Geologic Resource Evaluation Scoping Summary
Chaco Culture National Historical Park, New Mexico

Geologic Resources Division
National Park Service
US Department of the Interior

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Administered by the NPS Geologic Resources Division (GRD), the Geologic Resource Evaluation (GRE) Program provides each of 270 identified natural-area units in the National Park System with a geologic scoping meeting, a digital geologic map, and a geologic resource evaluation report. The purpose of scoping is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and potential monitoring and research needs. Outcomes of this scoping process are a scoping summary (this report), a digital geologic map, and a geologic resource evaluation report. Participants at geologic scoping meetings evaluate the adequacy of existing geologic maps for resource management, discuss park-specific geologic management issues, and if possible tour the site with park staff and geologists knowledgeable about the park's geologic resources.

The National Park Service held a GRE scoping meeting for Chaco Culture National Historical Park on February 14, 2007. Participants at the meeting included NPS staff from the park and the Geologic Resources Division, and cooperators from the New Mexico Bureau of Geology & Mineral Resources, U.S. Geological Survey, and Colorado State University (table 1). Superintendent Barbara West welcomed the participants, and Natural Resource Manager Brad Shattuck (who is acting facilities manager) expressed the need and appreciation of having a digital geologic map for planning. Tim Connors (GRD) facilitated the evaluation of map coverage, and Lisa Norby (GRD) led the discussion regarding geologic processes and features. Dave Love (New Mexico Bureau of Geology & Mineral Resources) presented an overview of the geologic history of the park. After discussions, participants took a brief field trip to Pueblo Bonito, viewing the landscape, ruins, and Threatening Rock.

This scoping summary highlights the GRE scoping meeting for Chaco Culture National Historical Park, including the geologic setting, the plan for providing a digital geologic map, a list of geologic resource management issues, descriptions of significant geologic features and processes, and a record of meeting participants.

Park and Geologic Setting

Planned and constructed in stages between A.D. 850 and 1150, the pueblos of Chaco Culture National Historical Park were the center of the Chacoan world, which covered a vast area of the present-day Southwest, including the San Juan Basin of New Mexico, and portions of the Four Corners area of Colorado, Utah, and Arizona (National Park Service, 2006). Covering more than 26,000 square miles (67,340 km^2), the San Juan Basin is the dominant structural and physical feature in the northwestern part of New Mexico. It is a nearly circular, bowl-shaped depression containing a thick sequence of sedimentary rocks, ranging in age from 570 to 2 million years old (Brister and Price, 2002). The folded sediments of the San Juan Basin contain groundwater aquifers, reservoirs for oil and gas, and other mineral deposits (e.g., coal and uranium). Chaco Culture National Historical Park lies near the center of the San Juan Basin at the southeastern edge of the much larger Colorado Plateau. Encompassing an area of approximately 140,000 square miles (36,260 km^2), the Colorado Plateau is a high-standing crustal block of relatively undeformed rocks surrounded by the highly deformed Rocky Mountains and Basin and Range provinces.

The rocks exposed at Chaco Culture National Historical Park record an episode of sea-level rise between 95 and 70 million years ago. At the time of deposition of these horizontal sedimentary layers, which now form plateaus, mesas, buttes, and canyons, Chaco Culture National Historical Park was part of the migrating coastline of an ancient inland sea called the Cretaceous Interior Seaway. This seaway was hundreds of miles wide and divided North America into two separate land masses. Chaco Canyon was situated on the western shoreline. The northwest-southeast oriented epicontinental seaway stretched from the Arctic Ocean to the Gulf of Mexico. As the seaway repeatedly inundated and then receded from parts of the Four Corners area, Cretaceous rocks in Chaco Canyon were deposited in coastal and marine settings such as barrier islands, lagoons, tidal inlets, stream deltas, estuaries, and swamps (fig. 1). Changes in sea level, sediment transport and deposition, and offshore subsidence caused multiple northeast-southwest shifts in shoreline position (Love, 2007).

The majority of the exposed strata at Chaco Culture National Historical Park belong to a suite of rocks known as the Mesaverde Group, which geologists have subdivided into the Point Lookout Sandstone, the Menefee Formation, and the Cliff House Sandstone. Two additional rock units—Lewis Shale and the Pictured Cliffs Sandstone—were also deposited in the Cretaceous Interior Seaway. The Menefee and Cliff House formations and the Lewis Shale are visible in the park, but the Menefee and Cliff House are the most prominent. Lewis Shale is beneath the eolian sands north of the upper Cliff House Sandstone cliffs and interfingers with it but is not prominent enough to be mapped at 1:24,000 scale.

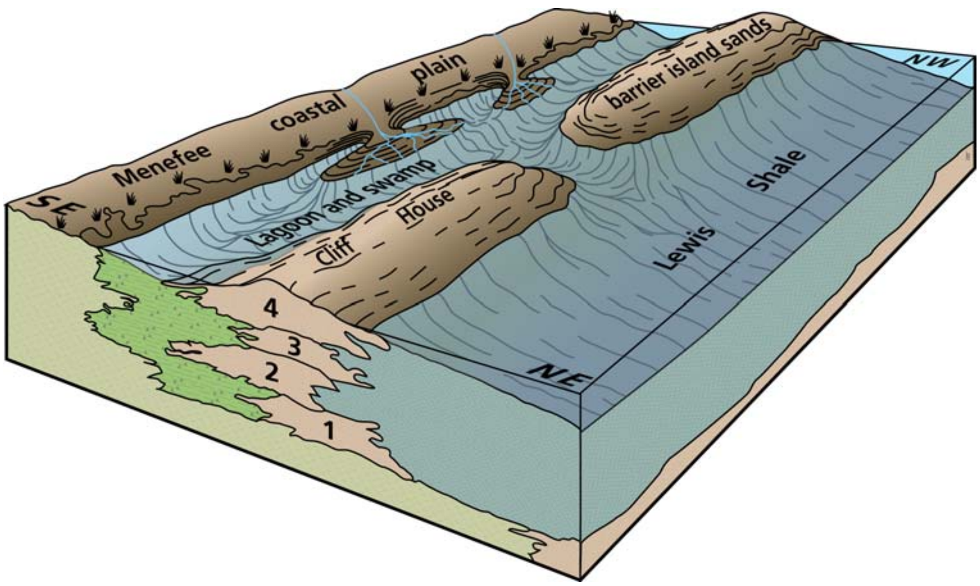

Figure 1. Stratigraphy of Chaco Culture National Historical Park. The rock units in the park (Menefee Formation, Cliff House Sandstone, and Lewis Shale) record a marine setting when the Cretaceous Interior Seaway covered the area between 95 and 70 million years ago. *Source*: Donselaar (1989); modified as part of scoping presentation (Dave Love, New Mexico Bureau of Geology & Mineral Resources, February 14, 2007).

Menefee Formation

The oldest bedrock exposed at Chaco Culture National Historical Park is the middle unit of the Mesaverde Group—the Menefee Formation. During a major regression (sea-level fall / shoreline progradation) of the Cretaceous Interior Seaway, upland streams transported and deposited sediments into the retreating seaway. At the edge of the seaway, the streams joined a flat coastal plain containing swamps, lagoons, and deltas. Plant materials, which accumulated in these areas, formed thin coal beds. These coastal, nonmarine sediments became the Menefee Formation, which now forms the slopes underlying the steep mesa walls in the park.

