Geologic Map of the Lemitar Quadrangle, Socorro County, New Mexico

By

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New Mexico Bureau of Geology and Mineral Resources
Open-file Digital Geologic Map OF-GM 038

Scale 1:24,000

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A division of New Mexico Institute of Mining and Technology

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 Mines 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 Data depicted on this geologic map are based on field geologic mapping, compilation of published and unpublished work, and photogeologic interpretation.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.

DESCRIPTION OF MAP UNITS:

POST-SANTA FE GROUP UNITS

af **Artificial fill** (uppermost Holocene)— Mostly represents compacted fill as roadway subgrades along Interstate 25; also represents conveyance channel levees and railroad subgrade. Thickness 0–12 m.

Qa **Active channels of Rio Grande** (upper Holocene)—Sand, gravel and minor mud of historically active Rio Grande channels. Solid contact shows margins of active channel in February, 1954; dotted contact shows active channel in October, 1999. Thickness range: probably 0–9 m.

Qe **Eolian deposits** (Holocene to middle Pliestocene) — Light gray, fine grained, well sorted, wind-blown sand; commonly caps older alluvial and terrace surfaces east of Rio Grande. Occurrs as thin sheets and climbing dunes. Thickness range: 0–5 m.

Qp **Fill of small closed basins--playas** (Holocene to lower Pleistocene)—Unconsolidated mud, silt and sand associated with delineated slide blocks near Polvadera Peak Less than 10 m thick.

Qc **Colluvium and alluvium, undifferentiated** (Holocene to lower Pleistocene) — Talus, colluvium and minor alluvium on steep to moderate slopes in the Lemitar 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). Colluvial veneers on dissected piedmont slopes in the Socorro Basin are generally not delineated. Usually 0.3-3 m. thick, locally as much as 10 m. thick.

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.

Qvyf **Younger valley fill, axial-fluvial facies** (Holocene to uppermost Pleistocene) — 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). Intertongues with Qvy and Qa. Thickness 0–30 m.

$Qvo_{1\text{-}5}$ **Older valley alluvium, piedmont facies** (middle to upper Pleistocene) — Inset terrace and terrace-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 modern drainages and the Rio Grande floodplain. West of Rio Grande these deposits consist of poorly to moderately sorted, bouldery to cobbly, volcanic-rich gravel, gravelly sand and muddy silts. East of the Rio Grande, terrace deposits contain abundant reddish sandstone clasts and gray limestone clasts derived from Permian formations. 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 approximately 0.6 m to 0.1 m thick. 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 0–20 m, average thickness 6–9 m.

$Qvof_{2\text{-}5}$ **Older valley fill, fluvial facies and minor piedmont facies** (upper Pleistocene) — Complexly intertonguing axial-river deposits (older Rio Grande) and distal alluvial-fan deposits of tributary arroyos. Locally divided into older ($Qvof_2$) and medial ($Qvof_3$) and younger ($Qvof_5$) units based on lateral continuity with older piedmont deposits (Qvo_2 ,Qvo_3, and Qvo_5). 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 of axial river beds that commonly *overlie* volcanic-rich piedmont-facies gravels or at topographic bluff line indicative of facies change. As much as 20 m thick.

Qvou **Older valley alluvium, undifferentiated** (middle to upper Pleistocene)— Undifferenentiated older terrace and terrace-fan deposits; includes equivalents of Qvo_1 to Qvo_4. 0-20m thick.

Qls **Landslide blocks** (lower to upper Pleistocene)— Slump blocks and toreva blocks on steep slopes north and south of Polvadera Mountain. Individual blocks are as much as 30 m 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 (Machette, 1978: QTsl_, Tsl_; upper Santa Fe Group of this report), and Miocene bolson fill of the Popotosa Formation, named by Denny, 1940 (Tp_, lower Santa Fe Group of this report). Also includes intercalated volcanic units such as the basaltic trachyandesite of Kelly Ranch and the trachyandesite of San Acacia (Osburn and Chapin, 1983).

UPPER SANTA FE GROUP:

QTs_
Ts_ **Sierra Ladrones Formation, upper and lower** (lower Pleistocene to Pliocene) — Late-stage basin fill of the Rio Grande valley characterized by an axial-river facies (ancestral

Rio Grande) and intertonguing piedmont facies (alluvial-fan deposits) derived from adjacent mountain ranges. As mapped here, younger piedmont facies (QTsp, upper member) and older piedmont facies (Tslp, lower member) locally lie in angular unconformity on tilted Popotosa beds at the west margin of the basin. Also, the younger piedmont facies (QTsp) is locally inset against or unconformably overlies the older piedmont facies (Tsp). Maximum thickness of Sierra Ladrones Formation probably 300–400 m.

