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National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Salinas Pueblo Missions National Monument

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Salinas Pueblo Missions National Monument

sapu_geology.pdf

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Geologic Resources Inventory Map Document for Salinas Pueblo Missions National Monument

Table of Contents

Geologic Resources Inventory Map Document 1
About the NPS Geologic Resources Inventory Program 2
GRI Digital Maps and Source Map Citations 4
Map Unit List 5
Map Unit Descriptions 7
Qaf - Artificial fill (Recent) 7
Qaa - Abo Arroyo steam terrace, active (upper Holocene to Recent) 7
Qa - Stream alluvium, undivided (upper Holocene to Recent) 7
Qayy - Stream alluvium, younger subunit (Holocene) 8
Qay - Stream alluvium, undivided (uppermost Pleistocene to Holocene) 8
Qaay - Abo Arroyo stream terrace, lower deposit (upper Peistocene to Holocene) 8
Qpy - Piedmont alluvium, younger deposits (upper Peistocene to Holocene) 8
Qayo - Stream alluvium, younger subunit (uppermost Pleistocene to Holocene) 9
Qae - Stream alluvium and eolian sand (late Pleistocene to late Holocene) 9
Qaam - Abo Arroyo stream terrace, intermediate deposit (upper Pleistocene) 9
Qgm - Gravel derived from Manzano Mountains sources (Pleistocene) 9
Qgc - Gravel derived from Chupadera Mesa sources (Pleistocene) 10
Qls - Landslide deposits (Pleistocene) 10
Qca - Colluvium and alluvium, undivided (middle to upper Pleistocene) 10
Qpm - Stream-valley alluvium, intermediate deposits (middle to late Pleistocene) 11
Qpm3 - Stream-valley alluvium, younger subunit (middle to late(?) Pleistocene) 11
Qpm2 - Stream-valley alluvium, Intermediate subunit (middle Pleistocene) 11
Qpm1 - Stream-valley alluvium, older subunit (middle Pleistocene) 11
Qpo - Stream-valley alluvium, older deposits (middle Pleistocene) 11
Qaao - Abo Arroyo stream terrace, older deposit (middle Pleistocene) 12
QTp - Piedmont alluvium, older deposits (upper Pliocene (?) to lower Pleistocene) 12
Tid - Diorite in intrusive bodies (Tertiary) 12
Tim - Mafic dike rocks (Tertiary) 12
Ts - Gravel (Tertiary) 13
Psa - San Andres Formation (Lower Permian) 13
Pg - Glorieta Sandstone (Lower Permian) 13
Pgy - Yeso Group, Glorieta Sandstone (Lower Permian, Leonardian) 14
Pyl - Yeso Group, Los Vallos Formation (Lower Permian (Leonardian)) 14
Pya - Yeso Group, Arroyo de Alamillo Formation (Lower Permian (Leonardian)) 14
Pu - Arroyo de Alamillo and Abo Formations, undifferentiated (Lower Permian (Leonardian and Wolfcampion)) 15
Pa - Abo Formation (Lower Permian (Leonardian and Wolfcampion)) 16
Pal - Abo Formation, lower units (Lower Permian (Leonardian and Wolfcampion)) 16
Pab - Abo and Bursum Formations (Lower Permian, Leonardian and Wolfcampion) 17
Pym - Yeso Formation, Mesa Blanca Member (Lower Permian (Leonardian))_2 17
Pyt - Yeso Formation, Torres Member (Lower Permian (Leonardian)) 17
Pb - Madera Group, Bursum Formation (Lower Permian) 17
PNu - Pennsylvanian stratigraphic units, undifferentiated (Pennsylvanian) 18
PNm5 - Madera Group, Wild Cow Formation, middle and upper part of La Casa Member (upper Pennsylvanian (Virgilian))_2 18

PNm4 - Madera Group, Wild Cow Formation, Pine Shadow Member and lower La Casa Member (upper Pennsylvanian (Virgilian)) 19
PNm3 - Madera Group, Wild Cow Formation, upper part of Solse Mete Member (upper Pennsylvanian (Missourian)) 19
PNm2 - Madera Group, Wild Cow Formation, lower portion of Solse Mete Member (upper Pennsylvanian (Missourian)) 19
PNm1 - Madera Group, Los Moyos Limestone (middle Pennsylvanian (Desmoinesian)) 19
PNs - Sandia Formation (middle Pennsylvanian (Desmoinesian)) 20
PCu - Precambrian rocks, undifferentiated (Precambrian) 20
Xbsu - Blue Springs Schist, upper schist (Proterozoic) 20
Xbr - Blue Springs Schist, rhyolite (Proterozoic) 20
Xbs - Blue Springs Schist (Proterozoic) 21
Xbq - Blue Springs Schist, Quartzite Member (Proterozoic) 21
Xes - Estadio Schist, marker unit (Proterozoic) 21
Xsq - Sais Quartzite (Proterozoic) 21
Xwq - White Ridge Quartzite (Proterozoic) 21
Ypp - Priest Pluton Granite (Proterozoic) 22
Geologic Cross Sections 23
Gran Quivera Quadrangle Cross Section A - A' 23
Punta De Agua Cross Section A - A' 23
Abo Quadrangle Cross Section A - A' 24
Scholle Quadrangle Cross Section A - A' 24
GRI Source Map Information 25
Preliminary Geologic Map of the Gran Quivira 7.5' Quadrangle 25
Correlation Of Map Units 25
Schematic Cross Section 26
Map Legend 27
Report 27
References 30
Preliminary Geologic Map of the Punta de Agua 7.5' Quadrangle 31
Correlation of Map Units 31
Table of Strike and Dip Measurements 32
Map Legend 33
Report 33
References 36
Preliminary Geologic Map of the Abo 7.5' Quadrangle 37
Correlation of Map Units 38
Table of Strike and Dip Measurements 39
Table of Rounded Quartzite Gravel Locations 39
Report 39
References 42
Preliminary Geologic Map of the Scholle 7.5' Quadrangle 43
Scholle Grouped Unit Descriptions 43
Tributary stream-valley alluvium 43
Alluvium of Abo Arroyo 43
Piedmont-slope alluvium 44
Artificial Fill and Mass-movement deposits 44
Map Legend 44
Report 45
Location Map 52
References 52
GRI Digital Data Credits 55

Geologic Resources Inventory Map Document

Salinas Pueblo Missions National Monument, New Mexico

Document to Accompany Digital Geologic-GIS Data

sapu_geology.pdf

Version: 8/16/2013

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Salinas Pueblo Missions National Monument, New Mexico (SAPU).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

For information about the status of GRI digital geologic-GIS data for a park contact:

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://irma.nps.gov/App/Reference/Search. To find GRI data for a specific park or parks select the appropriate park

(s), enter “GRI” as a Search Text term, and then select the Search Button.

For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

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The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division.

GRI Digital Maps and Source Map Citations

The GRI digital geologic-GIS maps for Salinas Pueblo Missions National Monument, New Mexico (SAPU):

GRI Digital Geologic Map of Salinas Pueblo Missions National Monument (*GRI MapCode SAPU)*

Oviatt, Charles G., 2012, Preliminary Geologic Map of the Gran Quivira 7.5' Quadrangle, Torrance and Socorro Counties, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-file Digital Geologic Map OF-GM 248, 1:24000 scale (Gran Quivira Quadrangle). (GRI Source Map ID 75649)

Oviatt, Charles G., 2011, Preliminary Geologic Map of the Punta de Agua 7.5' Quadrangle, Torrance County, New Mexico., New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 220, 1:24000 scale (Punta de Agua Quadrangle). (GRI Source Map ID 75584)

Oviatt, Charles G., 2010, Preliminary Geologic Map of the 7.5' Abo Quadrangle, Torrance County, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 199, 1:24000 scale (Abo Quadrangle). (GRI Source Map ID 75448)

Scott, L.A., Elrick, M., Connell, S., and Karlstrom, K., 2005, Preliminary Geologic Map of the Scholle 7.5' Quadrangle, Valencia, Torrance, and Socorro Counties, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 99, 1:24000 scale (Scholle Quadrangle). (GRI Source Map ID 7463)

Additional information pertaining to each source map is also presented in the GRI Source Map Information (SAPUMAP) table included with the GRI geology-GIS data.

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Salinas Pueblo Missions National Monument, New Mexico (SAPU) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qaf - Artificial fill). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (SAPUUNIT) table included with the GRI geology-GIS data.

Cenozoic Era

Quaternary Period

Qaf - Artificial fill
Qaa - Abo Arroyo stream terrace, active
Qa - Stream alluvium, undivided
Qayy - Stream alluvium, younger subunit
Qay - Stream alluvium, undivided
Qaay - Abo Arroyo stream terrace, lower deposit
Qpy - Piedmont alluvium, younger deposits
Qayo - Stream alluvium, younger subunit
Qae - Stream alluvium and eolian sand
Qaam - Abo Arroyo stream terrace, intermediate deposit
Qgm - Gravel derived from Manzano Mountains sources
Qgc - Gravel derived from Chupadera Mesa sources
Qls - Landslide deposits
Qca - Colluvium and alluvium, undivided
Qpm - Stream-valley alluvium, intermediate deposits
Qpm3 - Stream-valley alluvium, younger subunit
Qpm2 - Stream-valley alluvium, Intermediate subunit
Qpm1 - Stream-valley alluvium, older subunit
Qpo - Stream-valley alluvium, older deposits
Qaao - Abo Arroyo stream terrace, older deposit
QTp - Piedmont alluvium, older deposits

Tertiary Period

Tid - Diorite in intrusive bodies
Tim - Mafic dike rocks
Ts - Gravel

Paleozoic Era

Permian Period

Psa - San Andres Formation
Pg - Glorieta Sandstone
Pgy - Yeso Group, Glorieta Sandstone
Pyl - Yeso Group, Los Vallos Formation
Pya - Yeso Group, Arroyo de Alamillo Formation
Pu - Arroyo de Alamillo and Abo Formations, undifferentiated

Pa - Abo Formation
Pal - Abo Formation, lower units
Pab - Abo and Bursum Formations
Pym - Yeso Formation, Mesa Blanca Member
Pyt - Yeso Formation, Torres Member
Pb - Madera Group, Bursum Formation

Carboniferous Period

PNu - Pennsylvanian stratigraphic units, undifferentiated
PNm5 - Madera Group, Wild Cow Formation, middle and upper part of La Casa Member
PNm4 - Madera Group, Wild Cow Formation, Pine Shadow Member and lower La Casa Member
PNm3 - Madera Group, Wild Cow Formation, upper part of Sol se Mete Member
PNm2 - Madera Group, Wild Cow Formation, lower portion of Sol se Mete Member
PNm1 - Madera Group, Los Moyos Limestone
PNs - Sandia Formation

Precambrian Era

PCu - Precambrian rocks, undifferentiated

Proterozoic Period

Xbsu - Blue Springs Schist, upper schist
Xbr - Blue Springs Schist, rhyolite
Xbs - Blue Springs Schist
Xbq - Blue Springs Schist, Quartzite Member
Xes - Estadio Schist, marker unit
Xsq - Sais Quartzite
Xwq - White Ridge Quartzite
Ypp - Priest Pluton Granite

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

Qaf - Artificial fill (Recent)

af - Artificial fill (historic)
Dumped fill and areas effected by human disturbances. Mapped where deposits are really extensive.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Artificial Fill and Mass-movement deposits group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qaa - Abo Arroyo steam terrace, active (upper Holocene to Recent)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Alluvium of Abo Arroyo group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qa - Stream alluvium, undivided (upper Holocene to Recent)

Qa - Stream alluvium (late Holocene to late Pleistocene)
Poorly sorted, sandy to gravelly alluvium along valley bottoms; includes deposits underlying low stream terraces along some of the major drainages. Most Qa sediments are reddish in color. Thickness is less than 30 ft (10 m) in most places. (*GRI Source Map ID 75584)* (Punta de Agua Quadrangle, OF-GM 220).

