

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



Rainbow Bridge National Monument

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Rainbow Bridge National Monument

rabr_geology.pdf

Version: 6/3/2021

Geologic Resources Inventory Map Document for Rainbow Bridge National Monument

Table of Contents

Geologic Resources Inventory Map Document.....	1
About the NPS Geologic Resources Inventory Program.....	3
GRI Digital Map and Source Map Citation.....	5
Index Map	6
Map Unit List	7
Map Unit Descriptions.....	8
Qae - Alluvial and eolian deposits (Holocene)	8
Qae2 - Level-2 alluvial and eolian deposits (Holocene).....	8
Qmt - Talus deposits (upper Pleistocene to Holocene).....	8
Qmte - Talus deposits and eolian sand (upper Pleistocene to Holocene).....	8
Qe - Eolian sand (middle(?) Pleistocene to Holocene).....	8
Qea - Eolian and alluvial sand and silt (middle(?) Pleistocene to Holocene).....	8
Qagm - Intermediate alluvial gravel deposits (middle to upper Pleistocene).....	9
Qago - Older alluvial gravel deposits (lower to middle Pleistocene).....	9
Qatg - Alluvial river terrace deposits with older alluvial gravel (lower Pleistocene to Holocene).....	9
Jms - Morrison Formation, Salt Wash Member (Upper Jurassic).....	11
J-5 unconformity.....	11
Entrada Sandstone (Middle to Upper Jurassic).....	12
Jem - Entrada Sandstone, middle member (Middle Jurassic to Upper Jurassic).....	12
Jel - Entrada Sandstone, lower member (Middle Jurassic to Upper Jurassic).....	12
Jc - Carmel Formation (Middle Jurassic).....	12
Jp - Page Sandstone? (Middle Jurassic).....	12
J-? unconformity.....	12
Jn - Navajo Sandstone (Lower Jurassic).....	13
Jnl - Navajo Sandstone, limestone beds (Lower Jurassic).....	13
Jk - Kayenta Formation (Lower Jurassic).....	13
Ancillary Source Map Information.....	14
Lower San Juan River Area (Rainbow Bridge NMN area).....	14
Index to USGS 7.5' Quadrangles.....	14
Index to USGS 30' x 60' Quadrangles.....	15
Explanation of Map Symbols.....	16
Report	17
Figures	18
Figure 1: San Juan River from Honaker Trail in Goosenecks area.....	18
Figure 2: San Juan River near Government Rapids at sunset.....	19
Figure 3 San Juan River downstream from Grand Gulch.....	19
Figure 4: Near Clay Hills Crossing	20
Figure 5: Near Clay Hills Crossing at The Portal looking upstream.....	20
Figure 6: San Juan River near Mikes Mesa.....	21
Figure 7: Looking downstream toward Rock Spring syncline and Balanced Rock anticline near Nokai Dome	22
Figure 8: Steep east flank of Balanced Rock anticline.....	22
Figure 9: Kayenta Formation overlain by rounded cliffs of Navajo Sandstone in San Juan arm of Lake Powell	23
Figure 10: Looking down Cottonwood Canyon toward northwest.....	24

Figure 11: Wall of Wingate Sandstone, Kayenta Formation, and Navajo Sandstone near The Rincon on main channel	25
Figure 12: Rainbow Bridge in basal Navajo Sandstone. Kayenta Formation forms footing of bridge.....	25
Figure 13: Rainbow Bridge.....	26
References.....	26
Additional Information.....	30
GRI Digital Data Credits.....	31

Geologic Resources Inventory Map Document



Rainbow Bridge National Monument, Utah

Document to Accompany Digital Geologic-GIS Data

[rabr_geology.pdf](#)

Version: 6/3/2021

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Rainbow Bridge National Monument, Utah (RABR).

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.

This document contains the following information:

- 1) **About the NPS Geologic Resources Inventory Program** – A brief summary of the Geologic Resources Inventory (GRI) Program and its products. Included are web links to the GRI GIS data model, and to the GRI products page where digital geologic-GIS datasets, scoping reports and geology reports are available for download. In addition, web links to the NPS Data Store and GRI program home page, as well as contact information for the GRI coordinator, are also present.
- 2) **GRI Digital Map and Source Citation** – A listing of the GRI digital geologic-GIS map produced for this project along with the source used in its completion. In addition, a brief explanation of how the source was used is provided.
- 3) **Map Unit List** – A listing of all geologic map units present on maps for this project, listed from youngest to oldest.
- 4) **Map Unit Descriptions** – Descriptions for all geologic map units.
- 5) **Ancillary Source Map Information** – Additional source map information. This includes index maps, an explanation of map symbols, a brief report, figures (photographs with captions), references and additional source map information.
- 6) **GRI Digital Data Credits** – GRI digital geologic-GIS data and ancillary map information document production credits.

For information about using GRI digital geologic-GIS data contact:

Stephanie O'Meara
Geologist/GIS Specialist/Data Manager
Colorado State University Research Associate, Cooperator to the National Park Service
Fort Collins, CO 80523
phone: (970) 491-6655
e-mail: stephanie_o'meara@partner.nps.gov

About the NPS Geologic Resources Inventory Program

Background

The Geologic Resources Inventory (GRI) provides geologic map data and pertinent geologic information to support resource management and science-informed decision making in more than 270 natural resource parks throughout the National Park System. 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 GRI is one of 12 inventories funded by the National Park Service (NPS) Inventory and Monitoring Program. The Geologic Resources Division of the NPS Natural Resource Stewardship and Science Directorate administers the GRI. The NPS Geologic Resources Division partners with the Colorado State University Department of Geosciences to produce GRI products. Many additional partners participate in the GRI process by contributing source maps or reviewing products.

The GRI team undertakes three tasks for each park in the Inventory and Monitoring program: (1) conduct a scoping meeting and provide a summary document, (2) provide digital geologic map data in a geographic information system (GIS) format, and (3) provide a GRI report. These products are designed and written for nongeoscientists.

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: <https://www.nps.gov/articles/gri-geodatabase-model.htm>

Geologic Reports: GRI reports synthesize discussions from the original scoping meeting, follow up conference call(s), and subsequent research. Chapters of each report discuss the geologic setting of the park, distinctive geologic features and processes within the park, highlight geologic issues facing resource managers, and describe the geologic history leading to the present-day landscape. Each report also includes a poster illustrating these GRI digital geologic-GIS data.

