

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



Hovenweep National Monument

GRI Ancillary Map Information Document

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

hove_geology.pdf

Version: 8/16/2016

Geologic Resources Inventory Ancillary Map Information Document for Hovenweep National Monument

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Geologic Resources Inventory Map Document



Hovenweep National Monument, Colorado and Utah

Document to Accompany Digital Geologic-GIS Data

[hove_geology.pdf](#)

Version: 8/16/2016

This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Hovenweep National Monument, Colorado and Utah (HOVE).

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 Maps and Source Citations** – A listing of all GRI digital geologic-GIS maps produced for this project along with sources used in their completion. In addition, a brief explanation of how each source map was used is provided.
- 3) **Map Unit List** – A listing of all geologic map units present on maps for this project, generally listed from youngest to oldest.
- 4) **Map Unit Descriptions** – Descriptions for all geologic map units. If a unit is present on multiple source maps the unit is listed with its source geologic unit symbol, unit name and unit age followed by the unit's description for each source map.
- 5) **GRI Ancillary Source Map Information** – Additional source map information presented by source map. For each source map this may include a stratigraphic column, index map, map legend and/or map notes.
- 6) **References** – List of sources used used in mapping, features present, or which provided a unit description to this product.
- 7) **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:

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About the NPS Geologic Resources Inventory Program

Background

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

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

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

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

Products

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

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

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

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

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

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

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

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

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

GRI Digital Maps and Source Map Citations

The GRI digital geologic-GIS maps for Hovenweep National Monument, Colorado and Utah (HOVE):

The GRI compiled park extent and vicinity map (sources are listed with the individual 7.5' quadrangle component maps below).

Digital Geologic-GIS Map of Hovenweep National Monument and Vicinity, Colorado and Utah (GRI MapCode HOVE)

Individual 7.5' quadrangle GRI maps with source publications. These maps were compiled to produce the park and vicinity (HOVE) map. In addition to the source mapping listed below each component quadrangle map, as well as the compiled map, has structure contour lines as well as possibly uranium prospects there were derived (digitized) from the following publication.

Haynes, D.D., Vogel, J.D., and Wyant, D.G., 1972, Geology, Structure, and Uranium Deposits of the Cortez Quadrangle, Colorado and Utah, U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-629, scale 1:250,000.

Digital Geologic-GIS Map of the Arriola Quadrangle, Colorado (GRI MapCode ARRI)

Poole, Anne, 2000, Geologic Map of the Arriola Quadrangle, Montezuma County, Colorado: National Park Service Geologic Resources Inventory, unpublished mapping, scale 1:24,000.

Digital Geologic-GIS Map of the Hatch Trading Post Quadrangle, Utah (GRI MapCode HATP)

Poole, Anne, 2000, Geologic Map of the Hatch Trading Post Quadrangle, San Juan County, Utah: National Park Service Geologic Resources Inventory, unpublished mapping, scale 1:24,000.

Digital Geologic-GIS Map of the Navajo Canyon Quadrangle, Utah (GRI MapCode NACA)

Poole, Anne, 2000, Geologic Map of the Navajo Canyon Quadrangle, San Juan County, Utah: National Park Service Geologic Resources Inventory, unpublished mapping, scale 1:24,000.

Digital Geologic-GIS Map of the Negro Canyon Quadrangle, Colorado (GRI MapCode NECA)

Poole, Anne, 2000, Geologic Map of the Negro Canyon Quadrangle, Montezuma County, Colorado: National Park Service Geologic Resources Inventory, unpublished mapping, scale 1:24,000.

Digital Geologic-GIS Map of the Ruin Point Quadrangle, Utah and Colorado (GRI MapCode RUPO)

Poole, Anne, 2000, Geologic Map of the Ruin Point Quadrangle, San Juan County, Utah and Montezuma and Dolores Counties, Colorado: National Park Service Geologic Resources Inventory, unpublished mapping, scale 1:24,000.

Digital Geologic-GIS Map of the Wickiup Canyon Quadrangle, Utah and Colorado (*GRI MapCode WICN*)

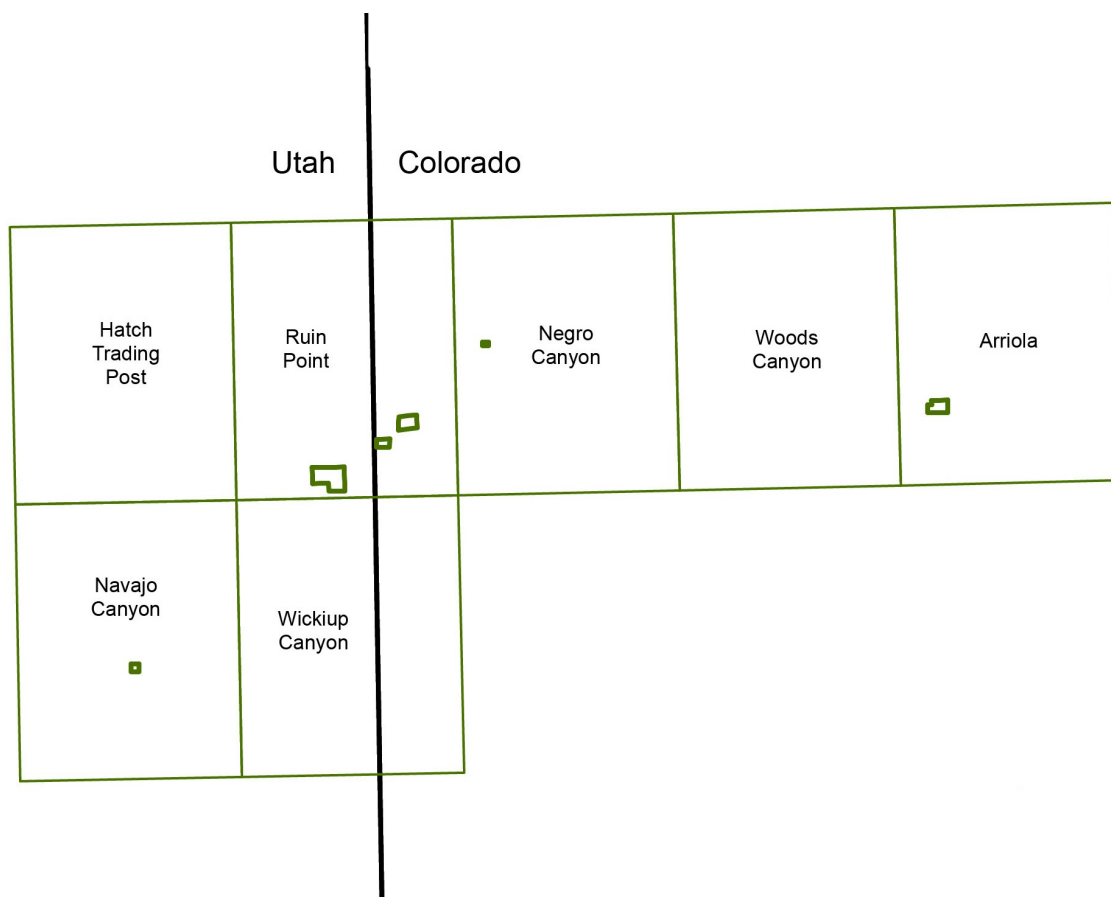
Poole, Anne, 2000, Geologic Map of the Wickiup Canyon Quadrangle, San Juan County, Utah and Montezuma County, Colorado: National Park Service Geologic Resources Inventory, unpublished mapping, scale 1:24,000.

Digital Geologic-GIS Map of the Woods Canyon Quadrangle, Colorado (*GRI MapCode WOCA*)

Poole, Anne, 2000, Geologic Map of the Woods Canyon Quadrangle, Montezuma County, Colorado: National Park Service Geologic Resources Inventory, unpublished mapping, scale 1:24,000.

