# Preliminary Geologic Map of the Scholle Quadrangle, Valencia, Torrance, and Socorro Counties, New Mexico

By

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**New Mexico Bureau of Geology and Mineral Resources**
***Open-file Digital Geologic Map OF-GM 99***

**Scale 1:24,000**

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**New Mexico Bureau of Geology and Mineral Resources**
**801 Leroy Place, Socorro, New Mexico, 87801-4796**

Scholle 7.5' Quadrangle
OF-GM 99

# GEOLOGY OF THE SCHOLLE 7.5-MINUTE QUADRANGLE, SOCORRO, TORRANCE AND VALENCIA COUNTIES, NEW MEXICO

by
Lea Anne Scott, Maya Elrick, Sean Connell, and Karl Karlstrom

Geologic mapping by
Lea Anne Scott (Paleozoic), Maya Elrick (Paleozoic), Sean Connell (Cenozoic), Karl E. Karlstrom (Precambrian), with previous mapping by Donald A. Myers and Steve Haden

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**ABSTRACT**

The Scholle 7.5-minute quadrangle is located at the southern end of the Manzano Mountains in central New Mexico in the Abo Pass region. The majority of the quadrangle is dominated by gently dipping (<10°) Paleozoic (Pennsylvanian and Permian) sedimentary strata of limestone and sandstone. These dipping strata form extensive dip slopes in the eastern portion of the map area and are often mantled by a thin layer (<1 ft) of Quaternary-aged deposits. Steep mesas composed of red sandstones of the Permian Abo Formation form a prominent feature in the landscape. The northwestern corner of the quadrangle is markedly more complex geologically, with narrow, linear ridges of Paleozoic strata faulted steeply against steep rounded hills of Precambrian units along the north-northeast-trending Laramide-aged Montosa fault. Pennsylvanian units form tightly folded monoclines against the Montosa fault; beds immediately adjacent to the fault are vertical to overturned, whereas those ~1500 feet (457 m) away from the fault dip less than 10° to the southeast.

Previous geologic maps in the area include Bates et al. (1947) and Myers (1977) maps of the Gran Quivira and Scholle quadrangles, respectively. The current mapping of the Scholle quadrangle was undertaken in conjunction with mapping of the adjoining Becker quadrangle to the west. Principal contributions to the current map include: 1) a revision of the Pennsylvanian units to correspond with lithology, rather than fusulinid biostratigraphy as defined by Myers (1977); 2) differentiation of an additional lower unit in the Permian Abo Formation; 3) refinement of contacts in Paleozoic units; 4) differentiation and correlation of Proterozoic metasedimentary and metavolcanic units with other parts of the Los Pinos-Manzano-Sandia Mountains; 5) delineation of previously unmapped Precambrian structures and refinement of the timing of these structures; 6) refinement of Paleozoic and younger structures and their relative sense of movement; 7) recognition and refined mapping of range-bounding structures; and 8) differentiation of the inset Neogene stratigraphy along the western front of the Manzano Mountains and in the Abo Arroyo drainage system.

**COMMENTS TO MAP USERS**

Mapping of this quadrangle was funded by a matching-funds grant from the 2003-2005 STATEMAP program of the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number 00HQAG0078, to the New Mexico Bureau of Geology and Mineral Resources (Dr. Peter 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 New Mexico Bureau of Geology and Mineral Resources 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 the report and map should not be considered final and complete until it is published by the New Mexico Bureau of Geology and Mineral Resources.***

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.

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.

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

For this map, Cenozoic deposits, mapped by Sean Connell, were mapped at a scale of 1:24,000. These maps were enlarged to a scale of 1:12,000 for transfer on the final map. Pennsylvanian units mapped by Lea Anne Scott and Maya Elrick, as well as Precambrian units mapped by Karl Karlstrom, were mapped at a scale of 1:12,000. Contacts for Paleozoic maps were checked against aerial photographs at a scale of 1:24,000, enlarged, and transferred to the 1:12,000-scale map for compilation.

## LOCATION AND ACCESSIBLITY

The Scholle 7.5-minute U.S. Geological Survey quadrangle encompasses an area of 158 $km^2$ (61 $mi^2$) at the southern end of the Manzano Mountains in central New Mexico. The adjoining Becker quadrangle, which was mapped in conjunction with the Scholle quadrangle, contains Abo Pass and the Los Pinos Mountains. The topographic base used in this mapping was published by the U.S.G.S. in 1995 at a scale of 1:24,000.

US Highway 60 runs approximately east-west through the center of the quadrangle. Land in the northern half of the quadrangle is largely contained within the Cibola National Forest and Casa Colorado Grant. The only public road extending north from Hwy 60 is Forest Service road 422, known as the “Priest Canyon” road, which continues north into the adjoining Manzano Peak quadrangle. Much of the land immediately south of Hwy 60 is privately owned, with minor portions contained on BLM lands; accessibility is by several dirt county roads. A major railroad single-track line runs east-west through the center of the map area, as well two major natural gas pipelines, which run northwest-southeast through the southern half of the quadrangle.

The largest parcel of privately owned land is encompassed within the Dripping Springs Ranch, which covers land immediately north and south of Hwy 60 from just east of the western boundary of the map area to where the railroad tracks cross Hwy 60, a distance of almost 3 miles.

## PRINCIPAL GEOLOGIC AND PHYSIOGRAPHIC FEATURES

The geology of the Scholle quadrangle is dominated by gently dipping (<10°) Pennsylvanian-Permian deposits (limestones and sandstones) cropping out as flat to low-lying benches and mesas within the central and eastern portions. Along the western edge of the quadrangle, vertical to locally overturned ridges of Pennsylvanian limestones are faulted against steep, more rounded hills of Precambrian rocks along the north-northeast-trending Montosa fault.