QTsp **Sierra Ladrones Formation, upper piedmont facies, west-derived** (lower Pleistocene to Pliocene) —High level remnants of alluvial-fan deposits emanating from ancestral canyons of the Lemitar Mountains. Deposit from ancestral Canoncito del Lemitar (Corkscrew Canyon) near center of quadrangle is locally capped by remnants of Stage 3 calcic soil, tentatively correlated with the Las Canas surface of McGrath and Hawley, 1987. Consists of reddish orange to reddish brown, poorly consolidated, volcanic-rich, gravels and gravely sandstones with sparse to rare clasts of metasomatized lower Popotosa Formation (Tpr). West of the Socorro Canyon fault, the uppermost piedmont facies is about 6–12 m thick Deposits north and west of Polvadera represent alluvial-fan deposits of ancestral San Lorenzo Canyon and Arroyo del Puerticito. These volcanic-rich gravels also contain sparse clasts of red, jasperoidal cemented, lower Popotosa conglomerates (Tpd / Tpr), which distinguish them from older Popotosa conglomerates. The upper piedmont facies (QTsp) disconformably overlies lower Sierra Ladrones piedmont facies (Tsp) of similar composition near San Lorenzo canyon.

QTse **Sierra Ladrones Formation, upper piedmont facies, east-derived** (lower Pliestocene to Pliocene)—Conglomerates and sandstones derived from older sedimentary sources in highlands to the east of the Rio Grande. Conglomerates contain abundant clasts of sandstone and limestone of Permian affinity; volcanic clasts are relatively minor component. Occurs east of the Rio Grande.

QTsf **Sierra Ladrones Formation, upper axial-fluvial facies** (lower Pleistocene to Pliocene) — Axial river deposits of the ancestral Rio Grande, and minor intertonguing distal piedmont-slope deposits. Projected QTsf–QTsp facies boundary is largely concealed; it is placed near the mountainward limit of well sorted, light-gray to pale yellowish brown, quartz-rich river sands or pebbly gravels. Axial river sands and gravels are usually non indurated. 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 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. Possibly 200-300 m thick near down faulted axis of Socorro Basin.

QTst **Sierra Ladrones Formation, upper transitional facies, axial-fluvial to piedmont** (lower Pleistocene to Pliocene)—Sandstone, mudstone and minor conglomeratic sandstone representing intercalated axial river (QTsf) and east-derived piedmont deposits (QTse). Axial sandstones contain sparse pebbles of quartzite, chert, limestone, sandstone, granite and volcanics; piedmont related beds contain clasts of red siltstone, sandstones, limestones and minor volcanics. Occurs east of modern Rio Grande; minimum exposed thickness is 60m.

Tsp **Sierra Ladrones Formation, lower piedmont facies, west derived** (lower to upper Pliocene) — Westerly derived (east transported) piedmont-slope deposits. Consists of poor to moderately indurated, light brown to pale reddish brown, conglomeratic sandstones and gravels with abundant locally derived volcanic clasts and sparse to rare dark red clasts of jasperoidal cemented (potassium metasomatized) lower Popotosa Formation (Tpr/Tpd). Rare clasts of limestone and gneiss are locally present in exposures near Canoncito del Lemitar; unit here probably contains internal unconformities, westerly dips decrease up section. Similar east-transported conglomeratic sandstones and gravels, with rare metasomatized Popotosa clasts, occur near San Lorenzo canyon, where they are moderately tilted and folded. Minimum exposed thickness is 240-300m.

Tsf **Sierra Ladrones Formation, lower fluvial facies** (lower to upper Pliocene ?)—Light brownish gray to pinkish gray, siliceous sandstone and conglomeratic sandstone; contains abundant volcanic clasts with rare clasts of granite and quartzite (south of Canoncito del Lemitar). Fine- to coarse-grained sands, tabular to trough cross bedded, locally moderately indurated with calcite cement. Axes of trough cross beds indicate southerly paleoflow suggesting correlation with an incipient Rio Grande facies. Siliceous cross-bedded sandstones near San Lorenzo Canyon may represent a fluvial-fan deposit graded to an incipient Rio Grande. Similar sandstones are present in the lower Sierra Ladrones Formation at Arroyo Tio Lino (San Acacia quadrangle, Machette, 1978) . As much as 200m thick.

Tso **Sierra Ladrones Formation, lower overbank facies** (lower to upper Pliocene ?)—Reddish brown to light brown poorly indurated, non-gypsiferous mudstones silt and minor sand; locally exposed south of Canoncito de Lemitar. In Socorro 7.5' Quad (near Nogal/Water Canyon), this fine-grained unit unconformably overlies locally east-tilted maroon gypsiferous mudstones of the Popotosa playa mudstone facies (Tpm) and an interbedded dacitic ash bed of late Miocene age (ca. 9.5 Ma; Chamberlin,1999). Unit may be as much as 60 m thick. Tso appears to grade eastward and upward into quartzite-bearing older axial river deposits (Tsf) just west of the Socorro Canyon fault.

Tas **Trachyandesite of San Acacia** (lower Pliocene)—Medium gray to light brownish gray, phenocryst-poor, vuggy microvesicular (diktytaxitic), xenocrystic, trachyandesite lava flow. Contains sparse (1-2%) fine-grained phenocrysts of plagioclase, greenish augite and very fine reddish brown iddingsite (after olivene ?). Also contains traces of xenocrystic quartz, rimmed with clinopyroxene, and rare phenocrysts of coarse-grained hornblende. Microvesicles are commonly filled with yellowish brown zeolites or clay minerals. Erupted from north-trending fissure vent near San Acacia dam (Machette, 1978). Sample collected northeast of dam yeilds $^{40}Ar/^{39}Ar$ age of 4.87 ± 0.04 Ma (Table 1). Chemical analysis indicates trachyandesite composition with 61% SiO_2. Appears to be interbedded in Sierra Ladrones Formation; overlies distal piedmont facies (Tse, derived from east) near San Acacia dam, disconformably(?) overlapped by axial-river facies (QTsf) north of Bowling Green. Maximum thickness is 40 m; thins to south near original edge of flow at Bowling Green.