For a complete listing of GRI products visit the GRI publications webpage: <https://go.nps.gov/gripubs>. GRI digital geologic-GIS data is also available online at the NPS Data Store: <https://irma.nps.gov/DataStore/Search/Quick>. 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: <https://www.nps.gov/subjects/geology/gri.htm>. At the bottom of that webpage is a "Contact Us" link if you need additional information. You may also directly contact the program coordinator:

Jason Kenworthy
Inventory Coordinator
National Park Service Geologic Resources Division
P.O. Box 25287
Denver, CO 80225-0287
phone: (303) 987-6923
fax: (303) 987-6792
email: Jason_Kenworthy@nps.gov

The Geologic Resources Inventory (GRI) program is funded by the National Park Service (NPS) Inventory and Monitoring (I&M) Division. Learn more about I&M and the 12 baseline inventories at the I&M webpage: <https://www.nps.gov/im/inventories.htm>.

GRI Digital Map and Source Map Citation

The GRI digital geologic-GIS map for Rainbow Bridge National Monument, Utah (RABR):

Digital Geologic-GIS Map of Rainbow Bridge National Monument and Vicinity, Utah (*GRI MapCode RABR*)

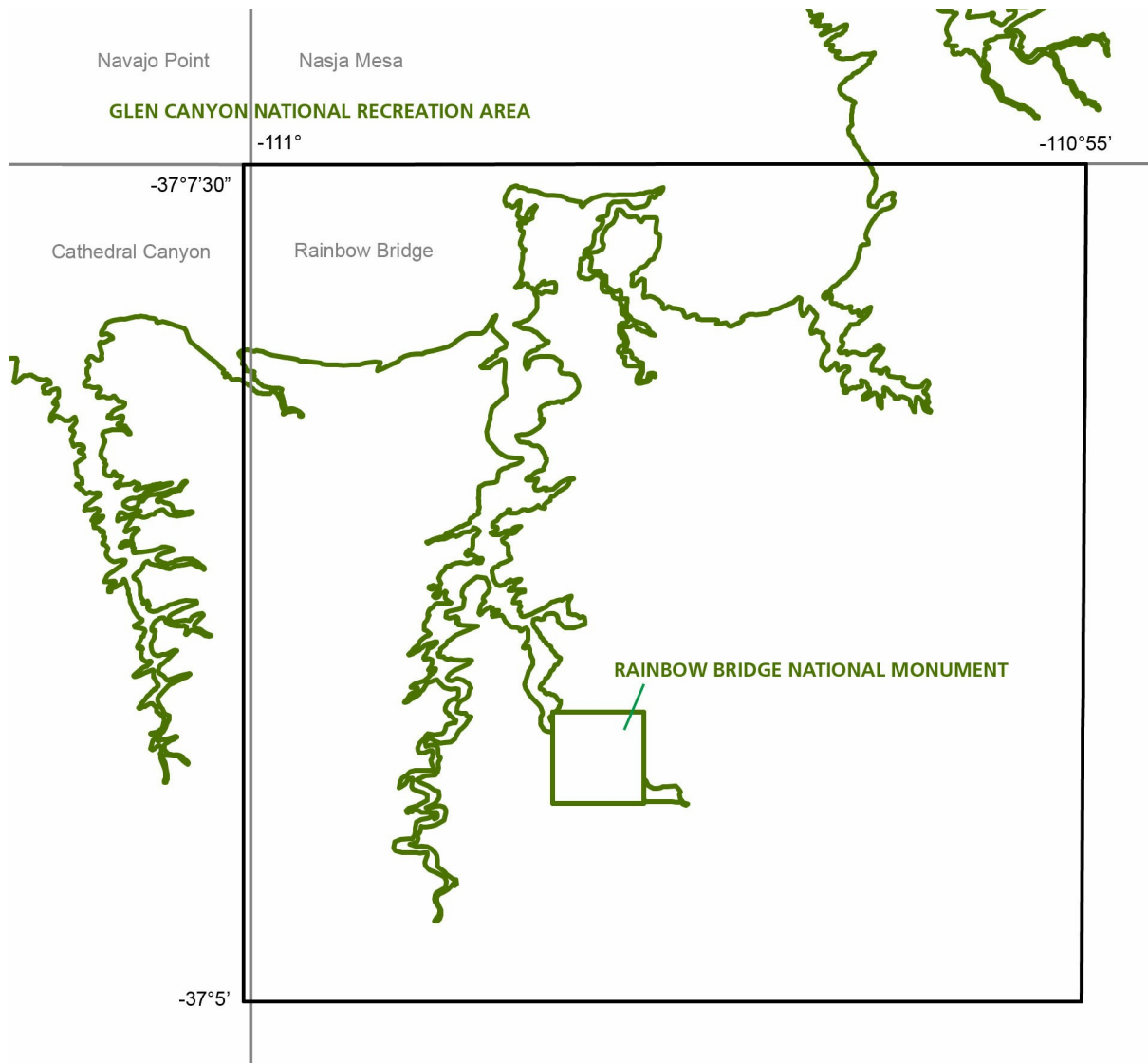
The map was produced using the following source map. Only a portion of the source map was used, however, all geologic features within this extent were used.

Willis, Grant C., 2004, Interim Geologic Map of the Lower San Juan River Area, Eastern Glen Canyon National Recreation Area and Vicinity, San Juan County, Utah: Utah Geological Survey, Open-File Report 443DM, 2 plates, scale 1:24,000 ([Lower San Juan River Area \(Rainbow Bridge NMON area\)](#)). (*GRI Source Map ID 7331*).

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

Index Map

The following index map displays the extent of the GRI digital geologic-GIS map (black line) produced for Rainbow Bridge National Monument (RABR). The bounding coordinates of the map are also shown. The boundary for Rainbow Bridge National Monument (as of June 2021) is displayed in green. The extent of Glen Canyon National Recreation Area (GLCA) is also shown (also in green). 7.5' quadrangles adjacent to or that encompass the GRI digital geologic-GIS map extent are shown in gray.



Index map by Stephanie O'Meara (Colorado State University).

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Rainbow Bridge National Monument, Utah (RABR) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qae - Alluvial and eolian deposits). Units are listed from youngest to oldest. No description for water is provided. Information about each geologic unit is also presented in the GRI Geologic Unit Information (RABRUNIT) table included with the GRI digital geologic-GIS data. Recognized unconformities are also listed.

Cenozoic Era

Quaternary Period

[Qae](#) - Alluvial and eolian deposits

[Qae2](#) - Level-2 alluvial and eolian deposits

[Qmt](#) - Talus deposits

[Qmte](#) - Talus deposits and eolian sand

[Qe](#) - Eolian sand

[Qea](#) - Eolian and alluvial sand and silt

[Qagm](#) - Intermediate alluvial gravel deposits

[Qago](#) - Older alluvial gravel deposits

[Qatq8](#) - Level 8 Alluvial river terrace deposits with older alluvial gravel

[Qatq9](#) - Level 9 Alluvial river terrace deposits with older alluvial gravel

[Qatq12](#) - Level 12 Alluvial river terrace deposits with older alluvial gravel

Mesozoic Era

Jurassic Period

[Jms](#) - Morrison Formation, Salt Wash Member

~ [J-5 unconformity](#) ~

[Jem](#) - Entrada Sandstone, middle member

[Jel](#) - Entrada Sandstone, lower member

[Jc](#) - Carmel Formation

[Jp](#) - Page Sandstone?