Qa - Stream alluvium (late Holocene to late Pleistocene)
Poorly sorted, sandy to gravelly alluvium along valley bottoms; includes deposits underlying low stream terraces along some of the major drainages. Most Qa sediments are reddish in color, except in some of the terraces along Cañon Latigo and nearby valleys where some sandy alluvium is pale yellow to white because of a significant component of fine-grained calcium carbonate and/or gypsum. Thickness is less than 30 ft (10 m) in most places. (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Tributary stream-valley alluvium group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qayy - Stream alluvium, younger subunit (Holocene)

Qayy - Stream alluvium, younger subunit (Holocene)
Unit is inset against older Qayo and sits less than 3 m above local base level.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Tributary stream-valley alluvium group. (GRI Source Map ID *7463*) (Scholle Quadrangle, OF-GM 99).

Qay - Stream alluvium, undivided (uppermost Pleistocene to Holocene)

Qay - Stream alluvium, undivided (uppermost Pleistocene to Holocene)
Poorly to moderately sorted, poorly consolidated light-brown and light reddish-brown to graybrown 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 palebrown (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. 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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Tributary stream-valley alluvium group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qaay - Abo Arroyo stream terrace, lower deposit (upper Peistocene to Holocene)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Alluvium of Abo Arroyo group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qpy - Piedmont alluvium, younger deposits (upper Peistocene to Holocene)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Piedmont-

slope alluvium group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qayo - Stream alluvium, younger subunit (uppermost Pleistocene to Holocene)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Tributary stream-valley alluvium group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qae - Stream alluvium and eolian sand (late Pleistocene to late Holocene)

Qae - Stream alluvium and eolian sand (late Holocene to late Pleistocene)
Poorly sorted, sandy to gravelly alluvium on valley bottoms, and eolian sand and silt in small dunes and mixed with alluvium and colluvium. Eolian deposits are present throughout the quadrangle, and these deposits, plus alluvium and colluvium, effectively cover the bedrock everywhere. Eolian sand in poorly developed longitudinal dunes appears on aerial photographs and satellite images as long streaks, having a southwest to northeast trend, but the longitudinal dunes are difficult to detect on the ground. Thickness is less than 30 ft (10 m). (*GRI Source Map ID 75649)* (Gran Quivira Quadrangle, OF-GM 248).

Qaam - Abo Arroyo stream terrace, intermediate deposit (upper Pleistocene)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Alluvium of Abo Arroyo group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qgm - Gravel derived from Manzano Mountains sources (Pleistocene)

Qgm - Gravel derived from Manzano Mountains sources (Pleistocene)
Poorly sorted alluvial gravel, including clasts ranging in size from small pebbles to large boulders. Clasts include metamorphic crystalline rocks (Precambrian gneiss, schist, quartzite) exposed in the Manzano Mountains to the west, and sedimentary rocks of Pennsylvanian and Early Permian age (limestone eroded from Pennsylvanian formations and from the Permian Bursum Formation; sandstone from the Permian Abo Formation). Broad surfaces capped by Qgm slope to the east and southeast and overlie rocks of the Abo Formation and Yeso Group. The surfaces mapped as Qgm have a wind-blown silt (loess) cap that may be a meter or more thick. Thickness of Qgm is less than 30 ft (10 m) in most places. (*GRI Source Map ID 75584)* (Punta de Agua Quadrangle, OF-GM 220).

Qgm - Gravel derived from Manzano Mountains sources (Pleistocene)
Poorly sorted alluvial gravel, including clasts ranging in size from small pebbles to large boulders. Clasts include metamorphic crystalline rocks (Precambrian gneiss, schist, quartzite) exposed in the Manzano Mountains to the northwest, and sedimentary rocks of Pennsylvanian and Early Permian age (limestone

eroded from Pennsylvanian formations and from the Permian Bursum Formation; sandstone from the Permian Abo Formation). Thick deposits (up to 30 ft; 10 m) of Qgm cap hills and low mesas north of Abo Arroyo. Broad surfaces capped by Qgm generally slope to the south, overlie rocks of the Los Vallos Formation, and are mapped as Qgm/Pyl. Some surfaces mapped as Qgm/Pyl have a wind-blown silt (loess) cap that may be a meter or more thick. Thickness of Qgm is less than 30 ft (10 m) in most places. (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

Qgc - Gravel derived from Chupadera Mesa sources (Pleistocene)

Qgc - Gravel derived from Chupadera Mesa sources (Pleistocene)
Poorly sorted alluvial gravel, including clasts ranging in size from small pebbles to large boulders. Clasts include limestone (San Andres) and sandstone (Glorieta) derived from Chupadera Mesa to the south and east. Qgc caps broad, flat-topped surfaces that slope generally to the northwest. Qgc that covers a large area of the Los Vallos Formation south of Abo Arroyo is mapped Qgc/Pyl, and locally may be capped by wind-blown silt (loess) that may be a meter or more thick. Thickness of Qgc is less than 30 ft (10 m) in most places. Note, this unit appears on both Abo Quadrangle, OF-GM 199 (*GRI Source Map ID 75448)* and Scholle Quadrangle, OF-GM 99 (*GRI Source Map ID 7463)* .

No description for this unit is available with OF-GM 99. Through communication with the New Mexico Geological Survey it was determined that the description from OF-GM 199 is sufficient for both maps.

Qls - Landslide deposits (Pleistocene)

Qls - Landslide deposits (Pleistocene)
Highly fractured bedrock and masses of jumbled, coarse angular gravel and boulders of limestone (San Andres) and sandstone (Glorieta). Landslide masses form cone-shaped hills at the base of the steep slopes of Chupadera Mesa in the eastern part of the quadrangle. Thickness up to 160 ft (50 m) in some places. (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Artificial Fill and Mass-movement deposits group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qca - Colluvium and alluvium, undivided (middle to upper Pleistocene)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Artificial Fill and Mass-movement deposits group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qpm - Stream-valley alluvium, intermediate deposits (middle to late Pleistocene)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Tributary stream-valley alluvium group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qpm3 - Stream-valley alluvium, younger subunit (middle to late(?) Pleistocene)

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

This unit appears in the Scholle Quandrangle source map information. It can be found in the Tributary stream-valley alluvium group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qpm2 - Stream-valley alluvium, Intermediate subunit (middle Pleistocene)

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

This unit appears in the Scholle Quandrangle source map information. It can be found in the Tributary stream-valley alluvium group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qpm1 - Stream-valley alluvium, older subunit (middle Pleistocene)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Tributary stream-valley alluvium group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qpo - Stream-valley alluvium, older deposits (middle Pleistocene)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Tributary stream-valley alluvium group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Qaao - Abo Arroyo stream terrace, older deposit (middle Pleistocene)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Alluvium of Abo Arroyo group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

QTp - Piedmont alluvium, older deposits (upper Pliocene (?) to lower Pleistocene)

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.

This unit appears in the Scholle Quandrangle source map information. It can be found in the Piedmont-slope alluvium group. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Tid - Diorite in intrusive bodies (Tertiary)

Ti - Diorite in intrusive bodies (Tertiary)
Fine- to medium-grained diorite in poorly exposed dikes at the south boundary of the quadrangle, and in a large, poorly exposed intrusive body in the southwestern quarter of the quadrangle, which could be a dike or a sill (or both). The diorite intrudes the Los Vallos Formation, and in places is overlain by Quaternary gravel derived from Chupadera Mesa sources (Qgc). These dikes are Oligocene in age, and are part of the Magdalena radial dike swarm described by Chamberlin et al. (2009). Thickness not determined. (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

Tim - Mafic dike rocks (Tertiary)

Ti - Mafic dike rocks (Tertiary)
Fine- to medium-grained basaltic andesite in poorly exposed dikes and sills that have intruded limestone and gypsum of the Permian Yeso Group and San Andres Formation. These dikes are Oligocene in age,

and are part of the Magdalena radial dike swarm described by Chamberlin et al. (2009). Because the dikes intrude the Permian rocks and are poorly exposed, they are mapped on the Gran Quivira quadrangle with the San Andres Formation using the symbol Psa/Ti. Small exposures of Ti are marked on the geologic map with an X symbol. Thickness not determined. (*GRI Source Map ID 75649)* (Gran Quivira Quadrangle, OF-GM 248).

Ti - Diorite in intrusive bodies (Tertiary)
Fine- to medium-grained diorite in poorly exposed dikes at the south boundary of the quadrangle, and in a large, poorly exposed intrusive body in the southwestern quarter of the quadrangle, which could be a dike or a sill (or both). The diorite intrudes the Los Vallos Formation, and in places is overlain by Quaternary gravel derived from Chupadera Mesa sources (Qgc). These dikes are Oligocene in age, and are part of the Magdalena radial dike swarm described by Chamberlin et al. (2009). Thickness not determined. (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

Ts - Gravel (Tertiary)

Ts - Gravel (Tertiary)
Coarse-grained gravel, including well-rounded pebbles, cobbles, and boulders of rocks exotic to the Gran Quivira quadrangle; clast lithology includes: quartzite, chert, quartz, fine-grained volcanic rocks, and red, ripple-laminated sandstone similar to that from the Abo Formation. None of these rock types is presently exposed in the Gran Quivira quadrangle; the closest potential sources for most of the rocks is west of Chupadera Mesa, in the vicinity of Abo Pass and the Manzano and/or Los Pinos Mountains. Pebbles of these rock types are mixed with Quaternary deposits in low-lying areas in the northern 1/3 of the quadrangle. Thickness not determined. (*GRI Source Map ID 75649)* (Gran Quivira Quadrangle, OF-GM 248).

Psa - San Andres Formation (Lower Permian)

Psa - San Andres Formation (Lower Permian or Leonardian)
Gray marine limestone and interbedded gypsum. Thickness greater than 200 ft (60 m); neither the top nor the base of the formation is exposed in the Gran Quivira quadrangle. (*GRI Source Map ID 75649)* (Gran Quivira Quadrangle, OF-GM 248).