Tse **Sierra Ladrones Formation, lower east-derived piedmont facies** (lower Pliocene)—Light brown to pale reddish brown sandstones and minor conglomeratic sandstones of distal east-derived piedmont facies. Conglomeratic beds contain variety of moderately rounded volcanic clasts with minor component of granite and gneiss; pebble imbrications indicate southwesterly paleocurrent directions. Only exposed below the trachyandesite of San Acacia (Tas) in northeast part of quadrangle, also well exposed near San Acacia dam (Machette, 1998). Minimum exposed thickness is 40m.

LOWER SANTA FE GROUP:

Tp_ **Popotosa Formation** (lower to upper Miocene)—Intermontane bolson fill deposits of early Rio Grande rift grabens and half grabens. Defined by Denny, 1940, and redefined by Machette, 1978. Can locally be divided into lower red and upper buff conglomeratic piedmont facies (Tpr and Tpb). The 9.8-Ma basaltic trachyandesite of Kelly Ranch (Table 1)is stratigraphically younger than Tpr and contemporaneous with Tpb. The red conglomerates(Tpr) are potassium metasomatized and unusually well indurated with jasperoidal silica. Metasomatic adularia in the lower Popotosa near Socorro Canyon (15 km to south) yields a $^{40}Ar/^{39}Ar$ age of 7.4 ±0.1 Ma (Dunbar and Miggins 1996). Further north the lower Popotosa facies contain rhyolitic ash-fall beds deposited at 14.5 Ma (Cather, et al 1994; Table 1). Upper Popotosa Formation consists mostly of maroon gypsiferous mudstones assigned to the playa facies (Tpm). Buff conglomeratic sandstones (Tpb) derived from the northwest locally intertongue with the playa facies. Undivided Popotosa Formation (Tp) is shown in cross section only. Probably as much as 900–1500 m thick under western flank of Socorro Basin.

Popotosa Formation South of Polvadera Mountain:

Tpm **Popotosa Formation, upper, playa mudstone facies** (upper Miocene)—Mostly red or maroon claystone with minor greenish claystone and thin bedded buff to light gray siltstones to fine-grained sandstones; locally well exposed south of Canoncito del Lemitar. Thin beds of gypsum and selenite veinlets are also widespread in this unit. Claystones are poorly indurated and commonly masked by colluvium (Qc) where they underlie gravel-capped Quaternary surfaces. Playa deposits are interbedded with and grade north-westward into buff conglomeratic sandstones (Tpb). Locally contains the basaltic trachyandesite of Kelly Ranch (Tbk). Minimum unfaulted thickness west of Kelly Ranch is 390 m; estimated maximum thickness is 750 m.

Tpb **Popotosa Formation, upper, buff conglomeratic sandstone facies** (upper Miocene). Pale brownish yellow (buff) conglomeratic sandstones and quartzo-feldspathic sandstones. Characterized by sparse to moderately abundant subrounded clasts of hydrothermally altered crystal-poor rhyolites. Altered clasts are yellowish brown to gray and speckled with small dots of yellow brown goethite, probably after pyrite. Clast compositions and easterly paleocurrent observations suggest the facies represents a distal alluvial fan or braided channel deposit shed from the Magdalena area about 25 km to west. Unit intertongues with and grades upwards into thick playa facies section in area about 1 km south of Canoncito del Lemitar; estimated thickness here is about 420 m. Locally contains the basaltic trachyandesite of Kelly Ranch(Tbk).

Tbk **Basaltic trachyandesite of Kelly Ranch** (upper Miocene)—Medium gray to greenish gray basaltic trachyandesite lava, vesicular and amygdaloidal zones common at base and tops of flows. Contains sparse to moderately abundant (4-8%), fine to medium-grained (0.5-2 mm) phenocrysts of plagioclase, olivene (commonly altered to yellowish antigorite), and minor clinopyroxene. Small mafic xenoliths are rare. Multiple flow unit (locally two stacked flows) is repeated in several fault blocks, south of Canoncito del Lemitar. Three samples from this unit yield a mean $^{40}Ar/^{39}Ar$ age of 9.77 ± 0.06 Ma (Table1). Chemical analyses indicate basaltic trachyandesite composition containing about 53% SiO_2 (Chamberlin, 1980). Interbedded in upper Popotosa Formation, locally overlaps facies boundary between westerly derived distal-piedmont facies (Tpb) and playa-facies claystones (Tpm). Maximum thickness of stacked flows is 30 m.