There, the Pennsylvanian Sandia Formation and Madera Group form tightly folded monoclines against the Montosa fault; beds immediately adjacent to the fault are vertical to overturned, while those ~1500 feet (457 m) away from the fault dip <10° to the east. These vertical beds of limestone form a persistent set of ridges that trends north-northeast along the western edge of the map area. Associated with this laterally extensive fault are abundant northwest-west trending faults; although most offsets along these faults are too small to appear at this map scale, the fault locations are included on the current map.

Gently dipping beds of Upper Pennsylvanian limestone and Permian limestone and sandstone form extensive dip-slopes east of the Montosa fault, with unit contacts often present just a few feet beneath the land surface. Small changes in topography (<5 feet) superimposed on these gentle dip slopes allow small islands and ridges of overlying units to be exposed at the surface; this trend forms a somewhat unusual map pattern composed of fingers and circles of the younger unit surrounding by large swaths of the older unit. These surfaces, in turn are often covered by <1 ft of Quaternary-aged colluvium. A prominent feature in the landscape is a long, fairly continuous northeast trending mesa with 300 + feet of relief composed of red sandstones of the Permian Abo Formation.

Precambrian units outcrop exclusively in the northwest portion of the quadrangle and consist of a ~1.43 Ga granitic pluton (Priest Canyon Pluton) and its aureole rocks that include ~ 1.66 Ga schist, rhyolite, and quartzite. These rocks have complex deformational fabrics that are interpreted to result deformations ~ 1.65 Ga and ~ 1.43 Ga.

Quaternary deposits include valley floor and piedmont slope alluvium, including significant deposits of inset and stranded, isolated terrace gravels of metamorphic clasts, originating from the Manzano Mountains to the north. Major drainages in the map area include Abo Arroyo and Priest Canyon.

## PREVIOUS WORK

The first geologic map of the area was published in 1947 by Bates et al. and included the Scholle 7.5-minute quadrangle area in the northwest portion of a larger map of the Gran Quivira quadrangle. This early map contains essentially the same map units and outcrop patterns as the Myers (1977) map of the Scholle quadrangle. Meyer's (1977) map, however, contains much more detail. The Abo Pass area is also the type section for the Permian Abo Formation (Lee, and Girty, 1909; Needham and Bates, 1943).

## PRINCIPAL CONTRIBUTIONS TO THE MAP

Paleozoic strata in the map area were mapped by Lea Anne Scott and Maya Elrick; Sean Connell was responsible for mapping Quaternary units, and Karl Karlstrom mapped the Precambrian units. The adjoining Becker quadrangle to the west was mapped in conjunction with the Scholle quadrangle.

Two revisions to the Paleozoic stratigraphy established by Myers (1977) were undertaken in the current mapping effort and mapped on both the Scholle and adjoining Becker quadrangles. 1) The Pennsylvanian units within the Wild Cow Formation of the Madera Group were subdivided and mapped as 5 different informal units (IPm-1 through IPm-5; Figures 1 & 3). These informal units were measured and described in a total of 5 locations, 3 of which are located on the Scholle quadrangle and 2 of which are located on the adjoining Becker quadrangle to the west. Lines of measured section are indicated on maps for both quadrangles. Informal units are based on outcrop patterns of laterally persistent, mappable cliff-forming (dominated by

limestone) and slope-forming (dominated by fine marine and nonmarine? siliciclastics) intervals. The comparison of these informal units with those defined earlier by Myers (1977) and Myers et al. (1981) are shown in Figure 1. Meyer's members were used only when readily identified in the field; those members defined by fusulinid foraminifera biostratigraphy were not utilized. Recently, Kues (2001) suggested that the Wild Cow Formation is essentially the same unit as the Atrasado Formation recognized to the west across the Rio Grande Rift (~80 km) in the Lucero Mesa region, and recommended changing the name to reflect this similarity. Similarly, the Los Moyos Limestone is equivalent to the Gray Mesa Formation (see detailed description below). For our mapping purposes, we did not assign any formal nomenclature to the Pennsylvanian units, but rather mapped out large-scale patterns in lithology (cliff versus slope intervals). 2) An informal unit in the basal Abo Formation was mapped separately based on a difference in grain size, sedimentary structures, color, and outcrop pattern (Figure 2). This unit is not regionally extensive, as it much thinner on the adjoining Becker quadrangle to the west, and does not extend across the Rio Grande Rift to the Lucero Mesa Area (~80 km; Lucas and Ziegler, 2004).

Unfortunately, access to a large portion of land (Dripping Springs Ranch) containing key contacts and outcrop exposures was denied; therefore, contacts in these areas were mapped by aerial photography. Where possible, contacts in this area from Myers (1977) map were field checked and used as well. The majority of the contacts of Permian units presented by Myers (1977) were refined in the field, but remain essentially the same as previously mapped. The contacts between the Permian Abo Formation and the Permian Mesa Blanca and the Torres Members of the Yeso Formation were taken directly from Myers (1977) and compared to aerial photographs and field checked for accuracy.

Faults splaying off the main Montosa fault were mapped by Steve Haden several years ago and are incorporated into the map along the Montosa fault; these faults were field checked for location accuracy. Quaternary units described and mapped in the current map provide significantly more detail than those mapped by Myers (1977).