Psa - San Andres Formation (Lower Permian or Leonardian)
Gray marine limestone and interbedded sandstone and gypsum. Limestone of the San Andres forms the caprock of Chupadera Mesa. Thickness greater than 200 ft (60 m); the top of the formation is not exposed in the Abo quadrangle. (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

Pg - Glorieta Sandstone (Lower Permian)

Pg - Glorieta Sandstone (Lower Permian or Leonardian)
Pale yellow to reddish brown medium-grained sandstone, exposed on the steep flanks of Chupadera Mesa. Thickness about 170 ft (50 m). (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

Pgy - Yeso Group, Glorieta Sandstone (Lower Permian, Leonardian)

Pgy - Glorieta Sandstone and Yeso Group (Lower Permian or Leonardian)
Sandstone, mudstone, gypsum, dolomite, limestone; Yeso Group consists of the Los Vallos and Arroyo de Alamillo Formations (Lucas et al., 2005). Thickness about 1100 ft (330) m. (*GRI Source Map ID 75649)* (Gran Quivira Quadrangle, OF-GM 248).

Pyl - Yeso Group, Los Vallos Formation (Lower Permian (Leonardian))

Pyl - Los Vallos Formation, Yeso Group (Lower Permian or Leonardian)
Reddish sandstone and mudstone, gray dolomite and limestone, and gypsum. The basal contact of Pyl is marked by a widespread 2-m thick gray dolomite or limestone unit, which is locally well exposed in the southwestern quarter of the Punta de Agua quadrangle. Members of the Los Vallos Formation, the Torres, Cañas, and Joyita Members (Lucas et al., 2005), are not discriminated on the Punta de Agua quadrangle because the contacts are poorly exposed. Thickness about 750 ft (230) m. Some areas mapped as Permian bedrock (Pyl, Pya, Pa, Pu) include small areas of Quaternary alluvium (Qa) and/or Quaternary gravel (Qgm). (*GRI Source Map ID 75584)* (Punta de Agua Quadrangle, OF-GM 220).

Pyl - Los Vallos Formation, Yeso Group (Lower Permian or Leonardian)
Reddish sandstone and mudstone, gray dolomite and limestone, and gypsum. The basal contact of Pyl is marked by a widespread 2-m thick gray dolomite or limestone unit, which is locally well exposed in the northwestern quarter of the Abo quadrangle. Members of the Los Vallos Formation, the Torres, Cañas, and Joyita Members (Lucas et al., 2005), are not discriminated on the Abo quadrangle because the contacts are poorly exposed. Thickness about 750 ft (230) m. (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

Pyl - Los Vallos Formation, Yeso Group (Lower Permian or Leonardian)
Reddish sandstone and mudstone, gray dolomite and limestone, and gypsum. The basal contact of Pyl is marked by a widespread 2-m thick gray dolomite or limestone unit, which is locally well exposed in the northwestern quarter of the Abo quadrangle. Members of the Los Vallos Formation, the Torres, Cañas, and Joyita Members (Lucas et al., 2005), are not discriminated on the Abo quadrangle because the contacts are poorly exposed. Thickness about 750 ft (230) m. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Pya - Yeso Group, Arroyo de Alamillo Formation (Lower Permian (Leonardian))

Pya - Arroyo de Alamillo Formation, Yeso Group (Lower Permian or Leonardian)
Dominated by orange to reddish sandstone and minor mudstone; includes some yellowish to pinkish white sandstones near the top of the unit. The Arroyo de Alamillo Formation was previously mapped in this area as the Meseta Blanca Formation (Myers, 1977), but has been redefined and renamed by Lucas et al. (2005). A good description of the contrast between sandstones of the Arroyo de Alamillo Formation and those of the Abo Formation is given by Lueth et al. (2009, p. 89): “The differences between the Abo and the [Arroyo de Alamillo] are obvious. The orange color of the [Arroyo de Alamillo] contrasts sharply with the red Abo. The [Arroyo de Alamillo] contains a larger percentage of sandstone than the Abo, and [Arroyo de Alamillo] sandstones are slightly coarser-grained and have a greater lateral uniformity of thickness. Abo sandstones have basal stratigraphic relief and fill scours, whereas [Arroyo de Alamillo] sandstones have constructional, dune-shaped relief on upper bedding surfaces. Planar laminations and small-scale cross laminations are abundant in the [Arroyo de Alamillo]. Many bedding surfaces are rippled, and some bear tracks and trails. Interference ripples are common. A shallow marine to beach environment is suggested for the [Arroyo de Alamillo].” Thickness about 210 ft (60 m). Some areas

mapped as Permian bedrock (Pyl, Pya, Pa, Pu) include small areas of Quaternary alluvium (Qa) and/or Quaternary gravel (Qgm). (*GRI Source Map ID 75584)* (Punta de Agua Quadrangle, OF-GM 220).

Pya - Arroyo de Alamillo Formation, Yeso Group (Lower Permian or Leonardian)
Dominated by orange to reddish sandstone and minor mudstone; includes some yellowish to pinkish white sandstones near the top of the unit. The Arroyo de Alamillo Formation was previously mapped in this area as the Meseta Blanca Formation (Myers, 1977), but has been redefined and renamed by Lucas et al. (2005). A good description of the contrast between sandstones of the Arroyo de Alamillo Formation and those of the Abo Formation is given by Lueth et al. (2009, p. 89): "The differences between the Abo and the [Arroyo de Alamillo] are obvious. The orange color of the [Arroyo de Alamillo] contrasts sharply with the red Abo. The [Arroyo de Alamillo] contains a larger percentage of sandstone than the Abo, and [Arroyo de Alamillo] sandstones are slightly coarser-grained and have a greater lateral uniformity of thickness. Abo sandstones have basal stratigraphic relief and fill scours, whereas [Arroyo de Alamillo] sandstones have constructional, dune-shaped relief on upper bedding surfaces. Planar laminations and small-scale cross laminations are abundant in the [Arroyo de Alamillo]. Many bedding surfaces are rippled, and some bear tracks and trails. Interference ripples are common. A shallow marine to beach environment is suggested for the [Arroyo de Alamillo]." Thickness about 210 ft (60 m). (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

Pya - Arroyo de Alamillo Formation, Yeso Group (Lower Permian or Leonardian)
Dominated by orange to reddish sandstone and minor mudstone; includes some yellowish to pinkish white sandstones near the top of the unit. The Arroyo de Alamillo Formation was previously mapped in this area as the Meseta Blanca Formation (Myers, 1977), but has been redefined and renamed by Lucas et al. (2005). A good description of the contrast between sandstones of the Arroyo de Alamillo Formation and those of the Abo Formation is given by Lueth et al. (2009, p. 89): "The differences between the Abo and the [Arroyo de Alamillo] are obvious. The orange color of the [Arroyo de Alamillo] contrasts sharply with the red Abo. The [Arroyo de Alamillo] contains a larger percentage of sandstone than the Abo, and [Arroyo de Alamillo] sandstones are slightly coarser-grained and have a greater lateral uniformity of thickness. Abo sandstones have basal stratigraphic relief and fill scours, whereas [Arroyo de Alamillo] sandstones have constructional, dune-shaped relief on upper bedding surfaces. Planar laminations and small-scale cross laminations are abundant in the [Arroyo de Alamillo]. Many bedding surfaces are rippled, and some bear tracks and trails. Interference ripples are common. A shallow marine to beach environment is suggested for the [Arroyo de Alamillo]." Thickness about 210 ft (60 m). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Pu - Arroyo de Alamillo and Abo Formations, undifferentiated (Lower Permian (Leonardian and Wolfcampion))

Pu - Arroyo de Alamillo and Abo Formations, undifferentiated (Lower Permian or Wolfcampian)
Red sandstones of the two formations where they cannot be separated easily on the ground, including in areas where exposures are not good, and in steep-walled canyons where the units cannot be easily separated at a scale of 1:24,000. Some areas mapped as Permian bedrock (Pyl, Pya, Pa, Pu) include small areas of Quaternary alluvium (Qa) and/or Quaternary gravel (Qgm). (*GRI Source Map ID 75584)* (Punta de Agua Quadrangle, OF-GM 220).

Pa - Abo Formation (Lower Permian (Leonardian and Wolfcampion))

Pa - Abo Formation (Lower Permian or Wolfcampian)
Red sandstone and mudstone; the upper member (Cañon de Espinoso Member of Lucas et al., 2005) is mudstone dominated, but contains sheet-like sandstone bodies that are ripple- and climbing-ripple laminated. White reduction spots, 1-3 cm in diameter, which are almost perfectly circular in cross section, are abundant in some of the red sandstone beds of the Abo. The Cañon de Espinoso Member is exposed in the Punta de Agua quadrangle. Thickness about 1000 ft (300 m) (Lucas et al., 2005). Some areas mapped as Permian bedrock (Pyl, Pya, Pa, Pu) include small areas of Quaternary alluvium (Qa) and/or Quaternary gravel (Qgm). (*GRI Source Map ID 75584)* (Punta de Agua Quadrangle, OF-GM 220).

Pa - Abo Formation (Lower Permian or Leonardian)
Red sandstone and mudstone; the lower part is dominated by mudstones and sandstones that are conglomeratic and trough cross-bedded (referred to as the Scholle Member by Lucas et al., 2005); the upper member (Cañon de Espinoso Member of Lucas et al., 2005) is also mudstone dominated, but contains sheet-like sandstone bodies that are ripple- and climbing-ripple laminated. White reduction spots, 1-3 cm in diameter, which are almost perfectly circular in cross section, are abundant in some of the red sandstone beds of the Abo. The Cañon de Espinoso Member is exposed in the Abo quadrangle. Thickness about 1000 ft (300 m) (Lucas et al., 2005). (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

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 (Pal). 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. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Pal - Abo Formation, lower units (Lower Permian (Leonardian and Wolfcampion))

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 coarsegrained, 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). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Pab - Abo and Bursum Formations (Lower Permian, Leonardian and Wolfcampion)

Pab - Abo and Bursum Formations (Lower Permian or Leonardian)
Sandstone, mudstone, limestone. Thickness about 1100 ft (330 m). (*GRI Source Map ID 75649)* (Gran Quivira Quadrangle, OF-GM 248).

Pym - Yeso Formation, Mesa Blanca Member (Lower Permian (Leonardian))_2

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 orangetan. 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. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Pyt - Yeso Formation, Torres Member (Lower Permian (Leonardian))

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. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Pb - Madera Group, Bursum Formation (Lower Permian)

Pb - Bursum Formation (Lower Permian or Wolfcampian)
Not exposed in the Punta de Agua quadrangle; shown on the cross section. In the neighboring Scholle quadrangle the Bursum Formation contains limestones and shales (Scott et al., 2005). Thickness about 115 ft (35 m) (Krainer et al., 2009). (*GRI Source Map ID 75584)* (Punta de Agua Quadrangle, OF-GM 220).

Pb - Bursum Formation (Lower Permian or Leonardian)
Not exposed in the Abo quadrangle; shown on the cross section. In the neighboring Scholle quadrangle the Bursum Formation contains limestones and shales (Scott et al., 2005). Thickness about 115 ft (35 m) (Krainer et al., 2009). (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

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. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

PNu - Pennsylvanian stratigraphic units, undifferentiated (Pennsylvanian)

IPu - Pennsylvanian stratigraphic units, undifferentiated (Pennsylvanian)
Limestone, mudstone. Thickness about 2100 ft (650 m). (*GRI Source Map ID 75649)* (Gran Quivira Quadrangle, OF-GM 248).