~ [J-? unconformity](#) ~

[Jn](#) - Navajo Sandstone

[Jnl](#) - Navajo Sandstone, limestone beds

[Jk](#) - Kayenta Formation

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below. All unit description form source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Qae - Alluvial and eolian deposits (Holocene)

Boulder to pebble gravel, sand, silt, and clay deposited in small drainages, mixed with windblown sand and silt; poorly to moderately sorted; locally include large angular boulders from rock falls, landslides, and debris flows; clast composition reflects local lithologies; similar in composition and setting to Qa and Qac deposits except has larger eolian component, especially in areas protected from active erosion; includes deposits in active part of wash and up to about 40 feet (12 m) above wash floor; 0 to 20 feet (0-6 m) thick.

Qae2 - Level-2 alluvial and eolian deposits (Holocene)

Similar in composition and setting to some Qae deposits; differentiated where levels are large enough to be mappable at this scale; incised by active washes forming inactive terraces and benches 20 to 40 feet (6-12 m) above adjacent wash; generally has eolian mantle since upper surface is isolated from most alluvial erosion; 0 to 20 feet (0-6 m) thick.

Qmt - Talus deposits (upper Pleistocene to Holocene)

Very poorly sorted, angular blocks mixed with minor fine-grained materials deposited on steep slopes; composed primarily of accumulated rock-fall debris; commonly includes minor to moderate amounts of eolian sand; 0 to 30 feet (0-9 m) thick.

Qmte - Talus deposits and eolian sand (upper Pleistocene to Holocene)

Similar to Qmt deposits except commonly blanketed by moderate to large amounts of eolian sand that locally completely covers the rock fall debris; 0 to 30 feet (0-9 m) thick.

Qe - Eolian sand (middle(?) Pleistocene to Holocene)

Well- to very well sorted, well-rounded sand with minor silt deposited by wind; forms poorly to well developed dunes, mounds, and sheet-like deposits in depressions and areas protected from erosion for long periods of time; locally slightly reworked by alluvial processes and burrowing animals; mostly derived from and present on upper surface of Navajo Sandstone; residual lag of underlying rock is common; 0 to 50 feet (0-15 m) thick.

Qea - Eolian and alluvial sand and silt (middle(?) Pleistocene to Holocene)

Well- to very well sorted, well-rounded sand and silt deposited by wind locally mixed with sand, silt, and fine gravel deposited by alluvial processes; forms poorly developed dunes, mounds, and sheet-like deposits in depressions and areas protected from erosion for long periods of time; similar in setting and composition to Qe deposits except evidence of alluvial activity is more common and dune forms are less developed; mostly derived from and present on upper surface of Navajo Sandstone; residual lag of underlying rock is common; 0 to 50 feet (0-15 m) thick.

Qagm - Intermediate alluvial gravel deposits (middle to upper Pleistocene)

Poorly to moderately sorted boulder to cobble gravel with varying amounts of sand, silt, and clay; clasts are mostly angular to subrounded, well-silicified sandstone and conglomerate boulders up to 6 feet (2 m) in diameter; many clasts were derived from the Jurassic Morrison Formation, and most have a dark-brown weathering patina that gives deposits a dark-brown to brownish-black color; consist of terrace-like remnants of alluvium and debris flow materials deposited in channels draining the flanks of Navajo Mountain; probably mostly reworked from Qago deposits; generally on benches and slopes 20 to 100 feet (6-30 m) above the floor of small streams and washes, but still within the canyons; 0 to 30 feet (0-9 m) thick.

Qago - Older alluvial gravel deposits (lower to middle Pleistocene)

Similar to Qagm deposits described above, but form pediment like mantle over sloping benches, and commonly have thick pedogenic carbonate accumulation in upper part of deposit; consist of remnants of alluvial pediment mantle and debris flow deposits that probably once formed an alluvial-fan apron around the flanks of Navajo Mountain; cap high, gently sloping benches and knolls up to about 1400 feet (430 m) above the floor of adjacent small streams and washes; 0 to 60 feet (0-18 m) thick; Hanks and others (2001) reported ages of 0.5 to 0.78 million years on these deposits, projected these surfaces to a higher ancestral river up to 1400 feet (430) above the modern Colorado River, and then used these surfaces to calculate an average incision rate of 1.64 feet (0.5 m) per thousand years. This rate is higher than most other rates discussed above, raising the question if these surfaces were ever graded to the ancestral river.

Qatg - Alluvial river terrace deposits with older alluvial gravel (lower Pleistocene to Holocene)

Qatg2 to Qatg12 Alluvial river terrace deposits with older alluvial gravel (age discussed below)
— Similar to Qat deposits described above but a major component is large boulders (as described in Qago) incorporated into terrace deposits along the Colorado River.

Note, only units Qatg8, Qatg9 and Qatg12 are present within the extent of the GRI digital geologic-GIS data.

Elevation and Estimated Age of Terrace Deposits

Rare volcanic ash beds, basalt flows, strath terrace and pediment deposits, and other dateable materials in surficial deposits in the Colorado River basin provide a means to calculate average regional incision rates of the major rivers (table 1). These rates vary significantly, raising considerable uncertainty about the calculated incision rates. When applied to the heights of river terrace deposits above adjacent rivers, the rates provide an estimate of ages of terrace and correlative deposits. However, the terrace ages are only considered rough estimates because the calculated rates vary over a broad range, dateable materials are rare, some data come from sites over 100 miles (160 km) away, interpretation of data is commonly debatable, and incision rates probably varied over time. I believe data supporting the lower rates are more reliable pending additional information. I use 0.66 feet (0.20 m) per thousand years for assigning series and age designations in table 2. Short-term cut-and-fill cyclicity of rivers probably also significantly skews estimated ages of younger low-level deposits (for example, some level 2 deposits may be as young as Holocene).

Table 1. Published Calculated Average Incision Rates of the Colorado River and Major Tributaries.

