National Park Service
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Natural Resource Program Center

White Sands National Monument

Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory Digital Geologic Data for White Sands National Monument

whsa_geology.pdf

Version: 11/03/09

Geologic Resources Inventory Map Document for White Sands National Monument

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Geologic Resources Inventory Map Document

White Sands National Monument, New Mexico

Document to Accompany Digital Geologic-GIS Data

whsa_geology.pdf

Version: 11/03/09

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

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

Digital geologic-GIS data in these WinZip files and all other digital geologic-GIS data prepared as products of the GRI program are available to download from the NPS Natural Resource Information

Reference Search Application: http://nrinfo.nps.gov/Reference.mvc/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) program. For more information on the Inventory and Monitoring (I&M) program visit: http://science.nature.nps.gov/im/index.cfm

For more information on this and other Inventory and Monitoring (I&M) Natural Resource inventories visit: http://science.nature.nps.gov/im/inventory/index.cfm

Geomorphic Map Unit List

The geomorphic units present in the digital geologic-GIS data on the Fryberger Map produced for White Sands National Monument, New Mexico (WHSA) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., ahlb -Active Holocene Lake Basin). No description for water is provided. Information about each geologic unit is also presented in the Geologic Unit Information (UNIT) table included with the GRI geology-GIS data. A "?" at the end of a unit name indicates a questioned occurrence by the source map author of the unit in an area. No descriptions beyond the unit name is provided. All units are considered "Recent". In October of 2012, this document, as well as the GIS data and other ancillary files pertaining to the White Sands Dune Field map were updated after additional edits and comments were provided by the source map author.

Geomorphic Map Units

Active Holocene Lake Basin Units
ahlb - Active Holocene Lake Basin
ahlb? - Active Holocene Lake Basin?
ahlb_ap - Active Holocene Lake Basin, active playa
ahlb_qcw - Active Holocene Lake Basin, quartz clastic wedge
ahlb_fap - Active Holocene Lake Basin, few active parabolic dunes
ahlb_masa - Active Holocene Lake Basin, more active sandy areas
ahlb_nll - Active Holocene Lake Basin, North Lake Lucero, active playa
ahlb_sll - Active Holocene Lake Basin, South Lake Lucero, active playa
ahlb_ps - Active Holocene Lake Basin, patchy sand
ahlb_ss - Active Holocene Lake Basin, sand sheet

Scour Platform Units
sp - Scour Platform
sp? - Scour Platform?
sp_qcw - Scour Platform, quartz clastic wedge
sp_d? - Scour Platform, deflation surface?
sp_fap - Scour Platform, few active parabolic dunes
sp_fe_ds - Scour Platform, flat eolian deflation surface
sp_los - Scour Platform, Lake Otero stratification
sp_naas - Scour Platform, narrow area of active sand
sp_pas - Scour Platform, patchy active sands
sp_sldd - Scour Platform, scattered low domelike dunes
sp_todd_d - Scour Platform, truncated older dune deposits
sp_zd - Scour Platform, zibar dunes

Barchanoid Dune Field Units
bdf - Barchanoid Dune Field
bdf_b? - Barchanoid Dune Field, barchan dunes?
bdf_bd_o - Barchanoid Dune Field, barchan dunes - outliers
bdf_bd_a - Barchanoid Dune Field, barchan dunes - active
bdf_csr - Barchanoid Dune Field, central sand ridge

Marginal Parabolic Dune Units
mpd - Marginal Parabolic Dunes
mpd_aap - Marginal Parabolic Dunes, abundant active parabolic dunes
mpd_ap - Marginal Parabolic Dunes, active parabolic dunes
mpd_asp - Marginal Parabolic Dunes, active small parabolic dunes
mpd_lar - Marginal Parabolic Dunes, leading active ridge of parabolic dunes

mpd_masa - Marginal Parabolic Dunes, more active sandy areas
mpd_pd - Marginal Parabolic Dunes, parabolic dunes
mpd_qd? - Marginal Parabolic Dunes, quartz dunes?
mpd_qs? - Marginal Parabolic Dunes, quartz sand?
mpd_spd - Marginal Parabolic Dunes, scattered parabolic dunes
mpd_ss_sd - Marginal Parabolic Dunes, sand sheet or small dunes
mpd_tp - Marginal Parabolic Dunes, The Pasture

Miscellaneous Geomorphic Feature Units
active_lake - Active lake
active_sand? - Active sand?
allvl_fan - Alluvial fan, quartz clastic low angle sheetflood fan in the playa
i_dune_p - Inactive dunes, mostly parabolic dunes
lo_outcrops - Lake Otero outcrops
masa - More active sandy areas
o_allvl_fan - Older alluvial fans
o_bas_floor - Older basin floor
plateau - Plateau
qci_ds - Quartz clastic input to dune system
quartzose_d - Quartzose dunes
sabkha - Sabkha
sbdd_eln_top - Subdued eolian topography
sg_outcrops - Sandy gypsiferous outcrops
shrln_dune - Shoreline dune
shrln_l_dune - Shoreline "lunette" dunes
veg_d - Vegetated dunes
yrdng - Yardangs

Geologic Map Unit List

The geologic units present on digital geologic-GIS data produced on the Geologic Map (Seager et. al., 1987) produced for White Sands National Monument, New Mexico (WHSA) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvium). Units are generally listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the Geologic Unit Information (UNIT) table included with the GRI geology-GIS data.

Cenozoic Era

Holocene and Pleistocene
Qpy - Younger piedmont-slope deposits (Qpy)
Qpa - Qpy and Qpo, undifferentiated (Qpa)
Qpa + Qegs - Qpa and Qegs, undifferentiated (Qpa + Qegs)

Holocene over Pliocene
Qpa/Qpu - Qpa units overlying Qpu units (Qpa/Qpu)

Holocene and/over Pleistocene
Qbf - Basin-floor sediments (Qbf)
Qbf/Qlg - Qbf overlying Qlg (Qbf/Qlg)
Qbf/Qpg - Qbf overlying Qpg (Qbf/Qpg)
Ql - Deposits of small, non-alkaline playa lakes and depressions (Ql)
Qlg - Gypsiferous lake deposits in the Tularosa Basin (Qlg)
Qegs - Eolian deposits associated with Tularosa Basin Lakes (Qegs)
Qegs/Qpg - Qegs overlying Qpg (Qegs/Qpg)
Qegs + Qbfg - Qegs and Qbfg, undifferentiated (Qegs+Qbfg)

Holocene and Pleistocene over Permian
Qegs/Ph? - Qegs overlying Ph? (Qegs/Ph?)

Holocene and Pleistocene
Qega - Active gypsum dunes (Qega)
Qes - Eolian quartz sand (Qes)

Holocene over Pleistocene and Pliocene
Qes/Qpu - Qes overlying Qpu units (Qes/Qpu)

Holocene over Pleistocene
Qes/Qbfg - Qes overlying Qbfg (Qes/Qbfg)

Holocene over Pliocene
Qes/Qcl - Qes overlying Qcl (Qes/Qcl)

Pleistocene
Qpo - Older piedmont-slope deposits (Qpo)

Pleistocene and Pliocene
Qpu - Qpo and Qcp, undifferentiated (Qpu)

Pleistocene
Qpg - Older gypsiferous basin-floor and distal piedmont slope deposits (Qpg)
Qbfg - Older gypsiferous basin-floor deposits and lake beds (Qbfg)

Qegi - Inactive gypsum dunes (Qegi)

Pleistocene and Pliocene
Qb - Olivine basalt (Qb)
Qcp - Camp Rice Formation, piedmont-slope facies (Qcp)
QTcu - Qcp and QTcc, undifferentiated (QTcu)
Qcl - Camp Rice Formation, sediments associated with La Mesa surface (Qcl)
QTcc - Camp Rice Formation, fanglomerate facies (QTcc)

Oligocene
Tii - Intermediate-composition plutonic rocks (Tii)
Tri - Non foliated rhyolite intrusives (Tri)
Tis - Silicic plutonic rocks (Tis)
Tlr - Love Ranch Formation (Tlr)

Cenozoic and Mesozoic Eras

Tertiary and Cretaceous
TKru - Sarten and Dakota Sandstone with unknown rocks, undifferentiated (TKru)

Paleozoic Era

Permian
PZu - Paleozoic rocks, undifferentiated (Pu)
Ps - San Andres Formation (Ps)
Psy - San Andres Formation and Yeso Formation, undivided (Psy)
Py - Yeso Formation (Py)
Pya - Yeso (?) beds and Abo Formation (Pya)
Pa - Abo Formation (Pa)
Ph - Hueco Formation (Ph)

Pennsylvanian
PNps - Panther Seep Formation (PNps)
PNlc - Lead Camp Limestone (PNlc)
PNlc/ls - Lead Camp Limestone overlying ls (PNlc/ls)

Mississippian and Devonian
MDr - Mississippian And Devonian Rocks (MDr)

Silurian and Ordovician
SOfm - Fusselman Dolomite and Montoya Group, undivided (SOfm)

Ordovician and Cambrian
OCeb - El Paso Group and Bliss Sandstone, undivided (OCeb)

Precambrian

Precambrian
PCg - Precambrian rocks, granite (PCg)
PCq - Precambrian rocks, quartzite (PCq)

PCs - Precambrian rocks, schist and phyllite (PCs)
PCa - Precambrian rocks, amphibolite (PCa)
PCmd - Precambrian rocks, metadiabase (PCmd)
PCgn - Precambrian rocks, gneiss (PCgn)

Geologic Map Unit Descriptions

Descriptions of all geologic map units present on the Geologic Map (Seager et. al., 1987), generally listed from youngest to oldest, are presented below.

Qpy - Younger piedmont-slope deposits (Holocene and latest Pleistocene)

Unconsolidated sand, gravel, and loamy sediments of drainageways that cross and are inset below or bury older piedmont slopes, and of fans constructed on distal piedmont slopes at lower end of such drainageways; up to 15 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qpa - Qpy and Qpo, undifferentiated (Holocene and late Pleistocene)

Qpy Younger piedmont-slope deposits (Holocene and latest Pleistocene) - Unconsolidated sand, gravel, and loamy sediments of drainageways that cross and are inset below or bury older piedmont slopes, and of fans constructed on distal piedmont slopes at lower end of such drainageways; up to 15 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qpo Older piedmont-slope deposits (late to middle Pleistocene) - Fan and terrace deposits and erosion-surface veneers on piedmont slopes graded to closed-basin floors postdating river-valley incision; mostly weakly consolidated gravel and sandy gravel, grading downslope to gravelly loam, with thin horizons (surficial and buried) of soil-carbonate and clay accumulation; gravelly carbonate horizons are commonly indurated and form thin pedogenic calcretes; at least two generations of fans are present at most places along the San Andres-Organ-Franklin Mountains front; up to 50 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qpa + Qegs, undifferentiated (Holocene and late Pleistocene)

Unit consists of Qpa (Qpy and Qpo units) and Qegs.

Qpy Younger piedmont-slope deposits (Holocene and latest Pleistocene) - Unconsolidated sand, gravel, and loamy sediments of drainageways that cross and are inset below or bury older piedmont slopes, and of fans constructed on distal piedmont slopes at lower end of such drainageways; up to 15 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qegs Eolian deposits associated with Tularosa Basin Lakes (Holocene and latest Pleistocene) - Mostly inactive, ridge-like dunes of yellowish to tan, gypsiferous quartzose silt and fine quartzose sand with gypsite layers; located on the lee (east) side of lake (Qlg) beds; many have 1-2 ft of pedogenic gypsite (gypcrete capping the deposits, up to 75 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qpo Older piedmont-slope deposits (late to middle Pleistocene) - Fan and terrace deposits and erosion-surface veneers on piedmont slopes graded to closed-basin floors postdating river-valley incision; mostly weakly consolidated gravel and sandy gravel, grading downslope to gravelly loam, with thin horizons (surficial and buried) of soil-carbonate and clay accumulation; gravelly carbonate horizons are commonly indurated and form thin pedogenic calcretes; at least two generations of fans are present at most places along the San Andres-Organ-Franklin Mountains front; up to 50 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qpa/Qpu - Qpa overlying Qpu (Holocene and late Pliocene)

Unit consists of Qpa (Qpy and Qpo units) overlying Qpu (Qpo and Qcp units).

