U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Chaco Culture National Historical Park

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Chaco Culture National Historical Park

chcu_geology.pdf

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Geologic Resources Inventory Ancillary Map Information Document for Chaco Culture National Historical Park

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Geologic Resources Inventory Map Document

Chaco Culture National Historical Park, New Mexico

Document to Accompany Digital Geologic-GIS Data

chcu_geology.pdf

Version: 1/8/2016

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Chaco Culture National Historical Park, New Mexico (CHCU).

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 Chaco Culture National Historical Park, New Mexico (CHCU):

Compiled Park Extent and Vicinity Geologic Map

Digital Geologic Map of Chaco Culture National Historical Park and Vicinity, New Mexico (*GRI MapCode CHCU*)

The park and vicinity geologic map was compiled from the GRI component geologic maps (listed below), and thus all of the component source maps were used to produce this map as well.

Component Geologic Maps

GRI source maps are listed (indented) with each component map.

Digital Geologic Map of Part of Chaco Culture National Historical Park, New Mexico (*GRI MapCode CCNH*)

Scott, Glenn R., O'Sullivan, Robert, B., and Weide, David L., 1984, Geologic Map of the Chaco Culture National Historical Park, Northwestern New Mexico: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1571, scale 1:50,000. (*GRI Source Map ID 1055*).

*** Source for the Kin Klizhin Ruins and Sergeant Ranch quadrangles, and the upper third of the Pueblo Bonito quadrangle. The lower two-thirds of the Pueblo Bonito quadrangle was not captured from this source map (but the extent was from another source map, I-1777; see below).*

O'Sullivan, R.B., Scott, G.R., Weide, D.L., 1979, Preliminary Geologic Map of the Kin Klizhin Ruins Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey, Miscellaneous Field Studies Map MF-1094, scale 1:24,000. *(GRI Source Map ID 1049).*

*** Source for only two geologic contacts, contacts used to enclose two geologic unit areas on the map.*

Digital Geologic Map of the Northern Part of the Chaco Canyon-2 Quadrangle, New Mexico (*GRI MapCode CHC2*)

Kover, A.N., 1960, Photogeologic Map of the Chaco Canyon-2 Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-315, 1:62,500 scale. (*GRI Source Map ID 1057*).

*** Source for the Seven Lakes NW and Seven Lakes NE quadrangles. The extent of the Seven Lakes and Seven Lakes SE quadrangles was not captured from this source map.*

Digital Geologic Map of the Crownpoint Quadrangle, New Mexico (*GRI MapCode CRWN*)

Robertson, Jacques F., 1986, Geologic Map of the Crownpoint Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Geologic Quadrangle Map GQ-1596, scale 1:24,000. (*GRI Source Map ID 8387*).

*** The full extent of this source map was captured.*

Digital Geologic Map of the Northeastern Part of the Gallup 30' X 60' Quadrangle, New Mexico (*GRI MapCode GALL*)

Dillinger, Jean K., 1990, Geologic Map of the Gallup 30' x 60' Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Miscellaneous Investigations Series Map I-2009 (Sheet 1), scale 1:100,000. (*GRI Source Map ID 1060*).

Dillinger, Jean K., 1990, Structure Contour Map of the Gallup 30' x 60' Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Miscellaneous Investigations Series Map I-2009 (Sheet 2), scale 1:100,000. (*GRI Source Map ID 191*).

** For both source maps only the extent of the Milk Lake and Nose Rock quadrangles was captured.*

Digital Geologic Map of the Heart Rock Quadrangle, New Mexico (*GRI MapCode HERO*)

Robertson, Jacques F., 1992, Geologic Map of the Heart Rock Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Geologic Quadrangle Map GQ-1697, scale 1:24,000. (*GRI Source Map ID 1050*).

*** The full extent of this source map was captured.*

Digital Geologic Map of the La Vida Mission Quadrangle, New Mexico (*GRI MapCode LVMI*)

Miller, Ralph, L., Carey, Mary Alice, and Thompson-Rizer, Carolyn L., 1991, Geology of the La Vida Mission Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey, Bulletin 1940, scale 1:24,000. (*GRI Source Map ID 1047*).

*** The full extent of this source map was captured.*

Digital Geologic Map of the Southern Part of the Pueblo Bonito Quadrangle, New Mexico (*GRI MapCode PUBO)*

Mytton, James W., and Schneider, Gary B., 1987, Interpretive Geology of the Chaco Area, Northwestern New Mexico: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1777, scale 1:24,000. (*GRI Source Map ID 1048*)

** Source for only the southern two-thirds of the Pueblo Bonito quadrangle.*

Digital Geologic Map of the Pueblo Pintado Quadrangle, New Mexico (*GRI MapCode PUPI*)

Weide, David L., Scott, Glenn, R., and Mytton, James W., 1980, Geologic Map of the Pueblo Pintado Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Miscellaneous Field Studies Map MF-1219, scale 1:24,000. (*GRI Source Map ID 1052*).

*** The full extent of this source map was captured.*

Compiled Park Extent and Vicinity Coal Map

Digital Coal Resources Map of Chaco Culture National Historical Park and Vicinity, New Mexico (*GRI MapCode CHCO*)

This map was compiled from the following source maps. All geologic features were captured from the below source maps, however, for some measured localities and stratigraphic section lines only a portion of the information associated with a feature was captured in the GIS data. Users should refer to coal bed thickness drill hole figures and other ancillary information found with each source coal map to obtain some of this information.

Berge Exploration Inc., 1979 Coal Resource Occurrence and Coal Development Potential Maps of the Heart Rock Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-642, scale 1:24,000. (*GRI Source Map ID 32100*).

Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Kin Klizhin Ruins Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-1047, scale 1:24,000. (*GRI Source Map ID 41629*).

Berge Exploration Inc., 1979, Federal Coal Resource Occurrence and Coal Development Potential Maps of the La Vida Mission 7 1/2-Minute Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-1378, scale 1:24,000. (*GRI Source Map ID 74539*).

Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Milk Lake Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-1377, scale 1:24,000. (*GRI Source Map ID 74535*).

Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Nose Rock Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-641, scale 1:24,000. (*GRI Source Map ID 32099*).

Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Seven Lakes NW Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-1123, scale 1:24,000. (*GRI Source Map ID 74537*).

Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Seven Lakes NE Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-638, scale 1:24,000. (*GRI Source Map ID 74537*).

Dames Moore., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Crownpoint Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-1125, scale 1:24,000. (*GRI Source Map ID 41614*).

Dames and Moore, 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Pueblo Bonito Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-156, scale 1:24,000. (*GRI Source Map ID 30911*).

Dames and Moore, 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Pueblo Pintado Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-113, scale 1:24,000. (*GRI Source Map ID 30647*).

Dames and Moore, 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Sargent Ranch Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-157, scale 1:24,000. (*GRI Source Map ID 29890*).

Map Unit List and Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below. Unit symbol, name and age are only listed with a unit description if the unit has multiple unit descriptions and/or if any these (the unit symbol, name and/or age) were changed on the GRI digital geologic-GIS map.

Cenozoic Era

Quaternary Period
Qaf1 - Earth dam
Qaf2 - Gravel fill
Qsl - Soil, large area
Qss - Soil, small area
Qsb - Sandstone blocks
Qs - Surficial deposits
Qae - Alluvium and eolian deposits
Qls - Landslide deposits
Qfd - Fan deposit
Qswd - Slope-wash deposit
Qal - Alluvium
Qa1 - Alluvial deposits, Unit 1
Qn - Naha Alluvium of Hack (1941)
Qnt - Naha and Tsegi Alluviums of Hack (1941), undivided
Qa2 - Alluvial deposits, Unit 2
Qe - Younger eolian deposits
Qsd - Dune deposit
Qa3 - Alluvial deposits, Unit 3
Qsw - Sheetwash alluvium
Qes - Eolian sand
Qess - Eolian sand and soil
Qoe - Older eolian deposits
Qoesd - Older eolian deposits, seif dunes
Qp - Pediment gravel
Qf - Alluvial fan deposits
Qc - Colluvium
Qt - Talus deposits
Qlsb - Landslide deposits and slump blocks
Qj - Jeddito Alluvium of Hack (1941)
Qgs7 - Gravelly sand
Qgs6 - Gravelly sand
Qgs5 - Gravelly sand
Qoa - Older alluvium
Qoac - Older alluvium, calcrete
Qg - Gravel
Qtl - Low terrace deposit
Qti - Intermediate terrace deposit
Qth - High terrace deposit

Mesozoic Era

Cretaceous Period

Kk - Kirtland Shale
Kf - Fruitland Formation
- Kfr - Fruitland Formation coal zone
- Kfr3 - Fruitland 3 coal bed
- Kfr2 - Fruitland 2 coal bed
- Kfr1 - Fruitland 1 coal bed

Kpc - Pictured Cliffs Sandstone
Kl - Lewis Shale
- Klt - Tongue of Lewis Shale

Kch - Cliff House Sandstone
- Kchu - Cliff House Sandstone, upper sandstone bed
- Kchwu - Cliff House Sandstone, white to light-gray sandstone, upper unit
- Kchwl - Cliff House Sandstone, white to light-gray sandstone, lower unit
- Kchm - Cliff House Sandstone, middle sandstone
- Kchi - Cliff House Sandstone, intermediate unit
- Kchl - Cliff House Sandstone, lower sandstone
- Kchz - Cliff House Sandstone coal zone

Kmf - Menefee Formation
- Kmft - Tongue of Menefee Formation
- Kmfa - Menefee Formation, Allison Member
  - Kmfaz - Menefee Formation, Allison Member, coal zone
  - Kmfav - Menefee Formation, Allison Member, La Vida Beds of Miller (1984)
    - Kmfavsd - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), sandstone dike
    - Kmfaw4 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), upper coal bed
    - Kmfaw3 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), upper coal bed
    - Kmfaw2 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), coal bed W2
    - Kmfavn2 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), coal bed N2
    - Kmfave2 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), coal bed E2
    - Kmfaw1 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), coal bed W1
    - Kmfavn1 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), coal bed, N1
    - Kmfave1 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), coal bed, E1
  - Kmfaj - Menefee Formation, Allison Member, Juans Lake Beds of Miller (1984)
  - Kmfal - Menefee Formation, lower part of Allison Member
- Kmfc - Menefee Formation, Cleary Coal Member
  - Kmfc3 - Menefee Formation, Cleary No. 3 coal bed
  - Kmfc2 - Menefee Formation, Cleary No. 2 coal bed
  - Kmfc1 - Menefee Formation, Cleary No. 1 coal bed
- Kmfz - Menefee coal zone

Point Lookout Sandstone
- Kplu - Point Lookout Sandstone, upper sandstone member
- Kplh - Point Lookout Sandstone, Hosta Tongue

Mancos Shale
- Kms - Mancos Shale, Satan Tongue
- Kmm - Mancos Shale, Mulatto Tongue
- Km - Mancos Shale, main body
- Kmj - Mancos Shale, Juana Lopez Member
- Kmw - Mancos Shale, Whitewater Arroyo Member

Crevasse Canyon Formation
- Kcg - Crevasse Canyon Formation, Gibson Coal Member
- Kcda - Crevasse Canyon Formation, Dalton Sandstone Member

Kcb - Crevasse Canyon Formation, Borrego Pass Lentil
Kcdi - Crevasse Canyon Formation, Dilco Coal Member
Gallup Sandstone
Kg - Gallup Sandstone, main body
Kgb - Gallup Sandstone, bed B
Kga - Gallup Sandstone, bed A
Dakota Sandstone
Kdt - Dakota Sandstone, Twowells Tongue
Kd - Dakota Sandstone, main body

Jurassic Period
Morrison Formation
Jmb - Morrison Formation, Brushy Basin Member,
Jmbs - Morrison Formation, Brushy Basin Member, sandstone lenses
Jmw - Morrison Formation, Westwater Canyon Member
Jmr - Morrison Formation, Recapture Member

Qaf1 - Earth dam (Recent)

Mapped from 1975 aerial photographs and may not fit topographic base. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qaf2 - Gravel fill (Recent)

Gravel stockpiles and road fill. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qsl - Soil, large area (Holocene)

sl - Soil (Holocene) Developed principally on mudstone of the Menefee Formation. Sedentary soil in large uninterrupted area. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qss - Soil, small area (Holocene)

ss - Soil (Holocene) Developed principally on mudstone of the Menefee Formation. Sedentary soil in small area or larger area broken up by other units. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qsb - Jumbled fine-grained sandstone blocks (Quaternary?)

sb, sb? Jumbled fine-grained sandstone blocks (Holocene)
Forms artificial island in Juans Lake. Only one of five islands visited. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qs - Surficial deposits (Quaternary)

No description provided on source map. (*GRI Source Map ID 1057*) (Seven Lakes NW and Seven Lakes NE Quadrangles).

Qae - Alluvium and eolian deposits (Holocene and Pleistocene?)

Windblown silt and sand on mesas, benches, and in broad valleys; reworked in part by running water. South of lat 35° 45' N., most eolian deposits are mapped separately. (*GRI Source Map ID 1060*) (Milk Lake and Nose Rock Quadrangles).

Qls - Landslide deposit (Holocene)

In small landslide in SW1/4 sec. 30, T. 22 N.,R. 12 W. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qfd - Fan deposit (Holocene)

Qf - Fan deposit (Holocene)
Forms small alluvial fan in secs. 26 and 27, T. 22 N., R. 13 W. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qswd - Slope-wash deposit (Holocene)

On gently sloping smooth surfaces swept bare of vegetation by sheetflood erosion. Most surfaces are developed on mudstone of the Menefee Formation. Surfaces may be partly mantled by chips and cobbles of sandstone from nearby outcrops or partly to fully mantled by chips of ironstone from breakup of concretions. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qal - Alluvium (Holocene)

Qal - Alluvium (Holocene)
Sand, silt, and clay deposited along major drainages. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qal - Alluvium (upper Holocene)
Alluvium in lowest channels cut into flood-plains of larger ephemeral streams throughout the area. Composed primarily of dark-gray silt and white, fine to coarse sand derived from shale or sandstone bedrock, or reworked from deposits of older alluvium. Contains clasts of sandstone and sideritic ironstone from local bedrock. Thickness ranges from less than 10 ft (3 m) to more than 50 ft (15 m) in the bed of Escavada Wash. (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Qal - Alluvium (Holocene)
Stream-deposited clay, silt, sand, and gravel. Maximum thickness is approximately 5 ft throughout. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Qal - Alluvium (Holocene)
Light-gray to white fine- to coarse-grained sand and dark-gray silt derived from sandstone bedrock or reworked from deposits of older alluvium. Contains clasts of sandstone and ironstone from local bedrock and sparse well-rounded red quartzite pebbles and fragments of petrified wood. Fills channels of Chaco Wash. Thickness probably about 3-4 m (10-13 ft). (*GRI Source Map ID 1052*) (Pueblo Pintado).

Qa1 - Alluvial deposits, unit 1 (upper Holocene)

Qa1 - Alluvial deposits, unit 1 (upper Holocene)
Mostly light-yellowish-gray sand and gravel deposited in arroyos and on valley floors since about 1850, which was the beginning of the latest cycle of arroyo cutting (Bryan. 1954, p. 15). Includes some eolian sand reworked by flood waters and minor clay and silt deposited in ephemeral ponds and reservoirs. Generally thin, probably does not exceed 3 m in thickness. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qa1 - Alluvial deposits, unit 1 (upper Holocene)
Mostly light yellowish gray sand and gravel deposited in arroyos and on valley floors since the latest cycle of arroyo cutting, beginning about 1850 (Bryan, 1954, p. 15). Downstream from the arroyos generally mantles the broad valley flood plains, underlain by alluvium of unit 2 (Qa2). Locally, the thin mantle deposits have been incised by very recent arroyos, as in the northeast corner of the quadrangle. Includes some eolian sand reworked by flood waters and minor clay and silt deposited in ephemeral ponds and reservoirs. Generally thin, probably does not exceed 3 m in thickness. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qn - Naha Alluvium of Hack (1941) (Holocene)

Qn - Naha Alluvium of Hack, 1941 (Holocene)
Laminated and cross-stratified sand and silt filling stream channels. Contains abundant archeological remains of pottery cultures along Chaco Wash. Naha Alluvium overlies Tseigi Alluvium of Hack, 1941, along deep arroyos of Chaco Wash. Thickness ranges from 10 to about 20 ft. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Qn - Naha Alluvium of Hack (1941) (Holocene)
Grayish-brown, poorly consolidated, laminated and cross-stratified sand and silt filling washes of ephemeral streams. Contains some rounded chert and quartzite pebbles, and some sheetwash with blocks of sandstone along valley walls. Lacks zonal soil in the upper part. Thick deposits may contain as many as 6 buried clay or humus-rich layers. Commonly shows a complex sequence of cut-and-fill channels where exposed in vertical banks along main washes. Forms terrace about 6 m (20 ft) above arroyo floors. Near Pueblo Pintado (ruins) contains abundant archeological remains of ceramic cultures. Thickness ranges from 3 to more than 4.5 m (10-15 ft). (*GRI Source Map ID 1052*) (Pueblo Pintado).

Qnt - Naha and Tsegi Alluviums of Hack (1941), undivided (upper Holocene)

Qnt - Naha and Tsegi Alluviums (Formations of Hack, 1941) Undifferentiated (Upper Holocene)
Each formation is identifiable in many places, but the units were not differentiated for this report

Naha Alluvium - Grayish-brown, friable to slightly hard, thinly laminated and cross-stratified sand and silt in discontinuous layers. Fills washes of ephemeral streams. Forms entire alluvial column near center of Chaco Wash. Forms upper 4 ft (1.2 m) of alluvial column where it overlies Tsegi Alluvium near sides of Chaco Wash. Lacks zonal soil in the upper part, but thicker deposits may contain buried clay or humus-rich horizons. In vertical banks along centers of deep washes, commonly shows a complex sequence of cut-and-fill channels (Bryan, 1954, and Hall, 1977). As mapped includes some sheetwash alluvium and alluvial fans along valley walls. Top of terrace lies as much as 33 ft (10 m) above arroyo floors. Locally contains abundant sherds of prehistoric pottery in upper 20 ft (6 in) or less along Chaco Wash (Bryan, 1954). Thickness ranges from 10 ft (3 m) to more than 20 ft (6 m). Naha Alluvium overlies Tsegi Alluvium along deep arroyos of Chaco Wash

Tsegi - Yellowish-gray or grayish-brown, firmly consolidated, fine to coarse sand, silt, and clay

containing several clay and humus-rich layers. In the upper part is weakly developed soil with a yellowish-brown B horizon 6-24 in. (15-61 cm) thick and an underlying moderately firm Cca horizon 15-30 in. (38-76 cm) thick. B horizon contains large well-developed columnar peds as much as 8 in. (20 cm) wide and 24 in. (61 cm) high. Where the soil was removed by erosion, Tsegi Alluvium cannot easily be differentiated from overlying Naha Alluvium. Tsegi Alluvium either makes up the whole terrace or lies beneath the Naha in the deep arroyo along Chaco Wash and probably is widespread beneath Naha Alluvium in the valley fills. Thickness about 10ft (3 m). (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Qa2 - Alluvial deposits, unit 2 (Holocene)

Qa2 - Alluvial deposits, unit 2 (Holocene)
Light-yellowish-gray, unconsolidated silt, sand, and gravel in aggraded valley bottoms and flood plains. Locally stabilized by vegetation and exhibits incipient soil formation. Deposited prior to the latest cycle of arroyo cutting. Grades upslope into colluvium (Qc). Thickness 0-12 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qa2 - Alluvial deposits, unit 2 (Holocene)
Yellowish-gray (5Y7/4), unconsolidated silt, sand, and gravel in aggraded valley bottoms and on flood plains. Locally, contains thin clay lenses and eolian deposits. Generally stabilized by vegetation and incipient soil formation. Deposited prior to the latest cycle of arroyo cutting. Grades upslope into colluvium (Qc). Observed thickness 0-4 m, but probably more than 8 m thick in some alluviated valleys. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qe - Younger eolian deposits (Holocene)

Qe - Younger sand deposits (Holocene)
Very pale orange to white, fine-to very fine grained, moderately well sorted, unconsolidated sand and silt accumulated as dunes on flood plains (Qa1, Qa2) and alluvial fans (Qf). Most prevalent where sand and silt, deposited by flood waters at the mouth of arroyos, are transported and redeposited by the wind. Thickness 0-6 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qe - Younger sand deposits (Holocene)
Very pale orange (10YR8/2) and yellowish-gray (5Y7/2) to white, fine- to very fine grained, moderately well sorted, unconsolidated sand and silt accumulated in dunes, mostly on broad flood plains (Qa1, Qa2) and alluvial fans (Qf). Forms barchan and seif or longitudinal dunes, and large composite sheets of sand. Orientation of dunes and crossbedding indicate winds dominantly from the southwest. Thickness 0-3 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qsd - Dune deposit (Holocene)

Forms large and small hummocks of fine-grained, windblown sand completely or almost completely devoid of vegetation. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qa3 - Alluvial deposits, unit 3 (lower Holocene and Pleistocene)

Qa3 - Alluvial deposits, unit 3 (lower Holocene)
Grayish-orange-pink, semi-consolidated silt, sand, and gravel in terraces 1.5-6.5 m above the aggraded valley flood plain deposits (Qa2). Well preserved in adjacent quadrangles to south, generally in the upper reaches of stream valleys. Commonly exposed in arroyo walls where it underlies unit Qa2, as well as

pediment gravel (Qp) and some alluvial fan (Qf) deposits. Generally underlain by older alluvium (Qoa). Mapped only in Puerco River valley, southern margin of map. Thickness 0-8 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qa3 - Alluvial deposits, unit 3 (lower Holocene and Pleistocene)
Grayish-orange (10YR7/4) to light-brown (5YR6/4), semi-consolidated silt, sand, and gravel, in terraces 1.5-6.5 m above the flood plain of aggraded valley deposits (Qa2). Commonly exposed in arroyo walls beneath unit Qa2 and, in places, below colluvium (Qc) and some alluvial-fan deposits (Qf). Generally underlain by older alluvium (Qoa). Has a well developed soil profile as thick as 120 cm, which generally includes a moderately well developed caliche zone. Terraces, traversed by State Highway 57 in the southwestern part of the quadrangle, are underlain by older sand and gravel alluvium (Qoa). Thickness 0-3. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qsw - Sheetwash alluvium (upper Pleistocene to Holocene)

Qsw - Sheetwash alluvium (Upper Holocene to Upper Pleistocene)
Consists of poorly consolidated clay, silt, and coarse to medium sand containing rock fragments ranging from pebbles to large sandstone slabs. Chiefly sheet-wash material derived from shale and sandstone bedrock on gently sloping tops of mesas and gently to steeply sloping valley walls. In part derived from older surficial deposits. Includes small unmapped rock falls and talus cones derived from bedrock on steep valley walls, and colluvium subjected to creep on steep slopes. Locally covered by unmapped eolian sand. Locally well-cemented on south side of Chaco Canyon between Wijiji and Pueblo del Arroyo Ruins. Small areas of gravelly sheetwash alluvium along Fajada Wash are considered to be equivalent to gravelly Jeddito Alluvium (Qj) in the gravel pit one-half mile southwest of the Park headquarters. Zonal soil in upper part contains a B horizon 6-24 in. (15-61 cm) thick having weakly developed coarse columnar structure, clayey texture, and yellowish-brown color. Underlying Cca horizon is 15-30 in. (38-76 cm) thick, and contains weakly developed floury or spotty accumulation of calcium carbonate. Thickness of unit is as much as 20 ft (6 m). (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Qsw - Sheetwash alluvium (Holocene to upper Pleistocene)
Poorly consolidated clay, silt, and sand. Thickness is as much as 10 ft. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Qes - Eolian sand (upper Pleistocene to Holocene)

Qes - Eolian sand (Upper Holocene to Upper Pleistocene)
Includes both young and old deposits. Younger eolian sand is white, well-sorted, cross-stratified loose quartz sand in active barchan and climbing dunes. Sand was blown from channels of major washes and from sandy bedrock by winds that still trend N. 60° to 70° E. Older eolian deposits consist of light-brown, slightly consolidated, fine to medium sand containing subrounded to rounded, frosted quartz grains in stabilized linear dunes and sand sheets on the uplands. Discontinuous soil in upper part of older sand is marked by a reddish-brown oxidized B horizon up to 10 in. (25 cm) thick underlain by a firmly consolidated, light-brown Cca horizon up to 18 in. (46 cm) thick containing scattered carbonate nodules. This soil probably formed during the Altithermal middle part of Holocene time and shows that part of the sand has been stable for more than 4,000 years. Thicknesses of eolian sand are more than 40 ft (12 m) in active dune fields along the Chaco River and Chaco Wash and more than 7 ft (2 m) in the older sand deposits. (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Qes - Eolian sand (Holocene)
Fine-grained, windblown sand stabilized by vegetation. May mantle large surface area. (*GRI Source Map*

ID 1047) (La Vida Mission Quadrangle).

Qes - Eolian sand (Holocene to upper Pleistocene)
Wind-blown, loose quartz sand in dunes and sand sheets. Thickness is as much as 6 ft. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Qes - Eolian sand (Holocene and Upper Pleistocene)
Younger deposits consist of white, well-sorted, cross-stratified, loose quartz sand in active linear dunes along valleys. Sand was blown from channels of major washes and from sandstone bedrock by winds having a prevailing direction of about N 60° to 70° E. Older deposits consist of light-brown, slightly consolidated fine- to medium-grained sand containing subrounded to rounded frosted grains in stabilized linear dunes and sand sheets on the uplands. Thin, stabilized deposits of eolian sand locally overlie deposits of gravelly sand. A discontinuous soil is developed in the upper part of the older sand deposits; it is marked by a reddish-brown oxidized B horizon as much as 25 cm (10 in.) thick -- underlain by a firmly consolidated light-brown Cca horizon as much as 46 cm (18 in.) thick containing scattered carbonate nodules. This soil probably formed during the Altithermal middle part of Holocene time and shows that part of the sand has been stable for more than 4,000 years. Thickness reaches 4.6 m (15 ft) in the dune fields along Chaco Wash and more than 2 m (6.5 ft) for the older sand sheets. (*GRI Source Map ID 1052*) (Pueblo Pintado).

Qess - Eolian sand and soil (upper Pleistocene to upper Holocene)

Stabilized surface of intricately intermingled windblown sand and sedentary soil developed on Menefee bedrock. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qoe - Older eolian deposits (Pleistocene to Holocene)

Qoe - Older sand deposits (Holocene to Pleistocene?)
Moderate-yellowish-brown (10YR 5/4) (Goddard and others, 1948), pale-reddish-brown (10R 5/4), and dusky-yellow (5Y 6/4), fine- to very fine grained sand and silt, somewhat clayey, oxidized, and semiconsolidated; caliche moderately to well developed. Stabilized by vegetation and soil development. Much of the older eolian deposits probably accumulated slowly by accretion over a long period of time. Covers large areas as blanketlike deposits on flanks and tops of ridges and low mesas in northern half of quadrangle; lightly masks many areas mapped as bedrock. Some older eolian deposits are mixed with colluvium (Qc), older alluvium (Qoa), and pediment gravel (Qp). Thickness 0-6 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qoe/sd - Older eolian deposits (Holocene to Pleistocene)
Grayish-orange-pink (5YR6/2) to grayish-orange (10YR7/4-6/4) and light-brown (5YR6/6-5/4), fine- to very fine grained semiconsolidated sand and silt, somewhat clayey and oxidized; caliche moderately to well developed. Stabilized by vegetation and soil formation. Covers large areas as blanketlike deposits on flanks and tops of ridges and low mesas; lightly masks many areas mapped as bedrock. Large-scale seif dunes, some combined with barchan dunes, rise 1-6 m above the blanketlike deposits in places; they are outlined on the map by short dashed lines and labeled sd. Some older eolian deposits are mixed with and mapped as colluvium (Qc), older alluvium (Qoa), and pediment gravel (Qp). Thickness 0-7 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qoesd - Older eolian deposits, seif dunes (Pleistocene to Holocene)

Grayish-orange pink (5YR6/2) to grayish-orange (10YR7/4-6/4) and light-brown (5YR6/6-5/4), fine- to very fine grained semi-consolidated sand and silt, somewhat clayey and oxidized; caliche moderately to well developed. Stabilized by vegetation and soil formation. Covers large areas as blanket-like deposits on

flanks and tops of ridges and low mesas; lightly masks many areas mapped as bedrock. Large-scale self dunes, some combined with barchan dunes, rise 1-6 m above the blanket-like deposits in places; they are outlined on the map by short dashed lines and labeled sd. Some older eolian deposits are mixed with and mapped as colluvium (Qc), older alluvium (Qoa), and pediment gravel (Qp). Thickness 0-7 m (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qp - Pediment gravel (Holocene and Pleistocene?)

Qp - Pediment gravel (Holocene and Pleistocene?)
Thin deposits of light-gray, poorly sorted, unconsolidated, subangular pebbles, cobbles, and sand that lie on dissected pediment surfaces. Tightly packed lag gravel forms thin continuous pavement in head-ward parts of pediments; in lower parts, gravel occurs as residual patches and in reworked deposits mixed with the older eolian silt and sand (Qoe). Pediment surfaces decline gradually from 6 degrees at base of cliffs to 1.5 degrees downslope. Bedrock surfaces show through the gravel in many places, but have not been mapped separately. Thickness 0-8 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qp - Pediment gravel (Holocene and Pleistocene?)
Thin deposits of yellowish-gray (5Y7/4) to pale-yellowish-brown (10YR6/2) and light-brown (5YR6/4), poorly sorted, unconsolidated, subangular pebbles, cobbles, and sand that lie on dissected pediment surfaces. Tightly packed lag gravel forms thin continuous pavement in headward parts of pediments; downslope, gravel occurs as residual patches and in reworked deposits mixed with the older eolian silt and sand (Qoe). Pediment surfaces decline gradually from 6° at base of cliffs to 1.5° downslope. Bedrock surfaces, as well as underlying older alluvium (Qoa), show through the gravel in many places, but have not been mapped separately everywhere. Pediment surfaces along the southern border of the quadrangle are more extensive in the Casamero Lake quadrangle to south. Similar sloping surfaces, cut on the eroded tops of north-dipping resistant beds, are widespread in the quadrangle; these stripped stratum planes form upland surfaces, which are mantled generally by older eolian sand deposits (Qoe) and locally by thin gravels. Thickness 0-3 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qf - Alluvial fan deposits (Holocene and Pleistocene?)

Qf - Alluvial fan deposits (Holocene and Pleistocene?)
Poorly sorted, unconsolidated sand, silt, and gravel in fan-shaped deposits on valley sides, in tributary valleys, and in the upper parts of some main stream valleys. Formed by aggradation where the detrital bedload exceeded the capacity of the streams to transport it. Grades laterally into colluvium (Qc). (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qf - Alluvial-fan deposits (Holocene and Pleistocene?)
Poorly sorted, unconsolidated sand, silt, and gravel in fan-shaped deposits on valley floors, in upper parts of some main stream valleys, and in tributary valleys. Formed by aggradation where the detrital bedload exceeded the transporting capacity of the streams. Grades laterally into colluvium (Qc). (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qc - Colluvium (Holocene and Pleistocene)

Qc - Colluvium (Holocene and Pleistocene?)
Unsorted to poorly sorted silt, sand, and gravel deposited on valley walls between talus slopes and alluvium (Qa1 , Qa2) in graded stream valleys. Material has moved by sheetwash and locally by mudflow processes. Includes some talus debris (Qt), as well as some valley alluvium (Qa1, Qa2) and eolian sand (Qe); grades laterally into fan (Qf) deposits. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qc - Colluvium (Holocene and Pleistocene)
Unsorted to poorly sorted silt, sand, and gravel deposited on valley sides between talus slopes and alluvium (Qa1, Qa2). Material has moved downslope by sheet-wash and locally by mudflow processes. Includes some talus debris (Qt), as well as some valley alluvium (Qa1, Qa2) and eolian sand (Qe); grades laterally into alluvial-fan deposits (Qf). (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qt - Talus deposits (Holocene and Pleistocene)

Qt - Talus deposits (Holocene and Pleistocene?)
Fallen rock fragments and blocks accumulated as cones of talus that form steep unstable slopes below cliffs. Includes disaggregated landslide blocks and debris-flow material; concentrated on steep slopes of north-facing escarpments where ground-water seepage has accelerated collapse and mass movement of bedrock. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qt - Talus deposits (Holocene and Pleistocene)
Fallen rock fragments and blocks accumulated as cones of talus that form steep unstable slopes below cliffs. Includes disaggregated blocks and debris-flow material. Only accumulation of talus sufficient to show on map occurs in southwest corner of quadrangle. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qlsb - Landslide deposits and slump blocks (Holocene and Pleistocene?)

Large masses of rock material that have become detached from cliffs and have slid, fallen, or slumped as more or less integral units. Two landslides are shown in southwest quarter of map. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qj - Jeddito Alluvium (Formation of Hack, 1941) (upper Pleistocene to lower Holocene)

Dark-yellowish-brown sand containing moderate yellowish-brown, angular, pebble- to cobble-sized clasts of sandstone and very dark brown to black, pebble-sized clasts of ironstone. Along Kin Klizhin and Fajada Washes, most clasts are from the underlying Menefee Formation (Kmf). Along the Chaco River, the Jeddito contains clasts of quartzite, petrified wood, quartz, and chert as large as 12 in. (30.5 cm) in diameter derived from Ojo Alamo Sandstone of Paleocene age, and other sources. (Some clasts were a source of flaking material for the manufacture of prehistoric stone tools.) Some Jeddito Alluvium along Fajada Wash is of sheetwash origin. Along Fajada Wash, a reddish-brown, well-developed Altithermal soil formed in the upper part of the alluvium. It contains in descending order: a sandy humic A horizon about 2.7 in. (7 cm) thick, a reddish-brown clayey firm B horizon 12 in. (30.5 cm) thick, and a nodular to densely concentrated Cca horizon more than 27 in. (70 cm) thick. In terraces along Kin Klizhin Wash and the Chaco River, the B horizons of original soils generally were removed by erosion, but part of the calcium carbonate of the Cca horizon remains as coatings on the undersides of pebbles. Altithermal soil is exposed locally in the lower parts of arroyo walls along Chaco Wash, which suggests that, near the center of the wash the Jeddito Alluvium forms a deep and seldom-exposed fill. Emplacement of Tsegi Alluvium was shallower, but still deeper than Naha Alluvium. Jeddito Alluvium forms a terrace about 23 ft (7 m) above the Chaco River, Fajada Wash, and Kin Klizhin Wash. Maximum thickness along Fajada Wash is about 33 ft (10 m). (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Qgs7 - Gravelly sand (upper Pleistocene)

Very pale brown, dark-yellowish-brown or grayish-orange, gravelly, medium to coarse sand containing pebbles averaging about 1 in. (2.5 cm) in diameter. Pebbles decrease in abundance upward. Size and composition of clasts varies with location and proximity of source. Quartzitic sandstone, quartz, and chert clasts are chiefly from Ojo Alamo Sandstone of Paleocene age, which crops out 7.4 miles (12 km) north of the Park: ironstone and clinker (baked shale) are chiefly from the Fruitland Formation (Kf). Sandstone and ironstone clasts found along the Chaco River are chiefly from the Cliff House Sandstone (Kch) and Menefee Formation (Kmf). A soil zone in the upper part of the alluvium contains an A horizon 14-20 in. (36-51 cm) thick, underlain by a dark brown hard clayey B horizon 12-24 in. (30.5-61 cm) thick and a white, very calcareous, friable, pebbly Cca horizon 24-40 in. (61-102 cm) thick that locally contains nodules of calcium carbonate. Deposits occur as sheets overlying pediment-like surfaces that cut across nonresistant bedrock and slope toward the Chaco River or other local major valleys. At least seven erosion surfaces and their associated gravelly sand deposits are recognized in the drainage basin of the Chaco River. Each reflects an erosional episode related to changes in the grade of the Chaco River or the San Juan River. Various surfaces from highest and oldest (Qgs1) to lowest and youngest (Qgs7) are distinguished from each other by the height of the erosion surface above the Chaco River and its major tributaries. In addition, soils that developed on the higher and older deposits of gravelly sand are more strongly developed than those on the lower and younger deposits. The three youngest geomorphic levels of gravelly sand are present in the Park area, and range from 60-200 ft (18-60 m) above the local drainage. Thickness of each deposit ranges from 8-20 ft (2.5-6 m). (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

** *Unit description shared with Qgs6 and Qgs5*.

Qgs6 - Gravelly sand (upper Pleistocene)

Qgs6 - Gravelly sand (Upper Pleistocene)
Very pale brown, dark-yellowish-brown or grayish-orange, gravelly, medium to coarse sand containing pebbles averaging about 1 in. (2.5 cm) in diameter. Pebbles decrease in abundance upward. Size and composition of clasts varies with location and proximity of source. Quartzitic sandstone, quartz, and chert clasts are chiefly from Ojo Alamo Sandstone of Paleocene age, which crops out 7.4 miles (12 km) north of the Park: ironstone and clinker (baked shale) are chiefly from the Fruitland Formation (Kf). Sandstone and ironstone clasts found along the Chaco River are chiefly from the Cliff House Sandstone (Kch) and Menefee Formation (Kmf). A soil zone in the upper part of the alluvium contains an A horizon 14-20 in. (36-51 cm) thick, underlain by a dark brown hard clayey B horizon 12-24 in. (30.5-61 cm) thick and a white, very calcareous, friable, pebbly Cca horizon 24-40 in. (61-102 cm) thick that locally contains nodules of calcium carbonate. Deposits occur as sheets overlying pediment-like surfaces that cut across nonresistant bedrock and slope toward the Chaco River or other local major valleys. At least seven erosion surfaces and their associated gravelly sand deposits are recognized in the drainage basin of the Chaco River. Each reflects an erosional episode related to changes in the grade of the Chaco River or the San Juan River. Various surfaces from highest and oldest (Qgs1) to lowest and youngest (Qgs7) are distinguished from each other by the height of the erosion surface above the Chaco River and its major tributaries. In addition, soils that developed on the higher and older deposits of gravelly sand are more strongly developed than those on the lower and younger deposits. The three youngest geomorphic levels of gravelly sand are present in the Park area, and range from 60-200 ft (18-60 m) above the local drainage. Thickness of each deposit ranges from 8-20 ft (2.5-6 m). (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

** *Unit description shared with Qgs7 and Qgs5*.

Qgs6 - Gravelly sand (Upper Pleistocene)
Very pale brown to grayish-orange gravelly sand containing pebbles averaging about 2.5 cm (1 in.) in

diameter. Pebbles are less abundant in upper part and increase in abundance and size downward. Size and composition of clasts varies with location and proximity to source. Quartzitic sandstone and chert clasts are chiefly derived from the Paleocene Ojo Alamo Sandstone; ironstone and clinker (rock baked by heat from burning coal) are chiefly derived from the Fruitland Formation. A soil zone in the upper part contains a well-developed A horizon 7.610.2 cm (3-4 in.) thick, a brown clayey B horizon 25 cm (10 in.) thick, and a white, very calcareous, friable stony Cca horizon about 61 cm (24 in.) thick that locally contains nodules of calcium carbonate. Deposits occur as sheets overlying pediment-like surfaces cut across nonresistant bedrock and sloping toward the Chaco River or other local major valleys. At least seven erosion surfaces and their associated gravelly sand deposits (Qgs7-Qgs1) are recognized in the drainage basin of the Chaco River. One geomorphic level (Qgs6) of gravelly sand is present in this quadrangle, at about 24 m (80 ft) above present drainage level. Thickness is as much as 6 m (20 ft). (*GRI Source Map ID 1052*) (Pueblo Pintado).

Qgs5 - Gravelly sand (upper Pleistocene)

Very pale brown, dark-yellowish--brown or grayish-orange, gravelly, medium to coarse sand containing pebbles averaging about 1 in. (2.5 cm) in diameter. Pebbles decrease in abundance upward. Size and composition of clasts varies with location and proximity of source. Quartzitic sandstone, quartz, and chert clasts are chiefly from Ojo Alamo Sandstone of Paleocene age, which crops out 7.4 miles (12 km) north of the Park: ironstone and clinker (baked shale) are chiefly from the Fruitland Formation (Kf). Sandstone and ironstone clasts found along the Chaco River are chiefly from the Cliff House Sandstone (Kch) and Menefee Formation (Kmf). A soil zone in the upper part of the alluvium contains an A horizon 14-20 in. (36-51 cm) thick, underlain by a dark brown hard clayey B horizon 12-24 in. (30.5-61 cm) thick and a white, very calcareous, friable, pebbly Cca horizon 24-40 in. (61-102 cm) thick that locally contains nodules of calcium carbonate. Deposits occur as sheets overlying pediment-like surfaces that cut across nonresistant bedrock and slope toward the Chaco River or other local major valleys. At least seven erosion surfaces and their associated gravelly sand deposits are recognized in the drainage basin of the Chaco River. Each reflects an erosional episode related to changes in the grade of the Chaco River or the San Juan River. Various surfaces from highest and oldest (Qgs1) to lowest and youngest (Qgs7) are distinguished from each other by the height of the erosion surface above the Chaco River and its major tributaries. In addition, soils that developed on the higher and older deposits of gravelly sand are more strongly developed than those on the lower and younger deposits. The three youngest geomorphic levels of gravelly sand are present in the Park area, and range from 60-200 ft (18-60 m) above the local drainage. Thickness of each deposit ranges from 8-20 ft (2.5-6 m). (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

** *Unit description shared with Qgs7 and Qgs6*.

Qoa - Older alluvium (Pleistocene?)

Qoa - Older alluvium (Pleistocene?)
Mostly grayish-orange to yellowish-gray, poorly to partly consolidated silt, sand, and gravel, locally cemented by calcium carbonate to form caliche. The gravel ranges from pebbles to boulders, is subangular to subrounded, and is unsorted to moderately well sorted. Older alluvium occurs as ancient valley fill and as remnants of dissected piedmont alluvial plains, fans, and pediments. Exposed deposits generally lie on bedrock surfaces more than 6.5 m above the level of valley flood plains (Qa2), but are also concealed in stream valleys where they underlie younger alluvium; older alluvium deposits are exposed locally in arroyos and along dissected margins of pediments. Exposures in cutbanks and arroyos indicate four or more alluvial cycles commonly separated by soil zones or scour surfaces; they are not differentiated on the map. The unit also includes some older eolian sand (Qoe). Thickness 0-18 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qoa - Older alluvium (Pleistocene?)
Mostly moderate yellowish brown (10YR5/4) to grayish orange (10YR7/4) and light-brown (5YR6/4) to moderate-brown (5YR4/4), poorly to partly consolidated silt, sand, and gravel, locally cemented by calcium carbonate to form caliche. Gravel ranges from pebbles to boulders of sandstone, chert, and quartzite, is subangular to subrounded, and is unsorted to moderately well sorted. Occurs as ancient valley fill and as remnants of dissected piedmont alluvial plains, fans, and pediments. Exposed deposits generally lie on bedrock surfaces more than 6.5 m above the level of valley flood plains (Qa2), but are also concealed in stream valleys where they underlie younger alluvium; older alluvial deposits are exposed locally in arroyos and along dissected margins of pediments. Such exposures indicate four or more alluvial cycles commonly separated by soil zones or scour surfaces; they are not differentiated on the map. Sand and gravel deposits, as thick as 12 m, well cemented with calcium carbonate, and exposed in terraces and arroyos in the southwest part of the quadrangle, have been quarried to a limited extent for aggregate. Includes some older eolian sand (Qoe). Thickness 0-15 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Qoac - Older alluvium, calcrete (Pleistocene?)

Unit is unit Qoa (older alluvium) that is calcrete, calcium carbonate-cemented older alluvium. Thickness 0 -18m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Qg - Gravel (Pleistocene)

Qg - Gravel deposit south of the Chaco River (Pleistocene)
Coarse gravel composed largely of chunks of sandstone and fragmented ironstone concretions of the Menefee Formation. Caps buttes and other high areas that are remnants of a dissected pedimentlike surface that sloped toward Kim-me-ni-oli Valley and Chaco River. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qg - Gravel (Pleistocene)
Quartzitic and lithic pebbles and cobbles. Overlies Cliff House Sandstone, at north end of West Mesa. Thickness is about 5 ft. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Qti - Gravel deposit mostly north of the Chaco River, intermediate terrace deposit (Pleistocene)

Coarse gravel deposited at two levels, one 130 ft (40 m) and the other 65 ft (20 m) above the Chaco River. Principal constituents are identical with the high terrace deposit, but also contains some pebbles of ironstone locally derived from concretions in the Menefee Formation. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qtl - Gravel deposit mostly north of the Chaco River, low terrace deposit (Pleistocene)

Coarse gravel 20 + ft (6+ m) above the Chaco River. Gravel consists principally of varicolored pebbles of chert and quartzite 0.5 to 2.5 in. (1.3 to 6.4 cm) in diameter; also contains subrounded pebbles and cobbles of sandstone and ironstone locally derived from the Menefee Formation. Gravel veneers an extensive surface north of the Chaco River in secs. 26 and 27, T. 22 N., R. 13 W. and caps a tiny knob south of the river on the boundary between secs. 29 and 30, T. 22 N., R. 12 W. Interbedded sand and gravel is 15 + ft (4.6 + m) thick in road cut north of new State Route 371 bridge across Chaco River. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Qth - Gravel deposit mostly north of the Chaco River, high terrace deposit (Pleistocene)

Coarse gravel deposited at two levels, one 330 ft (101 m) and the other 210 ft (64 m) above the Chaco River. Gravel consists of rounded and flattened oval pebbles of varicolored quartzite and chert and, in some places, chunks of petrified wood. Diameter of gravel ranges from 0.5 to 2.5 in. (1.3 to 6.4 cm). Source of gravel is from the east, probably from the Ojo Alamo Sandstone. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Kk - Kirtland Shale (Upper Cretaceous)

Kk - Kirtland Shale (Upper Cretaceous)
Light-olive-gray to greenish-gray, silty and sandy mudstone and a few yellowish-gray, thin sandstone beds. Contains sparse black, carbonaceous mudstone beds that contain some swelling clay and commonly show a popcorn-like appearance on weathered exposures. The Kirtland Shale commonly forms badlands showing curious erosional forms such as pedestals, knobs, and spires. Contains some gray to white silicified wood. Probably more than 490 ft (150 m) thick, but only lower part of formation is present in report area. (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Kk - Kirtland Shale, lower part (Upper Cretaceous)
Consists of silty and sandy mudstone and a few thin sandstone beds. The mudstone is light olive gray to greenish gray, and contains carbonaceous beds and some swelling clay that commonly has a popcorn-like appearance on weathered exposures. Forms badlands showing grotesque erosional forms. Thickness is about 52 m (170 ft). (*GRI Source Map ID 1052*) (Pueblo Pintado).

Kf - Fruitland Formation (Upper Cretaceous)

Kf - Fruitland Formation (Upper Cretaceous)
Highly variable sequence of intercalated lenticular sandstone, siltstone, mudstone, carbonaceous shale, and coal. Siltstone and mudstone are dusky yellow to moderate brown. Mudstone units generally are 5-20 ft (1.5-6 m) thick, but locally are as much as 50 ft (15 m) thick. Contains layers of swelling clay. White to yellowish-gray, medium-grained, friable sandstone beds of this unit are lenticular, and most are less than 10 ft (3 m) thick; locally they contain sideritic ironstone concretions as large as 4 ft (1.2 m) in maximum dimension. Forms picturesque badland topography. Local individual coal beds are more-than 6.5 ft (2 m) thick. Red clinker beds mark the outcrops of burned coal beds. Total thickness of unit probably is less than 295 ft (90 m). (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Kf - Fruitland Formation (Upper Cretaceous)
Highly variable, poorly exposed sequence of intercalated lenticular sandstone, siltstone, mudstone, carbonaceous shale, and coal. The siltstone and mudstone are dusky yellow to moderate brown. The mudstone units contain swelling clay layers. Sandstone lenses are yellowish gray, and medium grained. The contact between the Fruitland Formation and Kirtland Shale is arbitrarily placed at the top of the uppermost principal coal bed. Thickness probably less than 45 m (150 ft). (*GRI Source Map ID 1052*) (Pueblo Pintado).

The following coal beds are present within the Fruitland Formation:

Kfr - Fruitland Formation coal zone
Kfr3 - Fruitland 3 coal bed
Kfr2 - Fruitland 2 coal bed

Kfr1 - Fruitland 1 coal bed

Kfr - Fruitland Formation coal zone (Upper Cretaceous)

Kfr - Fruitland Formation coal zone (Upper Cretaceous)
No description provided on source map. (*GRI Source Map ID 30911*) (Pueblo Bonito Quadrangle - coal map).

Kfr - Fruitland Formation coal zone (Upper Cretaceous)
No description provided on source map. (*GRI Source Map ID 29890*) (Sargent Ranch Quadrangle - coal map).

*** Unit is designated FR Zone on Coal Bed Thickness Drill Hole and Measured Section figures.*

Kfr3 - Fruitland 3 coal bed (Upper Cretaceous)

Kfr3 - Fruitland 3 coal bed (Upper Cretaceous)
No description provided on source map. (*GRI Source Map ID 30647*) (Pueblo Pintado Quadrangle - coal map)

Kfr3 - Fruitland 3 coal bed (Upper Cretaceous)
No description provided on source map. (*GRI Source Map ID 29890*) (Sargent Ranch Quadrangle - coal map).

*** Unit is designated FR3 on Coal Bed Thickness Drill Hole and Measured Section figures.*

Kfr2 - Fruitland 2 coal bed (Upper Cretaceous)

No description provided on source map. (*GRI Source Map ID 30647*) (Pueblo Pintado Quadrangle - coal map).

*** Unit is designated FR2 on Coal Bed Thickness Drill Hole and Measured Section figures.*

Kfr1 - Fruitland 1 coal bed (Upper Cretaceous)

No description provided on source map. (*GRI Source Map ID 30647*) (Pueblo Pintado Quadrangle - coal map).

*** Unit is designated FR1 on Coal Bed Thickness Drill Hole and Measured Section figures.*

Kpc - Pictured Cliffs Sandstone (Upper Cretaceous)

Kpc - Pictured Cliffs Sandstone (Upper Cretaceous)
Yellowish-gray to grayish-orange, thick-bedded and crossbedded, cliff-forming, well-sorted, friable, fine-grained sandstone comprises the upper part of the formation. Contains brown, hard, round, slabby, calcareous sandstone concretions that are parallel to bedding and as large as 4 ft (1.2 m) in diameter. Lower part consists of alternating thin beds of yellowish-gray to moderate-brown, fine-grained to very fine grained sandstone and light-gray to dark-gray, silty shale. Upper 6.5 ft (2 m) of shaly unit contains thin discontinuous layer of hard fine-grained ironstone. Contains fossil marine invertebrates and casts and impressions of burrows of *Ophiomorpha major*, which are indicative of near-shore marine environment.

Forms low bluffs. Formation is about 60 ft (18 m) thick. (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Kpc - Pictured Cliffs Sandstone (Upper Cretaceous)
Cross-stratified marine sandstone interbedded with a few thin beds of shale. Sandstone contains fossilized burrows (the trace fossil *Ophiomorpha major*) whose outer walls have a knobby appearance that resembles a corn cob. Forms cliffs and ledges. Thickness is about 60 ft. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Kpc - Pictured Cliffs Sandstone (Upper Cretaceous)
Mostly yellowish gray to grayish-orange thick-bedded and crossbedded ledge-forming, fine-grained, well-sorted, friable sandstone. Contains brown hard slabby calcareous sandstone concretions as large as 1.2 m (4 ft) in diameter. Lower part contains alternating thin beds of yellowish-gray to moderate-brown fine-grained to very fine grained sandstone and light-gray to dark-gray silty shale. (*GRI Source Map ID 1052*) (Pueblo Pintado).

Kl - Lewis Shale (Upper Cretaceous)

Kl - Lewis Shale (Upper Cretaceous)
Upper part is calcareous, sandy shale that contains light-brown sandstone beds 1-5 ft (0.3-1.5 m) thick. It is transitional into the overlying Pictured Cliffs (Kpc). Middle part is light-gray to dark-olive or olive-gray claystone and siltstone that contains a few thin sandstone zones and scattered beds of sandy concretionary limestone. Lower part is sandy and transitional into underlying Cliff House Sandstone (Kch). Calcareous concretions in the formation contain marine invertebrate fossils equivalent in age to middle Pierre Shale (Campanian) of eastern Colorado. Formation is about 100-115 ft (30-35 m) thick. (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Kl - Lewis Shale (Upper Cretaceous)
Olive-gray marine shale with thin interbeds of claystone, siltstone, and sandstone, and scattered beds of limestone that contain marine invertebrate fossils. Forms gentle slopes. Thickness is about 100 ft. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Kl - Lewis Shale (Upper Cretaceous)
Upper part is calcareous sandy shale that contains decreasing abundance downward of light-brown sandstone beds 0.3-1.5 m (1-5 ft) thick, and is transitional upward with the Pictured Cliffs Sandstone (Kpc). Middle part is light-gray to dark-olive or olive-gray claystone and siltstone that contains a few thin sandstone zones and scattered beds of sandy concretionary limestone. Lower part is sandy and transitional downward with the Cliff House Sandstone (Kch). Concretions in the formation contain marine invertebrate fossils common to the middle Pierre Shale of eastern Colorado. Thickness is about 30-35 m (100-115 ft). (*GRI Source Map ID 1052*) (Pueblo Pintado).

Kl - Lewis Shale (Upper Cretaceous)
No description provided on source map. (*GRI Source Map ID 1057*) (Seven Lakes NW and Seven Lakes NE Quadrangles).

Klt - Tongue of Lewis Shale (Upper Cretaceous)

Greenish-gray, slope-forming, thin-bedded siltstone, sandy shale, and shale. Crops out near junction of Escavada and Chaco Wash and in Ah-shi-sle-pah Wash area. Thickens northward and joins main body of the Lewis Shale in the subsurface. Thickness 0-90 ft (0-27 m). Along north side of Chaco Canyon, a conspicuous broad bench in the Cliff House Sandstone separates two high sandstone cliffs. This broad bench is developed south of the pinchout and at the stratigraphic level of the tongue of Lewis Shale. (*GRI*

Source Map ID 1055) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Kch - Cliff House Sandstone (Upper Cretaceous)

Kch - Cliff House Sandstone (Upper Cretaceous)
White to dark -yellowish-orange , thin- to thick-bedded, fine- to coarse-grained, lenticular and crossbedded or massive sandstone. Contains gray or brown carbonaceous shale lenses. Forms high bold cliffs and ridges. Mapped as Chacra Sandstone Member (name now abandoned) of Mesaverde Formation by Dane (1936). Intertongues with both Lewis Shale and Menefee Formation. Some tongues of Menefee Formation are mapped with the Cliff House; other tongues are mapped separately. Contains casts of the burrows of *Ophiomorpha major* indicative of a near-shore marine environment and marine fossil invertebrates. Cliff House Sandstone is as much as 430 ft (131 m) thick. (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Kch - Cliff House Sandstone (Upper Cretaceous)
Mostly white to dark- yellowish-orange thin- to thick-bedded, fine- to medium-grained, lenticular and crossbedded or massive sandstone. Contains gray or brown carbonaceous shale lenses or tongues. Mapped as Chacra Sandstone Member (name now abandoned by Dane, 1936) of the Mesaverde Formation. Intertongues with both the Lewis Shale and the Menefee Formation; marine shale tongues in the Cliff House are as thick as 7.5 m (25 ft). Forms high bold cliffs and ridges; makes a steep escarpment in the southwest quarter of the quadrangle that provides an excellent overview of the regional geology. Total thickness is about 100-112 m (330-370 ft). (*GRI Source Map ID 1052*) (Pueblo Pintado).

Kch - Cliff House Sandstone (Upper Cretaceous)
No description provided on source map. (*GRI Source Map ID 1057*) (Seven Lakes NW and Seven Lakes NE Quadrangles).

The following coal bed is present within the Cliff House Sandstone:

Kchz - Cliff House Sandstone coal zone

Kchu - Cliff House Sandstone, upper sandstone/bed (Upper Cretaceous)

Kchu - Upper bed of Cliff House Sandstone (Upper Cretaceous)
Brown and yellowish-gray, massive sandstone. Commonly capped by a dark-brown sandstone about 2 ft (0.6 m) thick, which contains abundant broken bits of marine fossil invertebrates. Forms conspicuous ledge that is everywhere separated by a tongue of the Menefee Formation from underlying parts of the Cliff House Sandstone. As much as 55 ft (17 m) thick. Thin and grades northward into Lewis Shale at localities to the northwest of the report area. (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Kchu - Cliff House Sandstone, upper member (Upper Cretaceous)
Fine-grained, massive-bedded, marine sandstone. Forms cliff or shelving ledges. Thickness is 33+ ft (10.1+ m) at best exposure in secs. 20 and 21, T. 22 N., R. 12 W. Unexposed beds at top of unit probably only a few feet thick. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Kcu - Cliff House Sandstone, upper sandstone (Upper Cretaceous)
Thick-bedded, cross-stratified, massive marine sandstone. Includes fossilized burrows (*Ophiomorpha major*). Forms ledges and cliffs. Present only south of Chaco Canyon on West, South, and Chacra Mesas. Thickness on West Mesa increases southwestward from about 30 to more than 60 ft.

