Geologic Map of the Water Canyon Quadrangle, Socorro County, New Mexico

By Richard M. Chamberlin and G. Robert Osburn

May, 2006

New Mexico Bureau of Geology and Mineral Resources Open-file Digital Geologic Map OF-GM 118

Scale 1:24,000

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PRELIMINARY GEOLOGIC MAP OF THE WATER CANYON 7.5 MINUTE QUADRANGLE, SOCORRO COUNTY, NEW MEXICO

(EAST HALF)

By

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Comments to Map Users

Mapping of this quadrangle was funded by a matching-funds grant from the 1998 STATEMAP program of the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number 00HQAG0078, to the New Mexico Bureau of Geology and Mineral Resources (Dr. Peter A. Scholle, Director; Dr. Paul W. Bauer, P.I. and Geologic Mapping Program Manager).

This quadrangle map has been Open-filed in order to make it available as soon as possible. The map has not been reviewed according to NMBMMR standards, and due to the ongoing nature of work in the area, revision of this map is likely. As such, dates of revision are listed in the upper right corner of the map and on the accompanying report. *The contents of this report and map should not be considered final and complete until it is published by the NMBMMR*.

A geologic map graphically displays information on the distribution, nature, orientation, and age relationships of rock and surficial units and the occurrence of structural features such as faults and folds. Geologic contacts are irregular surfaces that form boundaries between different types or ages of units. Data depicted on this geologic map are based on field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation.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. Significant portions of the study area may have been mapped at scales smaller than the final map; therefore, the user should be aware of potentially significant variations in map detail. 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 everywhere.

Any enlargement of this map could cause misunderstanding in the detail mapping and may result in erroneous interpretations. The information provided on this map cannot be substituted for site-specific geologic, hydrogeologic, or geotechnical investigations. The use of this map to precisely locate buildings relative to the geological substrate is not recommended without site-specific studies conducted by qualified earth-science professionals.

The cross-sections in this report are constructed based on surficial geology, and where available, subsurface and geophysical data. The cross sections are interpretive and should be used as an aid to understand the geologic framework and not used as the sole source of data in locating or designing wells, buildings, roads, or other structures.

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DESCRIPTION OF MAP UNITS:

POST-SANTA FE GROUP UNITS

- **af** Artificial fill (uppermost Holocene)— Mostly represents compacted fill as roadway subgrades along U. S. Highway 60, also represents earthen dams at stock reservoirs. Thickness 0–6m.
- Qvy Younger valley alluvium, piedmont facies (Holocene to uppermost Pleistocene) —
 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 entrenchment and backfilling.
 Thickness 0–30 m.
- **Qpy Younger piedmont-slope alluvium** (Holocene to upper Pleistocene)— Pebbly to sandy alluvial fan and arroyo-fill deposits on piedmont slopes. Graded to the closed basin floor at La Jencia basin playa. Probably less than 10 m thick
- Qe Eolian deposits (Holocene to middle Pleistocene) Light gray to pale red, fine-grained, well-sorted, wind-blown sand and loess. Small dune fields locally cap older surfaces at slope breaks east of the La Jencia playa and east of La Jencia Creek. Thin eolian sand veneers (<0.3m), on graded piedmont slopes, are mapped as piedmont deposits (i.e. Qpy, Qpo). Thickness range: 0–3 m.
- QcaColluvium and alluvium, undifferentiated (Holocene to Middle Pleistocene) Talus
and colluvium on steep to moderate slopes in the western Socorro Mountains, Lemitar
Mountains and Northeastern Magdalena Mountains. Also, gravelly slope wash on erosion

surfaces cut in poorly consolidated upper Cenozoic deposits in the southern La Jencia Basin. Gravelly colluvium is typically shown where it masks playa deposits of the Popotosa Formation (Tpm) . Widespread colluvial veneers on dissected piedmont slopes near Sedillo Hill are generally not delineated. Usually 0.3-3 m. thick, locally as much as 10 m. thick.