Cliff House Sandstone

Forming the prominent cliffs seen throughout the park, the Cliff House Sandstone overlies and is younger than the Menefee Formation. The Cliff House Sandstone represents four separate barrier-island complexes that were deposited during sea-level rise (Dave Love, New Mexico Bureau of Geology & Mineral Resources, presentation, February 14, 2007; Donselaar, 1989). According to Donselaar (1989), the barrier islands of the Cliff House Sandstone were tidally dominated, not wave dominated. Cretaceous tidal channels record lunar/tidal cycle in "bundles." These channels moved with the tides and show the cyclicity of deposition. Good examples of these tidal bundles occur in Gallo Canyon (fig. 2). The Cliff House Sandstone is generally known as a transgressive (sea-level rise / landward advance) sequence; the islands built upward and prograded seaward with the accumulation of sediment (Dave Love, written communication, May 15, 2007). However, the positions of the barrier-island complexes shifted back and forth during sediment accumulation. As a result, cliffs now vary in height and record different depositional environments across Chaco Canyon and adjacent mesas (Love, 2007).

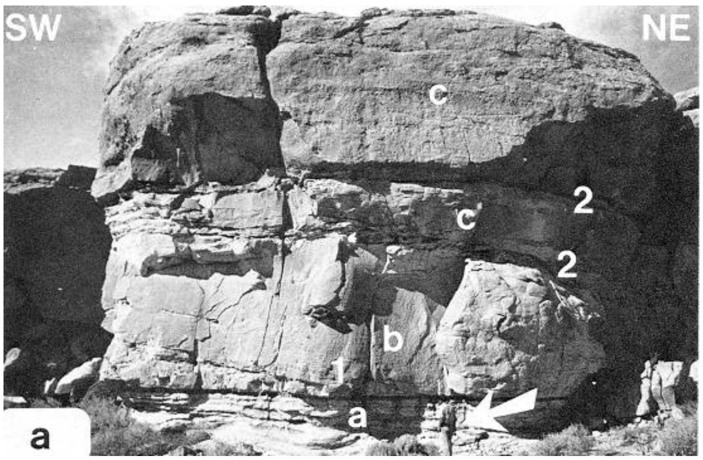

Figure 2. Tidal Channel and Deltas of the Cliff House Sandstone. Tidal channels in Gallo Canyon record lunar/tidal cycle of the Cretaceous Interior Seaway barrier-island system. *Source*: Donselaar (1989).

Lewis Shale

The Lewis Shale, consisting of gray shale, siltstone, and mudstone, with some sandstone beds, was deposited offshore in the Cretaceous Interior Seaway. It represents another significant seaway advance. Most of the Lewis Shale is composed of smectitic clay, derived from the alteration of volcanic glass. The Lewis Shale now forms a narrow, rolling, upland plain north of Chaco Culture National Historical Park.

Pictured Cliffs Sandstone

The coastally deposited Pictured Cliffs Sandstone represents the final retreat of the Cretaceous Interior Seaway. This massively bedded unit is resistant to erosion and forms cliffs. For the most part, the Pictured Cliffs Sandstone is located north of the park, appearing as sandstone ridges and outcrops.

Canyon Cutting

In Chaco Culture National Historical Park and vicinity, the Chaco River and its tributaries have incised deeply into the sandstones and produced excellent three-dimensional exposures of Cretaceous deposits (Donselaar, 1989). The unintrenched, unglaciated headwaters of the Chaco River are on the Continental Divide east of Chaco Canyon. Once this meandering river became established, it began to cut into bedrock at lower elevations, creating nine different levels of geomorphic features, consisting of gravel deposits, alluvial fills and terraces, cemented sand dunes, and incised and buried channels (fig. 3). Though evidence for geomorphic evolution along the reaches of the Chaco River is ample, investigators have yet to address the exact timing of incision and determine any absolute ages for pre-Holocene alluvial deposits within the Chaco River basin. Bryan (1954) and Love (1980) are the only investigations to have addressed canyon cutting. Maximum excavation of Chaco Canyon likely predates late-Pleistocene time (120,000–10,000 years ago)

(Love and Connell, 2005). Love (1980) proposes that incision below 6,233 feet (1,900 m) probably began less than 2 million years ago.

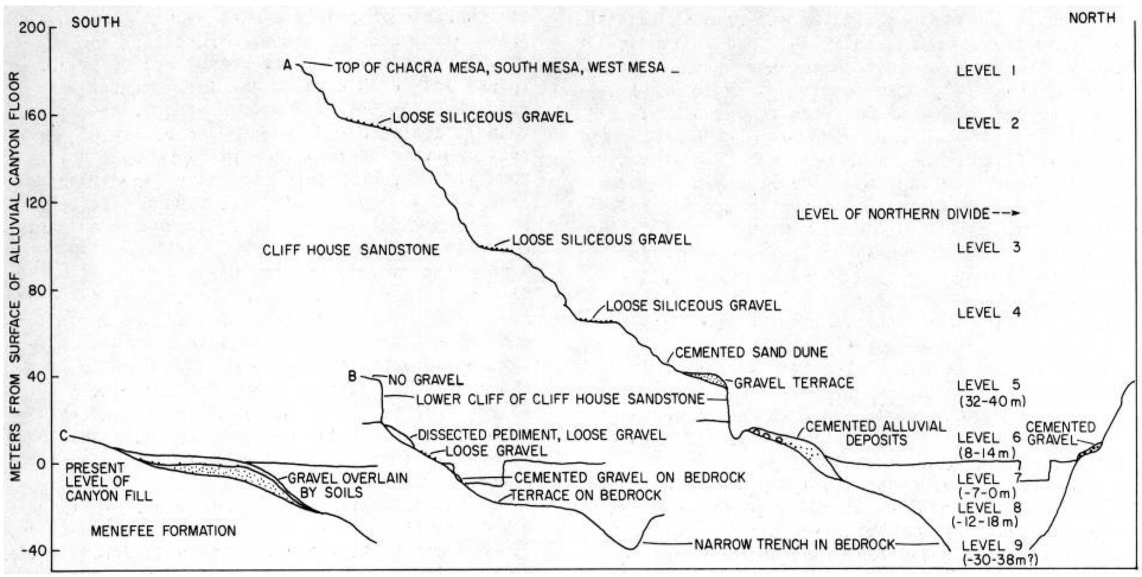

Figure 3. Schematic Topographic Levels of Deposits and Geomorphic Features in Chaco Canyon. Profiles A, B, and C illustrate different exposures on the south side of Chaco Canyon. *Source*: Dave Love, scoping presentation, February 14, 2007, and Love and Connell (2005).

The modern valley floor has alternated between being deeply gullied with arroyo channels, as it is now, and having no gullies. These two situations have alternated throughout the Holocene Epoch to make a complex set of cuts, fills, and lateral deposits (Love, 1983a). The primary driving force for arroyo cutting and filling in Chaco Canyon appears to be episodic climatic oscillations, which affect magnitudes of discharges and the stream's ability to transport sediment beyond the canyon (Love, 1983a; 1983b).