White to light-gray sandstone - Medium to thick, cross-stratified to evenbedded. Contains few fossilized

burrows. Forms ledges and benches. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Kchwu - Cliff House Sandstone, white to light-gray sandstone, upper unit (Upper Cretaceous)

Overlies middle sandstone (Kcm) and thins southwestward from more than 30 ft on north side of Chaco Canyon to less than 30 ft on south end of West Mesa. On South Mesa, unit changes southwestward into mudstone and carbonaceous shale of Menefee Formation. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Kchwl - Cliff House Sandstone, white to light-gray sandstone, lower unit (Upper Cretaceous)

Overlies lower sandstone (Kcl) in West and South Mesas and has a maximum thickness of 30 ft. Changes southwestward into mudstone and carbonaceous shale of Menefee Formation. Changes northeastward and southeastward into finer grained sandstone of intermediate unit (Kci). (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Kchm - Cliff House Sandstone, middle sandstone (Upper Cretaceous)

Thick-bedded, cross-stratified, massive marine sandstone. Forms prominent cliffs and ledges. Fossilized burrows (*Ophiomorpha major*) are conspicuous on surfaces of benches above cliffs. Includes highly fossiliferous beds containing clams. Middle sandstone is present throughout the Chaco area and thickens southwestward from about 80 ft on north side of Chaco Canyon to about 130 ft on south end of West Mesa. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Kchi - Cliff House Sandstone, intermediate unit (Upper Cretaceous)

Thin- to thick-bedded, lenticular and cross-stratified marine sandstone containing fossilized burrows (*Ophiomorpha major*). Forms gentle slopes and benches. Marine shale, lithologically similar to Lewis Shale, is locally interbedded with sandstone on north side of Chaco Canyon. Light-gray, cross-stratified sandstone similar to Kcwl, but too thin to show on map, is locally present near base of unit. Thickness of unit is about 120 ft. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Kchl - Cliff House Sandstone, lower sandstone (Upper Cretaceous)

Kchl - Cliff House Sandstone lower member (Upper Cretaceous)
Fine-grained, pale-orange and pale-yellow, massive-bedded, marine sandstone. Forms high sheer cliffs, lower cliffs, and ledges north of Chaco River; south of river, unit caps three mesas in northeast part of quadrangle and one small butte in sec. 29, T. 22 N., R. 13 W. in northwest part of quadrangle. In sharp contact with underlying Menefee Formation in most places; elsewhere, intertongues with topmost beds of Menefee in intervals as much as 10 ft (3 m) thick. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Kcl - Cliff House Sandstone, lower sandstone (Upper Cretaceous)
Thick-bedded, cross-stratified, massive marine sandstone. Forms prominent cliffs nearly 100 ft high above ruins on north side Chaco Canyon. Contains churned beds produced by burrowing organisms and includes local highly fossiliferous beds containing clams. Fossilized burrows (*Ophiomorpha major*) are very common and are seen in sandstone blocks in the Anasazi ruins at Pueblo Bonito and Chetro Kettle. Lower sandstone thins from nearly 100 ft in Chaco Canyon to slightly more than 10 ft on south end of West Mesa. Wedges out southwestward into mudstone and carbonaceous shale of Menefee

Formation. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Kchz - Cliff House Sandstone coal zone (Upper Cretaceous)

CH Zone - Cliff House coal zone (Upper Cretaceous)
No description provided on source map. (*GRI Source Map ID 32096*) (Seven Lakes NE Quadrangle - coal map).

Kmf - Menefee Formation (Upper Cretaceous)

Kmf - Menefee Formation (Upper Cretaceous)
Heterogeneous sequence of thick, lenticular beds of grayish-yellow to brown, fine- to medium-grained, crossbedded sandstone and interbeds of dusky-yellow to olive-gray, sandy shale and mudstone, moderate-brown, sandy limestone: and lenticular beds of carbonaceous shale and shaly coal. Coal beds occur sporadically in the upper 246 ft (75 m) of Menefee Formation. The coal beds are commonly burned at the outcrop; red outcrops across from Casa Chiquita are result of burned coal. The Menefee Formation is widely exposed in southern San Juan Basin; base of the formation crops out 18.6 miles (30 km) south of the Park. Unit is 400 ft (122 m) thick at the type locality at Menefee Mountain in southwestern Colorado about 87 miles (140 km) north of Chaco Canyon; it thickens southward. In a drill hole 5.9 miles (9.6 km) north of the northern boundary of the map area, unit is about 1,500 ft (457 m) thick. (*GRI Source Map ID 1055*) (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles).

Kmf - Menefee Formation (Upper Cretaceous)
Mudstone and siltstone interbedded with cross-stratified lenticular sandstone. Contains carbonaceous shale and thin coal beds. Coal is burned in areas on south side of West and South Mesas. Forms steep to gentle slopes. Upper part wedges out between sandstone units of Cliff House. Thickness of main body is over 160 ft; Menefee wedges out between lower and middle sandstones from a maximum thickness of about 100 ft; Menefee wedges out between middle and upper sandstones from a maximum thickness of about 50 ft. (*GRI Source Map ID 1048*) (Pueblo Bonito Quadrangle).

Kmf - Menefee Formation (Upper Cretaceous)
Yellowish-gray lenticular, crossbedded fine- to coarse-grained sandstone interbedded with greenish-gray claystone, gray shale and siltstone, black carbonaceous shale, and thin beds of coal. Some coal beds have been burned. Exposed thickness is about 165 m (540 ft). (*GRI Source Map ID 1052*) (Pueblo Pintado).

Kmf - Menefee Formation (Upper Cretaceous)
No description provided on source map. (*GRI Source Map ID 1057*) (Seven Lakes NW and Seven Lakes NE Quadrangles).

The following coal bed is present within the Menefee Formation:

Kmfaz - Menefee coal zone.

Kmft - Tongue of Menefee Formation (Upper Cretaceous)

Kmft - Tongues of Menefee Formation (Upper Cretaceous)
Gray and brown, lenticular sandstone interbedded with black, carbonaceous shale, gray claystone and siltstone, some thin beds of highly weathered coal. Occurs as beds within Cliff House Sandstone (Kch) that thin northward. Beds undoubtedly represent two or more separate tongues extending northward from main body of Menefee Formation (Kmf). Stratigraphic connection, however, has since been removed by erosion in map area. Thickness 0-80 feet (0-24 m). (*GRI Source Map ID 1055*) (Kin Klizhin Ruins,

Sergeant Ranch and Pueblo Bonito Quadrangles).

Kmt - Tongue of Menefee Formation (Upper Cretaceous)
Mudstone, thin gray beds of fine-grained sandstone, and bands of dusky-brown, organic-rich mudstone (humate). Thins eastward from 24 to 5 ft (7.3 to 1.5 m). Does not include coal beds in La Vida Mission quadrangle, but does in the Tanner Lake quadrangle to the north. Present only in northeast corner of quadrangle. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Kmfa - Menefee Formation, Allison Member (Upper Cretaceous)

Kmfa - Allison Member of Menefee Formation (Upper Cretaceous)
Interbedded sequence of yellowish-gray and dusky-yellow to grayish-olive shale and minor siltstone; very pale orange to pale-yellowish-brown, very fine grained to medium-grained, well to poorly sorted, lenticular, crossbedded, calcareous sandstone; minor carbonaceous shale; and a few lenticular subbituminous coal beds less than 35 cm (14 in.) thick; continental in origin. Upper part of unit eroded away over most of map area. Lower contact gradational and interfingering with Cleary Coal Member of Menefee Formation. Allison Member is distinguished from Cleary Coal Member by absence of coal beds more than 35 cm (14 in.) thick. Position of contact between Allison and Cleary Members changes stratigraphically with change in thickness of coal beds. Thickness estimated to be as much as 250 m (820 ft) in area of Big Rock Hill 7 1/2-minute quadrangle and as much as 609 m (1,998 ft) thick in north half of map area. (*GRI Source Map ID 1060*) (Milk Lake and Nose Rock Quadrangles).

The following coal bed is present within the Allison Member of the Menefee Formation:

Kmfaz - Menefee Allison zone.

Kmfaz - Menefee Formation, Allison Member, coal zone (Upper Cretaceous)

Kmfaz - Menefee Allison zone (Upper Cretaceous)
No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfaz - Menefee Allison zone (Upper Cretaceous)
No unit description provided on source map. (*GRI Source Map ID 32096*) (Seven Lakes NE Quadrangle - coal map).

Kmfaz - Menefee Allison zone (Upper Cretaceous)
No unit description provided on source map. (*GRI Source Map ID 74537*) (Seven Lakes NW Quadrangle - coal map).

*** Unit is designated MA Zone on Coal Bed Thickness Drill Hole and Measured Section figures.*

Kmfav - Menefee Formation, Allison Member, La Vida Beds of Miller (1984) (Upper Cretaceous)

Kmav - Menefee Formation, La Vida Beds of Miller (1984, p. A35–A40)
Fine-grained, nearly white, thin- to thick-bedded sandstone and dark-gray mudstone containing numerous bands of dusky-brown organic-rich mudstone (humate) and numerous lenticular coal beds that are mostly thin, but may be up to 5 ft (1.5 m) thick; petrified wood present, but rare. Crops out only in northern part of quadrangle. Topmost bed containing large calcareous concretions defines the base of La Vida Beds. Thickness is 200 to 230 ft (61 to 70 m). (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

The following coal beds and linear units are present within the La Vida Beds, Menefee Formation in the La Vida Mission Quadrangle.

Kmfavsd - Sandstone dike, La Vida Beds of Miller, Allison Member, Menefee Formation
Kmfavw4 - Uppermost coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation
Kmfavw3 - Uppermost coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation
Kmfavw2 - Upper coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation
Kmfavn2 - Upper coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation
Kmfave2 - Upper coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation
Kmfavw1 - Lower coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation
Kmfavn1 - Lower coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation
Kmfave1 - Lower coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation

Kmfavsd - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), sandstone dike

Kmfavsd - **Sandstone dike, La Vida Beds of Miller, Allison Member, Menefee Formation**.
No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfavw4 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), uppermost coal bed W4

Kmfavw4 - Uppermost coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation.
No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfavw3 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), uppermost coal bed W3

Kmfavw3 - Uppermost coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation.
No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfavw2 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), upper coal bed W2

Kmfavw2 - Upper coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation.
No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfavn2 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), upper coal bed N2

Kmfavn2 - Upper coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation.
No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfave2 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), upper coal bed E2

Kmfave2 - Upper coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation. No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfavw1 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), lower coal bed W1

Kmfavw1 - Lower coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation. No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfavn1 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), lower coal bed N1

Kmfavn1 - Lower coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfave1 - Menefee Formation, Allison Member, La Vida Beds of Miller (1984), lower coal bed E1

Kmfave1 - Lower coal bed, La Vida Beds of Miller, Allison Member, Menefee Formation No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfal - Menefee Formation, lower part of Allison Member (Upper Cretaceous)

About 735 ft (225 m) thick, of which only the uppermost 35 ft (11 m) is exposed in La Vida Mission quadrangle. Fine-grained sandstone, gray mudstone, and minor amounts of siltstone; no calcareous concretions and few ironstone (siderite) concretions. Poorly exposed. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Kmfaj - Menefee Formation, Allison Member, Juans Lake Beds of Miller (1984) (Upper Cretaceous)

Fine-grained, light-gray to white, thin- to thick-bedded sandstone and dark-gray mudstone that weathers light gray. Characterized by numerous large calcareous concretions that are present at base or top of some sandstone units, but are less common downward; concretions are hard and have a conchoidal fracture. Juans Lake Beds also contain small ironstone (siderite) concretions scattered along individual horizons or coalescing into thin beds. Petrified wood present, but rare. Bands of dusky-brown organic-rich mudstone (humate) several feet thick are present in upper part of beds. Very local thin coal lenses occur in uppermost part of beds; carbonaceous shale units are common. Base of the Juans Lake Beds is defined as the lowest occurrence of calcareous concretions. Thickness is about 750 ft (230 m). (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle).

Kmfc - Menefee Formation, Cleary Coal Member (Upper Cretaceous)

Kmfc - Menefee Formation, Cleary Coal Member (Upper Cretaceous)
Interbedded, very light gray to dark-gray, carbonaceous shale, siltstone, sandstone, and thin, discontinuous coal beds. Sandstone generally medium to coarse grained, locally very coarse grained, moderately well sorted to poorly sorted, trough crossbedded and high-angle planar crossbedded; contains clay clasts and carbonized plant detritus. Member includes a few coal layers mostly less than 15 cm thick. Of marshy and deltaic origin. Only lowest 10 m exposed in this quadrangle. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Kmfc - Menefee Formation, Cleary Coal Member (Upper Cretaceous)
Interbedded, very light gray (N7) to dark-gray (N3), carbonaceous, clayey shale, siltstone, sandstone, and thin discontinuous coal beds. Sandstone generally very fine to medium-grained, locally coarse grained, moderately well sorted to poorly sorted, trough crossbedded and high-angle planar crossbedded; contains clay clasts and carbonized plant detritus. Limited shallow drilling in the northeastern part of the quadrangle shows as many as 8 beds of subbituminous coal, ranging from 30 cm to 3 m in thickness, with an aggregate thickness of 6 m. Of marshy and deltaic origin. Estimate only lowest 37 m exposed in quadrangle. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

*** Unit is designated MC Zone on Coal Bed Thickness Drill Hole and Measured Section figures.*

The following coal beds are present within the Cleary Coal Member:

Kmfz - Menefee Cleary Coal Zone
Kmfc1 - Cleary Coal #1
Kmfc2 - Cleary Coal #2
Kmfc3 - Cleary Coal #3

Kmfc3 - Menefee Formation, Cleary No. 3 coal bed (Upper Cretaceous)

Kmfc3 - Menefee Formation, Cleary Coal #3 (Upper Cretaceous)
No unit description provided on source map. (*GRI Source Map ID 32100*) (Heart Rock Quadrangle - coal map).

Kmfc3 - Menefee Formation, Cleary Coal #3 (Upper Cretaceous)
No unit description provided on source map. (*GRI Source Map ID 74535*) (Milk Lake Quadrangle - coal map).

Kmfc3 - Menefee Formation, Cleary Coal #3 (Upper Cretaceous)
No unit description provided on source map. (*GRI Source Map ID 32096*) (Seven Lakes NE Quadrangle - coal map).

*** Unit is designated MC3 on Coal Bed Thickness Drill Hole and Measured Section figures.*

Kmfc2 - Menefee Formation, Cleary No. 2 coal bed (Upper Cretaceous)

No unit description provided on source map. (*GRI Source Map ID 1047*) (La Vida Mission Quadrangle - coal map).

*** Unit is designated MC2 on Coal Bed Thickness Drill Hole and Measured Section figures.*

Kmfc1 - Menefee Formation, Cleary No. 1 coal bed (Upper Cretaceous)

Kmfc1 - Menefee Formation, Cleary Coal #1.
No unit description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map)

Kmfc1 - Menefee Formation, Cleary Coal #1.
No unit description provided on source map. (*GRI Source Map ID 74535*) (Milk Lake Quadrangle - coal map)

Kmfc1 - Menefee Formation, Cleary Coal #1.
No unit description provided on source map. (*GRI Source Map ID 32099*) (Nose Rock Quadrangle - coal map)

Kmfc1 - Menefee Formation, Cleary Coal #1.
No unit description provided on source map. (*GRI Source Map ID 32096*) (Seven Lakes NE Quadrangle - coal map)

Kmfc1 - Menefee Formation, Cleary Coal #1.
No unit description provided on source map. (*GRI Source Map ID 74537*) (Seven Lakes NW Quadrangle - coal map).

*** Unit is designated MC1 on Coal Bed Thickness Drill Hole and Measured Section figures.*

Kmfz - Menefee Formation coal zone (Upper Cretaceous)

Kmfc - Menefee Cleary Coal Zone.
No description provided on source map. (*GRI Source Map ID 74539*) (La Vida Mission Quadrangle - coal map).

Kmfc - Menefee Cleary Coal Zone.
No description provided on source map. (*GRI Source Map ID 74535*) (Milk Lake Quadrangle - coal map).

Kmfc - Menefee Cleary Coal Zone.
No description provided on source map. (*GRI Source Map ID 32099*) (Nose Rock Quadrangle - coal map).

Kmfc - Menefee Cleary Coal Zone.
No description provided on source map. (*GRI Source Map ID 32096*) (Seven Lakes NE Quadrangle - coal map).

Kmfc - Menefee Cleary Coal Zone.
No description provided on source map. (*GRI Source Map ID 74537*) (Seven Lakes NW Quadrangle - coal map).

*** Unit is designated ME Zone on Coal Bed Thickness Drill Hole and Measured Section figures.*

Point Lookout Sandstone (Upper Cretaceous)

Kplu - Point Lookout Sandstone, upper sandstone member (Upper Cretaceous (Campanian))

Kplu - Point Lookout Sandstone, upper sandstone member (Upper Cretaceous)
Very light gray (N8) to pale-yellowish-gray (5Y 8/2), very fine grained sandstone; grades upward to medium-grained, well-sorted, friable sandstone. Some beds are calcareous. Beds in lower part are mostly thick bedded and structureless, or are faintly horizontally laminated, and contain some slump structures and a few burrows. Beds in upper part are thinner and show large- to medium-scale, low-angle tangential and trough crossbedding, as well as wedge-planar and tabular-planar crossbedding, and minor horizontally laminated and undulatory bedding; contains some ironstone concretions, clay clasts, and finely divided carbonized plant detritus in upper part of member. Upper 20-50 cm of some beds are bioturbated and contain trace fossil burrows of *Ophiomorpha* and *Skolithos*. Unit displays characteristic marine regressive sequence. Thins northward as lower part intertongues with, and grades into, underlying Satan Tongue of Mancos Shale (Kms). Thickness 24-46 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Kplu - Point Lookout Sandstone, upper sandstone member (Upper Cretaceous (Campanian))
Medium-grained, well-sorted, friable sandstone in uppermost part; grades downward into very light gray (N8) to yellowish-gray (5Y8/2), very fine grained sandstone. Some beds are calcareous. Beds in upper part are thin and show large-to medium-scale, low-angle tangential and trough crossbedding, as well as wedge-planar and tabular-planar crossbedding, and minor horizontally laminated and undulatory bedding; included are a few thin interbeds of siltstone and shale. Sandstone beds in upper part contain some ironstone concretions, clay clasts, and finely divided carbonized plant detritus. Upper 20-50 cm of some beds are bioturbated and contain trace fossil burrows of *Ophiomorpha* and *Skolithos*. Beds in lower part are mostly thick bedded and structureless, or are faintly horizontally laminated, and contain some slump structures and a few burrows. All beds were deposited in a progradational marine sequence, characterized by upper shoreface facies in the upper third of the formation and offshore to lower shoreface facies in the lower two-thirds. Foreshore and backshore facies are missing at the top, apparently eroded before deposition of paludal units in the overlying Cleary Coal Member of the Menefee Formation (Kmfc). Thins northward as lower part intertongues with, and grades into, underlying Satan Tongue of Mancos Shale (Kms). Thickness 29-46 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Kplh - Point Lookout Sandstone, Hosta Tongue (Upper Cretaceous (Santonian))

Kplh - Point Lookout Sandstone, Hosta Tongue (Upper Cretaceous)
Light-brown (5YR 6/4) to grayish-orange-pink (5YR 6/2) sandstone and interbedded siltstone and shale; weathers pale yellowish gray (5Y 7/2). Sandstone highly variable in basal 1-3 m, ranging from fine to coarse grained and from moderately well sorted to poorly sorted; sandstone was deposited as thin to very thin sets of low-angle tangential- and trough-crossbedded strata and interlayered horizontally laminated beds. Some basal beds contain chert and quartz granules and pebbles; other beds contain clay galls and carbonate concretions, carbonized plant detritus, shark teeth, and shell fragments; some beds are bioturbated and burrowed. Some poorly sorted beds suggest reworked material. Contact with underlying Gibson Coal Member of the Crevasse Canyon Formation (Kcg) generally is an erosional surface, but Hosta beds locally interfinger with the Gibson. Basal interval probably deposited during marine transgression.

Upper part is mostly fine- to very fine grained, well-sorted sandstone in thick to very thin, flaggy beds that are horizontally and ripple laminated, low-angle tangential and trough crossbedded and hummocky crossbedded. Includes some soft-sediment slump structures. Shale, siltstone, and minor limestone

beds become more abundant and thicker northeastward in the quadrangle and replace sandstone, so that the Hosta Tongue interfingers with, and grades laterally into, the overlying Satan Tongue of Mancos Shale (Kms) in the central part of the quadrangle and is replaced by Satan Tongue in the northern part of the quadrangle. The character of the Hosta Tongue indicates deposition mostly in regressive marine sequences of upper and lower shoreface (Harms and others, 1975, p. 84). Total Hosta Tongue thickness 0-43 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Kplh - Point Lookout Sandstone, Hosta Tongue ((Upper Cretaceous (Santonian))
Light-brown (5YR6/4) to grayish-orange-pink (5YR6/2), very fine to fine-grained, well-sorted to moderately well-sorted sandstone, and minor interbedded siltstone and shale; weathers pale yellowish gray (5Y7/2) to white. Deposited in beds, 30-130 cm thick, containing low-angle tangential-, tabular-planar-, and trough-crossbedded strata, with a few interlayered horizontally laminated beds; some are ripple laminated, have contorted bedding and slump structures, or have hummocky crossbedding. Some beds are bioturbated in their upper parts or contain burrows of *Ophiomorpha* or other trace fossils. Basal beds commonly contain clay galls, carbonate concretions, carbonized plant detritus, fish teeth, and shell fragments, probably deposited during marine transgression. Contact with underlying Gibson Coal Member of the Crevasse Canyon Formation (Kcg) generally is an erosional surface, but beds of the Hosta locally interfinger with paludal beds of the Gibson. The Hosta is locally absent in the west-central part of the quadrangle (SE1/4 sec. 16, T. 17 N., R. 12 W), where marine shale and minor interbedded offshore silty sandstone of the Satan Tongue (Kms) rest directly on the Gibson Coal Member (Kcg). Deposition mostly in a transgressive marine environment; abbreviated sequences of upper shoreface, foreshore, and tidal-channel deposits (Harms and others, 1975, p. 84), are eroded, truncated, and overlain by offshore marine shale, siltstone, and limestone of the overlying Satan Tongue of Mancos Shale (Kms). Thickness 3-9 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Mancos Shale (Upper Cretaceous)

Kms - Mancos Shale, Satan Tongue (Upper Cretaceous (Santonian))

Kms - Mancos Shale, Satan Tongue (Upper Cretaceous)
Interbedded, medium- to light-gray (N5 -N7), laminated claystone, shale, siltstone, and thinly bedded, pale-yellowish-gray, very fine grained, well-sorted, calcareous sandstone. Weathers yellowish gray (5Y 7/2) to grayish orange (10YR 7/4); forms clayey slopes broken by more resistant, thin sandy ledges. Becomes sandier and includes a few carbonaceous to lignitic shale beds as it thins and pinches out southwestward between the upper sandstone member of the Point Lookout Sandstone (Kplu) and the Hosta Tongue (Kplh). The Satan thickens toward the northeast at the expense of the enclosing sandstone units, largely replaces the underlying Hosta Tongue (Kplh) in the middle of the quadrangle, and lies directly on the Gibson Coal Member of the Crevasse Canyon Formation (Kcg) in the northern part of the quadrangle. The Satan Tongue was deposited in a nearshore marine environment. Thickness 3-85 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Kms - Mancos Shale, Satan Tongue (Upper Cretaceous (Santonian))
Interbedded, medium- to light-gray (N5-N7) and light-olive-gray (5Y5/2), laminated claystone, shale, siltstone, and thinly bedded, pale-yellowish-gray, very fine grained, well-sorted, calcareous sandstone. Weathers yellowish gray (5Y7/2) to grayish orange (10YR7/4); forms clayey slopes broken by resistant, thin sandy ledges. Some beds have wave ripples; some contain limestone concretions. Occurs stratigraphically between the upper sandstone member of the Point Lookout Sandstone (Kplu) and the Hosta Tongue (Kplh). Thickens toward the north and east, and replaces most of the underlying Hosta Tongue (Kplh). Deposited in a nearshore marine environment. Maximum thickness about 80 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Kmm - Mancos Shale, Mulatto Tongue (Upper Cretaceous (Santonian))

Interbedded, medium- to light-gray (N5-N7) and light-greenish- to light-bluish-gray (5G/B 6/1), laminated shale, siltstone, silty claystone, and platy limestone and thinly bedded, very fine grained, pale-gray to yellowish-gray, calcareous sandstone. Some beds are ripple laminated; others are bioturbated and burrowed. Limestone forms thin lenses, pods, and concretions and contains sparse fossil mollusks. Contact with overlying Dalton Sandstone Member (Kcda) is gradational and interfingered; contact with the underlying Dilco Coal Member (Kcdi) is unconformable. Thickness 70-100 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Km - Mancos Shale, main body (Upper Cretaceous (Santonian))

Shown in cross section only.
Mainly medium- to medium-dark-gray (N4-N6) shale containing sparse, thin-bedded, gray to brown, sandy limestone and limy siltstone. Deposited as offshore marine shale that lies stratigraphically between the Twowells Tongue of the Dakota Sandstone (Kdt) and the Gallup Sandstone (Kg). Interbedded with sandstone beds A and B of the Gallup Sandstone (Kga and Kgb); includes the Juana Lopez Member (Kmj). Thickness approximately 220 m. (GRI Source Map ID 8387) (Crownpoint Quadrangle).

Kmj - Mancos Shale, Juana Lopez Member (Upper Cretaceous (Santonian))

Kmj - Mancos Shale, Juana Lopez Member (Upper Cretaceous) - *Shown in cross section only*.
Consists of pale¬yellowish-brown to light-olive-gray, silty limestone in thin platy beds, 15-45 cm thick, interbedded with thicker intervals of dark-gray shale. The limestone layers, which number four or more, contain abundant fossil shell fragments and shark teeth, are persistent, and are marked by sharp attenuations on resistivity and spontaneous potential drill-hole logs. Interbedded with Mancos Shale (Km). Thickness of Juana Lopez Member varies between 15 and 30 m depending on the thickness, number, and spacing of limestone beds. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Kmj - Mancos Shale, Juana Lopez Member (Upper Cretaceous (Turonian)) - *Shown in cross section only*.
Consists of pale-yellowish-brown to light-olive-gray, silty limestone in thin platy beds, 15-45 cm thick, interbedded with thicker intervals of dark-gray shale of the Mancos (Km). The limestone layers, which number four or more, contain abundant fossil shell fragments and shark teeth, are persistent, and are marked by sharp attenuations on resistivity and spontaneous potential drill-hole logs. Ranges stratigraphically from 97 to 107 m above the base of the Mancos. Thickness of Juana Lopez Member 25-30 m, depending on the thickness, number, and spacing of limestone beds. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Kmw - Mancos Shale, Whitewater Arroyo Tongue (Upper Cretaceous)

Kmw - Mancos Shale, Whitewater Arroyo Tongue (Upper Cretaceous) - *Shown in cross section only*.
Medium-to dark-grayish-green silty shale. Contains Exogyra sp., Gryphaea sp., and other fossil mollusks. Includes scattered thin lenses and concretions of pale-yellowish-orange (10YR 8/6) limestone, as thick as 1 m, that has cone-in-cone structure. Locally contains thin interbeds of fine-grained sandstone and siltstone. Gradational contact with overlying Twowells Tongue of the Dakota Sandstone (Kdt); sharp contact with Dakota Sandstone (Kd) at base. Combined thickness of Whitewater Arroyo Tongue (Kmw) and Twowells Tongue (Kdt) is nearly constant at 37 m; shale thickness varies from 19 to 34 m. (GRI Source Map ID 8387) (Crownpoint Quadrangle).

Kmw - Mancos Shale, Whitewater Arroyo Tongue (Cenomanian) - *Shown in cross section only.* Medium- to dark-grayish-green silty shale. Contains Exogyra sp., Gryphaea sp., and other fossil mollusks. Includes scattered thin lenses and concretions of pale-yellowish-orange (10YR8/6) limestone, as thick as 1 m, that has cone-in-cone structure. Locally contains thin interbeds of fine-grained sandstone and siltstone. Contact gradational with overlying Twowells Tongue of the Dakota Sandstone (Kdt); contact sharp with underlying Dakota Sandstone (Kd). Combined thickness of Whitewater Arroyo Tongue and Twowells Tongue is nearly constant at 35 m; shale thickness 24-31 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Crevasse Canyon Formation (Upper Cretaceous)

Kcg - Crevasse Canyon Formation, Gibson Coal Member (Upper Cretaceous (Santonian))

Kcg - Crevasse Canyon Formation, Gibson Coal Member
Lithology highly variable and beds are laterally discontinuous. Includes light- to dark-gray (N7-N3), carbonaceous shale, siltstone, and claystone; thin discontinuous coal beds; and pale-yellowish-gray (5Y 8/4) to white, very fine to medium-grained, locally coarse to very coarse grained, poorly sorted sandstone. Sandstone beds are 0.5-14 m thick; some are horizontally bedded and bioturbated, but most are trough and wedge-planar crossbedded, and some contain carbonaceous plant debris, petrified logs, clay clasts, and kaolinized feldspar. Most of the sandstone beds appear to represent estuarine, fluvial channel, or distributary channel deposits. Contacts are generally sharp, but locally intertongue with, or grade laterally into, tidal-channel and marine- beach and bar deposits of the overlying Hosta Tongue of the Point Lookout Sandstone (Kplh) and underlying Dalton Sandstone Member (Kcda). Gibson Coal Member is overlain by the Satan Tongue of the Mancos Shale (Kms) in northern part of quadrangle. Thickness ranges from 104 m in southern part of quadrangle to 37 m in northern part. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Kcg - Crevasse Canyon Formation, Gibson Coal Member (Santonian)
Lithology highly variable and laterally discontinuous. Includes very light to dark-gray (N8-N3) carbonaceous shale, siltstone, and claystone; thin discontinuous coal beds; and yellowish-gray (5Y7/2) and grayish-yellow (5Y8/4) to white, poorly to well-sorted sandstone. Sandstone beds 0.5-12 m thick; many beds horizontally laminated or ripple laminated, fine to very fine grained, silty to clayey, carbonaceous, and interbedded with carbonaceous shale and siltstone; other beds generally coarser grained and thicker bedded, occupy channels that scour underlying units, are trough and tabular-planar cross-bedded, and contain carbonaceous plant debris, petrified logs, clay clasts, and kaolinized feldspar. Most of the sandstone beds appear to represent estuarine, fluvial-channel, distributary-channel, or splay deposits. Contacts generally sharp, but locally intertongue with, or grade laterally into, tidal-channel and marine-beach and bar deposits of the overlying Hosta Tongue (Kplh) and underlying Dalton Sandstone Member of the Crevasse Canyon Formation (Kcda). Twelve or more lenticular and discontinuous, subbituminous coal beds, 15-36 cm thick, scattered through the Gibson Coal Member. Thickness 74 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

The following coal bed is present within the Crevasse Canyon Gibson Coal zone:

Kcg - Crevasse Canyon Gibson Coal zone.

*** Unit is designated CG Zone on Coal Bed Thickness Drill Hole and Measured Section figures.*

Kcda - Crevasse Canyon Formation, Dalton Sandstone Member (Upper Cretaceous (Santonian))

Kcda - Crevasse Canyon Formation, Dalton Sandstone Member
Generally very light gray (N8) to pale-yellowish-gray (5Y 8/1) and pale-orangish-yellow (10YR 8/2) sandstone that forms prominent cliffs consisting of one to three massive units, each 2-22 m or more thick. The Dalton can be divided into a succession of nearshore marine progradational sandstone facies, which grade upward from lower shoreface deposits to upper shoreface and foreshore deposits (Harms and others, 1975, p. 84). These are described below, but are undifferentiated on the map. Total thickness ranges from 25 to 55 m.

Foreshore facies - Beach or swash zone sandstone deposits. fine-to medium-grained, well-sorted; in thin to thick, gently dipping beds that have planar laminae, undulating laminae, some small-scale ripple laminae, and very low angle tangential cross-laminae and crossbeds. Contains few burrows. Gradational with underlying upper shoreface facies. Only locally preserved; commonly eroded before deposition of overlying marginal marine units. Thickness 0-5 m.

Upper shoreface facies - Sandstone, well-sorted, coarsens upward from fine- to medium-grained; contact with underlying lower shoreface facies is a generally sharp scour surface, but is locally gradational. Beds 50-150 cm thick, in low-angle tangential- and wedge-planar crossbed sets interlayered with subhorizontal to ripple-laminated and bioturbated beds; locally contains vertical burrows of *Skolithos* and *Ophiomorpha* , as well as horizontal burrows of *Thalassinoides*. Thickness 4-12 m.

Lower shoreface facies - Constitutes lower third to lower half of member. Ranges from siltstone and very fine grained sandstone with interbedded shale at base to fine-grained sandstone at top. Intertongues and grades into underlying marine shale. Well sorted, calcareous: contains finely divided carbonaceous detritus and few *Ophiomorpha* and *Skolithos* trace fossils; thick bedded and structureless or faintly laminated to very thin bedded. Contains mostly planar bedding, some subhorizontal and wavy bedding, some medium-scale hummocky crossbedding (Harms and others, 1975, p. 87-89), and wave-ripple laminations. Commonly displays soft-sediment deformation as flow rolls and ball-and-pillow structures in basal part. Thickness 4-18 m.

Lagoonal sandstone - Foreshore and upper shoreface facies grade laterally in places into sandstone characterized as lagoonal (Reading, 1978, p. 158; Dickenson and others, 1972, p. 202). Ranges from medium light brown (5YR 5/4) to dark gray (N3), fine to very fine grained, moderately well to poorly sorted, and commonly has a silty to clayey matrix. Contains abundant carbonized plant debris and detritus; indistinctly horizontally laminated, ripple laminated, or massive; is widely burrowed and bioturbated; and contains traces of probable root structures. Thickness 0-10 m.

Tidal or estuarine channel sandstone - Similar to deposits described by Molenaar (1973, p 88). Locally rests on surfaces in the foreshore and upper shoreface facies. The sandstone is generally pale yellowish gray, fine to coarse grained becoming finer upward, and moderately well to poorly sorted. It contains some lenses of very coarse grained pebbly sandstone and locally contains clay clasts and galls. It occurs in thin to thick trough , wedge-planar, and tangential-crossbedded sets interlayered with horizontal- to subhorizontal-bedded sets. Some beds are bioturbated, or are burrowed and contain the trace fossils *Ophiomorpha*, *Thalassinoides*, and *Skolithos*. Channel deposits grade laterally to the south and west into fluvial sandstone beds that interfinger with carbonaceous beds of the overlying Gibson Coal Member (Kcg). Transition beds occur in southwestern corner of map area. Thickness 0-12 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Kcda - Crevasse Canyon Formation, Dalton Sandstone Member (Santonian)
Generally very light gray (N8) to yellowish gray (5Y8/1) and very pale orange (10YR8/2) sandstone that forms prominent cliffs consisting of 1-3 massive units, each 2-22 m or more thick. Can be divided into a

succession of nearshore marine progradational sandstone facies, which grade downward and laterally from foreshore and lagoonal deposits to upper and lower shoreface deposits (Harms and others, 1975, p. 84). These facies, described below, are not shown separately on the map. The succession of facies as presented, though generally valid, is somewhat idealized, because it is commonly modified locally by repetitions or interruptions in the cycle. Total thickness 37-48 m.

In the southwest corner of the quadrangle, some contacts between the Dalton Sandstone Member and both the overlying Gibson Coal Member (Kcg) and underlying Mulatto Tongue of the Mancos Shale (Kmm) do not match with those in the adjoining Crownpoint quadrangle. This is due partly to lateral gradational changes in units and resulting changes in interpretation, and the addition of new mapping and information. Contacts in the Heart Rock quadrangle are assumed to be correct.

Lagoonal facies - Foreshore and upper shoreface fades grade laterally in places into sandstone characterized as lagoonal (Reading, 1978, p. 158; Dickinson and others, 1972, p. 202). Ranges from light brown (5YR5/4) to dark gray (N3), fine to very fine grained, moderately well to poorly sorted, and commonly has a silty to clayey matrix. Contains abundant carbonized plant debris and detritus; indistinctly horizontally laminated, ripple laminated, or massive; widely burrowed and bioturbated; and contains traces of probable root structures. Thickness 0-10 m.

Tidal or estuarine channel facies - Similar to sandstone deposits described by Molenaar (1973, p. 88). Rests on surfaces in the foreshore and upper shoreface facies. Consists generally of pale-yellowish-gray, coarse- to fine-grained, fining upward, moderately well to poorly sorted sandstone. Contains lenses of very coarse grained pebbly sandstone; locally contains clay clasts and galls. Occurs in thin to thick trough-, wedge-planar, and tangential crossbedded sets, interlayered with horizontal- to subhorizontal-bedded sets. Some beds are bioturbated or burrowed, and contain the trace fossils *Ophiomorpha*, *Thalassinoides*, and *Skolithos*. Channel deposits grade laterally to the south and west into fluvial sandstone beds that interfinger with carbonaceous beds of the overlying Gibson Coal Member (Kcg). Thickness 0-12 m.

Foreshore facies - Beach or swash-zone deposits, consisting of fine- to medium-grained, well- to poorly sorted sandstone, and interbedded thin streaks and lenses of coarse-grained sandstone and sparse granule-pebble conglomerate. Sandstone beds range from thin to thick, and have parallel and subparallel to undulating laminae, some small-scale ripple laminae, and very low angle tangential and wedge-planar cross laminae. Contains fish teeth, broken shell fragments, carbonate and iron oxide nodules and concretions, sparse erratics of chert and quartzite pebbles, and few fossil burrows. Gradational with underlying upper shoreface facies. Generally scoured and eroded before deposition of overlying estuarine or fluvial units. Top bed commonly has a rind of secondary silica and iron carbonate 15 cm thick. Thickness 0-5 m.

Upper shoreface facies - Sandstone, well sorted, generally coarsens upward from very fine to fine grained, and to medium grained in places; contact with underlying lower shoreface is generally a sharp scour surface, but locally is gradational. Beds 50-150 cm thick, in low-angle tangential- and wedge-planar crossbed sets, are interlayered with subhorizontal to ripple-laminated and bioturbated beds; locally contain vertical burrows of *Skolithos* and *Ophiomorpha*, as well as horizontal burrows of *Thalassinoides*. Contains minor interbeds of carbonaceous shale, and calcareous laminated siltstone and claystone. Thickness 4-13 m.

Lower shoreface facies - Constitutes lower third to lower half of the Dalton Sandstone Member. Ranges from clayey siltstone and very fine grained sandstone with interbedded shale at base to fine-grained sandstone at top. Intertongues and grades into underlying marine shale. Well sorted, calcareous; some beds contain finely divided carbonaceous detritus, calcium carbonate concretions, and a few *Ophiomorpha* and *Skolithos* trace fossils; thick bedded and structureless or faintly laminated. Contains mostly planar bedding, some subhorizontal and wavy bedding, some medium-scale hummocky

crossbedding (Harms and others, 1975, p. 87-89), and wave-ripple laminations. Lower part commonly displays soft-sediment deformation, such as flow rolls and ball-and-pillow structures. Thickness 4-18 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Kcb - Crevasse Canyon Formation, Borrego Pass Lentil (Upper Cretaceous (Santonian))

Shown in cross section only.
Named by Correa (1970, p. 99); informally referred to as the "stray sandstone" by Sears and others (1941, p. 113). Consists of yellowish-gray (5Y811) to grayish-yellow (5Y8/4) and very light gray (N8), fine-grained to very fine grained, thin-bedded, generally clean, well-sorted sandstone. Ranges from very fine grained and silty, very thinly planar-bedded and laminated sandstone containing carbonaceous plant debris, to fine-grained sandstone having thin sets of low-angle trough, tabular-planar, and wedge-planar crossbedding and small-scale ripple crossbedding. Some beds display Ophiomorpha burrows and worm tracks; some have obscure bedding and are lumpy because of burrowing and bioturbation. Contains a few thin inter-beds of carbonaceous shale and siltstone. Intertongues with underlying Dilco Coal Member and is overlain unconformably by the Mulatto Tongue of the Mancos Shale (Kmm). Interpreted by Molenaar (1973, p. 103) as transgressive sand deposits of lagoons, tidal channels, and tidal deltas, overlain or supplanted by coastal barrier and beach deposits. Thickness 6-15 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Kcdi - Crevasse Canyon Formation, Dilco Coal Member (Upper Cretaceous (Coniacian))

Kcdi - Crevasse Canyon Formation, Dilco Coal Member
Thin-bedded, light- to dark-gray (N7 -N3), carbonaceous to coaly shale, siltstone, claystone, and interbedded light-yellowish-gray (5Y 8/1), fine- to very fine grained, silty to clayey sandstone. The sandstone mostly occurs as thin planar, horizontally laminated, and ripple-laminated beds that are uniform and persistent, but also includes small-scale low-angle trough- and wedge-planar crossbeds in thin lenses. Upper part of individual sandstone units are commonly bioturbated and, in places, contain vertical *Ophiomorpha* burrows. Mostly of marshy and deltaic origin. In adjacent quadrangles the Dilco Coal Member intertongues with the underlying Gallup Sandstone (Kg). Only uppermost 10 m exposed in southwestern corner of map area. Total thickness, shown in cross section and taken from geophysical logs of drill holes, ranges from 61 m in the southern part of quadrangle to 29 m in the northern part. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

The following coal beds are present within the Crevasse Canyon Dilco Coal zone:

Kcdi - Crevasse Canyon Dilco Coal zone
No unit description provided on source map. (*GRI Source Map ID 41614*) (Crownpoint Quadrangle - coal map).

Kcdi - Crevasse Canyon Dilco Coal zone
No unit description provided on source map. (*GRI Source Map ID 32100*) (Heart Rock Quadrangle - coal map).

Kcdi - Crevasse Canyon Dilco Coal zone
No unit description provided on source map. (*GRI Source Map ID 74535*) (Milk Lake Quadrangle - coal map).

*** Unit is designated CD Zone on Coal Bed Thickness Drill Hole and Measured Section figures.*

Gallup Sandstone (Upper Creteceous)

Kg - Gallup Sandstone, main body (Upper Cretaceous (Turonian to Coniacian))

Shown in cross section only.
Composed of well-developed regressive shoreline deposits, ranging from stacked lower and upper shoreface facies at top of the formation to offshore marine facies at bottom, similar to sequence of facies in the Dalton Sandstone Member of the Crevasse Canyon Formation (Kcda). Mainly consists of pale-yellowish-gray (5Y8/2) to white, well-sorted sandstone, which coarsens upward from very fine at bottom to medium-grained near the top. Both massive and thin beds, parallel bedded to laminated, occur in lower part. In upper part beds are thin and trough and wedge-planar crossbedded. Contact with overlying Dilco Coal Member of the Crevasse Canyon Formation (Kcdi) is sharp, and commonly erosional, but is also intertonguing in places. Contact with underlying Mancos Shale (Km) is gradational, within an interbedded, transitional zone, that changes upward from offshore marine shale to near-shore sandstone. Varying zone thickness probably reflects a fluctuating shoreline. Thickness 20-30 average 26 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Kgb - Gallup Sandstone, bed B (Upper Cretaceous)

Kgb - Gallup Sandstone, bed B (Upper Cretaceous) - *Shown in cross section only.*
Pale-yellowish-gray (5Y 8/2), fine-grained, well-sorted, parallel-bedded and massive sandstone. Upper 30 cm generally calcareous. Separated from overlying main body of Gallup Sandstone (Kg) by 5-15 m of Mancos Shale (Km), with which it is interbedded. Upper contact sharp, lower contact gradational. Probably deposited as offshore marine sandbar. Thickness 0-11 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Kgb - Gallup Sandstone, bed B (Upper Cretaceous) - *Shown in cross section only.*
Pale-yellowish-gray (5Y8/2), fine-grained, well-sorted, parallel-bedded and massive sandstone. Upper 30 cm generally calcareous. Separated from overlying main body of Gallup Sandstone (Kg) by 9-14 m of Mancos Shale (Km), with which it is interbedded. Upper contact sharp, lower contact gradational. Probably deposited as offshore marine sandbar. Thickness 6-9 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Kga - Gallup Sandstone, bed A (Upper Cretaceous)

Shown in cross section only.
Yellowish-gray to light-brown, fine-grained, well-sorted sandstone. Separated from bed B by 3-7 m of Mancos Shale (Km), with which it is interbedded. Upper contact sharp, lower contact gradational. Probably deposited as offshore marine sandbar. Thickness 0-9 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Dakota Sandstone (Upper Cretaceous)

Kdt - Dakota Sandstone, Twowells Tongue (Upper Cretaceous (Cenomanian))

Shown in cross section only.
Yellowish-gray (5Y7/2-5Y7/4), very fine grained to fine-grained, silty sandstone for the most part, grading to medium grained at top. Thin argillaceous sandstone beds in lower part are parallel and ripple laminated, and interbedded with clayey shale and siltstone. Upwards, sandstone becomes better sorted and cleaner, contains more siliceous and calcareous cement, and, in places, has low-angle trough and

tabular-planar crossbedding. Commonly contains the fossil mollusks Exogyra and Pycnodonte and trace fossil burrows is sharp, lower contact is gradational. Probably deposited as shallow marine offshore bar. Thickness 4-12 m, thickening at the expense of the Whitewater Arroyo Tongue (Kmw). (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Kd - Dakota Sandstone, main body (Upper Cretaceous (Cenomanian))

Shown in cross section only.
Grayish-yellow (5Y8/4) to white, very fine to medium-grained, well-sorted, generally siliceous sandstone, in beds 0.5-15 m thick, that are interbedded with gray to black, carbonaceous to coaly shale and siltstone, from 1 cm to 5 m thick. Sandstone contains medium- to small-scale, tabular-planar and trough crossbedding and some horizontal and subhorizontal laminations; some beds contain carbonaceous plant material and detritus. Lagoonal, deltaic, and beach origins are indicated. R.H. Tschudy (written commun., 1981) established the age as early Cenomanian (early Late Cretaceous) from pollen and spores. Contact is sharp with overlying Whitewater Arroyo Tongue (Kmw). Deposited on widespread erosional unconformity. Thickness 44-66 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

*** Coal zones within this unit are designated DK Zone on Coal Bed Thickness Drill Hole and Measured Section figures*.

Morrison Formation (Upper Jurassic)

Jmb - Morrison Formation, Bushy Basin Member (Upper Jurassic)

Jmb - Morrison Formation, Brushy Basin Member (Upper Jurassic) - *Shown in cross section only*.
Pale-olive (10Y 6/2) and olive-gray (5Y 5/2), massive, sandy mudstone; greenish- and reddish- to purplish-gray, thinly bedded and laminated siltstone, claystone, and shale. Beds are largely ben¬tonitic from the alteration of incorporated air-fall and water-laid tuffaceous material. Contains lenses of interbedded feldspathic sandstone. Intertongues with underlying Westwater Canyon Member. Deposited as fluvial, flood plain, and lacustrine sediments. Thickness variable, from 16 to 78 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Jmb - Morrison Formation, Brushy Basin Member (Upper Jurassic) - *Shown in cross section only*.
Pale-olive (10Y6/2) and olive-gray (5Y5/2), massive, sandy mudstone; greenish- and reddish- to purplish-gray, thinly bedded and laminated siltstone, claystone, and shale. Beds are largely bentonitic from the alteration of incorporated air-fall and water-laid tuffaceous material. Contains lenses of interbedded feldspathic sandstone. Intertongues with underlying Westwater Canyon Member. Deposited as fluvial, flood-plain, and lacustrine sediments. Thickness highly variable, ranging from 38 to 75 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Kmbs - Morrison Formation, Brushy Basin Member, sandstone lenses

Jmbs - Morrison Formation, sandstone lenses within Brushy Basin Member (Upper Jurassic) - Shown in cross section only.
Fine- to coarse-grained, poorly sorted, friable, trough¬crossbedded, feldspathic sandstone similar to underlying sandstone of Westwater Canyon Member (Jmw). Locally sandstone is con¬glomeratic and contains abundant chert pebbles, clay clasts, and a variety of igneous rock fragments. Geometry of sandstone bodies and textural characteristics indicate deposition as fluvial-channel sandstones. Thickness 0-15 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Jmw - Morrison Formation, Westwater Canyon Member (Upper Jurassic)

Jmw - Morrison Formation, Westwater Canyon Member (Upper Jurassic) - *Shown in cross section only*.
Moderate-to pale-red to gray, fine- to coarse-grained, moderately well to poorly sorted, trough-crossbedded, feldspathic sandstone. Con¬tains thin lenses of grayish-red claystone. Locally includes very coarse sandstone and chert-pebble conglomerate. Clay-clast con¬glomerates commonly occur in basal part of scour channels. Speck¬led appearance is common from concentrations of white kaolin scattered through the matrix. Deposited from extensive braided and coalesced streams. Thickness varies greatly from 53 to 116 m. (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Jmw - Morrison Formation, Westwater Canyon Member (Upper Jurassic) - *Shown in cross section only*.
Moderate- to pale-red to gray, fine- to coarse-grained, moderately to poorly sorted, friable, trough-crossbedded, feldspathic sandstone. Contains thin lenses of grayish-red claystone. Locally includes very coarse grained sandstone and chert-pebble conglomerate. Clay-clast conglomerates commonly occur in basal part of scour channels. Speckled appearance is common from concentrations of white kaolin scattered through the matrix. Deposited from extensive braided and coalesced streams. Host to undeveloped, primary and redistributed, tabular uranium deposits in the west-central part of quadrangle, in the vicinity of the Chaco Canyon National Monument. The deposits appear to be extensions of those that underlie the Crownpoint quadrangle to west, deposits which have an east-southeast to east longitudinal trend (Kirk and Condon, 1986, p. 131). One tongue of uranium ore, at least 2,000 m long by 500 m wide, has been outlined by drilling. Thickness highly variable, ranges from 48 to 93 m. (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Jmr - Morrison Formation, Recapture Member (Upper Jurassic)

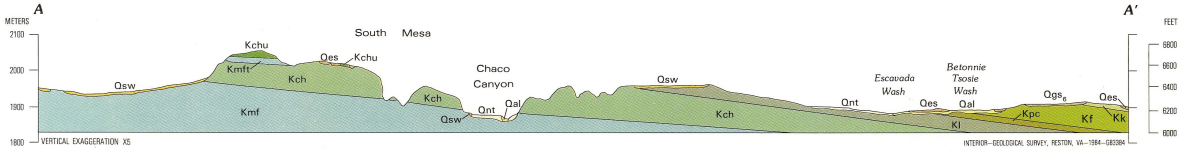
Jmr - Morrison Formation, Recapture Member (Upper Jurassic) - *Shown in cross section only, where it is incomplete*.
Drill-hole logs indicate mostly mudstone and claystone and a few thin interbedded siltstone and sandstone lenses in the upper part. Top appears to be scoured by basal sandstone of overlying Westwater Canyon Member (Jmw). (*GRI Source Map ID 8387*) (Crownpoint Quadrangle).

Jmr - Morrison Formation, Recapture Member (Upper Jurassic) - *Shown in cross section only, where it is incomplete*.
Drill-hole logs indicate mostly mudstone and claystone and a few thin interbedded siltstone and sandstone lenses in the upper part. Top appears to be scoured by basal sandstone of overlying Westwater Canyon Member (Jmw). (*GRI Source Map ID 1050*) (Heart Rock Quadrangle).

Geologic Cross Sections

The geologic cross sections present in the GRI digital geologic-GIS data produced for Chaco Culture National Historical Park, New Mexico (CHCU) are presented below. Note that some cross section abbreviations (e.g., A - A') have been changed from their source map abbreviation in the GRI digital geologic-GIS data so that each cross section abbreviation in the 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).

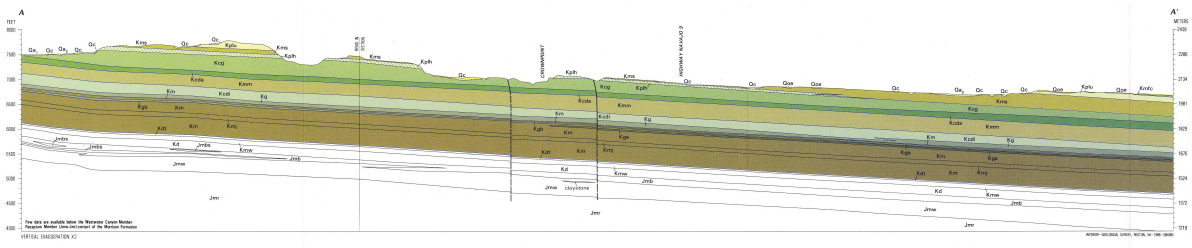
Cross Section A-A'



Extracted from: (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles). (*GRI Source Map ID 1055*).

***Only the northern portion of the cross section exactly matches the GRI geologic-GIS data. For the southern portion of the cross section the GRI geologic-GIS data was produced using a different source map.*

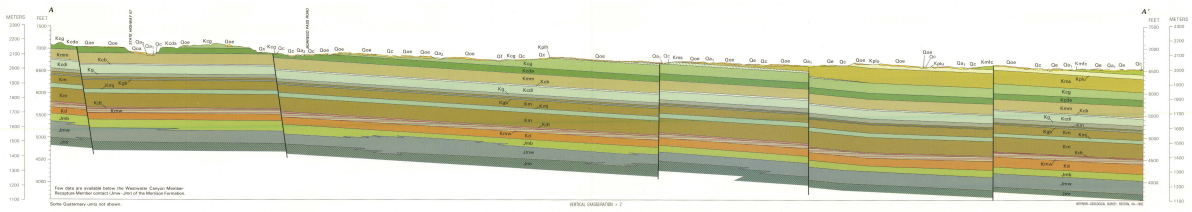
Cross Section B-B'



Extracted from: (Crownpoint Quadrangle). (*GRI Source Map ID 8387*).

*** Cross section A-A' on source map, but renamed B-B' in GRI digital geologic-GIS data and accompanying ancillary files.*

Cross Section C-C'



Extracted from: (Heart Rock Quadrangle). (*GRI Source Map ID 1050*).

*** Cross section A-A' on source map, but renamed C-C' in GRI digital geologic-GIS data and accompanying ancillary files.*

Coal Bed Thickness Drill Holes and Measured Sections

The following are figures extracted from source coal maps, and relate to coal bed thickness measured section localities in the Geologic Measurement Localities (CHCOGML) data layer in the GRI geologic-GIS data.

Figure abbreviations: GL = ground level (of well), NR = No record, R = rock interval, C = coal, TD = total depth (of well).

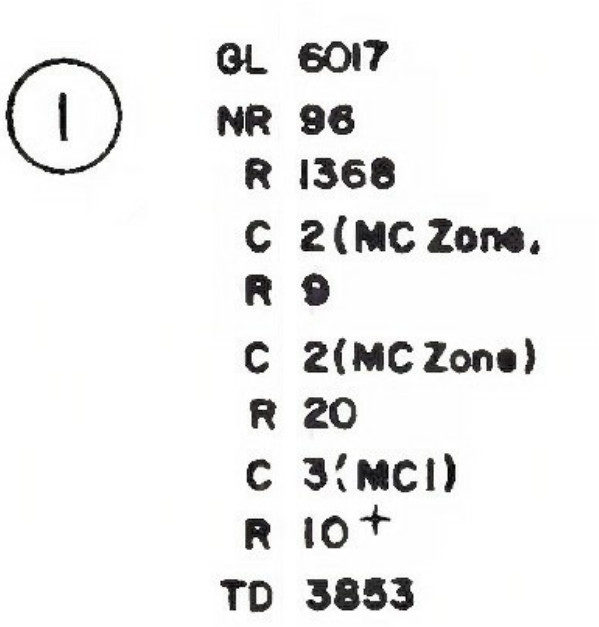
Unit designations (listed from youngest to oldest):

Unit Designation (on Source)	(GRI) Unit Symbol	(GRI) Unit Name
FR Zone	Kfr	Fruitland Formation, coal zone
FR3	Kfr3	Fruitland 3 coal bed
FR2	Kfr2	Fruitland 2 coal bed
FR1	Kfr1	Fruitland 1 coal bed
MA Zone	Kmafz	Menefee Formation, Allison Member, coal zone
MC Zone	Kmfc	Menefee Formation, Cleary Coal Member
MC3	Kmfc3	Menefee Formation, Cleary No. 3 coal bed
MC2	Kmfc2	Menefee Formation, Cleary No. 2 coal bed
MC1	Kmfc1	Menefee Formation, Cleary No. 1 coal bed
ME Zone	Kmfz	Menefee Formation, coal zone
CG Zone	Kcg	Crevasse Canyon Formation, Gibson Coal Member
CD Zone	Kcdi	Crevasse Canyon Formation, Dilco Coal Member
DK Zone	Kd	Dakota Sandstone, main body (coal zone within)

All values indicated with intervals in figures are in feet.

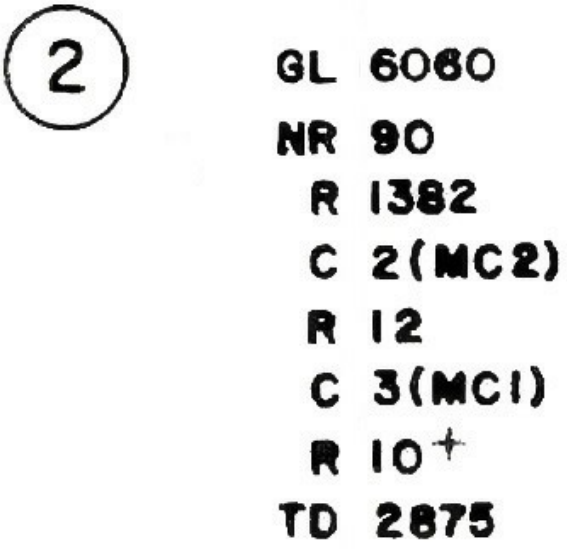
*** Note that many drill hole numbers in the GRI geologic-GIS data and this document have been changed from the number assigned on its source map so that each drill hole in the GRI geologic-GIS data has a unique assigned number. The original source map drill hole number is present with each drill hole graphic (typically circled), as well as being preserved in the GIS data in the Notes field.*

Drill Hole 1



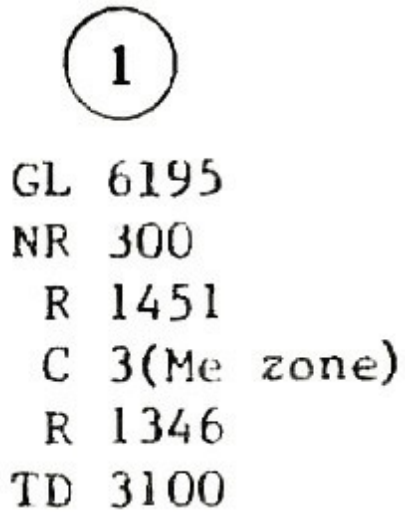
Extracted from: (La Vida Mission Quadrangle - coal map). (*GRI Source Map ID 74539*).

