Open-File Report 417
Initial filing 1/96

GEOLOGIC MAPS OF UPPER CENOZOIC DEPOSITS OF THE CENTRAL SOCORRO BASIN

by
Steven M. Cather
New Mexico Bureau of Mines & Mineral Resources
Socorro, New Mexico 87801

INTRODUCTION

This report comprises a series of topical geologic maps of detailed reconnaissance nature that primarily address the structure and facies architecture of the Santa Fe Group within parts of six quadrangles in the central Socorro Basin (Mesa del Yeso, Loma de las Cañas, San Antonio, Luis Lopez, Socorro, and Lemitar 7.5' quadrangles). Within these quadrangles, outcrops of the Santa Fe Group are apportioned among 14 sedimentary lithofacies and two volcanic lithofacies which are designed to provide information concerning both the hydrology and the physical stratigraphy of the Neogene fill of the Socorro Basin. Because the focus of this study is the syn-rift Santa Fe Group, my treatment of pre- and post-Santa Fe strata is rather cursory (see Description of Units).

The term "Santa Fe Marls" was coined by Hayden (1869) for the sediments of the Rio Grande valley near Santa Fe. Darton (1922) substituted the term Santa Fe *Formation* for these rocks. In a 1938 paper, Kirk Bryan exported the term Santa Fe Formation throughout the basin-fill of the Rio Grande rift. One of Bryan's students, C. S. Denny (1940), however, restricted the usage of the term near Socorro to the youngest part of the basin-fill (later termed Sierra Ladrones Formation). Denny regarded the older, more voluminous basin-fill deposits in the Socorro area as pre-Santa Fe, and named them the Popotosa Formation. The

Santa Fe was raised to group rank by Spiegel and Baldwin (1963). Bruning (1973) and Chapin and Seager (1975) included Denny's (1940) Popotosa Formation in the Santa Fe Group. The upper part of the Santa Fe Group (formerly the entirety of Denny's Santa Fe Formation) was termed Sierra Ladrones Formation by Machette (1978).

In the Socorro area, the contact between the Popotosa Formation and the underlying Tertiary volcanic rocks ranges from a disconformity to a pronounced angular unconformity. The Popotosa consists of closed-basin deposits that accumulated in half-grabens of Miocene age (Bruning, 1973; Cather et al., 1994a). The maximum thickness of the Popotosa near Socorro is unknown, but may be as much as 2 to 3 km. Rapid strain rates during the late Miocene caused tilting, offlap, and erosion of hanging-wall dipslopes within the developing Popotosa half grabens. Subsequent onlap of these eroded areas in late Santa Fe time produced the angular unconformity that typically intervenes between the Popotosa and Sierra Ladrones Formations. In the more deeply subsided parts of the Socorro Basin, however, this angular unconformity may give way to conformity or even transitional beds (Cather et al., 1994a).

The Plio-Pleistocene Sierra Ladrones Formation contains both piedmont deposits and sediments related to development of throughgoing axial drainage (ancestral Rio Grande). Due to lack of deep well penetrations, the maximum thickness of the Sierra Ladrones in the Socorro Basin is unknown, but is likely less than about 300 m. The top of the Sierra Ladrones Formation is marked by locally preserved constructional surfaces (Las Cañas and Sedillo Hill surfaces of McGrath and Hawley, 1987) that represent the end of basin aggradation and the beginning of post-Santa Fe incision. Onset of incision appears to have been diachronous, beginning in early or middle Pleistocene time.

The Santa Fe Group is the principal sedimentary record of Neogene rifting in New Mexico. It is also the principal aquifer in the state. The Santa Fe Group exhibits a great variety of clastic textures and bedding styles that represent diverse paleoenvironments of deposition during Santa Fe time (early Miocene to early Pleistocene). For example, during deposition of the Popotosa Formation (lower Santa Fe Group) deposits ranged from boulder conglomerate of debris-flow and fluvial origin near the mountain fronts to closed-basin playa claystone near basin centers. Similarly diverse are the deposits of the Sierra Ladrones Formation (upper Santa Fe Group), which range from coarse conglomerate in the proximal piedmont to sands, muds, and gravels of the ancestral Rio Grande in the basin center. The nature and distribution of porosity and permeability in these various rock units has profound implications for the regional hydrology of the Socorro Basin.

Most previous workers in the Socorro Basin either have not attempted to subdivide the Santa Fe Group at all, or have simply divided the Santa Fe into upper and lower parts (Popotosa and Sierra Ladrones Formations). Other workers have recognized and mapped lithofacies within the Santa Fe and interpreted their paleoenvironmental significance. For example, Bruning (1973) and Chapin and Seager (1975) subdivided the Popotosa Formation into fanglomerate and playa facies; Machette (1978) did the same but also recognized a transitional playa facies. Chamberlin (1980, 1981) subdivided the Popotosa into piedmont and playa facies, which in turn were further divided on the basis of stratigraphic position, provenance and induration. Piedmont and axial river lithofacies in the Sierra Ladrones Formation have been mapped by Denny (1940), Debrine et al. (1963), Machette (1978) and Chamberlin (1980, 1981). Two *provenance-related* units (i.e. petrofacies) within the Popotosa have also been recognized [fanglomerate of Dry Lake Canyon (Bruning, 1973; Chapin and Seager, 1975), fanglomerate of Ladron Peak (Bruning, 1973; Chapin and Seager, 1975; Machette, 1978)]. Subdivision of piedmont deposits on the basis of textural and bedding criteria that are indicative of *depositional paleoenvironment* (i.e. lithofacies), however, has not been attempted prior to this study, nor has a rigorous definition of boundaries between other lithofacies mapped by previous workers been published.

Because the transition from proximal piedmont deposits to distal piedmont deposits to basin-floor deposits in the Santa Fe Group is largely gradational, any lithologic subdivision of these deposits is, by necessity, somewhat arbitrary. The lithofacies defined and used in this report are largely based on textural criteria that are designed to lend predictability to the hydrologic properties of the Santa Fe. Paleocurrent and provenance data are also used to reconstruct the position of these textural subdivisions within the paleolandscape (i.e. piedmont vs. axial stream; volcaniclastic piedmont vs. siliciclastic piedmont). It is thus hoped that the proposed lithofacies classification will aid in understanding both the hydrology and the physical stratigraphy of the Socorro Basin. It is important to note that lithofacies map patterns may differ significantly from those of typical geologic maps in that lithofacies contacts are commonly at a high angle to bedding. In other words, in a simple aggradational system, contacts between lithofacies will be *subvertical* (Fig. 1). Only during episodes of