Geologic Mapping Plan for Chaco Culture National Historical Park

During the scoping meeting, Tim Connors (GRD) showed some of the main features of the GRE Program's digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of being GIS compatible. The NPS GRE Geology–GIS Geodatabase Data Model incorporates the standards of digital map creation set for the GRE Program. Staff members digitize maps or convert digital data to the GRE digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in geodatabase, shapefile, and coverage format, layer files, FGDC-compliant metadata, and a Windows HelpFile that captures ancillary map data. Completed digital maps are available from the NPS Data Store at http://science.nature.nps.gov/nrdata/.

Chaco Culture National Historical Park (CHCU) is situated on multiple 7.5-minute quadrangles (fig. 4): Sargent Ranch, Pueblo Bonito, Kin Klizhin Ruins, La Vida Mission, Pueblo Pintado, Seven Lakes NE, Seven Lakes NW, Milk Lake, and Heart Rock. Additionally, the Nose Rock and Crownpoint quadrangles are of interest to CHCU staff because of their proximity to park units. Existing data for these quadrangles include bedrock, surficial, and coal-potential coverages, which are published at adequate scales for resource management. Also, a New Mexico Bureau of Geology & Mineral Resources (NMBGMR) publication, *The Geology of Northern New Mexico's Parks, Monuments, and Public Lands* (in press), refines some of the contacts within the Seven Lakes NE and NW quadrangles. GRE staff will acquire the accompanying digital files from the bureau when they become available and incorporate them into the final map product.

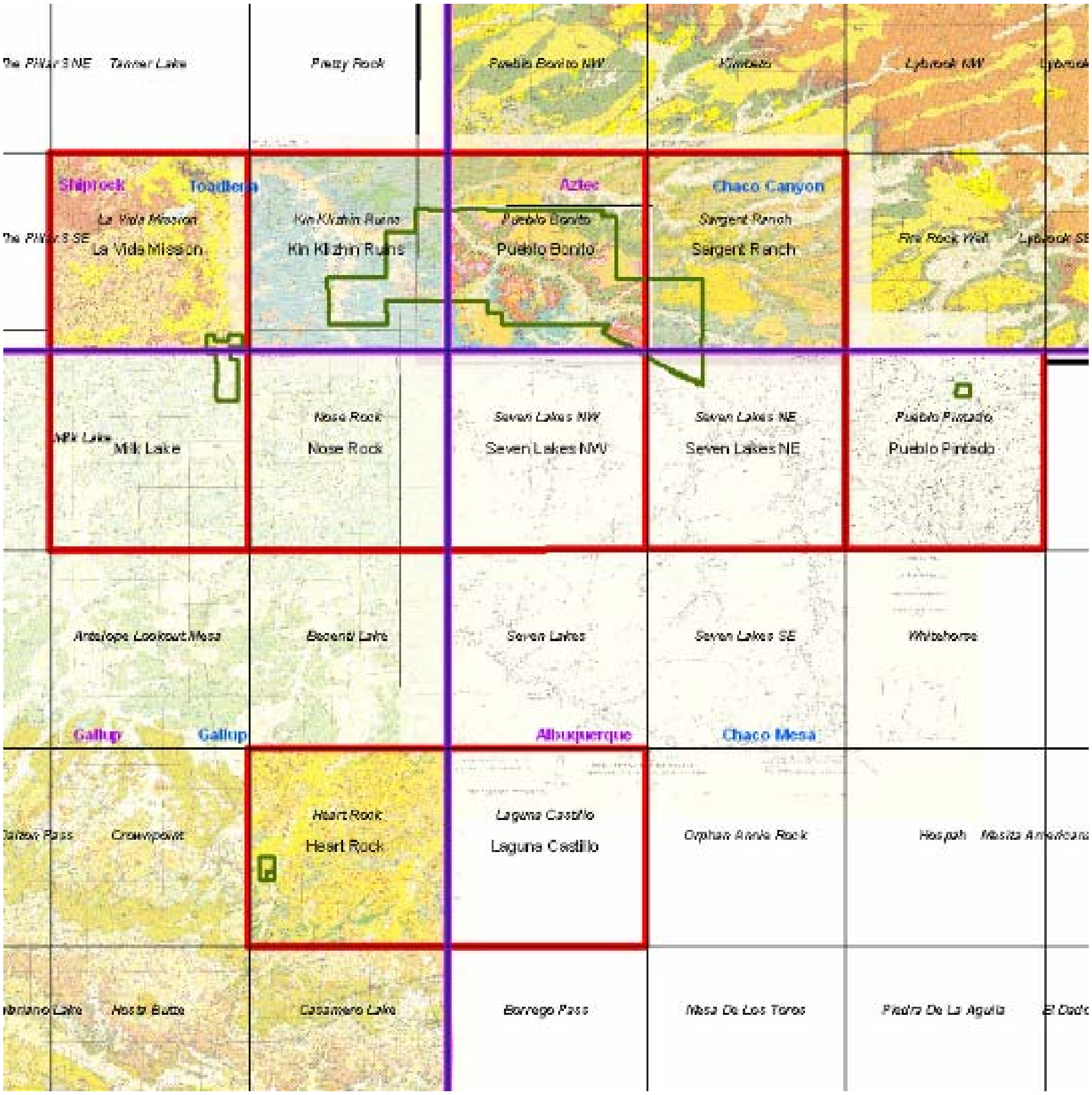

Figure 4. Published Geologic Maps for Chaco Culture National Historical Park. The footprint of these maps is shown in relation to park boundaries and 11 quadrangles of interest. During scoping, park staff requested that the digital map include the Crownpoint quadrangle, rather than the Laguna Castillo quadrangle. The park boundaries are the green outlines. The 1:24,000-scale quadrangles labeled in black. Blue type indicates the names of 30' × 60' maps; purple type indicates the names of 1° × 2° maps.

With the exception of the data that will accompany the upcoming NMBGMR publication, none of the selected maps are known to exist in a digital-GIS format. Hence, GRE staff will digitize the source maps (table 2) and create a geodatabase from them. Park staff requested that the data be delivered in UTM zone 13 coordinates. GRE staff has assigned each map with a unique "GMAP ID" used for data management purposes. These numbers appear in table 2 and with the map citations listed in this summary.

For the **Sargent Ranch**, **Pueblo Bonito**, and **Kin Klizhin Ruins** 7.5' quadrangles, GRE staff will use the following publication: (1055) Scott, G.R., O'Sullivan, R.B., and Weide, D.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, http://pubs.er.usgs.gov/usgspubs/i/i1571.

Also, for the **Pueblo Bonito** 7.5' quadrangle, a more detailed map supersedes portions of GMAP 1055. GRE staff will use these data where the two maps are coincident. That reference is as follows: (1048) Mytton, J.W., and Schneider, G.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.

For the **La Vida Mission** quadrangle, GRE staff will digitize the following map: (1047) Miller, R.L., Carey, M.A., and Thompson-Rize, C.L., 1991, Geologic map of La Vida Mission quadrangle, San Juan and McKinley counties, New Mexico (plate 1): U.S. Geological Survey Bulletin 1940, scale 1:24,000.

