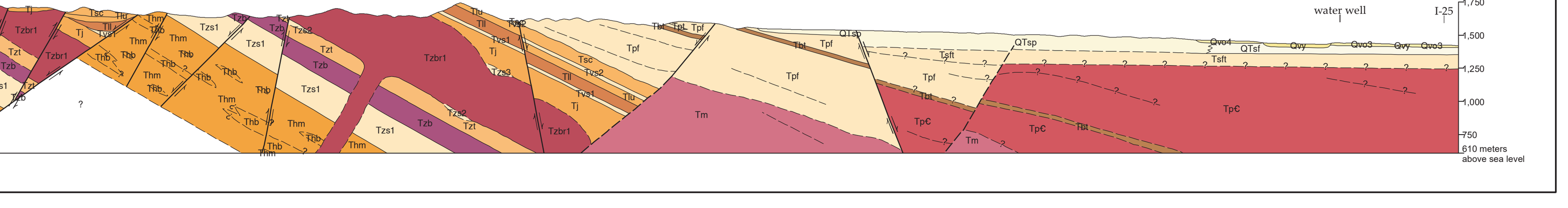
10-02-00-00-00–Unit–Xf–Feldspathic schists–Reddish orange quartzo-feldspathic schists, locally grades into minor pelitic schists (Kent, 1982). Foliated granite, also in this basement block,

10-03-00-00-00–Unit–Xu–Metamorphic basement rocks

11-01-00-00-00–Unit–Tim–Mafic dikes–Medium gray to purplish gray, aphanitic to phenocryst-poor, mafic to intermediate dikes about 3–10 m wide. Locally cuts upper rhyolite member of Luis Lopez Formation (Tzbr1) in area southeast of Esperanza Mine. Also includes a small, grayish red, andesite porphyry dike in large rhyolite plug (Tirz) south of Black Canyon. Aphanitic dike near Esperanza Mine is texturally unlike diabasic flows in Popotosa Formation and is probably not related to the Miocene

11-02-00-00-00–Unit–Tirs–Coarsely porphyritic rhyolite dikes and plug-like intrusion–Light pinkish gray, moderately phenocryst rich (15–20%) coarsely porphyritic rhyolite. Contains large phenocrysts (3–7 mm) of sanidine, with smaller plagioclase, quartz and biotite. Cuts lower caldera-facies Hells Mesa Tuff in area near Red Canyon. Larger exposures at west mouth of Red Canyon may represent top of cupola or small stock. Plagioclase is locally altered to metasomatic clays adjacent to the Chupadera fault. Main part of dike is unaltered where it cuts across the "red alteration zone" of Eggleston et.al, 1983. 40Ar/39Ar age of 10.99 ± 0.06 Ma (Table 1, no. 29) agrees well with published K-Ar age of 11.6 ± 0.6 Ma (Willard, 1971). This 40Ar/39Ar age is slightly younger than the lower rhyolite flow of the Pound Ranch member of the Socorro Peak Rhyolite of Osburn and Chapin (1983b) dated at 11.31 ± 0.08 Ma (Newell,

11-03-00-00-00–Unit–Tirx–Moderately phenocryst-rich rhyolite dike–Pale red, moderately phenocryst rich (15–20%), massive rhyolite dike (~3 m wide) in northeast-striking tension fracture north of Black Canyon (part of composite dike adjacent to Tiaz). Contains medium to coarse-grained phenocrysts of sanidine, quartz, argillized plagioclase and biotite. 40Ar/39Ar age of 28.33 ± 0.15 Ma from sanidine (Table 1, no. 28) indicates intrusion was coeval with silicic volcanism that backfilled the Sawmill Canyon caldera (Sawmill Canyon Formation of Osburn and Chapin, 1983b), about 14 km west of Black Canyon. Moderately porphyritic dike is geochemically distinct (62 ppm Y, 35 ppm Nb) from the phenocryst-poor rhyolite dikes of the Black Canyon fault zone (Tirz; 16ppm Y, 17 ppm Nb; Chamberlin et.al, in

11-04-00-00-00–Unit–Tirz–Phenocryst-poor rhyolite dikes and plugs–Light gray to light purplish gray, phenocryst poor, flow banded to massive, east-northeast striking high-silica rhyolite dikes (76 % SiO_2) and small to large plugs in area south of Black Canyon. Width of dikes ranges from 5 to 60 m. Rhyolite plugs near Torres Mine and Black Canyon are 300 to 600 m across and locally merge with northeast trending dikes. Plug at Torres mine includes a minor purplish gray mafic-rhyolite phase (69 % SiO_2 & 55 ppm Cr) along its eastern margin. Dikes and plugs typically contain sparse (3–8%) fine grained (1–3 mm) phenocrysts of plagioclase, sanidine, quartz and biotite. Plagioclase is commonly altered to white clay and generally weathers out leaving tabular holes in rock face. Mineralogy, phenocryst size, phenocryst abundance and trace element chemistry are similar to upper rhyolite member of Luis Lopez Formation (Tzc; Chamberlin et.al., in press) 40Ar/39Ar age of sanidine in dike at eastern range front (sec. 8, T1S, R4W) is 28.53 ± 0.14 Ma (Table 1, no. 27), which is analytically equivalent to the upper Luis Lopez rhyolites and La Jencia Tuff, but the latter is chemically unlike the phenocryst-poor likes (Chamberlin et.al, in press). Equivalent ages and lithologies suggest that these dikes may have fed Tzc flows. Correlation of similar phenocryst-poor rhyolite intrusions within Thm near Madera Canyon (SE¼ sec. 36, T4S, R2W) with

11-05-00-00-00–Unit–Tiaz–Andesite dikes–Dark gray to purplish gray, moderately porphyritic, northeast striking, andesitic dikes (5–20 m wide) cutting Hells Mesa Tuff and lower Luis Lopez members in area north of Black Canyon. These potassium metsomatized dikes contain sparse phenocrysts of plagioclase altered to white clay and pyroxene altered to Fe oxide. Dike approximately 2 km northeast of Tower Mine appears to feed Tza3 flow. Dike 3 km east-northeast of Tower Mine appears to