Precambrian units and structures were remapped, resulting in new insights into the regional stratigraphy and the tectonic evolution of the region. 1) Paleoproterozoic rocks of the Scholle and adjacent Becker quadrangles were previously mapped as a west-dipping homoclinal section with Sais Quartzite at the base and Sevilleta Rhyolite at the top (Myers, 1977; Myers et al., 1981). However, new mapping and identification of younging indicators (i.e. cross bedding, graded bedding), suggest that the stratigraphic order is actually reversed, with the Sevilleta Rhyolite near the base and the Sais and Blue Ridge Formations near the top of the section. 2) The rocks were folded into a tight to isoclinal regional-scale synclinorium cored by schist and rhyolite of the Blue Springs Formation. The axial plane of this syncline strikes NE in the adjoining Becker quadrangle, is folded into an F3 anticline near the boundary between the two quadrangles, and is truncated by the Priest pluton in the Scholle quadrangle. The resulting complex interference patterns are delineated by interlayered quartzite and schist units and fold overprinting; cross cutting foliations are portrayed by structural symbols in the new mapping. 3) The nature of tectonism associated with emplacement of the Priest pluton is better understood. In the Scholle quadrangle, portions of the southern contact with the pluton dip ~ 30º southward. Thus, Paleoproterozoic units of the Scholle quadrangle are in the roof of the pluton, and the strong development of fabric and metamorphic isograds in the northwestern Scholle and northeastern Becker quadrangles reflect thermal influences from the pluton. An increase in the intensity of S3 towards the pluton contact, as well as porhyroblast-matrix relationships, suggest that the pluton was emplaced synchronously with S3 shortening.

## STRATIGRAPHY

All map units are described at the end of the report. The age and stratigraphic relationships of these map units are summarized in the Correlation of Map Units.

### Quaternary and Pliocene Alluvial Deposits

Cenozoic alluvial deposits of the Manzano Peak 7.5-minute quadrangle contain variable proportions of gravel, sand and silt, deposited by intermittent and ephemeral streams; mass-movement deposits typically occur on hill slopes. These deposits were laid down by local streams during late Cenozoic times, probably starting from late Pliocene(?) through modern times. Map-unit differentiation is based on stratigraphic position (inset or depositional relations), surface morphology, degree of soil-profile development (see Gile et al., 1981) and sedimentary character. Deposits are a mixture of poorly sorted, poorly to moderately stratified, clast- and matrix-supported alluvium, having predominantly gravelly to sandy textures; silt-clay textures are locally common. Clast constituents typically reflect bedrock composition of local upland drainage systems associated with the western flank of the Manzano Mountains. Alluvial deposits are generally thin (<4 m), but locally range up to 20 m in thickness and unconformably overlie older rocks. Alluvial deposits are divided into three major classes: 1) valley-fill alluvium, 2) piedmont-slope alluvium, and 3) mass-movement deposits. Older deposits along the eastern slopes of the Manzano Mountains (unit QTp) were deposited as broad alluvial fans before the area became deeply entrenched. Younger deposits are progressively inset into incised drainages formed along the eastern dip-slope of the Manzano and Los Pinos Mountains. Many of the dip-slopes of upper Paleozoic rocks, especially those of the Permian Bursum Formation, contain thin veneers of locally derived alluvium, colluvium, and eolian sediments.

### Paleozoic Rocks

The Pennsylvanian strata exposed within the quadrangle include the siliciclastic Sandia Formation, mixed carbonates and siliciclastics of the Pennsylvanian Madera Group and the Permian Bursum Formation, and siliciclastics of the Permian Abo and Yeso Formations (Figures 1-3). The Pennsylvanian Madera Group was deposited within shallow seaways that formed in the basins of the Ancestral Rocky Mountains and for this mapping effort, was mapped as a series of cliff- and slope-formers. The overlying Permian Bursum Formation is interpreted to represent deposition in both marine and fluvial environments, while the overlying Permian Abo and Yeso Formations represent deposition in an entirely continental setting, including fluvial and rare lacustrine environments. The lower portion of the Abo unit mapped may represent a fluvial environment that was not laterally extensive, given that the unit thins to the west and north.

### Regional patterns in Los Moyos Limestone of the Madera Group

According to Myers (1977), unit IPm-1 (the Los Moyos Limestone of the Madera Group) is Desmoinesian in age. Kues (2001) recommends revising this name to the Gray Mesa Formation due to similarities in lithology and age to exposures of the Gray Mesa Formation. On such exposure is located approximately 80 km directly west across the Rio Grande Rift, where the Gray Mesa Formation (Mesa Sarca; Scott and Elrick, 2004) is well-exposed in the Lucero uplift area. In the Lucero uplift area, the Gray Mesa Formation is significantly thicker (~290 m at Mesa Sarca versus ~170 m in Scholle quadrangle) and is characterized by five mappable

slope- to limestone cliff-forming units (or sequences; ~20-80 m) representing deposition during distinct transgressive-regressive intervals. Transgressive-regressive sequences were not recognized within the Scholle quadrangle. However, several key similarities were observed in both units: 1) chert is abundant, as isolated pods, as a pervasive, interlocking network overprinting the host rock, and as silicified fossils, 2) fossil abundance and diversity are similar, 3) coarse-grained siliciclastic sandstone deposits are generally lacking in both locales, and 4) laterally persistent diagenetic features including diagenetic mottling and laminar black calcretes are present on many bed tops.

**Regional stratigraphy of Proterozoic Rocks**

Proterozoic rocks in the Scholle and adjoining Becker quadrangles consist of ductiley deformed and metamorphosed volcanic, sedimentary and plutonic rocks. Our interpretation is that these rocks formed in volcanic arcs and related arc basins along the growing southern periphery of cratonic North America ca. 1.67-1.65 Ga (Karlstrom et al., 2004). Due to the polyphase deformational history, construction of a coherent stratigraphy has been controversial and handled differently by different authors. Based on new mapping in the Manzano Peak, Scholle, and Becker quadrangles, there is an emerging regionally coherent stratigraphy that involves a lower metavolcanic suite (mafic and felsic rocks) overlain by a sedimentary succession of massive quartzites, overlain by schists and an upper rhyolite.