Quadrangle Index Map

The following index map displays 7.5' quadrangle extents, the Hovenweep National Monument (HOVE) park boundary in dark green (as of August, 2016), and the state boundary between Colorado and Utah.



Map Unit List

The geologic units present in the digital geologic-GIS data produced for Hovenweep National Monument, Colorado and Utah (HOVE) are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qal - Alluvium). 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 (HOVEUNIT) table included with the GRI geologic-GIS data. Some source unit symbols, names and/or ages may have been changed in this document. This was done if a unit differed from the GRI adopted unit symbol and/or unit name.

Cenozoic Era

Quaternary Period

[Qa](#) - Alluvium

[Qe](#) - Eolian deposits

[Qae](#) - Alluvial and eolian deposits

[Qc](#) - Colluvium

Mesozoic Era

Cretaceous Period

[Km](#) - Mancos Shale

[Kd](#) - Dakota Sandstone

[Kdb](#) - Burro Canyon Formation and Dakota Sandstone, undifferentiated

[Kbc](#) - Burro Canyon Formation

Jurassic Period

[Jm](#) - Morrison Formation

[Jmb](#) - Morrison Formation, Brushy Basin Member

[Jmw](#) - Morrison Formation, Westwater Canyon Member

[Jmr](#) - Morrison Formation, Recapture Member

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

[Jj](#) - Junction Creek Member

[Jw](#) - Wanakah Formation

[Je](#) - Entrada Sandstone

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below. Unit descriptions were taken from maps of the geology in the area. In most cases multiple unit descriptions are listed. See the [References section](#) of this document for these references. Unit descriptions are simply listed in order of authorship order and date if warranted.

Qa - Alluvium (Quaternary)

Qa – Alluvium (Quaternary)

Unconsolidated silt, sand, and gravel deposited mainly in stream beds and on flood plains. (Condon, 1991).

Qal – Alluvium (Quaternary)

Valley fill and terrace gravel. (Hackman, 1955a,b,c, and d).

Qa – Alluvial deposits (Pleistocene and Holocene)

Silt, sand, and gravel in stream valleys and flood plains; includes soil and locally some colluvial and eolian deposits. (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Alluvium along Montezuma Creek, Hatch Trading Post quadrangle, Utah. (Photograph by Anne Poole, 2000).

Qe - Eolian deposits (Quaternary)

Qe – Eolian sand and silt (Quaternary)

Light-brown to reddish-brown windblown silt and very fine-grained sand deposited on mesa tops and on pediment surfaces. (Condon, 1991).

Qe – Eolian deposits (Pleistocene and Holocene)

Reddish-brown loess on broad plains, mesas, and large benches; unconsolidated silt and sand

banked against cliffs and mantling large areas of broad valleys. (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Red eolian sand and silt on Cajon Mesa. (Photograph by Anne Poole, 2000).

Qae - Alluvial and eolian deposits (Quaternary)

Qae – Alluvial and eolian deposits (Pleistocene and Holocene)

Windblown silt and sand on benches and broad valleys, reworked in part by running water. (Haynes, Vogel, and Wyant, 1972).

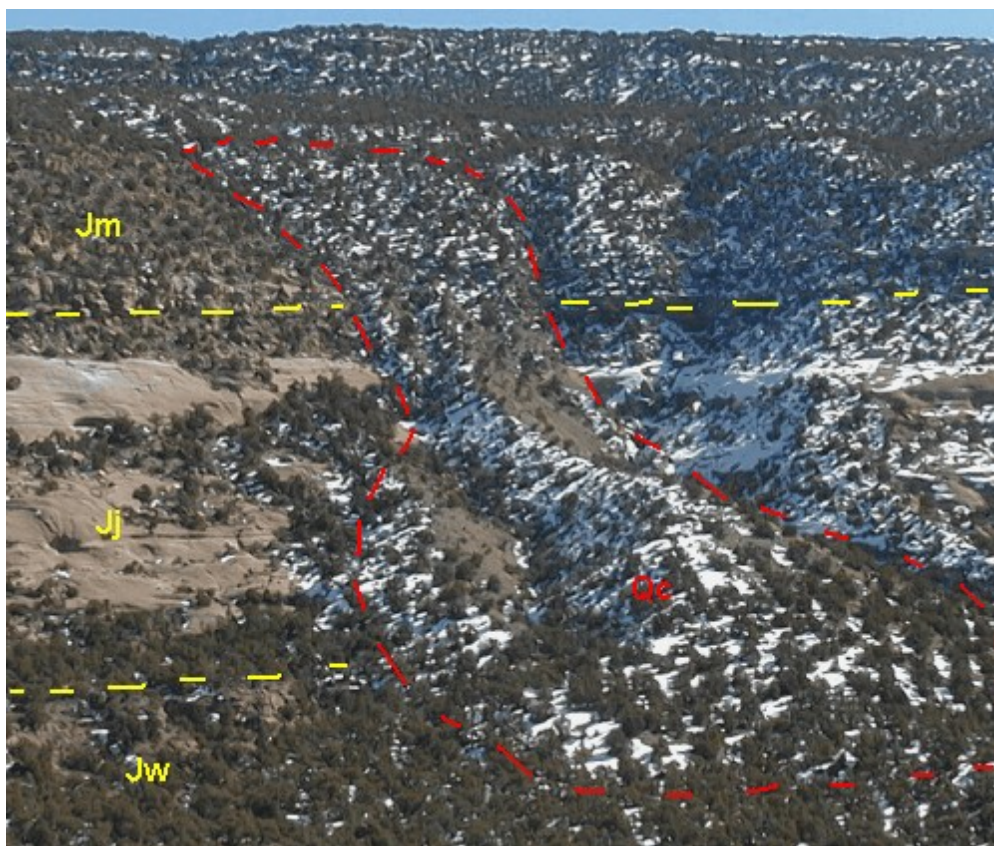
Qc - Colluvium (Quaternary)

Qt – Talus (Quaternary)

Heterogeneous deposits of rock debris that obscure underlying bedrock. Includes block rubble, rock glacier, and landslide deposits. (Condon, 1991).

Qc – Colluvial deposits (Pleistocene and Recent)

Talus, slope wash, block rubble, rock glaciers, and in some high cirques in the San Miguel Mountains, young glacial till. (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Landslide deposit in Sand Canyon, Colorado, southwest of Goodman Point Unit.

This deposit overlies the Wanakah Formation ([Jw](#)), the Junction Creek Sandstone ([Jj](#)), and the lower members of the Morrison Formation ([Jm](#)). (Photograph by Anne Poole, 2000).

Km - Mancos Shale (Upper Cretaceous)

Km – Mancos Shale, Main body (Upper Cretaceous)

Olive-gray to brownish-gray fissile marine shale interbedded with thin beds of light gray, fine-grained sandstone and limestone. Conformably overlies Dakota Sandstone. Thickness 1,900-2,000 feet (579-1,189 meters). (Condon, 1991).

Km – Mancos Shale (Upper Cretaceous)

Cross and Purlington (1899) named and described the Mancos Shale exposed along the Mancos River in eastern Montezuma County, Colo., where they estimated a thickness of 1,200 feet. The Mancos Shale in the Ute Mountains region consists of 1,900 feet of beds composed almost entirely of gray to dark-gray gypsiferous shale. The transition from swamp, tidal flat, and beach deposition during late Dakota time to marine deposition in Mancos time was gradual. In the southern and southwestern parts of the area, the Mancos sea reworked sands of Dakota age and deposited a pale-yellow to light-tan, weakly consolidated, structureless clayey sandstone about 35 feet thick. Fossils from this sandstone were identified by W.A. Cobban (written commun., 1956) as *Gryphaea* n. sp. Two conspicuous lithologic marker units are present in the lower part of the Mancos: the Greenhorn Limestone Member of the Mancos Shale (see Dane, 1957, and Wanek, 1959, p. 681) about 75 feet above the base, and the Juana Lopez Member of the Mancos Shale, about 475 feet above the base of the Mancos. (Ekren and Houser, 1965).