Drill Hole 2



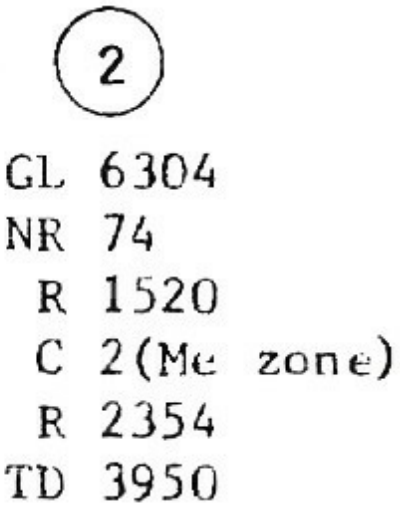
Extracted from: (La Vida Mission Quadrangle - coal map). (*GRI Source Map ID 74539*).

Drill Hole 3



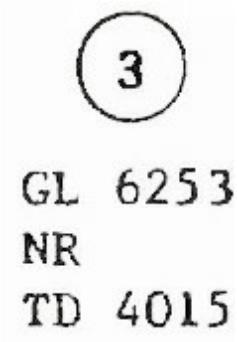
Extracted from: (Pueblo Bonito Quadrangle - coal map). (*GRI Source Map ID 30911*).

Drill Hole 4



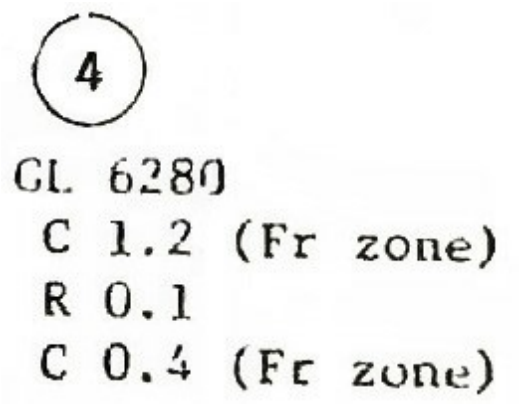
Extracted from: (Pueblo Bonito Quadrangle - coal map). (*GRI Source Map ID 30911*).

Drill Hole 5



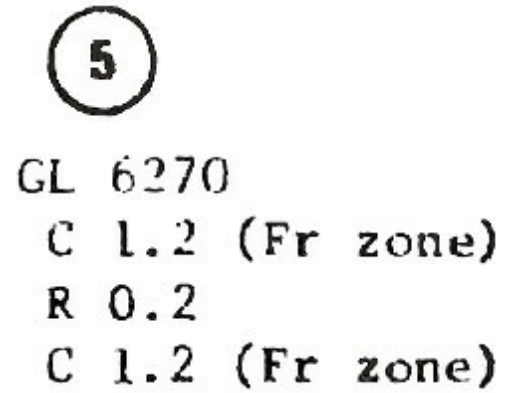
Extracted from: (Pueblo Bonito Quadrangle - coal map). (*GRI Source Map ID 30911*).

Drill Hole 6



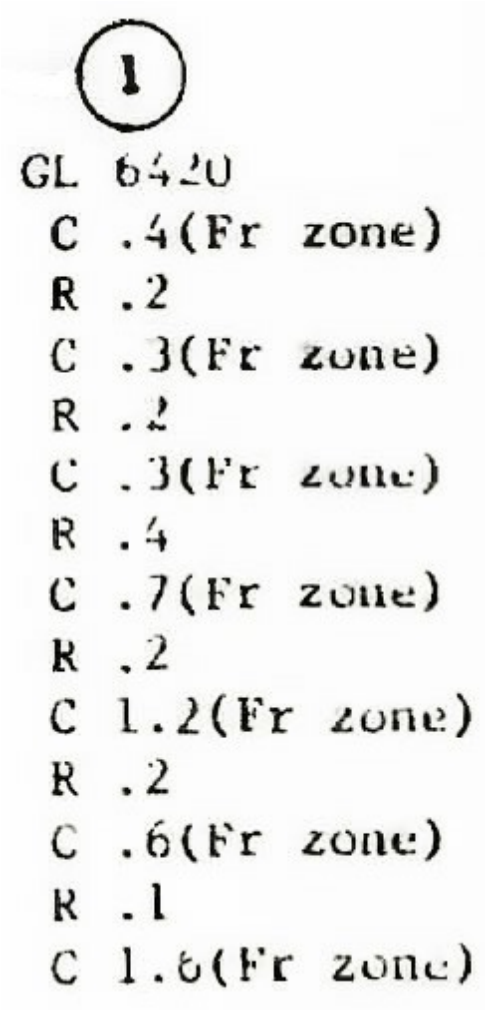
Extracted from: (Pueblo Bonito Quadrangle - coal map). (*GRI Source Map ID 30911*).

Drill Hole 7



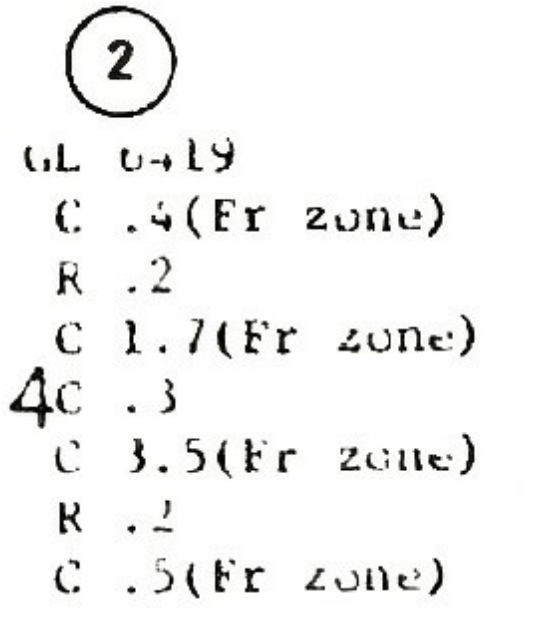
Extracted from: (Pueblo Bonito Quadrangle - coal map). (*GRI Source Map ID 30911*).

Drill Hole 8



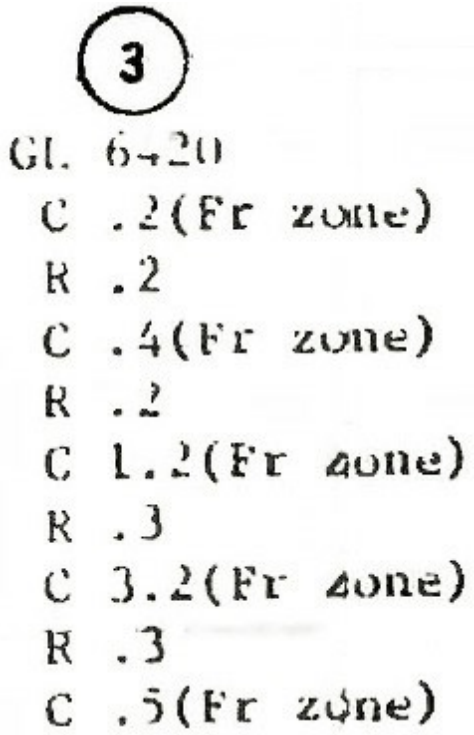
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 9



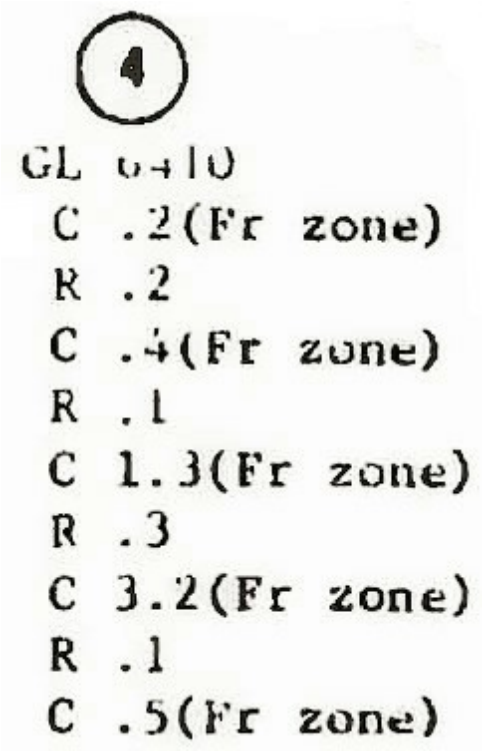
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 10



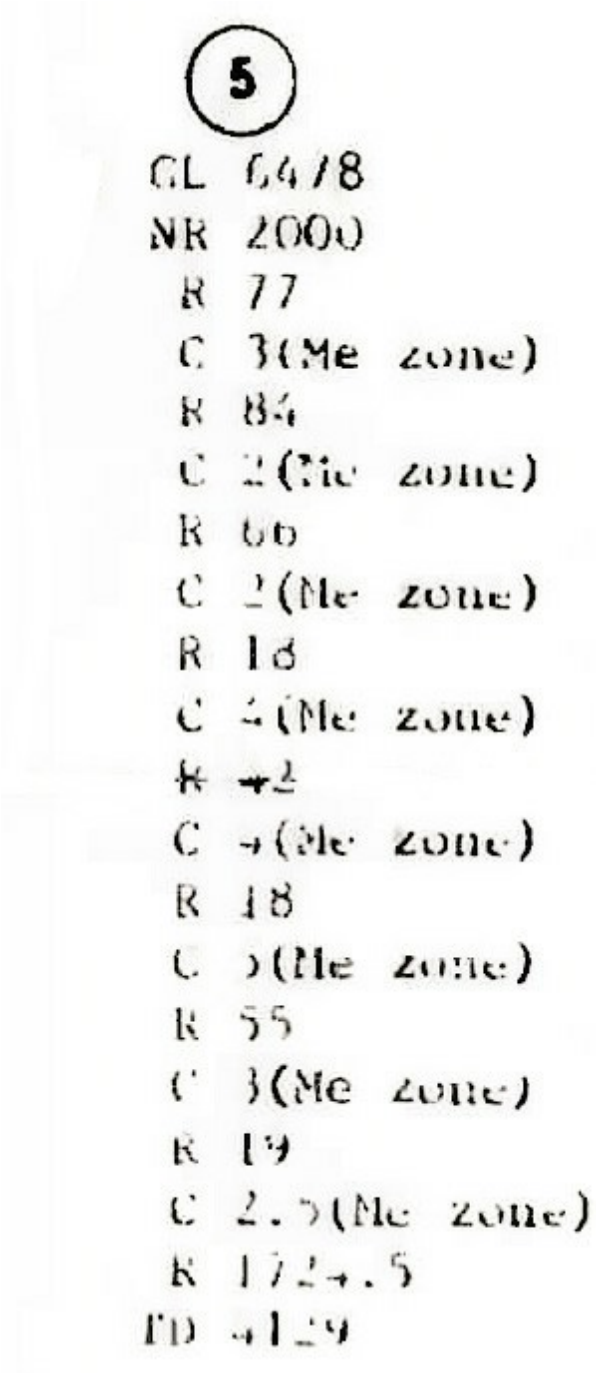
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 11



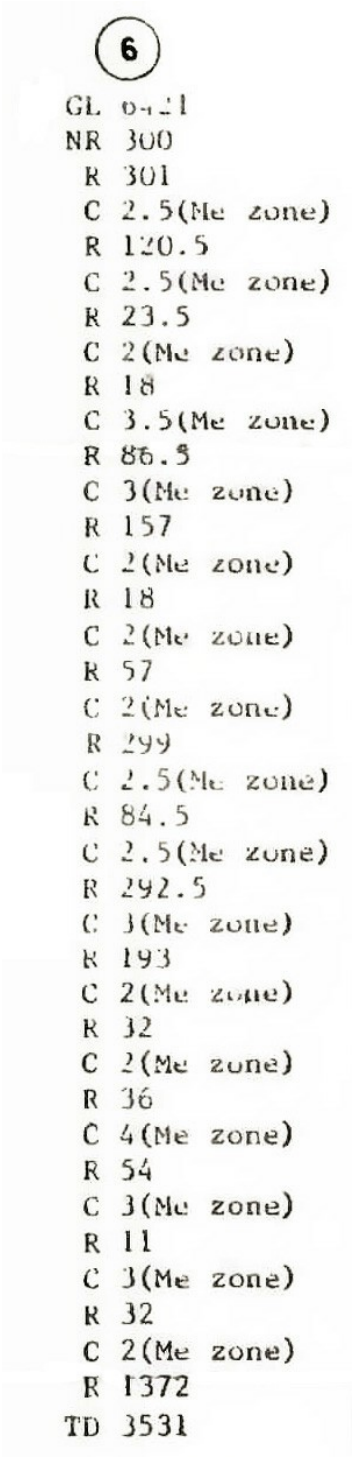
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Drill Hole 12



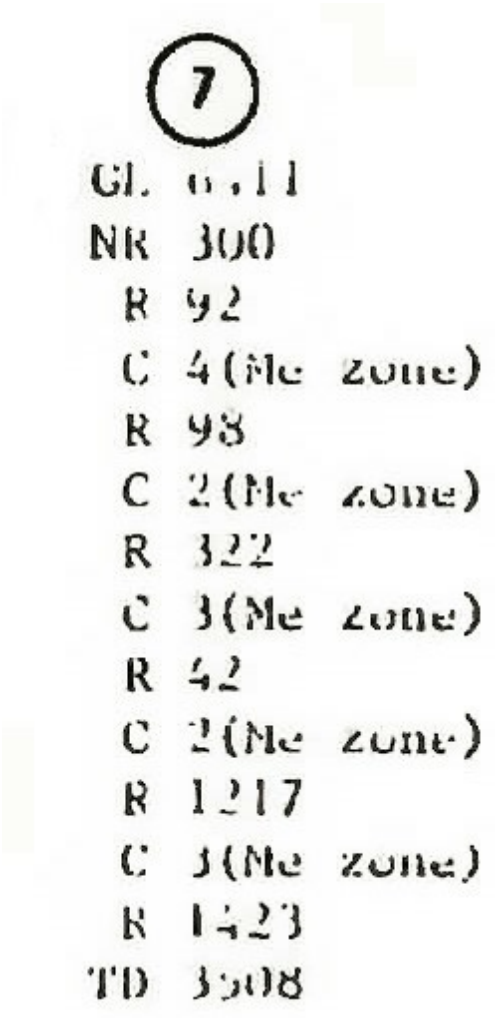
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Drill Hole 13



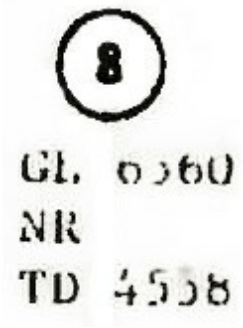
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Drill Hole 14



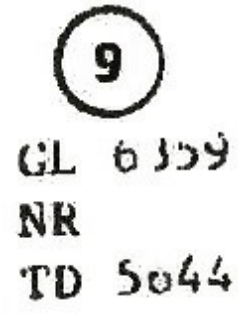
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Drill Hole 15



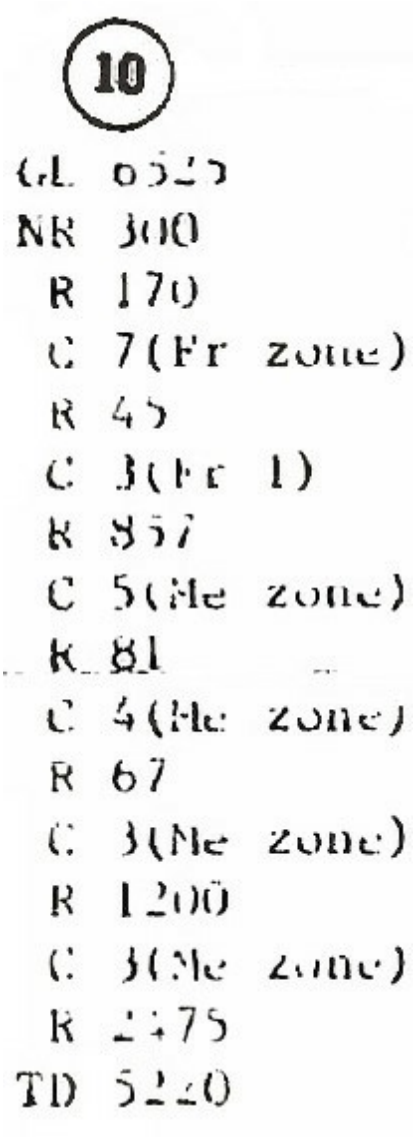
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 16



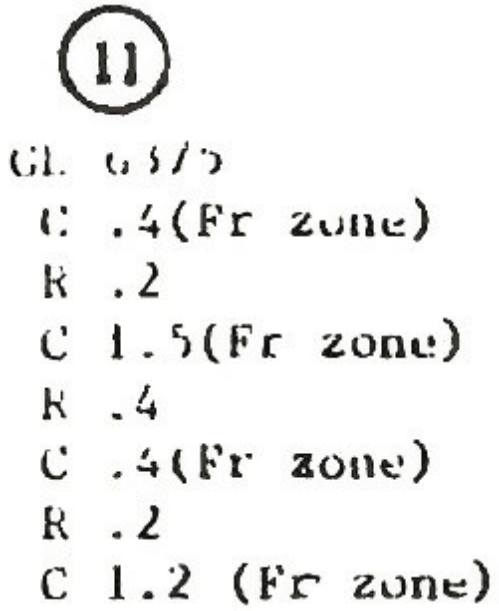
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Drill Hole 17



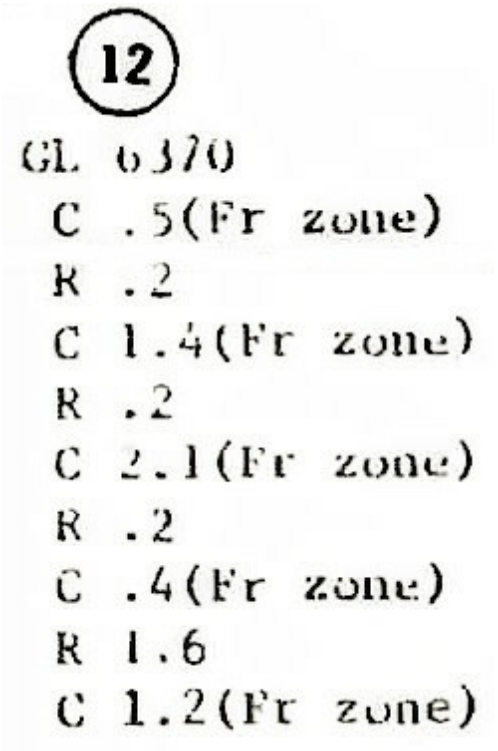
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 18



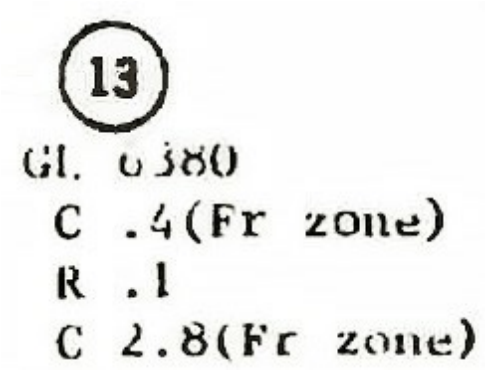
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 19



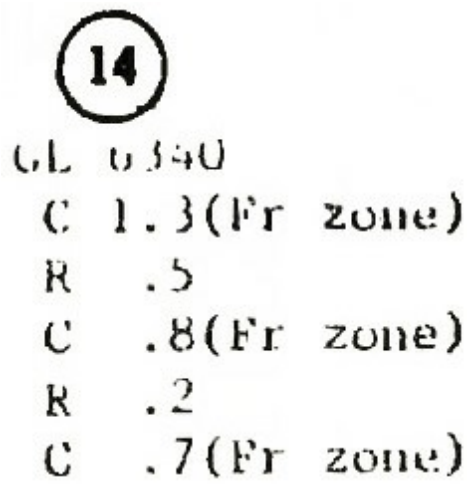
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 20



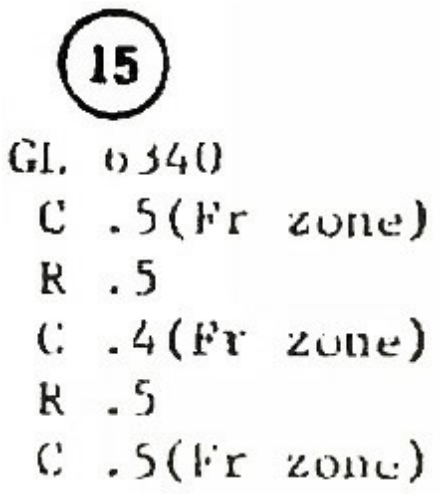
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Drill Hole 21



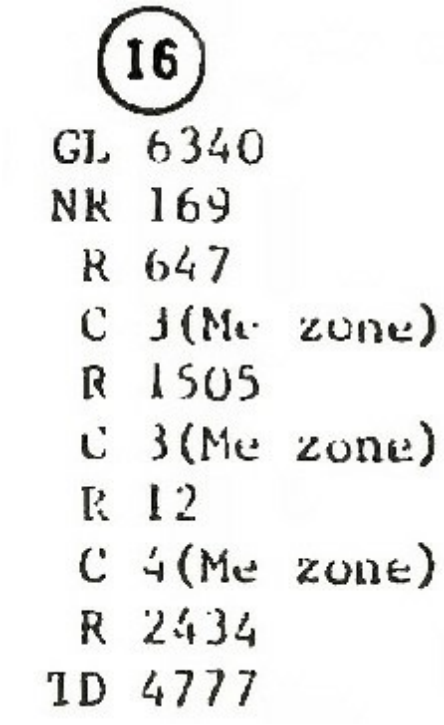
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 22



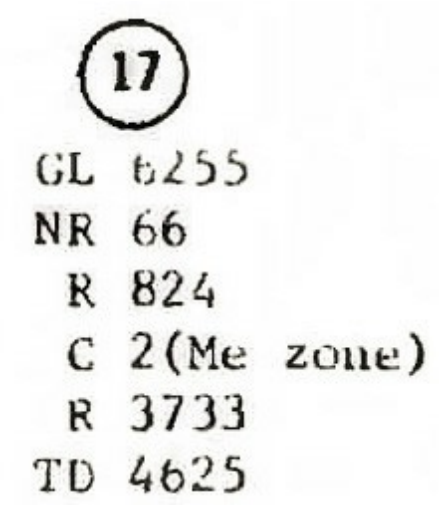
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 23



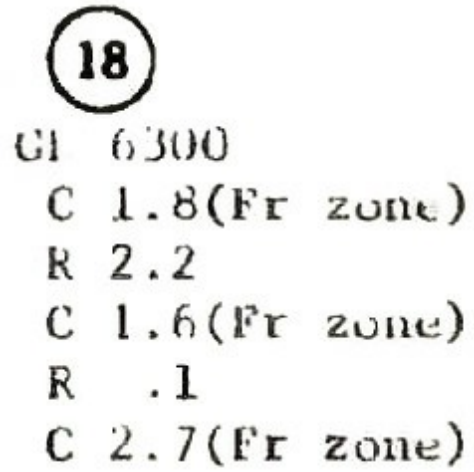
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Drill Hole 24



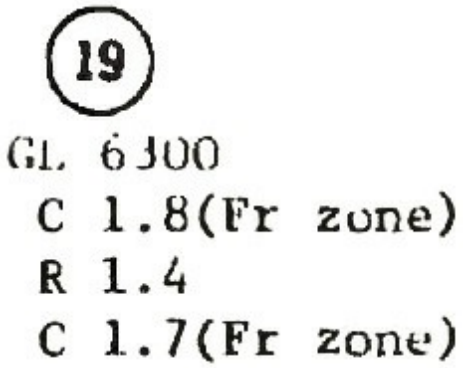
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Drill Hole 25



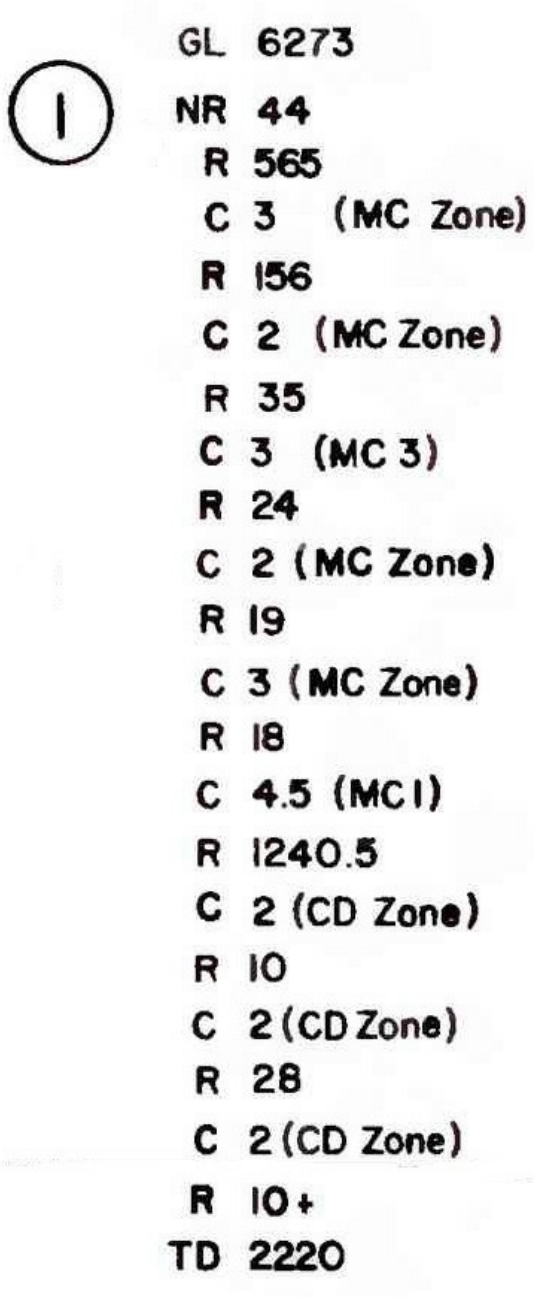
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 26



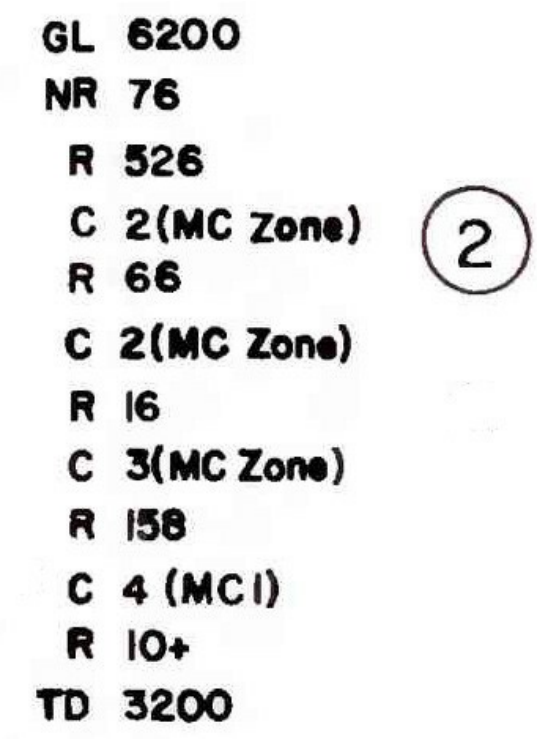
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole 27



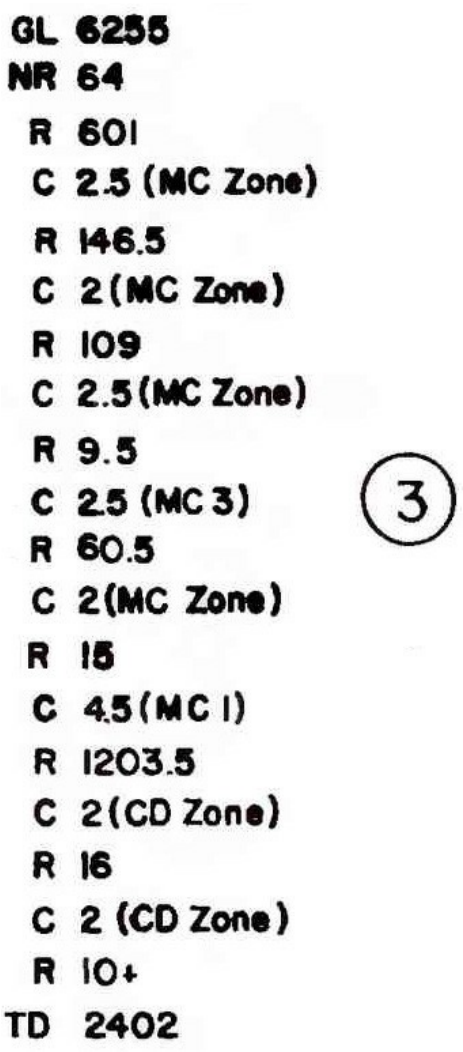
Extracted from: (Milk Lake Quadrangle - coal map). (*GRI Source Map ID 74535*).

Drill Hole 28



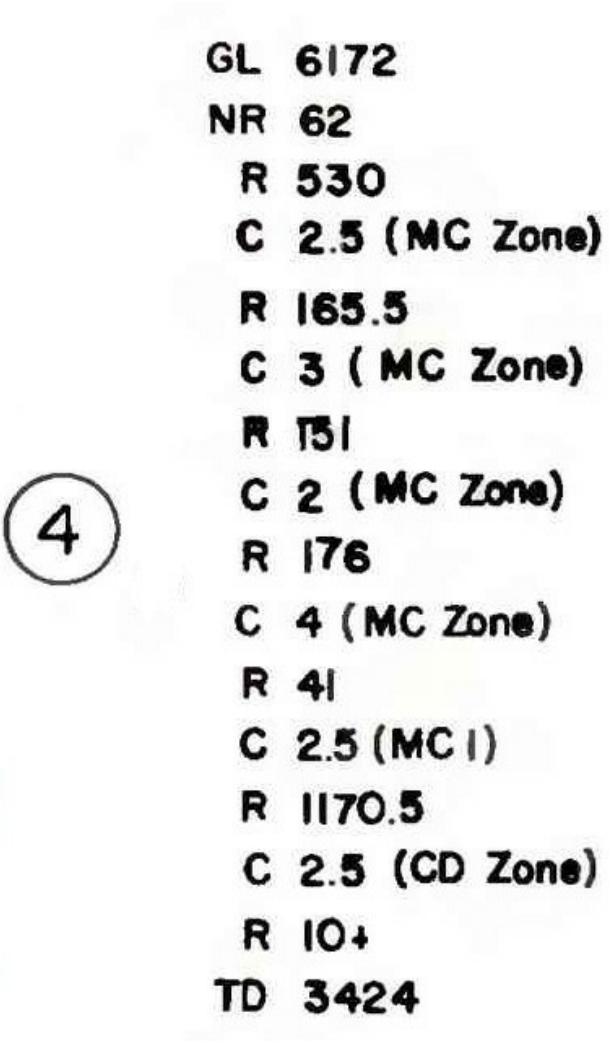
Extracted from: (Milk Lake Quadrangle - coal map). (*GRI Source Map ID 74535*).

Drill Hole 29



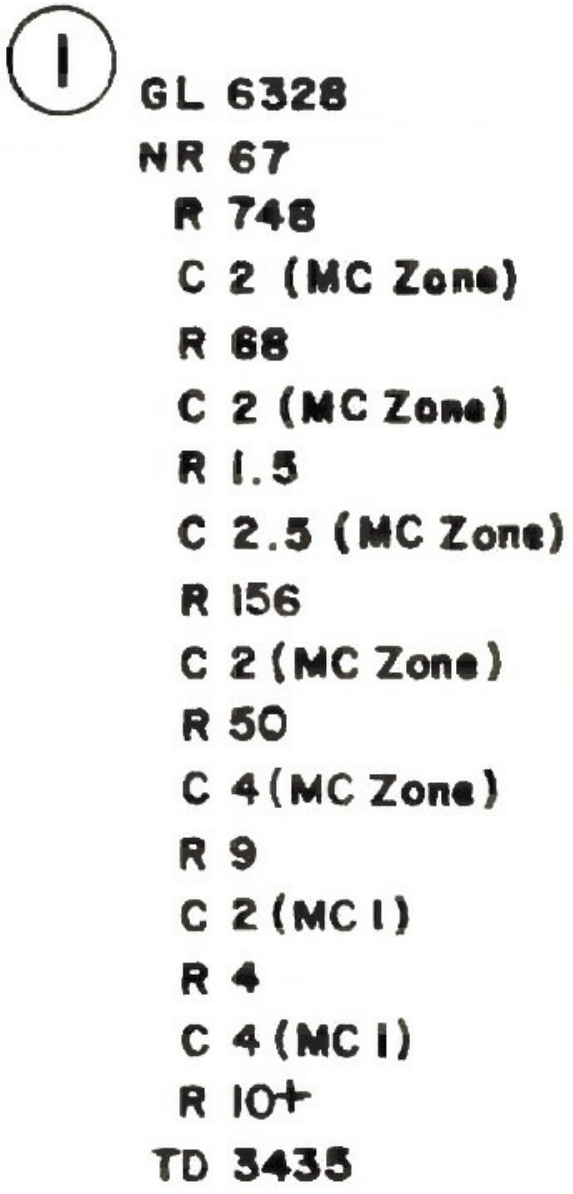
Extracted from: (Milk Lake Quadrangle - coal map). (*GRI Source Map ID 74535*).

Drill Hole 30



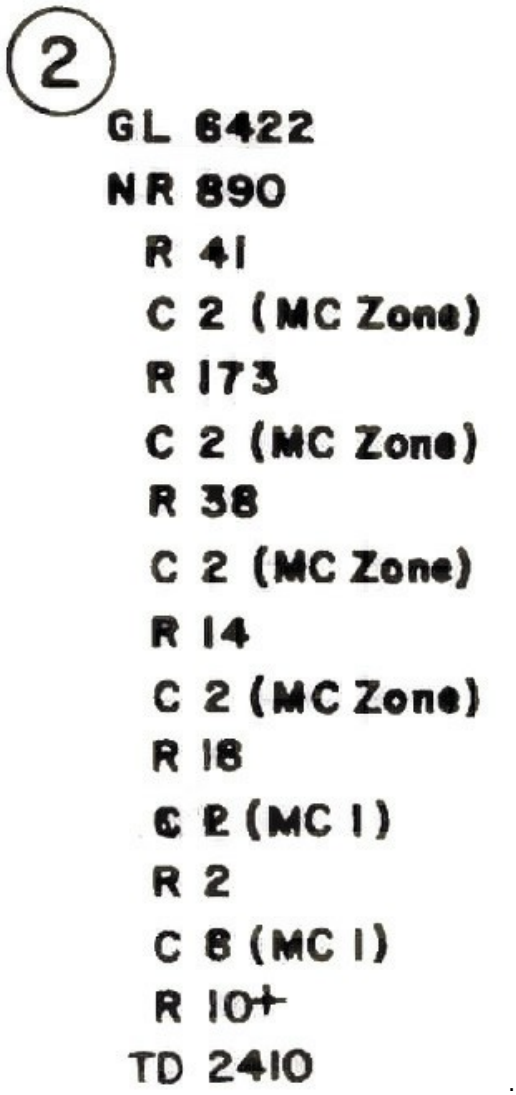
Extracted from: (Milk Lake Quadrangle - coal map). (*GRI Source Map ID 74535*).

Drill Hole 31



Extracted from: (Nose Rock Quadrangle - coal map). (*GRI Source Map ID 32099*).

Drill Hole 32



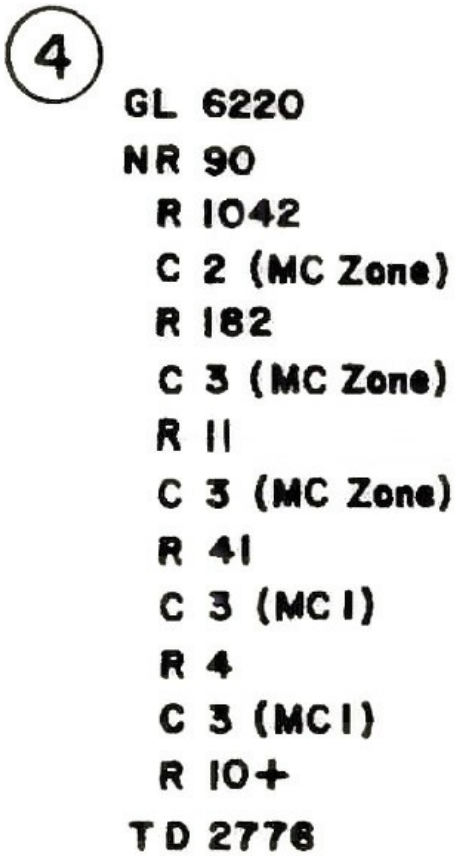
Extracted from: (Nose Rock Quadrangle - coal map). (*GRI Source Map ID 32099*).

Drill Hole 33



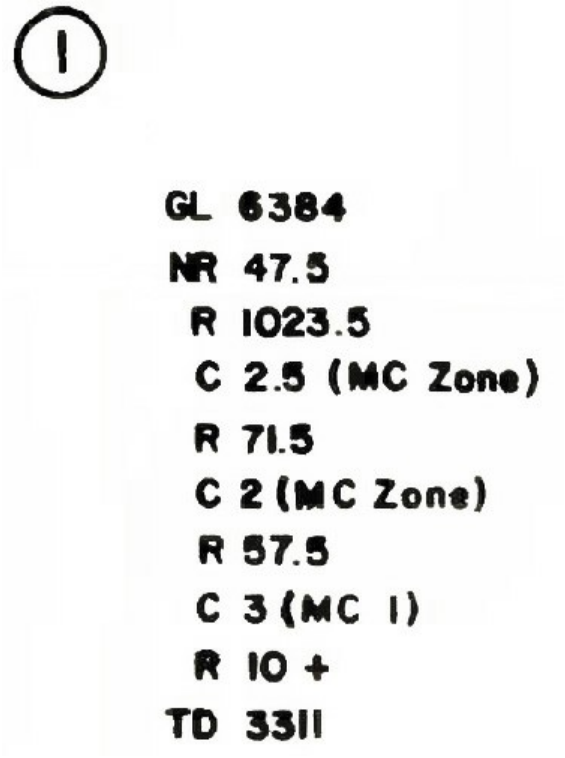
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Drill Hole 34



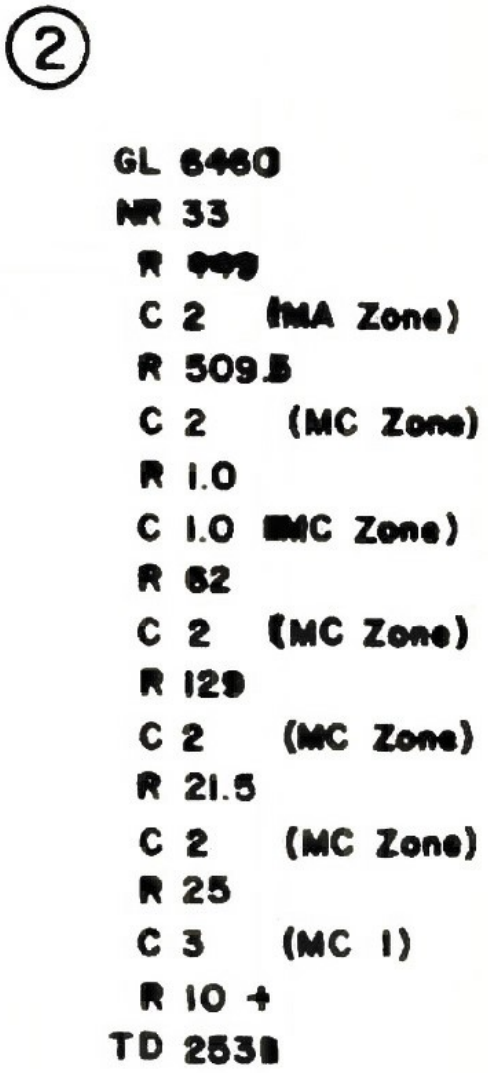
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Drill Hole 35



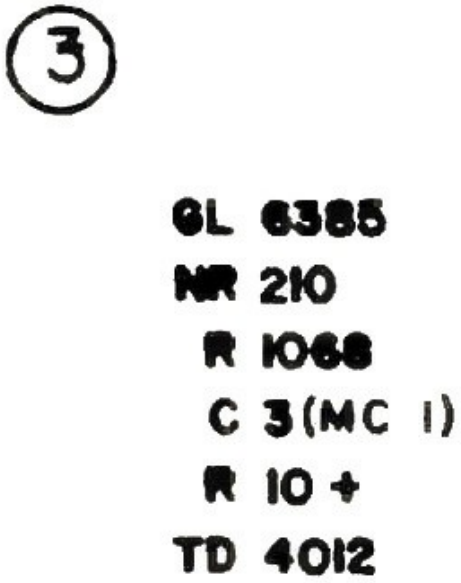
Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

Drill Hole 36



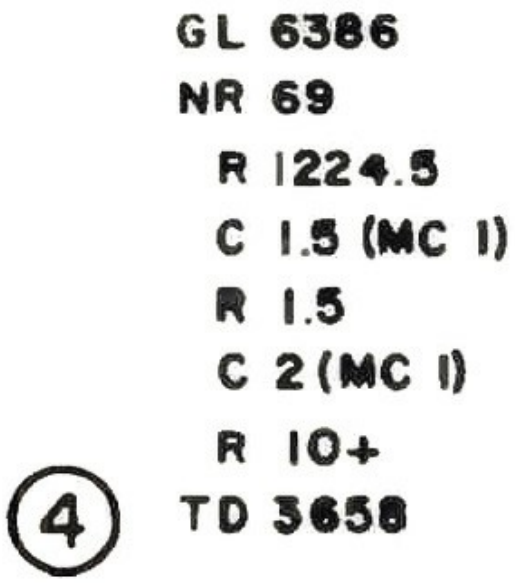
Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

Drill Hole 37



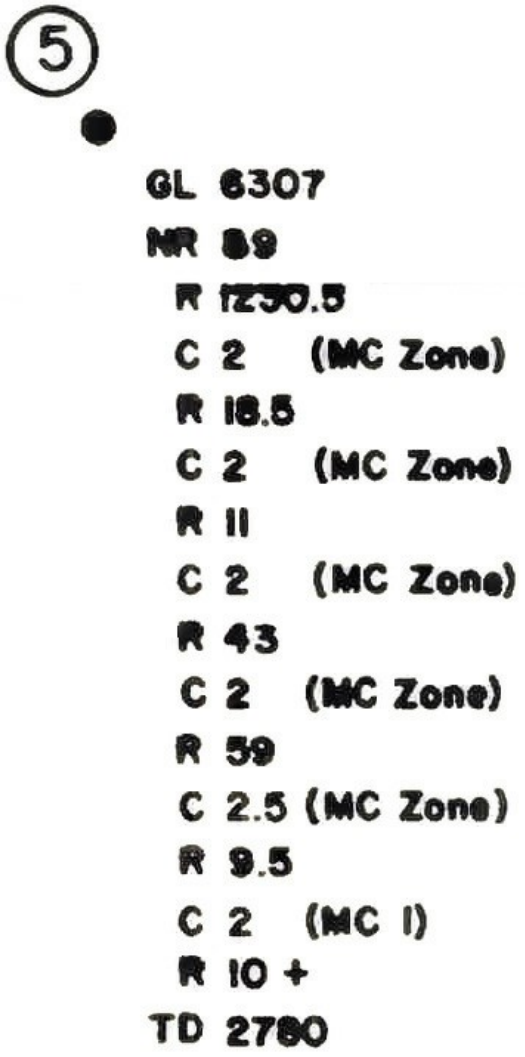
Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

Drill Hole 38



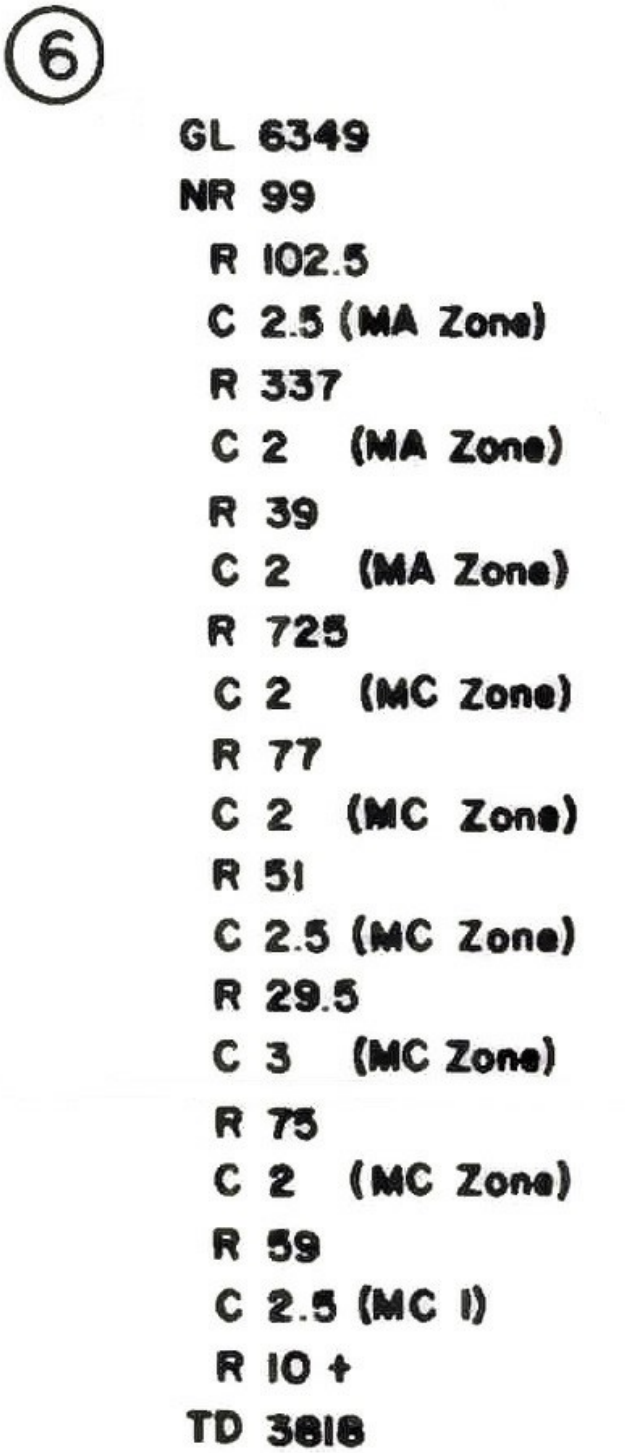
Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

Drill Hole 39



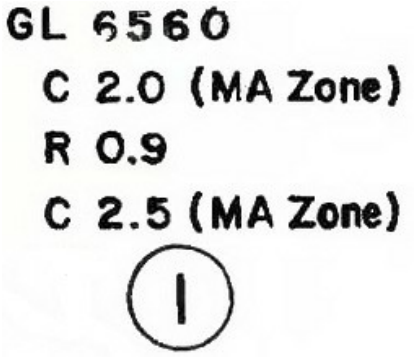
Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

Drill Hole 40



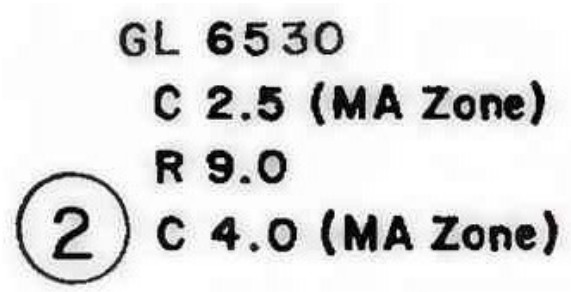
Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

Drill Hole 41



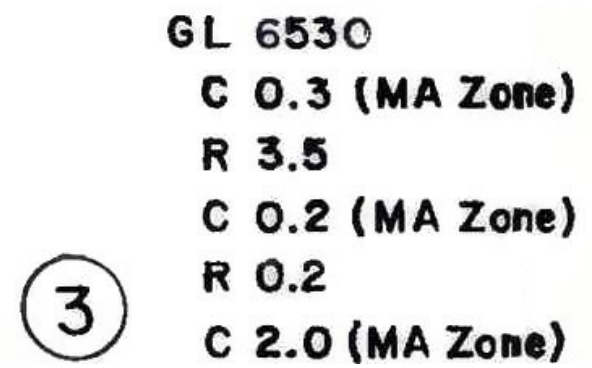
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole 42



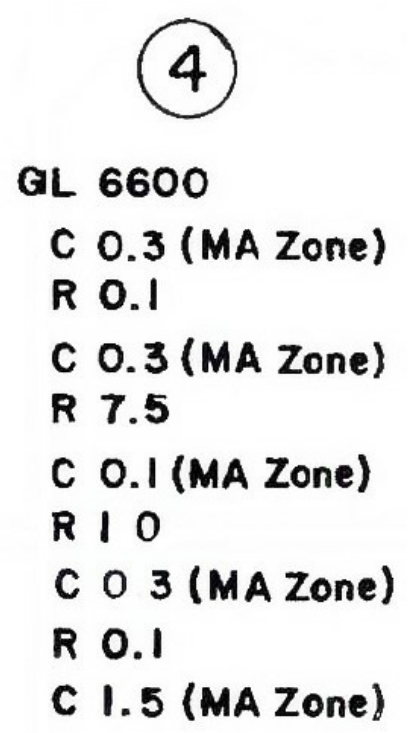
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole 43



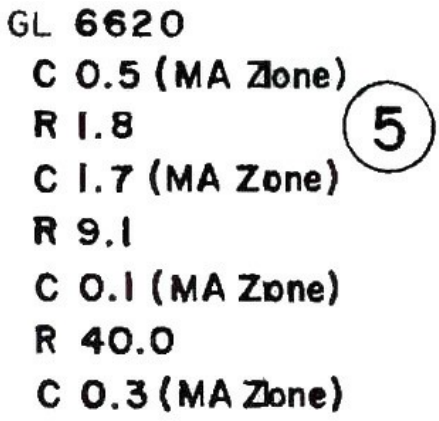
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole 44



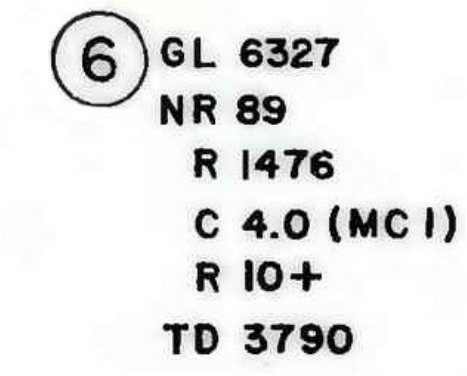
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole 45



Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole 46



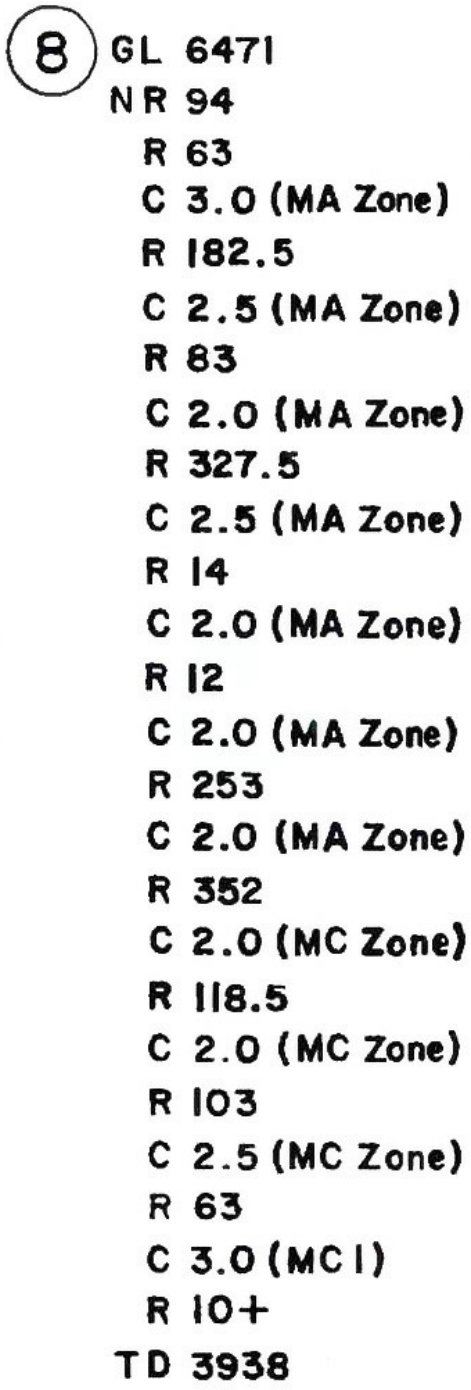
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole 47

GL 6416
NR 98
R 196
C 2.0 (MA Zone) (7)
R 46.5
C 2.5 (MA Zone)
R 38
C 3.0 (MA Zone)
R 11
C 2.0 (MA Zone)
R 81
C 1.5 (MA Zone)
R 1.0
C 0.5 (MA Zone)
R 3.5
C 0.5 (MA Zone)
R 256
C 2.0 (MA Zone)
R 144
C 2.0 (MA Zone)
R 160
C 2.0 (MA Zone)
R 102
C 2.0 (MC Zone)
R 2.5
C 1.5 (MC Zone)
R 228
C 0.5 (MC Zone)
R 1.0
C 2.0 (MC Zone)
R 40.5
C 3.0 (MC Zone)
R 3.5
C 1.5 (MC Zone)
R 46
C 2.0 (MC Zone)
R 26
C 2.0 (MC Zone)
R 46
C 4.0 (MC 1)
R 3.5
C 0.5 (MC 1)
R 10+
TD 4907

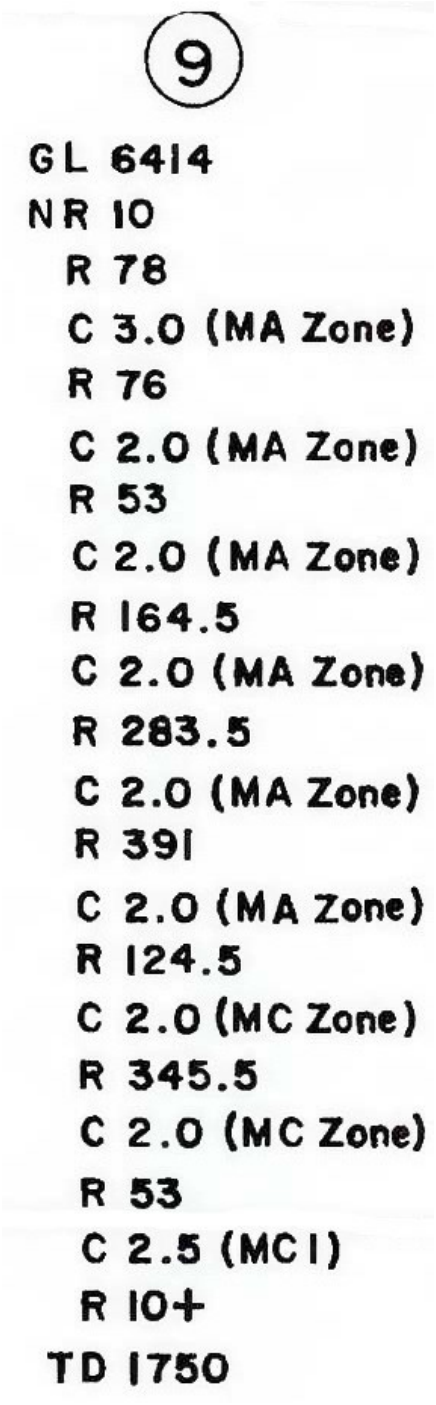
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole 48



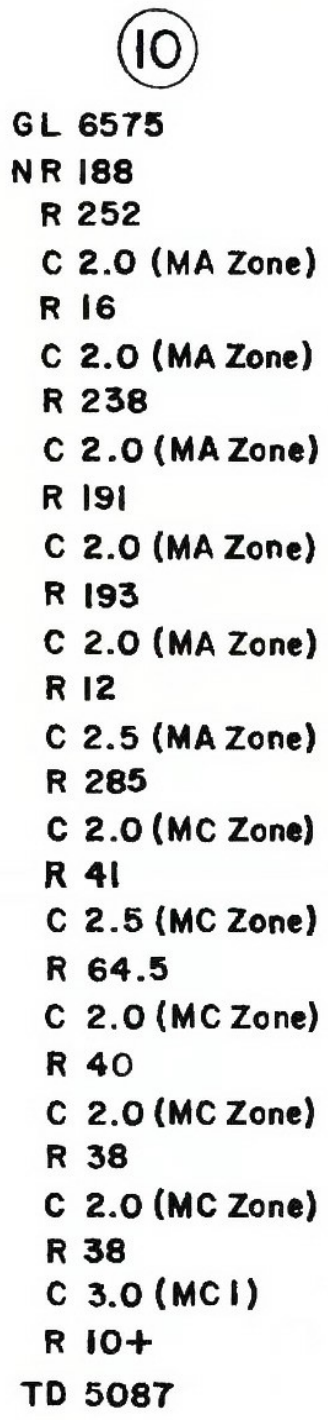
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Drill Hole 49