- Qls Landslide deposits and colluvium (upper Pleistocene to middle Pleistocene) Includes numerous toreva-type (rotated) slide blocks of lava (derived from Tsr, Tsrd, Tash) that have slipped down slope on underlying Popotosa playa deposits (Tpm). Suffix in parenthesis indicates composition of slide blocks (a= andesite, d= dacite/rhyodacite, r=rhyolite). Slide blocks and mudstones are mantled by abundant colluvium. Includes small mudflows and minor alluvium. Most slide areas are relatively stable or inactive. Landslides are widespread around Strawberry Peak, Sedillo Hill and western flank of the Socorro Mountains. Characterized by hummocky topography. Thickness of lava slide blocks is as much as 90 m.
- **Qp** Fill of small closed basins (playas) in landslide terrane (middle to upper Pleistocene)—
 Unconsolidated mud, silt and sand; generally flat lying locally dissected by recent rivulets.
 Probably less than 10 m thick in most smaller basins.
- **Qvo Older valley alluvium, piedmont facies** (middle to upper Pleistocene) 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 modern floodplain of the Rio Grande in the Socorro 7.5' Quadrangle (Chamberlin, 1999). The height of alluvial surfaces above modern drainages progressively decreases upslope into the Water Canyon quadrangle. The top of Qvo1 stands about 15-18m above the floor of Sixmile Canyon. 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. Correlation with alluvial units in Socorro Quadrangle is based on lateral continuity along Socorro Canyon and Sixmile Canyon drainages. 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). Thickness 0–12 m, average thickness 6–9 m.

Qpo Older piedmont-slope alluvium (middle to upper Pleistocene)— Bouldery to sandy alluvial-fan deposits graded to the central La Jencia Basin or to western slopes of Sedillo Hill. Large alluvial fans emanate from Water Canyon and South Canyon. Smaller highgradient fans emanate from Shakespeare, Garcia and Jordan canyons. Fan deposits disconformably overlie thick piedmont deposits of the Sierra Ladrones Formation (QTslp) that are lithologically very similar, since they have the same provenance. Basal unconformity not exposed; probably 3-10m thick.

SANTA FE GROUP

Intermontane basin fill of the Rio Grande rift. As redefined by Machette, 1978, includes the Pliocene and Pleistocene valley fill of the Sierra Ladrones Formation (of Machette, 1978), and Miocene bolson fill of the Popotosa Formation, named by Denny, 1940. Also includes intercalated volcanic units such as the Socorro Peak Rhyolite, rhyolitic ash-falls, and local basalt flows (Osburn and Chapin, 1983).

UPPER SANTA FE GROUP:

Qsh
QTslpSierra Ladrones Formation (lower Pleistocene to lower Pliocene) — Late-stage
basin fill of the Rio Grande valley characterized by an axial-river facies (ancestral
Rio Grande) and intertonguing piedmont facies (large alluvial fans) derived from adjacent
mountain ranges. In the Socorro Basin it is capped by Las Cañas geomorphic surface (Qlc)
of McGrath and Hawley, 1987 As mapped here, in the southern La Jencia Basin, only the
piedmont facies is exposed under the Sedillo Hill surface (Qsh) of McGrath and Hawley,
1987). Sierra Ladrones piedmont facies (QTslp) disconformably overlies the 6.9 Ma
basaltic trachyandesite of Sedillo Hill and underlying playa claystones of the upper
Popotosa Formation at the SE margin of the La Jencia Basin. Regional map data indicate
these same piedmont deposits (shed from the Magdalena Mountains) intertongue with
ancestral Rio Grande deposits in the Socorro Basin. Hence the piedmont facies in the La
Jencia Basin is correlative with piedmont facies in the Socorro Basin. Maximum thickness
of Sierra Ladrones Formation in southern La Jencia Basin is about 330m.

Qsh Sedillo Hill geomorphic surface of McGrath and Hawley, 1987 (lower Pleistocene) — Erosional remnants of constructional alluvial fan surface preserved between the mouth of Sixmile Canyon and the top of Sedillo Hill. From 6500 to 6100 feet elevation (227 ft/mi)

the surface projects eastward as a concave -upward slope that is continuous with the Las Canas surface at 5200-5100 ft (166 ft/mi) as mapped in the Socorro quadrangle (Chamberlin, 1999). Surface represents maximum level of aggradation of late Cenozoic basin fill along the Rio Grande valley near Socorro. Defines top of Santa Fe Group and Sierra Ladrones Formation where present. Characterized by a dark reddish brown clay-rich soil nearly 2 m thick (Ustollic Paleargid; McGrath and Hawley, 1987). Correlation with Las Canas surface in Socorro quadrangle is based on projection of graded surface and similar degree of soil development. In comparison, petrocalcic carbonate soils are typical of the Las Canas surface, which occurs at significantly lower elevations than the Sedillo Hill surface. Sedillo Hill and Las Canas surfaces are tentatively correlated with the lower La Mesa surface of the Las Cruces area, which has recently been dated at 0.73–0.9 Ma (Mack and others, 1993).