For the **Pueblo Pintado** quadrangle, GRE staff will digitize the following map: (1052) Weide, D.L., Scott, G.R., and Mytton, J.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.

For the **Seven Lakes NE** and **Seven Lakes NW** quadrangles, GRE staff will digitize the following: (1057) Kover, A.N., 1960, Photogeologic map of the Chaco Canyon-2 quadrangle, McKinley County, New Mexico: U.S. Geological Survey Miscellaneous Investigation Series Map I-315, scale 1:62,500.

Also, the upcoming publication from the New Mexico Bureau of Geology & Mineral Resources will contain geologic mapping that GRE staff will attempt to acquire because these new data will match better at the edges with GMAP 1055 than GMAP 1057 does.

For the **Nose Rock** and **Milk Lake** quadrangles, GRE staff will digitize the following maps:

- (191) Dillinger, J.K., 1990, Geologic map and structure contour maps of the Gallup 30' × 60' quadrangle, McKinley County, New Mexico (sheet 2—structure contours): U.S. Geological Survey Miscellaneous Investigations Series Map I-2009, 2 sheets, scale 1:100,000.
- (1060) Dillinger, J.K., 1990, Geologic map and structure contour maps of the Gallup 30' × 60' quadrangle, McKinley County, New Mexico (sheet 1—geology): U.S. Geological Survey Miscellaneous Investigations Series Map I-2009, 2 sheets, scale 1:100,000.

For the **Heart Rock** quadrangle, GRE staff will digitize the following: (1050) Robertson, J.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.

For the **Crownpoint** quadrangle, GRE staff will digitize the following: (8387) Robertson, J.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.

The coal occurrence maps for Chaco Culture National Historical Park are available digitally, but the supplied Web sites deliver them in a compressed format called "DjVu" by LizardTech (see fig. 5). This format is non-GIS based; to view these maps, users must first download a browser plug-in from http://www.lizardtech.com/download/dl_download.php?detail=doc_djvu_plugin&platform=win.

GRE staff will incorporate the following coal occurrence maps into the digital geologic data for Chaco Culture National Historical Park:

(29890) 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 OF-79-157, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr79157.

(30911) 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 OF-79-156, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr79156.

(41629) Berge Exploration, Inc., 1979, Coal resource occurrence and coal development potential for the Kin Klizhin Ruins quadrangle, San Juan and McKinley counties, New Mexico: U.S. Geological Survey Open-File Report OF-79-1047, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr791047.

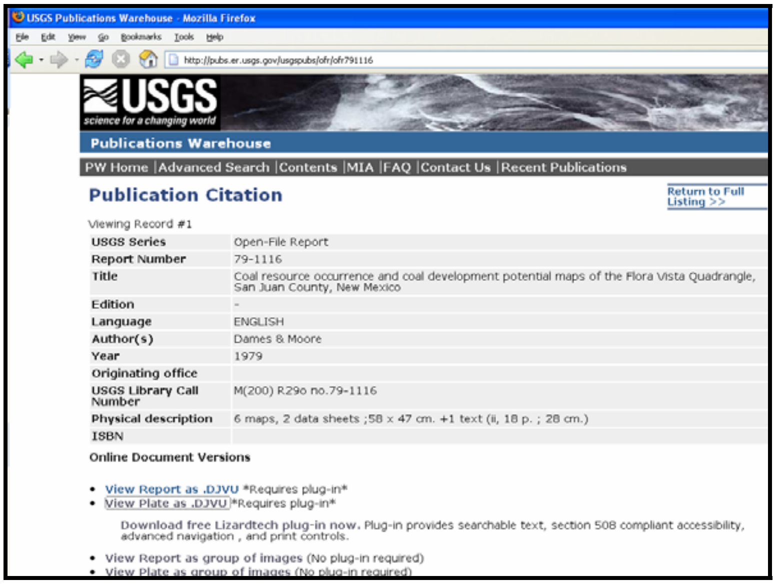

Figure 5. Screen Capture of USGS Web Site of Coal Maps.

(74539) Berge Exploration, Inc., 1979, Federal coal resource occurrence and coal development potential maps of the La Vida Mission 7½-minute quadrangle, San Juan and McKinley counties, New Mexico: U.S. Geological Survey Open-File Report OF-79-1378, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr791378.

(30647) 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 OF-79-113, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr79113.

(32096) 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 OF-79-638, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr79638.

(74537) Berge Exploration, Inc., 1979, Federal coal resource occurrence and coal development potential maps of the Seven Lakes NW 7½-minute quadrangle, McKinley County, New Mexico: U.S. Geological Survey Open-File Report OF-79-1123, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr791123.

(32099) Berge Exploration, Inc., 1979, Coal resource occurrence and coal development potential of the Nose Rock quadrangle, McKinley County, New Mexico: U.S. Geological Survey Open-File Report OF-79-641, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr79641.

(74535) Berge Exploration, Inc., 1979, Federal coal resource occurrence and coal development potential maps of the Milk Lake 7½-minute quadrangle, McKinley County, New Mexico: U.S. Geological Survey Open-File Report OF-79-1377, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr791377.

(32100) Berge Exploration, Inc., 1979, Coal resource occurrence and coal development potential of the Heart Rock quadrangle, McKinley County, New Mexico: U.S. Geological Survey Open-File Report OF-79-642, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr79642.

(41614) Dames and 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 OF-98-1125, scale 1:24,000, http://pubs.er.usgs.gov/usgspubs/ofr/ofr791125.

Specific plates from each publication are outlined in table 2 at the end of this document.

Geologic Resource Management Issues

The scoping session for Chaco Culture National Historical Park provided the opportunity to develop a list of issues that may be of concern to park managers, as well as a list of geologic features and processes in the park. These issues, features, and process will be further explained in the final GRE report. During the meeting, participants did not prioritize the issues, so they are listed alphabetically here.

Abandoned Mine Lands

During scoping, participants identified two small abandoned coal mines in the park at Marcia's Rincon and on the north slope of West Mesa. "Marcia's Rincon" was named for Marcia Truell, NPS archaeologist who led excavations in the rincon during the 1970s. These adits (horizontal openings), which predate establishment of the park, are estimated to extend 10 to 12 feet (3–4 m) into bedrock (Menefee Formation). Because these adits occur in areas of low visitation, they have not been gated. Nevertheless, GRD personnel suggested that park staff contact John Burghardt (GRD, geologist and certified mineral examiner, 303-969-2099; john_burghardt@nps.gov) for technical assistance with closure of the mine openings.

Correspondence with John Burghardt on March 13, 2007, revealed that in 1984 park staff had identified two abandoned uranium test drill holes, plus the access routes and clearing for the drill pads (Regional Director, Southwest Region, memorandum to Superintendent, Chaco Culture, October 18, 1989). According to Dave Love (written communication, May 15, 2007), "One well was east of the park on the Sargent Ranch quad at the junction of Sheep Camp Canyon and Chaco Canyon. It was drilled by Department of Energy and subcontractors at megabuck expense to look at Morrison Formation. I'm sure there's a DOE report somewhere. Access was from the northeast, down Sheep Camp Canyon, not through the park. I have a slide of the drill rig in place because we flew over the canyon in 1983. I think the other exploratory well was south or southwest of the park. It was probably also DOE, but I don't know that. I think all other uranium exploration had discontinued by then."