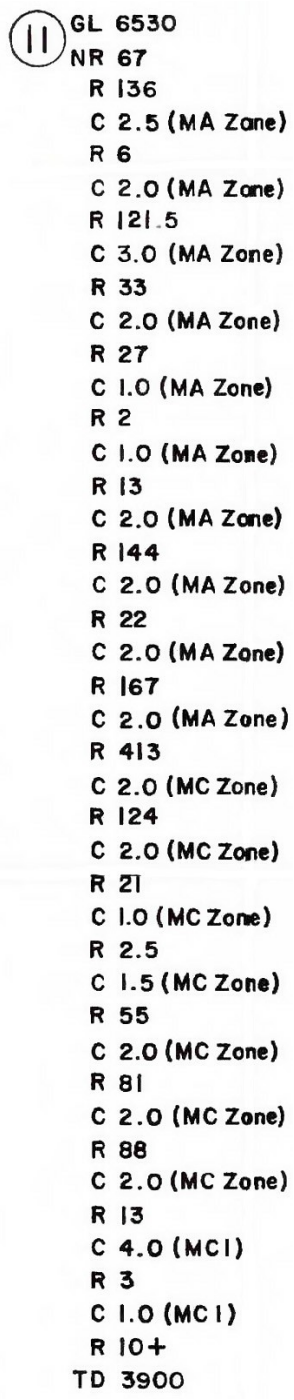
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole 50



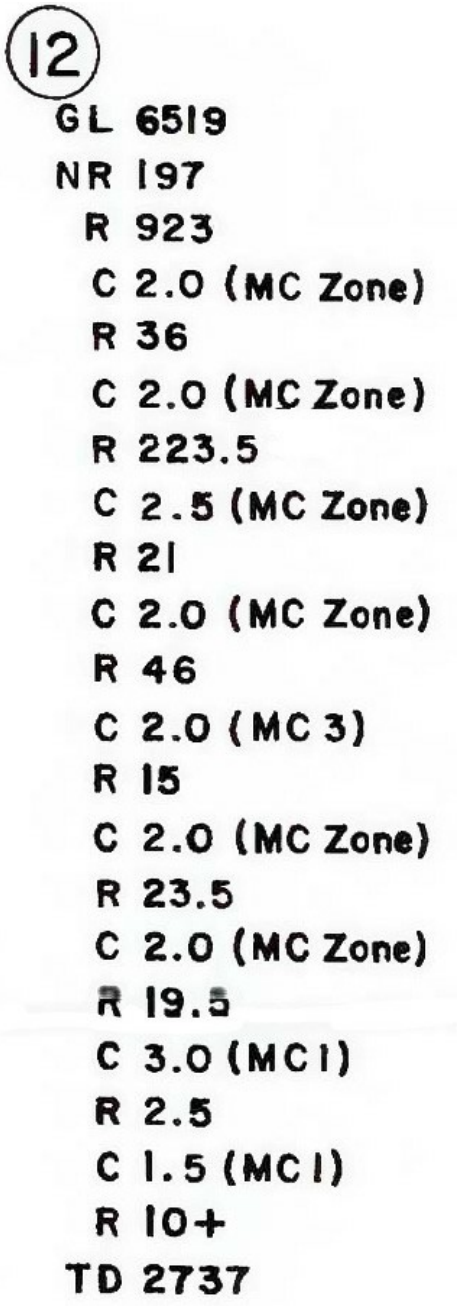
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole 51



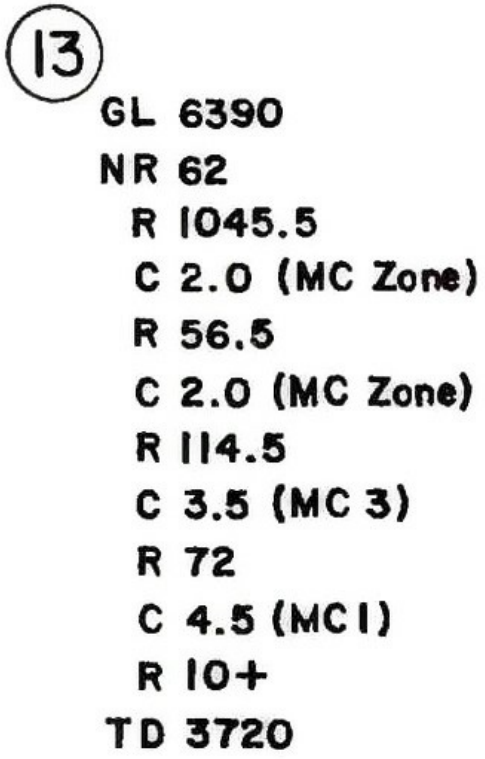
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Drill Hole 52



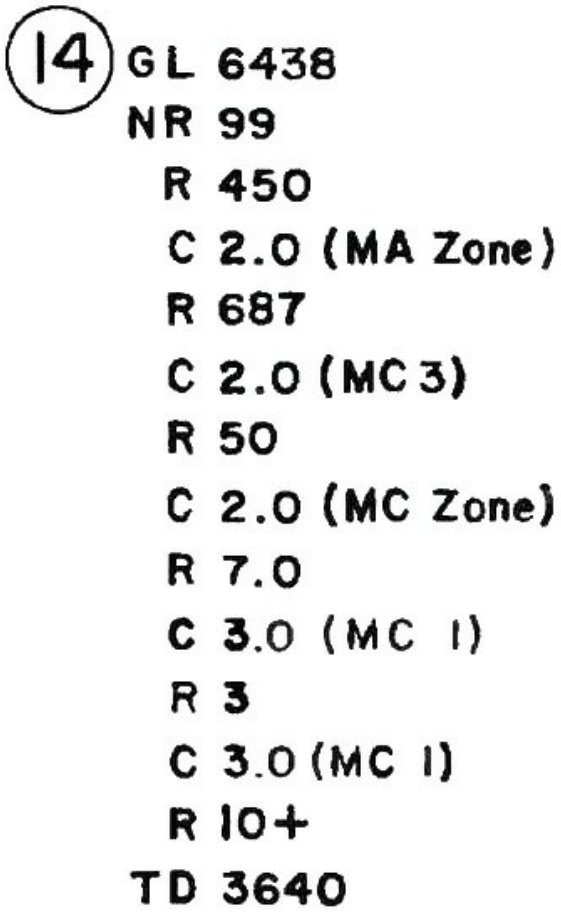
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole 53



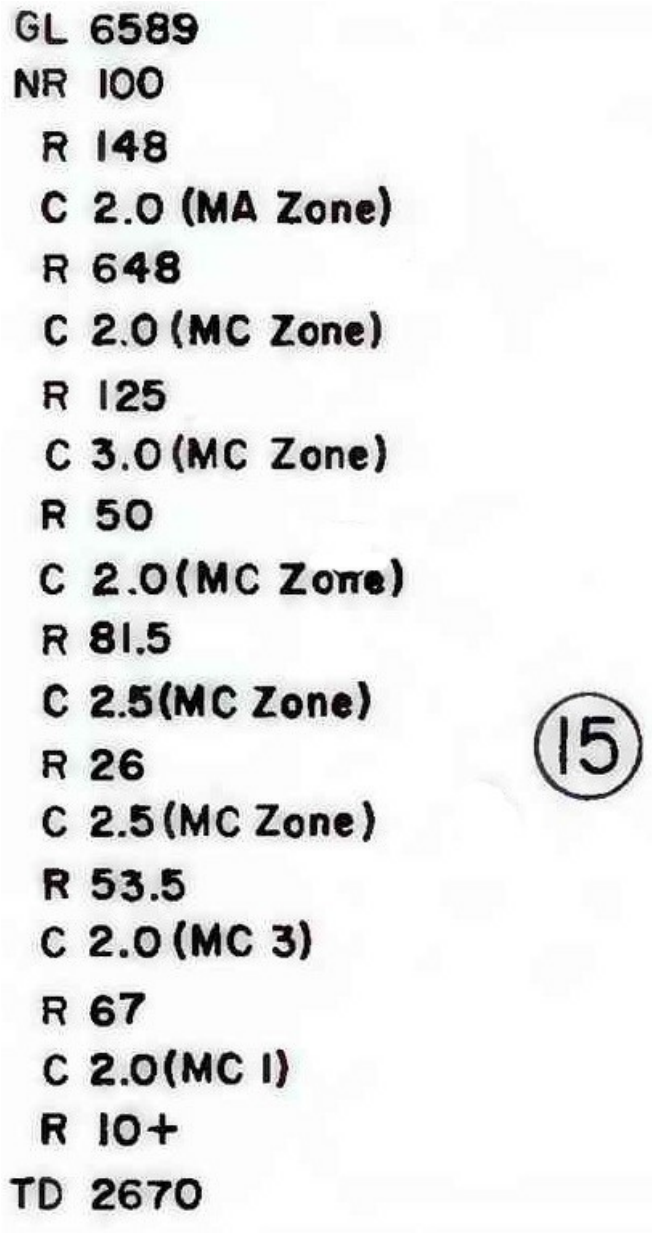
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Drill Hole 54



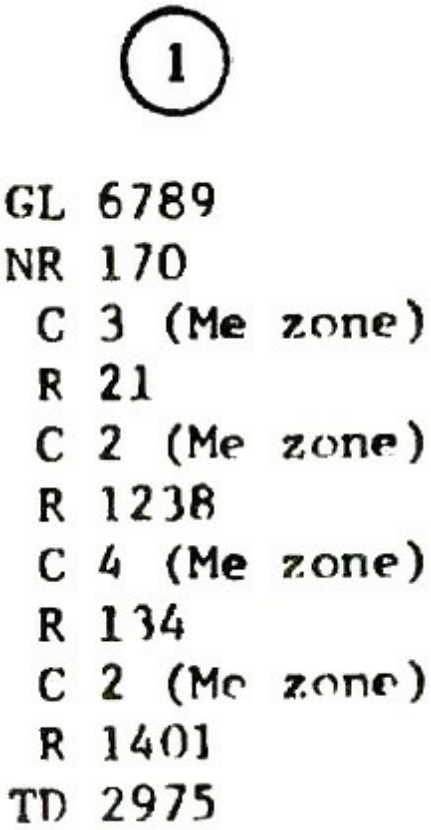
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Drill Hole 55



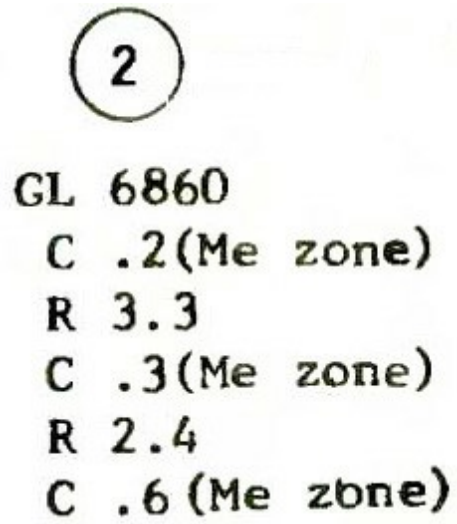
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Drill Hole 56



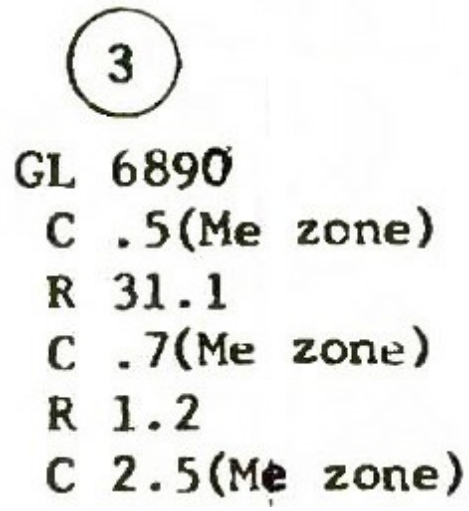
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Drill Hole 57



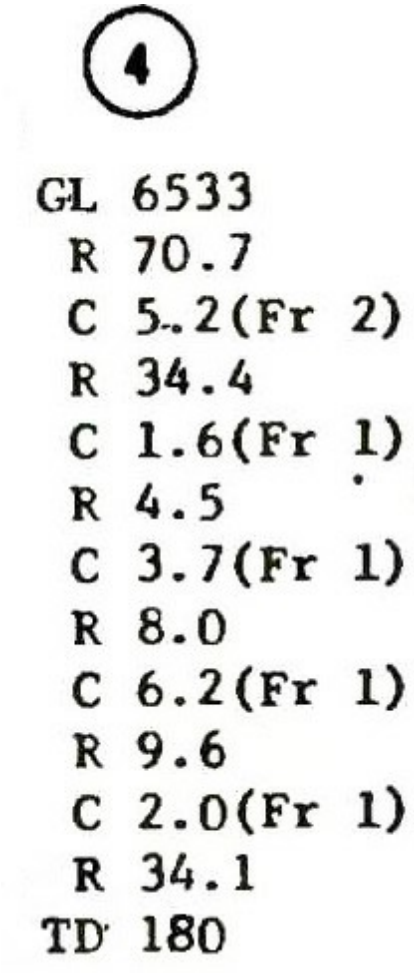
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Drill Hole 58



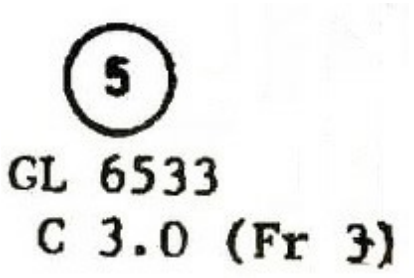
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Drill Hole 59



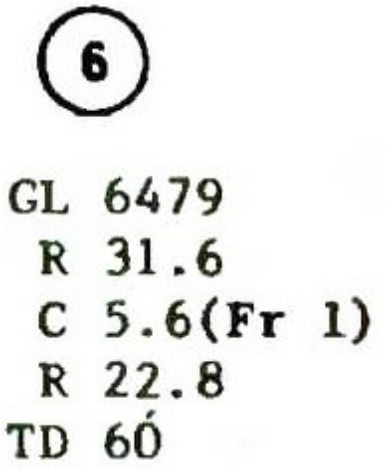
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Drill Hole 60



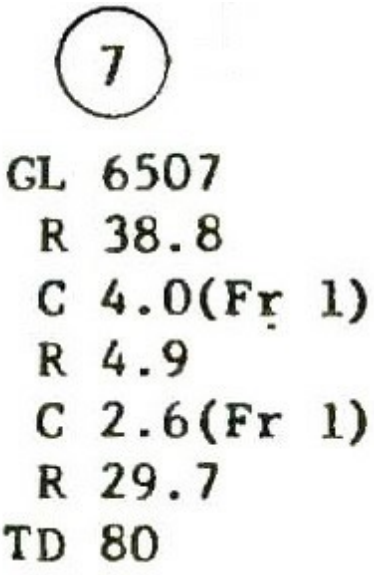
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Drill Hole 61



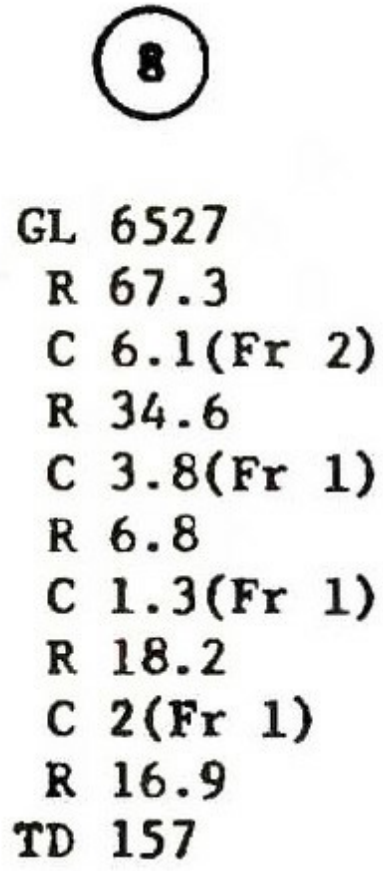
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Drill Hole 62



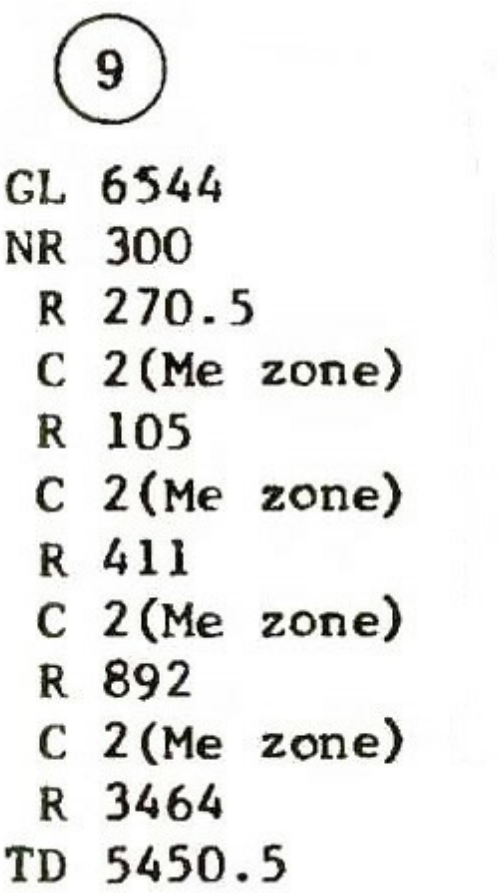
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Drill Hole 63



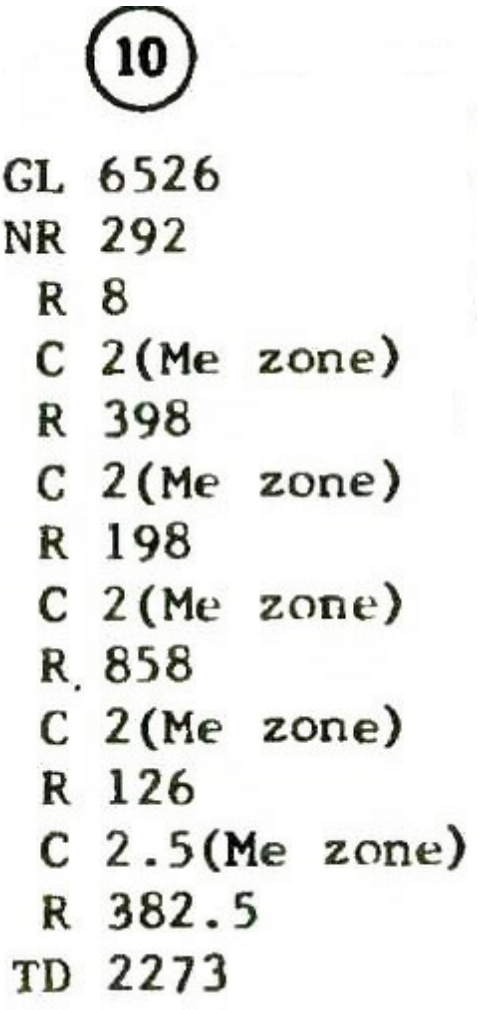
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Drill Hole 64



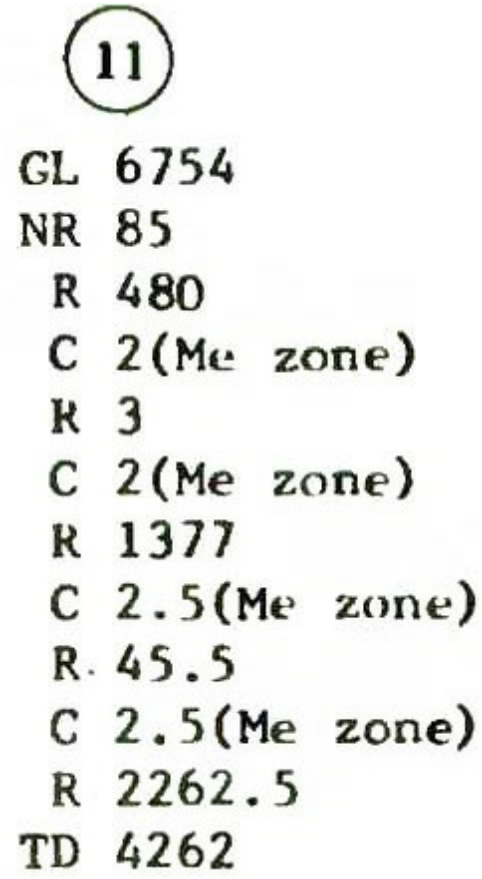
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Drill Hole 65



Extracted from: (Pueblo Pintado Quadrangle - coal map). (*GRI Source Map ID 30647*).

Drill Hole 66



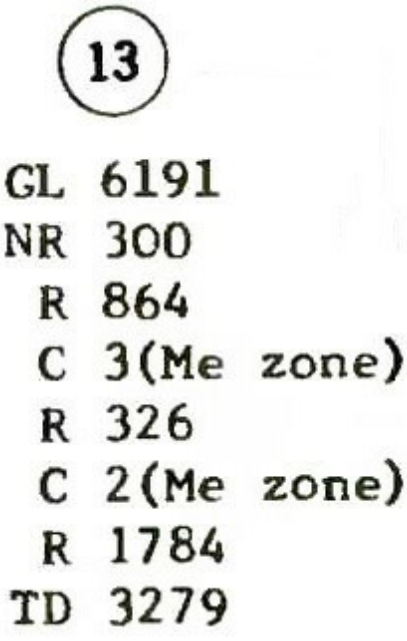
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Drill Hole 67



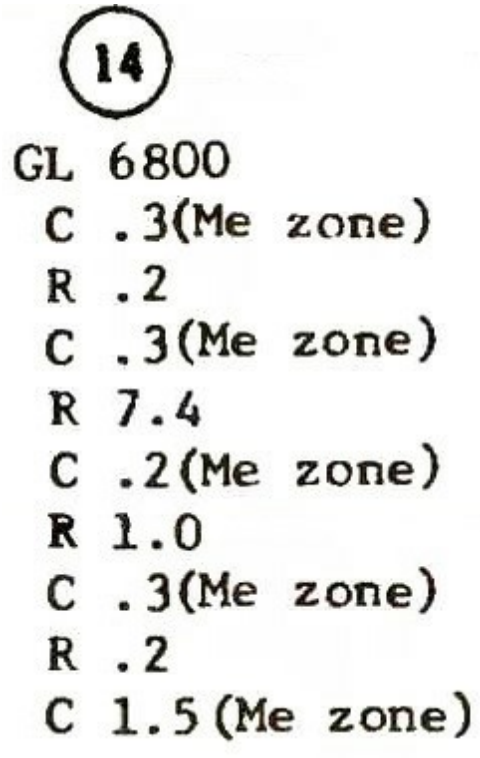
Extracted from: (Pueblo Pintado Quadrangle - coal map). (*GRI Source Map ID 30647*).

Drill Hole 68



Extracted from: (Pueblo Pintado Quadrangle - coal map). (*GRI Source Map ID 30647*).

Drill Hole 69



Extracted from: (Pueblo Pintado Quadrangle - coal map). (*GRI Source Map ID 30647*).

Drill Hole 70

GL 6875
NR 39
R 42
C 3 (CG Zone)
R 7
C 2.5 (CG Zone)
R 12
C 2 (CG Zone)

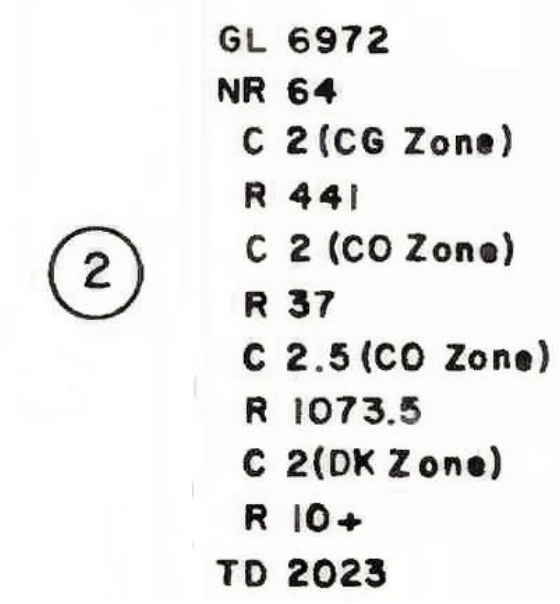
R 4.5
C 3 (CG Zone)
R 7
C 2 (CG Zone)
R 17
C 2.5 (CG Zone)
R 47
C 4 (CG Zone)
R 5
C 2.5 (CG Zone)
R 14
C 4 (CG Zone)
R 9
C 3 (CG Zone)
R 11
C 2 (CG Zone)
R 568
C 2.5 (CD Zone)
R 74.5
C 2 (CD Zone)

R 10+
TD 2376



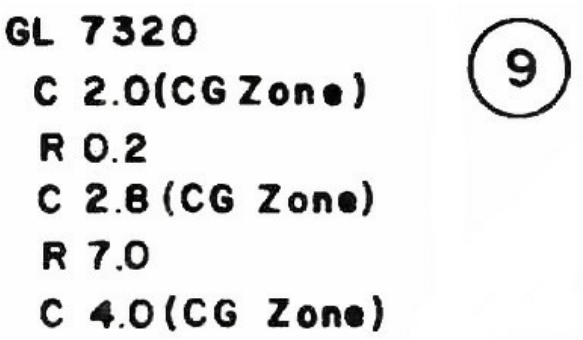
Extracted from: (Crownpoint Quadrangle - coal map). (*GRI Source Map ID 41614*).

Drill Hole 71



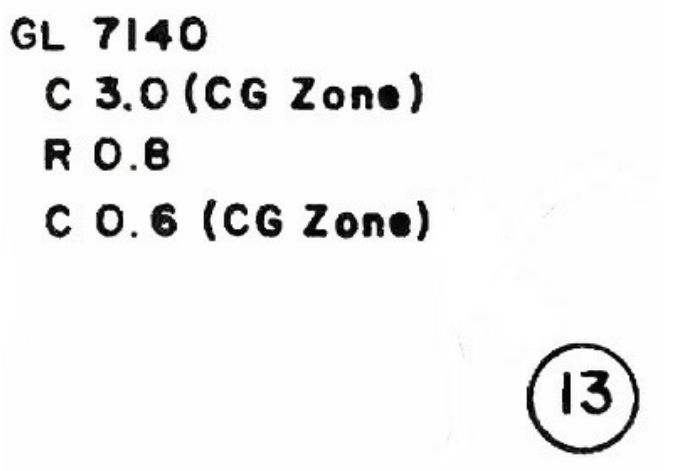
Extracted from: (Crownpoint Quadrangle - coal map). (*GRI Source Map ID 41614*).

Drill Hole 72



Extracted from: (Crownpoint Quadrangle - coal map). (*GRI Source Map ID 41614*).

Drill Hole 73



Extracted from: (Crownpoint Quadrangle - coal map). (*GRI Source Map ID 41614*).

Drill Hole 74



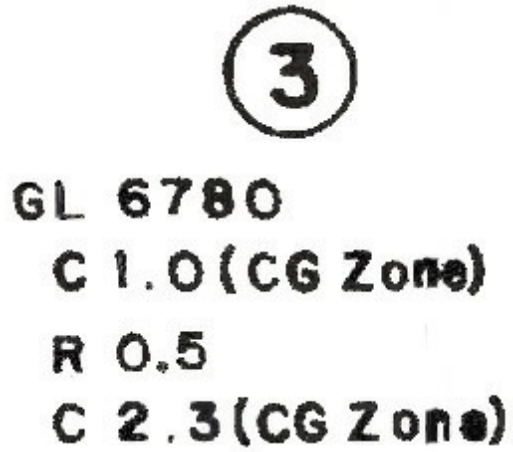
Extracted from: (Heart Rock Quadrangle - coal map). (*GRI Source Map ID 32100*).

Drill Hole 75



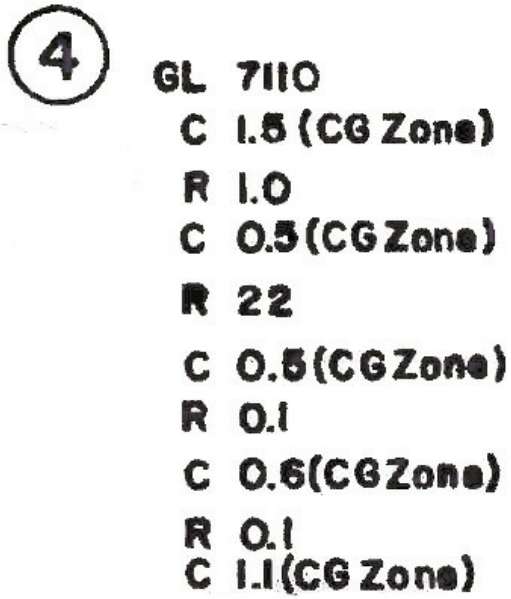
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Drill Hole 76



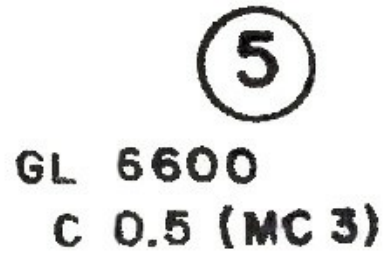
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Drill Hole 77



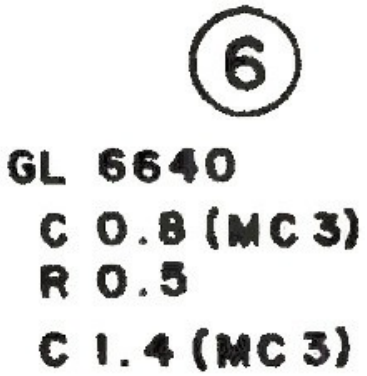
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Drill Hole 78



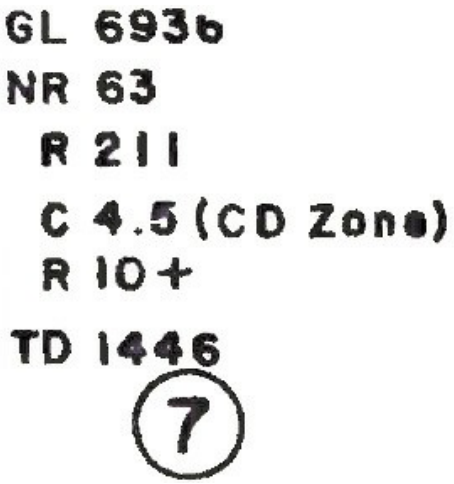
Extracted from: (Heart Rock Quadrangle - coal map). (*GRI Source Map ID 32100*).

Drill Hole 79



Extracted from: (Heart Rock Quadrangle - coal map). (*GRI Source Map ID 32100*).

Drill Hole 80



Extracted from: (Heart Rock Quadrangle - coal map). (*GRI Source Map ID 32100*).

Photographs

The following figures are photographs with site localities present in the Geologic Observation Localities (CHCUGOL and PUBOGOL) data layers in the GRI geologic-GIS data.

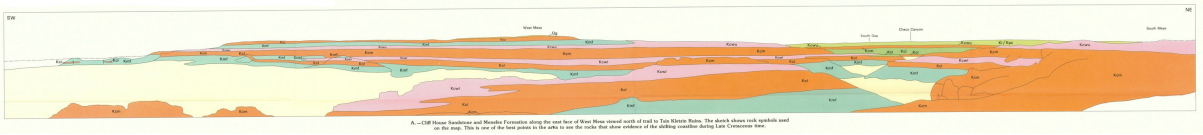
Panoramic A



A. Cliff House Sandstone and Menefee Formation along the east face of West Mesa viewed north of trail to Tsin Kletzin Ruins

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Panoramic Cross Section A-A'



Drawn from: Panoramic view A

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

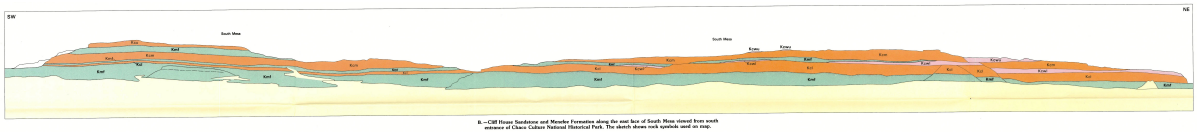
Panoramic B



B. Cliff House Sandstone and Menefee Formation along the east face of South Mesa viewed from south entrance of Chaco Culture National Historical Park

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Panoramic Cross Section B-B'



Drawn from: Panoramic view B

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

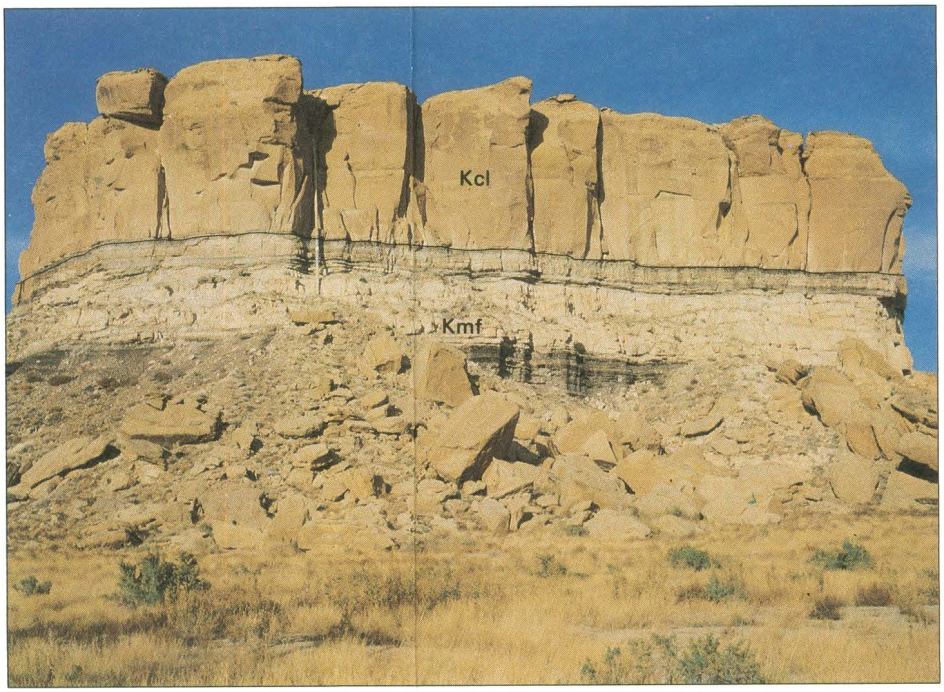
Photograph C



C.—Coastal plain deposits of the Menefee Formation viewed from the road between the visitor's center and the campground. Mudstone, carbonaceous shale, and coal representative of a swamp or marsh are overlain by a sandstone deposit that filled a river channel which post-dated and cut into coal deposits of an earlier swamp or marsh.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Photograph D



D.—Contact between the lower sandstone (Kcl) of the Cliff House Sandstone and the main body of the Menefee Formation, above Visitor's Center to north. A fairly rapid landward movement of the sea (deepening water) produced a change from peat-swamp deposits to overlying lagoonal deposits and shoreface deposits laid down closer to the open sea.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

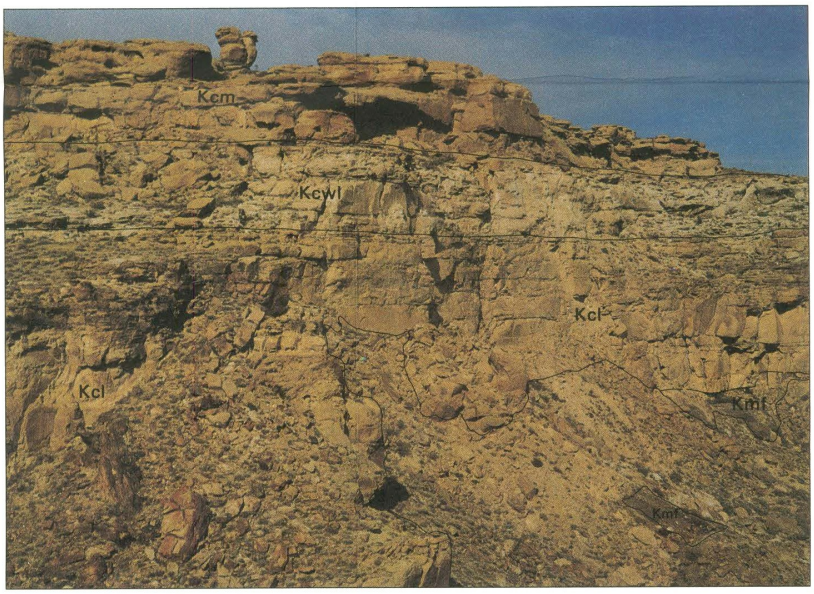
Photograph E



E.—The Cliff House Sandstone on the southwest edge of South Mesa. The Menefee wedges into the upper and middle sandstones (Kcu and Kcm) of the Cliff House, away from the camera, and thins out until it ends to the northeast. The lower sandstone (Kcl) of the Cliff House wedges into the Menefee, toward the site of the camera, and thins to the southwest. The wedging of the Menefee away from the site of the camera represents the retreat of the sea; the wedging of the Cliff House toward the camera, the advance of the sea.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Photograph F



F.—Cliffs of middle (Kcm) and lower (Kcl) Cliff House Sandstone on the east side of West Mesa. The lower sandstone is in contact with coaly beds of the Menefee Formation at the base of the cliff. The white rock (Kcwl) in the middle of the cliff face is coarser grained and is the lower of two conspicuous sandstones seen in panorama A. The finer grained lower sandstone represents an advance of the sea; the white sandstone a retreat of the sea. A subsequent advance of the sea covered these deposits with the finer grained middle sandstone (Kcm) of the Cliff House.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

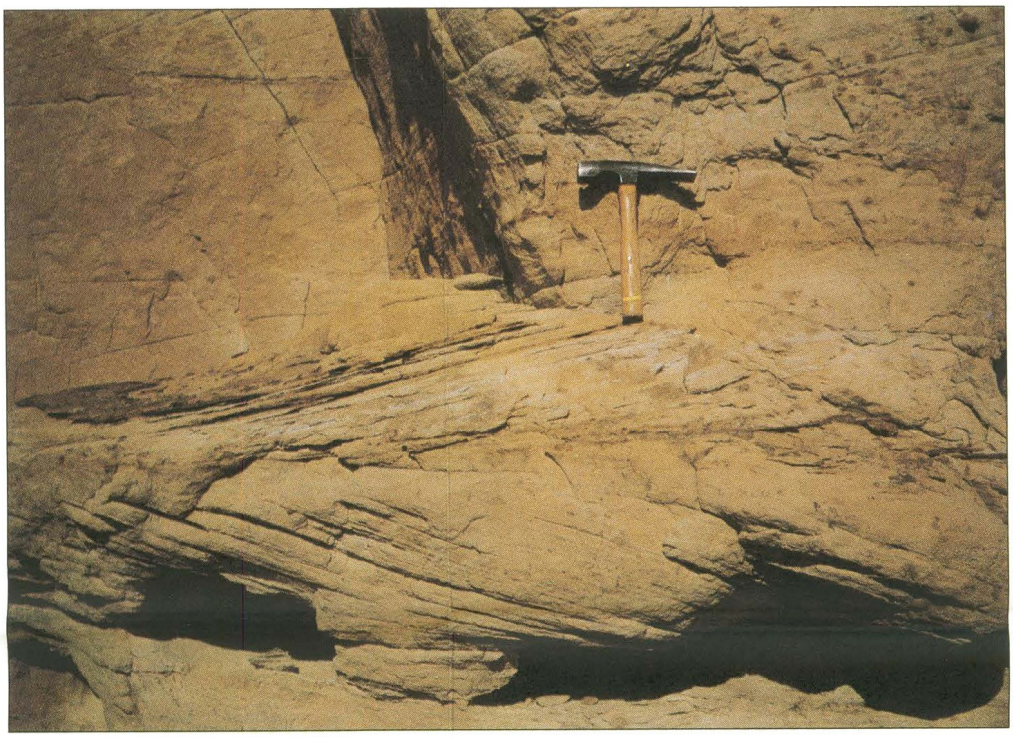
Photograph G



G.—White sandstone (Kcwl) on the trail to Tsin Kletzin Ruins, located above the lower sandstone (Kcl) of the Cliff House. This white sandstone is equivalent to the white sandstone shown in photographs F and I. The sandstone was deposited in the upper part of the zone between high and low tide (foreshore) or adjacent to it in slightly deeper water (upper shoreface). It is characterized by its color, a parallel even-bedded to crossbedded nature, and sparse churning by organisms.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

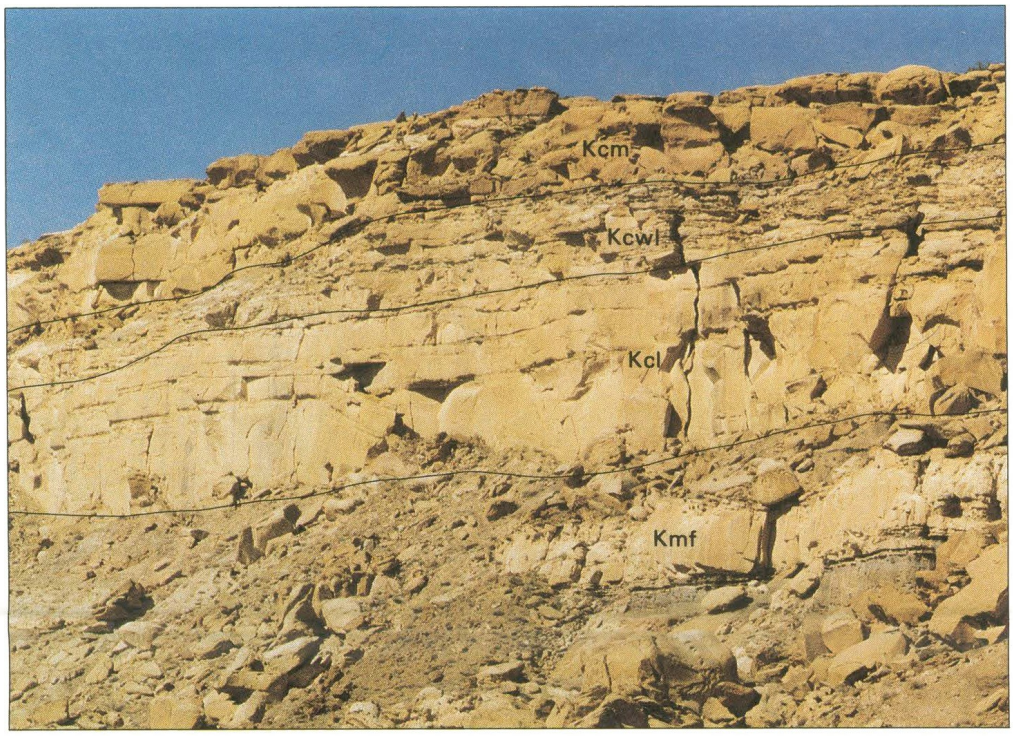
Photograph H



H.—White, crossbedded sandstone (Kcwl) on the west side of South Mesa on the trail to Tsin Kletzin Ruins. This rock overlies the sandstone shown in photograph G and was possibly deposited in a tidal inlet.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

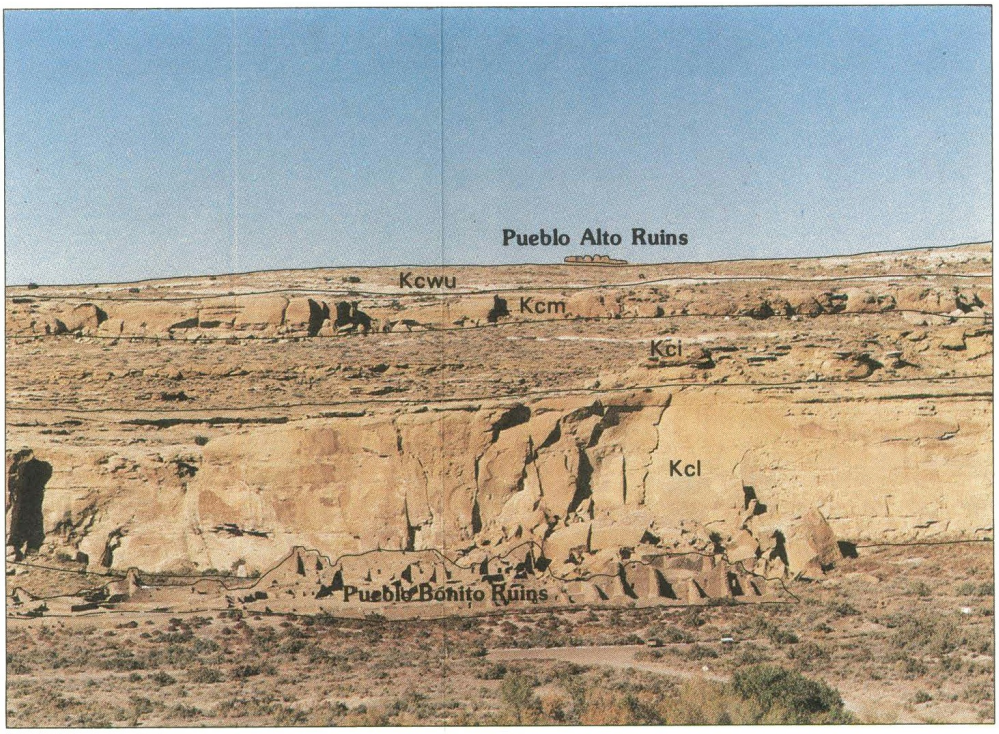
Photograph I



I.—Prominent cliff on east side of South Mesa, in view of visitors center. Stratigraphic sequence is similar to that of photograph F, but white sandstone (Kcwl) between middle and lower sandstone units (Kcm and Kcl) of Cliff House is less easily seen. To the southeast in the vicinity of Fajada Butte and Chacra Mesa, rocks (Kci) more similar to sandstones representative of the lower part of the shoreface and possibly the transition zone occupy the interval between the middle and lower sandstones of the Cliff House Sandstone.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Photograph J



J.—Cliff House Sandstone on the northeast side of Chaco Canyon above Pueblo Bonito Ruins. The middle and lower sandstones (Kcm and Kcl), which form imposing cliffs, represent an advance of the sea toward the site of the camera. The rocks (Kci) between them form slopes and benches that locally have interbeds of marine shale similar to the Lewis Shale and that indicate a change or transition from nearshore to offshore marine sedimentation. The white sandstone (Kcwu) above the middle sandstone (Kcm) represents a retreat of marine waters and sedimentation most probably within the breaker and surf zones. A major marine advance (deepening water) signaled the last phase in the encroachment of the Late Cretaceous seaway in the region. The Lewis Shale, which overlies the Cliff House to the north, was deposited at this time. Pueblo Alto Ruins is visible on the skyline.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Photograph K



K.—Crossbedding to horizontal parallel bedding overlain by a zone of rocks which were churned by burrowing organisms such as worms and shrimp. These rocks are in the cliff face of the lower sandstone (Kcl) of the Cliff House Sandstone between Pueblo Bonito and Kin Kletso Ruins. The crossbedding was produced by the action of waves generated by storms. The more horizontal bedding was developed when storm-generated wave action was not as intense. The churned zone represents a period when sand and silt were being deposited quietly, allowing bottom feeding organisms to move freely about and burrow in the sediment. The change back and forth from periods of storm to periods of quiet is seen in the repetition of these horizontal sandstone layers and churned zones. The sandstone layers and churned zones are each about 3 ft thick.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Photograph L



L.—A highly fossiliferous and churned bed about 1 foot thick in the lower sandstone unit (Kcl) of the Cliff House Sandstone above Kin Kletso Ruins on the trail to Pueblo Alto. Clam shells may represent infill by fossil debris moved seaward from the swash and surf areas by storm-generated waves that raked the bottom of the sea floor. An excellent example of this feature is seen in a fallen slab of Cliff House Sandstone that serves as part of the foundation for the west wall of Kin Kletso.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Photograph M



M.—Fossilized burrows in the middle sandstone (Kcm) of the Cliff House Sandstone near the head of Clys Canyon. Paleontologists refer to these kinds of burrows as trace fossils. The most abundant of these in both the Cliff House and the Pictured Cliffs Sandstones is *Ophiomorpha major*, whose outer walls resemble a corn cob. This form is believed to have been made by a type of shrimp similar to modern-day kinds. These trace fossils with their knobby appearance are commonly seen in sandstone blocks used by the Anasazi in the construction of their dwellings.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Source Geologic Map Ancillary Information

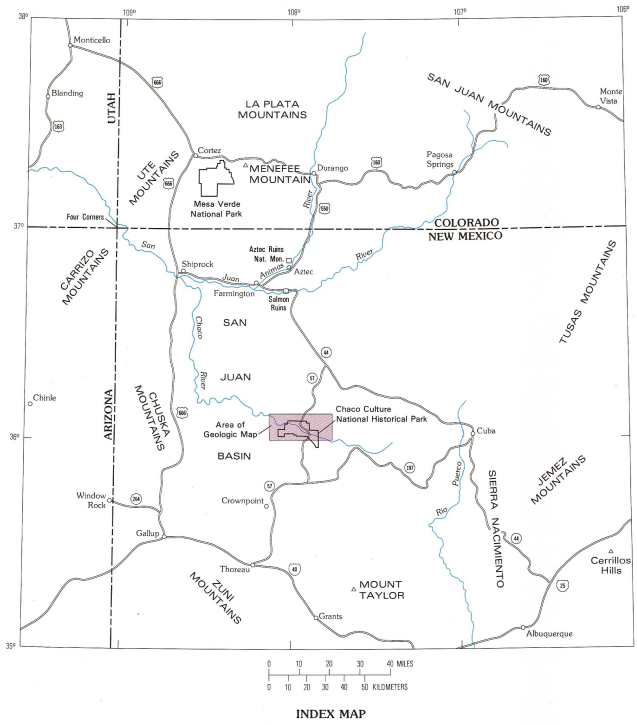
The digital geologic-GIS maps for Chaco Culture National Historical Park were compiled from several sources (as listed in the GRI Digital Maps and Source Map Citations section). Ancillary map information including figures, tables and text are presented with each source map. Source map MF-1094 (*GRI Source Map ID 1049)* did not have any ancillary graphics or text.

Chaco Culture National Historical Park (I-1571)

Scott, Glenn R., O'Sullivan, Robert, B., and Weide, David L., 1984, Geologic Map of the Chaco Culture National Historical Park, Northwestern New Mexico: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1571, scale 1:50,000. (*GRI Source Map ID 1055*).

*** Source for the Kin Klizhin Ruins and Sergeant Ranch quadrangles, and the upper third of the Pueblo Bonito quadrangle (GRI MapCode CCNH). The lower two-thirds of the Pubelo Bonito quadrangle were not captured from this source map. In addition, the GRI CCNH map also has two contacts taken from source map USGS MF-1094.*

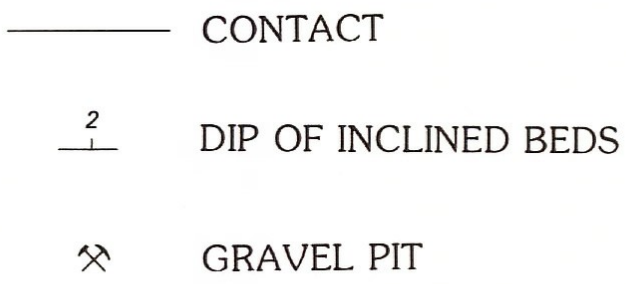
Index Map



INDEX MAP

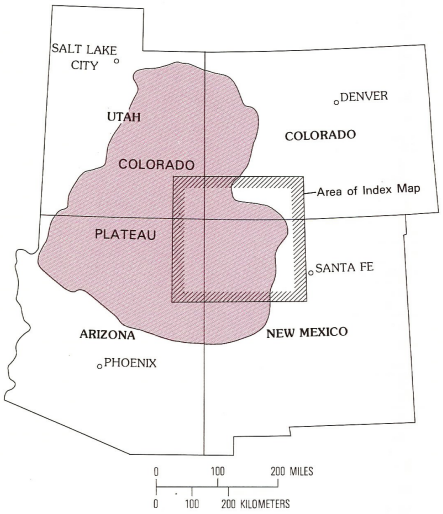
Extracted from: (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles). (*GRI Source Map ID 1055*).

Legend



Extracted from: (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles). (*GRI Source Map ID 1055*).

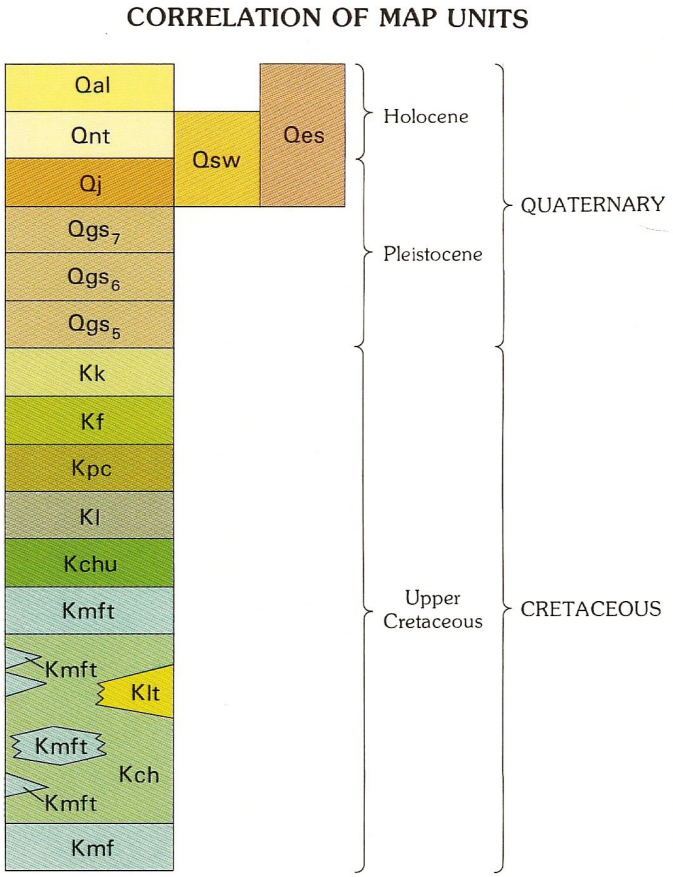
Colorado Plateau Index Map



MAP SHOWING LOCATION OF COLORADO PLATEAU AND AREA OF INDEX MAP

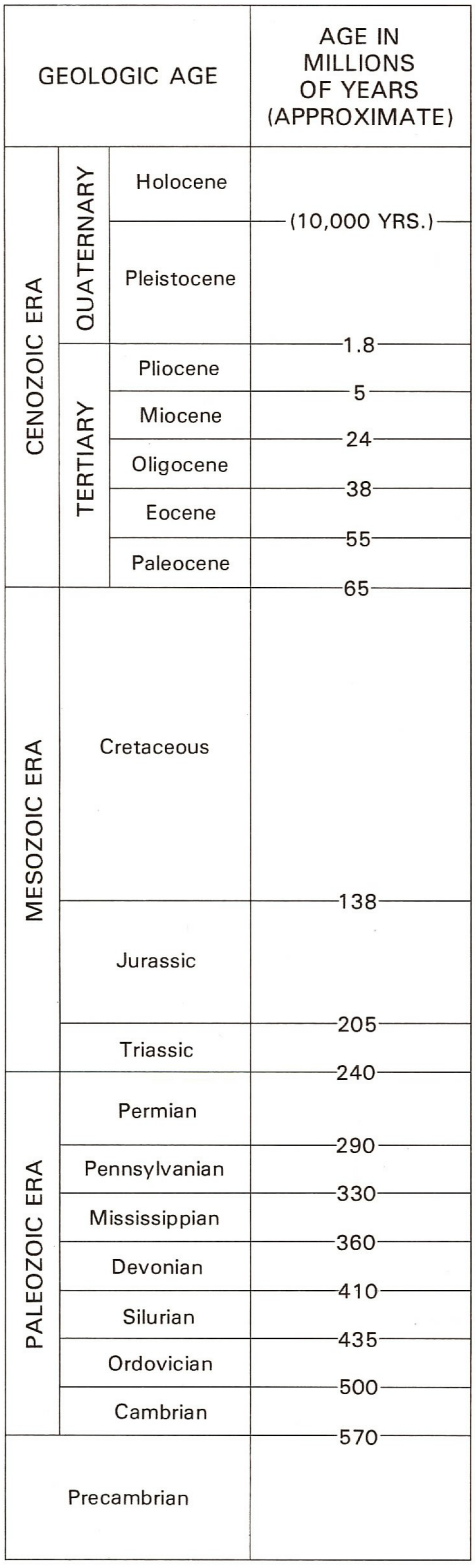
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Correlation of Units



Extracted from: (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles). (*GRI Source Map ID 1055*).

Geologic Time Chart



GEOLOGIC TIME CHART

Extracted from: (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles). (*GRI Source Map ID 1055*).

Report

Note

The surficial geology of the area and the bedrock of the eastern part were mapped in 1977 as part of a program designed to assess the impact on the environment of strip mining of coal-bearing strata in the western and southern San Juan Basin. The bedrock geology of the western part of the area was mapped in 1958 for the Shiprock 1° x 2° quadrangle (O'Sullivan and Beikman, 1963). The Chaco Culture National Historical Park lies within three 7-1/2 minute quadrangles—Kin Klizhin Ruins, Pueblo Bonito, and Sargent Ranch. The geology of these individual quadrangles was published separately in 1979 as Miscellaneous Field Studies Map MF- 1094 (O'Sullivan and others, 1979), MF-1119 (Weide and others, 1979a) and MF- 1120 (Weide and others, 1979b). The geology shown on these previously published maps, slightly modified, has been brought together on the geologic map included in this report. Lithologic descriptions of the various stratigraphic units are only summarized here. Reports describing the bedrock stratigraphy and economic geology of nearby areas, many of which concern the rocks of the Park, are by Bauer and Reeside (1921), Reeside (1924), Dane (1936), Fassett and Hinds (1971), Shomaker and others (1971), and O'Sullivan and others (1972). The stratigraphy and paleofauna of the Cliff House Sandstone in the park area are discussed by Siemers and King (1974). Subsurface correlations of rocks exposed in this area were studied by Fassett (1977) in the region from Pagosa Springs, Colorado, southward almost to the Park. More complete details on the lithology and regional aspects of the surficial deposits are in reports by Hack (1942), Richmond (1965). Love (1977) and Hall (1977).