Average calculated incision rate (per 1000 years)	Time interval forming basis for calculation	Location	References
0.79 feet (0.24 m)	3 million years	Glenwood Springs, Colorado	Kirkham and others, 2001; and references cited therein
0.59 feet (0.18 m)	620,000 years	Westwater Canyon, Utah	Willis, 1992, 1994; Willis and Biek, 2001
1.25 to 1.57 feet (0.38-0.48 m)	189,000 years	Fremont River about 80 miles (130 km) upstream of Lake Powell	Marchetti and Cerling, 2001
0.36 feet (0.11 m)	1.4 million years	Bluff about 30 miles (50 km) east of the eastern part of the map area	Wolkowinsky and Granger, 2004
1.64 feet (0.5 m)	500,000 years	Navajo Mtn pediments near Glen Canyon	Hanks and others, 2001
0.46 feet (0.14 m)	500,000 years	Eastern Grand Canyon	Pederson and others, 2002
1.31 feet (0.4 m)	500,000 years	Eastern Grand Canyon	Davis and others, 2001
1.02 to 1.64 (0.31-0.5 m)	600,000 years	Eastern Grand Canyon	Lucchitta and others, 2001

Table 2. Estimated ages of river terraces based on height of terraces above river and average incision rates discussed above.

Level	Height above river feet (meters)	Estimated ages using low and high long-term incision rates		Series/Age (based on low rate)
		low	high	
		0.2 meters/ky 0.5 meters/ky ka=thousand years BP Ma=million years BP		
2	40-90 (12-27)	long-term rates probably don't apply due to short-term cut-and-fill cyclicity		Holocene to Upper Pleistocene
3	90-140 (27-43)	135ka-215ka	54ka-86ka	Upper to Middle Pleistocene
4	140-210 (43-64)	230ka-320ka	86ka-130ka	Middle Pleistocene
5	210-290 (64-88)	320ka-440ka	130ka-180ka	Middle Pleistocene
6	290-380 (88-120)	440ka-600ka	180ka-240ka	Middle Pleistocene
7	380-430 (120-130)	600ka-650ka	240ka-260ka	Middle Pleistocene
8	430-550 (130-170)	650ka-850ka	260ka-340ka	Mid. to Low. Pleist.
9	550-670 (170-200)	850ka-1.0Ma	340ka-400ka	Lower Pleistocene
10	670-730 (200-220)	1.0Ma-1.1 Ma	400ka-440ka	Lower Pleistocene
11	730-830 (220-250)	1.1 Ma-1.3Ma	440ka-500ka	Lower Pleistocene
12	830-930 (250-280)	1.3Ma-1.4Ma	250ka-560ka	Lower Pleistocene

Jms - Morrison Formation, Salt Wash Member (Upper Jurassic)

Pale- to medium-yellowish-gray, reddish-gray, and greenish-gray, weathering to dark brown, very fine to medium-grained, cross-bedded sandstone, pebble conglomerate, and conglomeratic sandstone, interbedded with minor pale-grayish-green to medium-reddish-brown mudstone and siltstone; forms ledgy cliffs; resistant basal ledge commonly protrudes as an overhanging lip above the ledgy Entrada beds below; only present in map area in one small exposure southwest of Rainbow Bridge where it caps a ridge; this single outcrop is very remote and has not been examined, but float suggests that it may be strongly silicified; regionally, member is about 310 feet (94 m) thick (Peterson and Barnum, 1973), but only the lower about 200 feet (60 m) is preserved within the map area.

J-5 unconformity

Generally a sharp erosional contact; cuts out the upper member of the Entrada Sandstone and overlying units as mapped in areas to the west and southwest (Doelling, 1998; Doelling and Willis, 1999).

Entrada Sandstone (Middle to Upper Jurassic)

Jem - Entrada Sandstone, middle member (Middle Jurassic to Upper Jurassic)

Moderate-reddish-orange to moderate-reddish-brown, medium- to thick-bedded, cross-bedded, calcareous, very fine grained sandstone, interbedded with thin partings of moderate- to dark-reddish-brown siltstone and mudstone, and with scarce very thin beds of grayish-purple bentonitic clay; generally forms red and white banded ledgy cliffs; generally less contorted than lower member; upper contact is unconformable — in the southwestern part of Glen Canyon NRA the middle member is unconformably overlain by the Romana Sandstone, which thins eastward and is cut out about 2 miles (3 km) west of the Rainbow Bridge 7.5' quadrangle (Peterson and Barnum, 1973); about 360 feet (110 m) thick.

Jel - Entrada Sandstone, lower member (Middle Jurassic to Upper Jurassic)

Pale-reddish-yellow to moderate-reddish-orange, thick-bedded to massive, calcareous, fine-grained sandstone, interbedded with thin partings of moderate reddish-brown siltstone and mudstone; contorted bedding, small internal faults, and complex small-scale folds indicate extensive and complex soft-sediment deformation; fingers and tongues of Entrada Sandstone commonly sag or protrude as pedestals and bulges into the underlying Carmel Formation; forms massive smooth cliffs, rounded bare domes, and broad rolling slickrock swells with common large weathering pits; abundant secondary alteration and bleaching impart mottled, streaked, and banded appearance to outcrops; about 460 feet (140 m) thick (Peterson and Barnum, 1973).

Jc - Carmel Formation (Middle Jurassic)

Medium-grayish-red to pale-reddish-gray, earthy weathering, interbedded, fine- to very fine grained sandstone, silty sandstone, siltstone, and mudstone; generally gypsiferous and calcareous; commonly has highly contorted bedding showing a variety of soft-sediment structures produced by loading of the Entrada Sandstone before Carmel strata were lithified; some deformation may be due to dissolution of bedded gypsum, though no bedded gypsum has been recognized in outcrop; forms prominent red ledgy slope between the cliff-forming Entrada and Navajo/Page Sandstones; 100 to 140 feet (30-42 m) thick.

Jp - Page Sandstone? (Middle Jurassic)

Moderate-reddish-orange to moderate-reddish-brown, fine-grained, very thickly cross-bedded sandstone; locally has very sparse small angular chert fragments at base; 0 to 100 feet (0-30 m) thick. Citing the locally prominent planar base and the chert fragments, Peterson and Barnum (1973) and Peterson and Pipiringos (1979) suggested the lower contact is the regional J-2 unconformity. Field evidence supporting the presence of an unconformity is tenuous — if the unconformity is not present, then this sandstone interval may actually be part of the Navajo Sandstone.

J-? unconformity

J-2? unconformity: Peterson and Pipiringos (1979) suggested the contact between the Navajo and Page Sandstones is the regional J-2 unconformity. In most areas typical criteria for identifying an unconformity are missing and the contact is indistinct, while in others the contact is a sharp planar surface, but is difficult to correlate laterally. Thus, the presence of this unconformity is questionable.