Birthplace of Geoarchaeology

Chaco Canyon is the birthplace of geoarchaeology. Scientists in the field of geoarchaeology study the relationships between prehistoric humans and the environment. This interdisciplinary study strives to understand archaeological sites in their natural contexts, with particular emphasis on site formation processes. Geoarchaeologists of Chaco Canyon include the following:

- 1849—J. H. Simpson and R. H. Kern described Chaco Canyon and its ruins and speculated about environmental changes during occupation of the structures.
- 1877—W. H. Jackson drew Pueblo del Arroyo and methodically described the filled-in gully. He also found the remains of a prehistoric inhabitant of the area.
- 1878—W. J. Hoffman, the physician who examined the prehistoric cranium collected by Jackson in 1877, was the first to speculate about environmental degradation as a result of human activities.

- 1920s—Neil Judd and Kirk Bryan studied the paleochannel in Chaco Canyon and proposed that human-caused environmental degradation (e.g., over-farming) forced inhabitants to leave the area.
- 1970s and 1980s—As part of the Chaco Project, Steve Hall and Dave Love looked at exposures, charcoal, and pollen and extended interpretations of environmental changes over several thousand years.

As noted in Love (2007), the attraction of Chaco Canyon to researchers has continued for more than a century and a half, including early applications of tree-ring dating and biogeochemistry, palynology, physical and chemical anthropology, remote sensing, archaeological stratigraphy, and millennial-scale environmental reconstructions using packrat middens.

Caves

Alcoves form as a result of differential weathering along the shale-sandstone contact between the Cliff House Sandstone and Menefee Formation. Although alcoves are not a particularly distinctive feature at Chaco Culture National Historical Park, they are notable for the resources they contain: packrat middens and some of the earliest datable, perishable cultural material (e.g., corn and basketry).

Distinctive Geologic Features

The "Park and Geologic Setting" section of this scoping summary mentions many of the distinctive geologic features of Chaco Culture National Historical Park and places them in their geologic contexts, for instance, the Cretaceous barrier islands. Other interesting geologic features are highlighted in "Paleontological Resources" and "Mineral Resources and Mining" sections.

According to King et al. (1985), the most striking topographic feature of the canyon is the asymmetry of the canyon walls. The northern walls consist of Cliff House Sandstone, which are very steep to vertical, ranging from 100 to 160 feet (30 to 50 m) high. The southern walls are much gentler in relief and are breached by many side canyons. The north side of the canyon is more exposed to the sun, has more evaporation and less plant growth, and is the location of the large archaeological sites (King et al., 1985). Erosional features in Chaco Canyon include the canyon itself, other tributary canyons, Fajada Butte, Chacra Mesa, and other mesas and buttes along the course of the Chaco River, which were formed by fluvial and hillslope processes during the past couple million years (Love, 2007). Sandstones are more resistant to erosion than the interbedded mudrocks, so sandstone form cliffs and mesas, whereas mudstones eroded and form slopes and valleys (Love, 2007).

Disturbed Lands

More than 315,000 acres (127,480 ha) in 195 National Park System units have been disturbed by modern human activities. Some of these features may be of historical significance, but most are not in keeping with the mandates of the National Park Service. Disturbed lands are those park lands where the natural conditions and processes have been directly impacted by development (e.g., facilities, roads, dams, abandoned campgrounds, and user trails), agricultural practices (e.g., farming, grazing, timber harvest, and abandoned irrigation ditches), overuse, or inappropriate use. Usually, lands disturbed by natural phenomena such as landslides, earthquakes, floods, hurricanes, tornadoes, and fires are not considered for restoration unless influenced by human activities.

Restoration activities return the quality and quantity of an area, watershed, or landscape to some previous condition, often some desirable historic baseline. Restoration at disturbed areas directly treats the disturbance to accelerate site recovery and should aim to permanently resolve the disturbance and its effects. For more information about disturbed lands restoration, contact Dave Steensen (GRD, Restoration Program lead) at dave_steensen@nps.gov or 303-969-2014.

According to *Chaco Culture: Backcountry Trail Guide*, in the late 1800s and early 1900s, huge herds of sheep and cattle were moved from Chama, New Mexico, into the Chaco area for winter grazing. In 1947 the National Park Service fenced the park to exclude grazing; as a result native grasses, shrubs, and wildlife have returned. However, grazing is still allowed on six Indian allotments and could occur in these areas in the future.

No commercial logging has occurred in the park, although timber was collected for personal consumption on Chacra Mesa until the 1960s. Historical CCC-vintage disturbances include berms on the floor of Chaco Canyon, which were constructed for erosion control, and a CCC camp in Marcia's Rincon.

The National Park Service mined sand and gravel in the park for administrative uses until the late 1980s. Mining sites include material from Pleistocene terraces about 1 mile (1.6 km) south of the visitor center and in Clys Canyon (for sand only). In addition, building stone for the park housing area was extracted from the north side of Gallo Wash.

From the 1950s to the early 1990s, the National Park Service disposed of solid waste in wide trenches, which were cut with backhoes on the east side of South Gap. Present park managers are planning to have these dumps tested for toxicity and mobility of waste.

Efflorescence

The stones and masonry in many of the kivas at the park are deteriorating as a result of mechanical and chemical weathering. In arid regions, a whitish, fluffy or crystalline powder is produced as a surface encrustation by evaporation of water brought to the surface by capillary action. Efflorescence may consist of one or several minerals, commonly soluble salts such as gypsum and halite (Neuendorf et al., 2005). Efflorescence may be the cause of accelerated erosion of archaeological structures.

Eolian and Lacustrine Features and Processes

According to the 2006 Pueblo Bonito trail guide, "In the late 1800s—before the advent of the first archeological protection laws—travelers, vandals, and pothunters repeatedly knocked massive holes into the back wall of Pueblo Bonito, removing the contents of the rooms this way, rather than digging into the rooms from above through many feet of windblown sand." This description is an indication of the longevity and aggressiveness of eolian processes occurring at Chaco Culture National Historical Park.

Currently, dust storms are frequent in the spring, and dunes used to cover the old entry road (north) into the park. Additionally, eolian soils have been mapped on mesa tops in the park. Scoping participants mentioned huge sand dunes in tributary canyons such as Weritos Rincon and Pueblo Pintado. As an indicator of age, the Crownpoint dune overlies a 6,900-year-old turtle fossil, which has been dated using carbon-14. Dunes appear as unit Qes on existing geologic maps.

The idea that a sand dune dammed Chaco Wash and created a lake has worked itself into the literature (e.g., Force et al., 2002). Such information is included in *Chaco Culture Backcountry Trail Guide* (p. 23). Creation of so-called "Lake Chaco" is surmised to have happened on several occasions and has been associated with a prehistoric wall, which Chacoan people built to actively manage the dune/dam. Dave Love (New Mexico Bureau of Geology & Mineral Resources) and others at the GRE scoping meeting were skeptical of this idea, particularly because the existence of a lake has not been verified nor has the age of the dune been established. Hence, the existence of a lake and its connection with Chacoan activities has not been scientifically validated.