Km – Mancos shale (Upper Cretaceous)

Predominantly gray to black shaly mudstone. (Ekren and Houser, 1959b).

Km – Mancos shale (Upper Cretaceous)

Dark gray to black, soft, homogeneous marine shale with a few thin fossiliferous beds and a thin limestone near the base. Only the basal part of the formation is exposed in the area. Thickness (feet) 100+. (Finley, 1951).

Km – Mancos Formation (Upper Cretaceous)

Marine light to dark gray thin bedded shales and siltstones with well developed faunal zones. 2000 feet (at Mesa Verde National Park). (Griffitts, 1999).

Km – Mancos Shale (Upper Cretaceous)

Present in this area only as a thin mantle above Dakota Sandstone. (Hackman, 1955a,b,c, and d).

Km – Mancos Shale (Upper Cretaceous)

Gray to dark-gray soft fissile sparsely fossiliferous marine clay shale; a few thin distinctive calcareous sandstone and sandy clayey limestone ledges in lower 500 feet. Grades vertically into and intertongues with formations of the Mesaverde Group. 2,000 to 3,000 feet thick; thickens northeastward. (Haynes, Vogel, and Wyant, 1972).

Km – Mancos Shale (Upper Cretaceous)

Soft dark-gray to black marine shale containing thin lenses and concretions of sandy yellowish-orange limestone, 2000+/- feet thick; intertongues at top with the sandstone and shale member of the Point Lookout sandstone (Wanek, 1954).



Photograph Caption: Outcrop of Mancos Shale in the House Creek Fault zone, at Naraguinnep Reservoir, near Arriola, Colorado. (Photograph by Anne Poole, 2000).

Kd - Dakota Sandstone (Upper Cretaceous)

The Dakota Sandstone is an important formation at Hovenweep National Monument because many of the park's ruins were built on the rims of canyons eroded into this rock layer or on slump blocks of sandstone on the canyon floors. Much of the stone used in the construction of towers and dwellings appears to have been derived from this unit. Seeps and springs occurring in the Dakota (often at the heads of canyons or at the contact between the Dakota and the underlying Burro Canyon Formation) also determined which sites were best for settlement by ancestral Puebloans. For additional information on the Dakota Sandstone and its relevance to cultural resources at Hovenweep see [Dakota Sandstone \(Kd\) and Cultural Resources at Hovenweep](#).

Kd – Dakota Sandstone (Upper Cretaceous)

White, light-gray to medium-gray, and yellowish-brown conglomerate, conglomeratic sandstone, and fine- to medium-grained sandstone; dark- to medium-gray carbonaceous mudstone and siltstone; and interbedded coal and carbonaceous shale. Lower part fluvial, middle and upper parts coastal swamp, lagoon, and beach deposits. Unconformably overlies Burro Canyon Formation or Morrison Formation. Coal and carbonaceous shale in beds as much as 10 ft (3 m) thick. (Condon, 1991).

Kd – Dakota Sandstone (Upper Cretaceous)

The Dakota Sandstone of Late Cretaceous age ranges in thickness from 95 to 140 feet but averages 125 feet in most of the Ute Mountains area. It is composed of yellow-gray and tan carbonaceous sandstone of fluvial origin in the lower part and yellow-brown and yellow-gray sandstone of fluvial and beach origin in the upper part. These are interbedded with gray to dark-gray carbonaceous mudstone and coal that were probably deposited in a swamp or tidal flat environment. The coal beds are not persistent and range from a few inches to 3 feet in thickness. Sandstone cemented with iron oxide is common in the upper part of the formation.

The basal conglomerate of the Dakota has a maximum thickness of about 5 feet and is absent locally. Most of it is granule conglomerate but some is pebble conglomerate. In areas of relatively high pre-Dakota relief, slabs, chips, and, rarely, cobbles and boulders of quartzite are present in the conglomerate. Most of the granules and pebbles are chert and quartzite, although pebbles of mudstone and sandstone are common locally.

The sandstone beds of the lower part of the Dakota are cross-stratified at high angles. These beds are highly lenticular and have little value for structural interpretation. The uppermost sandstone bed in the Dakota is fairly continuous throughout the Ute Mountains area and is a useful horizon marker. The top of the Dakota was mapped at the top of this sandstone bed. The bed contains fossil pelecypods and is probably a reworked beach deposit. The pelecypods are the same as those occurring a few feet higher in the Mancos Shale, identified by W.A. Cobban (written commun., 1956) as *Gryphaea n. sp.*

The assignment of an age to the Dakota Sandstone is based on its lithologic similarity to the Dakota elsewhere on the Colorado Plateau and where a Late Cretaceous age has been established (Brown, 1950). Katich (1951, p. 2094) mentioned, however, that faunal evidence indicates that in parts of central Utah the lithologic unit called Dakota Sandstone is Early Cretaceous in age. Early Cretaceous fossils have also been found in a lower sandstone of the Dakota in the Carrizo Mountain area (J.D. Strobell, oral commun., 1957). In the latter areas the Burro Canyon Formation has not been recognized. Where the Burro Canyon Formation is recognized, the Dakota Sandstone is therefore apparently of Late Cretaceous age, and it is assigned this age in the Ute Mountains area. (Ekren and Houser, 1965).

Kd – Dakota Sandstone (Upper Cretaceous)

Yellowish lenticular sandstone and conglomerate with interbedded carbonaceous shale and impure coal. Average thickness about 125 feet. (Ekren and Houser, 1959b).

Kd – Dakota Sandstone (Upper and Lower Cretaceous)

Largely yellow-brown, cross-bedded, conglomeratic sandstone, shale, and carbonaceous shale. The carbonaceous shale changes rapidly to impure coal. The composition, texture, and cementing material of the sandstones vary widely. Locally the softer portions are thin to slabby sandstone interbedded with sandy shale. Contains petrified wood and chert locally. Thickness (feet) 200. (Finley, 1951).

Kd – Dakota Sandstone (Upper Cretaceous)

Dark brown medium to coarse grained marine sandstone. (Griffitts, 1999).

Dakota Sandstone

The Dakota Sandstone within the Hovenweep Monument is a fairly pure arenaceous sandstone with a variable amount of calcium carbonate and iron oxide cement. Some layers are fairly well cemented and withstand weathering reasonably well. Other layers are almost without visible cement and are held together primarily by the cohesiveness of the angular particles of quartz sand grains. The uppermost layer of Dakota at the Square Tower location is fairly well but not uniformly cemented with calcium carbonate and a little iron oxide which gives it a light brown color in places. Below this layer the rocks are somewhat lighter in color, light tan to white, gray or somewhat mottled due to scattered grains of iron oxide dispersed through the rock. The lighter colored rocks which were sampled had much less calcite cement, and the cement was not evenly distributed through the rocks. The Square Tower base block is part of this softer rock type. The Dakota Sandstone formation in this canyon is very strongly cross bedded, and much of the weathering has taken place along these prominent bedding planes.

Petrology (from specimens at Square Tower Group, Hovenweep Natl. Mon.): The Dakota Sandstone is a fairly pure arenaceous sandstone with grain size generally varying from about .05mm to .5 mm in diameter. The grain size was quite uniform within the individual specimens from which thin sections were made, but it varied from bed to bed. The coarser grained specimens generally showed more angular fragments and poorer sorting than the finer layers. This actually results in greater natural cohesiveness of the rock, because the individual grains fit more tightly together.