The stratigraphy is most completely exposed in the adjoining Manzano Peak and Becker quadrangles to the north and west, respectively; only the youngest 6 units are exposed in the Scholle quadrangle. The Sevilleta metarhyolite (Xsr), dated as 1662 +- 1 Ma (Shastri, 1993), is interpreted to be the oldest unit of the area based on stratigraphic relationships. In many areas, metarhyolite is interfingered with mafic units of the metavolcanic package including amphibolites (metabasalt and metagabbro) and mafic schists; these are interpreted as part of the "greenstone" packages mapped elsewhere in the Manzano and Los Pinos Mountains (Bauer, 1993). The overlying metasedimentary succession is a complex sequence of phyllite and metamorphosed metalithic arenite. Near the base of the sedimentary succession are lenticular outcrops of dacitic breccia that resemble the Lacorocah metadacite of Parchman (1980). The lithic arenite succession is compositionally variable, containing pelitic layers that with garnet and staurolite schist. All of these rocks are intensely interlayered with amphibolites, which have variable textures ranging from coarse-grained, resembling gabbroic sills and dikes, to fine-grained and vesicular, suggesting formation as eruptive units. Myers et al (1981) referred to this striped map pattern of amphibolite within lithic arenite as the "mixed flow" unit. The arenites grade upward into cleaner metasediments of the White Ridge Quartzite and related Sais Quartzite units, which are separated by the Estadio Schist, a pelitic schist that outcrops in Estadio Canyon in the Manzano Peak quadrangle to the north.

The remaining units in the regional stratigraphy, including the Sais Quartzite, are exposed in the Scholle quadrangle. The Sais Quartzite is overlain by the Blue Springs Quartzite, Blue Springs Schist, Blue Springs Rhyolite, and upper Blue Springs Schist. The Blue Springs metarhyolite is a banded metarhyolite defined by mm-10's cm scale compositional bands.

Metasedimentary rocks are intruded by two different plutons in the region. The Los Pinos granite of the adjoining Becker quadrangle appears to truncate S2 foliation in units present there and yields a U-Pb zircon age of 1655 +-3. Similarly, the strongly deformed Monte Largo quartz monzonite that intrudes the Blue Springs package in the NW corner of the Manzano Peak quadrangle to the north yields a U-Pb zircon date of 1656+/-10 Ma (Bauer et al., 1993). In the

Scholle quadrangle, the Priest Pluton intrudes the Blue Springs Formation in the northwest part of the quadrangle. This pluton yields a U-Pb zircon date of 1443 +/- 10 Ma (Thompson et al. 1996). An extensive metamorphic contact aureole is mapped at the margin of the Priest Pluton with concentric isograds extending away from the pluton (Thompson et al. 1996).

## STRUCTURAL GEOLOGY

Folds, faults and shear zones in the Scholle and adjoining Becker quadrangles exhibit several styles of deformation related to different periods of tectonic activity since the Proterozoic. This section discusses some of the recent refinements to the structural geology of the study area beginning with the oldest deformation and ending with the youngest deformation.

Evidence suggests three generations of deformation (Baer, 2004). The first phase of deformation (D1) involved west- directed thrusting, as indicated by field and thin section observations of an early foliation (S1), which is generally subparallel to bedding or associated with minor nappe folds (Karlstrom et al. 2001). The second phase of deformation (D2) involved upright folding and establishment of the main NE-trending cleavage observed. F2 folds refold F1 folds, and in the adjoining Becker quadrangle trend to the northeast and have shallow plunge. A large F2 synclinorium present in the western part of the Scholle quadrangle and the eastern part of the adjoining Becker quadrangle is named the Manzano Peak synclinorium (Baer, 2004). Preserved cross bedding in the quartzite units and bedding-cleavage relationships suggest the syncline is upright. The syncline is refolded in the Scholle quadrangle and truncated at the southern margin of the Priest pluton, indicating the fold developed before the pluton was emplaced. Its axial plane dips steeply to the west throughout the Becker quadrangle. The third phase of deformation (D3) is interpreted as pluton-related shortening based on porphyroblast-matrix studies using contact minerals, as well as the intensification of S3 fabrics with increasing proximity to the pluton. F3 folds fold, kink, or deflect the main S2 schistosity.

The Montosa reverse fault and associated monocline is well exposed in the northwestern Scholle and eastern Becker quadrangles. This structure is of presumed Laramide age based on its similarity to structures along the front ranges of Rocky Mountain uplifts. Essentially flat lying Paleozoic sedimentary rocks of the Great Plains to the east are folded into a monoclinal flexure with a steep to overturned limb that parallels the fault. The amount of throw on the fault/monocline is estimated to be 1000 meters based on restorable cross section, but significant right lateral strike slip on the fault was also likely.

The Manzano normal fault is the rift–bounding fault that forms the western margin of the Manzano Mountains. The fault itself is concealed by thin Neogene deposits, but a throw of roughly 1500 meters is estimated based on restorable cross sections. Paleozoic and Mesozoic strata are inferred to form a “bench” on the downthrown side, based on projecting outcrops and structural styles northwards (and down) into the line of cross section from the Los Pinos Mountains to the south (Myers et al., 1986). Normal slip on the Manzano fault decreases southwards from the Manzano Mountains (Manzano Peak and Scholle quadrangles) to the Los Pinos Mountains (Becker quadrangle).

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## SCHOLLE QUADRANGLE
## DESCRIPTION OF MAP UNITS

### CENOZOIC ERATHEM

*Tributary stream-valley alluvium*

Tributary stream-valley alluvium graded to modern and former levels of Abo Arroyo, but is derived from mountain-front drainages of the Los Pinos and southern Manzano Mountains. Stream-terrace deposits typically have an elongate planform shape and are associated with major tributaries to the Rio Grande. Gravels reflect upland drainage composition and are dominated by reddish-brown sandstone.