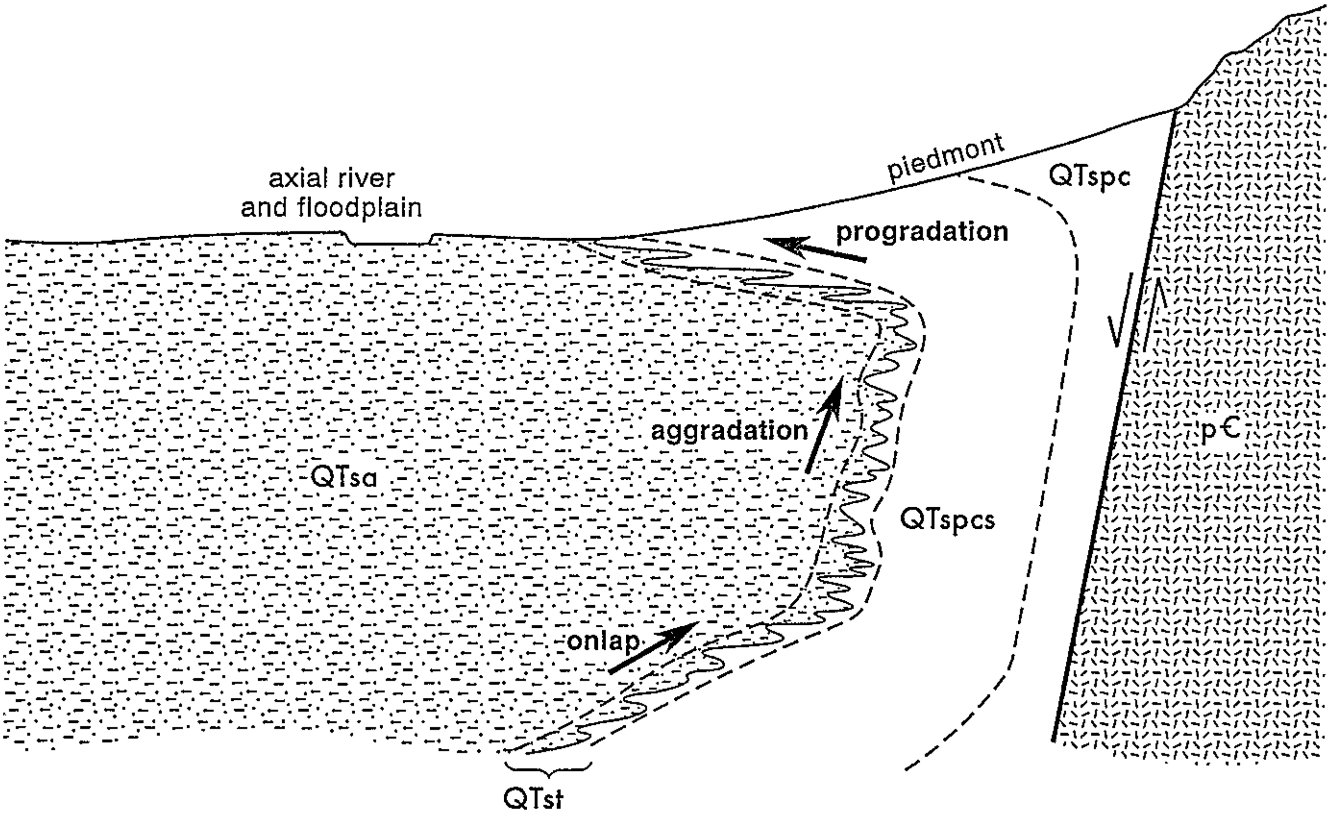


FIGURE 1—Schematic cross section of Sierra Ladrones axial fluvial (stippled) and piedmont systems. Note that lithfacies contacts (dashed lines) are at high angles to bedding during episodes of simple aggradation; only during rapid onlap or progradation do lithofacies contacts become subparallel to bedding. Lithofacies are axial-river (QTsa), transitional axial-piedmont (QTst), conglomerate–sandstone piedmont (QTspcs), and conglomeratic piedmont (QTspc). Bedding is subhorizontal.

rapid progradation or retrogradation (onlap) will lithofacies contacts be subparallel to bedding.

Correlations between permeability and lithologic character (particularly grain size) have been demonstrated for the Santa Fe Group in the Albuquerque Basin (Davis et al., 1993; Detmer, 1995). It should be emphasized, however, that the individual architectural elements analyzed by these workers are only small components of the larger lithofacies mapped herein. The permeability of many elements of these lithofacies have yet to be determined. This is particularly true for the conglomeratic portions of the facies tract which are not amenable to permeability measurement by either field or laboratory techniques.

The lithofacies of Miall (1977, 1978) comprise small and more homogeneous elements within the present lithofacies designation. In the sense of Miall (1978) and Rust (1978), the subdivisions of the Santa Fe proposed herein would more properly be considered *lithofacies assemblages*. Unlike those of Miall, the lithofacies recognized in this study are designed to be mappable at a scale of 1:24,000. A detailed description of the rationale behind the lithofacies criteria used in this report will be published in a forthcoming issue of *New Mexico Geology*.

Quadrangle maps which form the basis for this report will be sequentially placed on Open-File as they are completed. This is being done in order to make the maps available as soon as possible, rather than when mapping of the entire basin is complete. Due to the ongoing nature of this report, however, revision of completed quadrangles in this series is likely. As such, *dates of revision* will be listed in the upper right corner of the first page of text accompanying each quadrangle, beneath the initial filing date. *The contents of this report should not be considered final and complete until it is published as a NMBMMR Bulletin or Geologic Map.*

DESCRIPTION OF UNITS

POST—SANTA FE UNITS

Qsg	Sand and gravel (Holocene). Sand, gravel, and minor mud in modern active arroyo channels and in the channel of the Rio Grande. 0–30 m thick.
Qa	Alluvium (Holocene). Sand, gravel, and mud adjacent to modern arroyo and river channels. Alluvium is typically at or near grade of modern channels, except in local areas where cutting of toes of piedmont slopes by the Rio Grande has caused arroyos to incise deeply (1-3 m). 0–30 m thick.
Qe	Eolian deposits (upper Pleistocene-Holocene). Eolian sands and loessic silts; deposits are stabilized by vegetation in most areas, but active dunes are present on lee sides of hills in some areas. Includes thin, discontinuous eolian veneers on stable upland surfaces that are intimately intertongued with alluvium. 0–10 m thick.
Qpy	Younger piedmont alluvium (upper Pleistocene). Gravel, sand, and mud deposited at low elevations (less than about 30 m) above modern stream grade. Alluvium is representative of deposition in a variety of piedmont environments, including alluvial fans, paleovalley and arroyo fills, strath terraces, fill terraces, and pediments. At least two aggradational episodes are represented by Qpy. 0–25 m thick.
Qay	Younger axial-river alluvium (upper Pleistocene). Inset channel and floodplain deposits of ancestral Rio Grande. Intertongues with younger piedmont alluvium (Qpy).

Qpo Older piedmont alluvium (middle to lower (?) Pleistocene). Gravel, sand, and mud deposited at higher elevations (more than about 30 m) above modern stream grade. Range of depositional environments is similar to Qpy. At least two aggradational episodes are represented by Qpo. 0–40 m thick.

SANTA FE GROUP

Sierra Ladrones Formation (Pliocene to lower Pleistocene)

QTspc Conglomeratic piedmont facies. Characterized by conglomerate/sandstone ratio greater than 2/1. Conglomerate is typically poorly sorted and clast supported. Sandstone is typically medium to very coarse and crossbedded or horizontally stratified. Matrix-supported debris-flow deposits are common. Mudstone is rare. QTspc includes gravelly veneers on pediment surfaces.

In addition to the subdivision of piedmont deposits based on *textural* criteria, these deposits were further subdivided on the basis of *provenance*. Siliciclastic piedmont deposits containing a dominance (>50%) of Mesozoic, Paleozoic, and Precambrian detritus are denoted by (s); dominantly volcaniclastic rocks are indicated by (v). Where they do not coincide with textural subdivisions of piedmont, provenance contacts are denoted by a dot-dash symbol (see Explanation of Map Symbols).

QTspcs Conglomerate-sandstone piedmont facies. Characterized by conglomerate/sandstone ratio between 2/1 and 1/2; this is the volumetrically dominant piedmont facies within the Sierra Ladrones Formation. Conglomerate is mostly clast-supported and poorly sorted. Sandstone is typically medium to very coarse-grained, commonly pebbly, and exhibits crossbedding or horizontal stratification. Mudstone is minor. Provenance subdivisions (v) and (s) are same as for QTspc.

QTsps Sandstone-dominated piedmont facies. Characterized by conglomerate/sandstone ratio of less than 1/2. Conglomerate is clast-supported and occurs in tabular or lenticular units <2 m thick. Sandstone is very fine to very coarse grained and exhibits a dominance of horizontal stratification. Mudstone is common and occurs as tabular units which locally compose as much as 20% of the unit. Calcareous paleosols are locally well-developed. Provenance subdivisions (v) and (s) are same as for QTspc.

QTsa Axial-river facies. Channel and floodplain deposits of ancestral Rio Grande consisting of variable proportions of sandstone, mudstone, and conglomerate. Sandstone is typically crossbedded and poorly indurated. Clasts in conglomerate consist of well-rounded to sub-rounded pebbles of quartzite, chert, granite, gneiss, sandstone, volcanic lithics, siltstone, schist, phyllite, limestone, obsidian, and pumice. Mudstone ranges in color from reddish brown to greenish gray. Paleoflow was to the south. *Crosses* (x) on map indicate selected exposures of axial sandstone and conglomerate used to delineate areal extent of axial-river facies (QTsa) and transitional axial-piedmont facies (QTst).

QTst Transitional axial-piedmont facies. Intertongued axial river deposits and piedmont deposits. Transitional deposits are defined as the zone of overlap between the *basinward* extent of piedmont sand and gravel and the *mountainward* extent of axial river sand and gravel. Mudstone is commonly ambiguous as to its former position within the facies tract (i.e. piedmont vs. axial), and thus is not a factor in delineating the transitional facies.