The rock is generally composed of about 98% quartz and chert grains with minor amounts of hematite, potash feldspar (microcline mostly), a very small amount of plagioclase feldspar (albite), and scattered grains of tourmaline and zircon. In isolated spots in all the rocks very finely divided calcite is visible in thin sections. Along the outer weathered surfaces a very thin coating (mostly less than .2mm) of fine calcite is visible. Within the main body of the rock, isolated clumps of the calcite are visible, but there is no overall cementation and only very rare crystals of calcite. Although there is a great variation in surface appearance of the different rock specimens, all have nearly the same petrographic composition. The major differences are grain size and weathering phenomena. Many of the rocks which have been weathered have a secondary deposit of iron oxide, calcite, and in some cases clay minerals on the surface by ground water movement. The clay was probably of wind blown origin. This type of surface deposit is visible on rocks throughout the area, and once formed, protects the underlying softer sandstone until the surface is broken. (Griffitts, 1994).

Kd – Dakota Sandstone (Lower? Cretaceous)

Dominantly yellowish-brown to gray quartzitic sandstone and conglomeratic sandstone in thick beds; subordinate thin lenticular beds of gray claystone, impure coal, carbonaceous papery shale, and gray friable carbonaceous sandstone; local coarse basal conglomerate. Marine near top; fluvial near base. Intertongues with Mancos Shale. A few tens of feet to 225 feet thick; averages about 100 feet thick. (Haynes, Vogel, and Wyant, 1972).

Kd – Dakota Sandstone (Lower and Upper Cretaceous)

Gray to dark yellowish-orange cross-bedded sandstone that contains shale lenses and beds of coal, 100+/- feet thick. (Wanek, 1954).

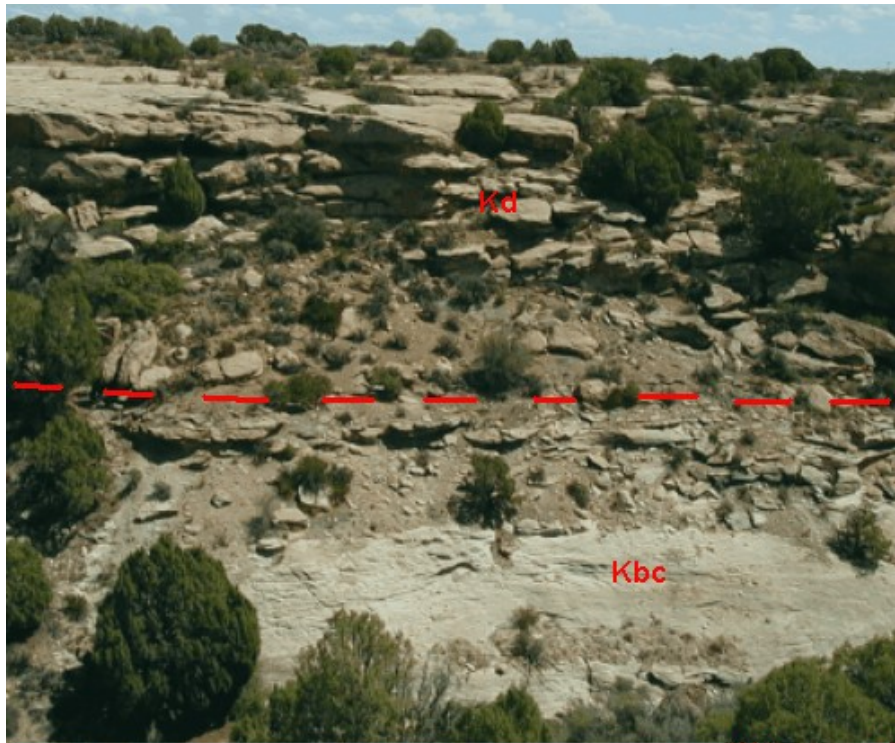


Photograph Caption: Sandstone slump blocks and carbonaceous shale in the Dakota Sandstone, Square Tower Unit, Hovenweep National Monument. (Photograph by Anne Poole, 2000).

Kdb - Burro Canyon Formation and Dakota Sandstone, undifferentiated (Upper and Lower Cretaceous)

The fluvial sandstone beds in the lower part of the Dakota are much like the sandstone in the upper part of the Burro Canyon Formation; where the disconformity is not apparent, distinction is difficult. Several criteria were used to distinguish the two formations, and these gave reliable results in mapping (Ekren and Houser, 1965):

Dakota Sandstone	Burro Canyon Formation
a.) Carbonaceous material common in all types of strata.	a.) Carbonaceous material absent or scarce.
b.) Sandstone contains very little conglomeratic material except in lowermost beds and are yellow-brown or yellow-gray.	b.) Sandstone beds are commonly conglomeratic and white.
c.) Interbedded mudstone commonly is medium gray to black, and very rarely light gray.	c.) Mudstone beds are mostly green and red; a few are very light gray to white.
d.) Mudstone pebbles in basal beds are mostly gray or black, but some are green, white, and red.	d.) Mudstone pebbles in conglomeratic material are red or green.



Photograph Caption: Contact between Dakota Sandstone (upper tan sandstone beds), and Burro Canyon Formation (lower gray rock layer), Square Tower Unit, Hovenweep National Monument. (Photograph by Anne Poole, 2000).

Kbc - Burro Canyon Formation (Lower Cretaceous)

Kb – Burro Canyon Formation (Lower Cretaceous)

White to light-gray conglomerate, conglomeratic sandstone, and fine- to medium-grained sandstone and grayish-green to grayish-red, generally nonbentonitic, hackly weathering mudstone. Fluvial channel and overbank origin. May intertongue with Morrison Formation. Thickness 0-200 ft (61 m). (Condon, 1991).

Kb – Burro Canyon Formation and Kbk – Karla Kay Conglomerate Member (Lower Cretaceous)

In the Ute Mountains area, the Burro Canyon Formation (Stokes and Phoenix, 1948) ranges from 30 to 200 feet in thickness and consists of green, predominantly nonbentonitic mudstone interbedded with lenses of conglomerate and conglomeratic sandstone that vary considerably in number and thickness. Red mudstone occurs sporadically in the lower part of the formation. The nonbentonitic mudstone weathers hackly or fissile.

The conglomerate and conglomeratic sandstone are commonly white or light gray. They contain pebbles and granules of colored chert, silicified limestone, and siltstone in a matrix of quartz sand. Fragments of petrified wood and silicified dinosaur bone are common in the lowermost lenses. Carbonized plant remains are extremely rare. The conglomerate lenses in the upper part of the formation are more numerous, finer grained, and blanket larger areas than those in the lower part.

The lowest unit in the Burro Canyon Formation, a system of shoestring lenses of conglomerate and conglomeratic sandstone, has been named the Karla Kay Conglomerate Member from an exposure at the Karla Kay mine in McElmo Canyon (Ekren and Houser, 1959a). The Karla Kay is highly resistant to weathering, and forms vertical cliffs and dark brown knobby outcrops. The shoestring lenses or channel fillings are rarely more than 2,000 feet wide or more than 65 feet thick; commonly they are 500 to 800 feet wide. The channel fillings have been undercut in many areas, and their former locations are marked by huge, resistant, dark blocks – many as large as a house – that have slumped down the slopes of soft underlying mudstone. Where the Karla Kay Conglomerate Member is absent, the base of the Burro Canyon is marked either by hackly-weathering mudstone or by fine-pebble and granule conglomerate or sandstone. These rocks, although basal, are stratigraphically younger than the Karla Kay. (Ekren and Houser, 1965).