Rather than ancient Lake Chaco ever being a source of surface water at Chaco Culture, participants suggested that natural potholes, called tinajas, may have been and continue to be a source of surface water within the park. Tinajas also provide seasonal habitat for wildlife and microorganisms.

Fluvial Features and Processes

Humans have repeatedly modified the channel of Chaco Wash for agricultural purposes. Erosion control measures beginning in the 1900s, but intensively in the 1930s–1960s, involved planting exotic vegetation (e.g., tamarisk and globe-pod hoary cress); this practice has affected stream hydrology. Park staff is controlling tamarisk in certain areas where spreading is extensive, channel morphology is changing, and cultural resources are being affected. In addition, the CCC graded berms in Gallo and Chaco washes, and the National Park Service built gabions along streams for channel stabilization. The Southern Colorado Plateau Network is developing a protocol to monitor changes in stream channel morphology, although funding is uncertain.

At present Chaco Wash is either in equilibrium or aggrading. Lateral movement of the stream channel and migration within the arroyo is occurring but is considered stable. Active sheetwash (deposition and erosion) occurs during monsoon-related flash floods.

Hillslope Processes

Common rockfall events are associated with the Cliff House Sandstone and Menefee Formation. Park staff estimates that significant rockfall events occur several times per year in developed areas. Based on Wachter (1985), park staff has established 18 monitoring sites on the cliffs above the housing area, which is the prime area of concern. Park staff checks these sites twice per year (Brad Shattuck, CHCU, personal communication, March 9, 2007). According to Wachter (1985), "any verifiable motion in any of these rock masses is cause for concern and should be followed by more frequent measurements, geologic examination and some means of hazard reduction." Motion could be sporadically reinitiated by earthquakes, unusually wet cycles, an abundance of freeze-thaw cycles, and construction vibrations (Wachter, 1985).

The sheet joints parallel to the rock face could be used as indicators of rockfall hazards in other areas; unfortunately these features are not mapped on *Geologic Map of the Chaco Culture National Historical Park, Northwestern New Mexico* (Scott et al., 1984), which will be incorporated into the digital geologic map for the park. However, meeting participants thought that this information could be retrieved from aerial photos that were used during soil mapping and incorporated into the geologic map.

Rockfall events are part of the overall erosion/widening of Chaco Canyon, which is a direct response to the Menefee Formation eroding from underneath the overlying Cliff House Sandstone. The undermined sandstone breaks away in blocks and tumbles into the canyon. This has led to the creation of the striking cliff faces and the talus slopes that rest at the base of the cliffs. One of the most dramatic examples of a massive rockfall is the immense slab of sandstone known as "Threatening Rock." When the ancient builders were constructing Pueblo Bonito, Threatening Rock rested in a precarious position just behind it. Aware of the danger it posed, the Chacoans built an earth and masonry retaining wall beneath this massive rock slab. The slab was first described in 1901 and was referred to as the "Elephant;" the Navajos called it "Braced-up Cliff," and the National Park Service coined "Threatening Rock." In an attempt to predict the fall of Threatening Rock, the National Park Service began monitoring its movement. However, very little could be done to prevent its fall, and on January 22, 1941, Threatening Rock collapsed and destroyed approximately 60 rooms of Pueblo Bonito.

Mineral Resources and Mining

The towering cliffs provided the Chacoans with ample building stone, which they quarried to construct the impressive great kivas (National Park Service, 2006). Most of the rock used at the height of Chacoan construction was quarried from a layer of dense, dark sandstone that capped the cliffs just behind the Chacoan great houses. Once quarried, it was probably dropped to the canyon floor where it would be shaped and dressed (Strutin, 1994). Stone for later buildings (early 12th century) likely was quarried from the softer sandstone near the base of the cliffs (Strutin, 1994). Some archaeologists believe that by the last quarter of the

11th century, much of the dark, dense stone used for classic Chacoan building had been stripped from the rim of the cliffs. The masonry style changes of the later buildings may have been due to this resource shortage, though new ideas and approaches to building were being adapted at Chaco and other regions at the time (Strutin, 1994).

Chacoan people used both local and "foreign" materials for fabricating tools, arts and crafts, and ceremonial items. From the Menefee Formation, burned coal seams (i.e., clinker), locally known as "red dog," was used for making tools and beads. Concretions from the Cliff House Sandstone decorated floors in kivas and may have possessed a particular Chacoan "value" or source of "power." Originally reduction of iron produced the iron-sulfide concretions; later, with near-surface weathering, oxidation of iron formed the red-brown colors of the concretions. Coal seams are clearly visible in Menefee Formation throughout the park, though Chacoan people are not known to have used coal for heating or cooking. Selenite crystals occur in some coal deposits.

Owners of nine Indian allotments have the authority to extract minerals on their lands; however, scoping meeting participants thought that this was unlikely because the parcels of land are small and no one lives there (i.e., use for personal consumption to heat homes). Potential coal leasing in the vicinity of Chaco Culture National Historical Park initiated a boundary expansion and designation change to national historical park status in 1980 to protect the lands from the impacts of coal mining.

Oil and Gas Development

New Mexico has some of the most significant energy reserves (e.g., oil, gas, coal, and uranium) in the lower 48 states and has been and will continue to be a major player in the energy future of the United States (Brister and Price, 2002). In particular, the northwestern portion of the state, the San Juan Basin, has played a vital role in the energy business and overall economy of New Mexico (Brister and Price, 2002). The San Juan Basin is the second largest source of natural gas in the United States. Chaco Culture National Historical Park is located in this basin, so oil and gas development in the vicinity of the park is a management concern. Potential impacts to park resources and values include scenic views, quiet, night skies, water and air quality, wildlife, and vegetation.

In March 2007, Superintendent Barbara West contacted the NPS Geologic Resources Division (GRD) for assistance regarding proposed oil and gas drilling adjacent to the park; Kerry Moss was the GRD lead on this project (303-969-2634; kerry_moss@nps.gov). Park staff provided GRD staff with photos and maps depicting the relatively flat, open terrain proposed for oil and gas development, only 1 mile (1.6 km) from the park boundary. The Geologic Resources Division contacted the State of New Mexico in order to minimize the short- and long-term impacts on irreplaceable park resources resulting from adjacent oil and gas development. On March 28, 2007, the *Albuquerque Journal* reported that State Land Commissioner Patrick Lyons "is pulling the plug on two oil wells proposed for just outside Chaco Canyon." After being inundated with complaints about allowing drilling so close to a national treasure, representatives of the state land commission office said they will ask the Colorado energy company, Cimarex Energy, to trade its oil and gas leases for different parcels of state trust land. If the company does not want to trade the leases, the land office will reject the application and refund the $10,000 that Cimarex paid for the leases. Moreover, Assistant Land Commissioner John Bemis said the office will begin to identify other tracts of state trust land where development might harm historical sites. The office could withdraw the tracts from leasing or trade the parcels to other agencies. This type of action would potentially build a "buffer" around Chaco Culture.