QTsm Pond and lake deposits. Laminated reddish-brown mudstone and minor sandstone that accumulated in local ponds and lakes.

QTsb Volcanic flows and cinders. Mafic to intermediate lava and coarse tephra within Sierra Ladrones sedimentary deposits. Radiometric ages are indicated where available.

QTsap Volcanic ash and pumice. Water-reworked rhyolitic pumice and ash. Radiometric ages shown where available.

Popotosa Formation (lower Miocene – upper Miocene)

Tppc Conglomeratic piedmont facies. Characterized by conglomerate/sandstone ratio of greater than 2/1. In this and other facies within the Popotosa Formation, detritus was derived dominantly from mid-Tertiary volcanic rocks. Conglomerate is mostly clast-supported, crudely imbricated, and poorly sorted. Matrix-supported debris-flow deposits are common in this facies; in areas where debris-flow deposits are voluminous, they are mapped separately as facies Tppcd. Sandstone in Tppc is medium to very coarse grained and commonly exhibits either crossbedding or

	horizontal laminations. Mudstone is rare, occurring mostly as thin discontinuous drapes.
Tppcd	Debris-flow-dominated conglomeratic piedmont facies. Characterized by a dominance of very poorly sorted conglomerate that is matrix-supported and typically very well indurated. Clasts are virtually all derived from Tertiary volcanic rocks. Comprises the basal part of the Popotosa Formation in the Lemitar Mountains area (Chamberlin, 1982; Cather et al., 1994a).
Tppcs	Conglomerate-sandstone piedmont facies. Characterized by conglomerate/sandstone ratio between 2/1 and 1/2. Conglomerate is mostly clast-supported and poorly sorted. Sandstone is fine to very coarse grained and commonly horizontally stratified or trough cross-bedded. Mudstone is minor.
Tpps	Sandstone-dominated piedmont facies. Characterized by conglomerate/sandstone ratio less than 1/2 and sandstone/mudstone ratio greater than 2/1. Sandstone is dominantly horizontally stratified with subordinate trough crossbedding. Conglomerate is mostly clast-supported and occurs commonly as shallow, channel-shaped units. Mudstone is common and occurs as drapes and as tabular units less than a meter thick.
Tpsm	Playa-margin facies. Characterized by sandstone/mudstone ratio of between 2/1 and 1/2. Sandstone is horizontally laminated and forms thin tabular beds (<0.5 m). Sandstone is intimately interbedded with tabular mudstones that are structureless and dominantly red-brown in color. Conglomerate is rare. The playa-margin facies

represents interfingering of distal piedmont and sand-flat deposits with playa mudstone.

Tpm Playa facies. Characterized by a dominance of mudstone (sandstone/mudstone ratio is less than 1/2). Mudstone is mostly red-brown with uncommon greenish-gray zones that are parallel to bedding. Bedding is generally indistinct, although horizontal lamination was occasionally noted. Sandstone is medium to very fine grained and occurs as thin tabular beds (< 0.3 m). Conglomerate is virtually absent. Gypsum is common.

Tpa Axial stream facies. Interbedded fluvial conglomerate, sandstone, siltstone, and claystone that represent longitudinal stream deposits within those parts of evolving Popotosa-age basins that did not contain playas. Tpa is characterized primarily as relatively fine-grained fluvial sequences that are stratigraphically juxtaposed between the relatively coarser deposits of laterally opposed piedmont systems. Paleoflow within Tpa was generally at a high angle to that exhibited by associated piedmont systems. These deposits are not related to the ancestral Rio Grande but instead were probably graded to local playa systems.

Tpv Volcanic flows, domes, and coarse tephra. Mafic to silicic in composition. Radiometric ages shown where available.

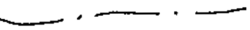
PRE-SANTA FE UNITS

Tv Tertiary volcanic and volcaniclastic rocks, undivided (upper Eocene-upper

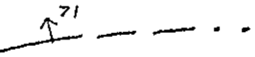
	Oligocene). Includes volcanic and volcaniclastic rocks of Spears, Datil, and Mogollon Groups (nomenclature of Cather et al., 1994b).
Tbc	Baca Formation (middle to upper Eocene). Conglomerate and sandstone consisting of detritus from Paleozoic, Precambrian, and Mesozoic sources.
Mz	Mesozoic rocks, undivided. Sandstones and mudstones of Triassic to Cretaceous age.
Pz	Paleozoic rocks, undivided. Sandstone, mudstone, limestone, gypsum, and conglomerate of Pennsylvanian and Permian age.
pꞒ	Precambrian rocks, undivided. Granite, quartzite, schist, gneiss, and phyllite of Late Proterozoic age.

EXPLANATION OF MAP SYMBOLS

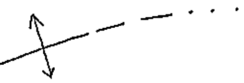
Contact between geologic units or facies within Santa Fe Group. Dashed where approximately located. Dotted where concealed (Santa Fe lithofacies only).



Contact between volcaniclastic (v) and siliciclastic (s) petrofacies where contact does not coincide with lithofacies contact.

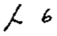


Fault showing direction and dip of fault plane. Dashed where approximately located; dotted where concealed. Bar and ball on downthrown block.



Anticline showing trace of axial plane and plunge direction. Dashed where approximately located, dotted where concealed.

Syncline showing trace of axial plane and plunge direction. Dashed where approximately located, dotted where concealed.



Strike and dip of bedding.

Vertical bedding.

Horizontal bedding.

┼┼┼┼┼	Tephra layer, showing radiometric age.
⌖	Well or windmill.
o~	Spring.
×	Selected exposure of axial sand or gravel in Sierra Ladrones Formation used to delineate areal extent of QTsa or QTst.
↗	Paleocurrent direction in piedmont deposit based on pebble imbrication or crossbedding.
o→	Paleocurrent direction in axial river deposit based on pebble imbrication or crossbedding.
....	Marker bed in Santa Fe Group.
▨	Erosional remnants of aggradational surface at top of Santa Fe Group (Las Cañas surface and Sedillo Hill surface of McGrath and Hawley, 1987). Characterized by well-developed calcareous paleosols.

REFERENCES

Bruning, J. E., 1973, Origin of the Popotosa Formation, north-central Socorro County, New Mexico [Ph.D. thesis]: Socorro, New Mexico Institute of Mining and Technology, 142 p.

Bryan, K., 1938, Geology and ground-water conditions of the Rio Grande depression in Colorado and New Mexico: Washington, [U.S.] Natural Resources Planning Board, The Rio Grande Joint Investigations in the Upper Rio Grande Basin, v. 1, pt. 2, p. 196–225.

Cather, S. M., Chamberlin, R. M., Chapin, C. E., and McIntosh, W. C., 1994a, Stratigraphic consequences of episodic extension in the Lemitar Mountains, central Rio Grande rift, *in* Keller, G. R., and Cather, S. M., eds., Basins of the Rio Grande rift: Structure, stratigraphy, and tectonic setting: Geological Society of America Special Publication 291, p. 157–170.

Cather, S. M., Chamberlin, R. M., and Ratté, J. C., 1994b, Tertiary stratigraphy and nomenclature for western New Mexico and eastern Arizona: New Mexico Geological Society Guidebook 45, p. 259–266.

Chamberlin, R. M., 1980, Cenozoic stratigraphy and structure of the Socorro Peak volcanic center, central New Mexico [Ph.D. thesis]: Golden, Colorado School of Mines, 495 p.

Chamberlin, R. M., 1982, Geologic map, cross sections, and map units of the Lemitar Mountains, Socorro County, New Mexico: New Mexico Bureau of Mines and

Mineral Resources Open-File Report 169, 3 plates, scale 1:12,000.

Chapin, C. E., and Seager, W. R., 1975, Evolution of the Rio Grande rift in the Socorro and Las Cruces areas: New Mexico Geological Society, Guidebook 26, p. 297–321.

Darton, N. H., 1922, Geologic structure of parts of New Mexico: U.S. Geological Survey Bulletin 726, p. 173–275.

Davis, J. M., Lohmann, R. C., Phillips, F. M., Wilson, J. L., and Love, D. W., 1993, Architecture of the Sierra Ladrones Formation—Depositional controls on the permeability correlation structure: Geological Society of America Bulletin, v. 105, p. 998–1007.