QTslp Sierra Ladrones Formation, piedmont facies (lower Pleistocene to lower Pliocene) — Piedmont-slope deposits below Sedillo Hill geomorphic surface of McGrath and Hawley, 1987. Consists of reddish orange to reddish brown, poorly consolidated, volcanic-rich, boulder to cobble conglomerates and conglomeratic sandstones and sandstones. Buried calcic soil horizons (bc) are locally present. Maximum thickness of piedmont facies, estimated from cross section, is about 330 m. Wedge-shaped unit thickens rapidly westward on hanging wall block of the La Jencia fault; approximately 9-12m thick on footwall block of La Jencia fault at near mouth of Sixmile Canyon.

LOWER SANTA FE GROUP:

Tp_ **Popotosa Formation** (lower to upper Miocene; basal graben fills may be latest Oligocene?)—Intermontane bolson fill deposits of early Rio Grande rift grabens and "half" grabens (tilted fault blocks). Defined by Denny, 1940, and redefined by Machette, 1978. In the San Lorenzo Spring quadrangle, north of Water Canyon, the Popotosa Formation can locally be divided into lower conglomeratic piedmont facies (Tpx, Tpd, Tpc) and upper conglomeratic piedmont facies (Tpcu) on the basis of clast suites (cf. Bruning, 1973) and relative stratigraphic position to dated lavas and ash beds. The 15.4-Ma "Silver Creek Andesite" (Chamberlin and McIntosh, unpublished data) and several water-laid ash beds (0-3 m thick) that include pumiceous sandstones (15.6-14.5 Ma; Cather et.al., 1994; Cather and Read, 2003) are interbedded in the medial to upper Popotosa Formation. Thin fall deposits are also present, but less visible than water-laid beds. The dated strata indicate a middle Miocene age for the medial and upper Popotosa Formation in the area northwest of Red Mountain (upper San Lorenzo Arroyo); correlative water-laid ash beds occur in the Canoncito de las Cabras area of the Lemitar quadrangle (Chamberlin et.al, 2001). An angular unconformity of 10–25 degrees is evident at the base of the lower Popotosa Formation in the southern Lemitar Mountains; this angularity generally decreases northward. Basal Popotosa debris flows and conglomerates are widely potassium metasomatized and often very well indurated with jasperoidal silica (Chapin and Lindley, 1986; Dunbar et al, 1994; Dunbar and Miggins, 1996; Chamberlin and Eggleston, 1996, Lueth et.al, 2004). Metasomatic adularia in the lower Popotosa near Socorro Canyon, yields a 40 Ar/ 39 Ar age of 7.4 ±0.1 Ma (Dunbar and Miggins 1996). Field relationships in the San Lorenzo Canyon area suggest that metasomatism and hydrothermal alteration may be significantly older in this area (e.g. late Oligocene to early

Miocene). Presently undated rhyolitic ash beds also occur in the lower Popotosa conglomerates. Assuming an unbroken floor to the La Jencia Basin, the projected thickness of the Popotosa Formation is about 4 to 5 km (cf. Cather and Read, 2003; section A-A'). However, map data in the San Lorenzo Spring quadrangle implies the floor of the La Jencia Basin (top of Oligocene volcanic pile) is probably broken by several down-to the-east normal faults that are concealed by upper Popotosa strata. Assuming concealed faults, the Popotosa Formation is more likely to be about 2 km thick under the central La Jencia Basin. Lower Popotosa conglomerates and debris flows at Red Mountain have an aggregate exposed thickness of about 600-700 m. Map units developed in the San Lorenzo Spring quad have been extended into the northeastern Water Canyon quadrangle.