IPu - Pennsylvanian stratigraphic units, undifferentiated (Pennsylvanian)
Not exposed in the Punta de Agua quadrangle; shown on the cross section. Rocks include limestone, sandstone, siltstone, and mudstone Scott et al. (2005). Total thickness of Pennsylvanian rocks about 2100 ft (650 m). (*GRI Source Map ID 75584)* (Punta de Agua Quadrangle, OF-GM 220).

IPu - Pennsylvanian stratigraphic units, undifferentiated (Pennsylvanian)
Not exposed in the Abo quadrangle; shown on the cross section. Rocks include limestone, sandstone, siltstone, and mudstone Scott et al. (2005). Total thickness of Pennsylvanian rocks about 2100 ft (650 m). (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

PNm5 - Madera Group, Wild Cow Formation, middle and upper part of La Casa Member (upper Pennsylvanian (Virgilian))_2

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. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

PNm4 - Madera Group, Wild Cow Formation, Pine Shadow Member and lower La Casa Member (upper Pennsylvanian (Virgilian))

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). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

PNm3 - Madera Group, Wild Cow Formation, upper part of Sol se Mete Member (upper Pennsylvanian (Missourian))

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). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

PNm2 - Madera Group, Wild Cow Formation, lower portion of Sol se Mete Member (upper Pennsylvanian (Missourian))

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 finegrained 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). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

PNm1 - Madera Group, Los Moyos Limestone (middle Pennsylvanian (Desmoinesian))

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). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

PNs - Sandia Formation (middle Pennsylvanian (Desmoinesian))

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. (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

PCu - Precambrian rocks, undifferentiated (Precambrian)

PC - Precambrian rock units, undifferentiated (Precambrian)
Includes metamorphic rocks, such as quartzite, schist, and gneiss, and igneous rocks, such as granite, in the Manzano and Los Pinos Mountains to the west and northwest (Baer et al., 2003; Scott et al., 2005). (*GRI Source Map ID 75649)* (OF-GM xxx).

PC - Precambrian rock units, undifferentiated (Precambrian)
Not exposed in the Punta de Agua quadrangle; shown on the cross section. Rocks include metamorphic rocks, such as quartzite, schist, and gneiss, and igneous rocks, such as granite (Baer et al., 2003; Scott et al., 2005). (*GRI Source Map ID 75584)* (Punta de Agua Quadrangle, OF-GM 220).

PC - Precambrian rock units, undifferentiated (Precambrian)
Not exposed in the Abo quadrangle; shown on the cross section. Rocks include metamorphic rocks, such as quartzite, schist, and gneiss, and igneous rocks, such as granite (Baer et al., 2003; Scott et al., 2005). (*GRI Source Map ID 75448)* (Abo Quadrangle, OF-GM 199).

Xbsu - Blue Springs Schist, upper schist (Proterozoic)

Xbsu - Blue Springs Schist, upper schist (Precambrian)
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). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Xbr - Blue Springs Schist, rhyolite (Proterozoic)

Xbr - Blue Springs Schist, rhyolite (Precambrian)
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). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Xbs - Blue Springs Schist (Proterozoic)

Xbs - Blue Springs Schist (Precambrian)
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) (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Xbq - Blue Springs Schist, Quartzite Member (Proterozoic)

Xbq - Blue Springs Schist, Quartzite Member (Precambrian)
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). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Xes - Estadio Schist, marker unit (Proterozoic)

Xes - Estadio Schist marker unit (Precambrian)
Staurolite, garnet biotite schist unit forms the main anticline exposed in Estadio Canyon. It is a coarse grained schistose unit. The schist's shows multiple episodes of deformation and contains local crenulation cleavage and at least three generations of foliation. Probably originally deposited as a mudstone layer within the sandstone. Equivalent to the Lower part of the Pine Shadow Springs of Myers and McKay (1974); called the White Ridge schist (ws1) of Bauer (1983). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Xsq - Sais Quartzite (Proterozoic)

Xsq - Sais Quartzite (Precambrian)
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). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Xwq - White Ridge Quartzite (Proterozoic)

Xwq - White Ridge Quartzite (Precambrian)
Course grained impure orange to gray thin-bedded aluminous quartzite. Fairly immature metasedimentary rock with well preserved cross bedding. Cross- bedding indicated that the bedding is overturned. The upper part of the unit has a distinctive andalusite –muscovite (Xwqa) foliated schistose layer. This unit forms the western limb of the Estadio Canyon fold. This may represent the base of a generally fining upward sequence of sediment. Part of the Lower part of the Pine Shadow Springs of

Myers and McKay (1974); called the White Ridge Quartzite 2 (wq2) of Bauer (1983). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

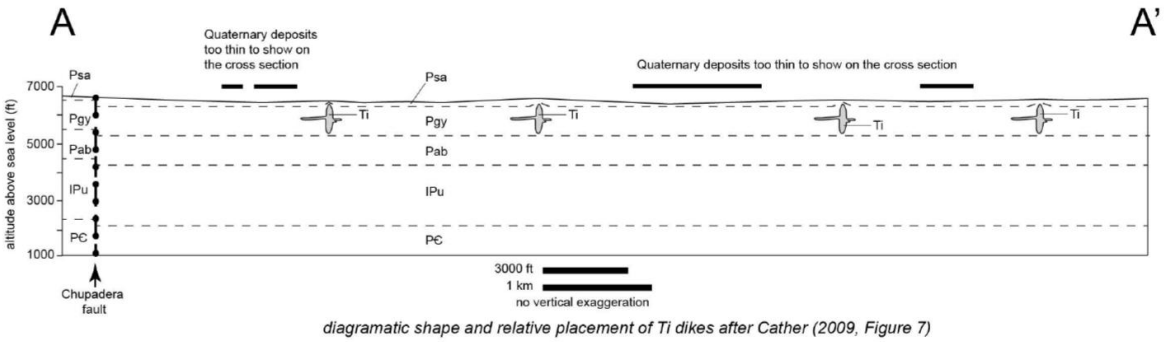
Ypp - Priest Pluton Granite (Proterozoic)

Ypp - Priest Pluton Granite (Precambrian)
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). (*GRI Source Map ID 7463)* (Scholle Quadrangle, OF-GM 99).

Geologic Cross Sections

The geologic cross sections present in the GRI digital geologic-GIS data produced for Salinas Pueblo Missions National Monument, New Mexico (SAPU) are presented below. Note that some cross section abbreviations (e.g., A - A') may have been changed from their source map abbreviation in the GRI data so that each cross section abbreviation in the GRI data is unique. Cross section graphics were scanned at a high resolution and can be viewed in more detail by zooming in (if viewing the digital format of this document).

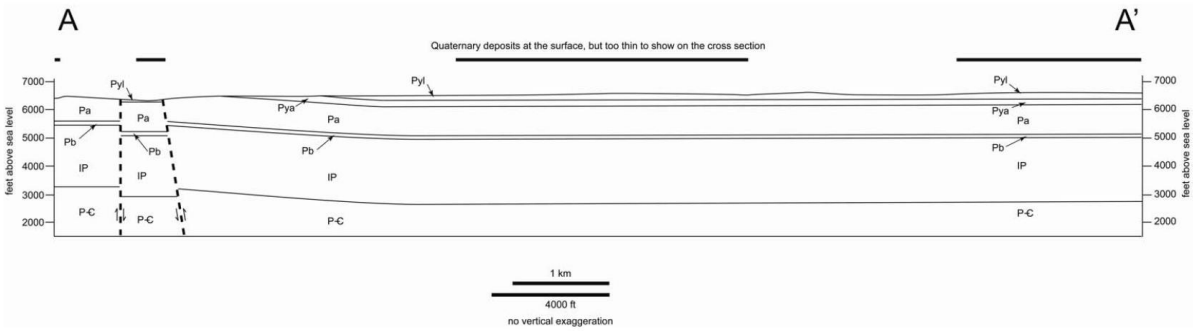
Gran Quivera Quadrangle Cross Section A - A'



diagramatic shape and relative placement of Ti dikes after Cather (2009, Figure 7)

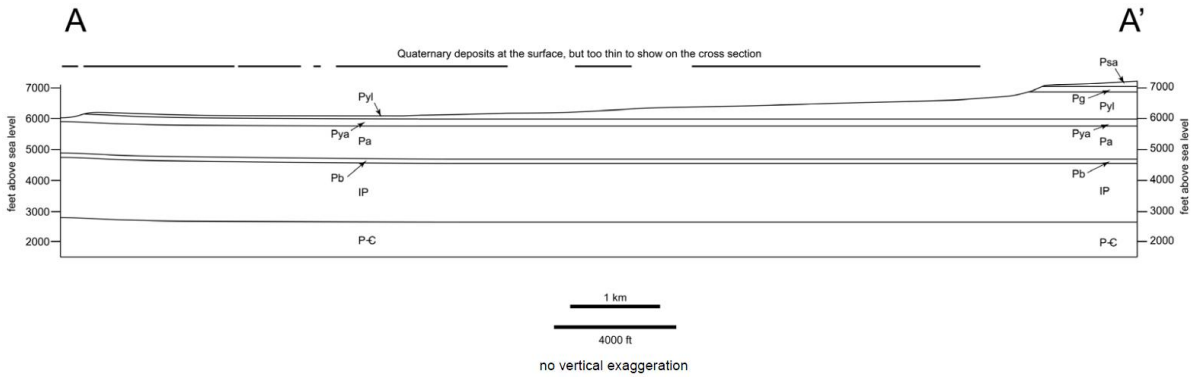
Attributed as section D-D' in GRI data. *Extracted from:* (Gran Quivira Quadrangle, OF-GM 248).

Punta De Agua Cross Section A - A'



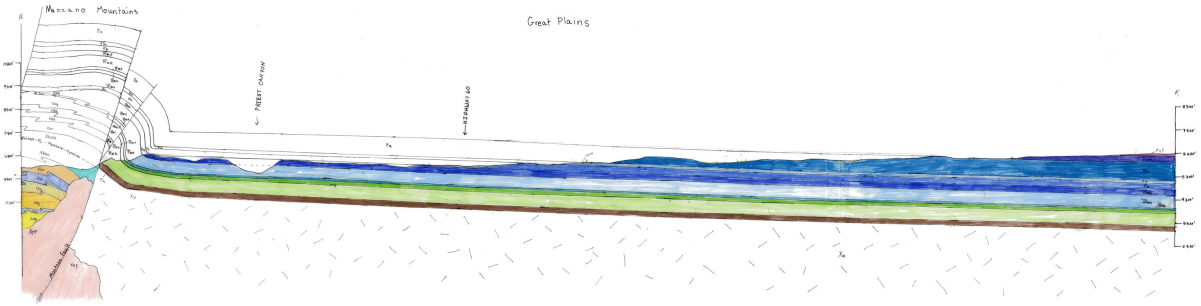
Attributed as section B-B' in GRI data. *Extracted from:* (Punta de Agua Quadrangle, OF-GM 220).

Abo Cross Section A - A'



Attributed as section C-C' in GRI data. *Extracted from:* (Abo Quadrangle, OF-GM 199).