Debrine, B., Spiegel, Z., and Williams, D., 1963, Cenozoic sedimentary rocks in Socorro Valley, New Mexico: New Mexico Geological Society Guidebook 14, p. 123–131.

Denny, C. S., 1940, Tertiary geology of the San Acacia area, New Mexico: Journal of Geology, v. 48, p. 73–106.

Detmer, D. M., 1995, Permeability, porosity, and grain-size distribution of selected Pliocene and Quaternary sediments in the Albuquerque Basin, central New Mexico [M.S. thesis]: Socorro, New Mexico Institute of Mining and Technology, 115 p.

Hawley, J. W., 1983, Geomorphic evolution of Socorro area of Rio Grande valley: New Mexico Geological Society, Guidebook 34, p. 13.

Hayden, F. V., 1869, Preliminary report of the U.S. Geological Survey of Colorado and New Mexico: U.S. Geological Survey Third Annual Report, 155 p.

Machette, M. N., 1978, Geologic map of the San Acacia quadrangle, Socorro County, New

Mexico: U.S. Geological Survey Geologic Quadrangle Map GQ 1415, scale 1:24,000.

Miall, A. D., 1977, A review of the braided river depositional environment: Earth Science Reviews, v. 13, p. 1–62.

Miall, A. D., 1978, Lithofacies types and vertical profile models in braided river deposits—A summary, *in* Miall, A. D., ed., Fluvial Sedimentology: Calgary, Canadian Society of Petroleum Geologists, Memoir 5, p. 597–604.

Rust, B. R., 1978, Depositional models for braided alluvium, *in* Miall, A. D., ed., Fluvial sedimentology: Calgary, Canadian Society of Petroleum Geologists, Memoir 5, p. 605–625.

Spiegel, Z., and Baldwin, B., 1963, Geology and water resources of the Santa Fe Area, New Mexico: U.S. Geological Survey Water-Supply Paper 1525, 258 p.

Open-File Report 417a
Initial filing 1/96

GEOLOGIC MAP OF UPPER CENOZOIC DEPOSITS OF THE MESA DEL YESO 7.5′ QUADRANGLE, NEW MEXICO

by
Steven M. Cather
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico 87801

Stratigraphy of the Santa Fe Group

Exposures of both the Popotosa Formation and Sierra Ladrones Formation are present in the Mesa del Yeso quadrangle. The Popotosa consists of conglomerate, sandstone, and minor mudstone that were derived entirely from mid-Tertiary volcanic rocks. Paleoflow, as shown by pebble imbrication, was to the west. The Popotosa overlies Tertiary volcanic rocks wherever its basal contact is exposed; the contact ranges from a disconformity to a moderate angular unconformity. Popotosa exposures on the Mesa del Yeso quadrangle were first noted by Beck (1993) in the Arroyo Rosa de Castillo area. Popotosa outcrops along Arroyo de la Parida were mapped as Santa Fe Group by DeBrine et al. (1963, fig. 2), but were not distinguished from the Sierra Ladrones Formation which forms the vast majority of Santa Fe exposures on their map. In the Puertecito of Bowling Green area, poor exposures mapped in this report as Popotosa may be, in part, ancient colluvium developed on the La Jara Peak basaltic andesite (Tv). In the Lemitar Mountains to the west, the Popotosa ranges in age from >16 Ma to about 7 Ma (see summary in Cather et al., 1994). In areas east of the Rio Grande, the Popotosa can only be constrained to be older than the basalt at San Acacia (4.5 ± 0.1 Ma, K-Ar age in Machette, 1978) and the younger than the underlying volcanic rocks

(27-28 Ma). East-derived Popotosa conglomerate and sandstone in Cañoncito de las Cabras (Lemitar 7.5' quadrangle) contain a tephra dated at 14.5 ± 0.3 Ma (W. C. McIntosh, unpublished date), and may be distal equivalents of the Popotosa exposed on the Mesa del Yeso quadrangle.

The Sierra Ladrones Formation composes the great majority of Santa Fe Group exposures on the Mesa del Yeso quadrangle. Of these exposures, approximately two-thirds consist of piedmont deposits, dominantly conglomeratic or conglomerate-sand lithofacies. Sandstone-dominated piedmont deposits are not present in this quadrangle; the conglomerate-sandstone piedmont lithofacies grades directly into transitional axial-piedmont or axial fluvial lithofacies in most areas. Piedmont deposits display evidence for west or southwest paleoflow. The siliciclastic petrofacies dominates piedmont deposits from the area near Arroyo del Veranito southward, whereas the volcaniclastic petrofacies is volumetrically more important north of Arroyo de Alamillo. On several fault blocks between the Alamillo and Veranito faults, in the area north of Arroyo del Veranito, the volcaniclastic petrofacies is conformably overlain by the siliciclastic petrofacies. On these fault blocks, volcaniclastic sedimentation was supplanted by siliciclastic sedimentation as local sources of volcanic detritus in the central and northern parts of the quadrangle were onlapped and buried by Paleozoic-dominated detritus derived from farther east. Part of a late Sierra Ladrones paleovalley system that transported siliciclastic material westward across Tertiary volcanic rocks is preserved in sec. 27, T1S, R1E.

The axial river lithofacies is locally present along the western boundary of the quadrangle. These exposures consist mostly of trough-crossbedded, well-sorted sand and gravel; floodplain mudstone is also present but typically not abundant. The zone of interfingering represented by the transitional axial-piedmont system averages about 1 km wide.

South of Arroyo del Veranito, the overall facies tract is progradational, with piedmont deposits lapping westward over older transitional deposits. North of Arroyo del Veranito, however, evidence for retrogradation or onlap of axial and transitional deposits is widespread. In this area, the uppermost Sierra Ladrones Formation commonly consists of a thin veneer of axial or transitional deposits that abruptly overlie piedmont deposits. The most likely explanation for these relations is that local subsidence due to down-to-the-west faulting was able to outpace sediment supply to parts of the eastern piedmont, resulting in rapid eastward onlap of basin-floor deposits.

The contact between the Sierra Ladrones Formation and the underlying Popotosa in the quadrangle is an unconformity that ranges in angularity from a few degrees to as much as about 30 degrees. The angularity of the unconformity generally increases northward within the quadrangle. The duration of the lacuna represented by the angular unconformity is unknown, but based on similar relations exposed in the Lemitar Mountains to the west (Cather et al., 1994) the lacuna may represent much of the late Miocene. The age of the Sierra Ladrones in the quadrangle is constrained by the interbedded 4.5 Ma San Acacia basalt nearby to the northwest of the quadrangle. Also, fossil mammal remains have been recovered from axial-river deposits in the transitional axial-piedmont facies exposed along the south bank of Arroyo de la Parida (Needham, 1936). These fossils are of late Blancan age (Tedford, 1981) and thus constrain these deposits to be about 2.5 to 1.5 Ma in age. The Sierra Ladrones axial deposits in the Mesa del Yeso quadrangle contain little or no pumice, indicating that these deposits predate the major ignimbrite eruptions of the Jemez Mountains at 1.2 and 1.6 Ma.

Structural Geology

Faults are the principal structures that are present within the Santa Fe Group outcrop of the Mesa del Yeso quadrangle. As best as can be determined due to poor exposures, most or all of these faults appear to be normal and high-angle. Recorded dips range from about 65 to 80 degrees. Most faults are down-to-the-west, although a few are down-to-the-east.

The Veranito fault extends north-south the length of the quadrangle. It is dominantly down-to-the-west, but a segment of the fault nearby to the south of Arroyo de Alamillo exhibits evidence for down-to-the-east displacement. To the south, the Veranito fault splays into several strands near Arroyo de la Parida. The principal locus of deformation appears to step left to the easternmost of these strands, the Coyote fault. The Coyote fault is a prominent normal fault that extends nearly the length of the Loma de las Cañas quadrangle to the south. To the north, the Veranito fault may be contiguous with the West Joyita fault (Beck, 1993) but this possibility has not yet been evaluated. In Arroyo del Veranito and Arroyo de la Parida, the Veranito fault juxtaposes Popotosa against Sierra Ladrones on the west. In Arroyo Rosa de Castillo, the fault juxtaposes the Sierra Ladrones against

Precambrian granite. At higher structural and topographic levels along the upland areas between these arroyos, the Veranito fault juxtaposes Popotosa against Sierra Ladrones or is simply marked by a slope break or a facies change in the Sierra Ladrones (QTspc vs. QTspcs on west). In sec. 27 about 2 km southwest of Puertecito of Bowling Green, the upper unit of the Sierra Ladrones is only slightly displaced by the fault. Taken together, these relations suggest the Veranito fault acted as a growth fault that exhibits increasing displacement with depth and locally controlled the basinward fining of lithofacies within the Sierra Ladrones piedmont.