A BRIEF OUTLINE OF THE GEOLOGY OF CHACO CULTURE NATIONAL HISTORICAL PARK

Setting

Chaco Culture National Historical Park is near the middle of the downfolded San Juan Basin, a broad bowl-shaped intermountain basin 100-150 miles (160-240 km) wide, lying at an elevation of about 6,000 feet (2000 m) in northwestern New Mexico. The basin is bordered by the high San Juan and La Plata Mountains on the north, the Chuska and Carrizo Mountains on the west, the Sierra Nacimiento and Tusas Mountains on the east, and the Zuni Mountains on the south. The San Juan Basin is but a part of the Colorado Plateau, an elevated block of relatively flat-lying beds, which covers large parts of Arizona, Colorado, New Mexico, and Utah. The map area is drained by the Chaco River which joins the San Juan River, a tributary of the Colorado River, near Shiprock. Access to the Park is by graded New Mexico State Highways 57 and 197. These routes traverse drab, nearly flat-lying rocks of Late

Cretaceous and early Tertiary age that surround and form Chaco Canyon. The Cretaceous rocks contain extensive energy resources including coal, natural gas, and oil. The formations that underlie Chaco Canyon are also found in the surrounding mountains and include Precambrian rocks and rocks of the Mississippian, Pennsylvanian, Permian, Triassic, and Jurassic Systems. The economic geology of the San Juan Basin as well as a discussion of the strata that overlie and underlie the rocks of the Chaco Canyon area is summarized in a report by Peterson and others (1965).

The Geologic Story

The oldest rocks seen at Chaco Canyon make up the Menefee Formation and are exposed at the edges of the valley floor along the Chaco River and Chaco Wash. This formation is also very widespread south and southwest of the park. These rocks are approximately 80 million years old and were laid down as sand, mud, and plant debris in coastal swamps and on alluvial plains that lay landward from a marine shoreline to the northeast. These ancient deposits are now preserved as coal, black carbonaceous shale, shale, and sandstone. During deposition, the geography of the coastline changed constantly as the shoreline retreated inland to the southwest in response to the encroachment of the ocean on the land, then moved northeast as sea level dropped. The evidence for this periodic oscillation is seen in the nonmarine coaly layers that interfinger with marine rocks. These interfingering sequences represent periodic transgressions and regressions of the sea. The buff-colored Cliff House Sandstone that overlies the Menefee Formation represents beach sand deposited at or very near the shoreline of this shallow Cretaceous sea. The Cliff House Sandstone forms the high cliffs of the Park and once served as a major source of building stone for the construction of the pueblos.

The Cliff House Sandstone interfingers with and is overlain by the Lewis Shale, a relatively deep water deposit that marks the most extensive transgression of the sea. Abundant fossils found in the beds of the Lewis Shale indicate that marine mollusks with lustrous pearly shells were plentiful. During both the beginning and the ending of the marine interval that produced the Lewis Shale, sea level changed. This resulted in the interlayering of relatively deep and shallow-water sediments. In addition to an ocean environment, volcanoes were active throughout the western United States during Late Cretaceous time. Ash from these eruptions was blown for great distances, and when it fell into the sea, was altered to bentonite, a sticky, expandable clay. The Lewis Shale contains many thin beds of bentonite.

As the sea withdrew for the last time from northwestern New Mexico, it moved gradually toward the northeast, followed by a shoreline that deposited sand on top of the Lewis Shale. This beach sand deposit is now called the Pictured Cliffs Sandstone. Final retreat of the sea must have required a considerable amount of time, for in places the Pictured Cliffs Sandstone is over 300 feet (90 m) thick. After the deposition of the buff-colored Pictured Cliffs Sandstone, the San Juan Basin, in response to great regional pressure on the earth's crust, began to sag, and bordering areas began to rise. As

marginal lands increased in elevation, rivers brought fine sediments and plant material into the basin. Coastal and floodplain sediments, deposited on top of the Pictured Cliffs Sandstone, became consolidated and formed the easily eroded beds now called the Fruitland Formation and the Kirtland Shale. Both formations contain local concentrations of bones of dinosaurs, turtles, crocodiles, and fish, which reflect this deposition in a low, swampy coastal environment.

At the beginning of the Tertiary, about 65 million years ago, increasing uplift caused increasing erosion of the region surrounding the San Juan Basin. One of the earliest signs of this erosion is a conglomerate containing abundant quartzite pebbles that makes up the Ojo Alamo Sandstone of Tertiary (Paleocene) age. The Ojo Alamo Sandstone formerly covered the Chaco Canyon area but was stripped off along with younger beds of the Paleocene Nacimiento Formation and the Eocene San Jose Formation.

Even younger deposits of Oligocene age (about 37 to 24 million years old) apparently once covered the basin. With the exception of the Chuska Sandstone in the Chuska Mountains, these terrestrial sediments have been stripped from the landscape by erosion and removed from the San Juan Basin by the ancestral Chaco, San Juan, and Puerco Rivers. Miocene and Pliocene deposits probably also were present in the San Juan Basin. Today, however, only the Bidahochi Formation of Miocene and Pliocene age, west of Gallup, and a few high terrace deposits of Pliocene age remain.

The deep, widespread stripping of these younger sediments took place in Pliocene and Quaternary time, for during that interval, erosion was greater in the San Juan Basin than in most intermountain basins in the Rocky Mountains. For example, the Animas River south of Durango, Colorado, has cut a canyon more than 500 feet (610 m) deep in the last 600,000 years. This is double the rate of erosion of some other Colorado streams such as the South Platte River near Denver.

In the area of Chaco Canyon, severe erosion has continued to the present. Nearly all of the Pliocene and early Quatemary, and most of the middle Quaternary stream deposits and stream-cut surfaces have been eroded away. Only a few middle and late Quaternary pediment-like surfaces covered by sandy gravel have been preserved (see, for instance, Qgs5, 6, and 7). These remnants show that the size of these ancient stream networks and their direction of flow were about the same as they are today. The ancestral Chaco River and its tributaries were more powerful than modern streams for they transported gravel instead of only sand, silt, and clay. Judging from the heights of remnants of pediment-like surfaces above the present streams and correlating with an excellent sequence of terraces along the San Juan River at Farmington, New Mexico, we estimate that the 300-foot-deep (90 m) Chaco Canyon has been cut in several stages during the 300,000 years since middle Quaternary time.

Surficial Deposits

Surficial deposits consist of unconsolidated or slightly consolidated gravel, sand, silt, and clay of thin and patchy distribution. In the Park, these sediments have resulted from erosion and deposition

by wind and running water, the same processes that shape the landscape today. Sheetwash alluvium accumulates when rain falls on a steep slope and moves fine sediments downslope where they grade into the alluvium deposited by running water. Wind-deposited (eolian) sand that now occurs in large sand sheets partially stabilized by vegetation and in long, thin linear dunes, was picked up partly from stream valleys and partly from the disintegration of bedrock units like the Cliff House and Pictured Cliffs Sandstone. The wind-blown sand was deposited on the upland surfaces by a strong prevailing wind blowing from southwest to northeast, the same direction taken by modern winds. Alluvium, a third form of widespread surficial deposit, is laid down by streams, even by the smallest ephemeral and intermittent streams that flow only after a severe rain storm.

During Pliocene and Quaternary time, pediments and terraces formed in and near Chaco Canyon as streams continuously cut downward. Each of these surface remnants is mantled by 10-20 feet (3-6 m) of alluvium composed of coarse gravel near the mountains and finer gravelly sand in the center of the basin near the Park. While as many as 10 of these surfaces are found in the San Juan Basin, and seven in the Chaco River basin, only the three youngest are preserved within the Park. No datable material has been found in the terraces to estimate their true age; we believe, however, that they precede the arrival of man in North America.

Throughout the southwestern United States in general, the earliest evidence of man is found in the late Quaternary to early Holocene alluvium correlated with the Jeddito Alluvium. In the park, this alluvium is composed of gravelly sand and its upper surface generally forms a terrace about 23-33 feet (7-10 m) above modern stream level. Jeddito Alluvium may be seen along the sides of Fajada Wash southwest of the Visitors Center. Recent erosion has removed most of the Jeddito Alluvium in the Park.

Younger Holocene alluvium is composed of fine-grained sediment including sand, silt, and clay. Erosion of the silty alluvium creates flat-floored arroyos with vertical walls often more than 30 feet (9 m) high. These rectangular arroyos are characteristic of a semiarid climate where torrential rainfall and flash floods are common. Chaco Canyon averages about 10-15 inches (25-38 cm) of rain per year, much of it falling from intense local thunderstorms during a wet season from July through September. Within the Park, erosion caused by summer thunder storms has exposed three different deposits of Holocene alluvium.

The earliest of the three deposits is correlated with the Tsegi Alluvium. This alluvium was deposited before pottery was in use but does contain a few stone tools from archaic cultures. An intermediate-age deposit of Holocene alluvium is correlated with the Naha Alluvium. This alluvium is critical to an interpretation of the archaeology of the Park because it forms the upper part of the main terrace along Chaco Canyon and relates directly to the period of most intense occupation of the canyon. Archaeological time in Chaco Canyon, as is common throughout North America, is defined in terms of named cultures. In Chaco Canyon intense occupation began with the Basketmaker III period (about A.D.

500) and ended at the close of the Pueblo III period (a little later than A.D. 1127). Pottery was extensively used throughout this period and sherds of plain and decorated ware are abundant in The Naha Alluvium.

In most valleys of the southwestern United States, whet a an arroyo was cut into the Tsegi Alluvium, the subsequently deposited Naha Alluvium only partly filled the arroyo; a later arroyo which cut into the Naha left two well-preserved terraces. In the Park, however, the Naha Alluvium first covered the Tsegi Alluvium as a sheet of alluvium; then, as arroyo cutting proceeded head-ward through the Park, the entire fill was trenched, especially near the center of Chaco Wash. According to Bryan (1954) and Hall (1977), the center of the wash was repeatedly cut and filled in latest Holocene time.

Within both the Tsegi and Naha times of alluviation, there were many episodes of cutting and filling. We find that these episodes did not produce mappable deposits. Therefore, we have mapped only the deposits of the gross events (complicated as they may be in detail), thus requiring the lumping of the Tsegi and Naha Alluviums into a single unit.

The modern alluvium that covers the floors of the Chaco arroyos has come from the very recent cutting of those arroyos. About 1850, an extensive cycle of arroyo trenching began in the southwest, reaching Chaco Canyon about 1860 (Bryan, 1954). Although arroyos make cross-country travel difficult and locally impossible, they do expose the internal composition, structure, and archaeological content of the Naha and Tsegi Alluviums; they are truly the geologists' and archaeologists' windows to the past.

Mass Wasting

Mass wasting is the downslope movement of bedrock or surficial material by the force of gravity. At Chaco Canyon numerous large rockfalls are the chief form of mass movement. Rockfalls, some involving blocks weighing thousands of tons, have been a major hazard along the sides of the canyon since at least Pueblo III time when the occupants of Pueblo Bonito placed stone supports under the cliff to prevent falling blocks from crushing the pueblo. This early engineering work was successful until January 22, 1941, when "Threatening Rock", weighing over 30,000 tons, fell and crushed a significant part of Pueblo Bonito (Schumm and Chorley, 1964). Abundant large blocks of the Cliff House Sandstone scattered along the bases of vertical cliffs show that rockfalls are a recurring hazard. In July 1977, a large block plunged into the Park housing area narrowly missing at least two structures. Such rockfalls create potential hazards for structures and roads built within the Park.

Similar hazardous mass wasting takes place along the walls of the arroyos cut into the valley floor. When the bases of the vertical walls of alluvium are undercut by running water or become saturated, the strength of the silty alluvium is decreased and large rectangular blocks bounded by broad, poorly defined joints fall suddenly into the arroyo. These "earth falls" range widely in size but some include several tons of alluvium. They are potentially extremely hazardous to anyone in the arroyos, especially during the wet season from July to September.

Folds and Artesian Water

The movement of underground water is controlled largely by the inclination of water-bearing beds or aquifers. The rocks forming the San Juan Basin dip toward the center of the basin about 45 miles (72 km) to the northeast of Chaco Canyon. The Park, therefore, lies on the northeastward-dipping southwestern flank of the basin. In the Park, the numerous layers of sedimentary rock are not flat but dip to the northeast at about two or three degrees. Thus, from south to north, younger rocks successively overlap older rocks (see cross section). Where dipping permeable rocks such as the Cliff House Sandstone are exposed at the surface, they absorb rain and melting snow and act as drains to carry the surface water underground. When the underground water meets an impervious barrier such as the Lewis Shale, it is forced along the contact and will finally emerge as natural springs where erosion and canyon cutting have exposed the contact between the sandstone and the shale. Such springs are common along the south side of Chaco Canyon and formed a significant part of the daily water supply of the Chacoan people. To the northeast of the Park, where the Cliff House Sandstone is overlain by the impervious Lewis Shale, the ground water is under pressure and wells drilled into the Cliff House Sandstone aquifer produce artesian water.

Conclusions

The geology and related landforms of Chaco Culture National Historical Park result from events that have taken place during the last 80 million years. Erosion and deposition, first in the ocean and later on the land, produced the sedimentary rocks and surficial deposits that characterize the Park area. Broad regional folding in Late Cretaceous and early Tertiary time tilted the sedimentary layers and exposed the rocks flanking the basin to erosion that partially filled the basin with additional sediment. Continued deep erosion in Pliocene and Quaternary time and deposition of that eroded material created the scenery of today. These geologic processes form an endless cycle that will slowly but persistently continue to change the Chaco Canyon landforms.

AN OVERVIEW OF THE ARCHAEOLOGY OF CHACO CANYON

Contribution No. 29, Chaco Center, National Park Service and the University of New Mexico

By William B. Gillespie

Chaco Culture National Historical Park is best known for the large multi-storied masonry pueblos contained within its boundaries. Pueblo Bonito and the other large ruins are some of the most spectacular prehistoric structures north of Mexico. The Park was created in 1907 specifically to protect and preserve these ruins after early explorers and archaeologists recognized both the aesthetic and scientific value of the sites. The Park has been the scene of considerable archaeological excavation over the past 80 years, including some of the earliest and largest projects in the southwest. The large amount of research, however, does not mean that the archaeological record is fully known; indeed, the more data

recovered, the more numerous the unanswered questions.

While the impressive masonry pueblos have received the most attention from archaeologists as well as the visiting public, they are only a small part of the archaeology of Chaco Canyon. Altogether some 2,400 sites have been located and recorded in the Park and its immediate environs. Only about one third of these are habitation sites while the others are locations of more limited use such as stairways, water control devices, and rock art.

The Archaic Period

The earliest inhabitants of Chaco Canyon were semi-nomadic hunters and gatherers who made use of the wild plants and animals available there. Man was present in Chaco as early as 5000 B.C. and may have been there even earlier. By the first century, domesticated corn, ultimately derived from Mexico, was added to the assemblage of utilized food plants. Corn was initially of only secondary, supplemental importance, but its use increased through time, and by about A.D. 500, was an integral part of the diet. In all, 70 sites, mostly small seasonal camps, have been identified in Chaco as representing a time of less intensive use before A.D. 500.

The Early Anasazi

Around A.D. 500, an important evolutionary transition led to a more sedentary life in small villages. Population was increasing; a concomitant increase in the reliance on agricultural production of corn, beans, and squash took place; pottery was used for the first time. Most people lived in small clusters of circular subterranean pithouses. The pattern of living in small villages of only a few families continued for several centuries, but by A.D. 900 another important transition had occurred: within the small villages, the locus of most domiciliary activities shifted from the pithouses to small contiguous masonry rooms built on the ground surface. At the same time, the pithouses evolved into structures known as kivas which were similar in size, location, and construction to pithouses, but limited in use primarily to ceremonial and socially integrative functions.

The same basic developments were occurring throughout most of the Anasazi region of the Colorado Plateau. As such, the early Pueblo archaeology of Chaco is not appreciably different from elsewhere in the Anasazi area. However, after A.D. 900 and particularly in the 1000's, developments took place in Chaco which set it apart from the other areas. The most conspicuous of these developments was the construction of the large communal houses or "towns" as they have frequently been called. Although most of the construction took place in the eleventh century, some of the towns were begun in the first half of the 900's. At three locations in the canyon—Pueblo Bonito, Penasco Blanco, and Una Vida—long curving arcs of large habitation rooms backed by smaller multi-storied rooms were laid out and built. This basic pattern was similar to contemporary village architecture, but there was a remarkable difference in scale: the room blocks at the town sites were much more extensive and the individual

rooms were substantially larger. At the three sites noted, these early room blocks formed the core for later additions.

Bonita Phase Architecture

The peak of the Chaco towns, the Bonito phase, occurred from about A.D. 1030 to 1125. The largest of the towns, Pueblo Bonito, grew to more than 600 rooms while 10 other sites had over 100 rooms. Altogether, there may have been as many as 5,000 people living in the canyon at this time.

Architecturally the towns have several characteristics which are rarely seen in other southwestern sites. Significantly, the basic units of construction and the patterns of growth are not -the same as in other Anasazi or modern Pueblo structures. Rather than continuing to add one or more rooms to dwellings as they were needed, construction of the Chaco towns was planned beforehand and completed as a single unit. The towns, or major sections of the longer-lived sites, were evidently designed, foundations for walls laid out, and then the rooms built as one large construction project. Town layouts vary but most have regular symmetrical plans, typically C-, D-, E-, or L-shaped and oriented to the south with a large enclosed plaza.

The masonry workmanship of the towns was exceptionally good. Walls were built with a rubble core and veneer or facing of carefully fitted pieces of tabular sandstone, frequently laid in banded patterns. Room blocks were as many as five stories high with the walls necessarily thicker at the bottom to support the tremendous weight. Rooms were characteristically large with ceilings as high as 13 feet (4 m) and floor areas commonly greater than 82 square feet (25 m2).

Kivas are present in the towns, but they are larger and fewer, relative to the number of rooms, than in contemporary village sites. However, the very large great kivas, rare throughout most of the Anasazi region, are comparatively abundant in or near the Chaco towns. A more unusual circular structure, the elevated or tower kiva is virtually unique to Chaco sites.

Several aspects of Chaco town architecture are suggestive of a more complex system of social organization than is characteristic of the Anasazi or the modern Pueblos. The evidence of planning, organized construction projects involving a large directed labor force, and craft specialization in the detailed masonry work all suggest a non-egalitarian division of labor and authority. In other words, the implication is of a "ranked" society headed by a social elite with enough authority to dictate some of the activities of the larger group. Evidence of such an elite may be present in the few burials from Pueblo Bonito where abundant and elaborate material accompaniments apparently indicate the high status of the individuals.

Other Bonito Phase Characteristics

Additional indications of a non-egalitarian social system are seen in some of the other developments in Chaco. Organized construction activities were not restricted to the large buildings.

Throughout the canyon, small but well-made irrigation systems involving diversion dams, canals, headgates, and gridded fields were built in an effort to increase agricultural production. The principal water source was not the main wash of the canyon, but rather the small ephemeral lateral channels draining the sides of the canyon. A substantial amount of labor was also expended in connecting many of the towns with broad, straight pathways or "roads" up to 29.5 feet (9 m) wide and featuring ramps and stairways where cliffs were encountered. Traces of prehistoric roads also extend outside the canyon to the north and south.

During the peak of the Bonito phase, Chaco appears to have been the focus of a large, regional, socio-economic system. Other large sites showing many of the attributes of the Chaco Canyon towns began to appear in the surrounding areas. Some of these are virtually indistinguishable from the Chaco towns and illustrate the same sophistication in planning and construction. The best known examples of these outlier communities are the Aztec and Salmon Ruins located about 62 miles (100 km) north of Chaco along the Animas and San Juan Rivers.

Many items were probably exchanged through this regional network, but two which are illustrative of the extent to which materials were transported are pottery and turquoise. Technological analysis has shown that much, if not most, of the pottery found in Chaco was not manufactured there, but was instead made in areas around the edges of the San Juan Basin. A reason for manufacturing ceramics in the higher peripheral areas may have been the greater availability of wood required for firing the vessels. On the other hand, Chaco evidently was a major center for the manufacture of turquoise ornaments (especially beads) yet turquoise does not occur naturally within the San Juan Basin. It had to be imported to the canyon in raw form from distant mines, most of which were probably in the Cerillos Hills south of Santa Fe, about 110 miles (175 km) to the east.

Long-distance trade with the advanced Toltec civilization of Mexico is also in evidence. Excavated Chaco sites, particularly Pueblo Bonito, have revealed some items which could only have come from Mexico. While they may seem few in number, there are far more in Chaco than in other contemporary sites in the northern southwest. Best known are the remains of brightly feathered scarlet macaws and small copper bells. Connections with Mexico are also seen in some of the architectural features such as masonry colonnades and broad steps ascending to small raised platforms.

The significance of these Mexican features in Chaco is a controversial topic among archaeologists today. Some suggest that the southern traits are simply high value items imported to Chaco through extensive trade connections. Others argue that these features are the physical evidence of the presence of traders from Mexico who came north to Chaco and established it as a regional center to serve as a northern outpost of the larger Mexican system. By either interpretation, turquoise is viewed as perhaps the main commodity transported south from Chaco.

At the time that the large towns were built and used, many inhabitants of the canyon continued

to live in small villages, most of which are scattered along the south side of the canyon. Archaeologists have long contemplated the relationship between the occupants of the two site types and the debate continues. Other than the obvious architectural differences, and the presence of more exotic items found in the towns, the material remains of the two are quite similar. In the past, researchers have viewed the two as separate cultural groups; the town dwellers were "better off" and presumably dominated the villagers. Alternatively, the canyon could have been occupied by a single group and the towns organized as "public work projects." A controlling social elite may have been present in the towns, but this does not imply that all of the town dwellers were of a privileged group.

Abandonment and Navajo Occupation

Sometime during the first half of the 1100's, Chaco lost its position as a major regional center and people began to leave the canyon. Major construction activities ceased and distinctive Chaco features indicative of an organized non-egalitarian society disappeared. Limited occupation in both towns and villages continued into the 1200's, but by 1300, Chaco, as with most of the Four Corners region dwellings, was abandoned. Reasons for the depopulation are still not firmly established, but in Chaco, the imbalance between a large population and inadequate resources may have been an integral factor.

The canyon was visited only sporadically until the Navajo began farming and herding sheep there in the early 1700's. Over 700 Navajo hogans, or one room dwellings, are located in the Park and adjacent areas with the greatest number dating from near the turn of the last century. An early trading post, operated by Richard Wetherill from 1897 until his death in 1910, helped to make Chaco a regional economic center once again. Development of the Park led to displacement of the local Navajos, but presence of the ruins continues to make the canyon a major attraction of northwestern New Mexico.

Extracted from: (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles). (*GRI Source Map ID 1055*).

References

Bauer, C. M., and Reeside, J. B., Jr., 1921, Coal in the middle and eastern parts of San Juan County, New Mexico, U.S. Geological Survey Bulletin 716-G, p. 155-237.

Bryan, Kirk, 1954, The geology of Chaco Canyon, New Mexico, in relation to the life and remains of the prehistoric peoples of Pueblo Bonito: Smithsonian Miscellaneous Collections, v. 122, no. 7, 65 p.

Dane, C. H., 1936 [1937], The La Ventana-Chacra Mesa coal field, part 3 of Geology and fuel resources of the southern part of the San Juan Basin, New Mexico, U.S. Geological Survey Bulletin 860-C, p. 81-166.

Fassett, J. E., 1977, Geology of the Point Lookout, Cliff House and Pictured Cliffs sandstones of the San Juan Basin, New Mexico and Colorado, in Guidebook of San Juan Basin III, northwestern New Mexico, New Mexico Geological Society, 28th Field Conference, 1977, p. 193-197.

Fassett, J. E., and Hinds, J. S., 1971, Geology and fuel resources of the Fruitland Formation and Kirtland Shale of the San Juan Basin, New Mexico and Colorado: U.S. Geological Survey Professional Paper 676, 76 p.

Hack, J. T., 1941, Dunes of the western Navajo country: Geographical Review, v. 31, no. 2, p. 240-263.

_____1942, The changing environment of the Hopi Indians of Arizona: Harvard University Peabody Museum of American Archaeology and Ethnology Papers, v. 35, no. 1, 85 p.

Hall, S. A., 1977, Late Quaternary sedimentation and paleoecologic history of Chaco Canyon, New Mexico, Geological Society of American Bulletin, v. 88, no. 11, p. 1593-1618.

Love, D. W., 1977, Dynamics of sedimentation and geomorphic history of Chaco Canyon National Monument, New Mexico, in Guidebook of San Juan Basin northwestern New Mexico, New Mexico Geological Society, 28th Field Conference, 1977, p. 193-197.

O'Sullivan, R. B., and Beikman, H. M., compilers, 1963, Geology, structure, and uranium deposits of the Shiprock quadrangle, New Mexico and Arizona: U.S. Geological Survey Miscellaneous Geologic Investigations Map 1-345, scale 1:250,000.

O'Sullivan, R. B., Repenning, C. A., Beaumont. E. C., and Page, H. G., 1972, Stratigraphy of the Cretaceous rocks and the Tertiary Ojo Alamo Sandstone, Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah: U.S. Geological Survey Professional Paper 521-E, 65 p.

O'Sullivan, R. B., Scott, 6. R., and Weide, D. L., 1979, Preliminary geologic map of the Kin Klizhin Ruins quadrangle, San Juan and McKinley Counties, New Mexico, U.S. Geological Survey Miscellaneous Field Studies Map MF-1094, scale 1:24,000.

Peterson, J. A., Loleit, A. J., Spencer, C. W., and Ullrich, R. A., 1965, Sedimentary history and economic geology of San Juan Basin: American Association of Petroleum Geologists Bulletin, v. 49, no. 11, p. 2076-2119.

Reeside, J. B., Jr., 1924, Upper Cretaceous and Tertiary formations of the western part of the San Juan Basin,, Colorado and New Mexico, U.S. Geological Survey Professional Paper 134, 70 p.

Richmond, G. M., 1965, Quaternary stratigraphy of the Durango area, San Juan Mountains, Colorado, in Geological Survey research 1965: U.S. Geological Survey Professional Paper 525-C, p. C137-C143.

Schumm, S. A., and Chorley, R. J., 1964, The fall of threatening rock: American Journal of Science, v. 262, no. 9, p. 1041-1054.

Shomaker, J. W., Beaumont, E. C., and Kottlowski, F. E., 1971, Strippable low-sulfur coal resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, 189 p.

Siemers, C. T., and King, N. R., 1974, Macroinvertebrate paleoecology of a transgressive marine sandstone, Cliff House Sandstone (Upper Cretaceous), Chaco Canyon, northwestern New Mexico, in central-northern New Mexico, New Mexico Geological Society, 25th Field Conference, 1974, p. 267-277.

Weide, D. L., Schneider, G. B., Mytton, J. W., and Scott, G. R., 4979a, Geologic map of the Pueblo Bonito quadrangle, San Juan County, New Mexico, U.S. Geological Survey Miscellaneous Field

Studies Map MF- 1119, scale 1:24,000.

_____1979b, Geologic map of the Sargent Ranch quadrangle. San Juan County, New Mexico, U.S. Geological Survey Miscellaneous Field Studies Map MF-1120, scale 1:24,000.

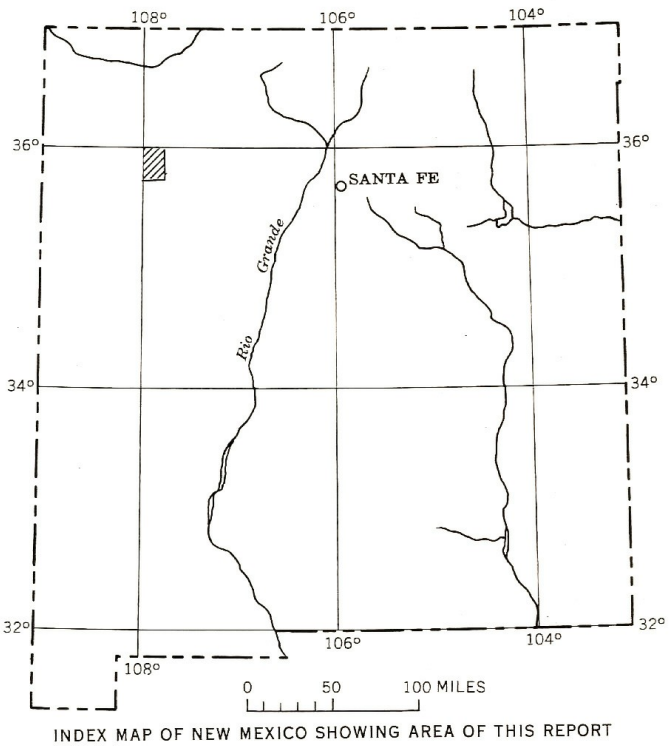
Extracted from: (Kin Klizhin Ruins, Sergeant Ranch and Pueblo Bonito Quadrangles). (*GRI Source Map ID 1055*).

Chaco Canyon-2 Quadrangle (I-315)

Kover, A.N., 1960, Photogeologic Map of the Chaco Canyon-2 Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-315, scale 1:62,500. (*GRI Source Map ID 1057*).

*** Source for the Seven Lakes NW and Seven Lakes NE quadrangles (GRI MapCodes CHCU and CHC2). The extent of the Seven Lakes and Seven Lakes SE quadrangles was not captured from this source map.*

Index Map



INDEX MAP OF NEW MEXICO SHOWING AREA OF THIS REPORT

Extracted from: (Seven Lakes NW and Seven Lakes NE Quadrangles). (*GRI Source Map ID 1057*).

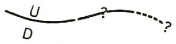
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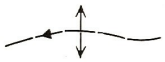
Contact
Dashed where approximately located



Trace of resistant or conspicuous bed within a formation



Fault
Dashed where approximately located, queried where probable, dotted where concealed. U, *upthrown side;* D, *downthrown side*



Anticline showing crest line and direction of plunge
Approximately located



Syncline showing trough line
Approximately located. Queried where probable

. . . . . .

Linear feature
Geologic significance uncertain from photointerpretation



Strike and dip of beds
Based on field measurement



Strike and dip of beds
Computed by photogrammetric methods



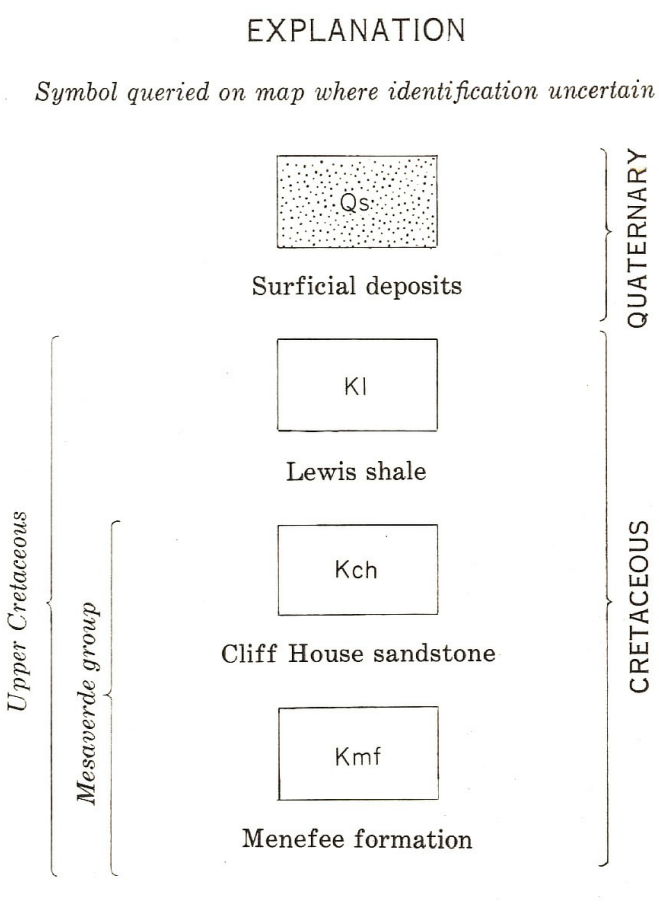
Approximate strike and dip of beds
Based on photointerpretation



Inferred strike and dip of bed rock
Based on photointerpretation of areas where bedding is obscure

Extracted from: (Seven Lakes NW and Seven Lakes NE Quadrangles). (*GRI Source Map ID 1057*).

Correlation of Units



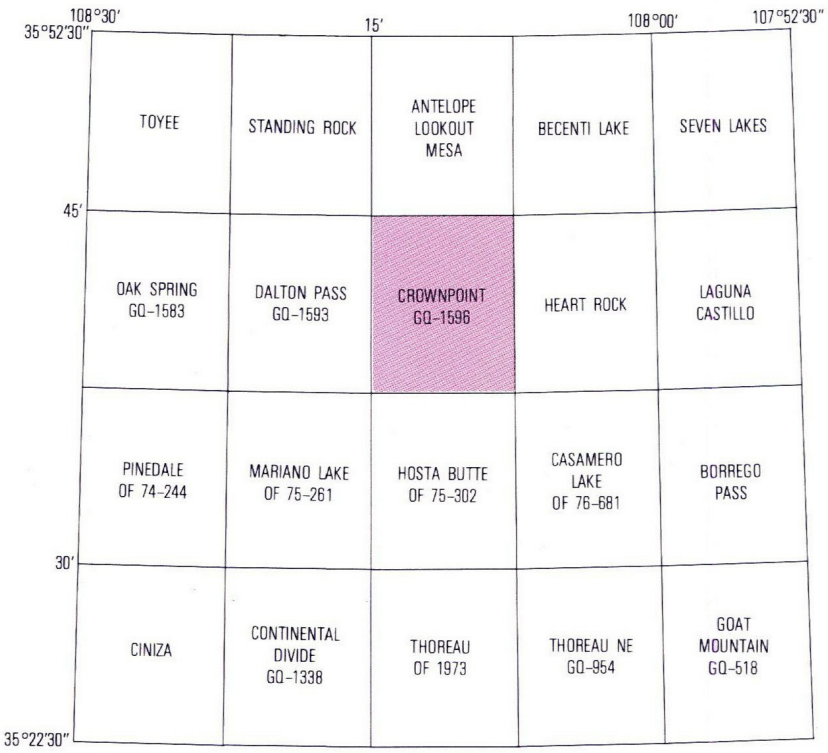
Extracted from: (Seven Lakes NW and Seven Lakes NE Quadrangles). (*GRI Source Map ID 1057*).

Crownpoint Quadrangle (GQ-1596)

Robertson, Jacques F., 1986, Geologic Map of the Crownpoint Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Geologic Quadrangle Map GQ-1596, scale 1:24,000. (*GRI Source Map ID 8387*).

*** The full extent of this source map was captured for the applicable GRI maps (GRI MapCodes CHCU and CRWN).*

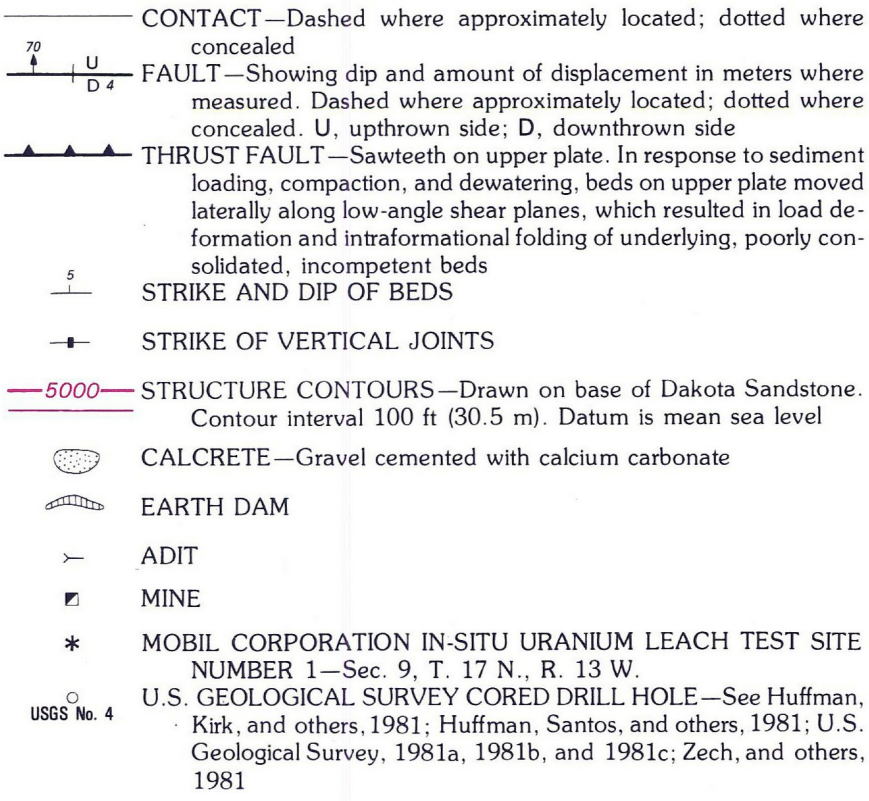
Index Map



INDEX SHOWING LOCATION OF CROWNPOINT QUADRANGLE, NEW MEXICO

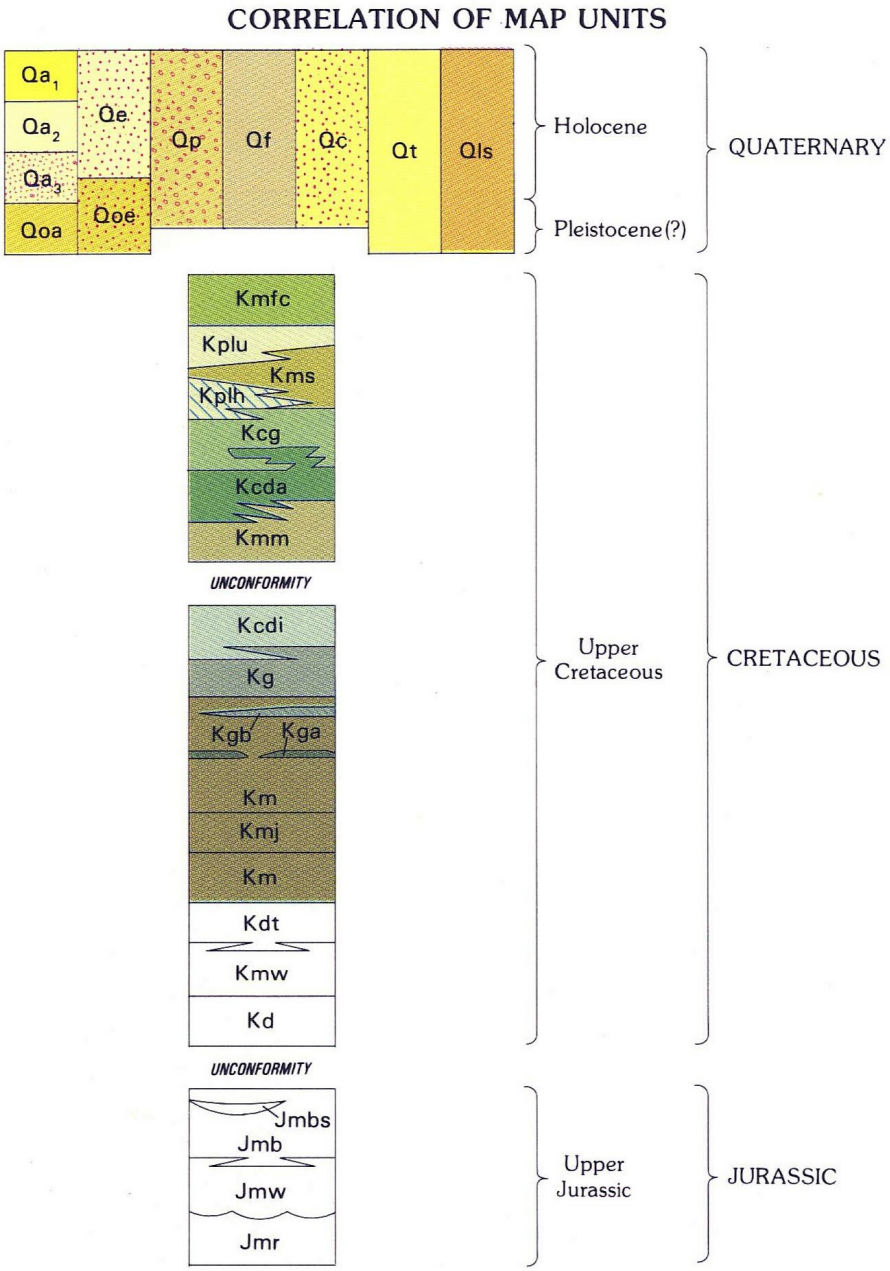
Extracted from: (Crownpoint Quadrangle). (*GRI Source Map ID 8387*).

Legend



Extracted from: (Crownpoint Quadrangle). (*GRI Source Map ID 8387*).

Correlation of Units



Extracted from: (Crownpoint Quadrangle). (*GRI Source Map ID 8387*).

References

Bryan, Kirk, 1954, The geology of Chaco Canyon, New Mexico-in relation to the life and remains of the prehistoric peoples of Pueblo Bonito: Smithsonian Miscellaneous Collections, v. 122, no. 7, 65 p.

Dickenson, K. A., Berryhill, .H. L., Jr., and Holmes, C. W., 1972, Criteria for recognizing ancient barrier

coastlines, in Rigby, J. K., and Hamblin, Kenneth, eds., Recognition of ancient sedimentary environments: Society of Economic Paleontologists and Mineralogists Special Publication 16, p. 192-214.

Goddard, E. N., chm., and others, 1948, Rock-color chart: National Research Council; reprinted by Geological Society of America, 1951, 1963, 1970, 6 p.

Harms, J. C., Southard, J. B., Spearing, D. R., and Walker, R. G., 1975, Depositional environments as interpreted from primary sedimentary structures and stratification sequences: Society of Economic Paleontologists and Mineralogists, Short Course Notes no. 2, 161 p.

Huffman, A. C., Jr., Kirk, A. R., Hammond, D. J., Zech, R. S., Franczyk, K. J., Steele-Mallory, B. A., Gundersen, L. C., Sikkink, P. G., Condon, S. M., Mruk, D. S.. Moore, Martha, Indelicato, L. A., and Hildebrandt, P. K., 1981, Lithologic descriptions, core and cutting samples, Mariano Lake-Lake Valley drilling project, Mc Kinley County, New Mexico, hole no. 3: U.S. Geological Survey Open-File Report 81-1202, 33 p.

Huffman, A. C., Jr., Santos, E. S., Hammond, D. J., Kirk, A. R., Aubrey, W. M., Mruk, D. S., Sikkink, P. G., Condon, S. M., Dubiel, R. F., Moore, Martha, Yost, Carl, Armstrong, Dan, Hildebrandt, P. K., and Indelicato, L. A.,1981, Lithologic descriptions, core and cutting samples, Mariano Lake-Lake Valley drilling project, Mc Kinley County, New Mexico, holes no. 4 and 4A: U.S. Geological Survey Open-File Report 81-1203, 39 p.

Molenaar, C. M., 1973, Sedimentary facies and correlation of the Gallup Sandstone and associated formations, northwestern New Mexico, in Fassett, J. E., ed., Cretaceous and Tertiary rocks of the southern Colorado Plateau: Four Corners Geological Society Memoir, p. 85-110.

Reading, H. G., ed., 1978, Sedimentary environments and facies: New York, Elsevier, 569 p.

U.S. Geological Survey, 1981a, Geophysical log suite from drill hole no. 3, Mariano Lake-Lake Valley drilling project, Mc Kinley County, New Mexico, U.S. Geological Survey Open-File Report 81-0439, 6 p.

_____1981b, Geophysical log suite from drill hole no. 4, Mariano Lake-Lake Valley drilling project, McKinley County, New Mexico, U.S. Geological Survey Open-File Report 81-0969, 9 p.

_____1981c, Geophysical log suite from drill hole no. 5, Mariano Lake-Lake Valley drilling project, McKinley County, New Mexico, U.S. Geological Survey Open-File Report 81-0970, 9 p.

Zech, R. S., Hammond, D. J., Kirk, A. R., Huffman. A. C., Jr., Aubrey, W. M., Schurman, R. L., Indelicato, L. A., and Hildebrandt, P. K., 1981, Lithologic descriptions, core and cutting samples, Mariano Lake-Lake Valley drilling project, McKinley County, New Mexico, hole no. 5: U.S. Geological Survey Open-File Report 81-1209, 29 p.

Extracted from: (Crownpoint Quadrangle). (*GRI Source Map ID 8387*).

Gallup 30' x 60' Quadrangle (I-2009 Sheet 1)

Dillinger, Jean K., 1990, Geologic Map of the Gallup 30' x 60' Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Miscellaneous Investigations Series Map I-2009 (Sheet 1), scale 1:100,000. (*GRI Source Map ID 1060*).

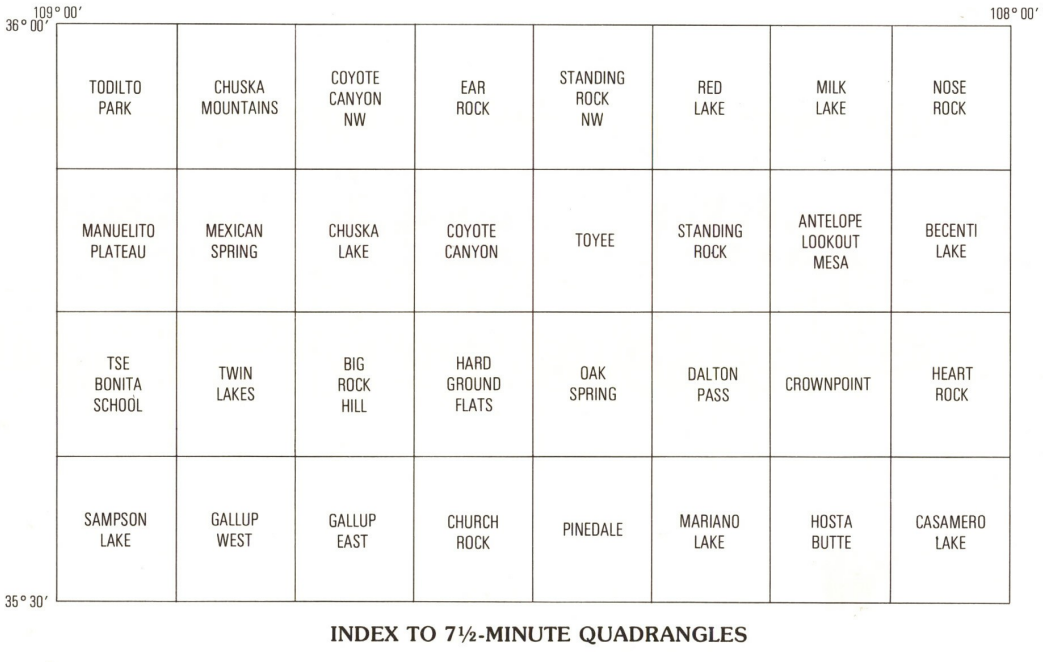
*** Source for the Milk Lake and Nose Rock quadrangles only (GRI MapCodes CHCU and GALL).*

Quadrangle Location



Extracted from: (Milk Lake and Nose Rock Quadrangles). (*GRI Source Map ID 1060*).

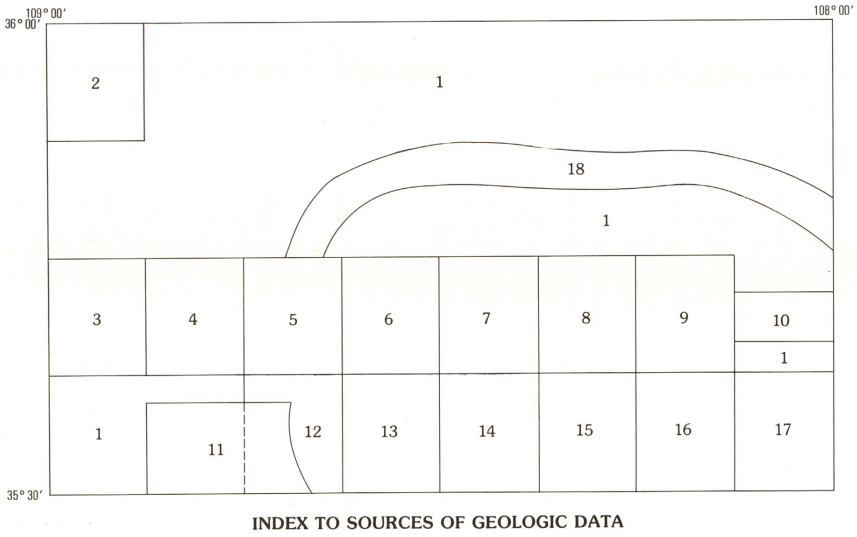
Index Map



INDEX TO 7½-MINUTE QUADRANGLES

Extracted from: (Milk Lake and Nose Rock Quadrangles). (*GRI Source Map ID 1060*).

Index to Sources



1. Hackman and Olson, 1977
2. Thaden, 1989
3. Zech, 1989a
4. Zech, 1989b
5. Kirk and Zech, 1987a
6. Kirk and Zech, 1987b
7. Kirk and Zech, 1984
8. Kirk and Sullivan, 1987
9. Robertson, 1986
10. Robertson, J.F., unpub. mapping, 1987
11. Dillinger, J.K., unpub. mapping, 1985
12. Green and Jackson, 1976
13. Green and Jackson, 1975a
14. Robertson, 1974
15. Green and Jackson, 1975b
16. Robertson and Jackson, 1975
17. Robertson, 1976
18. Thaden, R.E., and Zech, R.S., unpub. mapping, 1988

INDEX TO SOURCES OF GEOLOGIC DATA

Extracted from: (Milk Lake and Nose Rock Quadrangles). (*GRI Source Map ID 1060*).

Legend

Contact—Dashed where approximately located. Dotted at vertical breaks where one map unit is divided into two map units to show more detail

Break between sources of data—Occurs along lat 35° 45′ N., bordering eolian deposits and Allison Member of Menefee Formation

Fault—Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side. Faults having displacement of 20 ft or less not shown

Limestone Quarry—Mined primarily for road metal. Located in T. 15 N., R. 15 W., in Todilto Limestone Member of Wanakah Formation (Jcw)

Edge of slide block—Rock units shown where mapped within slide blocks

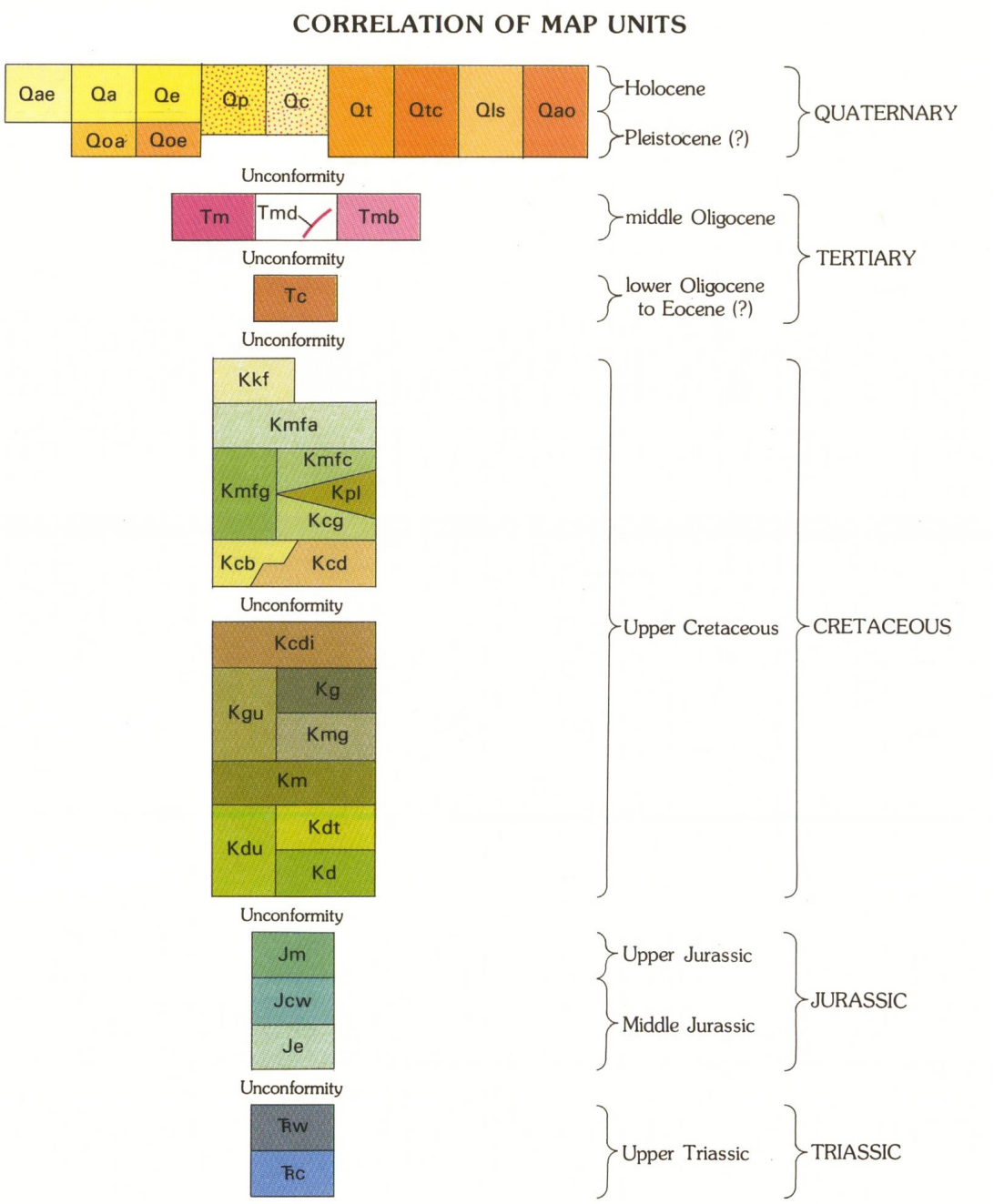
Anticline—Showing direction of plunge; dashed where approximately located

Syncline—Showing direction of plunge; dashed where approximately located

Monocline—Dashed where approximately located

Extracted from: (Milk Lake and Nose Rock Quadrangles). (*GRI Source Map ID 1060*).

Correlation of Units



Extracted from: (Milk Lake and Nose Rock Quadrangles). (*GRI Source Map ID 1060*).

References

Condon, S. M., and Peterson, F., 1986, Stratigraphy of Middle and Upper Jurassic rocks of the San Juan Basin-Historical perspective, current ideas, and remaining problems, in Turner-Peterson, C.

E., Santos, E.S., and Fishman, N.S., eds., A basin analysis case study-The Morrison Formation, Grants uranium region, New Mexico, American Association of Petroleum Geologists Studies in Geology, no. 22, p. 7-26.

Correa, A.C., 1970. Borrego Pass Lentil, a new member of the Crevasse Canyon Formation. southern San Juan Basin, New Mexico, Mountain Geologist, v. 7, no. 2, p. 99-102.

Green, M.W., and Jackson, T.J., 1975a, Geologic map of the Church Rock quadrangle, McKinley County, New Mexico, U.S. Geological Survey Open-File Report 75-258, scale 1:24,000.

_____19756, Geologic map of the Mariano Lake quadrangle, McKinley County, New Mexico, U.S. Geological Survey Open-File Report 75-261, scale 1:24,000.

_____1976, Geologic and structure contour maps of the Gallup East quadrangle, McKinley County, New Mexico, U.S. Geological Survey Open-File Report 76-453, scale 1:24,000.

Hackman, R.J., and Olson, A.B., 1977, Geology, structure, and uranium deposits of the Gallup 1° x 2° quadrangle, New Mexico and Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map 1-981, scale 1:250,000.

Kirk, A.R., and Condon. S.M., 1989, Maps showing structure contours at the base of the Dakota Sandstone, paleotopographic contours at the base of the Westwater Canyon Member of the Morrison Formation, and inferred actively rising structures and depocenter axes during Jurassic time. San Juan Basin, New Mexico, U.S. Geological Survey Miscellaneous Investigations Series Map I-1957-D, scale 1:100,000.

Kirk, A.R., and Sullivan, M.W., 1987, Geologic map of the Dalton Pass quadrangle, McKinley County, New Mexico, U.S. Geological Survey Geologic Quadrangle Map GQ -1593, scale 1:24,000.

Kirk. A.R., and Zech, R.S., 1984, Geologic map of the Oak Spring quadrangle, McKinley County, New Mexico, U.S. Geological Survey Geologic Quadrangle Map GQ-1583, scale 1:24,000.

_____1987a, Geologic map of the Big Rock Hill quadrangle, McKinley County, New Mexico, U.S. Geological Survey Geologic Quadrangle Map GQ -1594, scale 1:24,000.

_____19876, Geologic map of the Hard Ground Flats quadrangle, McKinley County, New Mexico, U.S. Geological Survey Geologic Quadrangle Map GQ-1592, scale 1:24,000.

Robertson, J.F., 1974, Preliminary geologic map of the Pinedale quadrangle, McKinley County, New Mexico, U.S. Geological Survey Open-File Report 74-244, scale 1:24,000.

_____1976, Preliminary geologic map of the Casamero Lake quadrangle, McKinley County, New Mexico, U.S. Geological Survey Open-File Report 76-681, scale 1:24,000.

_____1986, Geologic map of the Crownpoint quadrangle, McKinley County, New Mexico, U.S. Geological Survey Geologic Quadrangle Map GQ-1596, scale 1:24,000.

Robertson, J.F., and Jackson, T.J., 1975, Geologic and structure contour maps of the Hosta Butte quadrangle, McKinley County, New Mexico, U.S. Geological Survey Open-File Report 75-302, scale 1:24,000.

Sears, J.D., Hunt, C.B., and Hendricks, T.A., 1941, Transgressive and regressive Cretaceous deposits in southern San Juan Basin, New Mexico, U.S. Geological Survey Professional Paper 193-F, p.

101-121.

Thaden, R.E., 1989, Geologic map of the Todilto Park quadrangle, McKinley County, New Mexico, U.S. Geological Survey Geologic Quadrangle Map GQ-1646, scale 1:24,000.