Scholle Cross Section A - A'



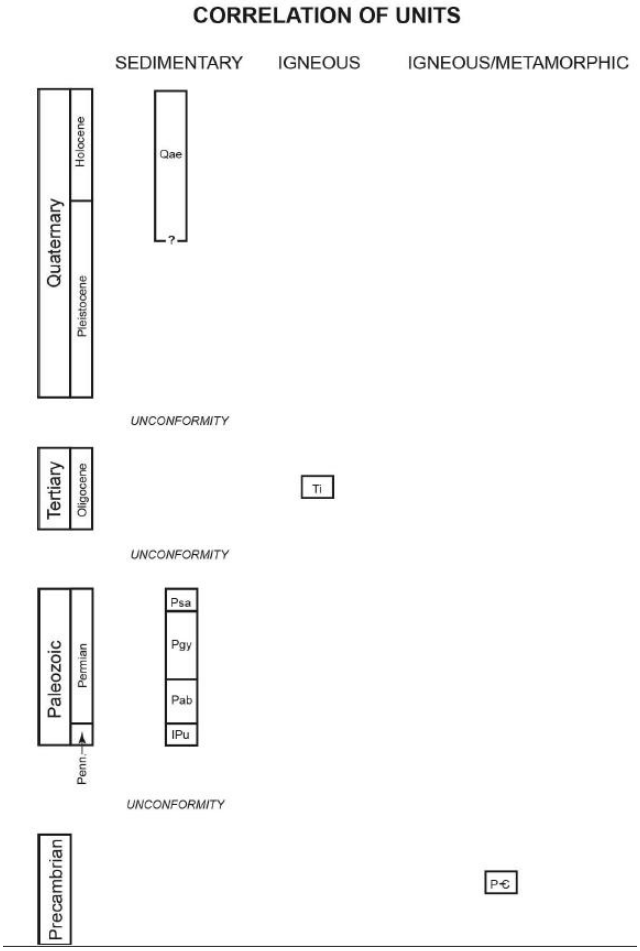
Attributed as section A-A' in GRI data. *Extracted from:* (Scholle Quadrangle, OF-GM 99).

GRI Source Map Information

Preliminary Geologic Map of the Gran Quivira 7.5' Quadrangle

Oviatt, Charles G., 2012, Preliminary Geologic Map of the Gran Quivira 7.5' Quadrangle, Torrance and Socorro Counties, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-file Digital Geologic Map OF-GM 248, 1:24000 scale. *(GRI Source Map ID 75649)*.

Correlation Of Map Units



Extracted from: (Gran Quivira Quadrangle, OF-GM 248).

Schematic Cross Section

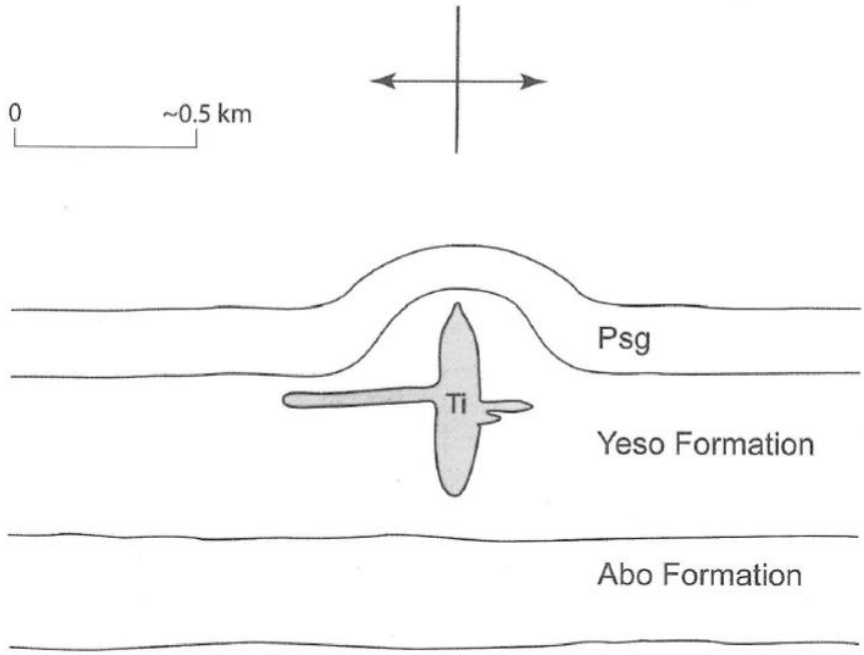
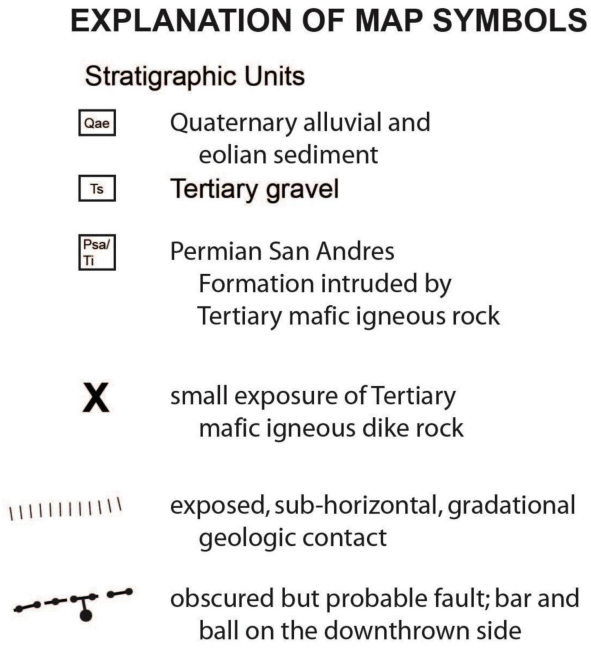


Figure 1. Modified from Cather (2009; Figure 7). Schematic cross section showing the relationship between dikes of the Tertiary intrusive igneous rocks (Ti) and the Permian sedimentary rocks in the Gran Quivira quadrangle. Psg = Permian San Andres and Glorieta Formations. The anticline symbol at the top of the diagram indicates that anticline structures were produced in the overlying sedimentary rocks; these anticline structures create elongate hills in the quadrangle; this includes the hill on which Gran Quivira pueblo and mission are built.

Extracted from: (Gran Quivira Quadrangle, OF-GM 248).

Map Legend



Extracted from: (Gran Quivira Quadrangle, OF-GM 248).

Report

Preliminary Geologic Map of the
Gran Quivira Quadrangle,
Torrance and Socorro County, New Mexico
(Year 1 of 1-Year)

By

Charles G. (Jack) Oviatt

June 2011

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

Scale 1:24,000

This work was supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program (STATEMAP) under USGS Cooperative Agreement 10HQPA0003 and the New Mexico Bureau of Geology and Mineral Resources.

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

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GEOLOGY OF THE GRAN QUIVIRA 7.5-MINUTE QUADRANGLE, TORRANCE COUNTY, NEW MEXICO

Charles G. (Jack) Oviatt

ABSTRACT

The Gran Quivira quadrangle, in central New Mexico, is dominated by low rolling hills and broad depressions. The hills are underlain by limestone and gypsum of the Permian San Andres Formation that have been deformed by dikes of Tertiary igneous rocks; the depressions are formed between the dike-cored hills, and in places are enhanced by subsurface dissolution of the limestone and gypsum. Total relief is low; the highest altitudes (about 6800 ft – 2070 m) are on Chupadera Mesa along the western edge of the quadrangle, and the lowest altitudes (about 6300 ft – 1900 m) are on the bottoms of closed depressions. All surface drainage in the Gran Quivira quadrangle terminates within the map area, or in closed depressions just outside the quadrangle. There is no surface-water connection to a master stream. Bedrock exposures are poor throughout the quadrangle, but roadcuts provide glimpses of the underlying bedrock units. Coarse-grained gravel, composed of well-rounded pebbles, cobbles, and boulders of rock types exotic to the quadrangle (such as quartzite, quartz, chert, red sandstone, and fine-grained volcanic rocks), is poorly exposed in one small area in the northwest corner of the quadrangle, and pebbles of these rock types are mixed with Quaternary deposits in low-lying areas in the northern 1/3 of the quadrangle. Sandy alluvium and eolian sand and silt, of Quaternary age, fills depressions and valleys between hills of bedrock. The Chupadera fault cuts Permian rocks and strikes north-south along the western margin of the quadrangle. The fault plane is not exposed, and the sense of motion (normal or reversed) cannot be determined on the Gran Quivira quadrangle.

INTRODUCTION

The Gran Quivira quadrangle is dominated by gently rolling hills and broad depressions. The hills are underlain by limestone and gypsum of the Permian San Andres Formation and dikes of Tertiary igneous rocks. There are no towns on the quadrangle. The Gran Quivira unit of Salinas Pueblo Missions National Monument is close to the southern margin of the quadrangle, and a few isolated homes and ranch houses are located near Highway 55, the only paved road in the quadrangle.

All ephemeral streams on the Gran Quivira quadrangle flow either into closed depressions within the map area, or into closed depressions just outside the quadrangle. A few streams enter the quadrangle from the east and west, and these streams terminate in closed depressions. There is no evidence that any of the closed depressions held surface water in lakes during wetter periods, and it is likely that all ephemeral surface water seeps into the surficial deposits and bedrock in the closed depressions. Altitudes range from as high as about 6800 ft (2070 m) along the western edge of the quadrangle, to as low as about 6300 ft (1900 m) in the Atkinson Flats closed depression in the southeast corner of the quadrangle and on the valley bottom southwest of Gran Quivira pueblo and mission.

Bedrock at the surface in the Gran Quivira quadrangle is Early Permian (Wolfcampian to Leonardian) in age, and consists of the San Andres Formation. Gray limestones dominate the rocks at the surface, and small outcrops of limestone and gypsum are present in the hilly areas. Blocks of Tertiary mafic intrusive rocks (probably basaltic andesite; Chamberlin et al., 2009) are present in the colluvium in some places, but the intrusive rocks are not well exposed. The bedrock structure is simple; the Permian rocks are essentially horizontal, except where they are deformed by the Tertiary intrusions, and by collapse related to subsurface dissolution of the limestone and gypsum.

The geology of the surrounding quadrangles has not been mapped. Bates et al. (1947) mapped the Gran Quivira 30’ quadrangle at a relatively small map scale (approximately 1:100,000). They showed the geology of the Gran Quivira 7.5-minute quadrangle as being dominated by the San Andres

Formation, and plotted roadcut and fence-line exposures of Tertiary intrusive rocks. A few scattered strike-and-dip symbols for Permian rocks on their map show the jumbled nature of the dips in this area. Cather (2009) discussed the Chupadera fault and the deformation of the Permian sedimentary rocks by the Tertiary intrusions.

Some additional references to previous geologic studies in the vicinity of the Gran Quivira quadrangle include: Lee (1909), Darton (1928), Needham and Bates (1943), Perhac (1970), Machette (1978), and Lueth et al. (2009).

STRATIGRAPHY AND DESCRIPTION OF MAP UNITS

At the surface of the Gran Quivira quadrangle, the bedrock sedimentary units are Early Permian in age, and consist of limestone and gypsum of the Lower Permian San Andres Formation. Tertiary igneous rocks intrude the Permian rocks. Older stratigraphic units (Paleozoic and Precambrian) are shown on the cross section but are not exposed on the Gran Quivira quadrangle.