Other evidence for syndepositional faulting is present in the quadrangle:

1) In NE¼ sec. 22, T2S, R1E, Sierra Ladrones piedmont deposits contain significant mudstone on the east side of a prominent down-to-the-east fault. Development of an east-facing scarp during deposition would temporarily pond the west-draining piedmont and explain the anomalous presence of mudstone in this area.

2) Isolated exposures of conglomeratic piedmont facies which are bounded on the east by down-to-the-west faults are present in sec. 4, T2S, R1E and secs. 19 and 20, T1S, R1E. These anomalously coarse deposits may reflect temporary uplift and erosion of the footwall due to faulting. Such uplift would cause transportation of detritus within paleocanyons across formerly depositional areas on the footwall, resulting in aggradation of coarse, proximal detritus in fan-head environments on the hanging wall.

3) As mentioned above, the onlap of basin-floor facies across former piedmont areas in the region north of Arroyo del Veranito may be indicative of fault-related subsidence.

The Alamillo fault is a down-to-the-west normal fault which is well exposed north of Arroyo Alamillo and parallels the north-striking Veranito fault. The Alamillo fault splays to the south along a series of northwest-striking, down-to-the-southwest faults that form a left step between the Veranito fault and the Alamillo fault. The anomalous presence of local lacustrine mudstone (QTsm) directly west of the Alamillo fault about 0.5 km south of Arroyo Alamillo suggests local syndepositional subsidence and ponding on the hanging-wall block.

Remarks

No remnants of the upper, aggradational surface of the Sierra Ladrones Formation (Las Cañas surface of McGrath and Hawley, 1987) are preserved in the quadrangle, although the summit area of Johnson Hill in secs. 10 and 11, T25, R1E (Hawley, 1983) and the upland area in sec. 27, T1S, R1E may be approximations of this surface. In the area north of Arroyo Alamillo in the northwest part of the quadrangle, Qpo is unusually fine grained and contains more eolian sand than other Qpo deposits to the south. Qpo deposits north of Arroyo Alamillo are also anomalous in that they overlie a prominent calcareous paleosol. In areas to the south, soils are typically weakly developed or not present beneath Qpo. Remnants of inset, post-Santa Fe geomorphic surfaces are preserved in the northwest part of the quadrangle (developed on Qpo about 1 mile southwest of Arroyo Rosa de Castillo; termed Cañada Mariana surface by Denny, 1941) and in sec. 17, T2S, R1E (where surfaces are developed on both Qpo and Qpy). Study of the age, distribution, and correlation of these surfaces, however, has not yet been undertaken.

For more information concerning the bedrock geology in the eastern part of the quadrangle, see Spradlin (1976) and Beck (1993).

REFERENCES

Beck, W. C., 1993, Structural evolution of the Joyita Hills, Socorro County, New Mexico [Ph.D thesis]: Socorro, New Mexico Institute of Mining and Technology, 187 p.

Cather, S. M., Chamberlin, R. M., Chapin, C. E., and McIntosh, W. C., 1994a, Stratigraphic consequences of episodic extension in the Lemitar Mountains, central Rio Grande rift, *in* Keller, G. R., and Cather, S. M., eds., Basins of the Rio Grande rift: Structure, stratigraphy, and tectonic setting: Geological Society of America Special Publication 291, p. 157–170.

DeBrine, B., Spiegel, Z., and Williams, D., 1963, Cenozoic sedimentary rocks in Socorro Valley, New Mexico: New Mexico Geological Society, Guidebook 14, p. 123–131.

Denny, C. S., 1941, Quaternary geology of San Acacia area, New Mexico: Journal of Geology, v. 49, p. 225–260.

Hawley, J. W., 1983, Geomorphic evolution of Socorro area of Rio Grande valley: New Mexico Geological Society, Guidebook 34, p. 13.

Machette, M. N., 1978, Geologic map of the San Acacia quadrangle, Socorro County, New Mexico: U.S. Geological Survey Geologic Quadrangle Map GQ-1415, scale 1:24,000.

McGrath, D. B., and Hawley, J. W., 1987, Geomorphic evolution and soil-geomorphic relationships in the Socorro area, central New Mexico, *in* McLemore, V. T., and

Bowie, M. R., compilers, Guidebook to the Socorro area New Mexico: New Mexico Bureau of Mines and Mineral Resources, p. 55–67.

Needham, C. E., 1936, Vertebrate remains from Cenozoic rocks: Science, v. 84, p. 537.

Spradlin, E. J., 1976, Stratigraphy of Tertiary volcanic rocks, Joyita Hills area, Socorro County, New Mexico [M.S. thesis]: Albuquerque, University of New Mexico, 73 p.

Tedford, R. H., 1981, Mammalian biochronology of the late Cenozoic basins of New Mexico: Geological Society of America Bulletin, Part I, v. 92, p. 1008–1022.

Open-File Report 417b
Initial filing 1/96

GEOLOGIC MAP OF UPPER CENOZOIC DEPOSITS OF THE LOMA DE LAS CAÑAS 7.5′ QUADRANGLE, NEW MEXICO

by
Steven M. Cather
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico 87801

Stratigraphy of the Santa Fe Group

Santa Fe Group exposures on the Loma de las Cañas quadrangle consist entirely of Sierra Ladrones Formation. No Popotosa outcrops are known south of Arroyo de la Parida, just to the north of the quadrangle. Lithofacies in the Sierra Ladrones are similar to those on the Mesa del Yeso quadrangle except that a mappable sandstone-dominated piedmont facies (QTsps) is also present. The Sierra Ladrones is extensively overlain by inset, post-Santa Fe piedmont deposits in the Loma de las Cañas quadrangle. These post-Santa Fe deposits are easily confused with the Sierra Ladrones Formation, and are recognized primarily by their position in the landscape and by their greater coarseness relative to Santa Fe Group deposits.

Sierra Ladrones piedmont deposits show evidence for westerly paleoflow, ranging between northwest and southwest. In several areas along the east edge of the Sierra Ladrones outcrop, piedmont deposits appear to have been erosionally truncated by post-Santa Fe erosion. It is likely that the Sierra Ladrones extended somewhat east of the present outcrop belt, although these missing deposits were probably quite thin (<50 m). The transitional axial-piedmont facies contains much fine-grained material and ranges in outcrop width from about 1 to 3 km. The axial-river facies is dominated by well sorted, poorly indurated, gravelly sands with subordinate reddish mudstone. The outcrop width of the axial-river facies broadens southward, and extends as much as 3 km east of the modern Rio Grande in some places.

Within the quadrangle, the Sierra Ladrones facies tract is generally progradational, with proximal piedmont deposits lapping westward across distal deposits. Several arroyos in the central and southern part of the quadrangle provide relatively complete transects through the entire facies tract. No fossil or radiometric age constraints have been determined within the Sierra Ladrones Formation in this quadrangle, although the lack of pumice in axial-river deposits suggest deposition occurred prior to eruption of the Bandelier Tuff (1.6 Ma).

Structural Geology

The Coyote fault is the principal normal fault that cuts Santa Fe strata in the Loma de las Cañas quadrangle. It is down-to-the-west and, at least in the northern part of the quadrangle, dips moderately west (41° to 50°). The Coyote fault juxtaposes Sierra Ladrones strata against Precambrian rocks in Arroyo Tio Bartolo. In the drainages of Arroyo de la Presilla and Arroyo del Tajo, however, there is no evidence of displacement between the Sierra Ladrones and the Precambrian. In these areas, the Sierra Ladrones appears to have simply onlapped and buried Precambrian rocks exposed in the footwall which had been upthrown earlier in Sierra Ladrones time or, perhaps, during deposition of the Popotosa Formation. In other areas, the Coyote fault juxtaposes the Sierra Ladrones on the west with Paleozoic strata, Tertiary volcanic rocks, or older Sierra Ladrones on the east. To the east of the Coyote fault the Sierra Ladrones is quite thin, forming a veneer of coarse clastic deposits less than about 50 m thick. Two springs (Ojo del Coyote and Ojo de Amado) are localized along the fault in the northern part of the quadrangle.