Jn - Navajo Sandstone (Lower Jurassic)**Jn, Jnl Navajo Sandstone; limestone beds in Navajo Sandstone (Lower Jurassic)**

Pale-yellowish-gray, moderate-reddish-brown, and moderate-reddish-orange, fine- to medium-grained, massive, cross-bedded sandstone; grains are primarily rounded to subrounded, frosted, well-sorted and equant quartz; conspicuously cross-bedded with cross-bed sets that range up to 60 feet (20 m) thick; contains scattered thin lenses of gray sandy limestone, dolomite, and siltstone up to 50 feet thick (15 m) and 2 to 3 miles (3-5 km) long (Jnl) with common algae laminae, ripple marks, and mudcracks; lower contact gradational and intertonguing; forms rounded knobs, buttes, and mesa rims marked by large parallel to conjugate near-vertical joints that are locally mapped and smaller weathering and unloading fractures; 900 to 1100 feet (270-340 m) thick.

Jnl - Navajo Sandstone, limestone beds (Lower Jurassic)

See [Jn](#) for unit description.

Jk - Kayenta Formation (Lower Jurassic)

Moderate- to pale-reddish-brown to reddish-orange, medium to thick lenticularly bedded, cross-bedded, fine- to medium-grained, poorly sorted sandstone, interbedded with very thin to thin-bedded, moderate- to dark-reddish-brown siltstone and muddy sandstone; grains are subangular to subrounded; calcareous cement; locally contains beds of intraformational pebble conglomerate with pebbles of sandstone, siltstone and claystone; forms thick ledges to ledgy cliffs; locally contains sparse fossil wood and thin beds of pinkish-gray limestone; upper and lower contacts gradational and intertonguing; 200 to 240 feet (60-73 m) thick.

Ancillary Source Map Information

The following section present ancillary source map information associated with source used for this project.

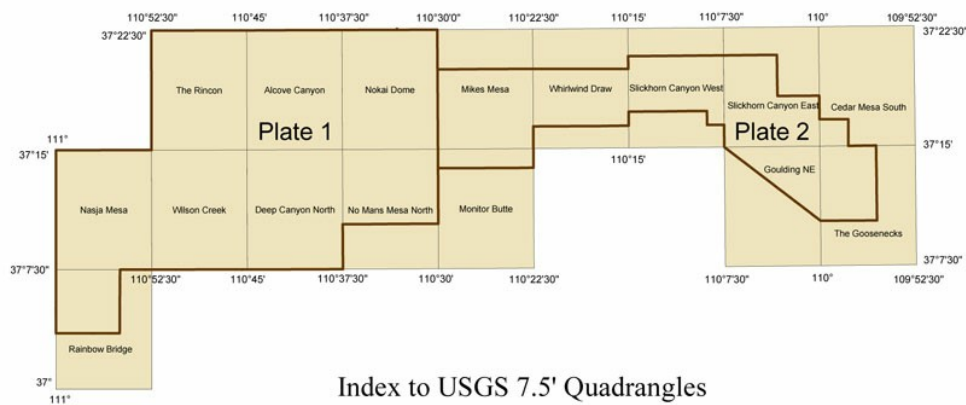
Lower San Juan River Area (Rainbow Bridge NMN area)

The formal citation for this source.

Willis, Grant C., 2004, Interim Geologic Map of the Lower San Juan River Area, Eastern Glen Canyon National Recreation Area and Vicinity, San Juan County, Utah: Utah Geological Survey, Open-File Report 443DM, 2 plates, scale 1:24,000 (*GRI Source Map ID 7331*).

Prominent graphics and text associated with this source.

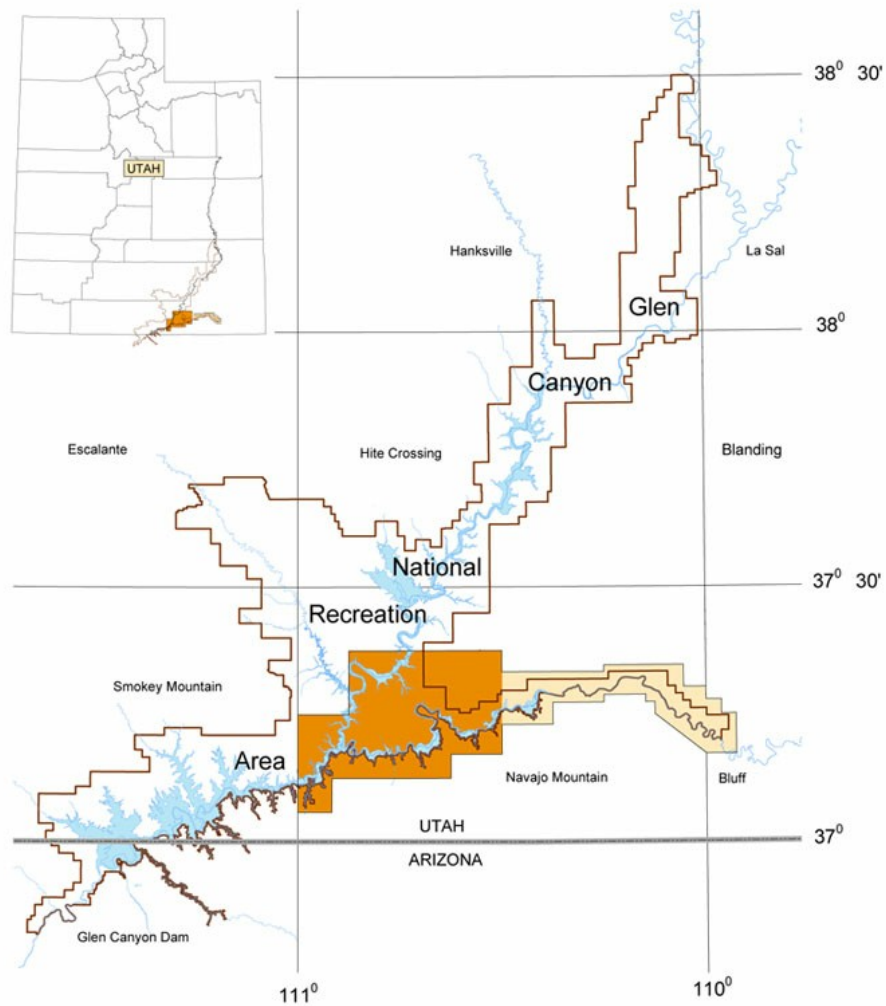
Index to USGS 7.5' Quadrangles



Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMN area\)](#).

As noted in the [GRI Digital Map and Source Map Citation](#) section only a portion of the source map was used. This extent is the source map extent within the Rainbow Bridge quadrangle on Plate 1.