STRUCTURAL GEOLOGY

Permian rocks in the Gran Quivira quadrangle are generally horizontal, although the dip of isolated bedrock exposures might be oriented in almost any direction. The jumble of dip directions is caused by complex sub-surface igneous intrusion and/or by dissolution and collapse of the limestone and gypsum.

The Chupadera fault (Cather, 2009) crosses the quadrangle and is parallel to the western margin of the quadrangle. The fault is expressed as a topographic escarpment, which marks the eastern edge of Chupadera Mesa, with altitudes dropping from west to east several hundred ft (up to about 100 m) across the escarpment. Highway 55 crosses the escarpment in the northwest corner of the quadrangle. Rocks are poorly exposed along the escarpment, so the sense of displacement, and the dip of the fault plane, thus whether the fault is normal or reversed, cannot be determined here. This situation is typical of the Chupadera fault all along its strike, and led Cather (2009) to conclude that the fault could be either a normal fault, with the east side faulted down along an east-dipping fault plane, or a reverse fault, with the west side faulted up along a west-dipping fault plane. If the fault is normal, it probably formed during the middle Cenozoic episode of crustal extension that affected this region, and if it is reversed, it probably formed during the late Mesozoic to early Cenozoic episode of crustal contraction (Cather, 2009). On the accompanying cross section the Chupadera fault plane is show as vertical in the subsurface because the dip has not been determined. Cather (2009) suggests a likely stratigraphic separation across the fault of 360 ft (110 m), or less. A direct quote from Cather (2009, p. 129) is appropriate here: “Throughout much of its length, the trace of Chupadera fault is marked by an east-dipping monocline as much as 0.8 km [0.5 mi] in width [. . .]. This monocline may be a fault-propagation fold related to west-up components of slip on the Chupadera fault. Because the fault is typically poorly exposed beneath alluvium at the toe of the monocline, the attitude of the fault has not been determined. Broad monoclines, however, are not typically associated with normal faults, thus the Chupadera fault may be a west-dipping fault with a reverse component of slip.”

The mafic dikes in the Gran Quivira quadrangle are the primary cause of the topographic relief in most of the map area. Previous workers (Bates et al., 1947; Cather, 2009) have hypothesized that the dikes intruded the sedimentary rocks (mudstone, sandstone, gypsum) of the Yeso Group, and caused overlying rocks (rocks of the Yeso Group, Glorieta Sandstone, San Andres Formation) to be bowed upward into anticlinal forms (Figure 1; Cather, 2009). The hill on which Gran Quivira pueblo and mission were built is one of these anticlines, and roadcut exposures along Highway 55 show the San Andres limestone beds dipping approximately parallel to the hill slopes. The mafic rock in the dikes deflects the needle of a Brunton compass, so it is likely that the rock would be detectable in aeromagnetic surveys. Aeromagnetic maps having sufficient resolution may reveal the presence of mafic rocks in the subsurface.

The mafic dikes may provide a clue to the relative age of the Chupadera fault, if, in addition to cutting Permian rocks (Cather, 2009), the fault also cuts Tertiary dike rocks. Tertiary dike rocks are found on both sides of the fault, but it is unknown whether they are actually cut by the fault. If the fault cuts the Oligocene igneous rocks, displacement on the fault is younger, and therefore the fault is most

likely normal. If the fault pre-dates the intrusions, it is most likely a reverse fault. Further investigations are required to determine these relationships.

ACKNOWLEDGEMENTS

I thank the following people for assistance with various aspects of the work that led to the production of this map: Mike Timmons, Mark Mansell, Phil Miller.

Extracted from: (Gran Quivira Quadrangle, OF-GM 248).

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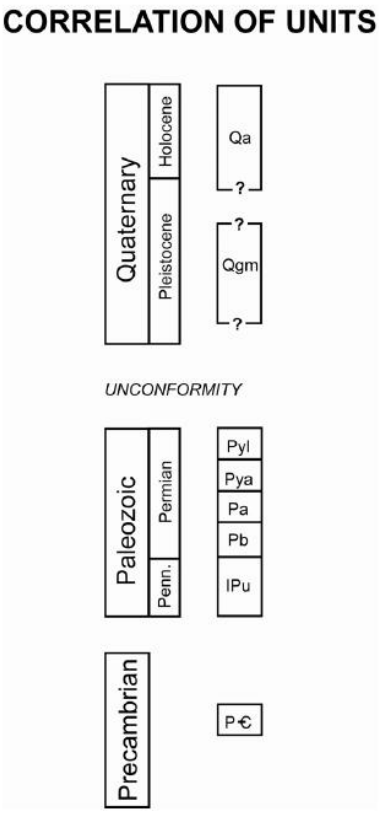
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Extracted from: (Gran Quivera Quadrangle, OF-GM 248).

Preliminary Geologic Map of the Punta de Agua 7.5' Quadrangle

Oviatt, Charles G., 2011, Preliminary Geologic Map of the Punta de Agua 7.5' Quadrangle, Torrance County, New Mexico., New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 220, 1:24000 scale. *(GRI Source Map ID 75584)*.

Correlation of Map Units



Extracted from: (Punta de Agua Quadrangle, OF-GM 220).

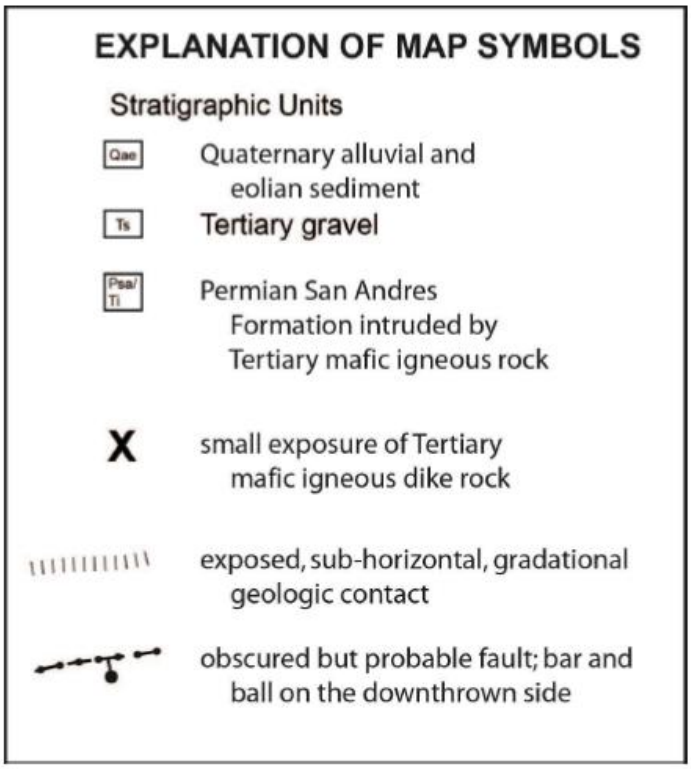
Table of Strike and Dip Measurements

UTM E (NAD27)	UTM N (NAD27)	dip angle	dip direction	map unit
375275	3818528	20	150	Pa
375299	3818848	45	95	Pa
375716	3819099	4	100	Pya
376097	3819240	25	95	Pa
375674	3819319	10	140	Pa
375993	3819579	0	---	Pya
374091	3819623	15	170	Pa
382041	3819738	5	180	Pyl
375178	3819744	5	175	Pya
373805	3819813	5	80	Pya
376172	3819907	5	85	Pya
376568	3820845	3	120	Pya
374681	3821299	5	130	Pa
376485	3821589	3	330	Pya
375034	3821638	2	160	Pya
378427	3821756	5	150	Pya
376178	3822112	10	180	Pya
375138	3822156	7	80	Pya
376550	3822322	25	110	Pya
375127	3822431	0	---	Pya
374837	3824189	5	90	Pya
374906	3829140	7	145	Pa
381086	3830251	12	70	Pa
381491	3830668	7	300	Pya

Table of locations for dip measurements on the Punta de Agua quadrangle. Note that these are all for Permian bedrock units; any that fall within areas of Qa on the map represent small outcrops of bedrock exposed beneath alluvium.

Extracted from: (Punta de Agua Quadrangle, OF-GM 220).

Map Legend



Extracted from: (Punta de Agua Quadrangle, OF-GM 220).

Report

Preliminary Geologic Map of the
Punta de Agua Quadrangle,
Torrance County, New Mexico.

By

Jack Oviatt

June 2011

New Mexico Bureau of Geology and Mineral Resources
Open-file Digital Geologic Map OF-GM 220

Scale 1:24,000

This work was supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program (STATEMAP) under USGS Cooperative Agreement 10HQPA0003 and the New Mexico Bureau of Geology and Mineral Resources.

New Mexico Bureau of Geology and Mineral Resources

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GEOLOGY OF THE PUNTA DE AGUA 7.5-MINUTE QUADRANGLE, TORRANCE COUNTY, NEW MEXICO

Charles G. (Jack) Oviatt

ABSTRACT

The Punta de Agua quadrangle in central New Mexico, is dominated by broad rolling surfaces capped by alluvial gravel from the Manzano Mountains. Low hills of sandstone are present in the northern part of the quadrangle, and valleys and mesas of sandstone, mudstone, gypsum, and limestone are present in the south. Altitudes range from over 7300 ft (2200 m) near the northwest corner of the quadrangle, to about 6400 ft (1950 m) along the southern map edge. Tributaries of Abo Arroyo, which flows westward to the Rio Grande valley, drain the southern third of the map area; the northern two thirds of the quadrangle drain to the east into Estancia Valley. Bedrock units exposed at the surface consist of the Lower Permian Abo Formation, and the Arroyo de Alamillo and Los Vallos Formations of the Yeso Group. Coarse gravel of late Cenozoic age, derived from the Manzano Mountains directly to the west, caps surfaces eroded into the Permian bedrock. Geologic structure in the Punta de Agua quadrangle is simple, with gentle southeasterly dips in the Permian bedrock, and a reverse-fault zone having total displacement of less than 200 ft (60 m) in the southwestern corner of the quadrangle.

INTRODUCTION

The Punta de Agua quadrangle is dominated by gently rolling to flat surfaces capped by gravel deposits of Pleistocene age. The gravels were derived from the Manzano Mountains directly to the west of the quadrangle, and they overlie Lower Permian rocks that are more easily weathered and eroded than the gravels. Outcrops of Permian red sandstones are present in areas where the gravel caps have been eroded, notably in the southern third of the quadrangle, and in low hills in the northwestern part of the quadrangle. The town of Mountainair lies at the far southeastern corner of the quadrangle, and the small villages of Punta de Agua and El Gato lie along Highway 14 in the northern third of the quadrangle. The Quarai unit of Salinas Pueblo Missions National Monument, and Manzano Mountains State Park, are in the northern third of the quadrangle. Numerous isolated homes and ranches are distributed throughout the quadrangle.