Tpr **Popotosa Formation, basal, red conglomerate facies, potassium metasomatized** (lower to middle Miocene)—Well indurated, medium reddish brown to dark red volcanic-rich conglomerates and debris flows. Clast compositions and imbrications generally indicate northerly transport. Eroded from fault blocks of underlying Luis Lopez Formation (andesite to rhyolite lavas) and regional tuffs (mostly Tsc and Tlu). Basal conglomerates were eroded from Miocene early rift fault blocks; an angular unconformity of 10–25 degrees is commonly evident at the base of the lower Popotosa Formation. Unit fills north-trending strike valleys in southern

Lemitar Mountains. Monolithic colluvial breccias derived from subjacent volcanic units are common at the base of the lower Popotosa Formation. Dark red color and moderate to extreme degree of induration is derived from jasperoidal silica cement, which is associated with potassium metasomatism of late Miocene age (Dunbar et al, 1994; Dunbar and Miggins, 1996; Chamberlin and Eggleston, 1996). Reddened conglomerates locally appear to grade upwards into buff conglomeratic sandstones, but at other localities they appear to be disconformably overlain by buff conglomeratic sandstones. Thickness of wedge-shaped fills are highly variable, from 0–300 m.

Popotosa Formation North of Polvadera Mountain:

Tpl **Playa-lake deposits** (Miocene)—mudstone and subordinate volcaniclastic sandstone. Mudstone is reddish brown and locally gypsiferous.

Tpt **Transitional distal piedmont/playa beds** (Miocene)— subequal reddish mudstone and volcaniclastic sandstone.

Tps **Piedmont deposits, distal sandstones** (Miocene)— sandstone-dominated volcaniclastic piedmont deposits. Unit contains subordinate mudstone and pebbly sandstone; it represents a southwest-facing distal piedmont system.

Tpcs **Piedmont deposits, medial conglomeratic sandstones** (Miocene)— subequal sandstone and conglomerate derived from Tertiary volcanic rocks; represents southwest-facing proximal piedmont system (derived from northeast).

Tpc **Piedmont deposits, proximal conglomerates** (Miocene)— conglomerate and subordinate sandstone derived from Tertiary volcanic rocks to the northeast.; represents southwest-facing proximal piedmont system. Intraformational unconformity appears to occur at base of unit.

Tpa **Basin-axis sandstones** (Miocene)— sandstone, mudstone, and minor pebbly sandstone deposited by northwest-flowing braided streams. Interfingers with piedmont deposits in the northwest part of the quadrangle. Thin rhyolitic ash fall near top of unit yields single-crystal sanidine $^{40}Ar/^{39}Ar$ age of 14.49 ± 0.08 Ma (Table 1).

Tpd **Conglomeratic debris-flow deposits** (Miocene)—reddish brown, well indurated (potassium metasomatized?), bouldery debris-flow deposits and conglomerates. Clasts consist of locally derived (first cycle) Oligocene volcanic rocks. Basal monolithic conglomerates (locally mapped as Tpda) are derived from underlying basaltic andesite lavas (Tl_3).

EOCENE-OLIGOCENE VOLCANIC ROCKS OF MOGOLLON-DATIL FIELD:

Note: Oligocene tuffs in the Lemitar Mountains are commonly potassium metasomatized; phenocrystic plagioclase is typically replaced by metasomatic adularia and clay minerals; sanidine and biotite are usually not altered.

Tm **MOGOLLON GROUP:** Oligocene volcanics undivided, in cross section only (30.0-27.3 Ma).

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 (ie. 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 thin 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.

Tl_3 **La Jara Peak Basaltic Andesite, upper tongue** (upper Oligocene)—In eastern Lemitar Mountains, this unit is formed by a thick pile of thin autobrecciated basaltic andesite lava flows. In SE Lemitar mountains at least 35 individual flows are exposed, averaging about 3–6 m thick, with a total composite thickness of about 180m. Individual flows consist of medium gray to grayish red purple, massive to vesicular basaltic andesite lava; they are characterized by moderately abundant (5–10%) fine grained phenocrysts of olivene, which are almost always completely altered to reddish brown iddingsite. Phenocrystic plagioclase is usually absent or very rare. Upper flows are about 10 m thick and locally associated with bedded cinder deposits 2–5 m thick. Calcite commonly fills vesicles and fractures. Basal flow near Corkscrew Canyon is grayish black and appears to be a relatively mafic trachybasalt. 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 divisable 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). Tl_3 is older than South Canyon Tuff and younger than Lemitar Tuff. Thickness of wedge-shaped prism ranges from 180-330 m.

Tlu/Tll **Lemitar Tuff; upper and lower members** (upper Oligocene)—Compositionally zoned (77

–65 wt% SiO_2), ignimbrite subdivided into a partially to densely welded, light gray, phenocryst-poor (5-15%), rhyolite lower member (Tll), and densely welded, dark red, phenocryst-rich (30–45%), dacitic to rhyolitic upper member (Tlu). Lower member (maximum thickness = 40 m) wedges out onto paleotopographic highs. 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 blobs" of dacite/andesite porphyry are typical in outflow of the upper member. Represents thin outflow sheet erupted from a small caldera in the west-central Magdalena Mountains (G. R. Osburn oral commun. 1997). Lemitar ignimbrite locally fills in early rift fault blocks in the Lemitar Mountains (Chamberlin, 1983). Mean $^{40}Ar/^{39}Ar$ age (bulk sanidine) is 28.00 ± 0.08 Ma ; paleomagnetic polarity is normal (McIntosh and others, 1991). Correlation here based on distinctive lithology and stratigraphic position. Thickness in wedge-shaped paleovalleys ranges from 0-90 m.