 Tpcu Popotosa Formation, upper, conglomeratic sandstone facies (middle to upper Miocene) —Light brownish gray to light gray, heterolithic conglomeratic sandstones, sandstones and minor mudstones. Characterized by wide variety of volcanic pebbles and minor cobbles representing the entire middle Tertiary volcanic pile; locally contain minor non-volcanic clasts. Conglomeratic beds are usually well cemented by carbonate.
 Conglomerate beds are commonly clast supported; low-angle trough crossbeds (cut and fill) and planar beds are common. Crystal-rich and crystal-poor ignimbrite pebbles (Hells Mesa-type and La Jencia type) are relatively common (5-10%) as are vesicular mafic lavas. Northeasterly paleocurrents and clast lithologies are consistent with a deeply dissected source highland near Magdalena. Unit appears to occur stratigraphically above or interbedded with middle Miocene ash beds that have been dated in the Silver Creek quadrangle (Cather and Read, 2003).

- Tpp Popotosa Formation, playa facies (upper Miocene)—Mostly red or maroon claystone with minor greenish claystone and thin bedded buff to light gray siltstones to fine-grained sandstones. Gypsum and selenitic veinlets are widespread in this unit. Claystones are poorly indurated and commonly masked by landslide deposits (Qls) and colluvium (Qca) where they underlie steeper slopes on west flank of Socorro Peak. Playa deposits contain lavas and ash beds ranging from 9.8 to 7.8 Ma (Chamberlin, 1999). The youngest known playa deposits locally underlie the east flank of Sedillo Hill, which is capped by a basaltic trachyandesite lava flow dated at 6.88 ± 0.02 Ma (W. C. McIntosh and R.M Chamberlin, unpublished data). Maximum thickness estimated from geothermal boreholes (Chapin et al. 1978) and cross sections is 750 m.
- Tpc_ Popotosa Formation, lower, conglomerates and conglomeratic sandstone facies (lower to middle Miocene)—Pale reddish gray, purplish gray, light gray and light brownish gray conglomerates and conglomeratic sandstones. Conglomerates are mostly clast supported and crudely bedded to planar bedded. Three distinct sub-units (overlapping fan lobes?) are recognized northwest of San Lorenzo Spring (Chamberlin,2004). The lowest unit consists of pale red to purplish gray, basaltic-andesite dominated conglomerates with sparse vein quartz and white felsite clasts (Tpc1). A medial sub-unit consists of pale red conglomerates that contain subequal South Canyon Tuff and basaltic andesite clasts (Tpc2). The highest unit is a light to medium brown boulder to pebble conglomerate containing dominantly South Canyon Tuff clasts with less abundant basaltic andesites and sparse flow-banded rhyolites (Tpc3). All these conglomerate sub-units underlie the 15.4-Ma Silver Creek Andesite. Another light brown conglomeratic sandstone unit (Tpc4) is similar to a mixture of Tpc3 and Tpc1. Tpc4 occurs stratigraphically above the Silver

Creek Andesite and appears to grade southwards into an stratigraphically higher **Tpc**₁ type conglomerate. Sub-units 0- 200 m thick. **Tpc3**, **Tpc4** and upper **Tpc1** are present in the Water Canyon quadrangle; lower **Tpc1 and Tpc2** are absent in the Water canyon quadrangle.

Tpd_ Popotosa Formation, lower, debris-flow and conglomerate facies (lower to middle Miocene)—Mostly well indurated, medium reddish brown to dark red, volcanic-rich, matrix supported, debris flows, conglomerates and minor fluvial conglomeratic sandstones. Commonly well cemented by red jasperoidal silica; but some red clayey cemented debris flows also form poorly exposed zones. Light gray poorly cemented zones also occur rarely. Cobble sized clasts are common; boulder beds occur locally near the base. Locally divided into three overlapping sub-units based on the dominant type of volcanic clasts. Deposits dominated by gray, iddingsite-bearing La Jara Peak Basaltic Andesite clasts are designated **Tpd**₁; deposits dominated by light-gray South Canyon Tuff clasts are designated **Tpd**₂; and deposits dominated by andesite porphyry clasts (Tar-type) are designated **Tpd**₃. Only **Tpd**₂ is present in the sourthern Lemitar Mountains. Sub-units grade laterally from one composition to another where facies boundaries are shown; debris-flow units also grade laterally into compositionally equivalent conglomerates. Units fill narrow north-trending fault-block depressions in the southern Lemitar Mountains; northerly paleocurrents are dominant here. Thickness of wedge-shaped fills is highly variable, from 0–300 m. Angular unconformity at base of **Tpd2** truncates a south facing monocline of late Oligocene age (Tlu-Tsc age) in the southwestern Lemitar Mountains.