Note: The Karla Kay member is mapped separately on U.S. Geological Survey maps MF-216, MF-217, and MF-221, but on many other published maps of the area. Outcrops of this member were found in Hovenweep Canyon east of the Cutthroat park unit on the Negro Canyon quadrangle.

Kbc – Burro Canyon Formation (Lower Cretaceous)

Sandstone and conglomerate with interbedded green and red shale; ranges from 30 to 200 feet in thickness; intertongues with mudstone of the Brushy Basin shale member of the Morrison Formation. (Ekren and Houser, 1959b).

Kbc Burro Canyon Formation (Lower Cretaceous)

Light-gray and light-brown fluvial quartzose sandstone and conglomerate in thick beds; lenticular greenish-gray, locally purplish, commonly nonbentonitic siltstone, shale, and mudstone; a few thin lenses of gray limestone and chert near top. Averages about 150 feet thick; thins southward to an irregular wedge edge near San Juan River south of which are only a few thin discontinuous conglomerate lenses. In northeast part of map (Cortez 1x2 degree quadrangle) thin discontinuous mudstone and sandstone lenses are locally mapped with the Brushy Basin Member of the Morrison Formation. A few uranium deposits occur in some thick sandy conglomeratic beds and in some beds of gray shale. (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Sandstone of the Burro Canyon Formation, at Square Tower Unit, Hovenweep National Monument. Note hat for scale. (Photograph by Anne Poole, 2000).

Jm - Morrison Formation (Upper Jurassic)

The Morrison Formation consists of four mapped members in the Hovenweep area. These members are, in descending order:

[Jmb](#) - Morrison Formation, Brushy Basin Member

[Jmw](#) - Morrison Formation, Westwater Canyon Member

[Jmr](#) - Morrison Formation, Recapture Member

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

Note: Jm is not an actual mapped unit on the GRI digital geologic-GIS maps for Hovenweep National Monument. The symbol is merely used in association with the Morrison Formation for unit listing.

Descriptions for the Morrison Formation. Some provide descriptions for, and/or mention the above members.

Jm – Morrison Formation and Jmb – Bluff Sandstone Member (Upper Jurassic)

Thickness (feet) 490. Green, red, purple, pink, and gray laminated and bentonitic shale; fine- to coarse-grained red, buff, and white conglomeratic sandstone; and shale, sandy shale, and shaly sandstone. The sandstones and conglomerates are rather lenticular and contain red chert locally. The Bluff sandstone member at the base is a white, medium-grained, friable, clean and uniform, heavily crossbedded sandstone 165 feet thick that lies unconformably on the Summerville (Wanakah) formation. (Finley, 1951).

Note: In the Hovenweep area, the Bluff Sandstone is now considered to be part of the Junction Creek Sandstone, although it is still classified as a member of the Morrison in parts of Utah, Arizona, and New Mexico. (Finley, 1951).

Morrison Formation (Upper Jurassic)

The Morrison Formation was named by Emmons, Cross, and Eldridge (1896) from the town of Morrison, near Denver, Colo., where the formation is about 200 feet thick and is composed of green or gray fresh-water marls and thin beds of limestone and sandstone.

Throughout the Colorado Plateau the Morrison Formation is composed of stream and flood-plain deposits. Sandstone and conglomeratic sandstone occur in ancient stream channels, and mudstone on contiguous flood plains. Fluvial deposition prevailed during early Morrison time and gradually gave way to predominant flood-plain deposition during late Morrison time.

The Morrison of the Ute Mountains area has been divided into four members. These are, in ascending order: the Salt Wash Sandstone Member, Recapture Shale Member, Westwater Canyon Member, and Brushy Basin Shale Member (Gilluly and Reeside, 1928; Gregory, 1938; and Lupton, 1914). A discussion of the regional aspects of the Morrison is given by Craig and others (1955, p. 134-159).

The lower three members – the Salt Wash, Recapture, and Westwater Canyon – are composed predominantly of lenticular light-tan and light-gray sandstone which is interstratified with thin red or green siltstone and claystone. The Brushy Basin, a bentonitic mudstone, is mainly green, but is subordinately red, purple, and gray.

Because the upper two members, and also the lower two, intertongue and intergrade to a considerable extent field division is arbitrary in many places. The Westwater Canyon Member intertongues with the Brushy Basin. The Westwater Canyon and the Recapture Members do not intertongue, but their distinction is extremely difficult and is based largely on the predominance of red mudstone in the Recapture in contrast to predominantly green mudstone in the Westwater Canyon. Where the Recapture is absent in eastern McElmo Canyon, the Westwater Canyon possibly intertongues with the upper lenses of the Salt Wash. The Salt Wash Member intertongues with the Recapture to a considerable degree in most places.

The intertonguing and intergrading of members of the Morrison Formation in the Ute Mountains area are believed to reflect alternating deposition from two different source areas. Sediments forming the Recapture and Westwater Canyon Members were derived from an area south of Gallup N. Mex. (Craig and others, 1955, p. 150). Sediments forming the Salt Wash and Brushy Basin probably were derived from a major source area in west-central Arizona and southeastern California. The lower three members of the Morrison in the Ute Mountains show considerable blending of sediments from the two sources.

Despite the complexities of deposition during Morrison time and considerable variation in the thicknesses of the individual members, the total thickness of the Morrison is consistently between 500 and 650 feet. Where one member is thin, generally another is correspondingly thick. The Brushy Basin Member and the overlying Burro Canyon Formation have a similar nearly constant total thickness. This consistency in total thickness is of value in determining structure below the Morrison from data obtained on formations above the Burro Canyon.

The assignment of a Late Jurassic age to the Morrison in the Ute Mountains area is based on lithologic correlation with the Morrison of other parts of the Colorado Plateau where a Late Jurassic age seems indicated by vertebrate remains (Stokes, 1944). (Ekren and Houser, 1965).

Jm – Morrison Formation (Upper Jurassic)

Dominantly fluvial, subordinately lacustrine, sandstone and mudstone alluvial deposits. Generally about 600 feet thick; thickness ranges from 550 feet in south center of map (Cortez 1x2 degree quadrangle) to 800 feet in northwest part. (Haynes, Vogel, and Wyant, 1972).

Jmb - Morrison Formation, Brushy Basin Member (Upper Jurassic)**Jmb – Morrison Formation, Brushy Basin Member (Upper Jurassic)**

Light greenish-gray to reddish-brown, bentonitic mudstone, very fine grained sandstone, and minor amounts of conglomeratic sandstone, limestone, and the zeolites analcime and clinopyrite. Fluvial and lacustrine origin. Intertongues with underlying Westwater Canyon Member. Thickness 100-350 ft (30-107 m). (Condon, 1991).

Jmb – Morrison Formation, Brushy Basin Shale Member (Upper Jurassic)

The uppermost member of the Morrison Formation, the Brushy Basin Member, was first described Gregory (1938, p.59) from the region around Brushy Basin, Utah. It is composed of bentonitic varicolored mudstone that forms slopes and becomes hard and frothy appearing where weathered. The frothy appearance is a result of swelling and subsequent drying of bentonite in the mudstone. Swelling muds are not known in the lower members of the Morrison nor in the overlying Burro Canyon Formation. Moderately persistent interbeds of thin resistant, very fine grained silicified sandstone are common, although in many places green friable conglomeratic sandstone about 20 feet thick occurs near the middle of the member. Locally, where there Brushy Basin Member is thin and the Burro Canyon is thick, the conglomerate is near the top of the member. The conglomerate contains many fragments of igneous rock.