Tl_2 **La Jara Peak Basaltic Andesite, medial tongue** (upper Oligocene)—Iddingsite-bearing basaltic andesite lavas very similar to Tl_3 in eastern Lemitar Mountains, but stratigraphically older. As many as 40 individual flows with aggregate thickness of about 150m are locally exposed in SE Lemitar Mountains.. Occurs between Lemitar Tuff and Vicks Peak tuff; top approximately located by projection where overlying Lemitar Tuff locally pinches out. Thickness of wedge-shaped prisms range from 75-210m.

Tv **Vicks Peak Tuff** (upper Oligocene)—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 erupted from the Nogal Canyon caldera in the southern San Mateo Mountains (Osburn and Chapin, 1983). Mean $^{40}Ar/^{39}Ar$ age is 28.56 ± 0.06 Ma; paleomagnetic polarity is reverse (McIntosh and others, 1991). Correlation here based on lithology and relative stratigraphic position. 0-75 m thick.

Tl_1 **La Jara Peak Basaltic Andesite, lower tongue** (upper Oligocene)—Medium gray to purphish gray, iddingsite-bearing basaltic andesite lava, similar to Tl_3; locally represents two or three stacked flows. Wedges out southward against Oligocene transverse fault near Corkscrew Canyon. Thickness = 0- 30m.

Tj **La Jencia Tuff** (upper Oligocene)—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 core grades to normal eutaxitic ignimbrite near base and top. Locally displays auto-intrusive relationships near probable Oligocene fault (low-angle fault) in SE Lemitar Mountains. Contains sparse (3–5%) phenocrysts of sanidine and quartz with traces of plagioclase and biotite. Represents thin outflow sheet erupted from the composite Sawmill Canyon-Magdalena caldera in the west-central and eastern Magdalena Mountains (Osburn and Chapin, 1983). Mean $^{40}Ar/^{39}Ar$ age is 28.85 ± 0.04 Ma; paleomagnetic polarity is reverse (McIntosh and others, 1991). Correlation here based on distinctive lithology and relative stratigraphic position. As much as 120 m thick in eastern Lemitar Mountains

Tz **Middle tuffs of Luis Lopez Formation** (upper Oligocene) — Light brownish gray to light gray, poorly welded, pumiceous, lithic-rich, rhyolitic ignimbrites. Contain moderately abundant pumice (mostly aphyric), and sparse to moderately abundant small lithic fragments in crystal-poor rhyolitic matrix. Lithic fragments consist primarily of andesite porphyries and densely welded, crystal-rich, quartz-rich, Hells Mesa Tuff clasts; the latter tends to be more abundant in upper half of unit (upper cooling unit?). Rare crystals of sanidine and quartz in matrix in lower part are probably primary phenocrysts; sparse crystals of sanidine, quartz and biotite in upper part are mostly xenocrysts. Medial tuffs of Luis Lopez Formation were erupted from a small collapse structure partly exposed in the Northern Chupadera Mountains approximately 15 km south of the Lemitar Mountains (Chamberlin et al., in press). Samples from Chupadera Mountains yield mean single-crystal sanidine $^{40}Ar/^{39}Ar$ age of 30.04± 0.16 Ma (Table 1) Thickness approximately 15-30 m.

Td **DATIL GROUP:** Oligocene-Eocene volcanic rocks undivided, in cross section only (38 -32.0 Ma).

Th **Hells Mesa Tuff** (lower Oligocene)—Reddish brown 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 km^3) erupted from Socorro caldera (Chamberlin et al, in press: McIntosh et al., 1991). Correlation is based on distinctive lithology and relative stratigraphic position. Thickness range is 90-150 m.

Tg **Tuff of Granite Mountain** (lower Oligocene)—Light gray to grayish red to light brownish gray, non-welded to densely welded, moderately pumiceous, phenocryst-rich, dacitic to rhyolitic ignimbrite. Contains abundant medium-grained phenocrysts (35-45%) of predominantly plagioclase (commonly replaced by adularia), with minor biotite, sanidine, altered hornblende and clinopyroxene (?), with traces of embayed quartz (<0.2%). Small lithics of andesitic composition are sparse to moderately abundant in thin zones; thin-bedded fall deposits locally occur near base. The absence of, or only trace amounts of phenocrystic quartz, distinguish the Tuff of Granite Mountain from the overlying quartz-rich Hells Mesa Tuff. Represents undated, small to moderate volume early ignimbrite sheet of Socorro-Magdalena region (Osburn and Chapin, 1983). Source area unknown, possibly erupted from small vent structure in Magdalena Mountains area that was later obliterated by Socorro caldera. Correlation based on lithology and relative stratigraphic position. 30-60m thick.

Tr **Rockhouse Canyon Tuff** (upper Eocene)—Light gray to pinkish gray, poorly welded, moderately pumiceous, phenocryst-poor, rhyolitic ignimbrite. Contains sparse, small phenocrysts of sanidine, plagioclase, biotite and traces of quartz. Lenticular thin outflow sheet fills shallow paleovalleys in upper Spears Formation. Locally exposed south of Polvadera Mountain and near Corkscrew Canyon. Source unknown; outflow sheet near Datil yields mean $^{40}Ar/^{39}Ar$ age of 34.42 ± 0.12 Ma, magnetic polarity is reverse (McIntosh et al. 1991). Correlation based on lithology and relative stratigraphic position. 0-20m thick.