Qpy Younger piedmont-slope deposits (Holocene and latest Pleistocene) - Unconsolidated sand, gravel, and loamy sediments of drainageways that cross and are inset below or bury older piedmont slopes, and of fans constructed on distal piedmont slopes at lower end of such drainageways; up to 15 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qpo Older piedmont-slope deposits (late to middle Pleistocene) - Fan and terrace deposits and erosion-surface veneers on piedmont slopes graded to closed-basin floors postdating river-valley incision; mostly weakly consolidated gravel and sandy gravel, grading downslope to gravelly loam, with thin horizons (surficial and buried) of soil-carbonate and clay accumulation; gravelly carbonate horizons are commonly indurated and form thin pedogenic calcretes; at least two generations of fans are present at most places along the San Andres-Organ-Franklin Mountains front; up to 50 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qcp Camp Rice Formation, piedmont-slope facies (middle Pleistocene to late Pliocene) - Deposits associated with piedmont slopes graded to basin floors predating river-valley incision; weakly to moderately cemented, boulder to cobble fan deposits and erosion-surface veneers near mountain fronts grading to gravelly silt, loam, or clay on distal piedmont slopes; discontinuous lenses of volcanic ash (0.6-0.7 m.y.; Gile and others, 1981) are locally present; surficial layers, up to 10 ft thick, usually with prominent horizons of soil-carbonate accumulation and, locally, reddish-brown horizons of clay accumulation; gravelly carbonate horizons are commonly indurated forming pedogenic calcrete zones up to 5 ft thick; multiple buried soils are present in thicker deposits; generally less than 80 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qbf - Basin-floor sediments (Holocene and late Pleistocene)

Mostly loam, silt, or clay, locally with thin pebble-gravel zones; Qbf deposits in eastern Tularosa Basin are commonly gypsiferous; up to 15 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qbf/Qlg - Qbf overlying Qlg (middle to late Pleistocene)

Unit consists of Qbf overlying Qlg.

Qbf Basin-floor sediments (Holocene to late Pleistocene) - Mostly loam, silt, or clay, locally with thin pebble-gravel zones; Qbf deposits in eastern Tularosa Basin are commonly gypsiferous; up to 15 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qlg Gypsiferous lake deposits in the Tularosa Basin (Holocene and latest Pleistocene) - Includes large ancestral Lake Otero with highest shoreline near 3,950 ft and several smaller lake beds in the eastern Tularosa Basin; mostly gypsite, gypsiferous red and green clay, and gypsiferous silt, locally covered by thin, loamy to silty, eolian deposits of alluvium; at least 25 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qbf/Qpg - Qbf overlying Qpg (middle to late Pleistocene)

Unit consists of Qbf overlying Qpg.

Qbf Basin-floor sediments (Holocene to late Pleistocene) - Mostly loam, silt, or clay, locally with thin pebble-gravel zones; Qbf deposits in eastern Tularosa Basin are commonly gypsiferous; up to

15 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qpg Older gypsiferous basin-floor and distal piedmont slope deposits (late to middle Pleistocene) - Primarily distal piedmont deposits in east-central Tularosa Basin; mostly gypsiferous red clay and silt, tan, eolian gypsum sand, yellow, limonitic quartzose sand, tan, clayey siltstone (adobe), all moderately well indurated, and gypsite; unit is capped everywhere by 1-3 ft of gypsite of probable pedogenic origin (gypcrete); age is uncertain but probably late Pleistocene, younger than 0.4 m.y.; up to 25 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Ql - Deposits of small, non-alkaline playa lakes and depressions (Holocene and latest Pleistocene)

Mostly clay and silt; up to 15 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qlg - Gypsiferous lake deposits in the Tularosa Basin (Holocene and latest Pleistocene)

Includes large ancestral Lake Otero with highest shoreline near 3,950 ft and several smaller lake beds in the eastern Tularosa Basin; mostly gypsite, gypsiferous red and green clay, and gypsiferous silt, locally covered by thin, loamy to silty, eolian deposits of alluvium; at least 25 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qegs - Eolian deposits associated with Tularosa Basin Lakes (Holocene and latest Pleistocene)

Mostly inactive, ridge-like dunes of yellowish to tan, gypsiferous quartzose silt and fine quartzose sand with gypsite layers; located on the lee (east) side of lake (Qlg) beds; many have 1-2 ft of pedogenic gypsite (gypcrete) capping the deposits, up to 75 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qegs/Qpg - Qegs overlying Qpg (Holocene and late Pleistocene)

Unit consists of Qegs overlying Qpg.

Qegs Eolian deposits associated with Tularosa Basin Lakes (Holocene and latest Pleistocene) - Mostly inactive, ridge-like dunes of yellowish to tan, gypsiferous quartzose silt and fine quartzose sand with gypsite layers; located on the lee (east) side of lake (Qlg) beds; many have 1-2 ft of pedogenic gypsite (gypcrete) capping the deposits, up to 75 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qpg Older gypsiferous basin-floor and distal piedmont slope deposits (late to middle Pleistocene) - Primarily distal piedmont deposits in east-central Tularosa Basin; mostly gypsiferous red clay and silt, tan, eolian gypsum sand, yellow, limonitic quartzose sand, tan, clayey siltstone (adobe), all moderately well indurated, and gypsite; unit is capped everywhere by 1-3 ft of gypsite of probable pedogenic origin (gypcrete); age is uncertain but probably late Pleistocene, younger than 0.4 m.y.; up to 25 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qegs + Qbfg - Qegs and Qbfg, undifferentiated (Holocene and late Pleistocene)

Unit consists of the following units that have not been differentiated.

Qegs Eolian deposits associated with Tularosa Basin Lakes (Holocene and latest Pleistocene) - Mostly inactive, ridge-like dunes of yellowish to tan, gypsiferous quartzose silt and fine quartzose sand with gypsite layers; located on the lee (east) side of lake (Qlg) beds; many have 1-2 ft of pedogenic gypsite (gypcrete) capping the deposits, up to 75 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qbfg Older gypsiferous basin-floor deposits and lake beds (late to middle Pleistocene) - Mostly red and green gypsiferous clay and silt interbedded with gypsite; upper 1-3 ft is gypsite of probable pedogenic origin; unit crops out as high as 3,995 ft and underlies much of the central Tularosa Basin north of the Jarilla Mountains; grades to Qpg above 4,000 ft; age of exposed beds is uncertain, probably late Pleistocene, younger than 0.4 m.y.; at least 25 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qegs/Ph? - Qegs overlying Hueco Formation? (Holocene, latest Pleistocene, and Permian?)

Unit consists of Qegs overlying Ph?.

Qegs Eolian deposits associated with Tularosa Basin Lakes (Holocene and latest Pleistocene) - Mostly inactive, ridge-like dunes of yellowish to tan, gypsiferous quartzose silt and fine quartzose sand with gypsite layers; located on the lee (east) side of lake (Qlg) beds; many have 1-2 ft of pedogenic gypsite (gypcrete) capping the deposits, up to 75 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Ph? Hueco Formation (Permian) - Algal limestone, gastropod-echinoid-brachipod limestone, fusulinid limestone, chert-pebble conglomerate, sandy limestone, gray shale, shaly limestone, siltstone, massive cherty limestone, in the Dona Ana Mountains, sandstone, porcellanite, black shale, and stromatolitic limestone; light to dark gray, cream, yellow, orange; Wolfcampian (Early Permian) age, 1,900 ft thick in the Robledo Mountains (including both a tongue of Abo Formation 320 ft thick in the upper part an, at the base, approximately 200 ft of limestone correlative with Bursum Formation; Seager and others, in preparation); as much as 2,250 ft thick in the Dona Ana (Seager and others, 1976); 1,450 ft thick in the southern San Andres Mountains, thinning northward to 325 ft thick at Hembrillo Canyon (Kottlowski and others 1956; Bachman and Myers, 1969; Seager, 1981) 1,900 ft thick in the central Organ Mountains (Seager, 1981); 3,620 ft thick in the Grimm and others deep oil test (Thompson and Bieberman, 1975); at least 2,300 ft thick in the Franklin Mountains (Harbour, 1972); and 1,600 ft thick in the Hueco Mountains, including approximately 100 ft of basal Powwow Conglomerate Member (Hardie, 1958). *GRI Source Map ID 73352* (Geologic Map 57).

Qega - Active gypsum dunes (Holocene and latest Pleistocene)

White dunes of pure gypsum sand located east of and derived from modern and ancestral Lake Lucero; up to 60 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qes - Eolian quartz sand (Holocene and latest Pleistocene)

Dunes and irregular hummocks of quartz sand, especially extensive on western piedmont slopes of San Andrea Mountains, on the La Mesa surface southwest of Las Cruces, east of San Diego Mountain, and in the southern Tularosa Basin; the sand is derived largely from Camp Rice Formation (Qcf) *GRI Source Map ID 73352* (Geologic Map 57).

Qes/Qpu - Qes overlying Qpu (Holocene and late Pliocene)

Unit consists of Qes overlying Qpu (Qpo and Qcp units).

Qes Eolian quartz sand (Holocene and latest Pleistocene) - Dunes and irregular hummocks of quartz sand, especially extensive on western piedmont slopes of San Andrea Mountains, on the La Mesa surface southwest of Las Cruces, east of San Diego Mountain, and in the southern Tularosa Basin; the sand is derived largely from Camp Rice Formation (Qcf) *GRI Source Map ID 73352* (Geologic Map 57).

Qpo Older piedmont-slope deposits (late to middle Pleistocene) - Fan and terrace deposits and erosion-surface veneers on piedmont slopes graded to closed-basin floors postdating river-valley incision; mostly weakly consolidated gravel and sandy gravel, grading downslope to gravelly loam, with thin horizons (surficial and buried) of soil-carbonate and clay accumulation; gravelly carbonate horizons are commonly indurated and form thin pedogenic calcretes; at least two generations of fans are present at most places along the San Andres-Organ-Franklin Mountains front; up to 50 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qcp Camp Rice Formation, piedmont slope deposits (middle Pleistocene to late Pliocene) - Deposits associated with piedmont slopes graded to basin floors predating river-valley incision; weakly to moderately cemented, boulder to cobble fan deposits and erosion-surface veneers near mountain fronts grading to gravelly silt, loam, or clay on distal piedmont slopes; discontinuous lenses of volcanic ash (0.6-0.7 m.y.; Gile and others, 1981) are locally present; surficial layers, up to 10 ft thick, usually with prominent horizons of soil-carbonate accumulation and, locally reddish-brown horizons of clay accumulation; gravelly carbonate horizons are commonly indurated, forming pedogenic calcrete zones up to 5 ft thick; multiple buried soils are present in thicker deposits; generally less than 80 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qes/Qbfg - Qes overlying Qbfg (Holocene and late Pleistocene)

Unit consists of Qes overlying Qbfg.

Qes Eolian quartz sand (Holocene and latest Pleistocene) - Dunes and irregular hummocks of quartz sand, especially extensive on western piedmont slopes of San Andrea Mountains, on the La Mesa surface southwest of Las Cruces, east of San Diego Mountain, and in the southern Tularosa Basin; the sand is derived largely from Camp Rice Formation (Qcf) *GRI Source Map ID 73352* (Geologic Map 57).