The lower part of the Brushy Basin intertongues with the Westwater Canyon Sandstone Member in places, but in others the contact appears to be a nearly flat surface for long distances. The base is placed at the top of the highest sandstone of the Westwater Canyon lithology.

The upper part of the Brushy Basin intertongues in many places with the Burro Canyon Formation (Ekren and Houser, 1959d) . Localities where intertonguing is most pronounced are generalized on the geologic map (pl. 1 of Ekren and Houser, 1965)

In many areas the top of the Brushy Basin is identified by a change from bentonitic to nonbentonitic mudstone. Locally, the two mudstones are separated by a ledge of silicified siltstone about 1 foot thick, particularly in exposures southwest of the Ute Mountains. In other areas, bentonitic mudstone typical of the Brushy Basin is overlain directly by conglomeratic sandstone or conglomerate typical of the Burro Canyon. In still other areas, intertonguing is extensive. Most commonly, sandstone and conglomerate typical of the Burro Canyon are interbedded with mudstone typical of the Brushy Basin, but interbedding of bentonitic and nonbentonitic mudstone has been observed in western McElmo Canyon.

The Brushy Basin forms slopes throughout McElmo Canyon and its tributary canyons in the Moqui SW quadrangle west of the Ute Mountains. It ranges in thickness from 150 to 300 feet. (Ekren and Houser, 1965).

Jmb – Morrison Formation, Brushy Basin shale member (Upper Jurassic)

Brushy Basin shale member, Jmb, 150 to 300 feet thick, consists of varicolored bentonitic mudstone with a few conglomeratic sandstone lenses. (Ekren and Houser, 1959b).

Jmb – Morrison Formation, Brushy Basin Member (Upper Jurassic)

Variegated gray, pale-green, red-brown, or purple bentonitic mudstone; a few lenses of distinctive

green and red chert-pebble conglomeratic sandstone, some of which contain uranium-vanadium deposits. Thickness ranges from about 150 to more than 700 feet. (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Bentonitic mudstone in the Brushy Basin Member showing “frothy” appearance. Note glove for scale. Photo taken in Little Ruin Canyon near the Square Tower Unit, Hovenweep National Monument. (Photograph by Anne Poole, 2000).

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

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

Tan, light-gray, and yellowish-brown, fine to medium-grained sandstone and light greenish-gray to dark-gray mudstone. Fluvial origin. Conformably overlies Recapture Member. Thickness 50-350 ft. (Condon, 1991).

Jmw – Morrison Formation, Westwater Canyon Sandstone Member (Upper Jurassic)

The Westwater Canyon Member (Gregory, 1938, p. 59) ranges from 40 to more than 200 feet in thickness in the Ute Mountains area and averages about 100 feet. Slightly more than 240 feet of the member was measured at the south end of the Ute Mountains. The sandstone beds in the Westwater Canyon are pale yellow gray to light brown on fresh surfaces and weather to light yellow gray or yellow. They are composed of fine- to medium-grained subangular to subrounded quartz and numerous white, red, or pink accessory minerals. Detrital feldspar is sparse. The sandstone lenses are cross-stratified channel-fills. They form rounded and irregular cliffs.

The Westwater Canyon Member intertongues and intergrades with the mudstone beds of the Brushy Basin. It is conformable with the Recapture and may possibly intertongue with the Salt Wash. It is present throughout McElmo Canyon and to the north in Trail Canyon. The Westwater Canyon Sandstone Member is exposed in the dome south of Sentinel Peak and in Towaoc dome. (Ekren and Houser, 1965).

Jmw – Morrison Formation, Westwater Canyon sandstone member (Upper Jurassic)

Westwater Canyon sandstone member, Jmw, 75 to 100 feet thick, consists of pale yellow-brown fine- to medium-grained sandstone interbedded with green bentonitic mudstone. (Ekren and Houser, 1959b).

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

Mostly yellowish- and greenish-gray to pinkish-gray lenticular fine- to coarse-grained arkosic sandstone; some interbedded greenish-gray or grayish-red sandy shale and mudstone. About 180 feet thick in Bluff area; thins northeastward to a wedge edge between Blanding and Cortez. (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Sandstone and green mudstone in the Westwater Canyon Member of the Morrison Formation, McElmo Canyon, Colorado.
(Photograph by Anne Poole, 2000).

Jmr - Morrison Formation, Recapture Member (Upper Jurassic)

Jmr – Morrison Formation, Recapture Member (Upper Jurassic)

White to light-gray, fine-grained, lenticular sandstone beds and reddish-brown to pale-green mudstone. Fluvial origin. Intertongues with underlying Salt Wash Member. Member pinches out in western McElmo Canyon but is present throughout area west of Mesa Verde and south of Sleeping Ute Mountain in subsurface. Thickness 0-260 ft (79 m). (Condon, 1991).

Jmr – Morrison Formation, Recapture Shale Member (Upper Jurassic)

The Recapture Shale Member was first named and describe by Gregory (1938, p. 58) from Recapture Creek, southeastern Utah. In the Ute Mountains, it is composed of interbedded sandstone and mudstone. The sandstone beds are light gray, pinkish gray, or light brown on fresh surfaces and weather to pinkish gray or brownish gray. The quartz grains are fine grained, poorly sorted, and subangular to subrounded. Black, orange, pink, and white accessory grains are common. Detrital grains of feldspar are extremely sparse. The mudstone beds are pale red, reddish green, and pale green.

McElmo Canyon marks the approximate northern limit of the Recapture Member in southwest Colorado (Craig and others, 1955, p. 137-140). It is present west of a north-south line through the junction of Sand Creek with McElmo Creek. In the lower McElmo Canyon section measured by L.C. Craig (written commun., 1949), the Recapture is 117 feet thick. It is more than 260 feet thick south of the Ute Mountains where exposed in a breached dome south of Sentinel Peak. In this exposure the member contains more siltstone and claystone than in McElmo Canyon.

The intertonguing and intergrading relations of the Recapture with the overlying and underlying members have been discussed (see Morrison Formation topic). The Recapture is recognized regionally in an oval-shaped area stretching from west of Santa Fe, N. Mex., into southeastern Utah. In that area, it has been divided into three facies (Craig and others, 1955, p. 137-142): a conglomeratic sandstone facies, a sandstone facies, and a claystone and sandstone facies. The conglomeratic sandstone facies and the sandstone facies occupy the south-central part of the oval area. The Ute Mountains area is on the northeastern edge of the claystone and sandstone facies. (Ekren and Houser, 1965).

Jmr – Morrison Formation, Recapture shale member (Upper Jurassic)

Recapture shale member, Jmr, 50 to 80 feet thick, consists of tan-gray to reddish-gray fine-to medium-grained sandstone interbedded with red mudstone. (Ekren and Houser, 1959a).

Jmr – Morrison Formation, Recapture Member (Upper Jurassic)

Reddish-gray, white, and brown fine- to medium-grained sandstone characterized by dark- and light-colored grains; interbedded reddish-gray siltstone and mudstone. About 200 feet thick in southwest corner of map (Cortez 1x2 degree quadrangle); thins, intergrades, and intertongues northeastward with Salt Wash Member. Contains a few uranium deposits. (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Outcrop of Recapture Member of the Morrison Formation, near Aneth, Utah. (Photograph by Anne Poole, 2000).

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

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

Light-gray, yellow and tan, fine- to medium-grained sandstone and greenish-gray to reddish-brown mudstone. Overlies Junction Creek Sandstone erosively in some places and gradationally in others. Fluvial origin. Thickness 0-250 ft (76 m). (Condon, 1991).