In the central part of the quadrangle the Coyote fault is buried by the upper Sierra Ladrones, and thus has not been active since late Sierra Ladrones time in this area. To the south, however, the upper aggradational surface of the Sierra Ladrones (Las Cañas surface of McGrath and Hawley, 1987) is faulted down to the west along the Coyote fault. These relations suggest the fault has been segmented with respect to surface displacements since late Sierra Ladrones time.

A north-trending structural zone consisting of a down-to-the-west normal fault and related folds is exposed in secs. 28 and 33, T2S, R1E. In this zone the normal fault becomes buried and is replaced to the south by a west-facing monocline. About 1 km southeast of the monocline, a footwall (?) syncline is present that may have formed due to isostatic rebound along the buried normal fault. Anomalous accumulations of mudstone within sandstone-dominated piedmont deposits along the hinge area of this syncline suggests that this structural zone developed, at least in part, during Sierra Ladrones deposition. This structural zone may mark the western edge of a shallow structural bench that steps down toward the basin from an even shallower bench east of the Coyote fault. The presence of a heretofore unmapped exposure of Tertiary volcanics (probably La Jara Peak Basaltic Andesite) beneath the Santa Fe in sec. 34, T2S, R1E attests to the shallowness of basin-fill on this intermediate bench. This structural zone also serves as the eastward limit of basin-floor facies in the area.

The Gonzales fault, named for the Gonzales fluorite prospect in sec. 2, T3S, R1E, locally bounds the eastward extent of the Sierra Ladrones in the central part of the quadrangle. It is downthrown to the west, dips steeply west, and strikes north-northwest, parallel to the Coyote fault. A spring is located along a splay of the fault in sec. 13, T3S, R1E.

Remarks

Remnants of the upper aggradational surface of the Sierra Ladrones Formation are present near Arroyo de las Cañas in the southern part of the quadrangle. Termed the Las Cañas surface by McGrath and Hawley (1987), this surface is marked by well-developed calcic paleosols. It is cut by the Coyote fault and locally mantled by Quaternary eolian deposits. The Las Cañas surfaces grades to an elevation about 91 m above the modern Rio Grande (Smith et al., 1983, p. 19).

For additional information on the bedrock geology in the eastern part of the quadrangle, see Rejas (1965) and Bauch (1982).

REFERENCES

Bauch, J. H. A., 1982, Geology of the central area of the Loma de las Cañas quadrangle, Socorro County, New Mexico [M.S. thesis]: Socorro, New Mexico Institute of Mining and Technology, 116 p.

McGrath, D. B., and Hawley, J. W., 1987, Geomorphic evolution and soil-geomorphic relationships in the Socorro area, central New Mexico, *in* McLemore, V. T., and

Bowie, M. R., compilers, Guidebook to the Socorro area, New Mexico: Socorro, New Mexico Bureau of Mines and Mineral Resources, p. 55–67.

Rejas, A., 1965, Geology of the Cerros de Amado area, Socorro County, New Mexico [M.S. thesis]: Socorro, New Mexico Institute of Mining and Technology, 128 p.

Smith, C. T., Osburn, G. R., Chapin, C. E., Hawley, J. W., Osburn, J. C., Anderson, O. J., Rosen, S. D., Eggleston, T. L., and Cather, S. M., 1983, First-day road log from Socorro to Mesa del Yeso, Joyita Hills, Johnson Hill, Cerros de Amado, Lomas de las Cañas, Jornado del Muerto, Carthage, and return to Socorro: New Mexico Geological Society, Guidebook 34, p. 1–28.

Open-File Report 417a
Initial filing 1/96

GEOLOGIC MAP OF UPPER CENOZOIC DEPOSITS OF THE MESA DEL YESO 7.5′ QUADRANGLE, NEW MEXICO

by
Steven M. Cather
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico 87801

Stratigraphy of the Santa Fe Group

Exposures of both the Popotosa Formation and Sierra Ladrones Formation are present in the Mesa del Yeso quadrangle. The Popotosa consists of conglomerate, sandstone, and minor mudstone that were derived entirely from mid-Tertiary volcanic rocks. Paleoflow, as shown by pebble imbrication, was to the west. The Popotosa overlies Tertiary volcanic rocks wherever its basal contact is exposed; the contact ranges from a disconformity to a moderate angular unconformity. Popotosa exposures on the Mesa del Yeso quadrangle were first noted by Beck (1993) in the Arroyo Rosa de Castillo area. Popotosa outcrops along Arroyo de la Parida were mapped as Santa Fe Group by DeBrine et al. (1963, fig. 2), but were not distinguished from the Sierra Ladrones Formation which forms the vast majority of Santa Fe exposures on their map. In the Puertecito of Bowling Green area, poor exposures mapped in this report as Popotosa may be, in part, ancient colluvium developed on the La Jara Peak basaltic andesite (Tv). In the Lemitar Mountains to the west, the Popotosa ranges in age from >16 Ma to about 7 Ma (see summary in Cather et al., 1994). In areas east of the Rio Grande, the Popotosa can only be constrained to be older than the basalt at San Acacia (4.5 ± 0.1 Ma, K-Ar age in Machette, 1978) and the younger than the underlying volcanic rocks

(27-28 Ma). East-derived Popotosa conglomerate and sandstone in Cañoncito de las Cabras (Lemitar 7.5' quadrangle) contain a tephra dated at 14.5 ± 0.3 Ma (W. C. McIntosh, unpublished date), and may be distal equivalents of the Popotosa exposed on the Mesa del Yeso quadrangle.

The Sierra Ladrones Formation composes the great majority of Santa Fe Group exposures on the Mesa del Yeso quadrangle. Of these exposures, approximately two-thirds consist of piedmont deposits, dominantly conglomeratic or conglomerate-sand lithofacies. Sandstone-dominated piedmont deposits are not present in this quadrangle; the conglomerate-sandstone piedmont lithofacies grades directly into transitional axial-piedmont or axial fluvial lithofacies in most areas. Piedmont deposits display evidence for west or southwest paleoflow. The siliciclastic petrofacies dominates piedmont deposits from the area near Arroyo del Veranito southward, whereas the volcaniclastic petrofacies is volumetrically more important north of Arroyo de Alamillo. On several fault blocks between the Alamillo and Veranito faults, in the area north of Arroyo del Veranito, the volcaniclastic petrofacies is conformably overlain by the siliciclastic petrofacies. On these fault blocks, volcaniclastic sedimentation was supplanted by siliciclastic sedimentation as local sources of volcanic detritus in the central and northern parts of the quadrangle were onlapped and buried by Paleozoic-dominated detritus derived from farther east. Part of a late Sierra Ladrones paleovalley system that transported siliciclastic material westward across Tertiary volcanic rocks is preserved in sec. 27, T1S, R1E.

The axial river lithofacies is locally present along the western boundary of the quadrangle. These exposures consist mostly of trough-crossbedded, well-sorted sand and gravel; floodplain mudstone is also present but typically not abundant. The zone of interfingering represented by the transitional axial-piedmont system averages about 1 km wide.

South of Arroyo del Veranito, the overall facies tract is progradational, with piedmont deposits lapping westward over older transitional deposits. North of Arroyo del Veranito, however, evidence for retrogradation or onlap of axial and transitional deposits is widespread. In this area, the uppermost Sierra Ladrones Formation commonly consists of a thin veneer of axial or transitional deposits that abruptly overlie piedmont deposits. The most likely explanation for these relations is that local subsidence due to down-to-the-west faulting was able to outpace sediment supply to parts of the eastern piedmont, resulting in rapid eastward onlap of basin-floor deposits.