Tpu Popotosa Formation, undivided (lower to middle Miocene)— Poorly exposed Popotosa conglomerates and conglomeratic sandstones on west flank of Lemitar Mountains.
 Rounded hills are generally mantled with colluvial soils that contain abundant volcanic cobbles and pebbles.

VOLCANIC STRATA WITHIN THE LOWER SANTA FE GROUP:

Tbsh **Basaltic trachyandesite of Sedillo Hill** (upper Miocene) — Medium gray, massive to vesicular, xenocrystic basaltic andesite lava flows. Locally erupted from a NNE-trending fissure vent or plug about 2.5 km NE of Sedillo Hill Reservoir (UTM: 0313700 E, 3767600 N). A mixed magma origin is indicated by sparse fine-grained iddingsite (after olivine) in a matrix of plagioclase microlites and interstitial clinopyroxene (trachybasalt magmatic suite) and moderately abundant (3-5%) xenocrysts of plagioclase, sanidine, biotite, hornblende and quartz (rhyolitic magma suite) that commonly exhibit magmatic reaction rims of very fine clinopyroxene. Small rhyolitic/granitic xenoliths are also present. Maximum thickness near vent is 33m; distal flow at north end of Sedillo Hill is about 5m thick. Subtle flow foliations visible in the canyon walls are locally contorted and folded; flow fold axes trend ENE. Basaltic cinder beds (Tbsht), preserved west of the vent, are as much as 100m thick. Unit conformably caps thick playa sequence of the upper Popotosa Formation and is disconformably overlain by piedmont facies of the Sierra Ladrones Formation. Samples from the basaltic trachyandesite of Sedillo Hill (n = 4) yield a tightly clustered mean ${}^{40}\text{Ar}/{}^{39}\text{Ar}$ age of 6.88 ± 0.02 Ma from groundmass separates (W. C. McIntosh and R.M Chamberlin, unpublished data).

- Ts_____ Socorro Peak Rhyolite: cluster of Late Miocene silicic lava domes centered near Socorro Peak (Osburn and Chapin, 1983). Individual lava domes range in composition from hornblende dacite (69–70% SiO₂) to hornblende-biotite rhyodacite (70–73% SiO₂) to high silica-rhyolite (75–77% SiO₂) Bobrow, 1983. Dacitic domes are stratigraphically the oldest, rhyodacites are slightly younger, and rhyolites are associated with 4 younger eruptive centers. The more southerly eruptive centers for dacites and rhyolites appear to be the most siliceous. Pumiceous ash beds and bedded tuffs of dacitic to rhyolitic composition are locally mapped as tephra facies (t) of the Socorro Peak rhyolitic that are interbedded in the Popotosa Formation. Tuffs, lavas and associated shallow intrusions (Tid, Tir) are informally subdivided into three members: 1) early dacites (~9.6 Ma), 2) medial rhyodacites (~9.5 Ma), and 3) rhyolites of 4 different eruptive centers ranging in age from 8.8 to 7.0 Ma. Only the two younger rhyolites are present in the Water Canyon quadrangle.
- Tsd Socorro Peak Rhyolite, dacite member (upper Miocene)—Mostly medium gray to reddish brown dacitic porphyry lavas containing about 10 percent fine to medium grained phenocrysts of plagioclase and minor hornblende; biotite if present is rare (<0.5%). Medium-grained plagioclase phenocrysts are strongly resorbed and distinctly less abundant than fine-grained plagioclase phenocrysts. "Smooth Dome" is at the north end of a NNW-trending intrusive belt of early dacite domes. The dacite at M Mountain has yielded an apparently spurious ⁴⁰Ar/³⁹Ar age of 11.56 ± 0.9 Ma from biotite (see Fig. 1). Dacite lavas in the Socorro Peak area are younger than the basalt of Kelly Ranch (9.77 Ma) and older than the rhyolite at Signal Flag Hill (8.66 Ma). They are tentatively

estimated to be about 9.6 million years old (Chamberlin, 1999). Individual dacitic flows average about 60–120 m in thickness. Thickness range: 0–120 m.