**Qa** Stream alluvium, undivided (upper Holocene to historic) — Light-brown (7.5YR 6/4), poorly to moderately sorted, poorly consolidated pebble- to cobble conglomerate and fine-to coarse-grained sand with local accumulations of cobbles and small boulders. Soils are nonexistent to very weakly developed. Deposit underlies narrow to broad streams that are inset against broad valley floors. Deposits are correlative to unit Qaa of Abo Arroyo. Deposit thickness ranges from <1 m to about 4 m.

**Qay** Stream alluvium, undivided (uppermost Pleistocene to Holocene) — Poorly to moderately sorted, poorly consolidated light-brown and light reddish-brown to gray-brown pebble and cobble conglomerate and sand with minor accumulations of boulders. Forms broad valley floors that are inset by stream alluvium of unit **Qa**. Deposits draining limestone and granitic terrains north of Abo Arroyo contain pale-brown to very pale-brown (10YR 6/3-7/3) pebbly sand and gravel. Deposit surface sits about 1-2 m above local base level and contains weakly developed soils with Stage I pedogenic carbonate morphology. Locally overlies moderately to well developed calcic soils (Stage III pedogenic carbonate morphology) formed on older alluvium. Unit on east side of Manzano Mountains consists of light-brown (7.5YR 6/4), poorly consolidated, poorly exposed, poorly sorted pebbly to cobbly sand and gravel. Forms lowest deposit under valley floors. Commonly buries older alluvium upstream, but inset against unit **Qam** towards Abo Arroyo. Contains undifferentiated deposits of unit Qa in active stream bottoms. Correlative to unit **Qaay** of Abo Arroyo. Two terraces are locally differentiated based on inset relationships and relative height. Thickness ranges from <1 m to 4 m.

- **Qayy** Stream alluvium, younger subunit (Holocene) — Unit is inset against older Qayo and sits less than 3 m above local base level.
- **Qayo** Stream alluvium, younger subunit (Holocene to uppermost Pleistocene) — Unit is inset by younger alluvium of unit Qayy and sits about 3-4 m above local base level.

**Qpm** Stream-valley alluvium, intermediate deposits (middle to late Pleistocene) — Light-brown to brown (7.5YR 6/4-5/4), poorly sorted, moderately consolidated, pebbly to cobbly sand and gravel. Soils are moderately developed and locally exhibit Stage II+ to locally weak Stage III pedogenic carbonate morphology. Deposits are inset by younger stream alluvium of unit Qay downstream, but are commonly buried by younger alluvium upstream. Deposits sit about 6-12 m above local base level. Deposits are locally divided

into three units based on inset relationships in the Priest Canyon (and Cañon Arado) drainages. Deposit thickness ranges from 0 to 5 m.

**Qpm1** Older subunit (middle Pleistocene) — Inset against older alluvium of unit Qpo and inset by younger subunits of Qpm2 and younger stream alluvium of unit Qay.

**Qpm2** Intermediate subunit (middle Pleistocene) — Inset against unit Qpm1.

**Qpm3** Younger subunit (middle to late(?) Pleistocene) — Inset against unit Qpm2.

**Qpo** Stream-valley alluvium, older deposits (middle Pleistocene) — Pinkish-gray (7.5YR 6/3) pebble to cobble gravel. Inset against oldest alluvium of unit QTp and sits about 6-15 m above local base level. Deposit is about 6-7 m thick.

*Alluvium of Abo Arroyo*

Fluvial and alluvial deposits derived from the ancestral and modern Abo Arroyo. Deposits unconformably overlie upper Paleozoic limestone and sandstone and interfinger with local stream alluvium derived from the eastern slopes of the Los Pinos and southern Manzano Mountains.

**Qaa** Abo Arroyo stream terrace, active (upper Holocene to historic) — Brown to reddish-brown (5-75YR 5/4) to light-brown (7.5YR 6/4), poorly consolidated, poorly exposed, pebble to cobble gravel. Deposit exhibits no soil-profile development. Underlies active drainage of Abo Arroyo. Thickness of deposit is generally less than 2-3 m.

**Qaay** Abo Arroyo stream terrace, lower deposit (Holocene to upper Pleistocene) — Light-brown (7.5YR 6/4), poorly consolidated, poorly exposed, pebble to cobble gravel. Deposit exhibits little to no soil-profile development with disseminated calcium-carbonate cement. Deposit surface forms broad valley floor of Abo Arroyo and major tributaries. Thickness of deposit ranges from 0 to 10 m.

**Qaam** Abo Arroyo stream terrace, intermediate deposit (upper Pleistocene) — Light-brown (7.5YR 6/4), poorly consolidated, poorly exposed, pebble to cobble gravel. Deposit surface is about 6 m above the valley floor of Abo Arroyo. Deposit about 3 m thick.

**Qaao** Abo Arroyo stream terrace, older deposit (middle Pleistocene) — Light-brown (7.5YR 6/4) pebbly sand and gravel. Dominated by subrounded cobbles (up to 20 cm diameter; mostly < 4cm) of reddish-brown sandstone with minor limestone schist and quartzite. Lower 3 m is well cemented. Surface contains remnants of well developed calcic soils and thick calcium-carbonate rinds on gravel. Soil development is likely at least Stage III pedogenic carbonate morphology. Deposit surface is nearly 25 m above the valley floor of Abo Arroyo. Deposit is about 10 m thick.

*Piedmont-slope alluvium*

Alluvium associated with non-incised valleys. Typically recognized as alluvial fans that grade to high-level surfaces and are not integrated with Abo Arroyo. Gravels reflect upland drainage composition.