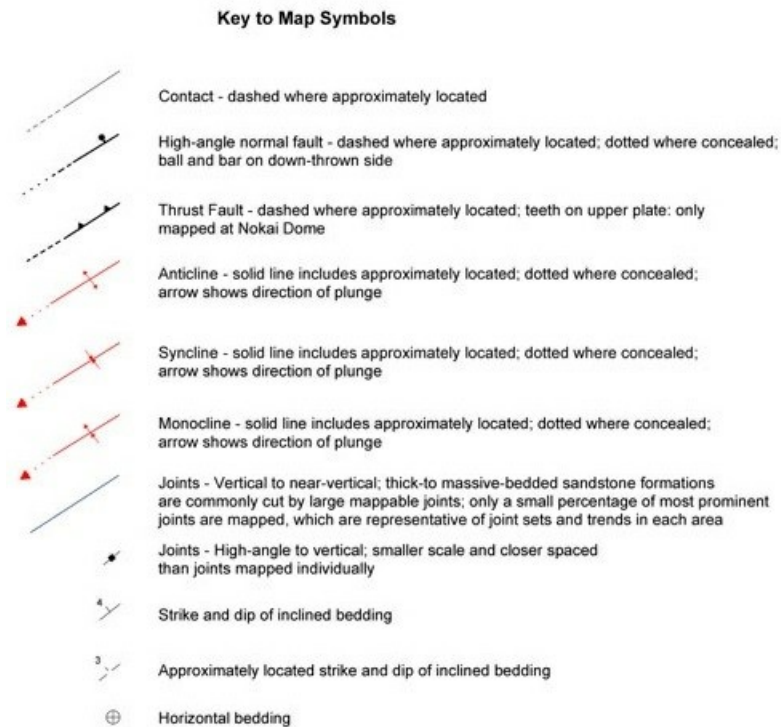
Index to USGS 30' x 60' Quadrangles



Index to USGS 30' x 60' Quadrangles

The extent of each map plate is shown in color. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Explanation of Map Symbols



Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMN area\)](#).

Of note, only some mapped geologic features are within the map extent of the GRI digital geologic-GIS data.

Report

**Interim Geologic Map of the Lower San Juan River Area,
Eastern Glen Canyon National Recreation Area and Vicinity,
San Juan County, Utah**

by

Grant C. Willis

Utah Geological Survey
a division of the
Utah Department of Natural Resources
in cooperation with
National Park Service

2004
(with scattered revisions to 2007)

Utah Geological Survey Open-File Report 443-DM
GIS Analysts: Darryl Greer, Peter Thompson, Kent Brown

Utah Geological Survey, 1594 W. North Temple, PO Box 146100
Salt Lake City, Utah 84114-6100
ph: 801-537-3300; fax 801-537-3400
www.geology.utah.gov

This open-file release makes information available to the public during the review and production period necessary for a formal UGS publication. It is in the review process and may not conform to UGS standards; therefore it may be premature for an individual or group to take action based on its contents.

Although this product represents the work of professional scientists, the Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, expressed or implied, regarding its suitability for a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

This geologic map was funded by the Utah Geological Survey and the National Park Service. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

The "Description of Map Units" section of the report is presented in the Map Unit Descriptions section for units present within the extent of the GRI digital geologic-GIS data.

Figures

Figures present in the associated source map report.

Figure 1: San Juan River from Honaker Trail in Goosenecks area



Figure 1. San Juan River from Honaker Trail in Goosenecks area. Thickest blocky cliff is The Horn. Top of The Horn is the contact between the Paradox Formation (lower part of canyon wall) and the Honaker Trail Formation (upper part of canyon wall). Red beds in background in upper Honaker Trail are part of Rico Formation of earlier workers. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 2: San Juan River near Government Rapids at sunset



Figure 2. San Juan River near Government Rapids at sunset. Cedar Mesa Sandstone forms canyon rim. Halgaito Shale forms red slope below. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 3 San Juan River downstream from Grand Gulch



Figure 3. San Juan River downstream from Grand Gulch. Cedar Mesa Sandstone forms canyon wall. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 4: Near Clay Hills Crossing



Figure 4. Near Clay Hills Crossing. Moenkopi forms red slopes in foreground. Chinle formation forms varicolored slopes. Note that no Shinarump Conglomerate Member is present at base. Lower gray beds are Monitor Butte Member. Purple slope is Petrified Forest Member. Grayish-pink slope is Owl Rock Member. Red ledgy beds at base of cliff are Church Rock Member (Rock Point of Lucas, 1993). Cliff is Wingate Sandstone capped by Kayenta Formation. Ragged landslide deposits locally cap Chinle outcrops. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 5: Near Clay Hills Crossing at The Portal looking upstream



Figure 5. Near Clay Hills Crossing at The Portal looking upstream. Hoskinnini Member of Moenkopi forms steep red slope. Main part of Moenkopi forms slightly browner ledges and slope. Contact at thin white bed. Ledge capped by Shinarump Conglomerate Member of Chinle Formation. Shinarump pinches out less than a mile to north (see [figure 4](#)). Bears Ears in distant background. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 6: San Juan River near Mikes Mesa



Figure 6. San Juan River near Mikes Mesa. Moenkopi Formation forms slope. Shinarump Conglomerate Member of Chinle Formation caps rim. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 7: Looking downstream toward Rock Spring syncline and Balanced Rock anticline near Nokai Dome



Figure 7. Looking downstream toward Rock Spring syncline and Balanced Rock anticline near Nokai Dome. Shinarump Conglomerate Member forms brown ledge dipping gently to west in foreground near river. It sweeps sharply upward in right middle distance, and then caps high mesa. White bed dipping toward photographer in distance is the White Rim Sandstone overlying the deep red Organ Rock Shale. White Rim pinches out near here and is not present to east. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 8: Steep east flank of Balanced Rock anticline



Figure 8. Steep east flank of Balanced Rock anticline. Dipping ledge is Shinarump Conglomerate Member repeated by a small thrust fault. Note flat-lying Shinarump at right side of photo. Moenkopi Formation forms dipping red and brown beds. White Rim Sandstone seen in figure 7 is just out of sight off left side of photo. Wingate Sandstone forms cliff in right background. High-water line of Lake Powell forms horizontal line across slope. Note slumping modern lake deposits near river. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 9: Kayenta Formation overlain by rounded cliffs of Navajo Sandstone in San Juan arm of Lake Powell



Figure 9. Kayenta Formation overlain by rounded cliffs of Navajo Sandstone in San Juan arm of Lake Powell. Navajo Mountain in background. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 10: Looking down Cottonwood Canyon toward northwest



Figure 10. Looking down Cottonwood Canyon toward northwest. Navajo Sandstone is cut by the Cottonwood fault. White ledge is a limestone “oasis” deposit in the Navajo Sandstone. Hiker is following the “wagon road” cut by early Mormon pioneers; they took advantage of natural weakness caused by the fault. Hole-in-the-Rock is across lake in distance. Straight Cliffs composed of Upper Cretaceous strata in background. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 11: Wall of Wingate Sandstone, Kayenta Formation, and Navajo Sandstone near The Rincon on main channel



Figure 11. Wall of Wingate Sandstone (lower cliff), Kayenta Formation (middle cliff and slope), and Navajo Sandstone (rounded cliffs) near The Rincon on main channel. Chinle Formation at lower left. Note modern slumps, which are common wherever Chinle is at lake level. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 12: Rainbow Bridge in basal Navajo Sandstone. Kayenta Formation forms footing of bridge



Figure 12. Rainbow Bridge in basal Navajo Sandstone. Kayenta Formation forms footing of bridge.