Jms – Morrison Formation, Salt Wash Sandstone Member (Upper Jurassic)

The name Salt Wash Sandstone Member was first proposed by Lupton (1914, p. 125-127) for a member of the McElmo Formation. The name McElmo Formation was later abandoned, and these rocks were divided into the Morrison, Summerville (Wanakah), Entrada, and Carmel formations; and the base of the Morrison was defined as the base of the Salt Wash (Baker and others, 1927; Gilluly and Reeside, 1928).

In the Ute Mountains area, the Salt Wash Member consists of interbedded sandstone and predominantly red mudstone. It lies upon massive crossbedded sandstone of the Junction Creek and is overlain by the Recapture, Westwater Canyon, or Brushy Basin Members. The sandstone lenses of the Salt Wash range from white or light gray to pale yellow or very pale brown. They are trough cross-stratified and are composed of fine- to medium fine-grained clear subangular to subrounded quartz accompanied by sparse to common accessory grains of black, white, red, or pink color. The sandstone lenses are interbedded with dark-red, dark purple, and red brown mudstone. Gray or green-gray mudstone is extremely rare.

The Salt Wash Member is exposed continuously for a distance of about 11 miles along the slopes of

McElmo Canyon. It is absent between the Junction Creek Sandstone and the Recapture Member on the structural dome just south of Sentinel Peak in the Sentinel Peak NE quadrangle, although some of the sandstone there mapped as the Westwater Canyon Member is lithologically similar to the Salt Wash of McElmo Canyon and may be a bed of the Salt Wash. The Salt Wash Member is absent also in northeastern Arizona, a few miles northwest of the Carrizo Mountains (L.C. Craig, oral commun., 1956).

The thickness of the Salt Wash Member varies considerably in McElmo Canyon. The member is 90 to 110 feet thick near the west end of the canyon, where it is overlain by the Recapture Member. Further east, it is approximately 150 feet thick, and Recapture Member is absent. Still further east, at Trail Canyon, the Salt Wash is 200 to 250 feet thick, and the overlying Westwater Canyon Member is thin.

The basal sandstone of the Salt Wash Member commonly is separated from the underlying Junction Creek Sandstone by red-brown mudstone 3 to 50 feet thick. Because this mudstone resembles the mudstone interlayered higher in the Salt Wash, it is included with the member. The contact of the Salt Wash with the overlying Recapture Member, and locally with the Westwater Canyon Member, is difficult to determine. In contrast to the Salt Wash, the sandstone beds of the Recapture and Westwater Canyon Members contain very sparse detrital grains of feldspar and generally are interbedded with red and green mudstones, respectively. The pink tone of the Recapture Shale Member is distinctive and contrasts with the colors of the Salt Wash and Westwater Canyon Members. In much of western McElmo Canyon the contact between the Salt Wash and Recapture is marked by a narrow bench formed on the top of the uppermost part of the Salt Wash Sandstone Member. (Ekren and Houser, 1965).

Jms – Morrison Formation, Salt Wash sandstone member (Upper Jurassic)

Salt Wash sandstone member, Jms, 150 to 250 feet thick, consists of tan-gray fine- to medium-grained sandstone interbedded with red-brown and purple mudstone. The Salt Wash sandstone member is uranium-bearing in many areas of the Colorado Plateau but no deposits are known in this quadrangle (7.5 minute Cortez SW). Adjacent members intertongue and intergrade to such an extent that in many places the contacts are arbitrary. (Ekren and Houser, 1959b).

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

Pale-gray, grayish-orange, or moderate-reddish-brown fine- to medium-grained fluvial sandstone in thick discontinuous beds; interbedded greenish- and reddish-gray mudstone; thin beds of limestone locally near base. In San Miguel Mountains may include at base a thin equivalent of Junction Creek Sandstone. As much as 550 feet thick; thin or absent from south of San Juan River nearly to south edge of map (Cortez 1x2 degree quadrangle). Thicker more continuous sandstone beds contain numerous small and some large uranium deposits. (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Salt Wash Member of the Morrison Formation (Jms), overlying the Junction Creek Sandstone (Jj), Sand Canyon, Colorado. (Photograph by Anne Poole, 2000).

Jj - Junction Creek Member (Upper Jurassic)

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Jj – Junction Creek Sandstone (Upper and Middle Jurassic)

Pink, reddish-orange, and brown, fine- to coarse-grained sandstone. Informally divided into three units by Ekren and Houser (1965, p 12); upper unit is fine-grained argillaceous sandstone with poorly exposed flat stratification; middle unit is thick-bedded sandstone with very large to large-scale, high-angle crossbeds; has coarse grains of chert concentrated on laminations; lower unit is alternating flatbedded and low-angle cross-stratified beds characterized by numerous horizontal bedding planes. Eolian dune and interdune origin. Upper two units correlate with Bluff Sandstone Member of Morrison Formation, present in Utah; lower unit probably correlates with Horse Mesa Member of Wanakah Formation (Condon and Huffman, 1988). Lower unit conformably overlies Wanakah Formation. Entire formation 200-300 ft (61-91 m) thick. (Condon, 1991).

Jj – Junction Creek Sandstone (Upper Jurassic)

The Junction Creek Sandstone was named by Goldman and Spencer (1941, p. 1750-1751) from an exposure between Junction Creek and the Animas River a few miles north of Durango. It correlates with the Bluff Sandstone of Utah, Arizona, and New Mexico.

In the McElmo Canyon area the Junction Creek Sandstone forms a conspicuous cliff, characteristically a “slick rim,” and its outcrops closely resemble those of the Entrada Sandstone. Generally, however, the Junction Creek Sandstone is light red, reddish orange, or pink, in contrast with the white to orange Entrada Sandstone. In the vicinity of igneous intrusions, the Junction Creek Sandstone is light brown. The formation averages about 280 feet in thickness and is divisible into three gradational units based on the type of bedding. The lower unit, 30 to 50 feet thick, is composed of alternating beds of flat-stratified and cross-stratified sandstone. The cross-strata dip at

low angles and are truncated by planar surfaces erosion. A few of the horizontal surfaces of erosion may be continuous across all the exposures in McElmo Canyon. The middle unit, 150 to 250 feet thick, is composed of thick-bedded fine to coarse-grained sandstone that is cross-stratified at high angles (nearly 30 in several exposures). The upper unit, 20 to 50 feet thick, is argillaceous fine-grained reddish sandstone, commonly mottled or blotched green and gray. This unit has obscure flat stratification and weathers to hoodoos.

Subangular red and orange chert grains are common in the lower and middle units. The chert commonly is concentrated in single beds within a set of strata. The angular chert grains contrast with the subrounded to rounded quartz grains.

The lithology of the lower unit of the Junction Creek Sandstone indicates alternating subaqueous and subaerial deposition, which in turn suggests an oscillating sea at the end of Summerville (Wanakah) time. The middle unit reflects predominantly eolian deposition. Sand dunes 50 feet high were common during this period. The flat stratification of the upper unit may indicate a return of subaqueous conditions or deposition on a low flood plain near sea level.

The contact with the overlying Salt Wash Member of the Morrison Formation is locally disconformable. In many places lenses of fluviatile sandstone of the Salt Wash Member have been deposited in channels scoured in the Junction Creek Sandstone. In other places the argillaceous sandstone of the upper unit grades into mudstone and siltstone typical of the Salt Wash.