**Qpy** Piedmont alluvium, younger deposits (upper Pleistocene to Holocene) — Light-brown to brown (7.5YR 5/4-6/4), weakly consolidated, poorly sorted, pebbly to cobbly sand and gravel. Deposits delineated along the western front of the southern Manzano Mountains. Deposits commonly contain matrix-supported gravelly sand with local clast-supported gravel lenses. Soils are generally poorly developed and exhibit Stage I pedogenic carbonate morphology. Deposits are at least 2 m thick.

**QTp** Piedmont alluvium, older deposits (upper Pliocene(?) to lower Pleistocene) — Pink (5YR 7/4) pebble gravel with scattered (<4 m diameter) of reddish-brown sandstone (Abo Fm) boulders. Moderately developed soils exhibiting Stage III+ pedogenic carbonate morphology. Clasts commonly engulfed with 1-8 mm thick carbonate rinds. Clast coatings locally form pisolitic structures, but no laminar carbonate layers. Ridge-crests commonly rounded and forms remnants of formerly widespread constructional surface that has been incised by younger valley fill deposits. Inset against older ridge-capping gravels exposed in adjacent Manzano Peak quadrangle (Karlstrom et al., 2003). Delineated in Priest Canyon on eastern slope of Manzano Mountains. Deposit range from about 4-60 m thick.

*Artificial Fill and Mass-movement deposits*

Surficial deposits are the name given to a group of generally thin sediments associated with mass movement and eolian processes. This category also includes sand and gravel deposited by mountain-front streams that are not integrated with entrenched tributary drainages to Abo Arroyo.

**af** Artificial fill (historic) — Dumped fill and areas effected by human disturbances. Mapped where deposits are areally extensive.

**Qls** Landslide deposits (upper to middle Pleistocene) — Poorly to well consolidated and very poorly sorted, sand, breccia. Formed by mass-movement, commonly along steep hill slopes. Arrows indicate direction of movement.

**Qca** Colluvium and alluvium, undivided (Holocene to upper Pleistocene) — Brown (7.5YR-10YR 5/3), poorly consolidated and poorly sorted, loose, fine- to coarse-grained silty sand with scattered pebbles and sparse cobbles. Soil development ranges from weakly to moderately developed and locally exhibits Stage II+ pedogenic carbonate morphology. Unit is of variable thickness, ranging from less than 30 cm to about 1 m thick and commonly mantles cuestas underlain by Pennsylvanian and Permian rocks.

## PALEOZOIC ERATHEM

**Pyt** Yeso Formation, Torres Member (Lower Permian or Leonardian) — Base of member mapped at base of gypsum. Poorly exposed gypsum with interbedded limestone lenses. Gypsum is bedded and weathers very light gray. Limestone lenses are up to 5 feet (1.5

m) thick and weather light-olive gray. Lower 100 feet (~30 m) exposed in southeast part of quadrangle; upper beds and contact not present in quadrangle.

**Pym** Yeso Formation, Mesa Blanca Sandstone Member (Lower Permian or Leonardian) — Gradational basal contact with underlying Abo Formation is mapped at change in topography from cliff forming Abo Formation to gentle slopes and undulating terrain of Yeso Formation. Basal sandstone is massive; overlying beds composed of thin-bedded, fine-grained sandstone (arenite to wacke) and siltstone. Weathers white and light orange-tan. Trace fossils observed on bedding surfaces along with ripple marks and cross bedding. Associated soil is orange to pink. Approximately 250 feet (76 m) thick.

**Pa** Abo Formation (Lower Permian or Leonardian and Wolfcampian) — Base of unit mapped the first bench of fine-grained siliciclastics overlying the coarser lower Abo Formation (Pla). Overall finer-grained than lower part of Abo Formation (Pal), and composed of thin – to thick-bedded micaceous siltstone and fine-grained sandstone. Upper portion contains sandstone and occasional granule conglomerate interbedded with siltstones and mudstones. Weathers light red and pale reddish brown, with local white and green oxidation/reduction spots. Cross laminae, ripple-marks, mudcracks and interbedded paleosols observed. Fossil plant debris and some bioturbation present. Uppermost 20-30 feet (6-9 m) interbedded with light orange-tan sandstones similar to those in the Yeso Formation. Approximately 800 ft (243 m) thick.

**Pal** Abo Formation, lower units (Lower Permian or Leonardian and Wolfcampian) — Base of unit mapped at top of last laterally extensive marine limestone of underlying Bursum Formation; disconformably overlies underlying Bursum Formation. Unit is coarser grained and darker in color than the upper portion of the Abo Formation (Pa) and weathers dark purple to dark reddish brown and is coated by abundant desert varnish. Contains poorly sorted medium- to coarse-grained, cross-bedded, thick-bedded sandstones (arkosic wacke to wacke) to granule conglomerates. May contain calcite cement. Sandstone beds are more laterally continuous than those of underlying Bursum Formation; basal sandstone may contain 10 cm limestone clasts. May contain thin (~1m) clast-supported limestone-sandstone pebble conglomerate bed 5-10 m above basal contact. Thin lenses (average <10 cm; up to 1 m thick;) of unfossiliferous, partially dolomitized, laminated limestone beds (non-marine?) at base. Thin interbeds of laminated, micaceous siltstone to fine sandstone present. Copper mineralization and calcite cement present. Unit is present throughout quadrangle, is present, but thinner in the adjoining Becker quadrangle, but is not regionally extensive, as it does not occur in the Lucero uplift region, ~80 km across the Rio Grande Rift (Lucas and Ziegler, 2004). Thickness less than 125 feet (38 m).