Qbfg Older gypsiferous basin-floor deposits and lake beds (late to middle Pleistocene) - Mostly red and green gypsiferous clay and silt interbedded with gypsite; upper 1-3 ft is gypsite of probable pedogenic origin; unit crops out as high as 3,995 ft and underlies much of the central Tularosa Basin north of the Jarilla Mountains; grades to Qpg above 4,000 ft; age of exposed beds is uncertain, probably late Pleistocene, younger than 0.4 m.y.; at least 25 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qes/Qcl - Qes overlying Qcl (late Pliocene to Holocene)

Unit consists of Qes overlying Qcl.

Qes Eolian quartz sand (Holocene and latest Pleistocene) - Dunes and irregular hummocks of quartz sand, especially extensive on western piedmont slopes of San Andrea Mountains, on the La Mesa surface southwest of Las Cruces, east of San Diego Mountain, and in the southern Tularosa

Basin; the sand is derived largely from Camp Rice Formation (Qcf) *GRI Source Map ID 73352* (Geologic Map 57).

Qcl Camp Rice Formation, sediments associated with La Mesa Surface (middle Pleistocene to late Pliocene) - Basin-floor sediments, the constructional top of which is the La Mesa geomorphic surface (shown on geologic map with horizontal-line pattern); generally consists of sand, silt, loam, or clay; includes fluvial, playa, and alluvial-flat deposits that are commonly wind reworked; surficial layers, up to 10 ft thick, have prominent horizons of soil-carbonate accumulation and, locally, reddish-brown horizons of clay accumulation; carbonate horizons are commonly indurated, forming pedogenic calcrete zones up to 5 ft thick; unit overlain by discontinuous veneer of Holocene eolian sand or, locally, by upper Quaternary playa or alluvial-flat deposits; up to 50 ft exposed; may be locally thicker in subsurface *GRI Source Map ID 73352* (Geologic Map 57).

Qpo - Older piedmont-slope deposits (late and middle Pleistocene)

Fan and terrace deposits and erosion-surface veneers on piedmont slopes graded to closed-basin floors postdating river-valley incision; mostly weakly consolidated gravel and sandy gravel, grading downslope to gravelly loam, with thin horizons (surficial and buried) of soil-carbonate and clay accumulation; gravelly carbonate horizons are commonly indurated and form thin pedogenic calcretes; at least two generations of fans are present at most places along the San Andres-Organ-Franklin Mountains front; up to 50 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qpu - Qpo and Qcp, undifferentiated (late Pliocene to late Pleistocene)

Unit consists of Qpo and Qcp, undifferentiated.

Qpo Older Piedmont-Slope Deposits (late to middle Pleistocene) - Fan and terrace deposits and erosion-surface veneers on piedmont slopes graded to closed-basin floors postdating river-valley incision; mostly weakly consolidated gravel and sandy gravel, grading downslope to gravelly loam, with thin horizons (surficial and buried) of soil-carbonate and clay accumulation; gravelly carbonate horizons are commonly indurated and form thin pedogenic calcretes; at least two generations of fans are present at most places along the San Andres-Organ-Franklin Mountains front; up to 50 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qcp Camp Rice Formation, Piedmont Slope Deposits (middle Pleistocene to late Pliocene) - Deposits associated with piedmont slopes graded to basin floors predating river-valley incision; weakly to moderately cemented, boulder to cobble fan deposits and erosion-surface veneers near mountain fronts grading to gravelly silt, loam, or clay on distal piedmont slopes; discontinuous lenses of volcanic ash (0.6-0.7 m.y.; Gile and others, 1981) are locally present; surficial layers, up to 10 ft thick, usually with prominent horizons of soil-carbonate accumulation and, locally reddish-brown horizons of clay accumulation; gravelly carbonate horizons are commonly indurated, forming pedogenic calcrete zones up to 5 ft thick; multiple buried soils are present in thicker deposits; generally less than 80 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qpg - Older gypsiferous basin-floor and distal piedmont slope deposits (late and middle Pleistocene)

Primarily distal piedmont deposits in east-central Tularosa Basin; mostly gypsiferous red clay and silt, tan, eolian gypsum sand, yellow, limonitic quartzose sand, tan, clayey siltstone (adobe), all moderately well indurated, and gypsite; unit is capped everywhere by 1-3 ft of gypsite of probable pedogenic origin (gypcrete); age is uncertain but probably late Pleistocene, younger than 0.4 m.y.; up to 25 ft thick. *GRI*

Source Map ID 73352 (Geologic Map 57).

Qbfg - Older gypsiferous basin-floor deposits and lake beds (late and middle Pleistocene)

Mostly red and green gypsiferous clay and silt interbedded with gypsite; upper 1-3 ft is gypsite of probable pedogenic origin; unit crops out as high as 3,995 ft and underlies much of the central Tularosa Basin north of the Jarilla Mountains; grades to Qpg above 4,000 ft; age of exposed beds is uncertain, probably late Pleistocene, younger than 0.4 m.y.; at least 25 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qegi - Inactive gypsum dunes (late and middle Pleistocene)

Dunes of gypsite with well-developed gypcrete crusts; may be sandy or silty (quartz) locally, grading into Qegs; up to 50 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

Qb - Olivine basalt (late Pliocene to late Pleistocene)

Mostly, if not entirely, alkali-olivine basalt; forms cinder cones and/or flows; radiometric dates (K-Ar): 0.183 ± 0.03 m.y.; 1.23 ± 0.06 m.y.; 0.55 ± 0.03 m.y.; 0.49 ± 0.02 m.y.; 0.025 ± 0.1 m.y.; 0.125 ± 0.1 m.y.; 0.150 ± 0.12 m.y.; 0.226 ± 0.08 m.y.; 0.040 ± .13 m.y.; 0.116 ± 0.08 m.y.; 0.161 ± 0.08 m.y.; 0.127 ± 0.13 m.y. (Seager and others, 1984; Hoffer, 1976, 1971; Luedke and Smith, 1978). *GRI Source Map ID 73352* (Geologic Map 57).

Qcp - Camp Rice Formation, piedmont-slope facies (late Pliocene to middle Pleistocene)

Deposits associated with piedmont slopes graded to basin floors predating river-valley incision; weakly to moderately cemented, boulder to cobble fan deposits and erosion-surface veneers near mountain fronts grading to gravelly silt, loam, or clay on distal piedmont slopes; discontinuous lenses of volcanic ash (0.6-0.7 m.y.; Gile and others, 1981) are locally present; surficial layers, up to 10 ft thick, usually with prominent horizons of soil-carbonate accumulation and, locally reddish-brown horizons of clay accumulation; gravelly carbonate horizons are commonly indurated, forming pedogenic calcrete zones up to 5 ft thick; multiple buried soils are present in thicker deposits; generally less than 80 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

QTcu - Qcp and QTcc, undivided (Pliocene to middle Pleistocene)

Unit consists of Qcp and QTcc, undivided.

Qcp Camp Rice Formation, Piedmont-Slope Facies (middle Pleistocene to late Pliocene) - Deposits associated with piedmont slopes graded to basin floors predating river-valley incision; weakly to moderately cemented, boulder to cobble fan deposits and erosion-surface veneers near mountain fronts grading gravelly silt, loam, or clay on distal piedmont slopes; discontinuous lenses of volcanic ash (0.6-0.7 m.y.; Gile and others, 1981) are locally present; surficial layers, up to 10 ft thick, usually with prominent horizons of soil-carbonate accumulation and, locally, reddish-brown horizons of clay accumulation; gravelly carbonate horizons are commonly indurated forming pedogenic calcrete zones up to 5 ft thick; multiple buried soils are present in thicker deposits; generally less than 80 ft thick. *GRI Source Map ID 73352* (Geologic Map 57).

QTcc Camp Rice Formation, Fanglomerate Facies (early Pleistocene to Pliocene) - Calcite-cemented, reddish-brown to tan fanglomerate and conglomerate underlying Qcp, Qct, or Qcf (see actual source map for unit designations); locally intertongues with Qcf; locally contains basalt flows dated 3.1± 0.07 m.y. (Seager and others, 1984); as thick as 300 ft where the formation filled late Pliocene valleys cut into uplifts, probably much thicker in grabens below range-boundary faults. *GRI Source Map ID 73352* (Geologic Map 57).

Qcl - Camp Rice Formation, sediments associated with La Mesa surface (late Pliocene to middle Pleistocene)

Basin-floor sediments, the constructional top of which is the La Mesa geomorphic surface (shown on geologic map with horizontal-line pattern); generally consists of sand, silt, loam, or clay; includes fluvial, playa, and alluvial-flat deposits that are commonly wind reworked; surficial layers, up to 10 ft thick, have prominent horizons of soil-carbonate accumulation and, locally, reddish-brown horizons of clay accumulation; carbonate horizons are commonly indurated, forming pedogenic calcrete zones up to 5 ft thick; unit overlain by discontinuous veneer of Holocene eolian sand or, locally, by upper Quaternary playa or alluvial-flat deposits; up to 50 ft exposed; may be locally thicker in subsurface *GRI Source Map ID 73352* (Geologic Map 57).

QTcc - Camp Rice Formation, fanglomerate facies (Pliocene to early Pleistocene)

Calcite-cemented, reddish-brown to tan fanglomerate and conglomerate underlying Qcp, Qct, or Qcf; locally intertongues with Qcf; locally contains basalt flows dated 3.1± 0.07 m.y. (Seager and others, 1984); as thick as 300 ft where the formation filled late Pliocene valleys cut into uplifts, probably much thicker in grabens below range-boundary faults. *GRI Source Map ID 73352* (Geologic Map 57).

Tii - Intermediate-composition plutonic rocks (Oligocene)

Medium- to dark-gray, equigranular monzodiorite stock in the Organ Mountains (~ 33 m.y.; Seager, 1981) largely obliterated by younger phases of the Organ batholith; grandiorite stock of the central Jarilla Mountains (47.1 ± 1.8 m.y.; Beane and others, 1975) and andesite porphyry to diorite of Cristo Rey pluton and Vado Hills (47.1 ± 2.3 m.y. by analogy with Campus Andesite; Hoffer, 1970). *GRI Source Map ID 73352* (Geologic Map 57).

Tri - Non foliated rhyolite intrusives (Oligocene)

Nonporphyritic to slightly porphyritic siliceous dikes, sills and small plugs in the Robledo Mountains-Selden Canyon area and northwest Organ Mountains and devitrified, yellow-brown, chaotic intrusive rhyolite and breccia in the western Dona Ana Mountains, 35 m.y. (Seager and Clemons, 1975). *GRI Source Map ID 73352* (Geologic Map 57).

Tis - Silicic plutonic rocks (Oligocene)

Quartz-monzonite porphyry, granite, quartz syenite, and syenite of the Organ batholith; monzonite-porphyry dikes, small stocks, and a laccolith of the Dona Ana Mountains; monzonite-porphyry dikes, sills, and stocks of the Jarilla Mountains; and syenitic sills and associated stocks (?) or laccoliths (?) in the Hueco Mountains; the Organ and Dona Ana intrusives (32.8 m.y. and 33.7 m.y., respectively; Seager, 1981; Loring and Loring, 1980; Seager and others, 1976) are associated with thick cauldron-fill, ash-flow tuffs; the Organ intrusives also are related to mineralization in the Organ mining district; the

Jarilla intrusives (late Eocene? or Oligocene?) are related to mineralization in the Orogrande district. *GRI Source Map ID 73352* (Geologic Map 57).

Tlr - Love Ranch Formation (Eocene to Paleocene)

Pebble to boulder conglomerate, red mudstone, and sandstone derived from Paleozoic rocks and (locally) Precambrian granite; as thick as 2000 ft in southern San Andres Mountains where it consists of two members separated by an angular unconformity (Seager, 1981); in the Exxon Prisor and Grimm and others oil tests, fine-grained red beds, coal, and sandstone, probably correlative with the Love Ranch, are several thousand ft thick (see cross sections); elsewhere, outcrops indicate that the formation is less than 300 ft thick and is a basal conglomerate of the Palm Park or Orejon Formations; thickest sections are in the Laramide basins; thin sections are on Laramide uplifts. GRI *Source Map ID 73352* (Geologic Map 57).