- Tsrd Socorro Peak Rhyolite, rhyodacite member at Strawberry Peak (upper Miocene)— Mostly pale red to light gray rhyodacite porphyry lavas containing about 10 percent fine to medium grained phenocrysts of plagioclase with minor hornblende and biotite (subequal). Larger plagioclase phenocrysts are strongly resorbed and hornblende commonly shows a magmatic reaction to form biotite. The deeply eroded flow dome at Strawberry Peak appears to be compositionally zoned (69.8–71.1% SiO₂) from dacite to low silica rhyolite (Bobrow, 1983); hence the compositional name is rhyodacite. Biotite from a slide block east of Strawberry Peak yielded a ⁴⁰Ar³⁹Ar age of 10.56 ± 0.11 Ma (Newell, 1997); however this date must be inaccurate because the rhyodacite at Strawberry Peak overlies the 9.77 Ma basaltic andesite of Kelly Ranch (Chamberlin, 1999). Biotite from the rhyodacite flow at Radar Peak has yielded an ⁴⁰Ar/³⁹Ar age of 9.51 ± 0.06 Ma, which appears to be in agreement with other dated units nearby (Chamberlin, 1999). The Strawberry Peak dome, as much as 220 m thick, was probably emplaced at about 9.5 Ma.
- Tsr4 Socorro Peak Rhyolite, Rhyolite of "Tripod Peak" member (upper Miocene)—Light gray, light brownish gray, and pinkish gray, moderately phenocryst rich (~15%), flow banded, low-silica rhyolite (72–73% SiO₂; Bobrow, 1983). Contains moderately abundant fine to medium-grained phenocrysts of plagioclase, sanidine and biotite with minor quartz. Tripod Peak lavas are petrographically similar to slightly older lavas from the "Jejenes Hill" eruptive center (Tsr3). Basal flow boundary with the older rhyolite (Tsr3) is locally marked by breccia and ash zone that tends to form a recessive slope. Flow units of Tripod Peak center (Socorro quadrangle, Chamberlin, 1999) yield ⁴⁰Ar/³⁹Ar ages on sanidine of

 7.02 ± 0.05 Ma and 7.06 ± 0.03 Ma (Newell, 1997). Rhyolitic surge deposits (**Tsrt**) and rhyolitic debris-flow conglomerates (**Tsrc**), locally exposed under the west dipping basaltic andesite of Sedillo Hill, are interpreted as pyroclastic and epiclastic facies from the Tripod Peak eruptive center.

Tsr3 Rhyolite of Socorro Peak, Rhyolite of "Jejenes Hill" member (upper Miocene)—Light gray, light brownish gray and pinkish gray, moderately phenocryst-rich (~15%), flow banded, rhyolite lavas (low silica-rhyolite 71–73% SiO₂; Bobrow, 1983). Contains moderately abundant, fine- to medium-grained (0.5–2 mm) phenocrysts of plagioclase, sanidine and biotite with minor quartz (~1%). Lava domes at "Jejenes Hill" and unnamed hill to north (6542 ft elevation) represent local source vents. Includes moderately eroded lava flow in low rolling hills to east of "Jejenes Hill". Yields two analytically equivalent 40 Ar/³⁹Ar ages of 7.52 ± 0.09 and 7.45 ± 0.08 Ma from sanidine (Newell, 1997). Flow unit boundaries (margins) are locally marked by breccia and ash zones, which tend to form recessive slopes. Maximum thickness of "Jejenes Hill" lava dome is about 270 m.

EOCENE-OLIGOCENE VOLCANIC ROCKS OF MOGOLLON-DATIL FIELD:

Note: Oligocene tuffs in the Lemitar and Magdalena Mountains are commonly potassium metasomatized; phenocrystic plagioclase is typically replaced by metasomatic adularia and clay minerals; sanidine and biotite are usually not altered. Stratigraphic nomenclature of Eocene-Oligocene volcanic rocks is from Osburn and Chapin, 1983.