The contact between the Sierra Ladrones Formation and the underlying Popotosa in the quadrangle is an unconformity that ranges in angularity from a few degrees to as much as about 30 degrees. The angularity of the unconformity generally increases northward within the quadrangle. The duration of the lacuna represented by the angular unconformity is unknown, but based on similar relations exposed in the Lemitar Mountains to the west (Cather et al., 1994) the lacuna may represent much of the late Miocene. The age of the Sierra Ladrones in the quadrangle is constrained by the interbedded 4.5 Ma San Acacia basalt nearby to the northwest of the quadrangle. Also, fossil mammal remains have been recovered from axial-river deposits in the transitional axial-piedmont facies exposed along the south bank of Arroyo de la Parida (Needham, 1936). These fossils are of late Blancan age (Tedford, 1981) and thus constrain these deposits to be about 2.5 to 1.5 Ma in age. The Sierra Ladrones axial deposits in the Mesa del Yeso quadrangle contain little or no pumice, indicating that these deposits predate the major ignimbrite eruptions of the Jemez Mountains at 1.2 and 1.6 Ma.

Structural Geology

Faults are the principal structures that are present within the Santa Fe Group outcrop of the Mesa del Yeso quadrangle. As best as can be determined due to poor exposures, most or all of these faults appear to be normal and high-angle. Recorded dips range from about 65 to 80 degrees. Most faults are down-to-the-west, although a few are down-to-the-east.

The Veranito fault extends north-south the length of the quadrangle. It is dominantly down-to-the-west, but a segment of the fault nearby to the south of Arroyo de Alamillo exhibits evidence for down-to-the-east displacement. To the south, the Veranito fault splays into several strands near Arroyo de la Parida. The principal locus of deformation appears to step left to the easternmost of these strands, the Coyote fault. The Coyote fault is a prominent normal fault that extends nearly the length of the Loma de las Cañas quadrangle to the south. To the north, the Veranito fault may be contiguous with the West Joyita fault (Beck, 1993) but this possibility has not yet been evaluated. In Arroyo del Veranito and Arroyo de la Parida, the Veranito fault juxtaposes Popotosa against Sierra Ladrones on the west. In Arroyo Rosa de Castillo, the fault juxtaposes the Sierra Ladrones against

Precambrian granite. At higher structural and topographic levels along the upland areas between these arroyos, the Veranito fault juxtaposes Popotosa against Sierra Ladrones or is simply marked by a slope break or a facies change in the Sierra Ladrones (QTspc vs. QTspcs on west). In sec. 27 about 2 km southwest of Puertecito of Bowling Green, the upper unit of the Sierra Ladrones is only slightly displaced by the fault. Taken together, these relations suggest the Veranito fault acted as a growth fault that exhibits increasing displacement with depth and locally controlled the basinward fining of lithofacies within the Sierra Ladrones piedmont.

Other evidence for syndepositional faulting is present in the quadrangle:

1) In NE¼ sec. 22, T2S, R1E, Sierra Ladrones piedmont deposits contain significant mudstone on the east side of a prominent down-to-the-east fault. Development of an east-facing scarp during deposition would temporarily pond the west-draining piedmont and explain the anomalous presence of mudstone in this area.

2) Isolated exposures of conglomeratic piedmont facies which are bounded on the east by down-to-the-west faults are present in sec. 4, T2S, R1E and secs. 19 and 20, T1S, R1E. These anomalously coarse deposits may reflect temporary uplift and erosion of the footwall due to faulting. Such uplift would cause transportation of detritus within paleocanyons across formerly depositional areas on the footwall, resulting in aggradation of coarse, proximal detritus in fan-head environments on the hanging wall.

3) As mentioned above, the onlap of basin-floor facies across former piedmont areas in the region north of Arroyo del Veranito may be indicative of fault-related subsidence.

The Alamillo fault is a down-to-the-west normal fault which is well exposed north of Arroyo Alamillo and parallels the north-striking Veranito fault. The Alamillo fault splays to the south along a series of northwest-striking, down-to-the-southwest faults that form a left step between the Veranito fault and the Alamillo fault. The anomalous presence of local lacustrine mudstone (QTsm) directly west of the Alamillo fault about 0.5 km south of Arroyo Alamillo suggests local syndepositional subsidence and ponding on the hanging-wall block.

Remarks

No remnants of the upper, aggradational surface of the Sierra Ladrones Formation (Las Cañas surface of McGrath and Hawley, 1987) are preserved in the quadrangle, although the summit area of Johnson Hill in secs. 10 and 11, T25, R1E (Hawley, 1983) and the upland area in sec. 27, T1S, R1E may be approximations of this surface. In the area north of Arroyo Alamillo in the northwest part of the quadrangle, Qpo is unusually fine grained and contains more eolian sand than other Qpo deposits to the south. Qpo deposits north of Arroyo Alamillo are also anomalous in that they overlie a prominent calcareous paleosol. In areas to the south, soils are typically weakly developed or not present beneath Qpo. Remnants of inset, post-Santa Fe geomorphic surfaces are preserved in the northwest part of the quadrangle (developed on Qpo about 1 mile southwest of Arroyo Rosa de Castillo; termed Cañada Mariana surface by Denny, 1941) and in sec. 17, T2S, R1E (where surfaces are developed on both Qpo and Qpy). Study of the age, distribution, and correlation of these surfaces, however, has not yet been undertaken.

For more information concerning the bedrock geology in the eastern part of the quadrangle, see Spradlin (1976) and Beck (1993).

REFERENCES

Beck, W. C., 1993, Structural evolution of the Joyita Hills, Socorro County, New Mexico [Ph.D thesis]: Socorro, New Mexico Institute of Mining and Technology, 187 p.

Cather, S. M., Chamberlin, R. M., Chapin, C. E., and McIntosh, W. C., 1994a, Stratigraphic consequences of episodic extension in the Lemitar Mountains, central Rio Grande rift, *in* Keller, G. R., and Cather, S. M., eds., Basins of the Rio Grande rift: Structure, stratigraphy, and tectonic setting: Geological Society of America Special Publication 291, p. 157–170.

DeBrine, B., Spiegel, Z., and Williams, D., 1963, Cenozoic sedimentary rocks in Socorro Valley, New Mexico: New Mexico Geological Society, Guidebook 14, p. 123–131.

Denny, C. S., 1941, Quaternary geology of San Acacia area, New Mexico: Journal of Geology, v. 49, p. 225–260.

Hawley, J. W., 1983, Geomorphic evolution of Socorro area of Rio Grande valley: New Mexico Geological Society, Guidebook 34, p. 13.

Machette, M. N., 1978, Geologic map of the San Acacia quadrangle, Socorro County, New Mexico: U.S. Geological Survey Geologic Quadrangle Map GQ-1415, scale 1:24,000.

McGrath, D. B., and Hawley, J. W., 1987, Geomorphic evolution and soil-geomorphic relationships in the Socorro area, central New Mexico, *in* McLemore, V. T., and

Bowie, M. R., compilers, Guidebook to the Socorro area New Mexico: New Mexico Bureau of Mines and Mineral Resources, p. 55–67.

Needham, C. E., 1936, Vertebrate remains from Cenozoic rocks: Science, v. 84, p. 537.

Spradlin, E. J., 1976, Stratigraphy of Tertiary volcanic rocks, Joyita Hills area, Socorro County, New Mexico [M.S. thesis]: Albuquerque, University of New Mexico, 73 p.

Tedford, R. H., 1981, Mammalian biochronology of the late Cenozoic basins of New Mexico: Geological Society of America Bulletin, Part I, v. 92, p. 1008–1022.

Open-File Report 417b
Initial filing 1/96

GEOLOGIC MAP OF UPPER CENOZOIC DEPOSITS OF THE LOMA DE LAS CAÑAS 7.5′ QUADRANGLE, NEW MEXICO

by
Steven M. Cather
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico 87801

Stratigraphy of the Santa Fe Group

Santa Fe Group exposures on the Loma de las Cañas quadrangle consist entirely of Sierra Ladrones Formation. No Popotosa outcrops are known south of Arroyo de la Parida, just to the north of the quadrangle. Lithofacies in the Sierra Ladrones are similar to those on the Mesa del Yeso quadrangle except that a mappable sandstone-dominated piedmont facies (QTsps) is also present. The Sierra Ladrones is extensively overlain by inset, post-Santa Fe piedmont deposits in the Loma de las Cañas quadrangle. These post-Santa Fe deposits are easily confused with the Sierra Ladrones Formation, and are recognized primarily by their position in the landscape and by their greater coarseness relative to Santa Fe Group deposits.