TKru - Sarten and Dakota Sandstone, undivided and rocks correlative with Mancos Shale and Gallup Sandstone (Late Cretaceous to early Tertiary)

TKru Sarten and Dakota Sandstone with unknown rocks, undifferentiated and unknown rocks - yellow-, tan-, and gray-weathering, soft sandstone, shale, and siltstone and massive, crossbedded, gray quartzite; minor pelecypod coquina; approximately 260 ft thick in southern San Andres Mountains; Mancos Shale and Gallup Sandstone—greenish-gray to olive-brown sandstone, shale, and siltstone and gray shale containing ammonite coquinas; Tres Hermanos Sandstone Member of Mancos consists of approximately 300 ft of tan to olive-brown sandstone near middle of the Mancos section; tan, massive, crossbedded sandstone possibly correlative with Gallup Sandstone at the top of Mancos; Mancos Shale, Tres Hermanos Member and Gallup Sandstone are as thick as 1000 ft in southern San Andres Mountains (Seager, 1981); Cretaceous rocks in subsurface near Point of Rocks are approximately 600 ft thick (Exxon Prisor well). *GRI Source Map ID 73352* (Geologic Map 57).

No description provided for unknown rocks other than they are correlative with the Mancos Shale and Gallup Sandstone.

PZu - Paleozoic rocks, undifferentiated (Paleozoic)

No description provided. *GRI Source Map ID 73352* (Geologic Map 57).

Ps - San Andres Formation (Permian)

Gray to dark-gray, medium-bedded to massive, fetid limestone with a basal (Glorieta) sandstone; limestones are fossiliferous , and basal sandstone is yellowish and cross-laminated; 200 or more ft thick in Hembrillo Canyon (central San Andres Mountains) area (top eroded) but more than 600 ft thick north of map area; Glorieta Sandstone is 30-40 ft thick (Kottlowski and others, 1956) *GRI Source Map ID 73352* (Geologic Map 57).

Psy - San Andres Formation and Yeso Formation, undivided (Permian)

Thick- to medium-bedded, light-, and dark-gray, fine-grained limestone; minor beds of soft, yellow, fine-grained sandstone; mapped only in East Potrillo Mountains and in southern San Andres Mountains near Love Ranch where the unit may be all Yeso limestone; approximately 550 ft thick (Seager, 11981). *GRI Source Map ID 73352* (Geologic Map 57).

Py - Yeso Formation (Permian)

Light-brown to light-red sandstone, light-gray to white gypsum, and sandy, medium- to dark-gray, fetid limestone; limestones are moderately to sparsely fossiliferous; approximately 900 ft thick near Hembrillo Canyon (Kottlowski and others, 1956) and 660 ft thick in Exxon Prisor well, apparently thinning southward. *GRI Source Map ID 7335* (Geologic Map 57).

Pya - Yeso (?) beds and Abo Formation (Permian)

Unit consists of beds of Py (?) and Pa. *GRI Source Map ID 73352* (Geologic Map 57).

Pa - Abo Formation (Permian)

Reddish-brown siltstone, fine sandstone, and arkosic sandstone, with red, green, and gray shale; approximately 615 ft thick at Hembrillo Canyon (Kottlowski and others, 1956), thinning southward to approximately 425 ft thick in southern San Andres Mountains (Bachman and Myers, 1969; Seager 1981); in latter area, the Abo interfingers downward with Hueco Limestone and grades up into approximately 125 ft of brick-red, orange, and yellow sandstone, siltstone, and shale that may be correlative with part or all or the Yeso Formation; Abo and Yeso (?) beds (Pay) were included in the same map unit in the southern San Andres; in the Robledo and Dona Ana Mountains, approximately 320 ft and 265 ft respectively, of red to tan sandstone, siltstone, and shale (with many interbeds of fossiliferous limestone) form tongues of Abo within the Hueco Formation (Seager and others, in preparation); the Abo is Early Permian (Wolfcampian) and the Yeso is middle Permian (Leonardian) in age. *GRI Source Map ID 73352* (Geologic Map 57).

Ph - Hueco Formation (Permian)

Algal limestone, gastropod-echinoid-brachiopod limestone, fusulinid limestone, chert-pebble conglomerate, sandy limestone, gray shale, shaly limestone, siltstone, massive cherty limestone; in the Dona Ana Mountains, sandstone, porcellanite, black shale, and stromatolitic limestone; light to dark gray, cream, yellow, orange; Wolfcampian (Early Permian) age; 1,900 ft thick in the Robledo Mountains (including both a tongue of Abo Formation 320 ft thick in the upper part and, at the base, approximately 200 ft of limestone correlative with Bursum Formation; Seager and others, in preparation); as much as 2,250 ft thick in the Dona Ana Mountains (Seager and others, 1976); 1,450 ft thick in the southern San Andres Mountains, thinning northward to 325 ft thick at Hembrillo Canyon (Kottlowski and others, 1956; Bachman and Myers, 1969; Seager, 1981); 1,900 ft thick in the central Organ Mountains (Seager, 1981); 3,620 ft thick in the Grimm and other deep oil test (Thompson and Bieberman, 1975); at least 2,300 ft thick in the Franklin Mountains (Harbour, 1972); and 1,600 ft thick in the Hueco Mountains, including approximately 100 ft of basal Powwow Conglomerate Member (Hardie, 1958). *GRI Source Map ID 73352* (Geologic Map 57).

PNps - Panther Seep Formation (Pennsylvanian)

Brown to gray shale, sandstone, siltstone, gypsum, and fine-grained, laminated limestone, mostly of Late Pennsylvanian age, deposited in the Orogrande Basin; grades downward into Middle Pennsylvanian beds and upward into Hueco Formation; approximately 1,800 ft thick near Hembrillo Canyon; 2,500 ft thick in the Ash Canyon-San Andres Canyon area (Kottlowski and others, 1956); approximately 2,000 ft thick in the southern San Andres and Organ Mountains (Bachman and Myers, 1969; Seager, 1981); approximately 2,400 ft thick in the vicinity of the Jarilla Mountains (Kottlowski; 1960c; this study); approximately 1,200 ft thick in the Franklin Mountains (Harbour, 1972); and at least 1,200 ft thick in the northern Hueco Mountains (Hardie, 1958) *GRI Source Map ID 73352* (Geologic Map 57).

PNlc - Lead Camp Limestone (Pennsylvanian)

Massive, thick- to medium-bedded, fossiliferous, cherty, gray limestone and dolomite cyclically interbedded with shale; sandstone, conglomerate, and quartzite form local pods lower third of the unit; mostly Early to Middle Pennsylvanian in age; formation becomes very dolomitic, shaly, and gypsiferous at top where it weathers orange, yellow, or olive and grades into Panther Seep Formation (PNps); 654-870 ft thick in southern San Andres and northern Organ Mountains (Bachman and Myers, 1969; Seager, 1981); 1,200 ft thick in central San Andres Mountains near Hembrillo Canyon (Kottlowski and others, 1956). *GRI Source Map ID 73352* (Geologic Map 57).

PNlc/ls - Lead Camp Limestone overlying limestone (Pennsylvanian)

Unit consists of PNlc overlying ls.

Lead Camp Limestone (Pennsylvanian) - Massive, thick- to medium-bedded, fossiliferous, cherty, gray limestone and dolomite cyclically interbedded with shale; sandstone, conglomerate, and quartzite form local pods lower third of the unit; mostly Early to Middle Pennsylvanian in age; formation becomes very dolomitic, shaly, and gypsiferous at top where it weathers orange, yellow, or olive and grades into Panther Seep Formation (PNps); 654-870 ft thick in southern San Andres and northern Organ Mountains (Bachman and Myers, 1969; Seager, 1981); 1,200 ft thick in central San Andres Mountains near Hembrillo Canyon (Kottlowski and others, 1956). *GRI Source Map ID 73352* (Geologic Map 57).

"ls" is unknown and no information was present on the source map nor provided by the NMBGMR despite requests by the GRI to identify the unit.

MDr - Mississippian and Devonian Rocks (Mississippian and Devonian)

In descending order, map unit includes: Mississippian rocks— 1) Helms Formation—Intertonguing, gray, marine shale, fossiliferous and oolitic limestone, and crinoidal limestone; 132-150 ft thick at Bishop Cap and northern Franklin Mountains (Seager, 1981; Harbour, 1972), eroded or not deposited in Organ-San Andres Mountains; 2) Rancheria Formation—Black or dark-gray, thin- to medium-bedded micrite containing as much as 70% chert locally; crinoidal beds locally at top; 360 ft thick in the northern Franklin Mountains (Harbour, 1972), 220 ft thick at Bishop Cap, and as much as 260 ft thick in the northern Organ-southern San Andres Mountains (Seager, 1981), thinning northward to feather edge near Salt and Ash Canyons; 3) Las Cruces Limestone—Light-gray- to blue-gray-weathering, black micrite in thin medium, parallel beds; scattered black chert; 50-90 ft thick in northern Franklin Mountains (Harbour 1972), 0-15 ft thick at Bishop Cap, and approximately 125 ft thick in the northern Organ-southern San Andres Mountains (Seager, 1981), thinning northward to a feather edge in Ash-Salt Canyon area; 4) Lake Valley Limestone—Crinoidal limestone, cherty limestone, sandy limestone, and soft, platy micrite; locally very fossiliferous; 82 ft thick in Hembrillo Canyon area (Kottlowski and others, 1956), 300 ft thick near San Andres Canyon (Kottlowski and others, 1956), approximately 200-400 ft thick in northern Organ-southern San Andres Mountains, thinning to 34 ft thick at Bishop Cap (Seager, 1981); at least 100 ft thick in the Robledo Mountains (Seager and others, in preparation); 5) Caballero Formation—Brown weathering dolomitic siltstone and nodular, gray, fossiliferous, shaly limestone; 6-60 ft thick in Organ-southern San Andres Mountains (Seager, 1981); Devonian rocks—6) Percha Shale—Black, gray, and purplish-gray, fissile shale with yellow-weathering, fine-grained, medium-bedded limestone locally at base, and thin, nodular limestone and siltstone interbedded throughout; Percha map unit includes Onate, Sly Gap, Contadero, and Percha units of Kottlowski and others (1956); 0-140 ft thick (Kottlowski and others, 1956; Bachman and Myers, 1969; Seager, 1981); 7) Canutillo Formation—Fissile, tan siltstone and cherty black limestone; present only at Bishop Cap and northern Franklin Mountains; 44-97 ft thick (Harbour, 1972; Seager, 1981) *GRI Source Map ID 73352* (Geologic Map 57).

SOfm - Fusselman Dolomite and Montoya Group, undivided (Silurian and Ordovician)

Fusselman Dolomite (Silurian) - Massive, dark-gray, cherty dolomite in northern part of map area, pale-tan-weathering, light-gray, massive dolomite in southern areas; unit thins regularly northward because of post-Fusselman erosion; Fusselman is 640 ft thick in northern Franklin Mountains (Harbour, 1972), 310 ft thick at Bishop Cap (Seager, 1981), 110 ft thick in southern San Andres Mountains (Seager, 1981), 61 ft thick at Hembrillo Canyon (Kottlowski and others, 1956), and 250 ft thick in Robledo Mountains (Seager and others, in preparation). *GRI Source Map ID 73352* (Geologic Map 57).

Montoya Group (Ordovician) - Basal, tan, coarse-grained Cable Canyon Sandstone overlain by massive, dark-gray Upham Dolomite, followed upward by cherty, light- and dark-gray Aleman Dolomite; Montoya is capped by light-gray, fine-grained, thin-to medium-bedded Cutter Dolomite; Montoya is approximately 380 ft thick in northern Franklin Mountains (Harbour, 1972), 470 ft thick at Bishop Cap (Seager, 1981), 340-400 ft thick in the southern San Andres Mountains as far north as Hembrillo Canyon (Kottlowski and others, 1956; Bachman and Myers, 1969; Seager, 1981), and 340 ft thick Robledo Mountains (Seager and others, in preparation). *GRI Source Map ID 73352* (Geologic Map 57).