Abandoned stream terrace gravels forming brush covered slope in middle left must have been deposited before bridge was cut. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

Figure 13: Rainbow Bridge



Figure 13. Rainbow Bridge. Photograph by Grant Willis, Utah Geological Survey. Graphic from source map: [Lower San Juan River Area \(Rainbow Bridge NMON area\)](#).

References

- Anderson, P.B., Chidsey, J.C., Jr., Sprinkel, D.A., and Willis, G.C., 2003, Geology of Glen Canyon National Recreation Area, Utah-Arizona, in Sprinkel, D.A., Chidsey, T.C., Jr., and Anderson, P.B., editors, Geology of Utah's parks and monuments, 2nd edition: Utah Geological Association Millennial Guidebook Publication 28, p. 301-336.
- Baars, D.L., 1979, The Permian System, in Baars, D.L., editor, Permianland: Four Corners 9th Annual Geological Society Field Conference, p. 1-6.
- Baars, D.L., Parker, J.W., and Chronic, J., 1967, Revised stratigraphic nomenclature of Pennsylvanian System, Paradox Basin: American Association of Petroleum Geologists Bulletin, v. 51, no. 3, p. 393-403.
- Baker, A.A., 1936, Geology of the Monument Valley-Navajo Mountain region, San Juan County, Utah: U. S. Geological Survey Bulletin 865, 106 p.
- Condon, S.M., 1997, Geology of the Pennsylvanian and Permian Cutler Group and Permian Kaibab Limestone in the Paradox Basin, southeastern Utah and southwestern Colorado: U. S. Geological Survey Bulletin 2000-P, 46 p.

- Davis, S.W., Davis, M.E., Luchitta, I., Hanks, T.C., Finkel, R.C., and Caffee, M., 2001, Erosional history of the Colorado River through Glen and Grand Canyons, in Young, R.A., and Spamer, E. E., editors, Colorado River origin and evolution: Grand Canyon, Arizona, Grand Canyon Natural History Association, symposium volume, p. 135-140.
- Doelling, H.H., 1998, Interim geologic map of the Smoky Mountain 30'x60' quadrangle, Kane and San Juan Counties, Utah, and Coconino County, Arizona: Utah Geological Survey Open-File Report 359, 2 plates, scale 1:100,000.
- _____, 2001, Geologic map of the Moab 30'x60' quadrangle, Grand County, Utah: Utah Geological Survey Map 180, 3 plates, scale 1:100,000.
- _____, 2004, Geologic map of the La Sal 30'x60' quadrangle, San Juan County, Utah: Utah Geological Survey Map 205, 2 plates, scale 1:100,000.
- Doelling, H.H., and Willis, G.C., 1999, Interim geologic map of the Escalante and parts of the Loa and Hite Crossing 30'x60' quadrangles, Garfield and Kane Counties, Utah: Utah Geological Survey Open-File Report 368, 19 p., 2 plates, scale 1:100,000.
- Dubiel, R.F., 1994, Traissic deposystems, paleogeography, and paleoclimate of the Western Interior, in Caputo, M.V., Peterson, J.A., and Franczyk, K.J., editors, Mesozoic systems of the Rocky Mountain region, USA: Rocky Mountain Section of Society for Sedimentary Geology, p. 133-168.
- Grundvig, D., 1980, Landslide surveillance of Lake Powell: U.S. Bureau of Reclamation, Region 4 Division of Design and Construction, Geology Branch, Geology Report G-321, unpaginated.
- Hanks, T.C., Luchitta, I., Davis, S.W., Davis, M.E., Finkel, R.C., Lefton, S.A., and Garvin, C.D., 2001, The Colorado River and the age of Glen Canyon, in Young, R.A., and Spamer, E.E., editors, Colorado River origin and evolution: Grand Canyon, Arizona, Grand Canyon Natural History Association, symposium volume, p. 129-134.
- Huffman, A.C., Jr., and Condon, S.M., 1993, Stratigraphy, structure, and paleogeography of Pennsylvanian and Permian rocks, San Juan Basin and adjacent area, Utah, Colorado, Arizona, and New Mexico: U.S. Geological Survey Bulletin 1808, 37 p.
- Kirkham, R.M., Kunk, M.J., Bryant, B., and Streufert, R.K., 2001, Constraints on timing and rates of late Cenozoic incision by the Colorado River in Glenwood Canyon, Colorado—a preliminary synopsis, in Young, R.A., and Spamer, E.E., editors, Colorado River origin and evolution: Grand Canyon, Arizona, Grand Canyon Natural History Association, p. 113-118.
- Loope, D.B., Sanderson, G.A., and Verville, G.J., 1990, Abandonment of the name Elephant Canyon Formation in southeastern Utah — physical and temporal implications: Mountain Geologist, v. 27, no. 4, p. 119-130.
- Lucas, S.G., 1993, The Chinle Group — revised stratigraphy and chronology of Upper Triassic nonmarine strata in western United States: Museum of Northern Arizona Bulletin 59, p. 27-50.
- Lucas, S.G., Heckert, A.B., Estep, J.W., and Anderson, O.J., 1997, Stratigraphy of the Upper Triassic Chinle Group, Four Corners region, in Anderson, O.J., Kues, B.S., and Lucas, S.G., editors, Mesozoic geology and paleontology of the Four Corners region: New Mexico Geological