Ts **Spears Formation** (upper Eocene)— Grayish red, grayish red purple, light brownish gray and light gray conglomerates, sandstones, siltstones and reddish mudstones derived from intermediate composition volcanic highlands, primarily to southwest of Lemitar Mountains. Subrounded to subangular dacite and andestite porphyry clasts range from boulders to pebbles; they are common in lenticular to tabular conglomeratic beds, usually 1-3m thick. Dacitic clasts are characterized by sparse to abundant phenocrysts of plagioclase, hornblende and biotite; andesitic clasts are typically plagioclase, pyroxene porphyries. Gray micritic limestone and red siltstone cobbles and pebbles are common in basal conglomerates (lowest 30m). Medium-grained pyroxene monzonite and dark gray, aphanitic basaltic andesite clasts occur sparsely in the upper half of the formation. Calcite and pinkish clays are dominant cements; chalcedonic quartz is relatively rare. Age range from K/Ar dates of volcanic clasts and interbedded tuffs is approximately 39-33 Ma (Osburn and Chapin, 1983). Thickness ranges from 120-330m; appears to thicken rapidly to north on downside of ENE-striking, high-angle fault exposed about 2 km south of Polvadera Mountain. Correlation based on lithology and relative stratigraphic position.

CONGLOMERATES ASSOCIATED WITH LARAMIDE UPLIFT:

Tb Baca Formation (Eocene)— Grayish to reddish brown, limestone- and sandstone-clast conglomerates and conglomeratic sandstones. Trough and tabular bedded conglomerates appear to fill paleovalley cut in underlying Madera Limestone about 2 km south of Polvadera Mountain; also present near Corkscrew Canyon. 0-30m thick. Non-volcanic character and position, at base of Eocene volcaniclastic sediments, implies correlation with Baca Formation.

TERTIARY INTRUSIVE ROCKS:

Tib **Basaltic dike and sill**(Oligocene?)—Medium to dark gray and greenish gray basaltic dike and sill in area south of central Corkscrew Canyon. Propylitically altered, fine-grained, intrusive contains abundant groundmass plagioclase, clinopyroxene and FeTi-oxides with sparse small phenocrysts of olivine. Clinopyroxene and olivene are mostly altered to or replaced by calcite and antigorite. Narrow NW-striking dike cuts Sandia Formation and appears to feed thin sill in lower Madera Limestone. Lithology and attitude (gentle east dip of dike) suggest basalitc intrusion is temporally correlative with the La Jara Peak Basaltic Andesite.

Tim **Biotite-bearing, altered mafic dikes**(Oligocene/Miocene?)—Mafic dikes in low-angle normal faults of Tertiary age cutting Proterozoic basement rocks and locally along Polvadera thrust fault (Atokan). Dark gray to brownish gray, fine-grained, biotite-rich dikes commonly weather with spheroidal habit. Contain abundant groundmass plagioclase, altered pyroxenes and FeTi-oxides, which suggests original basaltic composition. Polycrystalline silica commonly replaces small euhedral "phenocrysts" of olivene-like morphology. Apparent basaltic composition and occurrence in Tertiary low-angle normal faults (Chamberlin,1983) suggests a late Oligocene or Miocene age.

PALEOZOIC STRATA:

Pb **Bursum and Abo Formations, undivided** (lower Permian, Wolfcampian)—Gray, thin bedded micrites and pale reddish mudstones. Grades upwards into reddish brown to light gray conglomeratic sandstones and mudstones. Quartz and granite pebbles are abundant in the conglomeratic sandstones. Locally truncated by Eocene erosion surface associated with Laramide uplift. 0-60m thick.

IPm **Madera Limestone** (middle to upper Pennsylvanian, Desmoinsean to Missourian)—Mostly light- to medium-gray ledge and cliff forming micritic limestones interbedded with dark greenish gray limy shales and minor sandy limestones. Nodular black chert is common in the micritic limestones. Cliff-forming limestones are medium to thick bedded and moderately fossiliferous (fusulinids, brachiopods, crinoids and corals). Maximum total thickness is 210 m, locally eroded to less than 60m below Eocene surface.

IPs **Sandia Formation** (middle Pennsylvanian, Atokan)—Dark gray to black, slope-forming carbonaceous shales with minor fossiliferous biomicrites and fine-grained quartz arenites are dominant in the upper third. Lower 2/3 consists of ledge-and cliff-forming quartz arenites that are dark reddish brown to light gray, fine to coarse grained, massive to cross bedded, feldspathic to miaceous, and mostly medium to thick planar bedded. Arenites contain several 1–2 m thick interbeds of gray siltstone and limy mudstone. Upper contact with Madera Limestone is gradational and generally placed at break in slope to ledge and cliff-forming limestones. Quartz-pebble conglomerates locally occur in the medial Sandia just south of the Polvadera thrust fault (north of Corkscrew Canyon). The Sandia Formation is approximately 180m thick on southern lower plate of the Polvadera thrust; it is about 60m thick on the northern upper plate. Also, the Polvadera thrust does not appear to offset the overlying Madera Limestone. These observations indicate a late Pennsylvanian (Atokan) age for the Polvadera thrust.