Thaden. R.E., and Zech, R.S., 1984, Preliminary structure contour map on the base of the Dakota Sandstone in the San Juan Basin and vicinity, New Mexico, Arizona, Colorado, and Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF -1673, scale 1:500,000.

Zech, R.S., 1989a, Geologic map of the Tse Bonita School quadrangle, McKinley County, New Mexico, U.S. Geological Survey Geologic Quadrangle Map GQ-1661, scale 1:24,000.

_____19896, Geologic map of the Twin Lakes quadrangle, McKinley County, New Mexico, U.S. Geological Survey Geologic Quadrangle Map GQ -1659, scale 1:24,000.

Extracted from: (Milk Lake and Nose Rock Quadrangles). (*GRI Source Map ID 1060*).

Gallup 30' x 60' Quadrangle (I-2009 Sheet 2)

Dillinger, Jean K., 1990, Structure Contour Map of the Gallup 30' x 60' Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Miscellaneous Investigations Series Map I-2009 (Sheet 2), scale 1:100,000. (*GRI Source Map ID 191*).

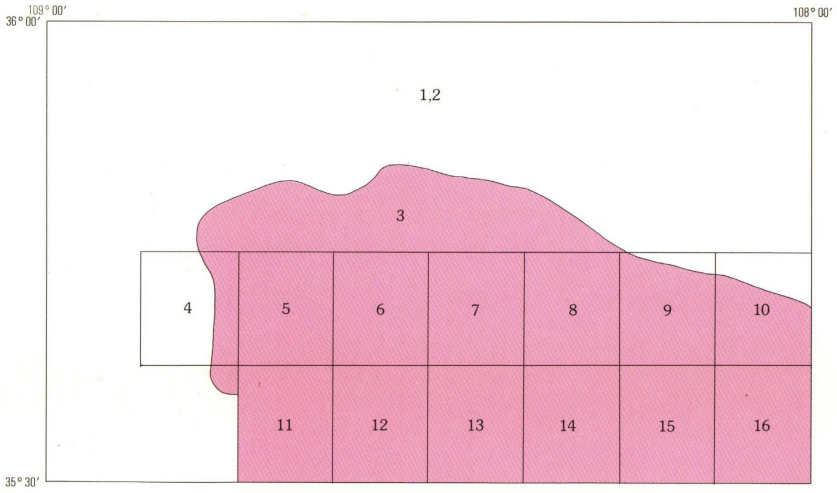
*** Source for the Milk Lake and Nose Rock quadrangles only (GRI MapCodes CHCU and GALL).*

Quadrangle Location



Extracted from: (Milk Lake and Nose Rock Quadrangles). (*GRI Source Map ID 191*).

Index to Sources



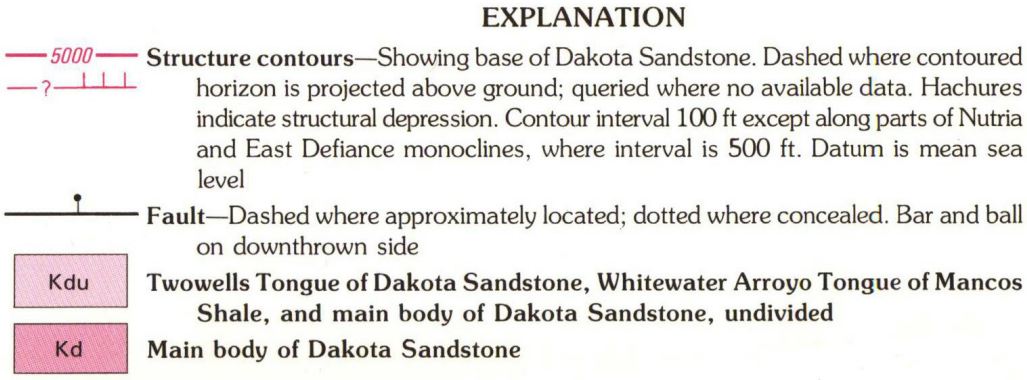
INDEX TO SOURCES OF STRUCTURE CONTOUR DATA

[Structure contours from 16 source maps (listed below) were adjusted as necessary to reconcile boundary mismatch. In a number of areas, available subsurface well control was used to modify prior structural interpretation, especially in the northeastern part of the map area. Fault locations remain as shown on geologic and source maps except for minor simplification.]

1. Hackman and Olson, 1977
2. Thaden and Zech, 1984
3. Kirk and Condon, 1989
4. Zech, 1989b
5. Kirk and Zech, 1987a
6. Kirk and Zech, 1987b
7. Kirk and Zech, 1984
8. Kirk and Sullivan, 1987
9. Robertson, 1986
10. Robertson, J.F., unpub. mapping, 1987
11. Green and Jackson, 1976
12. Green and Jackson, 1975a
13. Robertson, 1974
14. Green and Jackson, 1975b
15. Robertson and Jackson, 1975
16. Robertson, J.F., unpub. mapping, 1987

Extracted from: (Milk Lake and Nose Rock Quadrangles). (*GRI Source Map ID 191*).

Legend



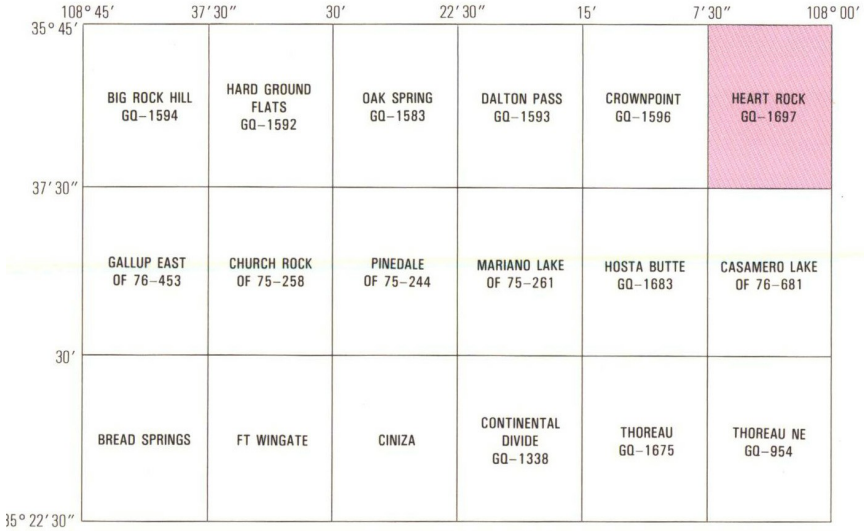
Extracted from: (Milk Lake and Nose Rock Quadrangles). (*GRI Source Map ID 191*).

Heart Rock Quadrangle (GQ-1697)

Robertson, Jacques F., 1992, Geologic Map of the Heart Rock Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Geologic Quadrangle Map GQ-1697, scale 1:24,000. (*GRI Source Map ID 1050*).

*** The full extent of this source map was captured for the applicable GRI maps (GRI MapCodes CHCU and HERO).*

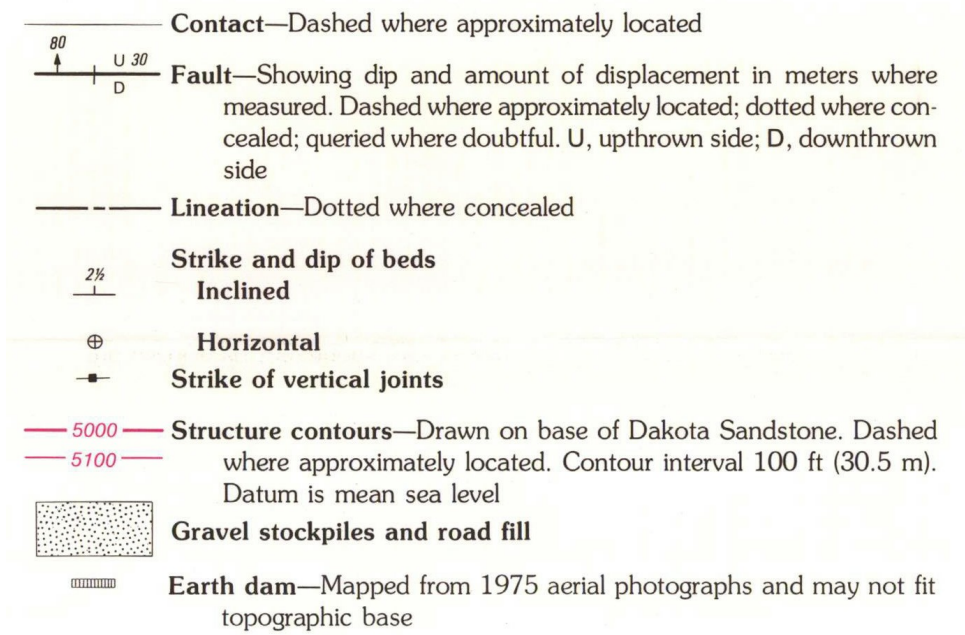
Index Map



INDEX SHOWING LOCATION OF HEART ROCK QUADRANGLE AND OTHER 7 ½-MINUTE GEOLOGIC MAPS IN THE SOUTHERN SAN JUAN BASIN. PUBLISHED MAPS INCLUDE U.S. GEOLOGICAL SURVEY GEOLOGIC QUADRANGLE MAPS (GQ) AND OPEN-FILE REPORTS (OF).

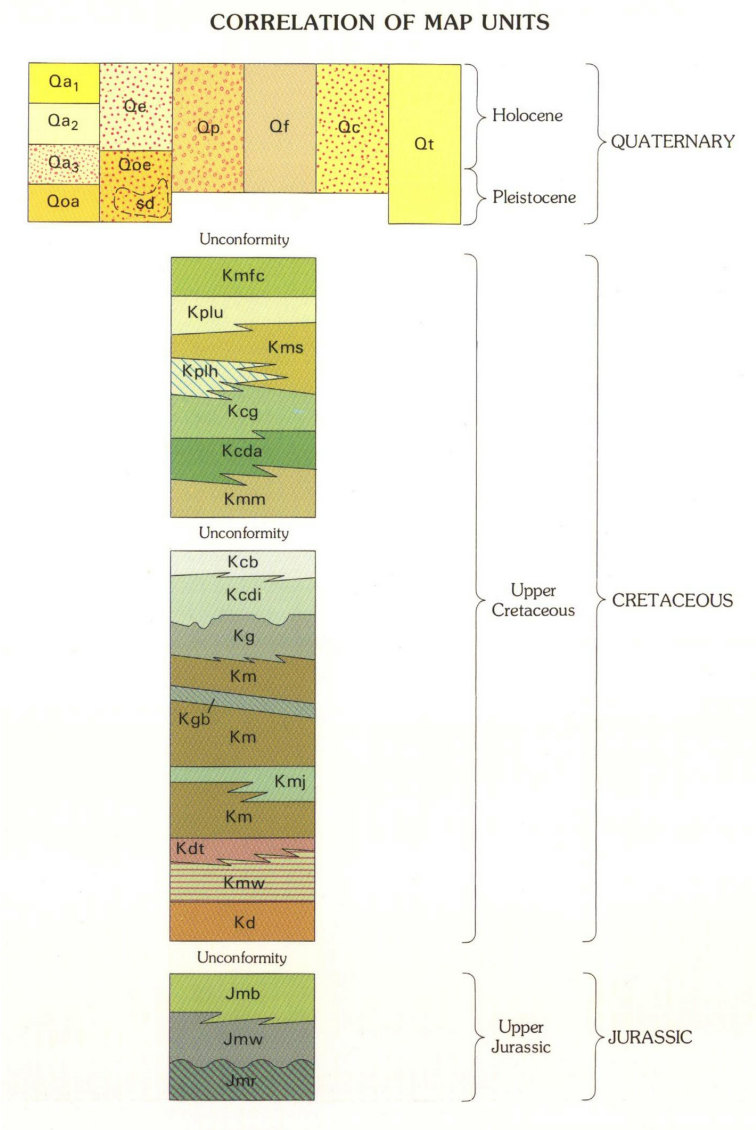
Extracted from: (Heart Rock Quadrangle). (*GRI Source Map ID 1050*).

Legend



Extracted from: (Heart Rock Quadrangle). (*GRI Source Map ID 1050*).

Correlation of Units



Extracted from: (Heart Rock Quadrangle). (*GRI Source Map ID 1050*).

Structure Report

The Heart Rock quadrangle is located on the Chaco Slope in the southern part of the San Juan Basin, about 50 km northeast of the Zuni Mountains. The Cretaceous bedrock forms a gentle homocline, with strata that strike generally N. 75° W. and dip from less than 1 ° to 3 ° to the north-northeast. From west to east across the quadrangle the strata are gently warped and are broken locally by normal faults. Strata in the eastern part of the quadrangle strike more nearly N. 60° W.

There is a dominant, northeast-oriented structural grain to the quadrangle, as outlined by a number of faults and joints and as reflected in the drainage pattern. A pair of parallel normal faults in the

north-central part of the quadrangle strike N. 45° E. and form a graben between them, which is 5.5 km long by 1.1 km wide. The graben is downdropped about 37 m in its central part, but displacement decreases from there both to northeast and southwest along the faults. The structural relationships are well shown across secs. 1, 11, 12, and 14, T. 17 N., R. 12 W. Several northeast-striking normal faults in the southwest corner of the quadrangle form small horst and graben blocks that include tilted and deformed strata. These faults are at the northern extremity of the Bluewater fault zone, which extends southward for 50 km into the Zuni Mountains.

Particularly unique are parallel lineaments in the northeast corner of the quadrangle, which strike N. 40° E. and extend south-southwest 2.25 km through the western part of sec. 33, T. 18 N., R. 11 W., and into NW1/4 sec. 4 and NE1/4 sec. 5, T. 17 N., R. 11 W; they form a zone 90-120 m wide within the Cleary Coal Member of the Menefee Formation (Kmfc). Although on aerial photographs they appear to be fault structures and appear to have shear planes in the zone between them, in actuality they bound a series of discrete, elongate, narrow, cigar-shaped bodies of fluviatile sandstone in stacked and overlapping channels that are oriented in the same direction and are more or less confined within the zone. The channels are etched out in sharp relief by differential erosion. Ground examination determined that there are no bounding faults or shear planes within the zone containing these channels of fluviatile sandstone.

East-striking normal faults occur in the southern part of the quadrangle; all of these faults exhibit downthrown basinward on the north sides. The largest of these faults has vertical displacement of 30 m and crosses the northern part of secs. 3, 4, and 5, T. 16 N., R. 12 W.; its trend is marked by a spring line of sinter deposits, composed of calcium carbonate and limonite, and by broken, sheared, and silicified wall rock.

Several normal faults with small displacements line up on the east side of the quadrangle for over 7 km and strike N. 15° W. The northernmost of these faults crosses the ridge of Heart Rock butte, immediately east of the summit knob in the SE1/4 sec. 17, T. 17 N., R. 11 W., and has 4 m of downthrow to the east. The southernmost fault is well exposed for 3 km and shows 4 m of downthrow to the west. About 300 m west of its north end are two closely spaced faults; they are exposed in outcrops in the SW1/4 sec. 28 and NW1/4 sec. 33, T. 17 N., R. 11 W.. Combined, these closely spaced faults show about 4 m of downthrow to the east. Evidence of their extension is buried by eolian sand and valley alluvium, but the projection southward of these faults lines up with the centerline of a long straight valley within the quadrangle. These faults would appear to form the west flank of a graben, with the exposed fault to east forming the east flank.

All of the faults in the Heart Rock quadrangle are normal faults with steep to vertical dips. They all show dip-slip, but no strike-slip, movement, and appear to be pene-contemporaneous. Although some faults terminate against others, no fault appears to have been cut or displaced by another. The pattern of

faulting, which involves some graben and horst blocks, suggest that deformation occurred in response to tensional stress, possibly related to uplift of the Zuni Mountains. Deformation probably took place in latest Cretaceous and earliest Tertiary time, during the period of Laramide orogeny (Kelly and Clinton, 1960, pgs. 22, 47).

Extracted from: (Heart Rock Quadrangle). (*GRI Source Map ID 1050*).

References

Bryan, Kirk, 1954, The geology of Chaco Canyon, New Mexico-in relation to the life and remains of the prehistoric peoples of Pueblo Bonito: Smithsonian Miscellaneous Collections, v. 122, no. 7, 65 p.

Correa, A.C., 1970, Borrego Pass Lentil-A new member of the Crevasse Canyon Formation, southern San Juan Basin, New Mexico, The Mountain Geologist, v. 7, no. 2, p. 99-102.

Dickinson, K.A., Berryhill, H.L., Jr.,and Holmes, C.W., 1972, Criteria for recognizing ancient barrier coastlines, in Rigby, J.K., and Hamblin, Kenneth, eds., Recognition of ancient sedimentary environments: Society of Economic Paleontologists and Mineralogists Special Publication 16, p. 192-214.

Goddard, E.N., chm., and others, 1948, Rock-color chart: National Research Council; reprinted by Geological Society of America, 1951, 1963, 1970, 6 p.

Harms, J.C., Southard, J.B., Spearing, D.R., and Walker, R.G., 1975, Depositional environments as interpreted from primary sedimentary structures and stratification sequences: Society of Economic Paleontologists and Mineralogists, Short Course Notes 2, 161 p.

Hook, S.C., and Cobban, W.A., 1981, Late Greenhorn (mid-Cretaceous) discontinuity surfaces, southwest New Mexico, in Contributions to mid-Cretaceous paleontology and stratigraphy of New Mexico, New Mexico Bureau of Mines and Mineral Resources Circular 180, p. 5-15.

Kelly, V C., and Clinton, N.J., 1960, Fracture systems and tectonic elements of the Colorado Plateau: Albuquerque, University of New Mexico Publications in Geology 6, 104 p.

Kirk, A.R, and Condon, S.M., 1986, Structural control of sedimentation patterns and the distribution of uranium deposits in the Westwater Canyon Member of the Morrison Formation, northwestern New Mexico-a subsurface study, in Turner-Peterson, C.E., Santos, E.S., and Fishman, N.S., eds., A basin analysis case study-The Morrison Formation, Grants Uranium Region, New Mexico, American Association of Petroleum Geologists Studies in Geology 22, p. 105-143.

Kirk, A.R., Huffman, A.C., Jr., Zech, R.S., Robertson, J.F., and Jackson, T.J., 1978, Review of the history and usage of the Gallup Sandstone and related units, southern and western San Juan Basin, New Mexico, U.S. Geological Survey Open-File Report 78-1055, 51 p.

Molenaar, C.M., 1973, Sedimentary facies and correlation of the Gallup Sandstone and associated formations, northwestern New Mexico, in Fassett, J.E., ed., Cretaceous and Tertiary rocks of the southern Colorado Plateau: Four Corners Geological Society Memoir, p. 85-110.

O'Sullivan, R.B., Repenning, C.A., Beaumont, E.C., and Page, H.G., 1972, Stratigraphy of the Cretaceous rocks and the Tertiary Ojo Alamo Sandstone, Navajo and Hopi Indian Reservations,

Arizona, New Mexico, and Utah: U.S. Geological Survey Professional Paper 521-E, 65 p.

Reading, H.G., ed., 1978, Sedimentary environments and facies: New York, Elsevier, 569 p.

Sears, J.D., 1925, Geology and coal resources of the Gallup-Zuni Basin, New Mexico, U.S. Geological Survey Bulletin 767, 53 p.

Sears, J.D., Hunt, C.B., and Hendricks, T.A., 1941, Transgressive and regressive Cretaceous deposits in southern San Juan Basin, New Mexico, U.S. Geological Survey Professional Paper 193-F, p. 101-119.

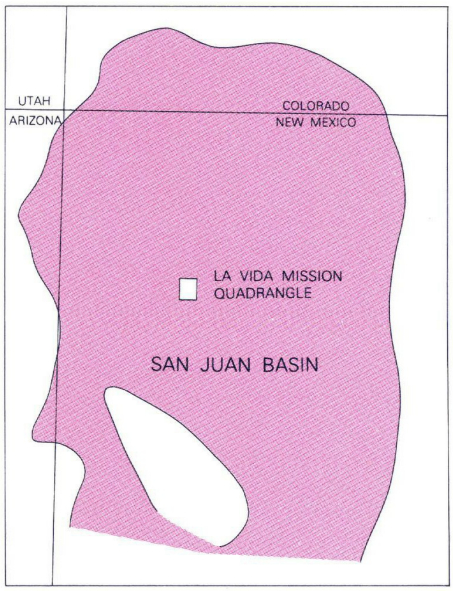
Extracted from: (Heart Rock Quadrangle). (*GRI Source Map ID 1050*).

La Vida Mission Quadrangle (Bulletin 1940)

Miller, Ralph, L., Carey, Mary Alice, and Thompson-Rizer, Carolyn L., 1991, Geology of the La Vida Mission Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey, Bulletin 1940, scale 1:24,000. (*GRI Source Map ID 1047*).

*** The full extent of this source map was captured for the applicable GRI maps (GRI MapCodes CHCU and LVMI).*

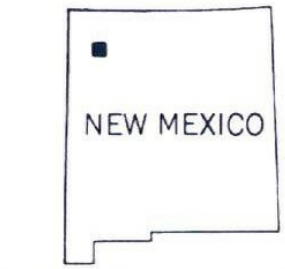
Index Map



INDEX SHOWING LOCATION OF LA VIDA MISSION QUADRANGLE AND SAN JUAN BASIN (SHADED)

Extracted from: (La Vida Mission Quadrangle). (*GRI Source Map ID 1047*).

Quadrangle Location



QUADRANGLE LOCATION

Extracted from: (La Vida Mission Quadrangle). (*GRI Source Map ID 1047*).

Legend

EXPLANATION

Contact—Dashed where concealed or arbitrary

Coal bed

W3, W4 Uppermost coal beds—Western area only

W2, N2, E2 Upper coal bed—Western, northern, or eastern area

W1, N1, E1 Lower coal bed—Western, northern, or eastern area

Anticline—SW¼, sec. 29, T. 22 N., R. 13 W.

Abandoned and filled gravel quarry

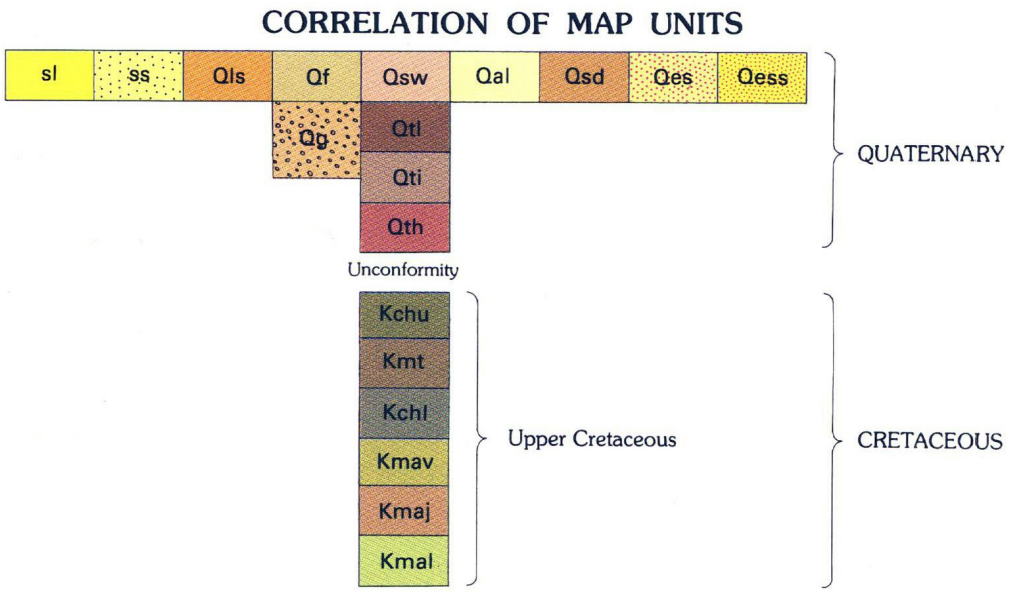
Dry hole for oil and gas

sb **Jumbled fine-grained sandstone blocks**—Forms artificial island in Juans Lake. Only one of five islands visited

Sandstone dike—NE¼, sec. 25, T. 22 N., R. 13 N.

Extracted from: (La Vida Mission Quadrangle). (*GRI Source Map ID 1047*).

Correlation of Units



Extracted from: (La Vida Mission Quadrangle). (*GRI Source Map ID 1047*).

Report

Link to Report Online:

Geology of the La Vida Mission Quadrangle, San Juan and McKinley Counties, New Mexico

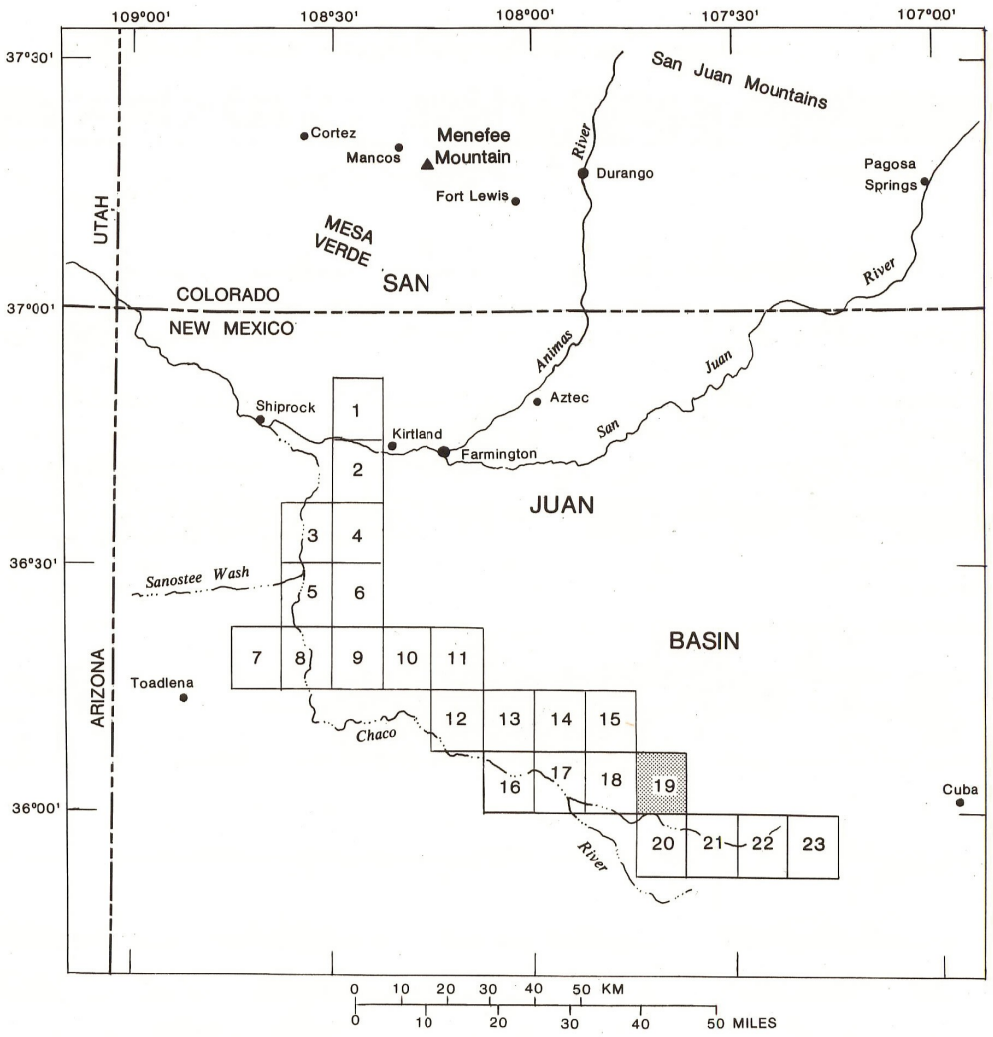
Extracted from: (La Vida Mission Quadrangle). (*GRI Source Map ID 1047*).

Pueblo Pintado Quadrangle (MF-1219)

Weide, David L., Scott, Glenn, R., and Mytton, James W., 1980, Geologic Map of the Pueblo Pintado Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Miscellaneous Field Studies Map MF-1219, scale 1:24,000. (*GRI Source Map ID 1052*).

*** The full extent of this source map was captured for the applicable GRI maps (GRI MapCodes CHCU and PUBI).*

Index Map



List of quadrangles

1. Waterflow
2. Fruitland MF-1089
3. The Hogback South MF-1093
4. Kirtland SW MF-1080
5. Newcomb NE MF-1092
6. The Pillar NW MF-1077
7. Newcomb
8. Newcomb SE MF-1026
9. Burnham Trading Post MF-1076
10. Bisti Trading Post MF-1075
11. Alamo Mesa West MF-1074
12. Tanner Lake
13. Pretty Rock
14. Pueblo Bonito NW MF 1117
15. Kimbeto MF-1118
16. Kin Klizhin Ruins MF-1094
17. Pueblo Bonito MF-1119
18. Sargent Ranch MF-1120
19. Fire Rock Well MF-1124
20. Pueblo Pintado MF-1219
21. Pueblo Alto Trading Post MF-1220
22. Star Lake
23. Ojo Encino Mesa

Index map showing location of this quadrangle (stippled) and other adjacent quadrangles along the Fruitland coal belt in the western and southern San Juan Basin, New Mexico.

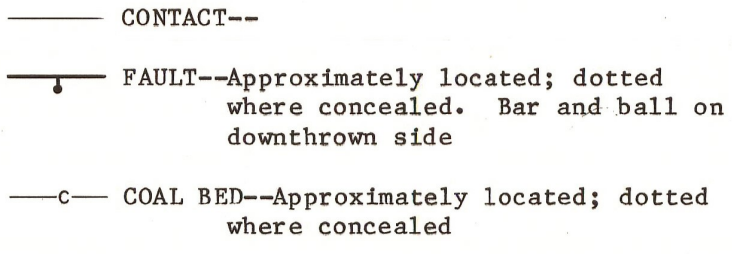
Extracted from: (Pueblo Pintado Quadrangle). (*GRI Source Map ID 1052*).

Quadrangle Location



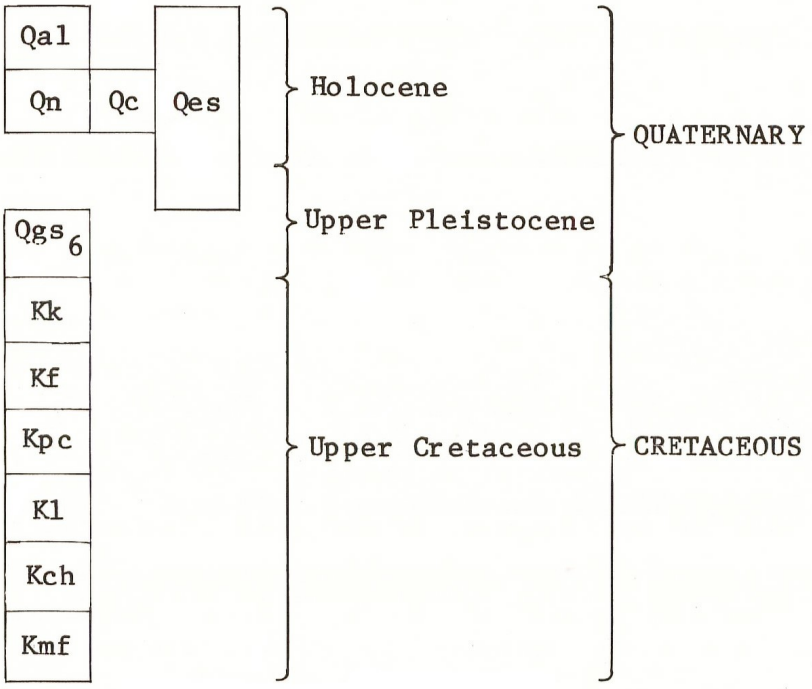
Extracted from: (Pueblo Pintado Quadrangle). (*GRI Source Map ID 1052*).

Legend



Extracted from: (Pueblo Pintado Quadrangle). (*GRI Source Map ID 1052*).

Correlation of Units



Extracted from: (Pueblo Pintado Quadrangle). (*GRI Source Map ID 1052*).

Note

NOTE

The bedrock and surficial geology were mapped in 1977 as part of a program designed to assess the impact on the environment of strip mining along the outcrop of the coal-bearing Fruitland Formation in the San Juan Basin. Coal in this quadrangle was mapped in 1978 primarily to evaluate the coal potential of the Fruitland Formation in the San Juan Basin. Lithologic descriptions of the outcropping stratigraphic units are only summarized here. Additional details of the bedrock and coal geology are in reports by Bauer and Reeside, 1921, Dane, 1936, Fassett and Hinds, 1971, O'Sullivan and others, 1972, Reeside, 1924, and Shomaker and others, 1971. Details of the lithology and regional aspects of the surficial deposits are in reports by Hack, 1941 and 1942, Hall, 1977, and Richmond, 1965.

Extracted from: (Pueblo Pintado Quadrangle). (*GRI Source Map ID 1052*).

References

Bauer, C. M., and Reeside, J. B., Jr., 1921. Coal in the middle and eastern parts of San Juan County, New Mexico, U.S. Geological Survey Bulletin 716, p. 155-237.

Dane, C. H., 1936, The LaVentana-Chacra Mesa coal field, Part 3 of Geology and fuel resources of the San Juan Basin, New Mexico. U.S. Geological Survey Bulletin 860-C, p. 81-166.

Fassett, J. E., and Hinds, J. S., 1971, Geology and Fuel resources of the Fruitland Formation and Kirtland Shale of the San Juan Basin, New Mexico and Colorado: U.S. Geological Survey

Professional Paper 676, 76 p.

Hack, J. T., 1941, Dunes of the western Navajo country: Geographical Review, v. 31, no. 2, p. 240-263.

_____1942, The changing environment of the Hopi Indians of Arizona: Harvard University Peabody Museum America Archeology and Ethnology Paper, v. 35, no. 1, 85 p.

Hall, S. A., 1977, Late Quaternary sedimentation and paleoecologic history of Chaco Canyon, New Mexico, Geological Society of America Bulletin, v. 88, p. 1593-1618.

O'Sullivan, R. B., Repenning, C. A., Beaumont, E. C., and Page, H. G., 1972, Stratigraphy of the Cretaceous rocks and the Tertiary Ojo Alamo Sandstone, Navajo and Hopi Indian Reservations, Arizona, New Mexico and Utah: U.S. Geological Survey Professional Paper 521-E, 65 p.

Reeside, J. B., Jr., 1924, Upper Cretaceous and Tertiary formations of the western part of the San Juan basin, Colorado and New Mexico, U.S. Geological Survey Professional Paper 134, 70 p.

Richmond, G. M., 1965, Quaternary stratigraphy of the Durango area, San Juan Mountains, Colorado: U. S. Geological Survey Professional Paper 525-C, p. C137-C143.

Shomaker, J. W., Beaumont, E. C., and Kottlowski, F. E., 1971, Strippable low-sulfur coal resources of the San Juan basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, 189 p.

Extracted from: (Pueblo Pintado Quadrangle). (*GRI Source Map ID 1052*).

Interpretive Geology of Chaco Area (I-1777)

Mytton, James W., and Schneider, Gary B., 1987, Interpretive Geology of the Chaco Area, Northwestern New Mexico: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1777, scale 1:24,000. (*GRI Source Map ID 1048*)

*** Source for only the southern two-thirds of the Pueblo Bonito quadrangle (GRI MapCodes CHCU and PUBO).*

Quadrangle Location



Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Legend

Boundary of the Chaco Culture National Historical Park

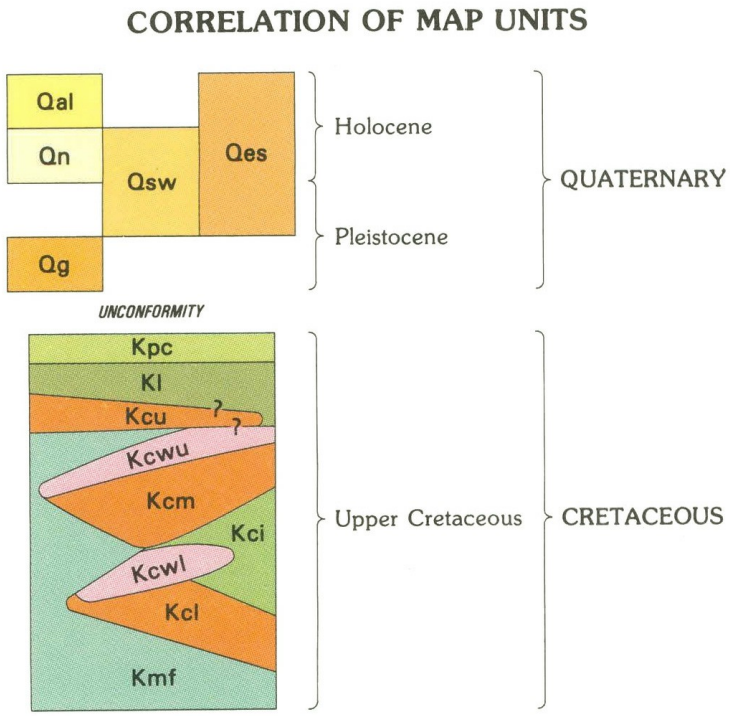
Contact

← C Site from which photograph was taken—Symbol shows direction camera faced

◁ B Panoramic view—Symbol shows direction camera faced

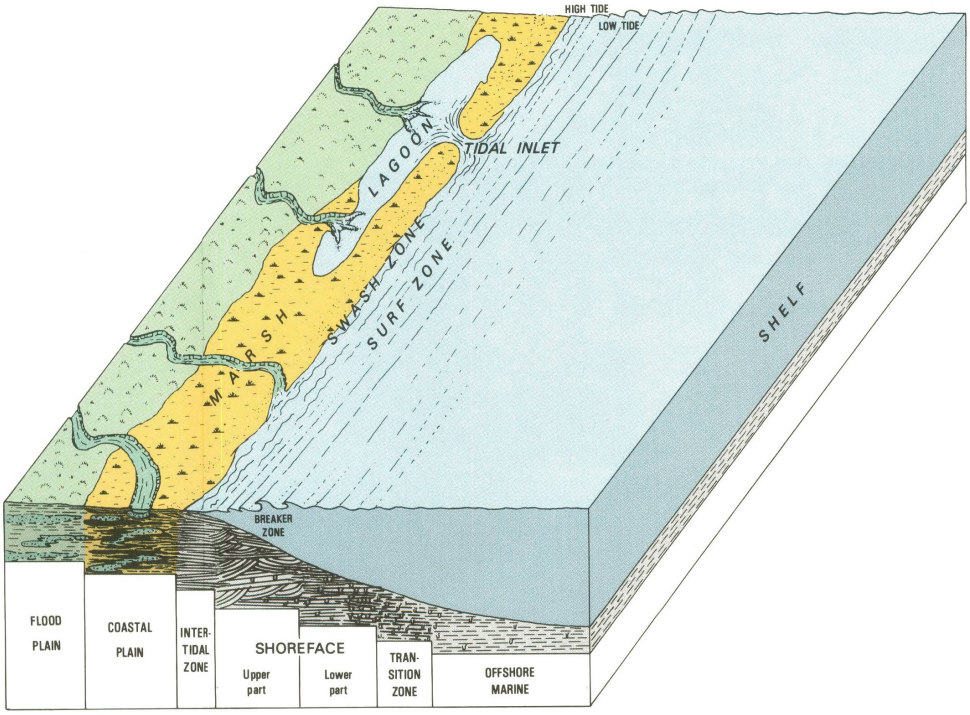
Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Correlation of Units



Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Schematic Diagram of Modern Coastal Area



SCHEMATIC DIAGRAM OF MODERN COASTAL AREA

Depositional environments believed to be most typical of those of the Chaco area nearly 80 million years ago. The Menefee Formation and Cliff House Sandstone have sedimentary features, shown in the photographs, that are similar to those illustrated in the diagram. These features are used to interpret ancient depositional environments of the Late Cretaceous seaway that once covered much of New Mexico.

EXPLANATION

Flood plain—The surface of relatively smooth land adjacent to a river channel, constructed by the present river in its existing course and covered with water when the river overflows its banks at times of high water. The flood plain is built of alluvium carried by the river during floods and deposited beyond the normal reaches of the river. Flood-plain deposits include lenticular sandstone bodies, representing filled river channels, as well as mudstones and siltstones that are adjacent to, overlie, and underlie the channel deposits. The Menefee Foramtion (Kmf) within the boundary of Chaco Culture National Historical Park does not have flood-plain deposits; however, outside the Park, rocks of the Menefee older than those shown on the geologic map represent the flood-plain environment.

Coastal plain—A low-lying plain which borders the sea and extends inland to the nearest elevated area such as an alluvial flood plain. Coastal-plain deposits include sands that fill river channels, muds and silts that fill lagoons, and dark carbonaceous mud and peat that accumulate in marshes or swamps. The Menefee Formation (Kmf) in the Chaco area is made up of coastal-plain sediments.

Intertidal zone—The zone between the high-water line (high tide) and low-water line (low tide) of the shoreline and referred to as the foreshore. The intertidal zone includes the swash zone, the sloping part of the beach that is alternately covered and uncovered by the uprush of waves and where longshore movement of water occurs in a zigzag (upslope-downslope) manner. Foreshore deposits are generally composed of light-colored, well-sorted quartzose sandstone, such as Cliff House units Kcwu and Kcwl, in beds that are nearly parallel and initially dip seaward at very low angles (2 to 6 degrees). Inland, the foreshore adjoins an area generally above the high-water level referred to as the backshore where sand dunes may form. The coastal plain can be nearly adjacent to the foreshore in cases where the backshore is poorly developed or nearly nonexistent, which may be the case in the Cliff House Sandstone of the Chaco area.

Shoreface—The nearshore area that is always submerged and is situated between low-water level (low tide) and the last point seaward where the action of waves effectively moves sediments of the sea bottom. The upper part of the shoreface in the Chaco area has cross-stratified and even-bedded, light-colored sandstone (Kcwu and Kcwl) that is coarser grained than the sandstone of the lower part and is indicative of deposition within the breaker and surf zones. The lower part encompasses the area from just seaward of the breakers to the base of the shoreface and is made up of quartzose sandstone that is cross stratified to horizontally parallel laminated. Compared to the intertidal zone (foreshore), the shoreface is barren of fossil shells except in places where violent storms have produced waves large enough to move shells from the beaches down the slope of the shoreface. Fossil burrows (trace fossils) are more common in the lower part than in the upper part of the shoreface and during quiescent periods between storms are formed by burrowing organisms in the sediment of the sea bottom. The rocks of this lower shoreface environment, as typified by the thick-bedded massive units (Kcu, Kcm, Kcl) of the Cliff House Sandstone, are highly burrowed sandstones that alternate with cross-stratified to horizontal parallel-laminated sandstone.

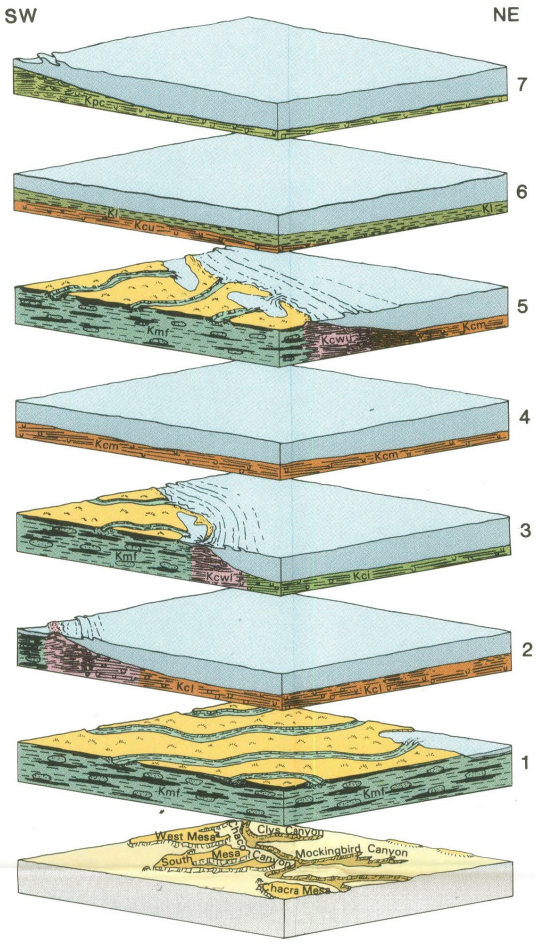
Transition zone—The depositional environment transitional between shoreface and offshore marine in which sand, silt, and mud are deposited and only burrowing organisms such as shrimp abide in the bottom sediment of the sea floor. Sand is supplied to the transition zone from the shoreface generally during major storms. Thin beds of sandstone alternating with thin beds of siltstone or mudstone are characteristic of this zone. In the Chaco area, a transition zone has been identified at the base of the Pictured Cliffs Sandstone (Kpc) where it grades downward into the Lewis Shale. The transition zone may be represented, in part, by beds of the intermediate unit (Kci) of the Cliff House Sandstone.

Offshore marine—Area below the maximum effect of waves and marked by a more gentle slope to a flattening of the sea bottom and by the accumulation of sediments which are typically silt and mud and, in part, limy. Sand is supplied only under rare and extraordinary conditions. Marine fossils of organisms more common to the open sea and the shelf area of the sea floor are present in the rocks. The Lewis Shale (Kl) represents the offshore marine environment.

Tidal inlet—A natural inlet, maintained by tidal currents, through which marine water from the open sea flows alternately landward with the rising tide and seaward with the falling tide. Deltas may form at the mouth of the inlet on both the seaward and lagooon sides of a barrier beach, barrier island, or barrier to a bay (baymouth bar) by the changing tidal currents that sweep sand in and out of the inlet. High-angle cross-stratified sandstones of the Cliff House (Kcwu and Kcwl) may be examples of this environment.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Block Diagrams of Paleogeography



BLOCK DIAGRAMS OF PALEOGEOGRAPHY

Diagrams show the shifting seas of the Chaco area during deposition of the Menefee Formation, Cliff House Sandstone, Lewis Shale, and Pictured Cliffs Sandstone. For explanation of geologic symbols, see Description of Map Units for geologic map. Coastal-plain deposits of the Menefee Formation (Kmf) (block 1) were buried by marginal marine sediments (lower Cliff House Sandstone, Kcl) deposited in an advancing sea (block 2). The marginal marine sediments (Kcl) accumulated in the lower part of the shoreface at depths which may have been as much as 70 ft below sea level. Sediments (Kci) that accumulated to the northeast during this time, and later were deposited on the lower sandstone, are transitional between the sands of the lower shoreface and silts and shales (Kl) offshore. The shoreline shown in block 2 is located southwest of the boundary of Chaco Culture National Historical Park where the Cliff House Sandstone has been removed by erosion. This shoreline is believed to be close to the position of the shoreline that marked the furthest advance of the sea before it began its retreat to the northeast. Retreat of the sea (block 3) resulted in the building up and out of sediments (Kcwl) from the shoreline by deposition in tidal inlets, in the zone between high and low tide, and in the upper part of the shoreface in water as deep as 20 ft. Coastal-plain deposits of the Menefee Formation (Kmf) accumulated southwest of the shoreline and lower shoreface deposits (Kci) accumulated seaward to the northeast. Renewed advance of the sea (block 4) brought complete inundation of coastal areas and deposition of lower shoreface sediments of the middle sandstone (Kcm) of the Cliff House. The seashore marking the furthest advance of marine waters during this episode would have been several miles southwest of the Park. Seaward, accumulation of sediments (Kci) transitional from those of the lower part of the shoreface to offshore marine would have taken place. Building upward and outward of the shoreline once again took place in response to the retreat of the sea (block 5) with deposition of material (Kcwu) in an inner tidal zone and upper shoreface that were advancing seaward and overiding sediments (Kcm) of the lower part of the shoreface. To the southwest, coastal-plain deposits of the Menefee (Kmf) accumulated. Building upward and outward of the shoreline (block 5) was followed by the final inundation by the Late Cretaceous sea during which time the upper sandstone (unit Kcu) of the Cliff House and the Lewis Shale (Kl) were deposited (block 6). Only a minimal amount of sediment accumulated and (or) was preserved in the lower part of the shoreface southwest of the advancing sea before the upper sandstone was buried by the Lewis Shale. The furthest advance of the sea probably was not to distant southwest of the Park boundary, because the Lewis Shale, in localities where it has not been removed by erosion, is much thinner than in the Park. The Pictured Cliffs Sandstone (Kpc), which overlies the Lewis Shale, represents a seaward advance of the shoreline to the northeast (block 7) and the beginning of the final retreat of the Late Cretaceous sea across northern New Mexico.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

References

Balsley, J. K., 1980, Cretaceous wave-dominated delta systems—Book Cliffs, east-central Utah: Denver, Colo., Amoco Production Company, 163 p.

Bates, R. L., and Jackson, J. A., eds., 1980, Glossary of geology (2d ed.): Falls Church, Va, American Geological Institute, 749 p.

Hack, J. T., 1941, Dunes of the western Navajo Country: Geophysical Review, v. 31, no. 2, p. 240-263.

Reinech, H. E., and Singh, I. B., 1980, Depositional sedimentary environments (2d ed.): New York, Springer-Verlag, 549 p.

Scott, G. R., O'Sullivan, R. B., and Weide, D. L., 1984, Geologic map of the Chaco Cultural National Historical Park, northwestern New Mexico, *with a chapter* on Archeology by W. B. Gillespie: U.

S. Geological Survey Miscellaneous Investigations Series I-1571, scale 1:50,000.

Weide, D. L., Schneider, G. B., Mytton, J. W., and Scott, G. R., 1979, Geologic map of the Pueblo Bonito quadrangle, San Juan County, New Mexico, U.S. Geological Survey Miscellaneous Field Studies Map MF-1119, scale, 1:24,000.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

Report

DISCUSSION

Rocks exposed at the surface in the Chaco area provide a record of a small part of earth history that started about 80 million years ago. These rocks represent a geographical setting that was completely different from what we see here today. The rocks, 75-80 million years old, record an interval of geologic time in the Late Cretaceous when Chaco Canyon and vicinity were the site of a shifting coastline reflecting the spread and retreat of an ancient sea that covered the Western Interior of the United States.

The oldest rocks exposed are the uppermost part of the Menefee Formation, predominantly mudstone containing carbonaceous shales and thin coal beds interspersed with sandstone beds. Within Chaco Culture National Historical Park, the Menefee forms steep slopes that underlie mesas capped by the Cliff House Sandstone. South of the Park, the Menefee underlies broad areas of low relief and isolated buttes and mesas. Fajada Butte, located south of the Visitors Center and perhaps the most impressive landmark in the Park, was formerly part of Chacra Mesa. In recent geologic time (Holocene) Fajada Butte has become detached from the mesa through erosion and is now but a remnant of Menefee overlain by a protective cap of Cliff House Sandstone.

Interbedded, wedge-shaped layers of the Cliff House Sandstone and Menefee Formation can be seen in the cliffs of West and South Mesas. Some of the rocks of the Menefee, which were originally laid down as sediments near the seashore, thin and disappear to the northeast. The marginal-marine sandstones of the Cliff House, whose imposing cliffs rise above the prehistoric ruins on the floor of the canyon, thin and disappear to the southwest. An intermediate unit (Kci) is shown between the lower and middle cliff-forming sandstones of the Cliff House. Characterized by thin- to thick-bedded sandstones, the intermediate unit forms benches and gentle slopes and is locally interbedded with shales similar to those of the Lewis Shale.

The Lewis Shale, a rock unit laid down in the open sea, lies above the Cliff House Sandstone northeast of Chaco Canyon, but, over a large area this shale is covered by loose surficial deposits.

Where not covered by surficial material, the Lewis Shale is overlain by the Pictured Cliffs Sandstone, rock similar to the Cliff House.

Beds that thin out progressively until they end, such as those in the main part of the Menefee Formation and the white sandstone (Kcwu and Kcwl) in sec. 30,T. 21 N., R. 10 W., on the southeast face of South Mesa, are actual changes in rock type. Apparent thinning-out and termination of units on the map, such as Kcl to the northeast in the same section and in sec.13, T. 21 N., R. 11 W., south of Chaco Wash, as well as those in the rock units on the northeast faces of the mesas above Chaco Canyon, are caused by cliffs and overhangs that make it difficult to portray these features easily on a map of this scale.

The unconsolidated to poorly consolidated Quarternary deposits, which partially mask the older rocks, reflect periods of sedimentation by water and wind from as long ago as 2 million years down to the present day. Geologic processes still actively sculpture the land surface into the canyons and high mesas we see today. The gravel cap on West Mesa is the oldest Quarternary deposit and is probably of Pleistocene age (the epoch associated with continental glaciation in North America). The gravel covers an old erosion surface related to changes in the downcutting of the Chaco and San Juan Rivers. In order of decreasing age the other surficial materials include wind-blown sand; poorly consolidated clay, silt, and sand called sheetwash alluvium; laminated and cross-stratified sand and silt, identified as Naha Alluvium; and present day stream-deposited alluvium of Chaco Wash. Archeologists believe the Naha Alluvium is the most notable surficial deposit because it contains buried artifacts, which are important clues to the sequence of events associated with the history and development of the Anasazi culture.

Extracted from: (Pueblo Bonito Quadrangle). (*GRI Source Map ID 1048*).

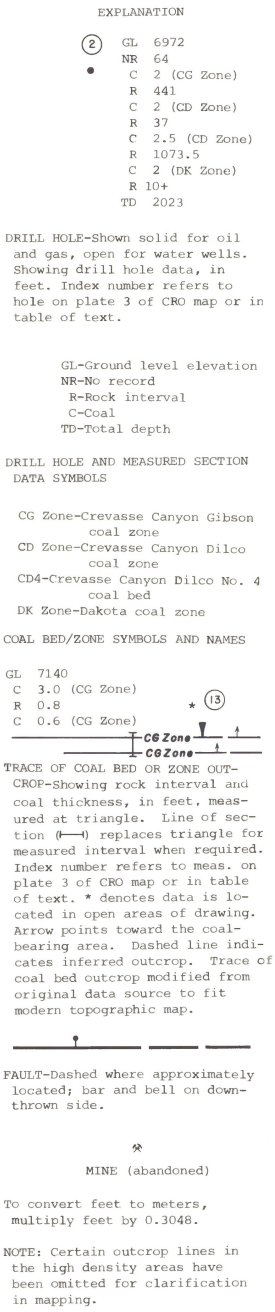
Source Coal Resource Map Ancillary Information

The digital geologic-GIS coal map for Chaco Culture National Historical Park, New Mexico was compiled from several sources (as listed in the GRI Digital Maps and Source Map Citations section). Ancillary map information including figures, tables and text are presented with each source map.

Coal Resources of the Crownpoint Quadrangle (OFR-79-1125)

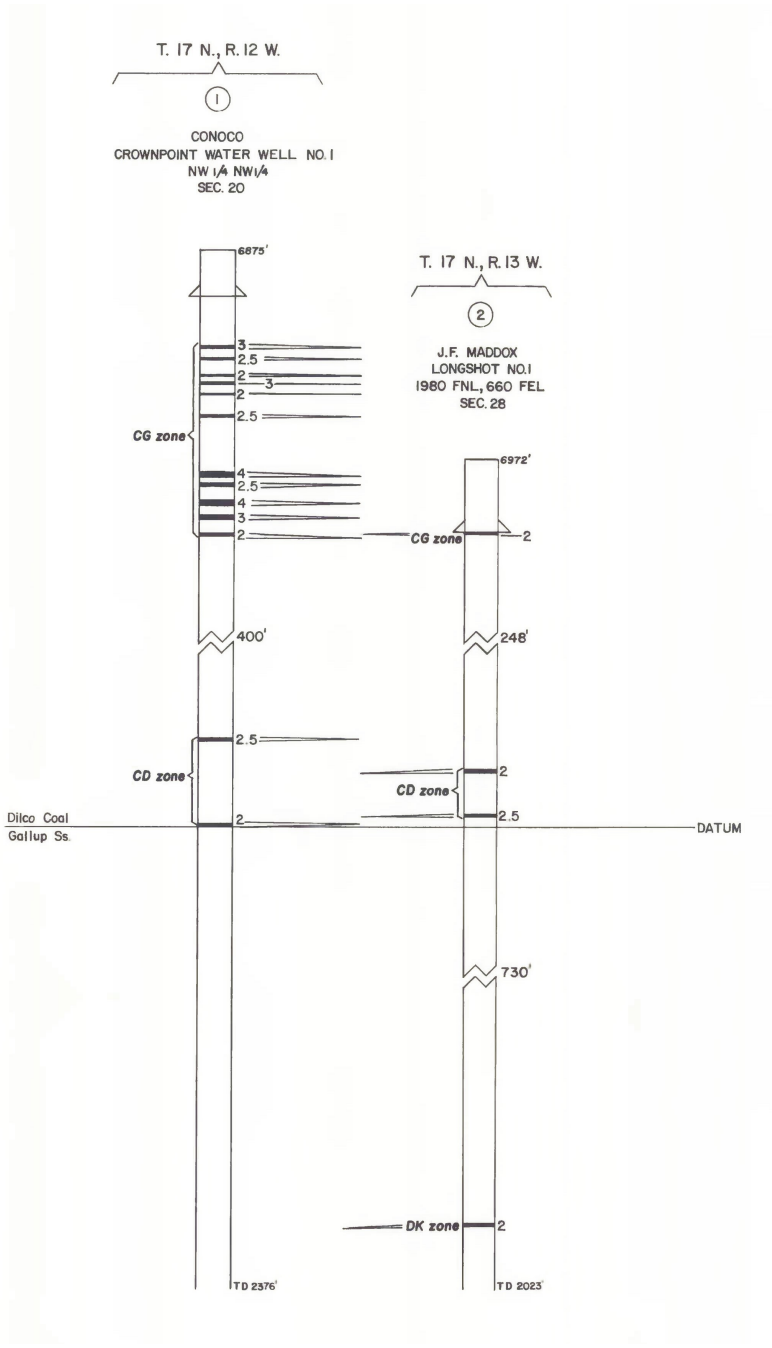
Dames Moore., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Crownpoint Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-1125, scale 1:24,000. (*GRI Source Map ID 41614*).