Sierra Ladrones piedmont deposits show evidence for westerly paleoflow, ranging between northwest and southwest. In several areas along the east edge of the Sierra Ladrones outcrop, piedmont deposits appear to have been erosionally truncated by post-Santa Fe erosion. It is likely that the Sierra Ladrones extended somewhat east of the present outcrop belt, although these missing deposits were probably quite thin (<50 m). The transitional axial-piedmont facies contains much fine-grained material and ranges in outcrop width from about 1 to 3 km. The axial-river facies is dominated by well sorted, poorly indurated, gravelly sands with subordinate reddish mudstone. The outcrop width of the axial-river facies broadens southward, and extends as much as 3 km east of the modern Rio Grande in some places.

Within the quadrangle, the Sierra Ladrones facies tract is generally progradational, with proximal piedmont deposits lapping westward across distal deposits. Several arroyos in the central and southern part of the quadrangle provide relatively complete transects through the entire facies tract. No fossil or radiometric age constraints have been determined within the Sierra Ladrones Formation in this quadrangle, although the lack of pumice in axial-river deposits suggest deposition occurred prior to eruption of the Bandelier Tuff (1.6 Ma).

Structural Geology

The Coyote fault is the principal normal fault that cuts Santa Fe strata in the Loma de las Cañas quadrangle. It is down-to-the-west and, at least in the northern part of the quadrangle, dips moderately west (41° to 50°). The Coyote fault juxtaposes Sierra Ladrones strata against Precambrian rocks in Arroyo Tio Bartolo. In the drainages of Arroyo de la Presilla and Arroyo del Tajo, however, there is no evidence of displacement between the Sierra Ladrones and the Precambrian. In these areas, the Sierra Ladrones appears to have simply onlapped and buried Precambrian rocks exposed in the footwall which had been upthrown earlier in Sierra Ladrones time or, perhaps, during deposition of the Popotosa Formation. In other areas, the Coyote fault juxtaposes the Sierra Ladrones on the west with Paleozoic strata, Tertiary volcanic rocks, or older Sierra Ladrones on the east. To the east of the Coyote fault the Sierra Ladrones is quite thin, forming a veneer of coarse clastic deposits less than about 50 m thick. Two springs (Ojo del Coyote and Ojo de Amado) are localized along the fault in the northern part of the quadrangle.

In the central part of the quadrangle the Coyote fault is buried by the upper Sierra Ladrones, and thus has not been active since late Sierra Ladrones time in this area. To the south, however, the upper aggradational surface of the Sierra Ladrones (Las Cañas surface of McGrath and Hawley, 1987) is faulted down to the west along the Coyote fault. These relations suggest the fault has been segmented with respect to surface displacements since late Sierra Ladrones time.

A north-trending structural zone consisting of a down-to-the-west normal fault and related folds is exposed in secs. 28 and 33, T2S, R1E. In this zone the normal fault becomes buried and is replaced to the south by a west-facing monocline. About 1 km southeast of the monocline, a footwall (?) syncline is present that may have formed due to isostatic rebound along the buried normal fault. Anomalous accumulations of mudstone within sandstone-dominated piedmont deposits along the hinge area of this syncline suggests that this structural zone developed, at least in part, during Sierra Ladrones deposition. This structural zone may mark the western edge of a shallow structural bench that steps down toward the basin from an even shallower bench east of the Coyote fault. The presence of a heretofore unmapped exposure of Tertiary volcanics (probably La Jara Peak Basaltic Andesite) beneath the Santa Fe in sec. 34, T2S, R1E attests to the shallowness of basin-fill on this intermediate bench. This structural zone also serves as the eastward limit of basin-floor facies in the area.

The Gonzales fault, named for the Gonzales fluorite prospect in sec. 2, T3S, R1E, locally bounds the eastward extent of the Sierra Ladrones in the central part of the quadrangle. It is downthrown to the west, dips steeply west, and strikes north-northwest, parallel to the Coyote fault. A spring is located along a splay of the fault in sec. 13, T3S, R1E.

Remarks

Remnants of the upper aggradational surface of the Sierra Ladrones Formation are present near Arroyo de las Cañas in the southern part of the quadrangle. Termed the Las Cañas surface by McGrath and Hawley (1987), this surface is marked by well-developed calcic paleosols. It is cut by the Coyote fault and locally mantled by Quaternary eolian deposits. The Las Cañas surfaces grades to an elevation about 91 m above the modern Rio Grande (Smith et al., 1983, p. 19).

For additional information on the bedrock geology in the eastern part of the quadrangle, see Rejas (1965) and Bauch (1982).

REFERENCES

Bauch, J. H. A., 1982, Geology of the central area of the Loma de las Cañas quadrangle, Socorro County, New Mexico [M.S. thesis]: Socorro, New Mexico Institute of Mining and Technology, 116 p.

McGrath, D. B., and Hawley, J. W., 1987, Geomorphic evolution and soil-geomorphic relationships in the Socorro area, central New Mexico, *in* McLemore, V. T., and

Bowie, M. R., compilers, Guidebook to the Socorro area, New Mexico: Socorro, New Mexico Bureau of Mines and Mineral Resources, p. 55–67.

Rejas, A., 1965, Geology of the Cerros de Amado area, Socorro County, New Mexico [M.S. thesis]: Socorro, New Mexico Institute of Mining and Technology, 128 p.

Smith, C. T., Osburn, G. R., Chapin, C. E., Hawley, J. W., Osburn, J. C., Anderson, O. J., Rosen, S. D., Eggleston, T. L., and Cather, S. M., 1983, First-day road log from Socorro to Mesa del Yeso, Joyita Hills, Johnson Hill, Cerros de Amado, Lomas de las Cañas, Jornado del Muerto, Carthage, and return to Socorro: New Mexico Geological Society, Guidebook 34, p. 1–28.

OFR 417a Map 1a

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

MESA DEL YESO QUADRANGLE
NEW MEXICO-SOCORRO CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

Produced by the United States Geological Survey

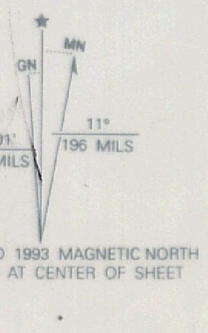
Control by USGS and NOS/NOAA

Compiled from aerial photographs taken 1956
Field checked 1959

1927 North American Datum (NAD 27). Projection and 10 000-foot ticks: New Mexico Coordinate System, central zone (Transverse Mercator)
Blue 1000-meter Universal Transverse Mercator ticks, zone 13

North American Datum of 1983 (NAD 83) is shown by dashed corner ticks. The values of the shift between NAD 27 and NAD 83 for 7.5-minute intersections are given in USGS Bulletin 1875

There may be private inholdings within the boundaries of the National or State reservations shown on this map



UTM GRID AND 1993 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY
DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

geology by S.M. Cather

QUADRANGLE LOCATION

ROAD CLASSIFICATION

Light-duty ══════ Unimproved dirt ========

MESA DEL YESO, N. MEX.
34106-B7-TF-024

1959

DMA 4652 III NE-SERIES V881

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OFR 417b Map 1b

LOMA DE LAS CAÑAS QUADRANGLE

NEW MEXICO-SOCORRO CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
SE/4 SOCORRO 15' QUADRANGLE

Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Topography by photogrammetric methods from aerial photographs taken 1956. Field checked 1959

Polyconic projection. 1927 North American Datum
10,000-foot grid based on New Mexico coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 13
shown in blue. The difference between 1927 North American Datum
and North American Datum of 1983 (NAD 83) for 7.5 minute
intersections is given in USGS Bulletin 1875. The NAD 83 is shown
by dashed corner ticks

To place on the predicted North American Datum 1983
move the projection lines 4 meters south and
52 meters east as shown by dashed corner ticks

UTM GRID AND 1979 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

Revisions shown in purple and recompilation of woodland areas compiled from aerial photographs taken 1977 and other source data. This information not field checked. Map edited 1979

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

geology by S. M. Cather

QUADRANGLE LOCATION

ROAD CLASSIFICATION
Unimproved dirt

LOMA DE LAS CAÑAS, N. MEX.
SE/4 SOCORRO 15' QUADRANGLE
N3400—W10645/7.5
1959
PHOTOREVISED 1979
DMA 4652 III SE—SERIES V881