- Society Guidebook, 48th Field Conference, p. 81-107.
- Lucchitta, I., Curtis, G.H., Davis, M.E., Davis, S.W., Hanks, T.C., Finkel, R.C., and Turrin, B., 2001, Rates of downcutting of the Colorado River in Grand Canyon region, in Young, R.A., and Spamer, E.E., editors, Colorado River origin and evolution: Grand Canyon, Arizona, Grand Canyon Natural History Association, symposium volume, p. 155-158.
- Marchetti, D.W., and Cerling, T.E., 2001, Bedrock incision rates for the Fremont River, tributary of the Colorado River, in Young, R.A., and Spamer, E.E., editors, Colorado River origin and evolution: Grand Canyon, Arizona, Grand Canyon Natural History Association, p. 125-128.
- Miser, H.D., 1924, Geologic structure of the San Juan Canyon and adjacent country, Utah: U.S. Geological Survey Bulletin 751-D, p. 115-155.
- Mullens, T.E., 1960, Geology of the Clay Hills area: U.S. Geological Survey Bulletin 1087-H, p. 259-336.
- Pederson, J., Karlstrom, K., Sharp, W., and McIntosh, W., 2002, Differential incision of the Grand Canyon related to Quaternary faulting — constraints from U-series and Ar/Ar dating: *Geology*, v. 30, p. 739-742.
- Peterson, F., and Barnum, B.E., 1973, Geologic map of the southeast quarter of the Cummings Mesa [Cathedral Canyon] quadrangle, Kane and San Juan Counties, Utah, and Coconino County, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I758, scale 1:24,000.
- Peterson, F., and Pipiringos, G.N., 1979, Stratigraphic relations of the Navajo Sandstone to Middle Jurassic formations, southern Utah and northern Arizona: U. S. Geological Survey Professional Paper 1035-B, p. 1-43.
- Pipiringos, G.N., and O'Sullivan, R.B., 1978, Principal unconformities in Triassic and Jurassic rocks, western interior United States — a preliminary survey: U. S. Geological Survey Professional Paper 1035-A, 29 p.
- Pray, L.C., and Wray, J.L., 1963, Porous algal facies (Pennsylvanian), Honaker Trail, San Juan Canyon, Utah, in Bass, R.O., editor, Shelf carbonates of the Paradox Basin, a symposium: Four Corners Geological Society 4th Annual Field Conference, p. 204-234.
- Ritter, S.M., Barrick, J.E., and Skinner, M.R., 2002, Conodont sequence stratigraphy of the Hermosa Group (Pennsylvanian) at Honaker Trail, Paradox Basin, Utah: *Journal of Paleontology*, v. 76, no. 3, p. 495-517.
- Stevenson, G.M., 2003, Geology of Goosenecks State Park, San Juan County, Utah, in Sprinkel, D. A., Chidsey, T.C., Jr., and Anderson, P.B., editors, Geology of Utah's parks and monuments, 2nd edition: Utah Geological Association Millennial Guidebook Publication 28, p. 433-448.
- Stewart, J.H., Poole, F.G., and Wilson, R.F., 1972a, Stratigraphy and origin of the Chinle Formation and related Upper Triassic strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 690, 336 p.
- _____, 1972b, Stratigraphy and origin of the Triassic Moenkopi Formation and related strata in the

- Colorado Plateau region: U.S. Geological Survey Professional Paper 691, 195 p.
- Wengerd, S.A., 1963, Stratigraphic section at Honaker Trail, San Juan Canyon, San Juan County, Utah, in Bass, R.O., editor, Shelf carbonates of the Paradox Basin, a symposium: Four Corners Geological Society 4th Annual Field Conference, p. 235-243.
- _____, 1973, Regional stratigraphic control of the search for Pennsylvanian petroleum, southern Monument upwarp, southeastern Utah, in James, H.L., editor, Guidebook of Monument Valley and vicinity, Arizona and Utah: New Mexico Geological Society 24th Field Conference, p. 122-138.
- Wengerd, S.A., and Matheny, M.L., 1958, Pennsylvanian system of Four Corners region: American Association of Petroleum Geologists Bulletin, v. 42, no. 9., p. 2048-2106.
- Wengerd, S.A., and Strickland, J.W., 1954, Pennsylvanian stratigraphy of Paradox salt basin, Four Corners region, Colorado and Utah: American Association of Petroleum Geologists Bulletin, v. 38, no. 10., p. 2157-2199.
- Willis, G.C., 1992, Lava Creek B volcanic ash in pediment mantle deposits, Colorado Plateau, east-central Utah — implications for Colorado River downcutting and pedogenic carbonate accumulation rates: Rocky Mountain Section Geological Society of America Abstracts with Programs, v. 24, no. 6, p. 68.
- _____, 1994, Geologic map of the Harley Dome quadrangle, Grand County, Utah: Utah Geological Survey Map 157, 18 p., scale 1:24,000.
- Willis, G.C., and Biek, R.F., 2001, Quaternary incision rates of the Colorado River and major tributaries in the Colorado Plateau, Utah, in Young, R.A., and Spamer, E.E., editors, Colorado River origin and evolution: Grand Canyon, Arizona, Grand Canyon Natural History Association, symposium volume, p. 119-124.
- Witkind, I.J., and Thadden, R.E., 1963, Geology and uranium-vanadium deposits of Monument Valley area, Apache and Navajo Counties, Arizona: U.S. Geological Survey Bulletin 1103, 171 p.
- Wolkowsky, A.J., and Granger, D.E., 2004, Early Pleistocene incision of the San Juan River, Utah, dated with ^{26}Al and ^{10}Be : *Geology*, v. 32, no. 9, p. 749-752.

Additional Information

Scenic Resources

Most of the map area is included in the Glen Canyon National Recreation Area which is administered by the National Park Service. The Recreation Area was established primarily to include Lake Powell, the reservoir currently forming behind Glen Canyon Dam which is about 20 miles west-southwest of the map area near Page, Ariz. The area is dissected into colorful buttes, canyons, and mesas that are carved in rocks of Triassic and Jurassic age.

Utah Geological Survey Open-File Report 443DM
GIS Analysts: Darryl Greer, Peter Thompson, Kent Brown

Utah Geological Survey, 1594 W. North Temple, PO Box 146100
Salt Lake City, Utah 84114-6100
Ph: 801-537-3300: fax 801-537-3400
www.geology.utah.gov

This open-file release makes information available to the public during the review and production period necessary for a formal UGS publication. It is in the review process and may not conform to UGS standards, therefore it may be premature for an individual or group to take action based on its contents.

Although this product represents the work of professional scientists, the Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, expressed or implied, regarding its suitability for a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by the users of this product.

This geologic map was funded by the Utah Geological Survey and the National Park Service. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

GRI Digital Data Credits

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

The information in this document was compiled from the GRI source map and is intended to accompany the digital geologic-GIS map and other digital data for Rainbow Bridge National Monument, Utah (RABR) developed by Stephanie O'Meara (see the [GRI Digital Map and Source Map Citation](#) section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS map). Initial GRI product produced by Georgia Hybels (NPS GRD), and Stephanie O'Meara and Heather Stanton (Colorado State University).

GRI finalization by Stephanie O'Meara.

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