Mk **Kelly and Caloso formations, undivided** (lower Missippian)— Gray to buff, fine- to coarse-grained bioclastic limestones of Kelly Formation paraconfomably overlie micritic limestones, shales and basal conglomeratic sandstones of the Caloso Formation. Kelly limestones locally contain red silty mudstones in cavernous pockets (paleokarst fills?) near the Polvadera thrust. Absent on upper plate of Polvadera thrust, where well exposed near Polvadera Mountain. 0-30m thick.

PALEOZOIC INTRUSIONS:

Oc **Carbonatite dikes, sills and fennites** (Ordovician)— Brownish gray to reddish brown, carbonate-rich dikes and sills, contain minor phenocrystic-like apatite, phlogopite and biotite. Xenoliths of wall rock are common. Found only in Proterozoic rocks. Phenocrystic biotite yields K/Ar date of 457 ± 16 Ma (McLemore, 1987), thus indicating an Ordovician age of intrusion.

PROTEROZOIC ROCK UNITS:

ZXmd **Mafic dikes and pods** (late to middle Proterozoic)—Dark gray to greenish gray, fine-grained intrusive rocks composed of green hornblende + plagioclase feldspar + magnetite. Found in all Proterozoic lithologies; discrete dikes are probably late Proterozoic in age (Z), mafic pods are probably older (X).

Xp **Pegmatitic dikes** (middle Proterozoic)—coarse-grained dikes and irregular pods consisting of potassium feldspar + quartz + muscovite with minor epidote. Pegmatites cut all Proterozoic rock units; they are most abundant along northern margin of Polvadera granite.

Xbg **Biotite granite** (middle Proterozoic)— Fine- to medium-grained quartz monzonite to granite composed of quartz + potassium feldspar + plagioclase feldspar + biotite.

Xmbg **Muscovite-biotite granite** (middle Proterozoic)— fine-grained granite consisting of quartz + potassium feldspar + plagioclase feldspar + biotite + muscovite.

Xpg **Polvadera granite** (middle Proterozoic)— Medium-to coarse-grained granite consisting of quartz + plagioclase feldspar + potassium feldspar with minor amounts of biotite + hornblende + magnetite. Generally unfoliated. Narrow shear zones (0.5 - 1.0 m) display gradational deformation textures from undeformed granite to strongly foliated granite. Lineation is generally absent Foliation also well developed along contact with mafic plutonic rocks.

Xfg **Foliated granite** (middle Proterozoic)— Strongly foliated granite consisting of potassium feldspar + quartz + plagioclase feldspar + biotite. Foliation defined by aligned biotite grains, augen of K-feldspar porphyroclasts and quartz rods. U-Pb age from zircon is 1648 ± 6 Ma (Bowring et al., 1983).

Xmp **Mafic plutonic rocks** (middle Proterozoic?)— Mostly dark gray plutonic rocks ranging in composition from diorite and gabbro to quartz diorite and quartz gabbro. Mineral assemblage includes hornblende + plagioclase feldspar + quartz. Foliation is generally lacking although locally, well developed along contacts with Polvadera Granite complex.

Xccs **Corkscrew Canyon metasediments** (middle Proterozoic)— Interlayered arkose, subarkose and quartzite. Contains small lenses of greenschist and pelitic schist. Relict cross bedding locally preserved, but also isoclinially folded in part; layering maybe transposed in some areas. Migmatitic zone present along northern boundary where adjacent to felsic and mafic igneous rocks. Metasedimentary unit near Corkscrew Canyon yielded a U-Pb age from zircon of 1659 ± 3 Ma (Bowring and others, 1983).

X **Proterozoic rocks undivided** (middle Proterozoic)—shown in cross section only.

Table 1. Apparent eruption ages (arithmetic means) of Oligocene to Pliocene volcanic units in the Lemitar 7.5' quadrangle. All dates are high precision 40Ar/39Ar analyses; except where noted as K/Ar. Note: bulk sanidine $^{40}Ar/^{39}Ar$ ages tend to be slightly older than single-crystal laser-fusion $^{40}Ar/^{39}Ar$ analyses.

Age (Ma)	±2s	No. Analyses	Unit/Symbol	Reference
4.73	0.04	1	Trachyandesite of San Acacia/Tas	1
9.77	0.06	3	Basaltic trachyandesite of Kelley Ranch/Tbk	1
14.49	0.08	1	Ash bed in Poptosa Fm./ in Tpa	2
27.37	0.07	3	South Canyon Tuff/Tsc	3
28.00	0.08	2	Lemitar Tuff/ Tlu-Tll	3
28.56	0.06	4	Vicks Peak Tuff/Tv	3
28.85	0.04	6	La Jencia Tuff/Tj	3
32.06	0.10	2	Hells Mesa Tuff/Th	3
30.04	0.16	2	Medial tuffs of Luis Lopez Fm./Tz	4
38.1	1.5 (K/Ar)	1	Spears Fm./Ts (clast, maximum age)	5

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1. W. McIntosh and R. Chamberlin, unpublished data
2. W. McIntosh and S. Cather, unpublished data
3. McIntosh et al. 1991 (bulk sanidine ages)
4. Chamberlin, McIntosh and Eggleston, in press (single-crystal laser fusion ages)
5. Wilks and Chapin, 1997, No. So-006

Explanation of Map Symbols:

Depositional contact, long dashed where approximately located, short dashed where inferred. Direction and angle of dip shown where observed. Note, all alluvial and colluvial contacts are approximately located; they are generally shown as continuous lines to aid map legibility.