OCeb - El Paso Group and Bliss Sandstone, undivided (Ordovician and Cambrian)

El Paso Group (Ordovician) - Thin-bedded, siliceous, sandy, orange- to brown-weathering limestone in lower third, thick- to medium-bedded gray dolomite or limestone in upper two-thirds; unit thins northward because of pre-Montoya erosion; El Paso Group 1,340 ft thick in northern Franklin Mountains (Harbour, 1972), at least 810 ft thick at Bishop Cap (Seager, 1981), 780-870 ft thick in northern Organ-southern San Andres Mountains (Seager, 1981); and 540 ft thick near Hembrillo Canyon (Kottlowski and others, 1956). *GRI Source Map ID 73352* (Geologic Map 57).

Bliss Sandstone (Ordovician and Cambrian) - Brown, gray, or black hematitic sandstone, shale, siltstone, and quartzite; approximately 200 ft thick in northern Franklin Mountains (Harbour, 1972), 125-144 ft thick in northern Organ-southern San Andres Mountains (Seager, 1981), thinning to approximately 45 ft thick at Hembrillo Canyon (Kottlowski and others, 1956) *GRI Source Map ID 73352* (Geologic Map 57).

PCg - Precambrian rocks, granite (Precambrian)

Pink to brown, coarse-grained granite cut by systems of northeast- or east-trending diabase-amphibolite dikes in Organ-southern San Andres Mountains. *GRI Source Map ID 73352* (Geologic Map 57).

PCq - Precambrian rocks, quartzite (Precambrian)

Variable-colored, fine- to medium-grained quartzite, feldspathic quartzite, and arkose interbedded with lenses and beds of phyllite and mica schist. *GRI Source Map ID 73352* (Geologic Map 57).

PCs - Precambrian rocks, schist and phyllite (Precambrian)

Medium- to fine-grained, quartz-mica schist and phyllite with interbeds of quartzite, talc, and minor bodies of amphibolite. *GRI Source Map ID 73352* (Geologic Map 57).

PCa - Precambrian rocks, amphibolite (Precambrian)

Black to greenish-black dikes, sills, and irregular bodies of hornblende-plagioclase amphibolite; includes gneissic bodies locally, mixed with amphibolite. *GRI Source Map ID 73352* (Geologic Map 57).

PCmd - Precambrian rocks, metadiabase (Precambrian)

Black to greenish-black metadiabase sills and dikes near Grandview Canyon. *GRI Source Map ID 73352* (Geologic Map 57).

PCgn - Precambrian rocks, gneiss (Precambrian)

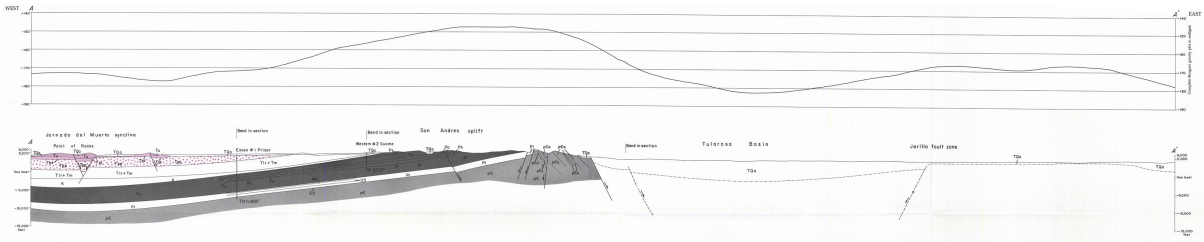
Quartz-feldspar-mica gneiss with granite pods; locally migmatic. *GRI Source Map ID 73352* (Geologic Map 57).

Geologic Cross Sections

The geologic cross sections present in the GRI digital geologic-GIS data produced for White Sands National Monument, New Mexico (WHSA) 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 GRI cross section abbreviation is unique.

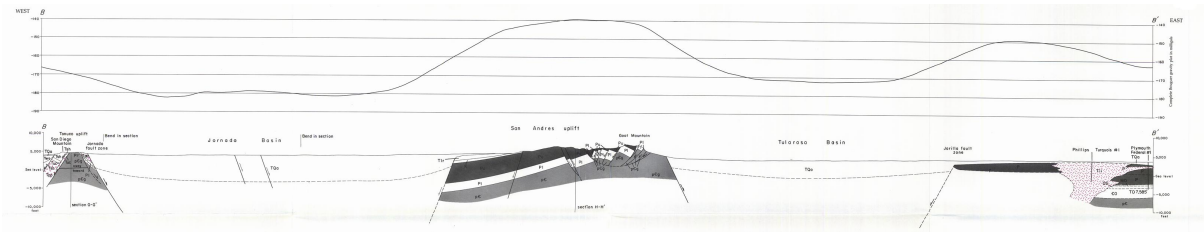
Cross section lines in the GRI digital geologic-GIS data are limited to the extent of the GRI "clipped" data, and thus the full cross section graphics depict a greater "section" than the section lines in the digital data.

Cross Section A-A'



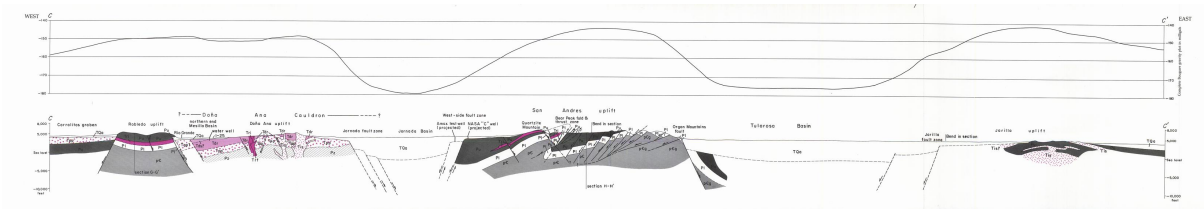
Extracted from: GRI Source Map ID 73352 (Geologic Map 57). Cross Section A-A' on source map.

Cross Section B-B'



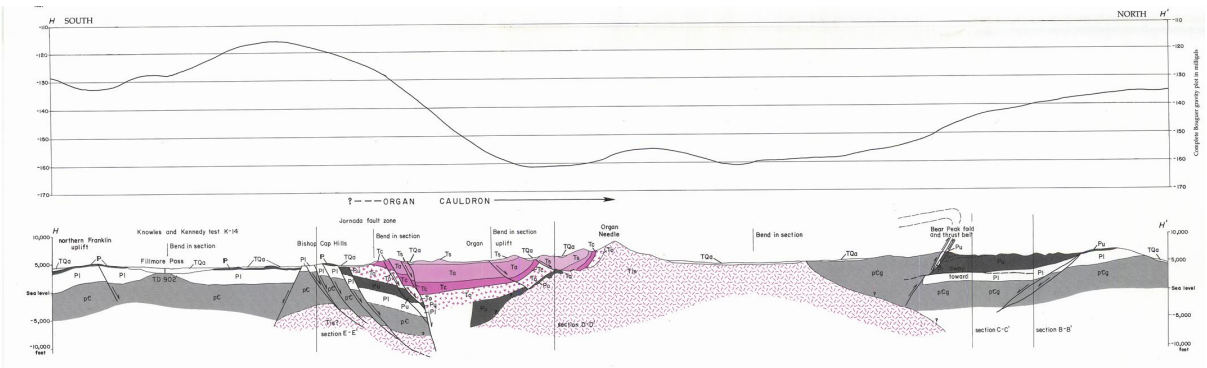
Extracted from: GRI Source Map ID 73352 (Geologic Map 57). Cross Section B-B' on source map.

Cross Section C-C'



Extracted from: GRI Source Map ID 73352 (Geologic Map 57). Cross Section C-C' on source map.

Cross Section D-D'



Extracted from: GRI Source Map ID 73352 (Geologic Map 57). Cross Section H-H' on source map.

GRI Source Map Citations

The GRI digital geologic-GIS map for White Sands National Monument, New Mexico (WHSA) was compiled from the following sources:

Seager, W.R., Hawley, J.W., Kottlowski, F.E., and Kelley, S.A., 1987, Geology of East Half of Las Cruces and Northeast El Paso 1º x 2º Sheets, New Mexico Bureau of Mines and Mineral Resources, Geologic Map 57, 1:125000 scale. (*GRI Source Map ID 75532*) (Geologic Map 57).

Fryberger, S.G., 2001, Reconnaissance Geomorphic Map of the Active White Sands Dune Field, New Mexico. Figure 2-17A. In Geological Overview of White Sands National Monument, Chapter 2: Quaternary Geology. (*GRI Source Map ID 75015)* (Figure 2-17A).

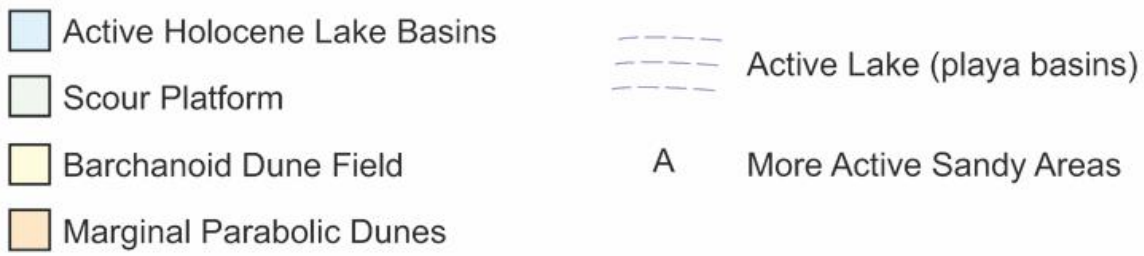
Geomorphic Map (Fryberger, 2001)

Fryberger, S.G., 2001, Reconnaissance Geomorphic Map of the Active White Sands Dune Field, New Mexico. Figure 2-17A, in Geological Overview of White Sands National Monument, Chapter 2: Quaternary Geology. (*GRI Source Map ID 75015*)

The full publication, Geological Overview of White Sands National Monument by Steven G. Fryberger, is available online at: http://www.nature.nps.gov/geology/parks/whsa/geows/index.htm

** In October of 2012 the GRI GIS data, as well as ancillary files pertaining to the GRI White Sands Dune Field map, were updated after additional edits and comments were provided by the source map author.