Tsc South Canyon Tuff (upper Oligocene)—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; crystals progressively increase upwards from about 5% near partly welded base to as much as 25% near densely welded top (where

preserved). Sanidine commonly shows blue chatoyancy (i.e. moonstones). Partially welded, phenocryst-poor, pumiceous basal zone is commonly about 30m thick and grades upwards into densely welded moderately crystal-rich zone. Generally lithic poor except near base; light gray pumice (1–5 cm) is moderately abundant (5-15%). Represents remnants of outflow sheet erupted from the Mount Withington caldera in the northern San Mateo Mountains (Ferguson, 1991). Mean 40 Ar/ 39 Ar age is 27.37 ± 0.07 Ma; magnetic polarity is reverse (McIntosh et al., 1991). Correlation here is based on lithology and relative stratigraphic position. Thickness ranges from 0-90 m.

TlpLa Jara Peak Basaltic Andesite, middle and upper tongues undifferentiated (upper
Oligocene)—Basaltic andesite lavas equivalent to Tl2 and Tl3 in the southwestern Lemitar
Mountains, where the Lemitar Tuff is missing. The La Jara Peak Basaltic Andesite
represents a widespread thick pile of alkaline basaltic lavas that accumulated on the SE
margin of the Colorado Plateau in upper Oligocene time (Osburn and Chapin, 1983). The
pile is locally divided into tongues where thin ash-flow sheets are intercalated with the
basaltic pile. Wedge-shaped prisms of basaltic lavas in Lemitar Mountains indicate they
were erupted contemporaneously with early extension and domino-style block rotation in
the Lemitar Mountains (Chamberlin 1983; Cather, et. al., 1994).

Tl₃ La Jara Peak Basaltic Andesite, upper tongue (upper Oligocene)— Mostly medium gray to purplish gray, massive and platy to vesicular basaltic andesite lavas characterized by moderately abundant (5–10%) fine- to medium-grained phenocrysts of olivine, usually altered to reddish brown iddingsite. Phenocrystic plagioclase is typically absent. A black to medium gray olivine-bearing basalt is often present immediately above the Lemitar Tuff Thin flows (3-6m) commonly exhibit vesicular tops and reddish basal zones. Upper flows

are locally interbedded with grayish to reddish brown, fine-grained sandstones that occasionally contain thin light-colored ash beds. Tl_3 is older than South Canyon Tuff and younger than the Lemitar Tuff. Thickness of wedge-shaped prism usually ranges from 60-330 m. Locally truncated by angular unconformity in SW Lemitar Mountains.

Tlu/Tll Lemitar Tuff; upper and lower members (upper Oligocene)—Compositionally zoned (77–65 wt% SiO₂), ignimbrite subdivided into a partially to densely welded, light gray, phenocryst-poor (5-15%), rhyolite lower member (Tll), and densely welded, red to gravish red, phenocryst-rich (30–45%), dacitic to rhyolitic upper member (**Tlu**). Contains sparse to abundant, medium-grained (1-4 mm) phenocrysts of quartz, sanidine, plagioclase (altered), 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 clots" of dacite/andesite porphyry are typical in outflow of the upper member. Basal vitrophyre often occurs where the lower member is absent. Represents outflow sheet erupted from the Hardy Ridge caldera in the west-central Magdalena Mountains (G. R. Osburn oral commun. 1997, Chamberlin et al, 2004). Lower member (< 40 m) and upper member (< 50 m) locally wedge out onto paleotopographic highs. Lemitar Tuff fills in tilted early rift fault blocks in the central Lemitar Mountains (Chamberlin, 1983). Mean ⁴⁰Ar/³⁹Ar age (bulk sanidine) is 28.00 ± 0.08 Ma; paleomagnetic polarity is normal (McIntosh and others, 1991). Locally preserved on down-warped southern side of south-facing monocline in southwestern Lemitar Mountains. Monocline represents pre-Lemitar uplift on the south

followed by post Lemitar subsidence to the south (i.e. pre-caldera tumescence and postcaldera subsidence).