**Pb** Madera Group, Bursum Formation (Lower Permian) — Base of unit mapped as last appearance of well-exposed cherty limestone from uppermost IPm-5, which is typically overlain by <5 m of cover followed by 1-2 m thick coarse-grained reddish arkosic sandstone with irregular bottom contact. In northern quarter of quadrangle, basal sandstone is replaced by gray-white crinoid packstone. Limestone beds overlying this basal sandstone (skeletal wackestone-lime mudstones) are thin (< 2m) and contain

fusulinids *Triticites creekensis* Thompson and *Leptrotriticites* sp. (Myers, 1977), finely abraded or large, intact gastropods, ramose bryozoa, crinoids, and bivalves, and rare small chert nodules (<2 cm). Middle portion of unit composed of interbedded fine-to coarse-grained cross-bedded sandstone (lithic to arkosic wacke and arkose), which may contain calcite cement, occasional granule-pebble conglomerate, red mud-shale, and micaceous siltstone; thickness of sandstone beds varies laterally. Top of unit composed of well- to poorly-exposed < 16 feet (5 m) thick light gray, thin bedded, nodular, fossiliferous limestone bed (skeletal wackestone) that contains small (1 mm thick) stringers of red sandstone, bivalves, crinoids, fenestrae, and fusulinids (*Scwagerina pinosensis* Thompson) sp. (Myers, 1977). Sandstone weathers reddish-brown to purplish-brown; limestone weathers olive-gray; shale and siltstone weather red. May be covered by thin (<1 ft) of Qca. About 250 feet (76 m) thick.

**IPm5-IPm1** Madera Group, informal map units within the Wild Cow Formation and Los Moyos Limestone (Lower Permian, Upper and Middle Pennsylvanian) — Informal map units within the Wild Cow Formation and Los Moyos Limestones as previously mapped by Myers (1977). Units broken out into three intervals that contain cliff-forming limestone (IPm-5, IPm-3, and IPm-1) interbedded with two slope-forming siliciclastic-dominated intervals (IPm-4 and IPm-2). Contains fusulinids of Virgilian, Missourian, and Desmoinesian ages (Myers, 1977).

**IPm5** Madera Group, middle and upper part of La Casa Member of the Wild Cow Formation (Upper Pennsylvanian -Virgilian) — Base of unit mapped at base of first cliff-forming limestone overlying slope-forming IPm-4. Cliff- and slope-forming interval composed of three distinctive, mappable, thick (~3-8 m) limestone cliffs separated by ~10-25 m-thick slope-forming intervals. Lower limestone cliff (~4 m) composed of thick-bedded limestone (skeletal wackestone) with laterally continuous dark chert band at base (<10 cm thick) and capped by meter-scale cross-bedded limestone or cross-bedded, laterally discontinuous sandstone. Middle limestone (~3 m; skeletal wackestone) contains irregular –shaped dark chert nodules in upper 2 meters. Upper limestone (~8 m; skeletal wackestone) contains large irregular-shaped light gray chert nodules. Upper 10's of meters of unit composed of recessed, 1-m thick limestone beds containing abundant dark brown chert nodules that weather light tan. Limestones contain phylloid algae, bivalves, crinoids, brachiopods, and abundant bioturbation. Slope-forming intervals composed of interbedded green and purple micaceous siltstone, sandstone, and mudstone. *Triticites creekensis* Thompson? fusulinids present (Myers, 1977). May be covered by thin veneer (<1 ft) of Qca where unit crops out on gentle slopes. Approximately 250 feet (76 m) thick.

**IPm4** Madera Group, Pine Shadow Member and lower La Casa Member of the Wild Cow Formation) (Upper Pennsylvanian – Virgilian) — Base of unit mapped at the top of the last limestone cliff in underlying IPm-3. Slope-former (poorly exposed) composed of interbedded sandstone, siltstone, and mudstone with occasional laterally discontinuous limestone beds. A thick sandstone interval (10's m thick) is present just north of gas pipeline road in middle of quadrangle and southern part of quadrangle. Mud-siltstones contain ripple laminations and soft sediment deformation. Plant debris and cross-bedding

observed in some sandstone beds. Base of unit marked by distinctive thin (<1 m) orange dolomite bed overlain by white sandstone (quartz arenite). Approximately 560 ft (170 m) thick. Thickness varies laterally within map area by 9 m and is thinner to north (Myers, 1977).

**IPm3** Madera Group, upper part of Sol se Mete Member of the Wild Cow Formation (Upper Pennsylvanian – Missourian) — Base of unit mapped at base of first limestone cliff overlying covered interval in lower portion of Sol se Mete Member (IPm-2). Thin- to thick-bedded cliff-forming limestone (wackestone through grainstone) containing three persistent, mappable cliffs: 1) lower limestone that contains dark chert bands (0.5 m long, <20 cm thick), 2) middle limestone interbedded with orange-weathering silty limestone and sparse chert bands, and 3) thick-bedded upper limestone with distinctive orange-brown mottling in upper 2 meters. Fossils include gastropods, bryozoan, rugose corals, phylloid algae, brachiopods, and abundant bioturbation. Approximately 65 ft thick (20 m).

**IPm2** Madera Group, lower portion of Sol se Mete Member of the Wild Cow Formation (Upper Pennsylvanian – Missourian) — Base of unit mapped as top of last limestone bed in underlying Los Moyos Limestone. Slope-former (poorly exposed) interpreted to be fine-grained siliciclastic deposits (siltstone) interbedded with limestone beds (mudstone through grainstone) with marl interbeds, rip-up clasts, and plane laminations, and laterally discontinuous white and green sandstones with local granules (subarkose) (1-2 m thick). About 100 ft thick (30 m).