Legend



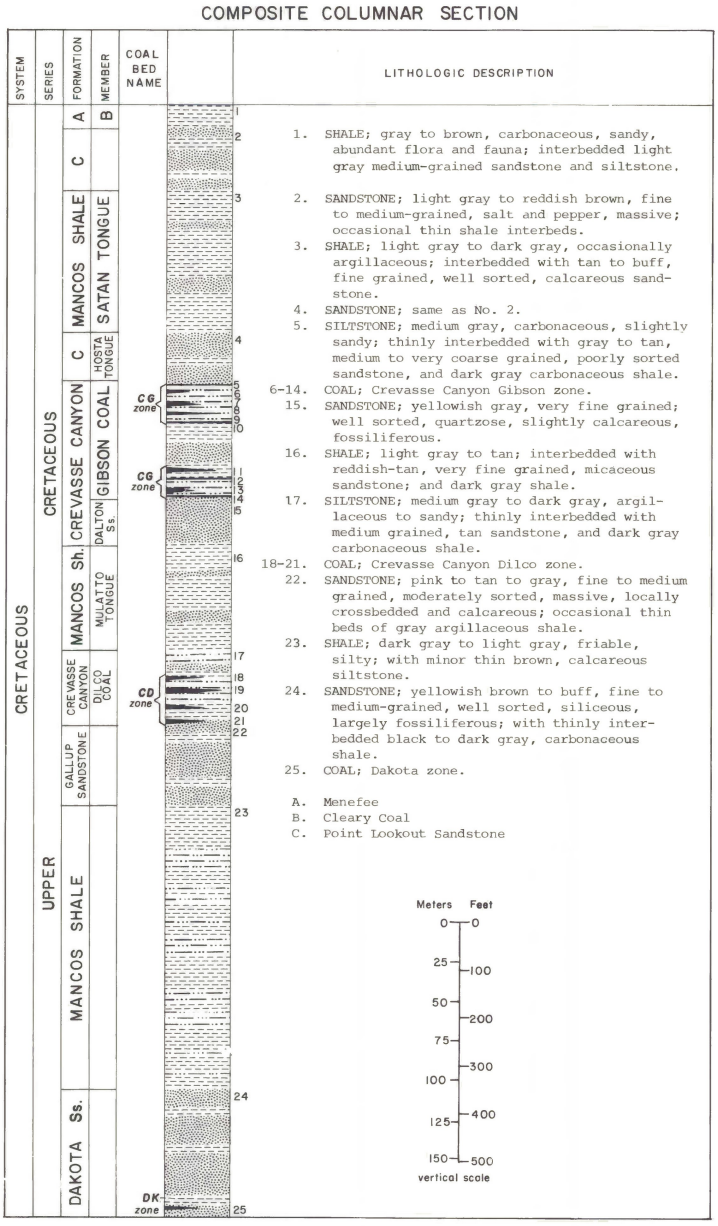
Extracted from: (Crownpoint Quadrangle - coal map). (*GRI Source Map ID 41614*).

Correlation of Coal Beds



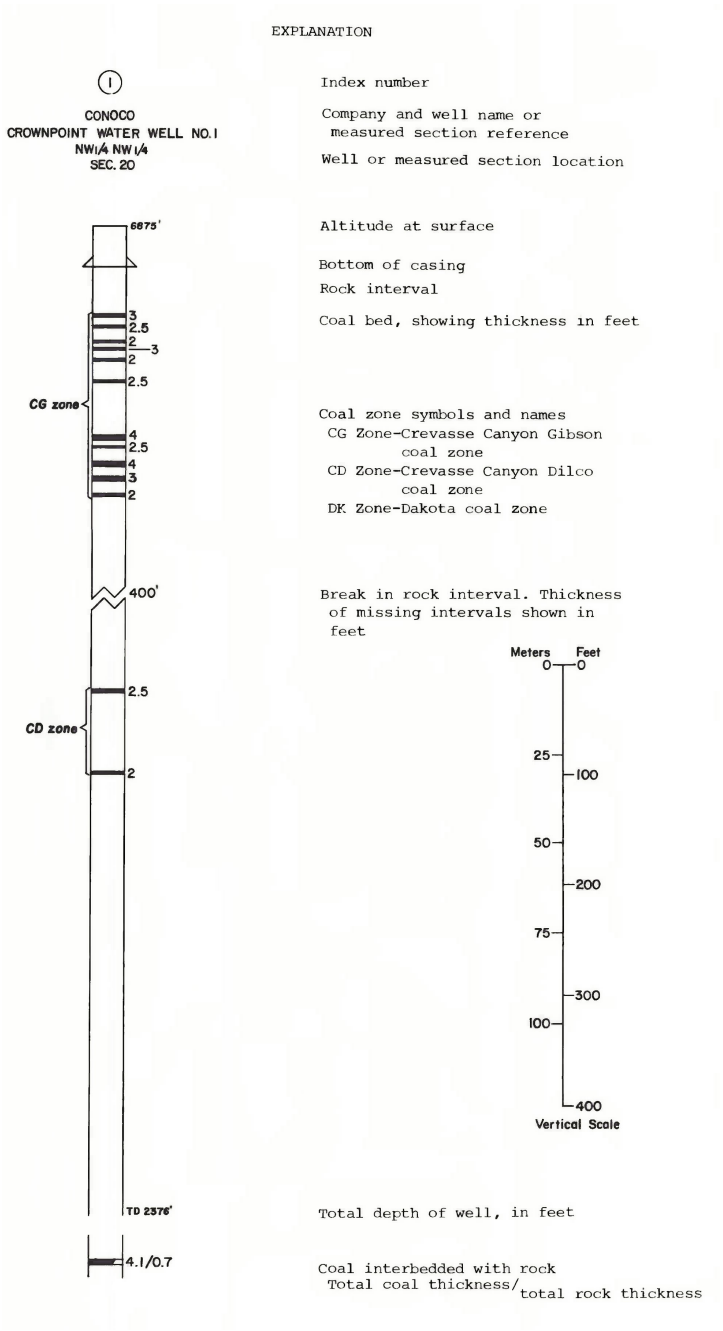
Extracted from: (Crownpoint Quadrangle - coal map). (*GRI Source Map ID 41614*).

Composite Columnar Section



Extracted from: (Crownpoint Quadrangle - coal map). (*GRI Source Map ID 41614*).

Drill Hole Legend



Extracted from: (Crownpoint Quadrangle - coal map). (*GRI Source Map ID 41614*).

Report

Link to Report Online:

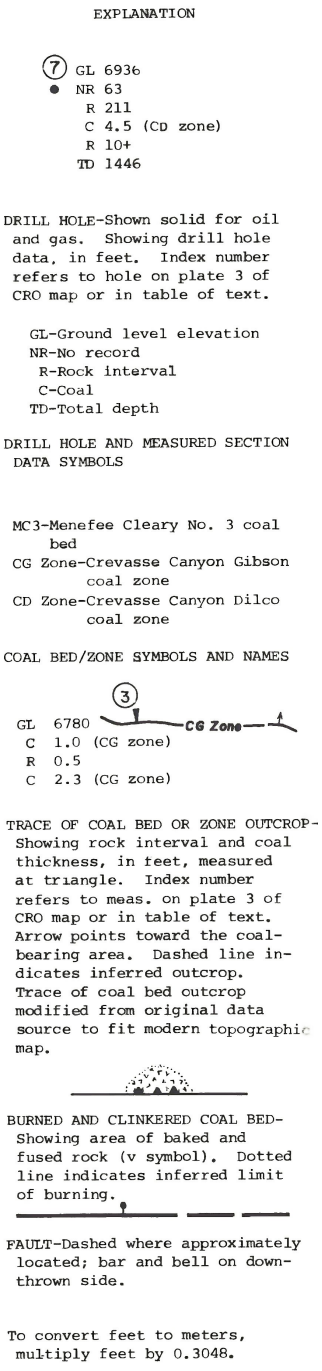
Coal Resources of the Crownpoint Quadrangle Report

Extracted from: (Crownpoint Quadrangle - coal map). (*GRI Source Map ID 41614*).

Coal Resources of the Heart Rock Quadrangle (OFR-79-642)

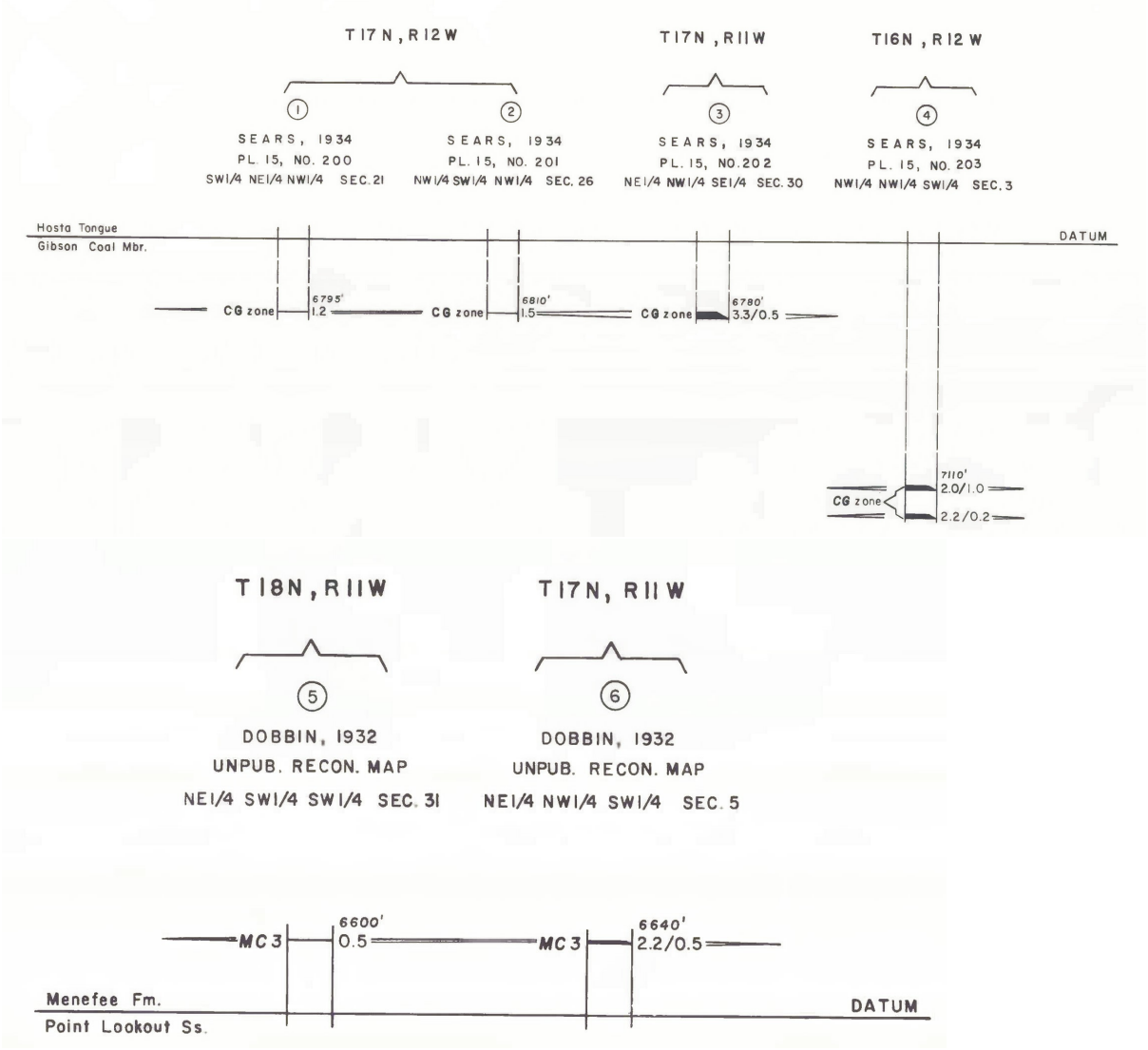
Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Heart Rock Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-642, scale 1:24,000. (*GRI Source Map ID 32100*).

Legend



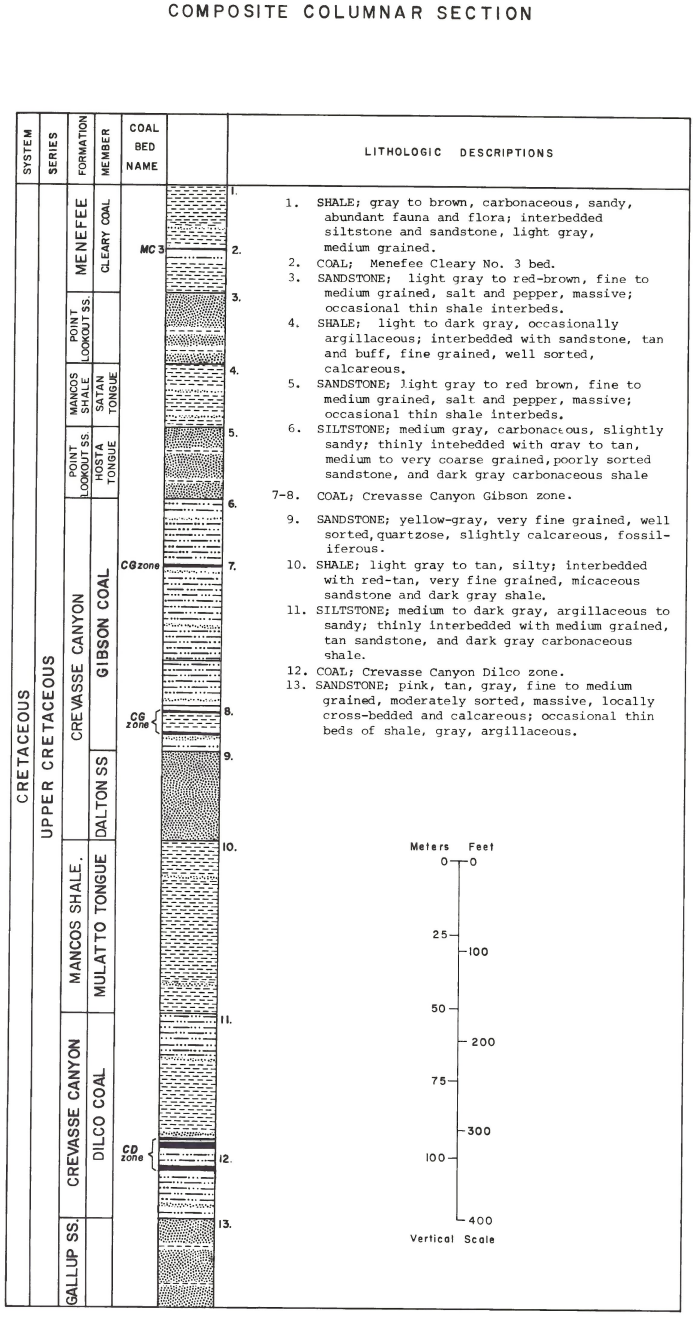
Extracted from: (Heart Rock Quadrangle - coal map). (*GRI Source Map ID 32100*).

Correlation of Coal Beds



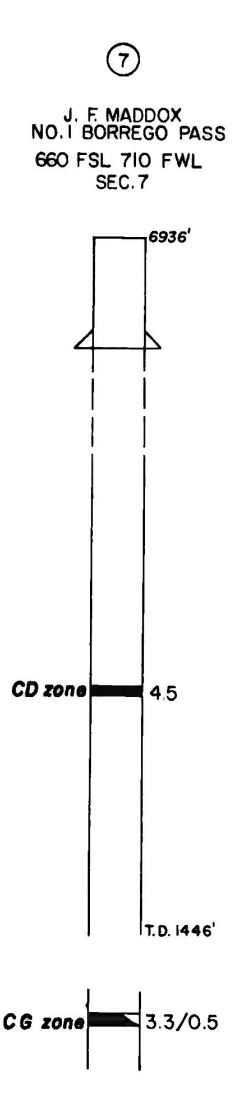
Extracted from: (Heart Rock Quadrangle - coal map). (*GRI Source Map ID 32100*).

Composite Columnar Section



Extracted from: (Heart Rock Quadrangle - coal map). (*GRI Source Map ID 32100*).

Drill Hole Legend



Index number

Company and well name or measured section reference

Well or measured section location

Altitude at surface

Bottom of casing

Rock interval, dashed where inferred interval of unknown composition.

Coal bed/zone symbols and names
MC3-Menefee Cleary No. 3 coal bed
CG Zone-Crevasse Canyon Gibson coal zone
CD Zone-Crevasse Canyon Dilco coal zone

Coal bed, showing thickness in feet

Total depth of well, in feet

Coal interbedded with rock
Total coal thickness/total rock thickness

Extracted from: (Heart Rock Quadrangle - coal map). (*GRI Source Map ID 32100*).

Report

Link to Report Online:

Coal Resources of the Heart Rock Quadrangle Report

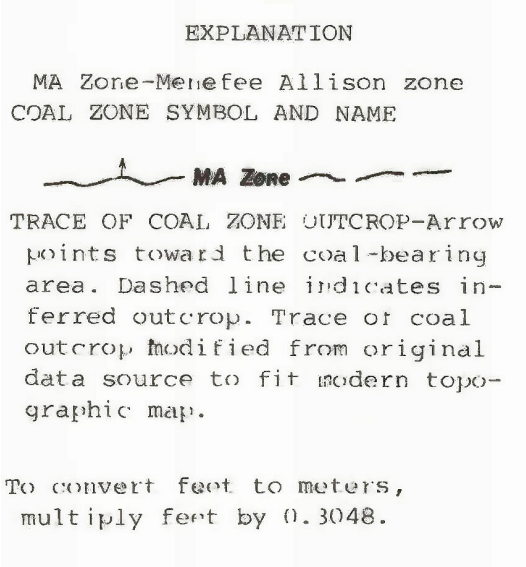
Extracted from: (Heart Rock Quadrangle - coal map). (*GRI Source Map ID 32100*).

Coal Resources of the Kin Klizhin Quadrangle (OFR-79-1047)

Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Kin Klizhin Ruins Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey,

Open-File Report OFR-79-1047, scale 1:24,000. (*GRI Source Map ID 41629*).

Legend



Extracted from: (Kin Klizhin Ruins Quadrangle - coal map). (*GRI Source Map ID 41629*).

Report

Link to Report Online:

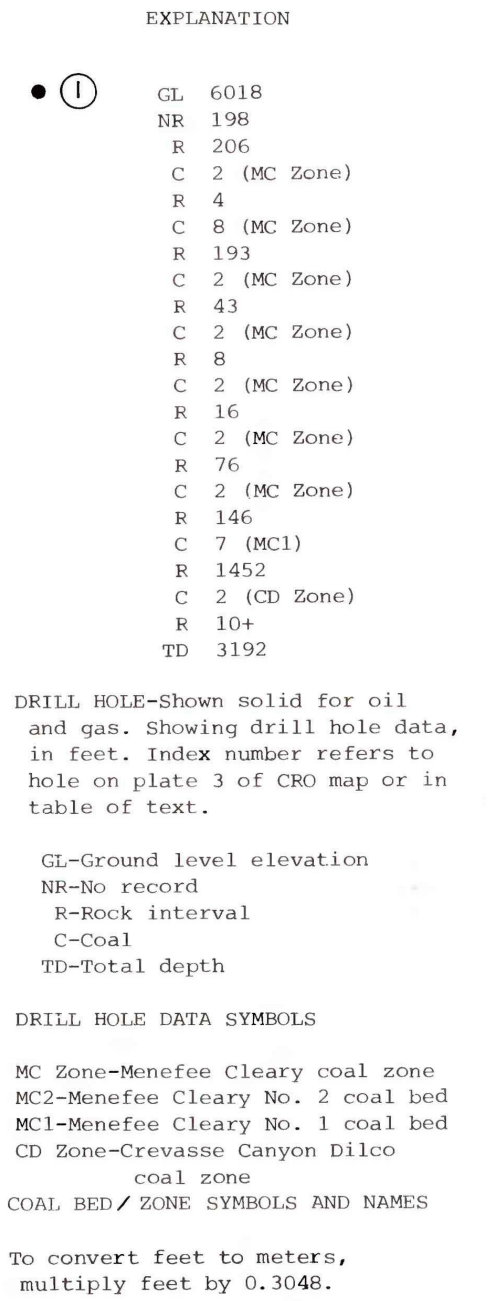
Coal Resources of the Kin Klizhin Quadrangle Report

Extracted from: (Kin Klizhin Ruins Quadrangle - coal map). (*GRI Source Map ID 41629*).

Coal Resources of the La Vida Mission Quadrangle (OFR-79-1378)

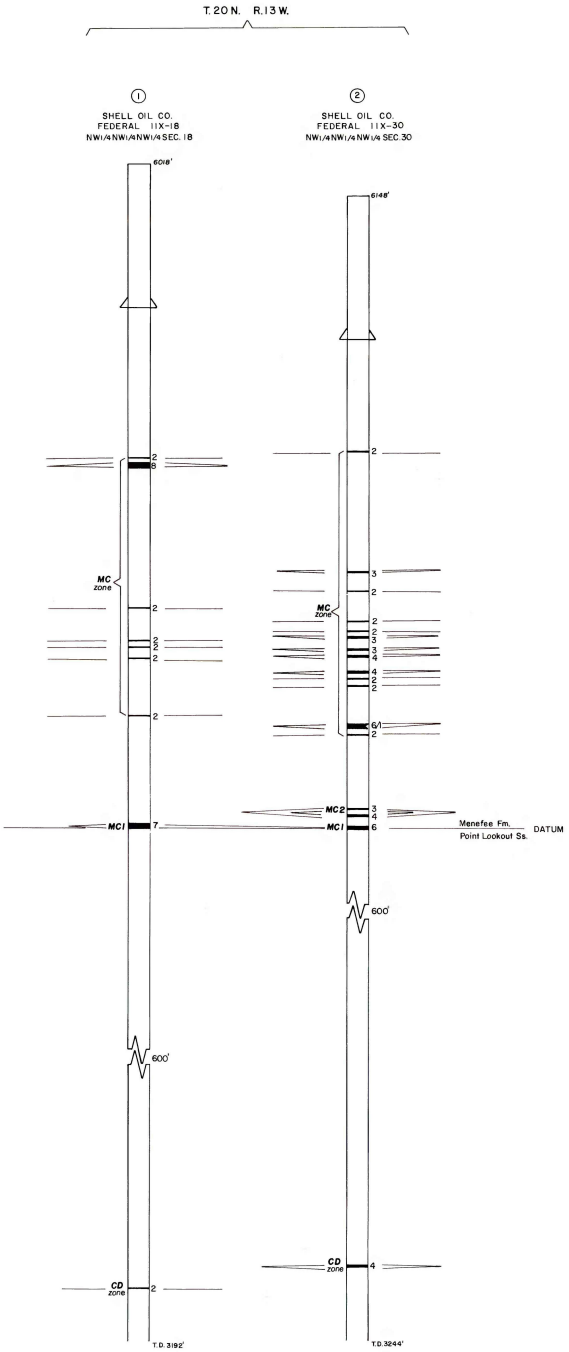
Berge Exploration Inc., 1979, Federal Coal Resource Occurrence and Coal Development Potential Maps of the La Vida Mission 7 1/2-Minute Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-1378, scale 1:24,000. (*GRI Source Map ID 74539*).

Legend



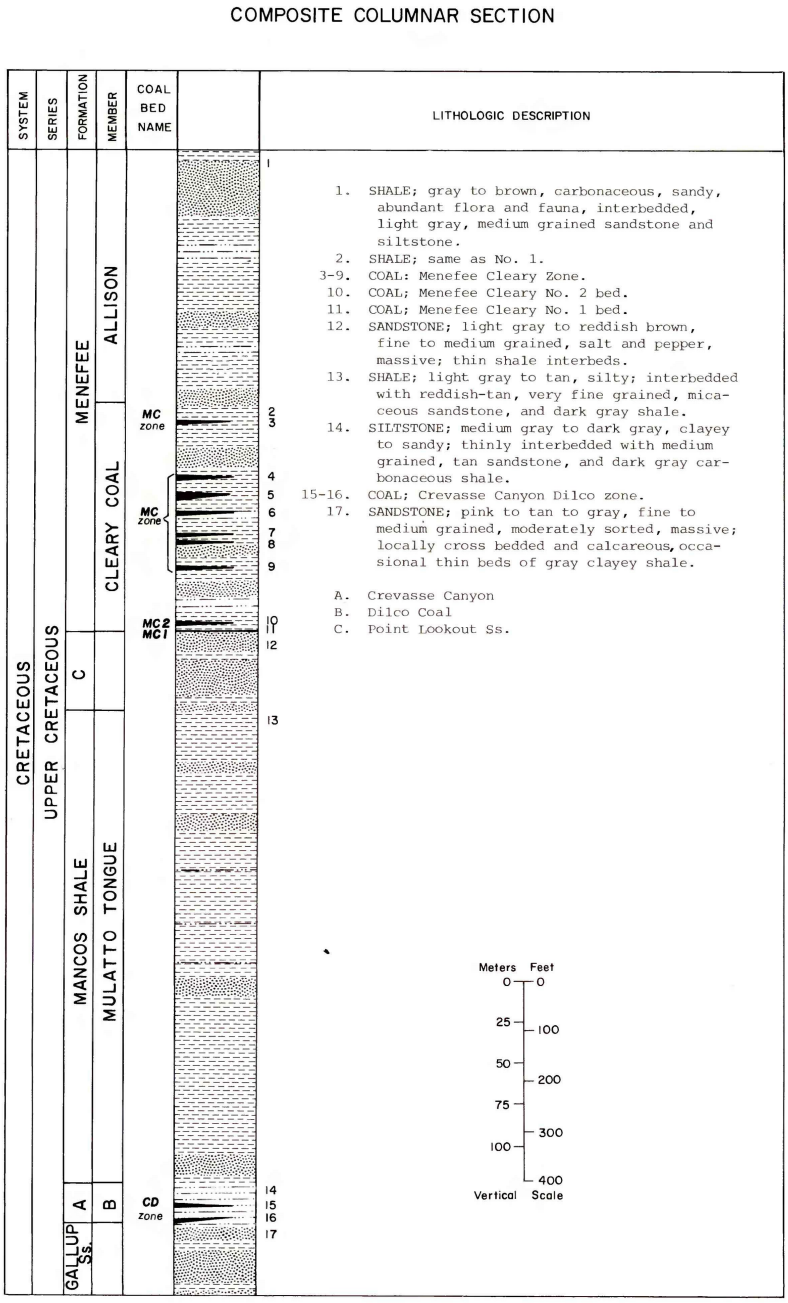
Extracted from: (La Vida Mission Quadrangle - coal map). (*GRI Source Map ID 74539*).

Correlation of Coal Beds



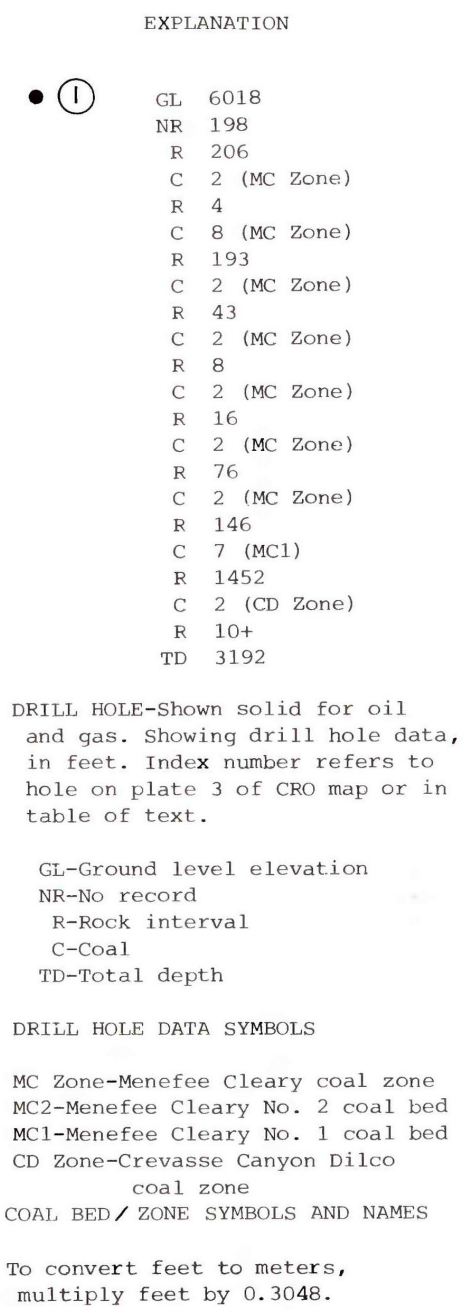
Extracted from: (La Vida Mission Quadrangle - coal map). (*GRI Source Map ID 74539*).

Composite Columnar Section



Extracted from: (La Vida Mission Quadrangle - coal map). (*GRI Source Map ID 74539*).

Drill Hole Legend



Extracted from: (La Vida Mission Quadrangle - coal map). (*GRI Source Map ID 74539*).

Report

Link to Report Online:

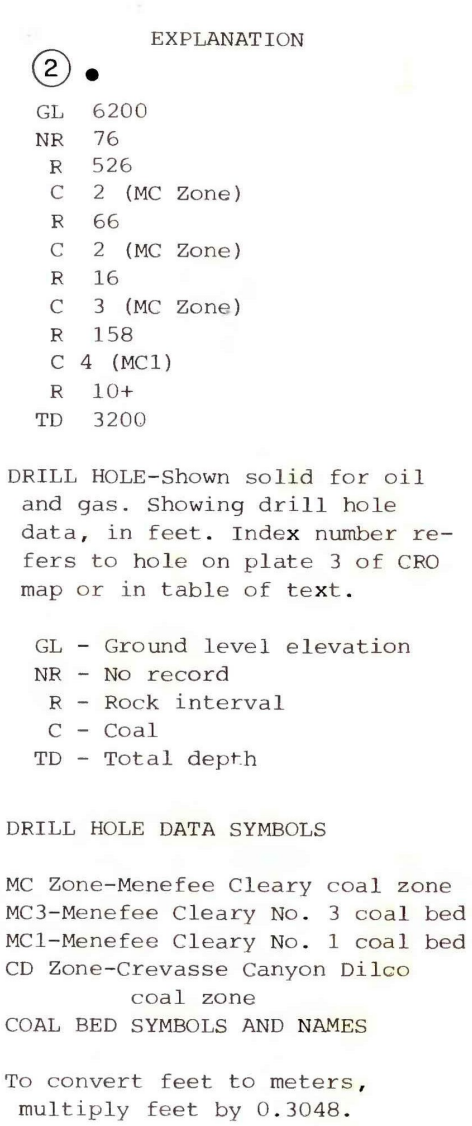
Coal Resources of the La Vida Mission Quadrangle Report

Extracted from: (La Vida Mission Quadrangle - coal map). (*GRI Source Map ID 74539*).

Coal Resources of the Milk Lake Quadrangle (OFR-79-1377)

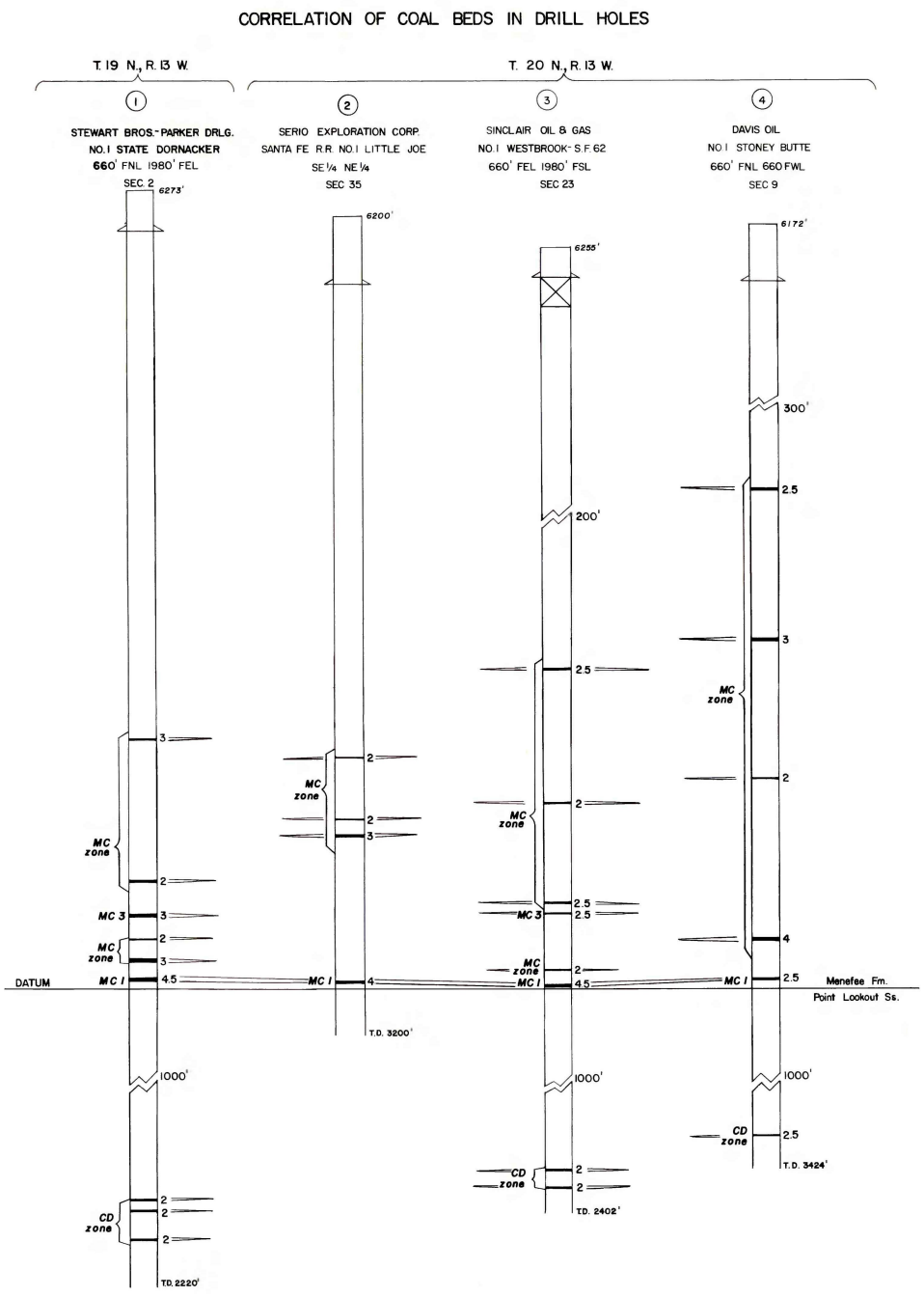
Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Milk Lake Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-1377, scale 1:24,000. (*GRI Source Map ID 74535*).

Legend



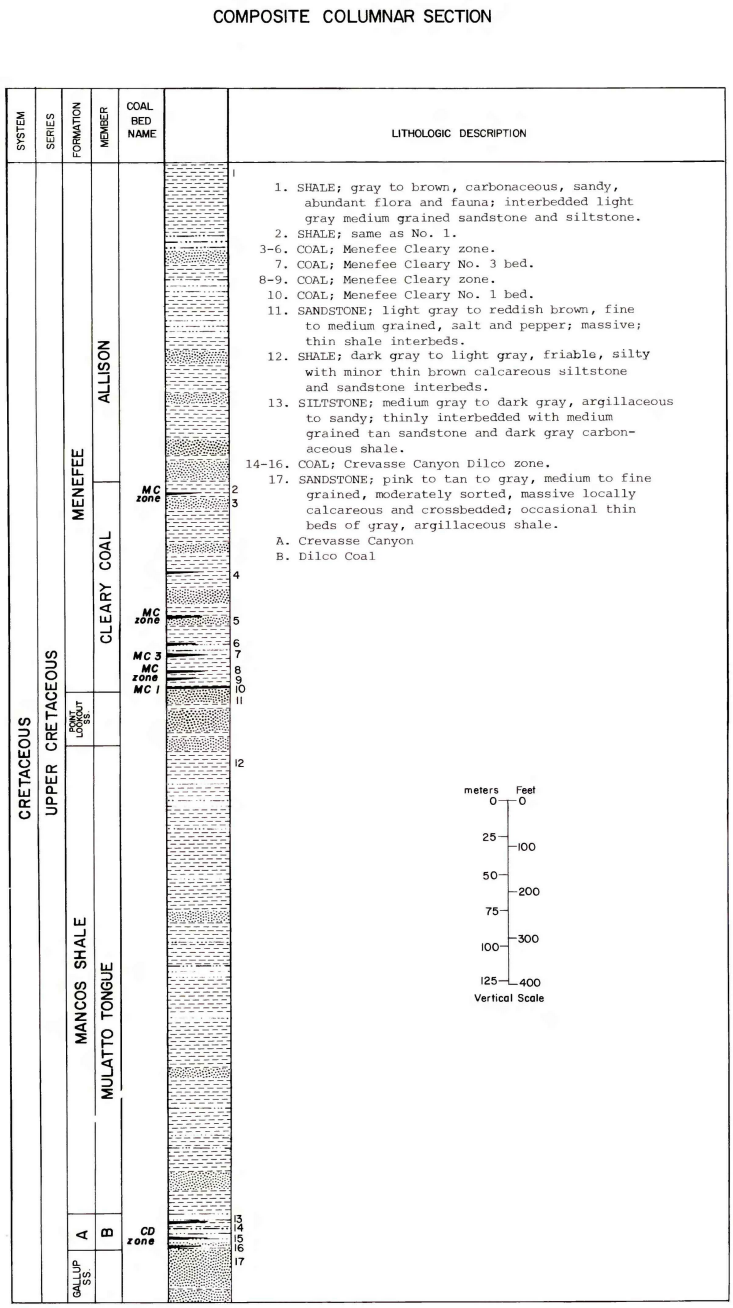
Extracted from: (Milk Lake Quadrangle - coal map). (*GRI Source Map ID 74535*).

Correlation of Coal Beds



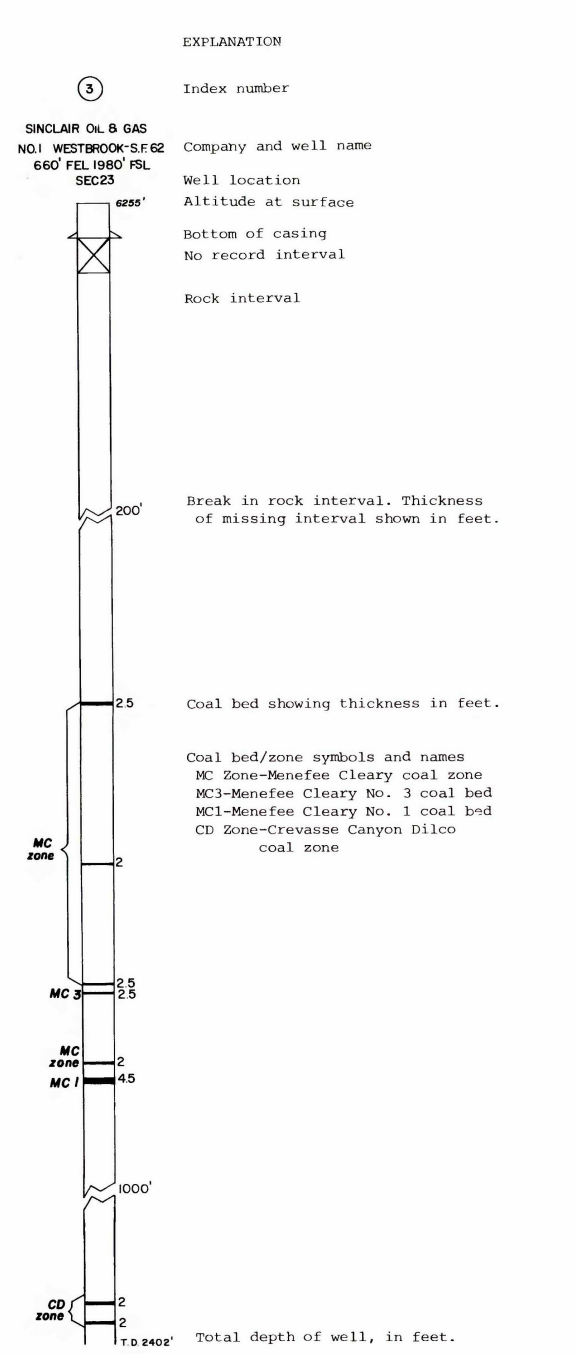
Extracted from: (Milk Lake Quadrangle - coal map). (*GRI Source Map ID 74535*).

Composite Columnar Section



Extracted from: (Milk Lake Quadrangle - coal map). (*GRI Source Map ID 74535*).

Drill Hole Legend



Extracted from: (Milk Lake Quadrangle - coal map). (*GRI Source Map ID 74535*).

Report

Link to Report Online:

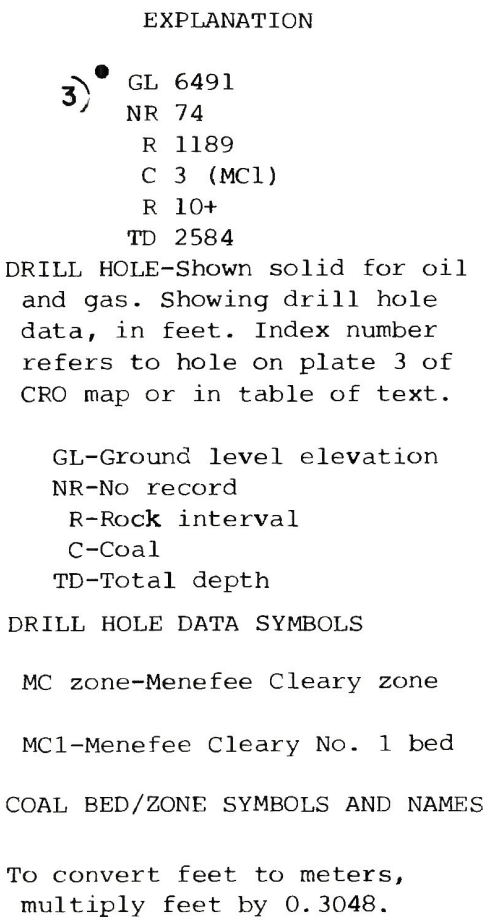
Coal Resources of the Milk Lake Quadrangle Report

Extracted from: (Milk Lake Quadrangle - coal map). (*GRI Source Map ID 74535*).

Coal Resources of the Nose Rock Quadrangle (OFR-79-641)

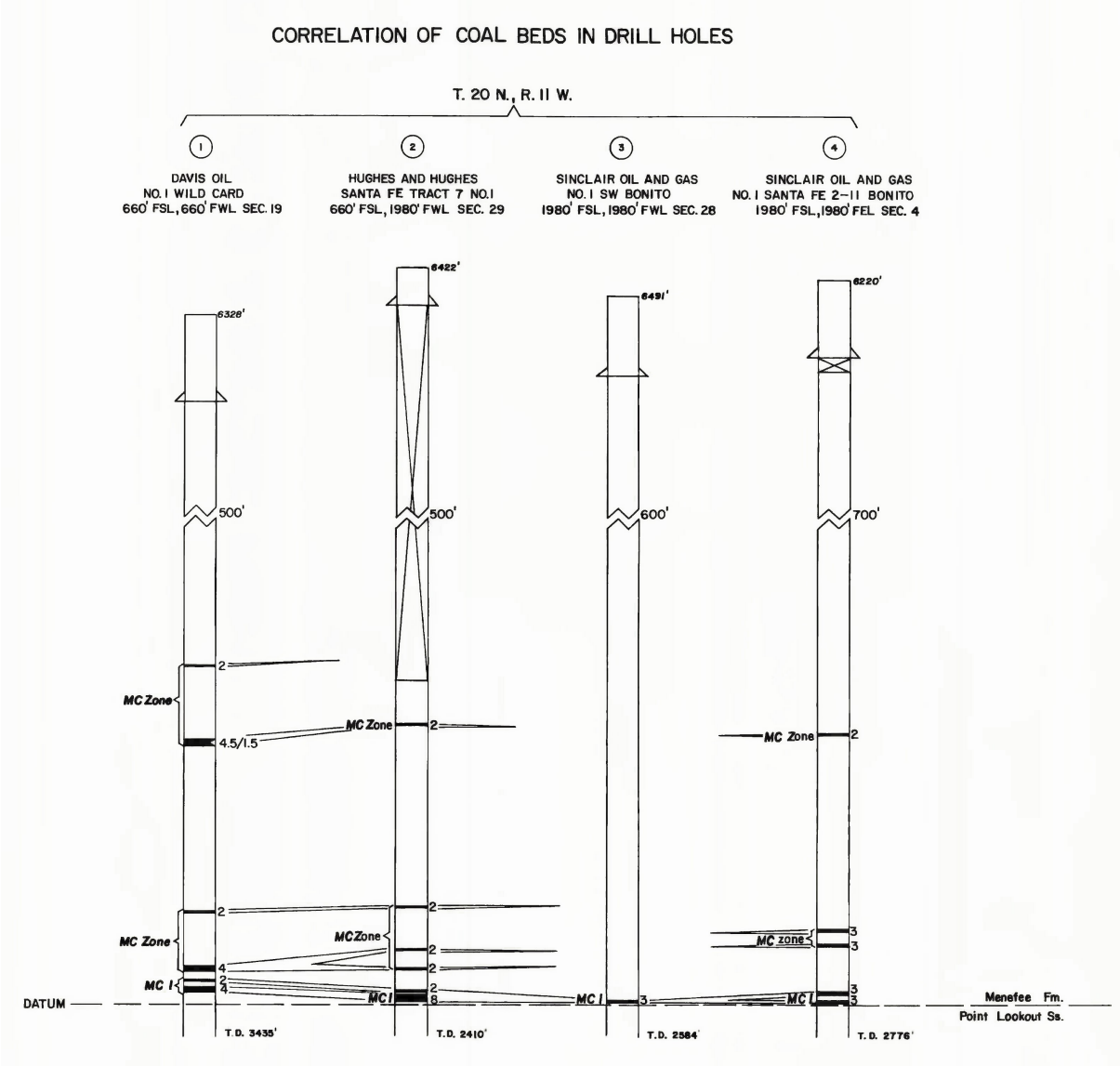
Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Nose Rock Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-641, scale 1:24,000. (*GRI Source Map ID 32099*).

Legend



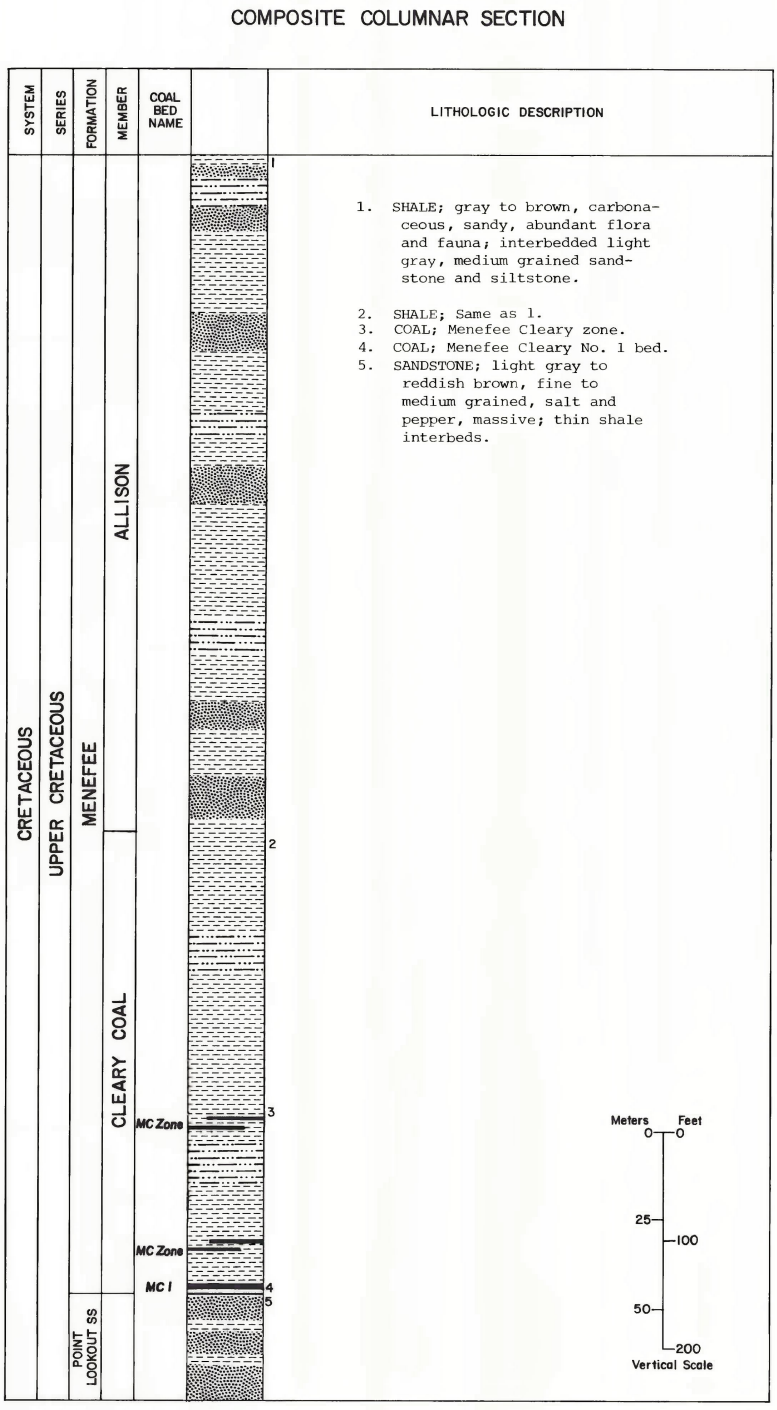
Extracted from: (Nose Rock Quadrangle - coal map). (*GRI Source Map ID 74535*).

Correlation of Coal Beds



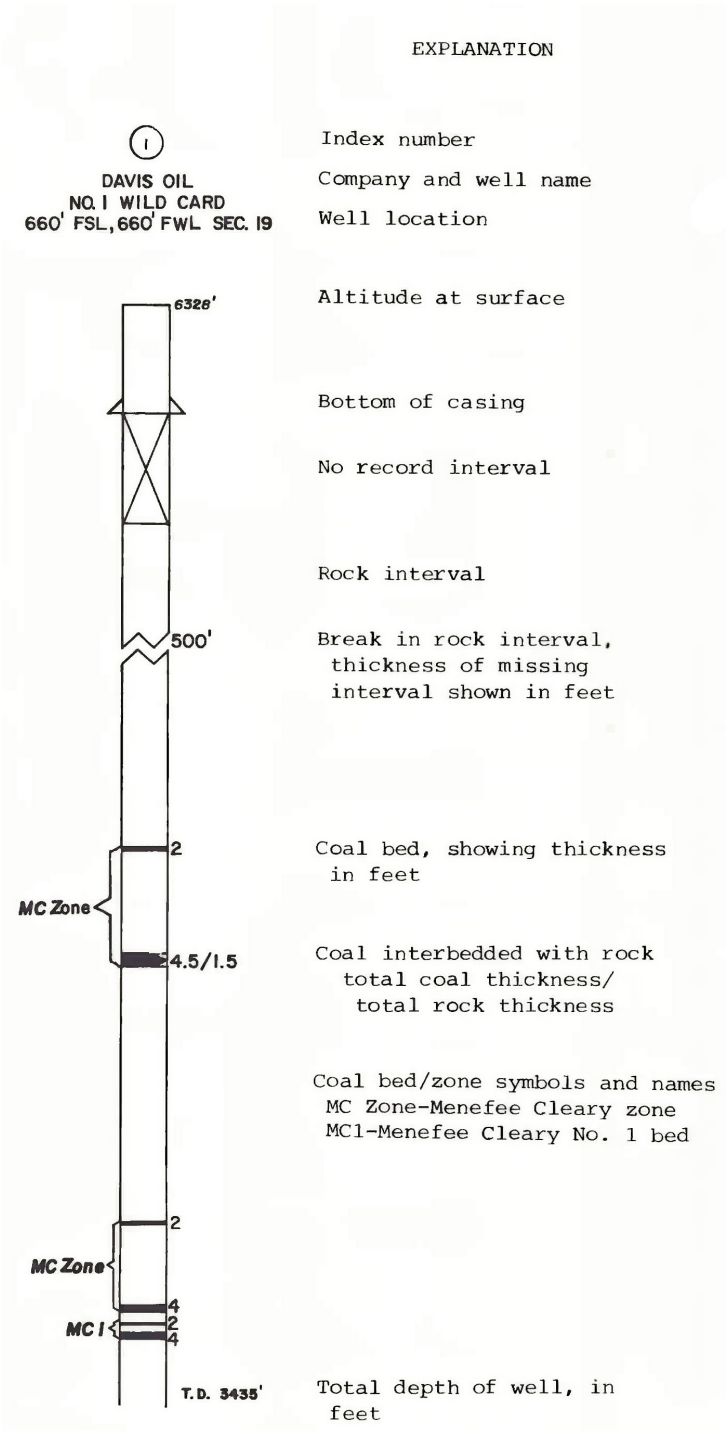
Extracted from: (Nose Rock Quadrangle - coal map). (*GRI Source Map ID 74535*).

Composite Columnar Section



Extracted from: (Nose Rock Quadrangle - coal map). (*GRI Source Map ID 74535*).

Drill Hole Legend



Extracted from: (Nose Rock Quadrangle - coal map). (*GRI Source Map ID 74535*).

Report

Link to Report Online:

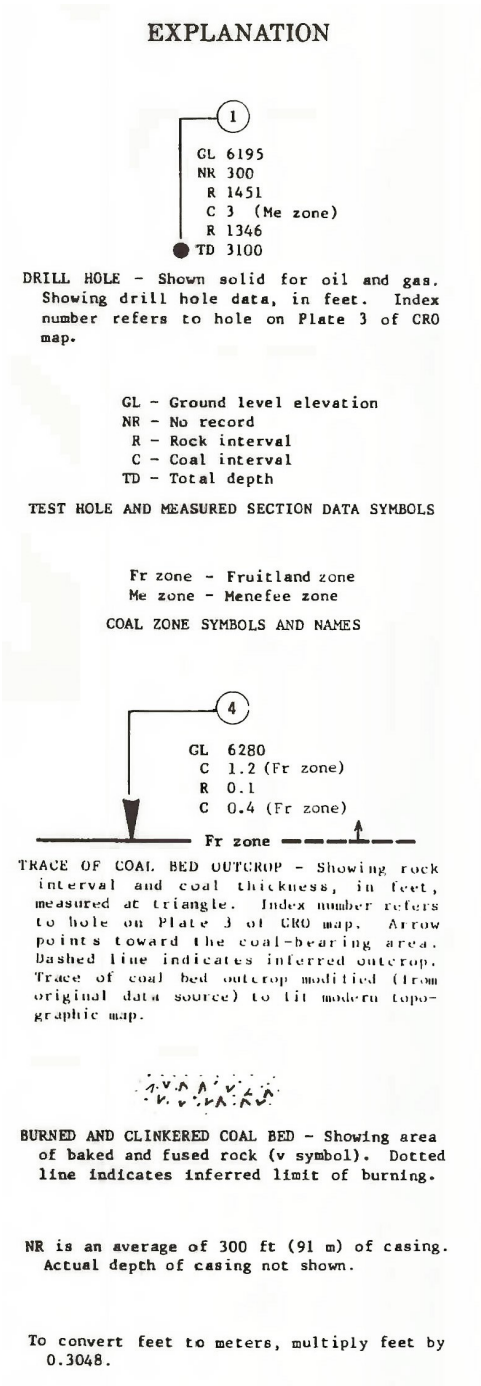
Coal Resources of the Nose Rock Quadrangle Report

Extracted from: (Nose Rock Quadrangle - coal map). (*GRI Source Map ID 74535*).

Coal Resources of the Pueblo Bonito Quadrangle (OFR-79-156)

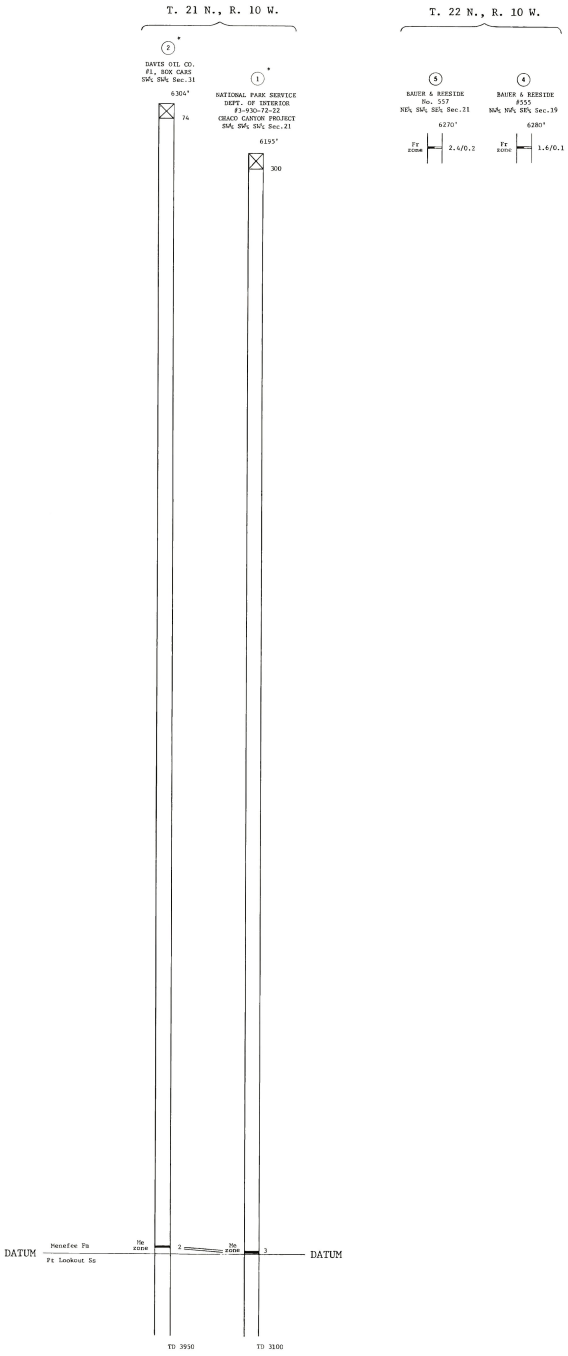
Dames and Moore, 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Pueblo Bonito Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-156, scale 1:24,000. (*GRI Source Map ID 30911*).