- Thrs Sandstone beds of the Hardy Ridge Formation (upper Oligocene) Red rhyolitic sandstones derived from the underlying upper Lemitar Tuff. 0-10m thick. Lies well outside the Hardy Ridge caldera, but occupies same stratigraphic position as the thick fill of the Hardy Ridge caldera (Chamberlin et.al, 2004), which is here recognized as the redefined Hardy Ridge Formation of post Lemitar Tuff age (not post Hells Mesa Tuff age, as initially defined by Osburn and Chapin, 1983).
- Tl₂ La Jara Peak Basaltic Andesite, medial tongue (upper Oligocene)—Mostly medium to dark gray and purplish gray, platy to vesicular, fine-grained basaltic andesite lavas generally characterized by sparse small reddish brown phenocrysts of "iddingsite" Generally represents thin flows, stacked one on another, commonly with vesicular tops and reddish basal zones. Amygdaloidal calcite is common in vesicular zones. Occurs between Lemitar Tuff and Vicks Peak Tuff. Anomalously thin interval (~10m) on southfacing monocline in SW Lemitar Mountains implies pre-Lemitar uplift here.
- Tv Vicks Peak Tuff (upper Oligocene)— Cliff-forming, brown to light brownish gray and light gray, phenocryst poor, pumiceous, densely welded rhyolite ignimbrite. Distinctive aspects include craggy cliff-forming character, pervasive well developed compaction foliation, and large "sandy" (vapor phase) pumice lapilli as much as 30 cm long. Contains 1-5 percent phenocrysts of sanidine and sparse quartz. Represents outflow sheet erupted from the Nogal Canyon caldera in the southern San Mateo Mountains (Osburn and Chapin, 1983). Mean ⁴⁰Ar/³⁹Ar age is 28.56 ± 0.06 Ma; paleomagnetic polarity is reverse (McIntosh and others, 1991). 60-75 m thick.

- Tl₁ La Jara Peak Basaltic Andesite, lower tongue (upper Oligocene)—Medium gray to purplish gray, basaltic andesite lavas characterized by sparse small reddish brown phenocrysts of "iddingsite" (oxidized and hydrated olivine), locally represents stacked flows. Thickness variations define relative up and down relationships of early rift normal fault blocks (Chamberlin, 1983). 0-30 m thick.
- Tj La Jencia Tuff (upper Oligocene)—Light gray, pale red and grayish red, phenocryst poor, rhyolite ignimbrite, characterized by gray massive basal zone and a medial zone of very densely welded rheomorphic (flow banded) ignimbrite. Flow-banded core grades to normal eutaxitic ignimbrite near base and top. Contains sparse (3–5%) phenocrysts of sanidine and quartz with traces of plagioclase and biotite. Represents outflow sheet erupted from the composite Sawmill Canyon caldera in the west-central and eastern Magdalena Mountains (Osburn and Chapin, 1983). Mean ⁴⁰Ar/³⁹Ar age from bulk sanidine separate is 28.85 \pm 0.04 Ma; paleomagnetic polarity is reverse (McIntosh and others, 1991). As much as 120 m thick in SW Lemitar Mountains
- Tza Andesite member of the Luis Lopez Formation, medium porphyritic subunit, (upper Oligocene) —Dark purplish gray, gray, and reddish brown, medium grained (1–3 mm) andesite porphyry lavas. Massive to platy and locally vesicular lavas contain moderately abundant (5–20%) phenocrysts of altered plagioclase and pyroxene. Distal flow about 20-30m thick. May represent fill of a paleovalley on north rim of the Socorro caldera. Fissure vents for equivalent lavas occur in the northern moat of the Socorro caldera, near Socorro Canyon.
- Th Hells Mesa Tuff (lower Oligocene)—Mostly pale reddish to purplish gray, densely welded, phenocryst-rich (40–50%), quartz-rich, rhyolite ignimbrite. Typically contains

abundant medium grained (1-3 mm) phenocrysts of sanidine, plagioclase, quartz and minor

biotite. Quartz is minor component (1-2%) only in thin basal zone. Mean 40 Ar/ 39 Ar age

(bulk sanidine) is 32.06 ± 0.1 Ma; paleomagnetic polarity is reverse (McIntosh et al. 1991).

Large volume ignimbrite (1200 km³) erupted from Socorro caldera (Chamberlin et. al,

2004: McIntosh et. al., 1991). Thickness of outflow sheet in Lemitar Mountains is typically

90-150 m.

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