Geomorphic Map Legend

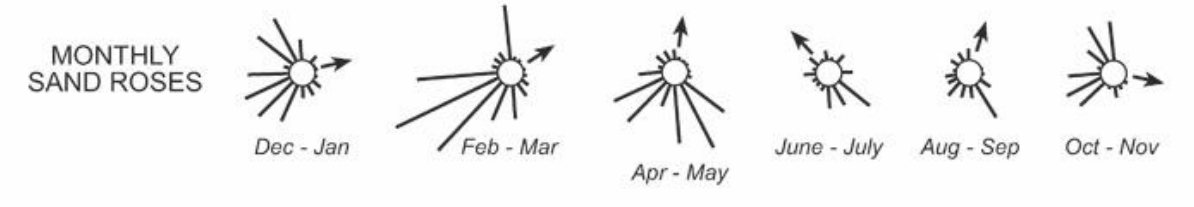


Extracted from: (Figure 2-17A)

Geomorphic Map Annual Sand Rose

Extracted from: (Figure 2-17A)

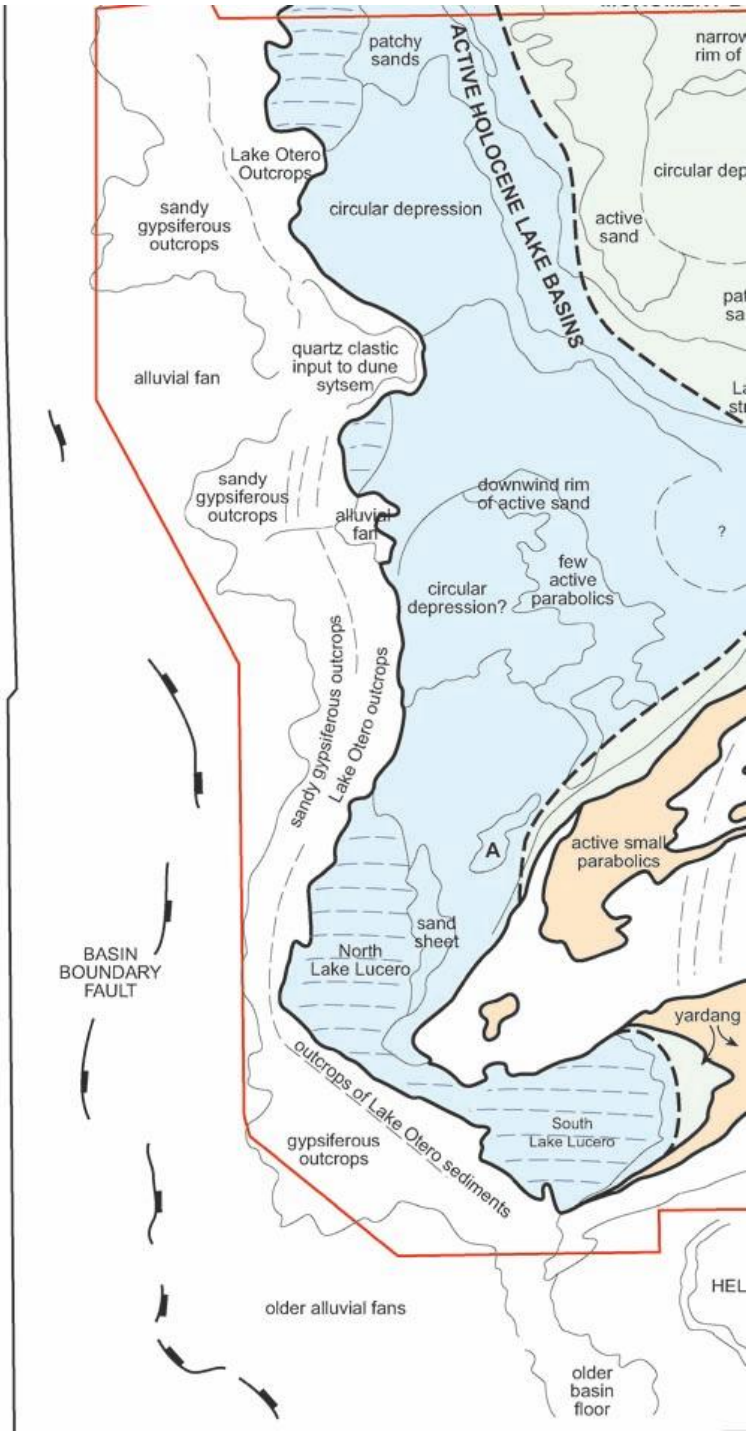
Geomorphic Map Monthly Sand Roses



Extracted from: (Figure 2-17A)

Geomorphic Map Data Issues

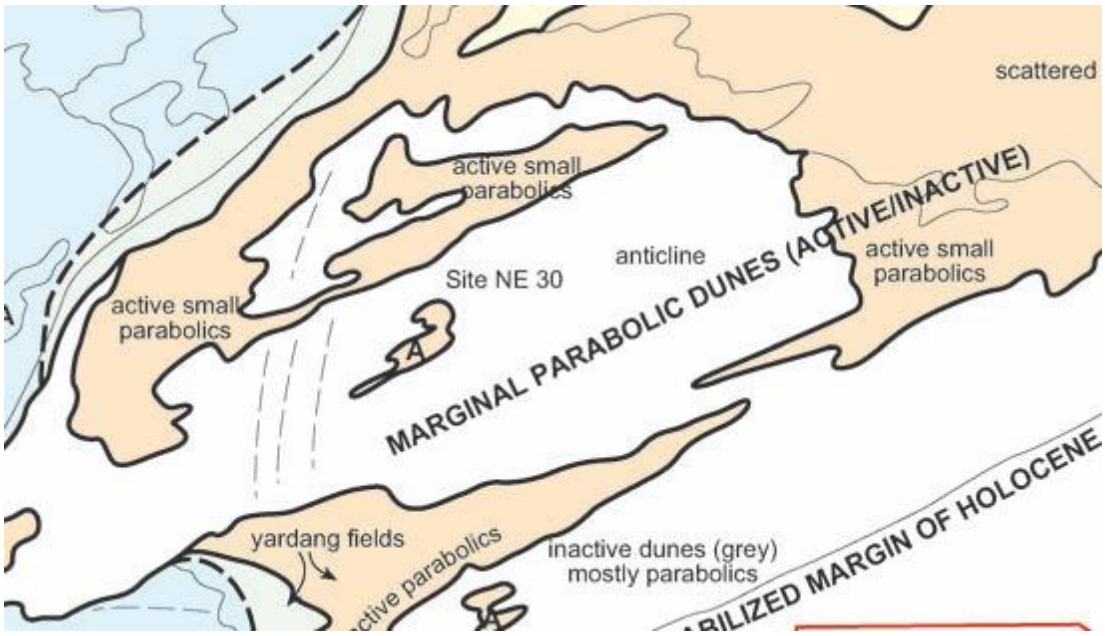
The following clipped images are taken from Fryberger Map and sent to the author addressing particular questions concerning the data and how it should be accurately captured and attributed for the Digital Geomorphic Map of White Sands National Monument and Vicinity, New Mexico.



Question # 1 from GRI:
Are the "outcrops of Lake Otero sediments" simply outcrops (or prominent outcrops or ridges) and not actual mapped linear geologic features?

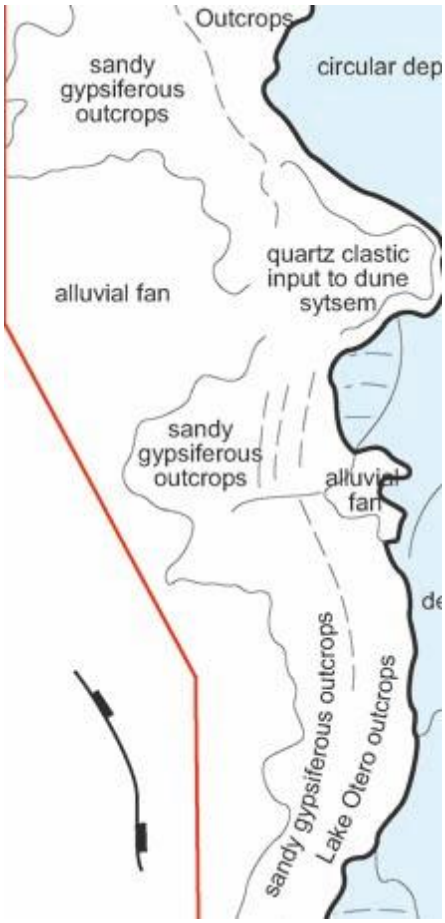
Steve Fryberger's response:

These Lake Otero Sediments are the remains of the older, larger Pleistocene Lake Otero that formerly covered much of the basin, that have not been deflated by wind or eroded by fluvial channels from the mountains. They consist mainly of bedded gypsum, with many small hopper crystals. Along the lake margin these occur as cliffs maybe 1-2 meters high. The Lake Lucero sediments are distinct from one the younger Lake Lucero sediments which consist where preserved of thin beds of clay and sand with some evaporites, limited to the Lake Lucero area. Holocene Lake Lucero essentially represents the diminished remains of the much older, much larger Lake Otero of Pleistocene age. Most of the gypsum at White Sands represents re-cycled Lake Otero Gypsum. Modern Lake Lucero is mainly a playa that is damp, and actually prevents the erosion of new sand for White Sands, while contributing very little new evaporites tot he dune field, if any.



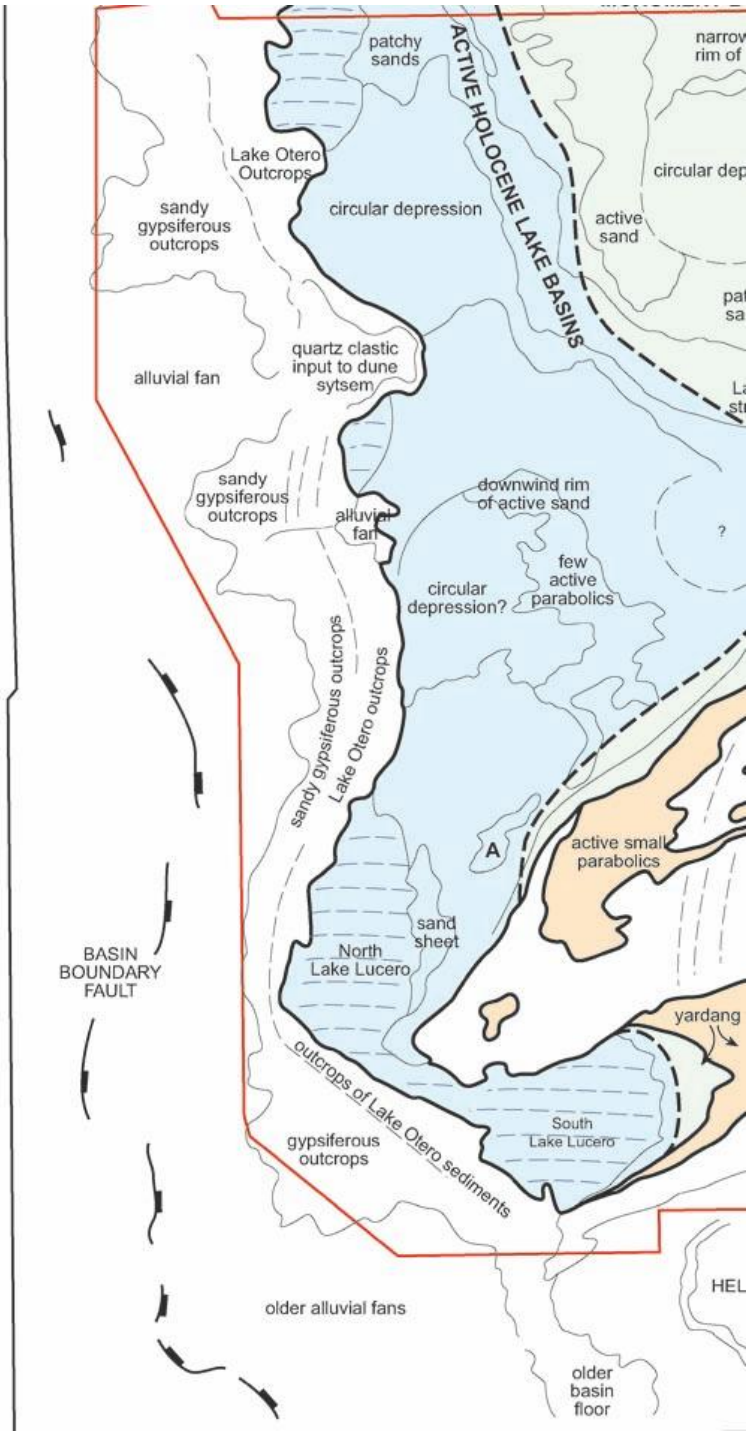
Question # 2 from GRI:
Are lines in Marginal Parabolic Dunes outcrops? Could these features could simply be dune ridges or perhaps prominent outcrops?

Steve Fryberger's response:
These lines represent subtle lineations seen on the air photographs that may represent a former shoreline trend appearing perhaps from beneath the parabolic dunes. They do not represent a geological unit per se.