Legend



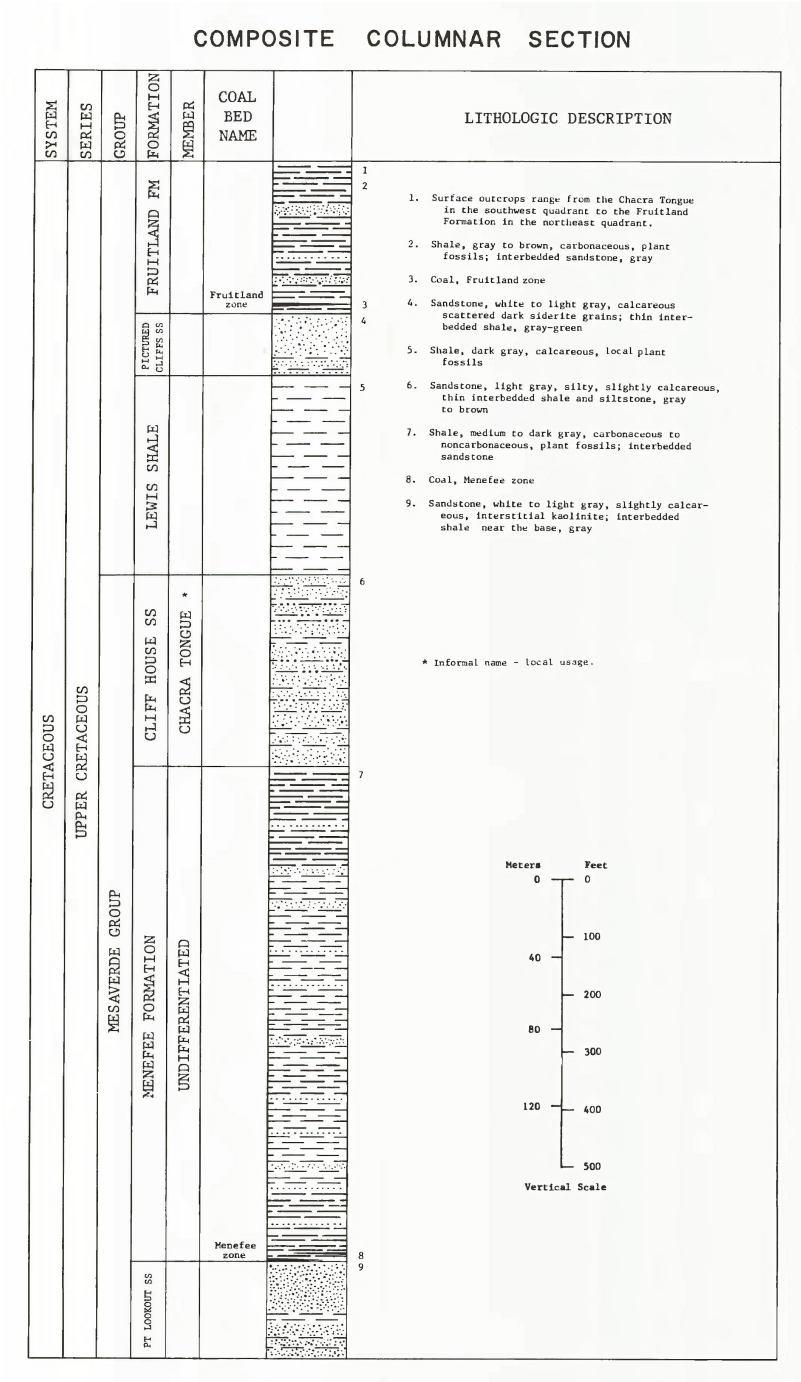
Extracted from: (Pueblo Bonito Quadrangle - coal map). (*GRI Source Map ID 30911*).

Correlation of Coal Beds



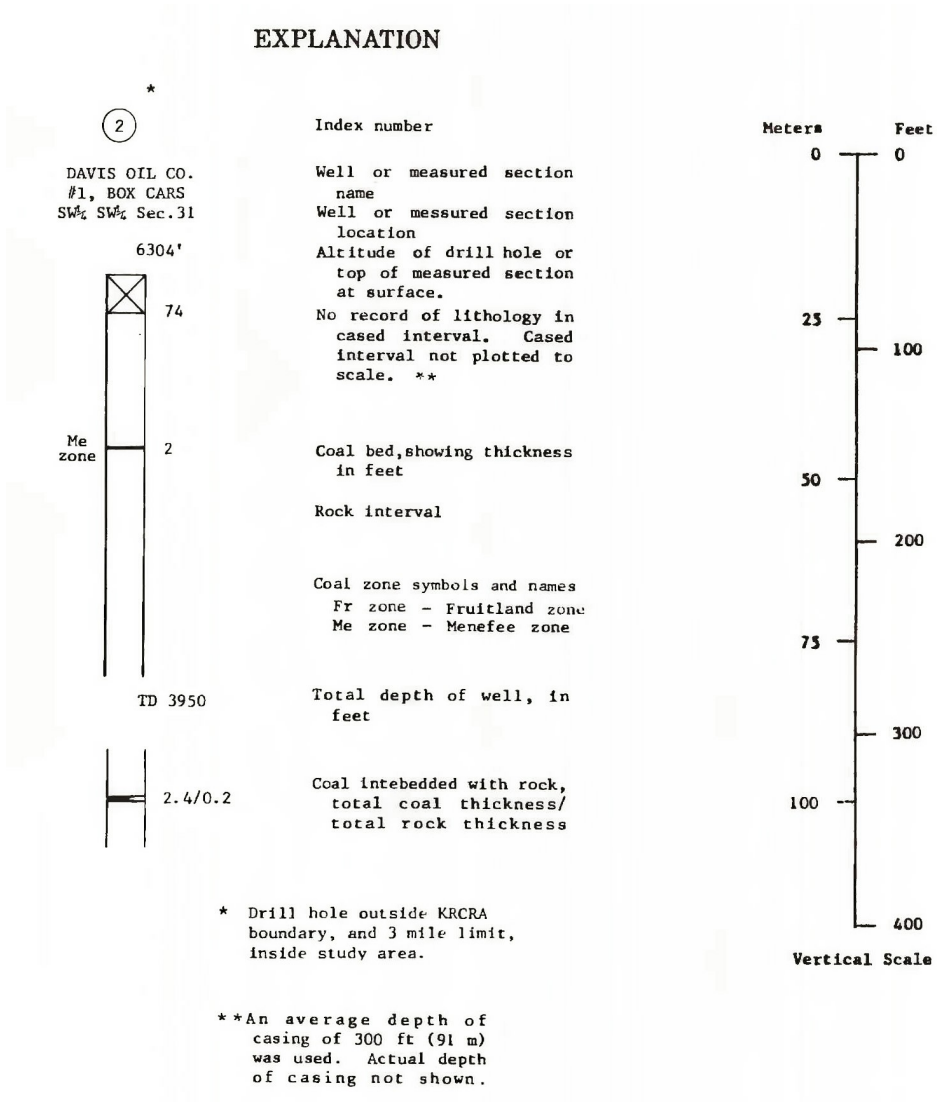
Extracted from: (Pueblo Bonito Quadrangle - coal map). (*GRI Source Map ID 30911*).

Composite Columnar Section



Extracted from: (Pueblo Bonito Quadrangle - coal map). (*GRI Source Map ID 30911*).

Drill Hole Legend



Extracted from: (Pueblo Bonito Quadrangle - coal map). (*GRI Source Map ID 30911*).

Report

Link to Report Online:

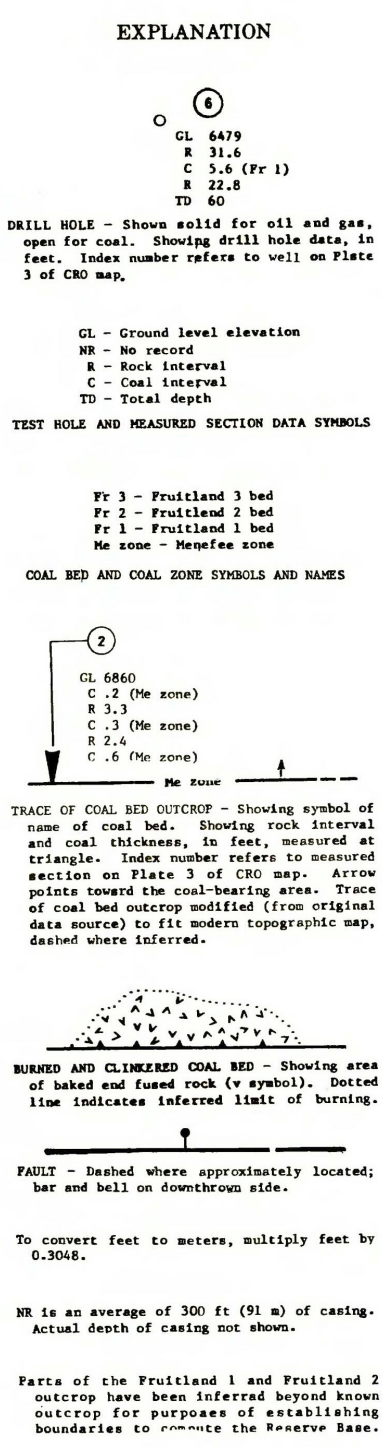
Coal Resources of the Pueblo Pintado Quadrangle Report

Extracted from: (Pueblo Bonito Quadrangle - coal map). (*GRI Source Map ID 30911*).

Coal Resources of the Pueblo Pintado Quadrangle (OFR-79-113)

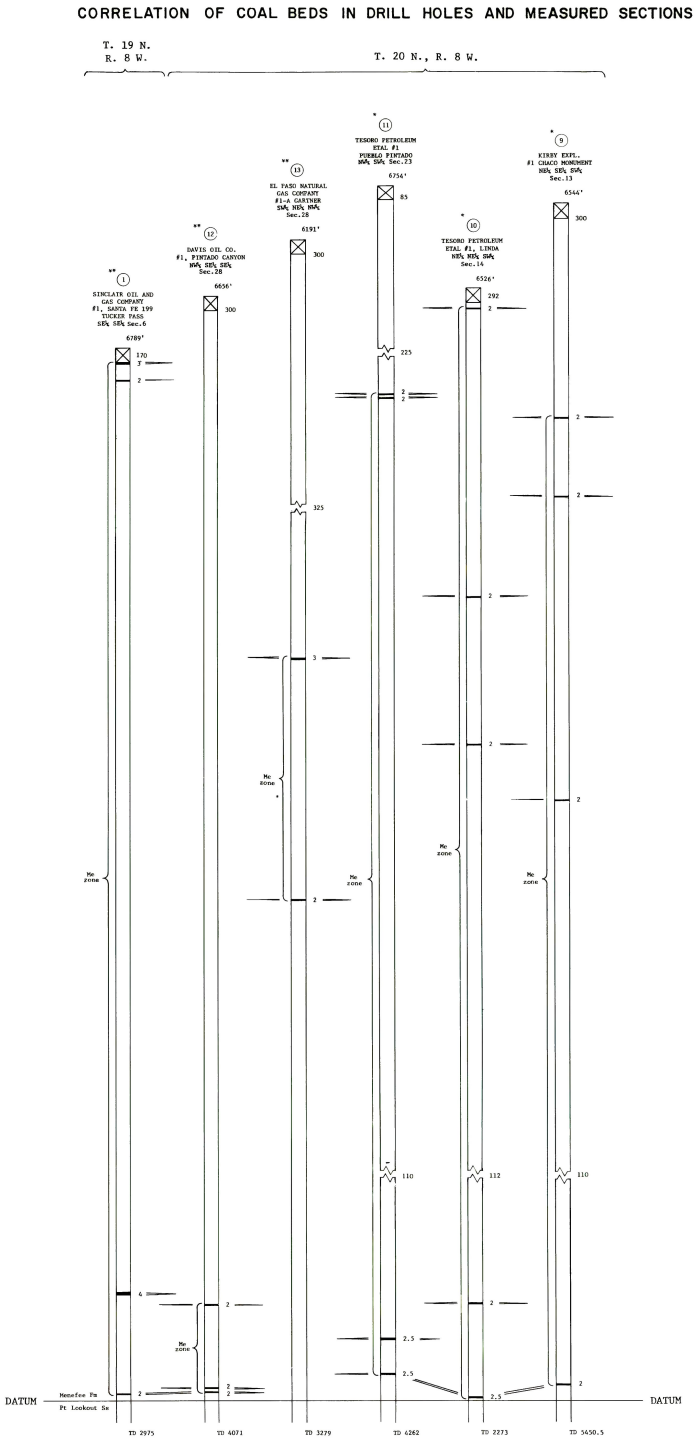
Dames and Moore, 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Pueblo Pintado Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-113, scale 1:24,000. (*GRI Source Map ID 30647*).

Map Legend



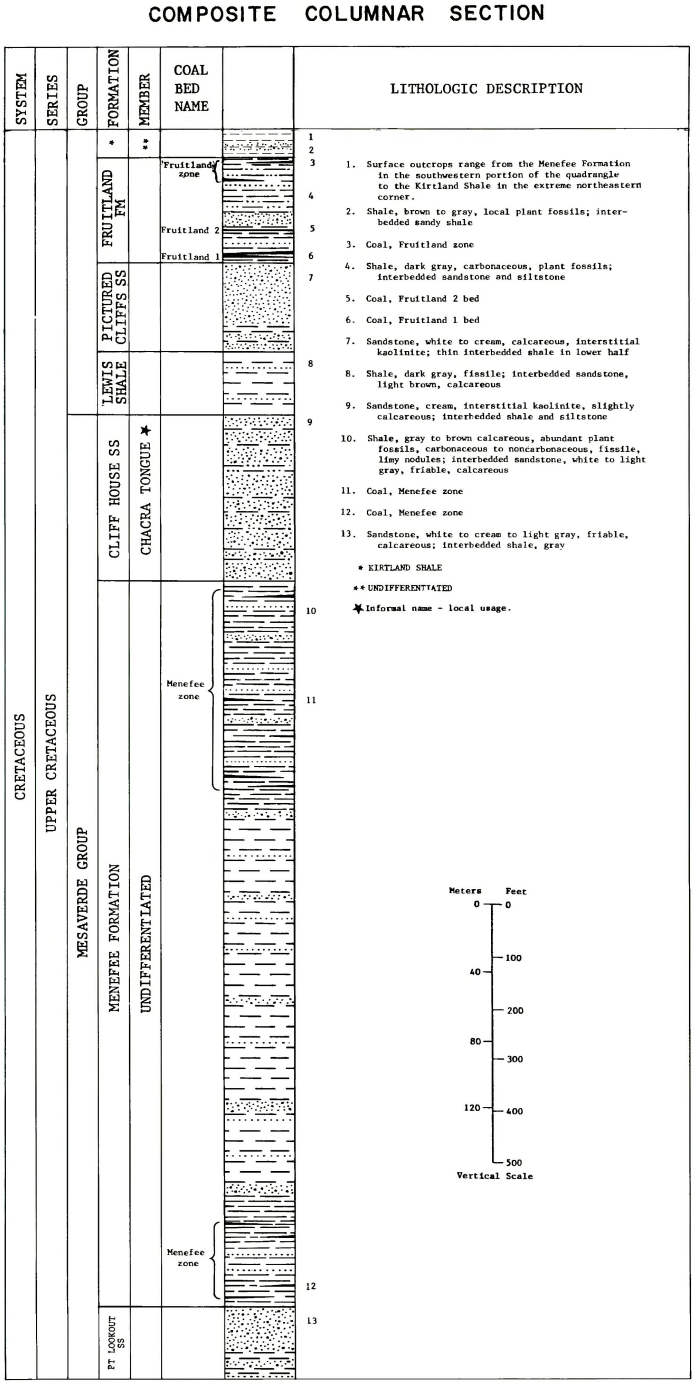
Extracted from: (Pueblo Pintado Quadrangle - coal map). (*GRI Source Map ID 30647*).

Correlation of Coal Beds



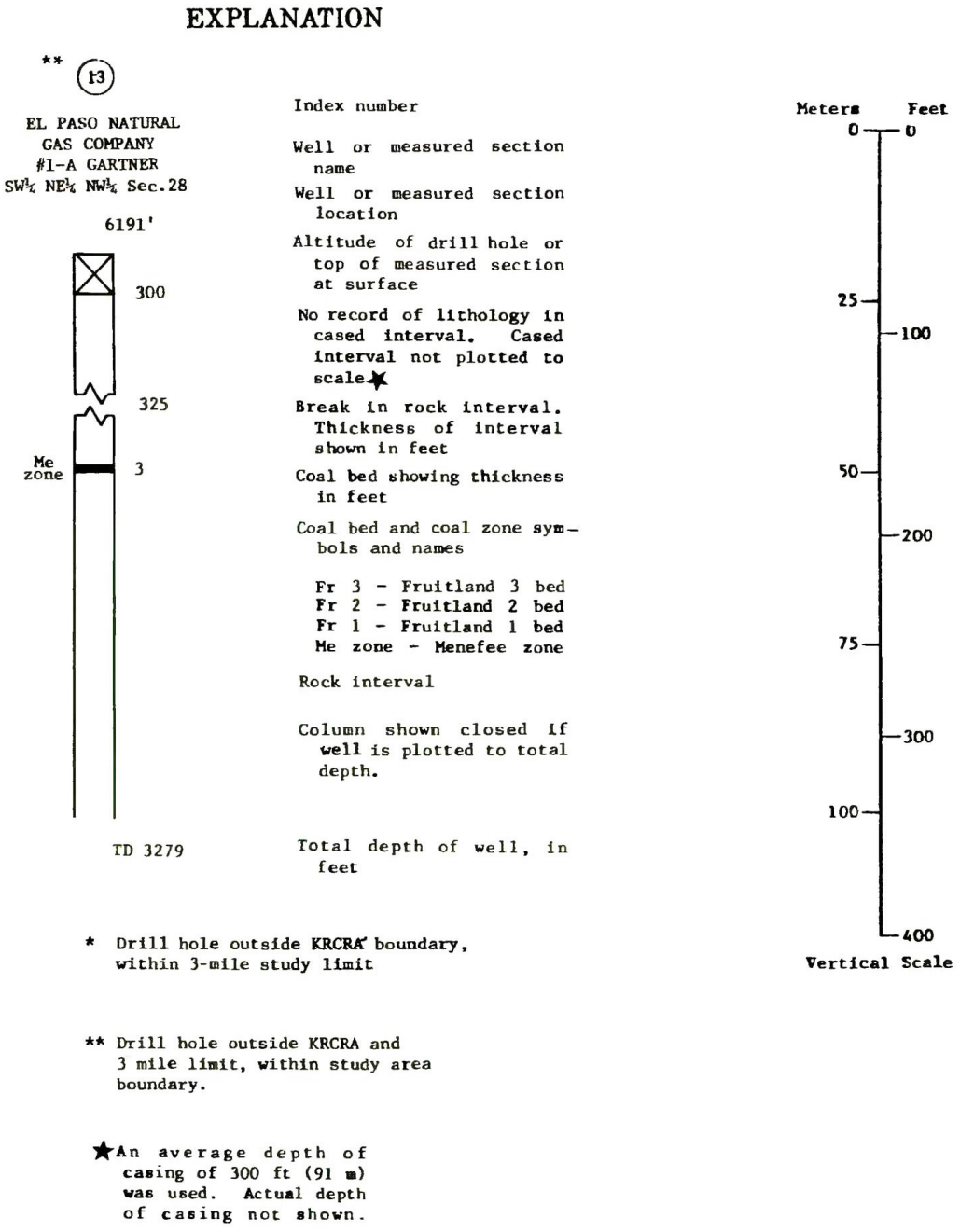
Extracted from: (Pueblo Pintado Quadrangle - coal map). (*GRI Source Map ID 30647*).

Composite Columnar Section



Extracted from: (Pueblo Pintado Quadrangle - coal map). (*GRI Source Map ID 30647*).

Drill Hole Legend



Extracted from: (Pueblo Pintado Quadrangle - coal map). (*GRI Source Map ID 30647*).

Report

Link to Report Online:

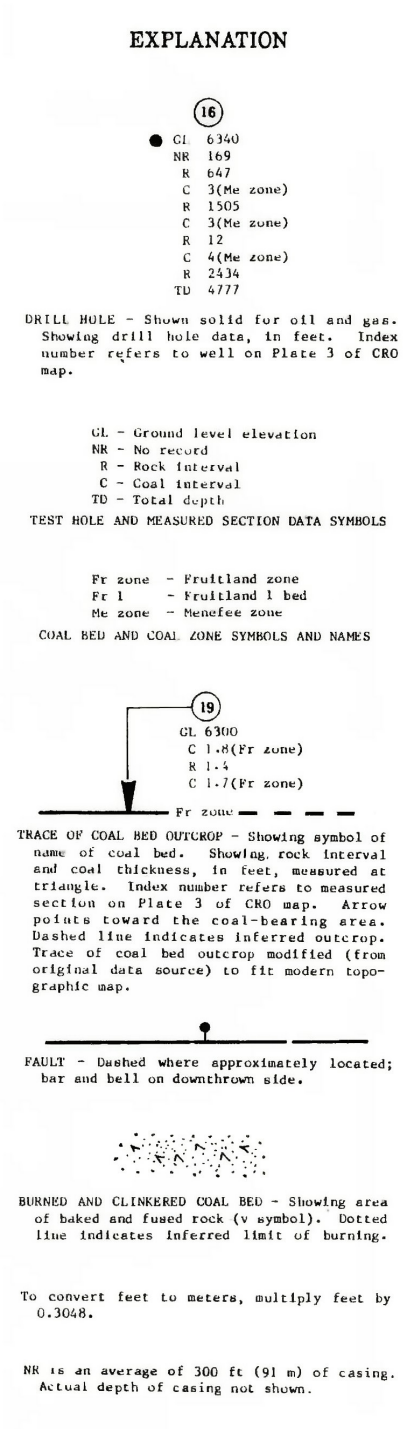
Coal Resources of the Pueblo Pintado Quadrangle

Extracted from: (Pueblo Pintado Quadrangle - coal map). (*GRI Source Map ID 30647*).

Coal Resources of the Sargent Ranch Quadrangle (OFR-79-157)

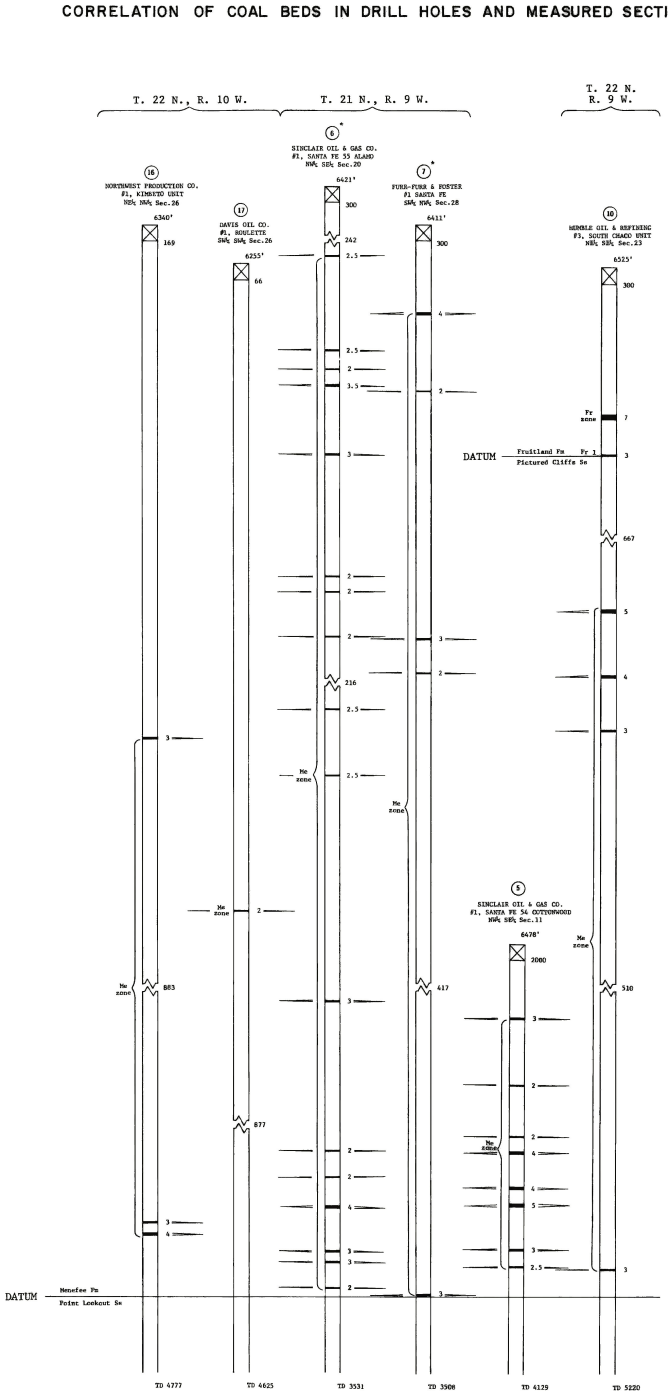
Dames and Moore, 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Sargent Ranch Quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-157, scale 1:24,000. (*GRI Source Map ID 29890*).

Legend



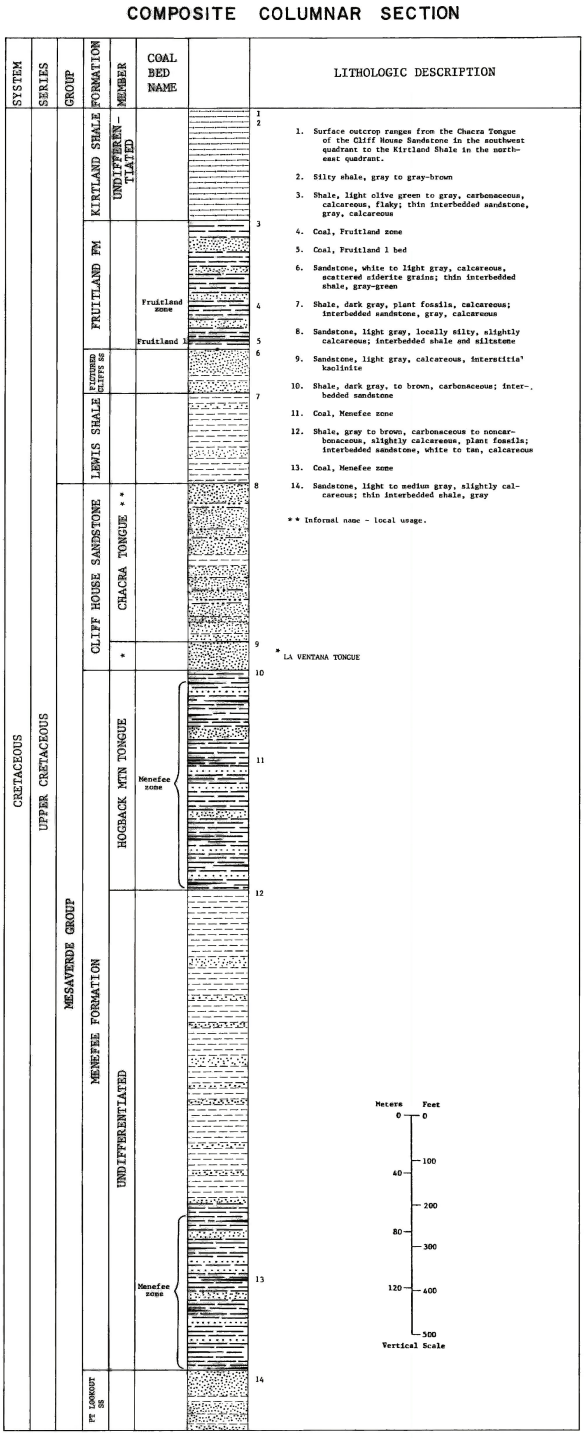
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Correlation of Coal Beds



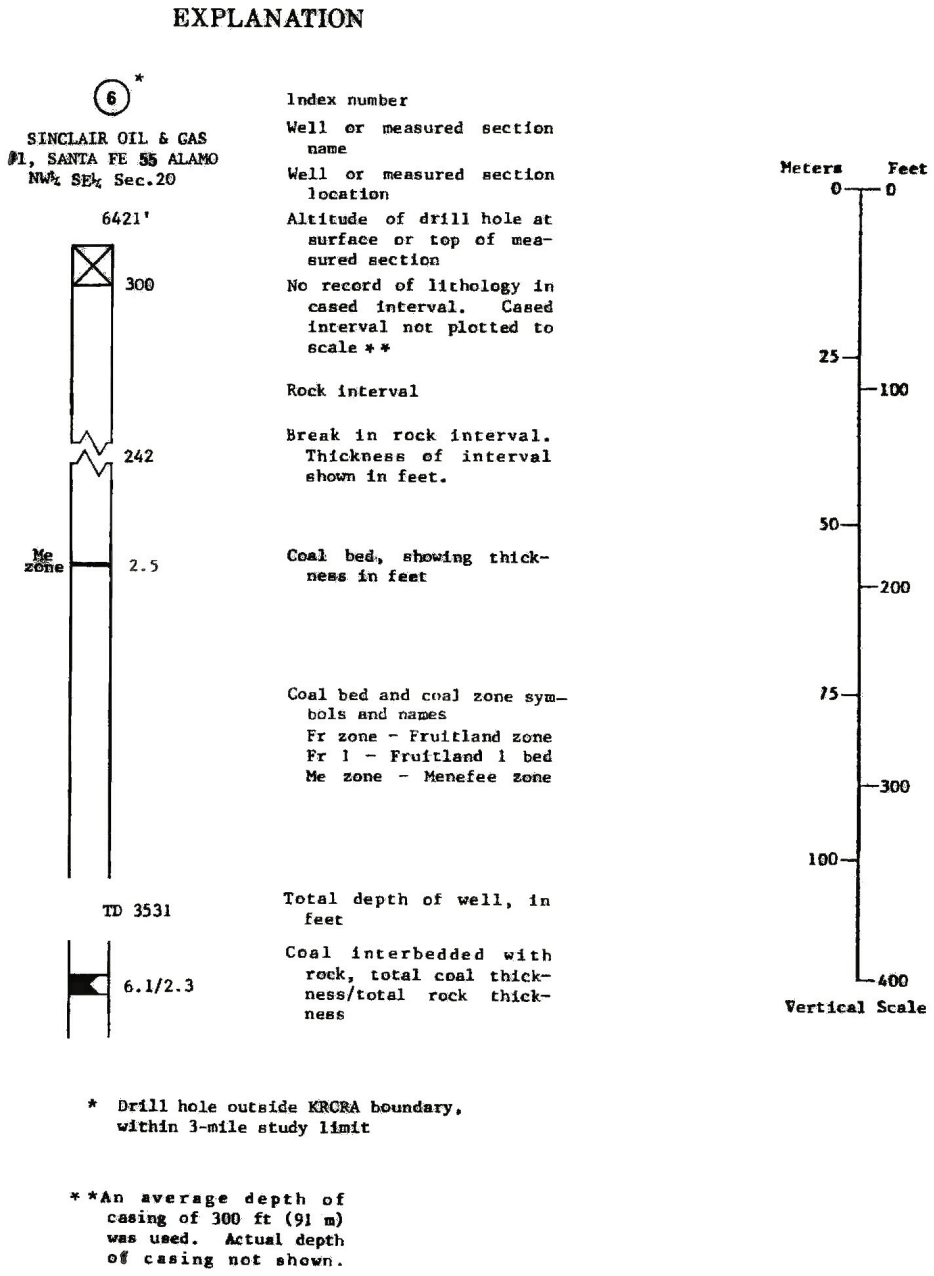
Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Composite Columnar Section



Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Drill Hole Legend



Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Report

Link to Report Online:

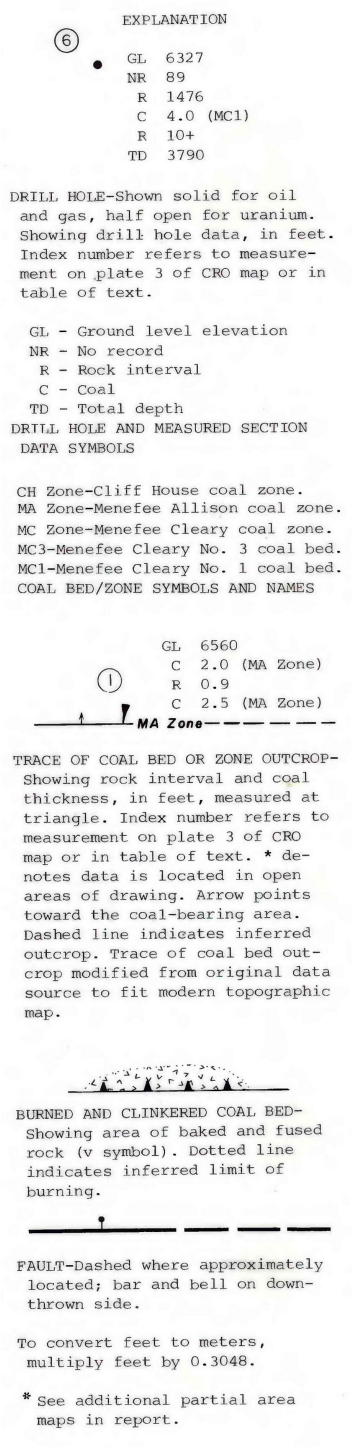
Coal Resources of the Sargent Ranch Quadrangle (OFR-79-157)

Extracted from: (Sargent Ranch Quadrangle - coal map). (*GRI Source Map ID 29890*).

Coal Resources of the Seven Lakes NE Quadrangle (OFR-79-638)

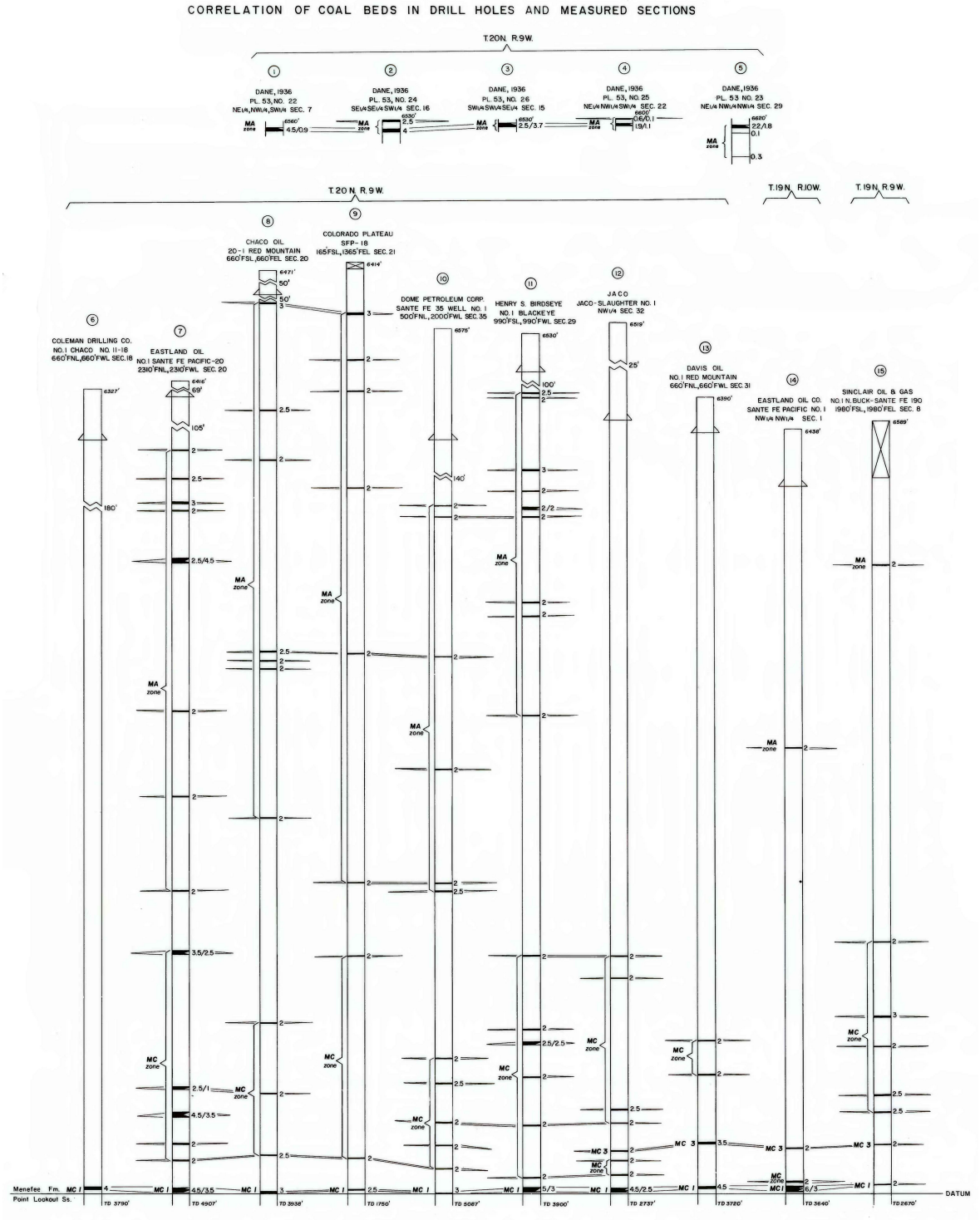
Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Seven Lakes NE Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-638, scale 1:24,000. (*GRI Source Map ID 74537*).

Legend



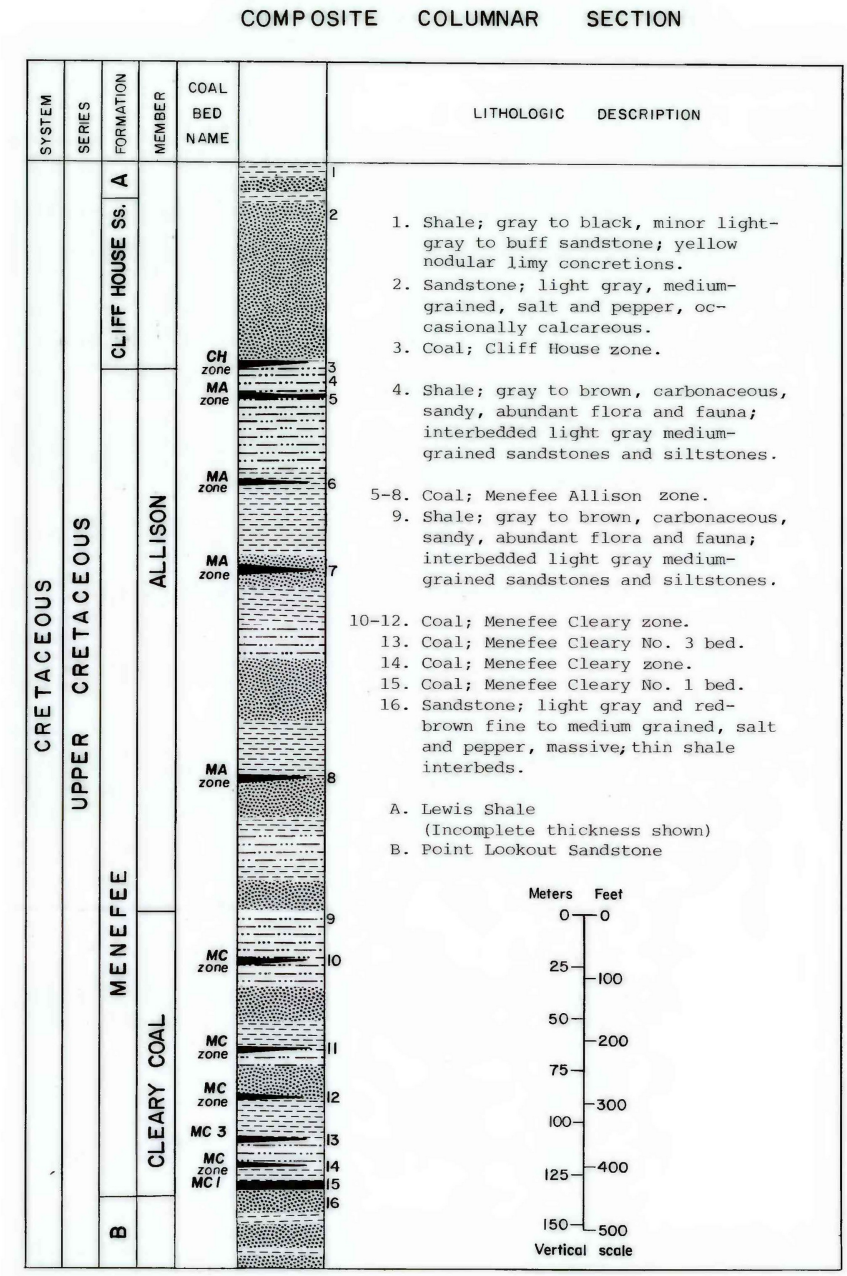
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Correlation of Coal Beds



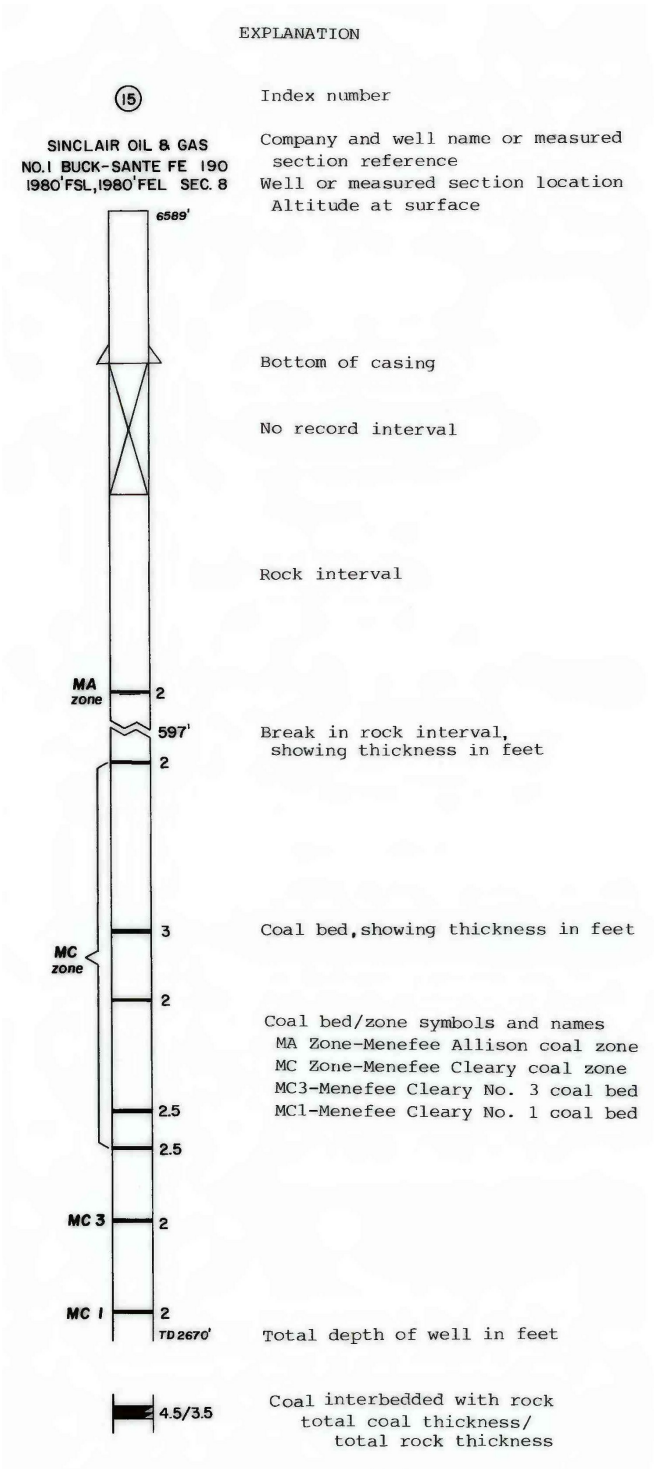
Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Composite Columnar Section



Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Drill Hole Legend



Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Report

Link to Report Online:

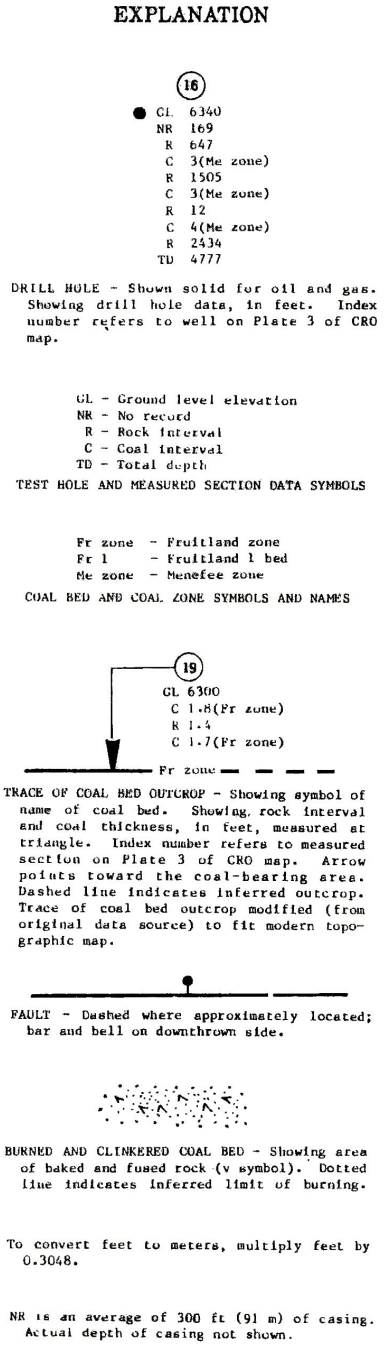
Coal Resource of Seven Lakes NE Quadrangle (OFR-79-638)

Extracted from: (Seven Lakes NE Quadrangle - coal map). (*GRI Source Map ID 32096*).

Coal Resources of the Seven Lakes NW Quadrangle (OFR-79-1123)

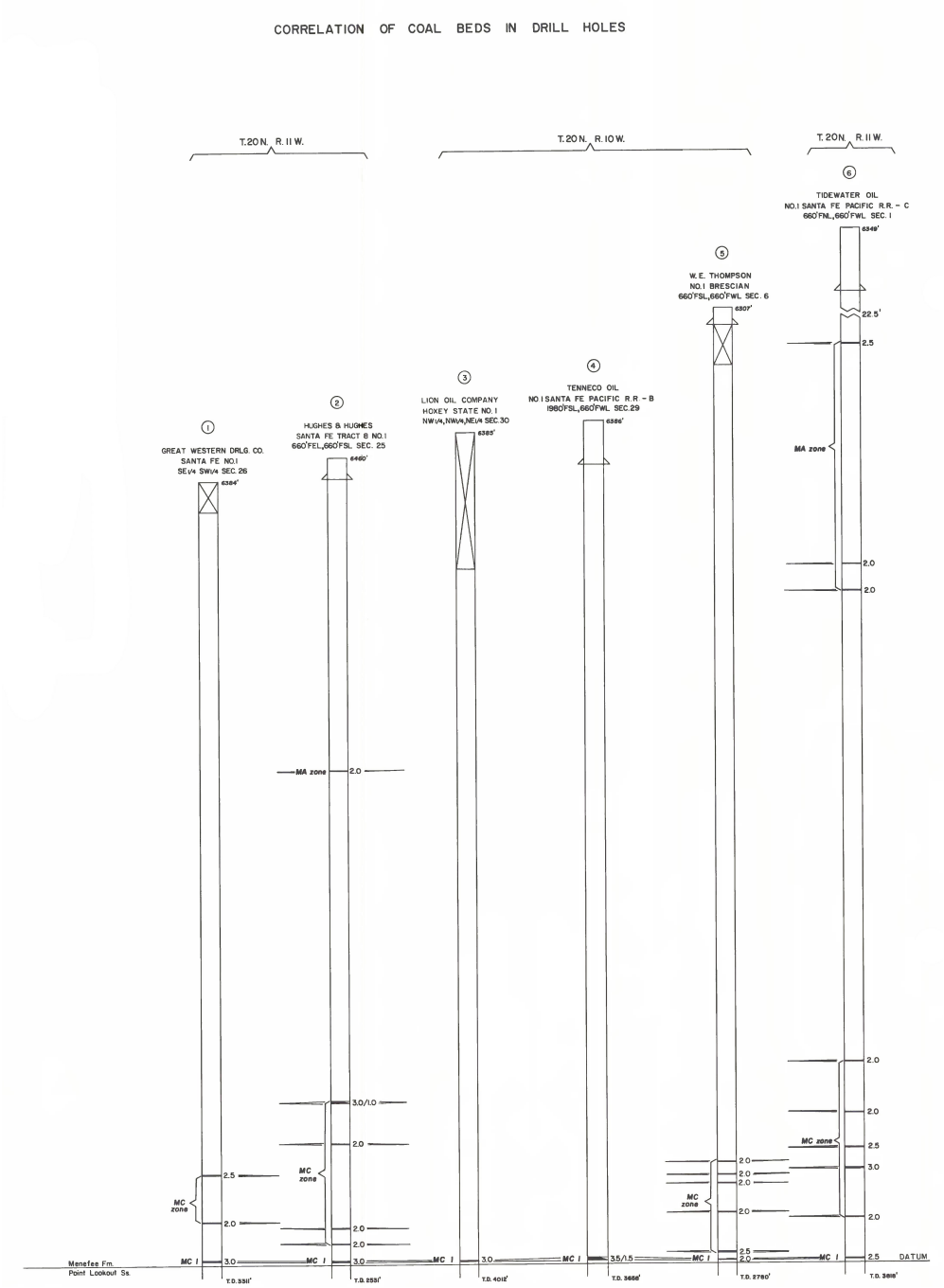
Berge Exploration Inc., 1979, Coal Resource Occurrence and Coal Development Potential Maps of the Seven Lakes NW Quadrangle, McKinley County, New Mexico: U.S. Geological Survey, Open-File Report OFR-79-1123, scale 1:24,000. (*GRI Source Map ID 74537*).

Legend



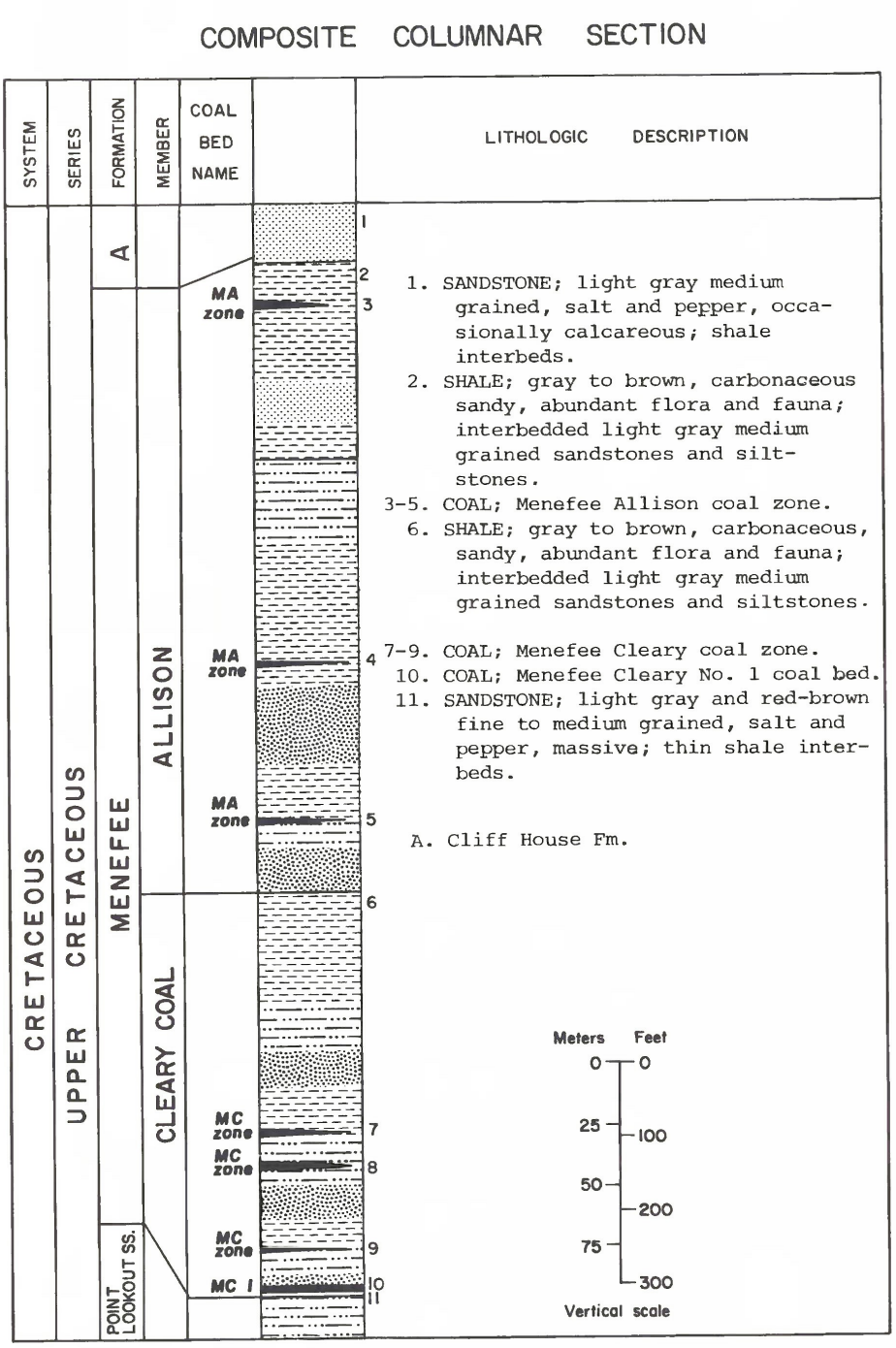
Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

Correlation of Coal Beds



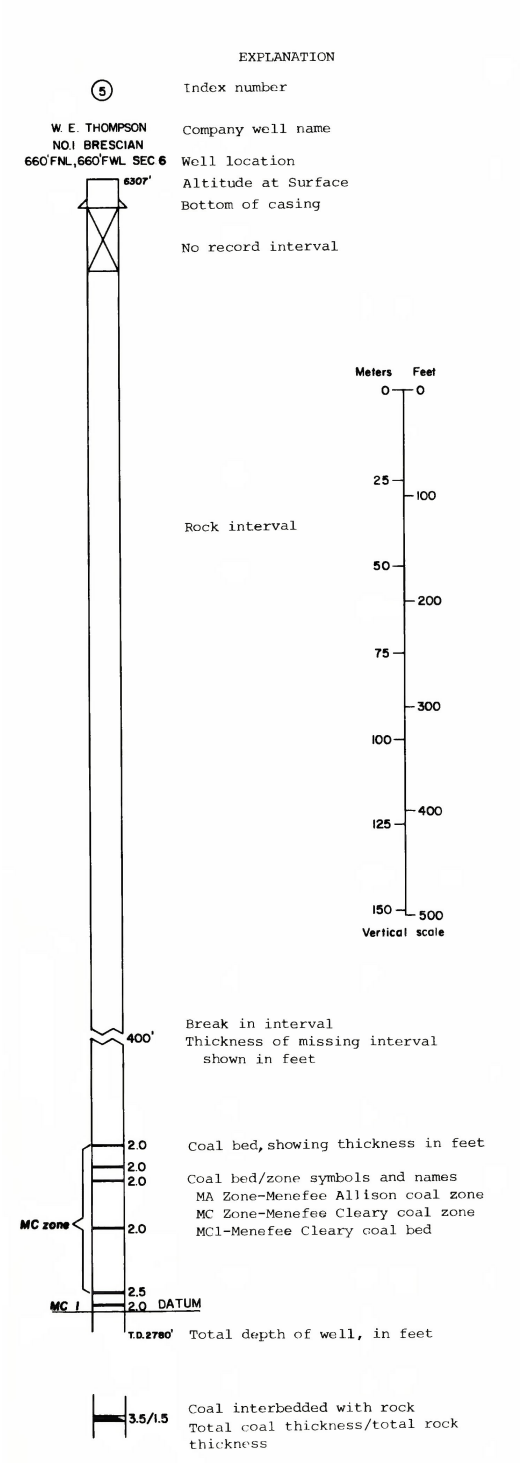
Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

Composite Columnar Section



Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

Drill Hole Legend



Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

Report

Link to Report Online:

Coal Resources of the Seven Lakes NW Quadrangle

Extracted from: (Seven Lakes NW Quadrangle - coal map). (*GRI Source Map ID 74537*).

GRI Digital Data Credits

This document was produced by Stephanie O'Meara and James Winter (Colorado State University) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory (GRI) Program. Initial document creation and compilation by Georgia Hybels (NPS GRD) and Heather Stanton (formally of Colorado State University).

The information contained here was compiled to accompany the digital geologic-GIS maps and other data for Chaco Culture National Historical Park, New Mexico (CHCU) prodcued by Derek Witt, Stephanie O'Meara, James Winter and Kari Lanphier (Colorado State University from initial digital GIS datasets digitized and compiled by Heather Stanton, Christopher Kizer, Elaine Jacobs, Georgia Hybels, Melissa Copfer, Cory Karpilo and John Detring (Colorado State University and NPS Geologic Resources Division) . Initial GRI digital GIS data quality control (QC) performed by the following: Georgia Hybels, Heather Stanton, Jason Isherwood, Tim Cleland (Colorado State University). Later quality control by Derek Witt, Stephanie O'Meara, James Winter and Kari Lanphier.

Initial GRI project management by Heather Stanton. Later project management by Stephanie O'Meara.

GRI program coordination and scoping provided by Bruce Heise and Tim Connors (NPS GRD, Lakewood, Colorado).