Uranium Development

Uranium prices are skyrocketing in anticipation of a future supply shortfall (Bland and Scholle, 2007). Spot market prices were $72 per pound as of January 2007, having risen six-fold in the last three years. High prices provide strong incentive for mining companies to explore and develop new mines and reopen old ones. According to the New Mexico Bureau of Geology & Mineral Resources, Strathmore Resources; Neutron

Energy, Inc.; Western Energy Development Corporation; and Urex Energy Corporation all submitted exploration permit applications to the state Mining and Minerals Division in 2006. Hydro Resources, Inc. is currently obtaining permits for uranium in situ leach extraction at two sites. All of these recent activities are in the Grants-Gallop area (Bland and Scholle, 2007), south of the park.

Closer to park boundaries, uranium mining has occurred near the Kin Ya'a unit. In the 1970s, the Department of Energy drilled a deep uranium test well east of the park on the Sargent Ranch 7.5-minute quadrangle. Uranium mining has occurred south of the park near Crownpoint and Ambrosia Lakes in the Morrison Formation. Adjacent energy development could affect park resources with water quality in the park being a major concern.

Paleontological Resources

Characteristic of their marine history, Cretaceous rocks are known to be fossiliferous (Siemers and King, 1974). For instance, the Menefee Formation contains fossil turtles, fish, and crocodiles, as well as fragments of hadrosaur dinosaurs and giant marine lizards known as mosasaurs. Plant fossils in the Menefee Formation include leaf impressions (e.g., palm and conifer), which closely resemble modern-day laurel, witch hazel, and camellia. At one point, the University of New Mexico, Earth and Planetary Sciences, housed the Siemers and King collection; however, these fossils may have been discarded during the "great purge" of the 1980s (Dave Love, written communication, May 15, 2007). Barry Kues, UNM professor, would be the person to contact about this collection (bkues@unm.edu, 505 277-3626).

Shark teeth and shells and casts from clams, ammonites, and snails are known from the Cliff House Sandstone. Because of their sheer number, shrimp (*Callianasa*) burrows—bioturbation in shoreface and shallow seafloor sediments—are noteworthy in the Cliff House Sandstone; the fossil burrows themselves are called *Ophiomorpha nodosa*.

As of April 2006, Tom Lyttle and Donna Smith, volunteers from the Los Alamos National Laboratory, had completed initial paleontological inventories of four of the units at Chaco Culture National Historical Park (i.e., Kin Bineola, Pueblo Pintado, Kin Ya'a, and Kin Klizhin). Significant finds include vertebrate fossils and upright tree stumps in the Menefee Formation. Lyttle and Smith are potentially continuing their work in summer 2007. During scoping, Brad Shattuck (CHCU) mentioned an interest in submitting a proposal for a Geoscientist-in-the-Park (GIP) to assist with preservation and documentation of the vertebrate fossils. In addition, Lisa Boucher (University of Nebraska) is studying the park's paleoecology and fossil flora, in particular petrified wood from the Menefee Formation. Scoping participants mentioned Pleistocene gravels as having potential for Quaternary fossils (e.g., camel or horse).

Piping

According to the USGS "Water Basins Glossary" at http://capp.water.usgs.gov/GIP/h2o_gloss/, piping is "erosion by percolating water in a layer of subsoil, resulting in caving and in the formation of narrow conduits, tunnels, or 'pipes' through which soluble or granular soil material is removed." Participants identified soil pipes as being active at Chaco Culture National Historical Park, particularly in Chaco Wash. Soil pipes are prevalent and affect cultural resources; they also provide bat habitat. According to Simons et al. (1982), some of the pipes extend hundreds of feet from the wash. Many, but not all, of the pipes have an outlet into the arroyo. Most of these outlets are in the arroyo walls, perched above the floor of the arroyo. As the pipes enlarge over time, the overlying material collapses: a small side ravine to the main arroyo forms.

At Chaco Culture National Historical Park, piping is a specific problem with the Notal and Battlerock soils (Pete Biggam, GRD, e-mail communication, February 23, 2007). During the original scoping session about soils, participants addressed the issue of piping. As a result, soil mapping focused on this management issue. The NPS Soils Program worked with park staff to identify problem areas. Park staff is referred to *Soil Survey* *of Chaco Culture National Historical Park, New Mexico* (Zschetzsche and Clark, 2004) and may contact Pete Biggam (NPS Soil Program Manger) at pete_biggam@nps.gov or 303-987-6948 with further questions.

Seismic Hazards

The U.S. Geological Survey classifies this area as having a low seismic hazard potential. No active faults occur in the park. The nearest well-defined seismic hazard zone is approximately 50 miles (80 km) southwest of Chaco Canyon (King et al., 1985). The closest deep earthquake (magnitude 4.3 on the Richter scale) occurred in 1966 near Crownpoint. According to King et al. (1985), ground motion from earthquakes could cause damage to the structures in the park.

King et al. (1985) analyzes the risk to the larger structures resulting from possible ground shaking associated with earthquakes, blasting, road building, and vehicular traffic. Based on normal blasting practices in the area, conventional rail traffic, usage of road building equipment, and normal vehicular traffic patterns, the report recommends that structures be a minimum distance of 0.7 mile (1.2 km) from blasting, 0.3 mile (0.5 km) from railroad traffic, 148 feet (45 m) from road building, and 82 feet (25 m) from vehicular traffic. As a result of these recommendations, in 1995 the National Park Service rerouted a park road to avoid vibration damage to cultural sites. This reroute closed the portion of State Road 57 from the park's north boundary, down Cly Canyon, to Pueblo del Arroyo. This route had passed within 50 feet (15 m) of Casa Chiquita, Kin Kletso, and Pueblo del Arroyo (Dabney Ford, CHCU, e-mail communication, March 19, 2007). Scoping participants surmised that present blasting in conjunction with coal mining is not close enough to cause damage to park structures or cultural sites.

Volcanic Features

The closest volcano to Chaco Culture National Historical Park is 70 miles (113 km) to the south at El Malpais National Monument. The volcanic rocks at El Malpais are part of the Zuni–Bandera volcanic field, which is on the Jemez lineament. The Jemez lineament is a zone of crustal weakness that shows a striking alignment of relatively young volcanic features. The most recent explosive event at El Malpais occurred approximately 3,800 years ago and produced the youngest lava flow in New Mexico—the McCartys flow.

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Table 1. Scoping Meeting Participants

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Table 2. GRE List of Maps for Chaco Culture National Historical Park