**IPm1** Madera Group, Los Moyos Limestone (Middle Pennsylvanian – Desmoinesian) — Basal contact with underlying Sandia Formation placed at the base of the first limestone bed. Medium- to thick-bedded, cliff-forming limestones (lime mudstones through skeletal wackestones and grainstones). Individual limestone beds 1- 2 m thick. Contains dark chert in small pods (<5 cm) in lower 40 meters, middle 20 meters, and in uppermost limestone bed. Minor amounts of interbedded sandstone (quartz arenite through micaceous lithic wacke), quartz and feldspar granule conglomerate, and poorly exposed siltstones and mudshales. Fossils include bivalves, bryozoa, crinoids, fusulinids, chaetetids, and abundant bioturbation obscuring primary sedimentary structures. Weathers medium gray. About 560 ft thick (172 m).

**IPs** Sandia Formation (Middle Pennsylvanian - Desmoinesian) — Interbedded sandy, fossiliferous limestones, shales, siltstones, sandstones, and conglomerates. Fossil types include marine fossils and plant debris. Limestone in upper part weathers light- to medium-gray with dark brown chert. Basal beds are quartz-pebble conglomerates with angular pink feldspar grains. Lower contact is fault contact with Precambrian rocks. About 600 feet (183 m) thick.

## PROTEROZOIC ERATHEM

**Ypp** Priest Pluton Granite — Gray to pink, megacrystic to coarse-grained biotite + quartz + feldspar ± epidote granite with cm- scale microcline phenocrysts. Slightly foliated at the pluton margins and in discrete shear zones within the pluton, but overall exhibits little to no tectonic foliation. Variably-developed alignment of megacrysts is interpreted as magmatic flow foliation. U-Pb zircon ages on the pluton yield a ca. 1.43 Ga emplacement age (Bauer et al., 1993).

**Xbsu** Blue Springs Schist, upper schist — green to white, chlorite + muscovite schist. The apparent uppermost unit of the Manzano Peak (F2) synclinorium, found west of the Priest pluton (Ypp) in the western region of the quadrangle. Equivalent to the Metaclastics Series pCm of Myers and McKay (1972).

**Xbr** Blue Springs Schist, rhyolite — Black and brown to gray, with lenticular quartz-feldspar pink colored stripes within darker layers. Interpreted as a metarhyolite due to the presence of potassium feldspar in the felsic lenses and a geochemical composition close to rhyolite. Contains numerous folds, some of which may be reminiscent of a rhyolitic flow folds; others are clearly F1 folds that are refolded by later generations of deformation. Equivalent to the part of pCa, the argillite of Myers and McKay (1972), named the Blue Springs Quartzite (bq1) by Bauer (1983).

**Xbs** Blue Springs Schist — Green to white, garnet + chlorite + quartz + muscovite schist. Just west of the synclinorium, this unit is highly kinked with well preserved garnet. Near the Priest pluton sericite nodules are common and probably formed during retrograde metamorphism after emplacement of the pluton. Equivalent to the part of pCa, the argillite of Myers and McKay (1972) and the Sais Quartzite (sq3) of Bauer (1983)

**Xbq** Blue Springs Schist, Quartzite Member — Thinly-bedded, medium-grained quartzites, interbedded with chlorite-muscovite schist and quartz-muscovite schist. Partly equivalent to Sais Formation and lower part of the Pine Shadow Springs of Myers and McKay (1972); mapped as Blue Springs Formation (bs1) by Bauer (1983).

**Xsq** Sais Quartzite — Thinly-bedded, reddish, schistose quartzite. Bedding planes commonly show mica concentrations. Grain size ranges from very fine to coarse sand. Primary structures include preserved cross-bedding. Originally called the White Ridge and Sais quartzites of Myers and McKay (1972), called the White Ridge Quartzite 2 (wq2) of Bauer (1983).

Geologic Map of the Scholle 7.5 quadrangle explanation of symbols


Location of geologic cross section

Geologic contact, dashed where approximately located or gradational, dotted where concealed by younger deposits.

Fault trace, dashed where approximately located, dotted where concealed, queried where uncertain or continuity uncertain. Barb on upthrown side of Laramide reverse fault; bar and ball on downthrown side of Miocene normal fault.

Overturned anticline-trace of axial plane showing direction of plunge

Overturned syncline-trace of axial plane showing direction of plunge; dashed where approximately located


Strike and dip of bedding and overturned bedding.

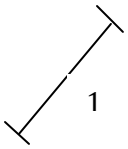
Cross bedding, truncated foresets represent top

Trace of axial plane of anticline, syncline showing plunge direction, dashed where approximately located.


Sl compositional layering in metasediments arrow represents F1 minor fold axis

S2 schistosity and crenulation cleavage, arrow represents F2 minor fold axis

S3 crenulation cleavage, and shear bands




Line of measured section

## FIGURE CAPTIONS

**Figure 1:** Generalized stratigraphic column of informal units within Pennsylvanian-aged strata as mapped in the Scholle quadrangle. Previous units mapped by Myers (1977) indicated.

**Figure 2:** Outcrop photographs of map units. A) Upper (Pau) and lower (Pal) subdivisions in the Abo Formation. Lower portion of Abo Formation contains coarser sandstones that outcrop dark purple-brown; whereas, upper portion of Abo Formation is finer-grained and weathers red. Photograph taken just east of Forest Service Road 422, looking east. B) Upper two Pennsylvanian-aged units, IPm5, which contains three distinctive limestone cliffs and IPm4, a slope former. View is towards southwest in Priest Canyon looking towards Los Pinos Mountains on adjoining Becker quadrangle. C) Precambrian units in fault contact along the Montosa fault (solid black line) with Pennsylvanian-aged Sandia Formation (IPms) and Los Moyos Limestone (IPm1). Pennsylvanian units are tightly folded and are vertical to overturned adjacent to fault; overlying beds (IPm 4 and 5) are gently dipping to east at < 10°. View is from just north of Highway 60, looking north towards Manzano Peak, on adjoining Manzano Peak quadrangle.

**Figure 3:** Detailed stratigraphic column of informal units within Pennsylvanian-aged strata as mapped in the Scholle quadrangle.