Question # 3 from GRI:
"Sandy gypsiferous outcrop". Are these lines outcrops?

Comments by Steve Fryberger:Steve Fryberger's response:
These lines represent step-like surfaces eroded into the older sandy gypsiferous outcrops. If you were walking out there, they would look like wide stairs going up the alluvial fan. They represent a weathering phenomenon, but are not themselves a geological unit, although clearly, something caused the step-like outcrop expression. Maybe bedding within the sandy, gypsiferous outcrops. I can recall whether the sandy gypsiferous outcrops are stratigraphically above or below the Lake Otero sediments. I suspect that they represent an older set of deposits stratigraphically below Lake Otero.



Question # 4 from GRI:
Boundary Basin Fault. Do the fault lines (basin boundary faults) indicate faults in the general area of the line and not actual mapped fault lines?

Steve Fryberger's response:
These lines were traced from the air photos, and probably do represent the traces of faults that extend

into the older sediments. However, they are not as certain as outcrops of the much younger sediments since OI did not field check them for displacement, etc. They represent marks seen on the air photos, but are probably not the only faults out there, etc. It seemed worth putting them on to define the "playing field" for younger Quaternary sediments of White Sands Dune Field.

All clipped images extracted from: (Figure 2-17A).

Geologic Map 57 (Seager et. al., 1987)

Seager, W.R., Hawley, J.W., Kottlowski, F.E., and Kelley, S.A., 1987, Geology of East Half of Las Cruces and Northeast El Paso 1º x 2º Sheets, New Mexico Bureau of Mines and Mineral Resources, Geologic Map 57, 1:125000 scale. (*GRI Source Map ID 75532*)

Digital Version of Source Map

Geologic Map 57 in Digital Form Using Arc/Info and Arc/View Format:

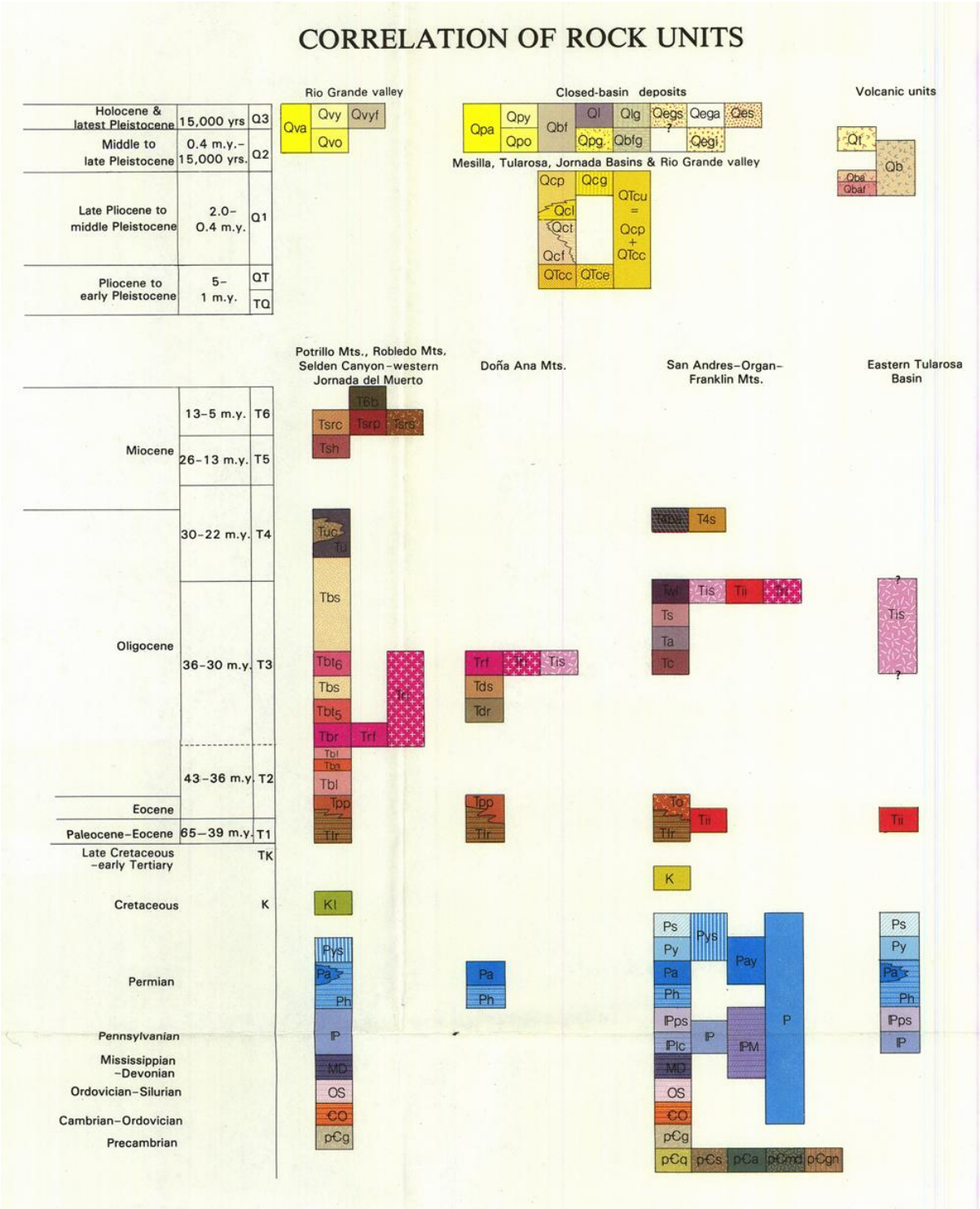
Digital Conversion By P. Dinterman, J. Kennedy, B. Nolen, and G. Jones in 1999

This is a digital draft GIS coverage map of NMBMMR GM-57. Construction of this GIS database was done in conjunction with New Mexico State University, New Mexico Bureau of Mines and Mineral Resources, and New Mexico Water Resources Institute. A review of this digital database is being conducted by the original authors. The coordinate system is UTM, Zone 13, NAD 27. The digital coverage was converted from a NMBMMR scribe sheet into an ARC/Info warp grid.

Geologic Map 57 Acknowledgments

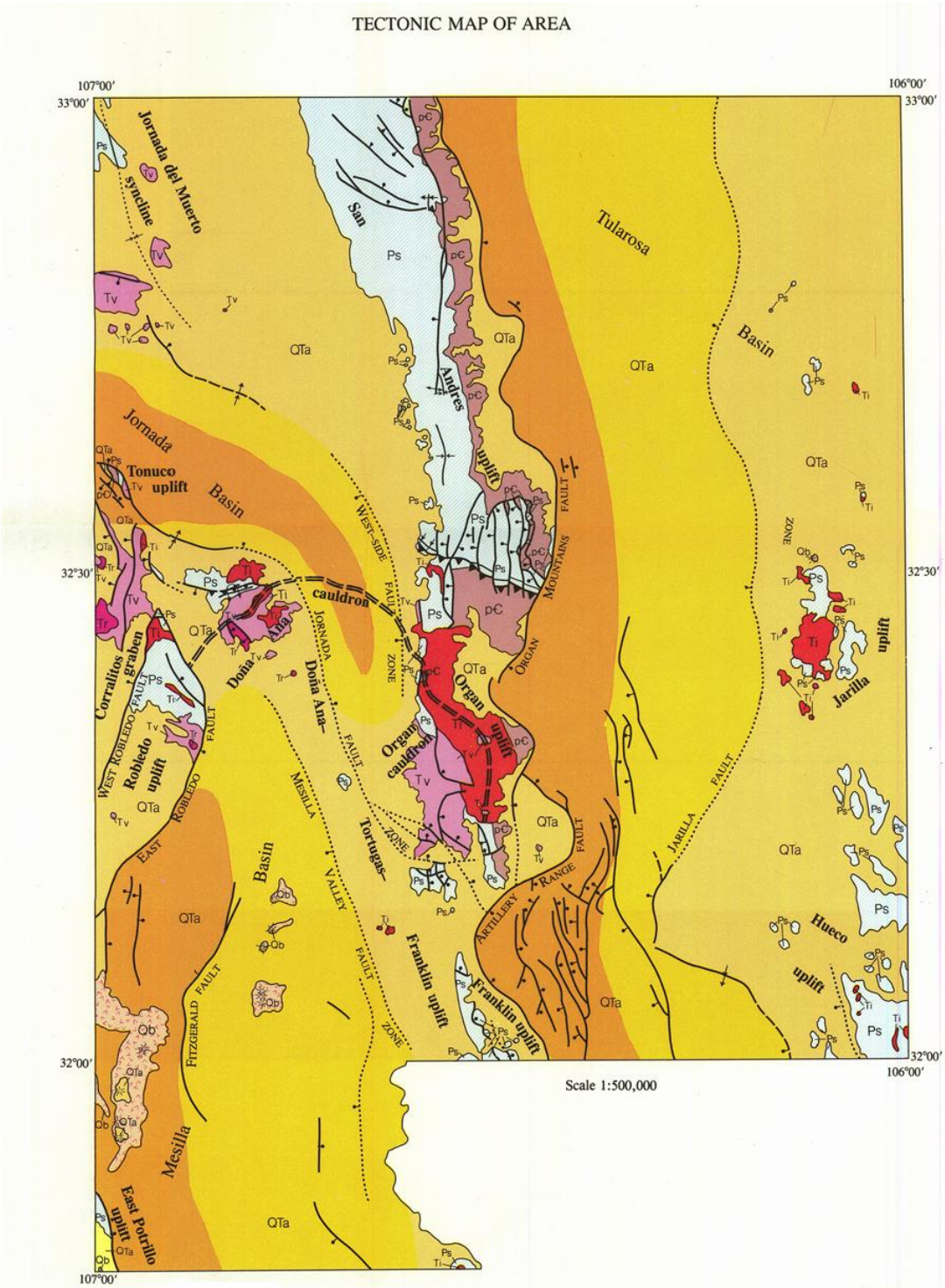
The authors are grateful to Warren Bennett and the N.M. Highway Department for supplying aerial photos for this project and to W.E. King for his help with the subsurface stratigraphy of the Tularosa Basin. We also thank Sam Thompson III, Jim Gross, and Robert G. Myers for help in locating well data for various parts of the area. R.G. Keller and P.Daggett, University of Texas (El Paso), supplied gravity data (sheets 2 and 3), and we appreciate their cooperation, S. Lopez helped in certain aspects of the field work and compilation. We are also grateful to R.E. Kelley for contributing his unpublished reconnaissance geologic map of the chicken Well 15-min quadrangle (northwest corner of sheet 1). Finally, we thank Richard Duncan, Clyde Treat, and Fred Janer for their assistance in obtaining access to White Sand Missile Range. Likewise, we appreciate Larry Mixon's help in securing access to Holoman Air Force Base. The New Mexico Bureau of Mine sand Mineral Resources financed the mapping of this sheet. We are grateful to Steve Blodgett and Jane Calvert Love for their careful editorial work and to Mickey Wooldridge and James Brannan for drafting. (Geologic Map 57).

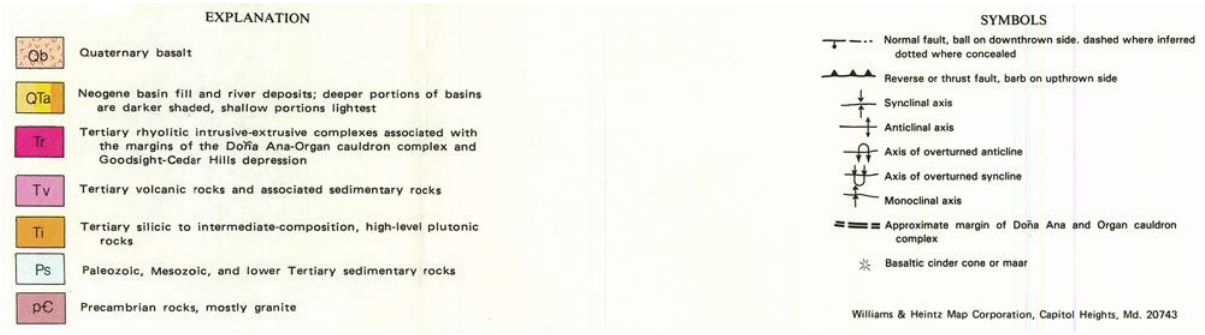
Geologic Map 57 Correlation of Units



Extracted from: (Geologic Map 57).