GMAP ID	Reference	GRE appraisal	GRE action	URL	Scale
1047	Miller, R.L., Carey, M.A., and Thompson-Rize, C.L., 1991, Geologic map of La Vida Mission quadrangle, San Juan and McKinley counties, New Mexico (plate 1): U.S. Geological Survey Bulletin 1940, scale 1:24,000.	2007-0302: GRE has digitized this; needs QC; ancillary information from USGS bulletin to be incorporated as well	Digitization	E:\gis-nps_by_gmap_id\1047_la_vida_mission_NM_7.5'	24000
1048	Mytton, J.W., and Schneider, G.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.	2007-0302: covers ⅔ of CHCU QOI for Pueblo Bonito 7.5' up to park boundary and is much more detailed than GMAP 1055 of the same area, so GRE used this; GRE has already digitized it; needs QC	Digitization	E:\gis-nps_by_gmap_id\1048_chaco_area	24000
1050	Robertson, J.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.	2007-0302: CHCU QOI; GRE has it digitized, needs QC; supercedes GMAP 1060. Also has structure contours superceding GMAP 1060	Digitization	E:\gis-nps_by_gmap_id\1050_heart_rock_NM_7.5'	24000
1052	Weide, D.L., Scott, G.R., and Mytton, J.W., 1980, Geologic map of the Pueblo Pintado quadrangle, McKinley County, New Mexico: U.S. Geological Survey Miscellaneous Field Investigations MF-1219, scale 1:24,000.	2007-0302: CHCH QOI; GRE has already digitized, needs QC; black-and-white map	Digitization	E:\gis-nps_by_gmap_id\1052_pueblo_pintado_NM_7.5'	24000
8387	Robertson, J.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.	2007-0302: CHCU QOI; GRE currently digitizing; supercedes GMAP 1060. Also has structure contours superceding GMAP 1060. Not true QOI for CHCU, but park staff requested it, so GRE incorporated	Digitization	E:\gis-nps_by_gmap_id\8387_crownpoint	24000
29890	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 OF-79-157, scale 1:24,000.	2007-0301: 20-page report to incorporate; 9 plates. Digitize plate 1 (coal map) and capture information from plate 3 (coal sheet).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr79157	24000
30647	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 OF-79-113, scale 1:24,000.	2007-0301: 22-page report to incorporate; 12 plates. Digitize plate 1 (coal map) and capture information from plate 3 (coal sheet).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr79113	24000
30911	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 OF-79-156, scale 1:24,000.	2007-0301: 16-page report to incorporate; 3 plates. Digitize plate 1 (coal map) and capture information from plate 3 (coal sheet).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr79156	24000
32096	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 OF-79-638, scale 1:24,000.	2007-0301: 23-page report to incorporate; 17 plates. Digitize plate 1 (coal map) and capture information from plate 3 (coal sheet).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr79638	24000
32099	Berge Exploration, Inc., 1979, Coal resource occurrence and coal development potential of the Nose Rock quadrangle, McKinley County, New Mexico: U.S. Geological Survey Open-File Report OF-79-641, scale 1:24,000.	2007-0301: 16-page report to incorporate; 9 plates. Digitize plate 1 (coal map) and capture information from plate 3 (coal sheet).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr79641	24000
32100	Berge Exploration, Inc., 1979, Coal resource occurrence and coal development potential of the Heart Rock quadrangle, McKinley County, New Mexico: U.S. Geological Survey Open-File Report OF-79-642, scale 1:24,000.	2007-0301: 15-page report to incorporate; 4 plates. Digitize plate 1 (coal map) and capture information from plate 3 (coal sheet).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr79642	24000
41614	Dames and 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 OF-98-1125, scale 1:24,000.	2007-0301: 18-page report to incorporate; 7 plates. Digitize plate 1 (coal map) and capture information from plate 3 (coal sheet).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr791125	24000

GMAP ID	Reference	GRE appraisal	GRE action	URL	Scale
41629	Berge Exploration, Inc., 1979, Coal resource occurrence and coal development potential for the Kinklizhin Ruins quadrangle, San Juan and McKinley counties, New Mexico: U.S. Geological Survey Open-File Report OF-79-1047, scale 1:24,000.	2007-0301: 13-page report to incorporate; 2 plates. Digitize plate 1(coal map).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr791047	24000
74535	Berge Exploration, Inc., 1979, Federal coal resource occurrence and coal development potential maps of the Milk Lake 7½-minute quadrangle, McKinley County, New Mexico: U.S. Geological Survey Open-File Report OF-79-1377, scale 1:24,000.	2007-0301: 20-page report to incorporate; 11 plates. Digitize plate 1 (coal map) and capture information from plate 3 (coal sheet).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr791377	24000
74537	Berge Exploration, Inc., 1979, Federal coal resource occurrence and coal development potential maps of the Seven Lakes NW 7½-minute quadrangle, McKinley County, New Mexico: U.S. Geological Survey Open-File Report OF-79-1123, scale 1:24,000.	2007-0301: 22-page report to incorporate; 10 plates. Digitize plate 1 (coal map) and capture information from plate 3 (coal sheet).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr791123	24000
74539	Berge Exploration, Inc., 1979, Federal coal resource occurrence and coal development potential maps of the Vida Mission 7½-minute quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey Open-File Report OF-79-1378, scale 1:24,000.	2007-0301: 20-page report to incorporate; 8 plates. Digitize plate 1 (coal map) and capture information from plate 3 (coal sheet).	Digitization	http://pubs.er.usgs.gov/usgspubs/ofr/ofr791378	24000
1055	Scott, G.R., O'Sullivan, R.B., and Weide, D.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.	2007-0302: covers 3 quadrangles of interest (QOI) for CHCU (Sargent Ranch, Pueblo Bonito, Kin Klizhin Ruins); however, GMAP 1048 supercedes it in part of the Pueblo Bonito 7.5', but is main source for rest of area it covers. GRE has it digitized and QC.	Digitization	http://pubs.er.usgs.gov/usgspubs/i/i1571	50000
1057	Kover, A.N., 1960, Photogeologic map of the Chaco Canyon-2 quadrangle, McKinley County, New Mexico: U.S. Geological Survey Miscellaneous Investigations Series Map I-315, scale 1:62,500.	2007-0302: gives four total 7.5' quads, but only two CHCU QOIs for Seven Lakes NE, Seven Lakes NW; other two not QOIs (Seven Lakes SE, Seven Lakes 7.5's). GRE digitized two QOIs for CHCU. The small triangle of CHCU in Seven Lakes NE should be superceded by newer unpublished NMBGMR mapping by Dave Love in the CHCU report he showed at scoping; GRE staff needs to acquire this enhanced piece.	Digitization	E:\gis-nps_by_gmap_id\1057_photogeologic	62500
191	Dillinger, J.K., 1990, Geologic map and structure contour maps of the Gallup 30' × 60' quadrangle, McKinley County, New Mexico (sheet 2—structure contour): U.S. Geological Survey Miscellaneous Investigations Series Map I-2009, 2 sheets, scale 1:100,000.	2007-0302: structure contours for two CHCU QOIs (Nose Rock, Milk Lake); supplements GMAP 1060 for these two QOIs	Digitization	E:\gis-nps_by_gmap_id\191_gallup_NM_30x60_STRUCTURE-CONTOUR	100000
1060	Dillinger, J.K., 1990, Geologic map and structure contour maps of the Gallup 30' × 60' quadrangle, McKinley County, New Mexico (sheet 1—geology): U.S. Geological Survey Miscellaneous Investigations Series Map I-2009, 2 sheets, scale 1:100,000.	2007-0302: gives two CHCU QOIs that don't have dedicated 7.5' coverage (Nose Rock, Milk Lake); other quads contained in this publication are superceded where they interest GRE (e.g., GMAP 1050 [Heart Rock 7.5'] supercedes this for Heart Rock; GMAP 8387 for Crownpoint). Wonder how well this edge-matches with La Vida Mission 7.5' (GMAP 1047) which is north of Milk Lake and Kin Klizhin Ruins (on GMAP 1055), which is north of Nose Rock	Digitization	E:\gis-nps_by_gmap_id\1060_gallup_NM_30x60	100000