Approximate location of facies boundary (piedmont to axial river) in Pliocene to Pleistocene basin-fill deposits; dotted where projected under younger deposits. Placed at mountainward limits of quartzite-bearing, well-sorted, axial-river sands in the upper Sierra Ladrones Formation (QTsf); and mountainward limit of axial river sands in post Santa Fe Group deposits (Qvof).

Approximate location of lateral facies boundary in the upper Popotosa Formation; separates playa facies mudstones (Tpm) from sandstones and conglomeratic sandstones of buff member (Tpb); southeast of Polvadera Mountain.

Marker bed in the Popotosa Formation; includes rhyolitic ash-fall beds and one silicified limestone bed that is immediately overlain (2m above) by a 14.49 Ma ash bed (Table 1). The latter occurs near the top of unit "Tpa" at Canoncito de las Cabras.

Fault trace, dashed where approximately located, dotted where projected under younger deposit. Ball and bar on downthrown side; where concealed U= upthrown side, D= downthrown side. Short dash indicates direction and angle of dip. Arrow indicates bearing and plunge of striations or mullions on fault surface.

Thrust fault of Pennsylvanian age (Polvadera thrust), offsets Kelly and Sandia Formations, but not the overlying Madera Limestone. Dip shown where observed.

Low-angle normal fault showing dip. Interpreted as initially high-angle, early rift, down-to-east, normal fault rotated (domino style) to present position of low-angle normal fault (dip = 0- 45º). Commonly expressed by klippe-like traces and cuspate traces.

pseudo reverse fault showing direction and angle of dip. Open squares on upthrown block. Within the strongly west-tilted Lemitar Mountains block, they are interpreted as early antithetic *normal* faults (downthrown to west) that have been rotated to present orientation of reverse faults by dominant down-to-east domino faults (Chamberlin,1983). A down-to-the-east reverse fault cutting the Popotosa Formation near Arroyo del Puerticito is tentatively interpreted as a psuedo-reverse fault since it occurs in a strongly east-tilted domain (north of Puerto fault).

pseudo thrust fault (younger over older) showing dip. Open barbs on upper plate. Interpreted as down-to-east, listric(?) normal fault that has been strongly rotated to position of east-vergent thrust fault (common near upper Corkscrew Canyon).

pseudo strike-slip fault; open half arrows show apparent sense of lateral shear. Interpreted as transvrse margins of rotated shovel-shaped normal fault (initially dip slip), that has been rotated to position of low-angle oblique- or strike-slip fault

Trace of Quaternary normal fault. Ball and bar on downthrown side; number indicates estimated surface displacement, at this location, in meters.

Slump fault bounding low-angle fault block reactivated by gravity sliding; common near Polvadera Mountain.

Representative exposure of late Cenozoic basin fill unit; indicates location of well sorted axial river sand or gravel where shown in QTsf.

Strike and dip of bedding or compaction foliation in welded tuffs.

Horizontal bedding.

Strike and dip of foliation in lava flow, rheomorphic tuff (Tj), or metamorphic rocks.

Foliation and associated lineation in metamorphic rocks; 1-3 cm wide, glassy pseudotachylite zones along foliation indicated by symbol "pt"

Syncline, showing approximate trend of trough line.

Anticline, showing approximate trend of crest line.

General direction of paleocurrents; based on pebble imbrication, axis of trough cross bed, cross bedding, and parting lineations. Observation point at base of arrow.

Excavation in Cenozoic basin-fill deposits.

Municipal water supply well.

CORRELATION OF MAP UNITS:

Epoch / Period

Qa af

Qvyf Qvy Qe Qp Qc Qls **Holocene**

Qvof$_5$ Qvo$_5$ upper

Qvo$_4$

Qvof$_3$ Qvo$_3$ Qvou **Pleistocene**

Qvof$_2$ Qvo$_2$ middle

Qvo$_1$

QTsf QTst QTse QTsp Sierra Ladrones Fm. lower

Tsf Tso Tsp upper

(lavas) **Pliocene**

Tse Tas lower

Tpm Tpl Tpt Popotosa Fm. Tbk upper

Tpb Tps Tpcs Tpc **Miocene**

Tpa Tp middle

Tpr Tpd

Tsc Mogollon-Datil volcanics

Tl$_3$

Tlu/Tll

Tl$_2$ (intrusives) upper

Tv Tm Tib Tim

Tl$_1$

Tj

Tz

Oligocene

Th

Tg Td lower

Tr Ts upper

Eocene

Tb Laramide conglomerates middle

Pb lower **Permian**

IPm upper **Pennsylvanian**

IPs middle **Pennsylvanian**

Mk upper **Mississippian**

Oc upper **Ordovician**

ZXmd late **Proterozoic**

Xp

Xbg Xpg Xmg Xfg X middle to early **Proterozoic**

Xmp

Xccs

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