Geologic Map 57 Tectonic Map of Area





Extracted from: (Geologic Map 57).

Geologic Map 57 Table 1

TABLE 1—Wells used for stratigraphic control in this study. See geologic map for well locations and cross sections (sheet 2) for additional information. Number adjacent to well symbol on geologic map corresponds to numbered well in this table.

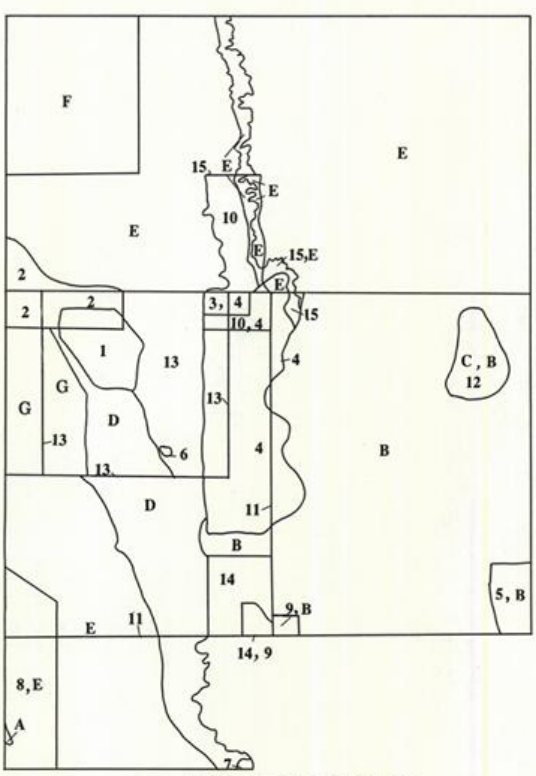
Well name	Total depth (in ft)	Units (youngest to oldest)	Thickness (in ft)
1. Texaco No. 1 Weaver Federal	6,620	Miocene and younger	
		basin fill	2,430
		volcanics	4,190
		Bottom in volcanics	
2. Grimm, Hunt, Brown, and American Arctic Ltd. No. 1 Mobil 32	21,759	Miocene and younger basin fill	1,920
		Middle Tertiary volcanics	3,850
		Lower Tertiary sedimentary rocks	7,030
		Cretaceous	1,050
		Jurassic	670
		Paleozoic	6,259
		Bottom in Montoya Dolomite	
3. Water test hole	296	Bottom in andesite	
4. K–14	900	Basin fill	888
		Bottom in granite	
5. K–13	976	Basin fill	970
		Bottom in limestone	
6. L–1	1,208	Bottom in basin fill	
7. G–2	1,209	Bottom in basin fill	
8. Ernest 1 Fee	3,941	Basin fill	1,436 (?)
		Pennsylvanian rocks	2,505 (?)
		Bottom in Pennsylvanian	
9. Page 1 Mans	731	Basin fill	731
		Bottom in basin fill	
10. Bechtel 1 Maris	986	Bottom in Pennsylvanian(?) or Hueco(?)	
11. Boles and Associates No. 1 Federal	5,180	Basin fill	3,790
		Volcanics	1,390
		Bottom in volcanics(?)	
12. Snowden and Clary No. 1 State	2,585	Basin fill	526
		Abo and Hueco(?)	894
		Hueco Formation	445
		Hueco Formation and Upper Pennsylvanian	720
		Bottom in Upper Pennsylvanian	
13. Picacho Oil and Gas Syn No. 1	3,196	Camp Rice Formation	165
		Palm Park and Love Ranch Formations	2,175
		Paleozoics	856
		Bottom in Hueco(?)	
14. Parker No. 1 State	4,260	Basin fill	4,260
15. Viking No. 1 Cox (State)	3,224	Basin fill	3,224
16. Parker et al. No. 1 Simmons	2,785	Basin fill	2,785
17. Sinclair No. 1 Federal Doña Ana 18	6,510	Camp Rice fanglomerate	280
		Palm Park Formation	2,570
		Paleozoics	3,660
		Bottom in Bliss Sandstone	
18. Water well	406	Basin fill	400
		Doña Ana Rhyolite	6
		Bottom in Doña Ana Rhyolite	
19. Las Cruces city test well 3 (approximately located)	1,017	Basin fill	650
		Palm Park Formation	367
		Bottom in Palm Park Formation	
20. T–14	6,015	Fine-grained basin fill	5,200
		Conglomerate and conglomeratic sandstone	815
		Bottom in basin fill	
21. Phillips Petroleum No. 1 Turquois	5,436	Basin fill	300
		Igneous rocks	5,136 +
		Bottom in diorite	
22. Plymouth Oil No. 1 Federal	7,585	Basin fill	1,180 +
		Abo Formation (including 400 ft of igneous rock)	1,420
		Pennsylvanian	3,570
		Helms Formation	130
		Rancheria Formation	340
		Lower Mississippian	45
		Percha Shale	5
		Fusselman Dolomite	120
		Montoya Group	450
		El Paso Group	325 +
		Bottom in El Paso Group	
24. Texaco 1 Federal E	7,785	Basin fill	175
		San Andres Limestone	550
		Yeso Formation	800
		Hueco and Abo Formations	1,805
		Upper Pennsylvanian	2,445
		Des Moines	445
		Atoka–Morrow	380
		Mississippian	400
		Percha Shale	50
		Fusselman Dolomite	200
		Montoya Group	280
		El Paso Group	260 +
		Bottom in El Paso Group	
25. Exxon No. 1 Prisor	11,650	Basin fill	250
		Palm Park Formation	1,650
		Love Ranch Formation–McRae Formation (mostly red shale)	2,860
		Basal McRae Formation (conglomerate)	140
		Cretaceous	600
		San Andres Limestone	280
		Yeso Formation	660
		Abo Formation	900
		Hueco Formation	50 (?)
		Pennsylvanian (Virgilian fusulinids 850–872 ft from top; Desmoinesian fusulinids 1,990–2,010 ft from top; upper Derryan(?) fusulinids approximately 2,440 ft from top)	2,770
		Mississippian	200
		Percha Shale	182
		Fusselman Dolomite	52
		Montoya Group	272
		El Paso Group	574
		Bliss Sandstone	156
		Precambrian	54 +
		Bottom in Precambrian	
26. Western 2 Guame Federal	3,507	Bottom in Bursum(?)	
27. Bruton 1 Guame	2,202	Bottom in Yeso	
28. Jornada test well no. 2	1,207	Basin fill	1,207
29. Hacienda Acres well	1,174	Basin fill	1,174
30. U.S. Army Radar Station well	685	Camp Rice Formation	440
		Palm Park Formation	245
31. Las Cruces city well no. 37	1,010	Basin fill	1,010
32. Las Cruces city well no. 36	1,500	Basin fill	1,500
33. U.S. Geological Survey test well	2,500	Basin fill	2,370
		Volcanics(?)	130
34. Asarco well	1,650	Basin fill	1,650
35. L'eggs well	1,870	Basin fill	1,660 +
		Volcanics	210
		Bottom in volcanics	
36. Mesquite well	2,033	Basin fill	2,033
37. Vado well	1,307	Basin fill	1,307
38. Berino well	1,212	Basin fill	1,212
39. South Lizard well	298	Basin fill	288
		Diorite	10
40. T–3 test well	450	Lower part of hole in bedrock	
41. T–12 test well	1,820	Basin fill	1,820
42. T–11 test well	1,808	Basin fill	1,808
43. T–15 test well	2,034	Basin fill	2,034
44. T–18 test well	894	Basin fill	780
		Granite	114
		Bottom in granite	
45. T–16 test well	2,007	Basin fill	2,007
46. Water test well	945	Basin fill	940
		Pennsylvanian(?)	5
		Bottom in Pennsylvanian(?)	
47. Las Cruces city test well no. 1	785	Basin fill	785

Table 1 continued.

23. Texaco 1 Federal G	7,660	Yeso Formation (well spudded in Yeso)	1,175
		Abo Formation (includes 200-ft-thick sill between 1,250–1,450 ft depth)	1,795
		Hueco Formation	300
		Panther Seep Formation	2,260 ±
		Middle, Lower Pennsylvanian (includes 100-ft-thick sill between 6,420–6,520 ft depth)	1,180 ±
		Mississippian	290
		Percha Shale	65
		Fusselman Dolomite	177
		Montoya Group	338
		El Paso Group	80 +
		Bottom in El Paso Group	
48. Las Cruces city test well no. 2	877	Camp Rice Formation	250
		Rhyolite porphyry	627
49. N.M.S.U. geothermal test	1,200	Camp Rice fluvial deposits	325
		Camp Rice and older fanglomerate	875
50. Chaffee Geothermal, Ltd. well 35–25	950	Alluvium	560
		Paleozoic limestone (Hueco? Formation)	390
51. Chaffee Geothermal, Ltd. well 12–24	1,315	Alluvium	400
		Paleozoic limestone	370
		Paleozoic dolomite	475
		Paleozoic limestone	60
52. Chaffee Geothermal, Ltd. well 55–25	2,645	Camp Rice fluvial deposits	230
		Camp Rice and older fanglomerate	465
		Orejon Andesite	735
		Paleozoic limestone and dolomite (faulted)	1,215
53. Santa Teresa Estates water well	1,980	Santa Fe Group	1,680
		Volcanic(?) rocks	300
54. Amax test 1	1,893	Basin fill	1,892
		Bottom in volcanics?	
55. NASA "C"	1,011	Basin fill	453
		Rhyolite and Love Ranch Formation(?)	558
		Bottom in Love Ranch Formation(?)	
56. Amax 2	1,920	Basin fill	1,620
		Orejon Andesite	300
		Bottom in andesite	

Extracted from: (Geologic Map 57).

Geologic Map 57 Sources of Data



SOURCES OF DATA

Explanation

Published maps

1) Seager, Kottlowski, and Hawley, 1976
2) Seager, 1975
3) Kottlowski, 1960b, c
4) Seager, 1981
5) Hardie, 1958 (with modifications by present authors)
6) King and Kelley, 1980
7) Lovejoy, 1976
8) Hoffer, 1976 (with modifications by present authors)
9) Harbour, 1972
10) Bachman and Myers, 1969 (with modifications by present authors)
11) Kottlowski, 1960a
12) Schmidt and Craddock, 1962
13) Gile, Hawley, and Grossman, 1981; Gile, 1981; Gile and Grossman, 1979
14) Kelley and Matheny, 1983
15) Condie and Budding, 1979 (with modifications by present authors)

Unpublished maps

A) W. E. Bowers, 1960, M.S. thesis
B) W. R. Seager and J. W. Hawley, 1981, reconnaissance maps
C) W. R. Seager, 1961, M.S. thesis
D) S. A. Kelley, 1979, reconnaissance maps
E) W. R. Seager, 1981, 1982, reconnaissance maps
F) R. E. Kelley, 1979, reconnaissance map
G) W. R. Seager, J. W. Hawley, F. E. Kottlowski, and W. E. King, in preparation

Extracted from: (Geologic Map 57).

Geologic Map 57 References

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Extracted from: (Geologic Map 57).

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This document was developed and completed by Georgia Hybels (NPS GRD, Lakewood, Colorado) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory(GRI) Program. Quality control of this document by Stephanie O'Meara and Jim Chappell (Colorado State University).

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