Tributaries of Abo Arroyo, which flows westward to the Rio Grande valley, drain the southern third of the map area, and the northern two thirds of the quadrangle drain to the east into Estancia Valley. Altitudes range from over 7300 ft (2200 m) near the northwest corner of the quadrangle, to about 6400 ft (1950 m) along the southern map edge.

Exposed bedrock in the quadrangle is Early Permian (Wolfcampian to Leonardian) in age, and consists of the Abo Formation and the Yeso Group. Red sandstones dominate the Abo and Yeso units. Coarse fluvial gravel of Pleistocene age covers the Permian rocks in most of the quadrangle, and is composed of igneous and metamorphic clasts derived from the Manzano Mountains. The bedrock structure is relatively simple, with gently dipping to horizontal bedding broken by two faults in the far southwestern corner of the quadrangle.

The Punta de Agua quadrangle is bounded on the west by the Manzano Peak quadrangle, the geology of which has been mapped by Baer et al. (2003). Myers (1977) and Scott et al. (2005) have mapped the geology of the Scholle quadrangle, which touches the Punta de Agua quadrangle at its southwestern corner. Oviatt (2010) has mapped the geology of the Abo quadrangle, which adjoins the Punta de Agua quadrangle along its southern boundary. No other quadrangles adjacent to the Punta de Agua quadrangle have been mapped.

Along the western edge of the Punta de Agua quadrangle, Quaternary alluvium (Qa) is roughly equivalent to the units Qaa, Qa, and Qay of Baer et al. (2003), and geologic contacts on the two maps

match reasonably well in canyons tributary to Cañon Espinoso, Cañon Barranco, Cañon Gotera, and Cañon Colorado. Geologic contacts of the Quaternary gravel deposits (Qgm) also match reasonably well with those of the unit referred to as Qp1 by Baer et al. (2003). The Arroyo de Alamillo (Pya) and Los Vallos (Pyl) Formations of the Yeso Group (Lucas et al., 2005) are mapped on the Punta de Agua quadrangle. These formations were not recognized at the time of mapping by Baer et al. (2003), so their map does not show the Arroyo de Alamillo Formation where it crosses the quadrangle boundary in the southeastern corner of the Manzano Peak quadrangle. Baer et al. (2003) mapped the Arroyo de Alamillo Formation as part of the Abo Formation.

Some additional references to previous geologic studies in the vicinity of the Punta de Agua quadrangle include: Lee (1909), Darton (1928), Needham and Bates (1943), Machette (1978), Hatchell et al. (1982); Myers (1982), Machette and McGimsey (1983), McLemore (2000), and Lueth et al. (2009).

STRATIGRAPHY AND DESCRIPTION OF MAP UNITS

In the Punta de Agua quadrangle, exposed bedrock sedimentary units are Early Permian in age, and consist of sandstone, mudstone, siltstone, limestone and dolomite, and gypsum. Stratigraphic units, in order of decreasing age, are the Abo Formation, and the Yeso Group, which includes the Arroyo de Alamillo and Los Vallos Formations. Most sandstones in the Abo and Yeso are red to orange, and these colors dominate roadcuts, natural exposures, and the younger alluvium derived from these rocks.

STRUCTURAL GEOLOGY

Rocks in the Punta de Agua quadrangle are flat-lying to gently dipping. In the southwestern quarter of the quadrangle, some dips are as great as 45° in fault zones, but dips flatten to nearly horizontal in the rest of the map area. Anomalous dips of some dolomite, limestone, and sandstone outcrops of the Los Vallos Formation are caused by local collapse related to subsurface gypsum dissolution. Gentle dips to the southeast of less than 5° are common in most of the quadrangle.

Two faults are mapped in the southwestern corner of the quadrangle; their sense of displacement is inferred from the relative ages of rocks displaced by them. The dip of one of the faults can be seen in exposures at Cottonwood Spring (approximately 376200 E, 3819900 N); at this locality, the fault zone dips to the east, and the sense of motion on the fault seems to be dip slip, with the hanging wall up relative to the footwall. The other fault is not well exposed in the quadrangle so its kinematics have not been determined. It is shown as a vertical fault on the cross section. Estimated total displacement along each of these faults ranges from negligible to greater than 200 ft (60 m).

Machette (1978) and Machette and McGimsey (1983) have mapped a Quaternary fault zone across the Punta de Agua quadrangle from southwest to northeast cutting Quaternary gravel (Qgm), however, I have not observed scarps in the Qgm surface. Observations that could be interpreted as evidence for a fault zone in the bedrock along the trace mapped by Machette and McGimsey (1983) come from a topographic gap between surfaces capped by Qgm near the common corner of sections 29, 30, 31, and 32, township 4 north, range 6 east (near 376500 E, 3822300 N). In this area, the bedrock, which consists of sandstone of the Arroyo de Alamillo Formation, dips about 25° to the east, a dip that is greater than the general dip of rocks in this area, and which could indicate that the rocks are in or near a fault zone. Several low hills in Qgm gravel in sections 9 and 16, T 4 N, R 6 E (378000 to 380000 E, 3825000 to 3828000 N) could be interpreted as up-thrown blocks on the east side of a northeast-striking fault zone, but the hills could be interpreted in alternative ways that are equally probable (e.g., differential erosion of underlying bedrock prior to gravel deposition at different levels). Considering these observations and interpretations, I have not shown a Quaternary fault on the Punta de Agua quadrangle along the trace proposed by Machette and McGimsey (1983). Although it is possible the bedrock units are deformed in a pre-Quaternary fault zone, subsurface investigations would be required to determine this.

ACKNOWLEDGEMENTS

I thank the following people for assistance with various aspects of the work that led to this map: George Duffy, Linda Fillipi, Spencer Lucas, and Mike Timmons.

Extracted from: (Punta de Agua Quadrangle, OF-GM 220).

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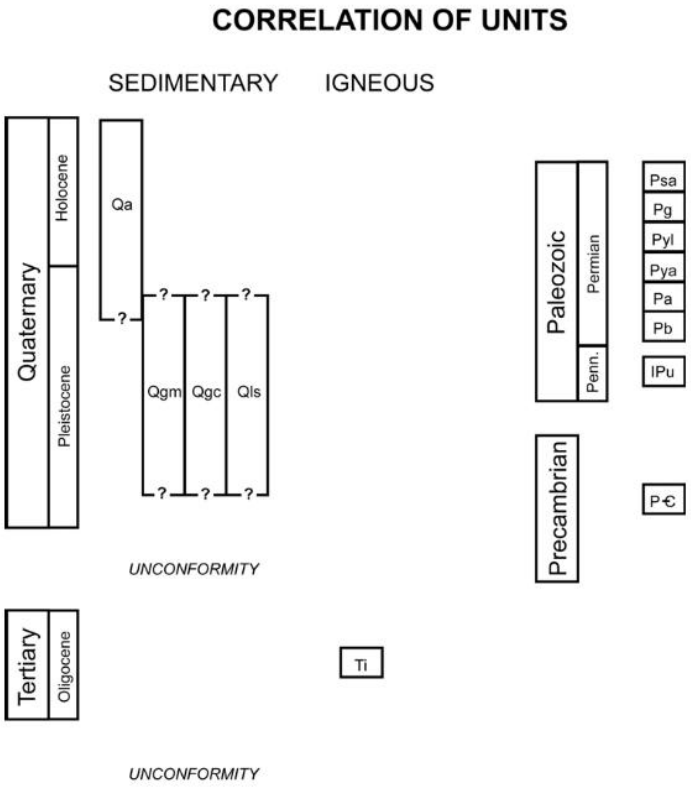
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Extracted from: (Punta de Agua Quadrangle, OF-GM 220).

Preliminary Geologic Map of the Abo 7.5' Quadrangle

Oviatt, Charles G., 2010, Preliminary Geologic Map of the 7.5' Abo Quadrangle, Torrance County, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 199, 1:24000 scale. *(GRI Source Map ID 75448)*.

Correlation of Map Units



Extracted from: (Abo Quadrangle, OF-GM 199).

Table of Strike and Dip Measurements

UTM E (NAD27)	UTM N (NAD27)	dip angle	dip direction	map unit
376120	3817608	6	105	Pyl
376259	3817936	9	150	Pyl
375727	3817119	6	190	Pyl
375502	3817008	7	0	Pyl
375256	3817663	14	290	Pyl
374152	3817332	9	140	Pa
375826	3816137	16	135	Pya
375639	3816400	2	40	Pyl
376039	3818217	5	160	Pya
375480	3818115	10	290	Pya
374889	3816346	5	150	Pya
376813	3812751	8	180	Pyl
375434	3812040	4	140	Pya
373786	3806607	5	120	Pyl
373816	3812416	3	100	Pya
378356	3804434	10	140	Pg
379026	3805045	5	200	Psa
383255	3814072	6	150	Pyl
383480	3807410	18	145	Pg
374689	3817787	15	330	Pya
374836	3817490	6	180	Pyl
374511	3817672	15	80	Pa
375628	3817266	10	200	Pya
382264	3809527	20	210	Pg
374302	3817167	27	50	Pya
373794	3816404	7	145	Pa

Extracted from: (Abo Quadrangle, OF-GM 199).

Table of Rounded Quartzite Gravel Locations

UTM E (NAD27)	UTM N (NAD27)	material
384741	3805598	gravel
384632	3805009	gravel
382895	3804291	gravel
382281	3804775	gravel
381963	3804866	gravel

Extracted from: (Abo Quadrangle, OF-GM 199).

Report

GEOLOGY OF THE ABO 7.5-MINUTE QUADRANGLE, TORRANCE COUNTY, NEW MEXICO

Charles G. (Jack) Oviatt

ABSTRACT

The Abo quadrangle in central New Mexico, is dominated by outcrops of Permian red sandstones in stream cuts and low mesas, and by gently sloping gravel-capped benches. Except for

Chupadera Mesa, which rises abruptly to an altitude of about 7200 ft (2200 m) along the eastern and southern margins of the map area, relief is generally low and ranges from approximately 6000 ft (1830 m) to 6500 ft (1980 m). Most of the map area is drained by tributaries of Abo Arroyo, which flows westward to the Rio Grande valley. Bedrock units exposed at the surface consist of the Lower Permian Abo Formation, the Arroyo de Alamillo and Los Vallos Formations of the Yeso Group, the Glorieta Sandstone, and the San Andres Formation. Coarse gravel caps sloping surfaces, and is derived from the Manzano Mountains and Chupadera Mesa. Geologic structure in the Abo quadrangle is simple, with gentle southeasterly dips in the northwestern part, flattening to nearly horizontal in most of the quadrangle. Two small-displacement faults cut Permian rocks in the far northwestern corner of the quadrangle.

INTRODUCTION

The Abo quadrangle is dominated by outcrops of Permian red sandstones in stream cuts and low mesas, and by gently sloping gravel-capped benches. Chupadera Mesa frames the quadrangle on its eastern and southern margins, and low-relief hills, mesas, and valley floors occupy most of the map area. U.S. highway 60 transects the northern half of the quadrangle; all other roads are gravel or dirt. The town of Mountainair lies a few miles northeast of the quadrangle boundary, and the hamlet of Abó consists of scattered dwellings along the highway in the central part of the quadrangle. Numerous isolated homes and ranches are distributed throughout the quadrangle. The ruins of Abó mission and associated pueblo structures, part of Salinas Pueblo Missions National Monument, are located about 1/2 mile (1/3 km) north of highway 60 near the western margin of the quadrangle.

Except for a few low-order streams that drain to the east on the top of Chupadera Mesa, the quadrangle is drained westward to the Rio Grande valley by Abo Arroyo and its many tributaries. Altitudes range from slightly less than 6000 ft (1830 m) where Abo Arroyo exits the quadrangle on the west, to slightly over 7200 ft (2200 m) on Chupadera Mesa. Relief in most of the map area is generally low (less than about 500 ft [150 m] over distances of 1 to 5 mi [2-8 km]).

Exposed bedrock in the quadrangle is Early Permian (Wolfcampian) in age, and consists of the Abo Formation, the Yeso Group, the Glorieta Sandstone, and the San Andres Formation, in order of decreasing age. Red sandstones dominate the Abo and Yeso units. Rocks of the Yeso Group are found throughout the quadrangle except on the top of Chupadera Mesa, and in the far northwestern corner. Coarse fluvial gravel of Pleistocene age covers the Yeso rocks in many areas; as shown by clast composition, south of Abo Arroyo the gravel was derived from Chupadera Mesa and north of Abo Arroyo the gravel source was the Manzano Mountains. Coarse-gravel landslide deposits are found along the steep flanks of Chupadera Mesa, and fine-grained alluvium fills major stream valleys. The bedrock structure is relatively simple, with gently dipping to nearly horizontal bedding broken by two faults in the far northwestern corner of the quadrangle. Gypsum dissolution in rocks of the Yeso, Glorieta, and San Andres formations has caused locally variable dips in the overlying sandstones and limestones.

The Abo quadrangle is bounded on the west by the Scholle quadrangle, the geology of which has been mapped by Myers (1977) and Scott et al. (2005). The Manzano Peak quadrangle, which touches the Abo quadrangle at its northwestern corner, has been mapped by Baer et al. (2003). No other quadrangles adjacent to the Abo quadrangle have been mapped. Along the western edge of the Abo quadrangle, Quaternary alluvium (Qa) is roughly equivalent to the units Qay and Qaay of Scott et al. (2005), and geologic contacts on the two maps match reasonably well at Abo Arroyo and north of there in the valley of Cañon de Espinoso. South of Abo Arroyo, Qa is mapped in places where alluvium was not recognized by Myers (1977) or Scott et al. (2005).

The bedrock contacts of Myers (1977) and Scott et al. (2005) could not be projected onto the Abo quadrangle. For the most part, Scott et al. (2005) borrowed bedrock geologic contacts mapped by Myers (1977) in the southern part of the Scholle quadrangle. The stratigraphy of the Yeso Group has been revised considerably since the maps by Myers (1977) and Scott et al. (2005) were published, and I have chosen to employ stratigraphic names that were not available to these mappers. Specifically, the Arroyo de Alamillo (Pya) and Los Vallos (Pyl) Formations of the Yeso Group (Lucas et al., 2005) are mapped on the Abo quadrangle, rather than the Meseta Blanca and Torres Members of the Yeso Formation (Myers, 1977; Scott et al., 2005). Because the definitions of Pya and Pyl are slightly different

than those of the Meseta Blanca and Torres Members, and because of other differences in interpretation of the bedrock in this area, the contacts along the western margin of the Abo quadrangle do not match those on the adjacent Scholle quadrangle. Neither Myers (1977) nor Scott et al. (2005) mapped Quaternary gravel derived from Chupadera Mesa (Qgc). An inferred fault at the contact between the Abo Formation and the Arroyo de Alamillo Formation in the northwest corner of the Abo quadrangle, was not recognized by Myers (1977) or Scott et al. (2005).

Some additional references to previous geologic studies in the vicinity of the Abo quadrangle include: Lee (1909), Darton (1928), Needham and Bates (1943), Machette (1978), Hatchell et al. (1982); Myers (1982), Machette and McGimsey (1983), and Lueth et al. (2009)

STRATIGRAPHY AND DESCRIPTION OF MAP UNITS

In the Abo quadrangle, exposed bedrock sedimentary units are Early Permian in age, and consist of sandstone, mudstone, siltstone, limestone and dolomite, and gypsum. Stratigraphic units, in order of decreasing age, are the Abo Formation, Yeso Group, including the Arroyo de Alamillo and Los Vallos Formations, Glorieta Sandstone, and San Andres Formation. Most sandstones in the Abo and Yeso are red to orange, and these colors dominate roadcuts and natural exposures and the younger alluvium derived from these rocks.

Igneous rocks in dikes of Tertiary (Oligocene) age are exposed in several places in the southwest quarter of the quadrangle. Coarse gravel of Pleistocene age caps surfaces that slope toward the axis of Abo Arroyo. Clast composition reflects the source areas of the gravel, either the Manzano Mountains, to the northwest, or Chupadera Mesa, to the east and south. The youngest deposits in the map area are sandy sediments in floodplain and terrace landforms in stream valleys.

> *Note:* Data in the GRI Geologic Observation Localities (sapugol) show locations of thin gravel deposits on San Andres Formation on the top of Chupadera Mesa. Gravel is composed of rounded pebbles of quartzite, chert, andesitic to rhyolitic volcanic rocks, and red sandstone probably derived from the Abo Formation.

STRUCTURAL GEOLOGY

Rocks in the Abo quadrangle are flat-lying to gently dipping. In the northwestern quarter of the quadrangle, some dips are as great as 6 to 9°, or over 15° in fault zones, but rocks are nearly horizontal in the rest of the map area. Anomalous dips of some dolomite, limestone, and sandstone outcrops of the Los Vallos, Glorieta, and San Andres are found in areas of local deformation caused by collapse related to subsurface gypsum dissolution. Hints of wavy bedding (with wave lengths on the order of a half a kilometer or more) visible from a distance on the western flank of Chupadera Mesa are probably also related to differential gypsum dissolution in the subsurface. Local variations in dip are not depicted in the cross section. The gentle dips (3-4°) in the Yeso rocks in the western quarter of the cross section flatten eastward to near 0°.

Two faults are mapped in the northwestern corner of the quadrangle; their sense of displacement is inferred from the relative ages of rocks displaced by them. The map symbols indicate normal displacement, but fault planes are not exposed in this quadrangle so it is not possible to determine whether the faults have normal, reverse, or strike-slip displacement. On the Punta de Agua quadrangle directly to the north, kinematic indicators (nearly horizontal slickenlines) associated with the same faults suggest that at least the most recent episode of motion in the fault zones was right-lateral strike-slip. Estimated fault displacement, in a vertical direction, ranges from negligible to greater than 200 ft (60 m).

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Extracted from: (Abo Quadrangle, OF-GM 199).

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Extracted from: (Abo Quadrangle, OF-GM 199).

Preliminary Geologic Map of the Scholle 7.5' Quadrangle

Scott, L.A., Elrick, M., Connell, S., and Karlstrom, K., 2005, Preliminary Geologic Map of the Scholle 7.5' Quadrangle, Valencia, Torrance, and Socorro Counties, New Mexico, New Mexico Bureau of Geology and Mineral Resources, Open-File Geologic Map OF-GM 99, 1:24000 scale. *(GRI Source Map ID 7463)*.

Scholle Grouped Unit Descriptions

This section contains descriptions of grouped map units in the Scholle Quadrangle. (*GRI Source Map ID* 7463*)* (Scholle Quadrangle, OF-GM 99).

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.

The following units were grouped together in the Scholle Quadrangle report: Qa, Qayv, Qay, Qayo, Qpm, Qpm1, Qpm2, Qpm3, and Qpo.

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.

The following units were grouped together in the Scholle Quadrangle report: Qaa, Qaay, Qaam, and

Qaao.

Piedmont-slope alluvium

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

The following units were grouped together in the Scholle Quadrangle report: Qpy and QTp.

Artificial Fill and Mass-movement deposits

Surficial deposits are the name given to a group of generally thin sediments associated with massmovement 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.

The following units were grouped together in the Scholle Quadrangle report: Qaf, Qls, and Qca.

Map Legend



Extracted from: (Scholle Quadrangle, OF-GM 99).

Report

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

By

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

May 2005

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

Scale 1:24,000

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

Scholle 7.5' Quadrangle
OF-GM 99

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

by

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Geologic mapping by
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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;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 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 km2 (61 mi2) 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 (lPm-1 through lPm-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; massmovement 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 dipslopes 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 lPm-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 finegrained 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 porphyroblastmatrix 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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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.

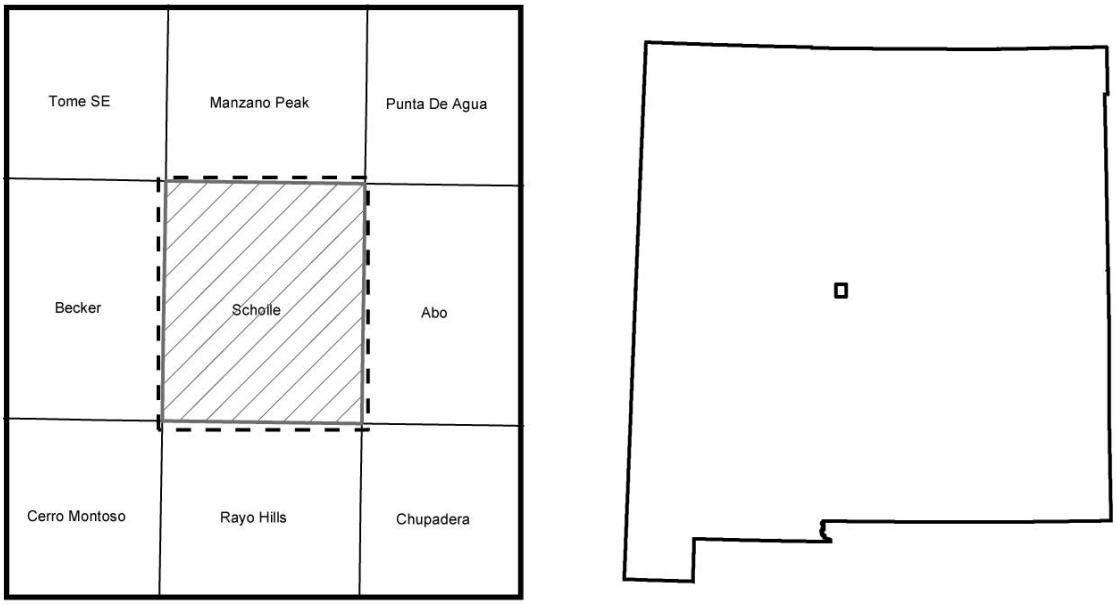
Figure 2: Outcrop photographs of map units. A) Upper (Pau) and lower (Pal) subdivisions in the Abo Formation. Lower portion of Abo Formation contains coarser sandstones that outcrop dark purple-brown; whereas, upper portion of Abo Formation is finer-grained and weathers red. Photograph taken just east 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.

Extracted from: (Scholle Quadrangle, OF-GM 99).

Location Map



Extracted from: (Scholle Quadrangle, OF-GM 99).

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