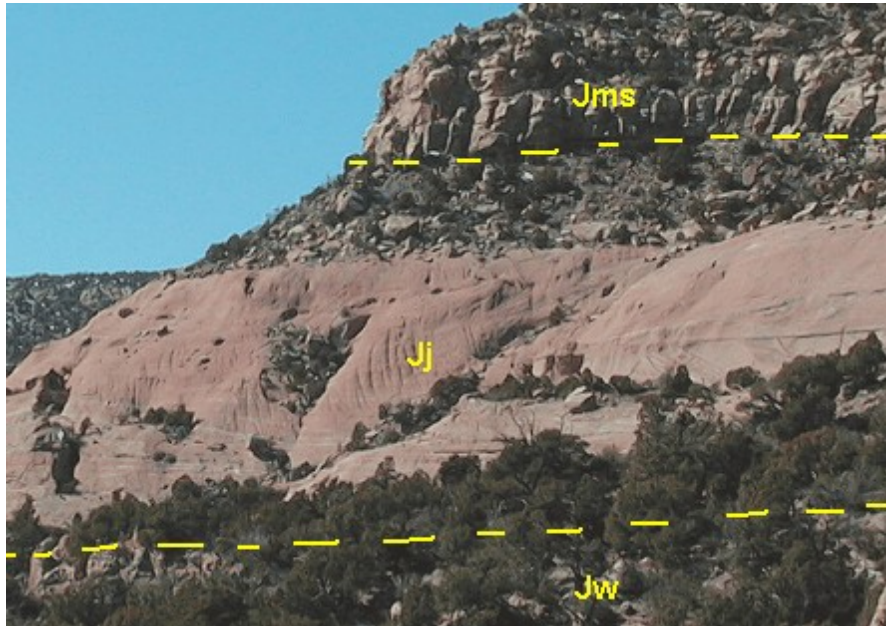
The irregular Junction Creek-Salt Wash contact suggests that the earliest streams of Salt Wash time flowed with sufficient velocity over a Junction Creek surface of low relief to cause down-cutting through the underlying soft muddy sands. In places, stream deposition of sand alternated with subaqueous (flood plain?) deposition of argillaceous sand, mud, and silt. (Ekren and Houser, 1965).

Jj – Junction Creek Sandstone (Upper Jurassic)

Consists of three gradational units. The upper unit, 20 to 50 feet thick, is argillaceous fine-grained reddish sandstone with obscure flat stratification. The middle unit, 150 to 200 feet thick, is pink to orange-red poorly sorted fine- to coarse-grained quartz sandstone with high-angle cross-stratification; weathers to a "slick rim". The lower unit, 30 to 50 feet thick, had the same general lithology as the middle unit, but with low-angle cross-stratification and numerous horizontal truncations. Thickness is 230 feet to 280 feet; contact with underlying Summerville Formation (Wanakah) is gradational. Correlates with the Bluff sandstone of Utah and Arizona. (Ekren and Houser, 1959b).

Jj – Junction Creek Sandstone (Upper Jurassic)

Lateral equivalent of Bluff Sandstone. Pink or reddish-orange fine- to coarse-grained poorly sorted eolian cross-bedded sandstone. Forms a rounded "slick rim." About 275 feet thick; merges northward with the upper part of Summerville Formation (a.k.a. Wanakah Formation); thins and becomes even bedded to the east and mapped with the Salt Wash Member of the Morrison Formation. (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Junction Creek Sandstone ([Jj](#)) overlain by the Salt Wash Member of the Morrison Formation ([Jms](#)) and overlying the Wanakah Formation ([Jw](#)); at Sand Canyon, Colorado. Note eolian crossbedding in the prominent middle “slick rim” unit. The (not visible) contact between the lowermost unit of the Junction Creek ([Jj](#)), and the Wanakah is gradational. (Photograph by Anne Poole, 2000).

Jw - Wanakah Formation (Middle Jurassic)

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Note: On the pre-1988 maps used for this project, the Wanakah Formation is referred to as the “Summerville Formation”. The nomenclature for these rocks has since been revised.

Jw – Wanakah Formation (Upper and Middle Jurassic)

Light to dark reddish-brown and reddish-orange, very fine grained, thin-bedded sandstone and dark reddish-brown mudstone. Sabkha and marginal marine origin. Conformably overlies Entrada Sandstone. Unit consists mainly of non-resistant beds except for a widespread sandstone ledge, 15-30 ft (4.5-9 m) thick, near top. 125-150 ft (38-46 m) thick (Ekren and Houser, 1965, p.11). (Condon, 1991).

Wanakah Formation

The Wanakah Formation conformably overlies the Entrada Sandstone from Bluff (UT) to Toadlena (NM). In the recent past the Wanakah was known as the Summerville Formation (Kocurek and Dott, 1983, p. 111). Investigations in east-central Utah, however, indicate that the Summerville is truncated by an unconformity at the base of the Morrison Formation and is not present in southeast Utah (O’Sullivan, 1980a, b). Instead, the term Wanakah Formation was brought in from southwest Colorado and applied to beds between the Entrada Sandstone and the Morrison Formation in southeast Utah (O’Sullivan, 1980b). The strata can be traced almost continuously south and southeastward from Utah, and subsequently Condon and Huffman (1988) extended the name Wanakah into northeast Arizona and northwest New Mexico to replace the name Summerville. In the Ouray area of southwest Colorado, the Wanakah was originally defined as the basal member of the

Morrison Formation (Burbank, 1930, p. 172). Later, Eckel (1949, p. 28) raised the Wanakah to formational status in the La Plata Mountains, near Durango, Colo., where it consists of, in ascending order, the Todilto Limestone, the Beclabito, and the Horse Mesa (Condon and Huffman, 1988); in Utah the terminology of O'Sullivan (1980b) is used. (Condon, 1989).

Wanakah Formation (Middle Jurassic)

Use of the name Summerville Formation in northwestern New Mexico and northeastern Arizona is here discontinued, and this name is replaced by the name Wanakah Formation in that area. In New Mexico and Arizona the Wanakah consists of the basal Todilto Limestone Member and two new members, the Beclabito and Horse Mesa Members. The Wanakah underlies the Morrison Formation, and intertongues laterally with the Cow Springs Sandstone. On the basis of previously established stratigraphic relations, the Wanakah is considered to be Middle Jurassic in age. (Condon and Huffman, 1988).

Js – Summerville Formation (Upper Jurassic)

The Summerville Formation of Late Jurassic age was named by Gilluly and Reeside (1928, p. 80) from exposures on Summerville Point in the San Rafael Swell, Utah. In the type locality the Summerville overlies the Curtis Formation. In the McElmo Canyon area the Summerville Formation overlies the Entrada Sandstone and underlies the Junction Creek Sandstone. The formation is dominantly brick red to red brown and is composed of alternating and gradational beds of very fine to fine-grained well-sorted sandstone and silty mudstone. Stratification is generally flat. The formation is from 125 to 150 feet thick and, with the exception of a resistant sandstone bed 10 feet below the top is bench forming. The lower 10 to 15 feet of the formation contains thin beds of white to pale-brown sandstone that resemble the Entrada Sandstone.

The resistant sandstone near the top of the Summerville is continuous throughout the McElmo Canyon area. This sandstone is generally reddish brown or pink, but near igneous intrusive rocks in the Ute Mountains and near some faults in McElmo Canyon it is yellow brown. It is radioactive near faults in the vicinity of Rock Creek in secs. 22 and 23, T. 36N., R 18 W.

The flat stratification and good sorting of grains in the Summerville Formation indicate deposition in clear water. The gradual increase in sand content upward in the formation suggests deposition in a receding sea.

The contact of the Summerville Formation with the overlying Junction Creek Sandstone is gradational throughout the McElmo Canyon area. Sandstone and mudstone of the Summerville Formation are interbedded with sandstone similar to that of the overlying Junction Creek in many places. The contact was chosen where rocks lithologically similar to the Junction Creek predominate above and rocks lithologically similar to the Summerville predominate below. (Ekren and Houser, 1965).

Js – Summerville Formation (Upper Jurassic)

Flat- and thin-bedded brick-red argillaceous sandstone and siltstone 120 to 130 feet thick, forms a bench. A 20-foot fine-grained well-sorted sandstone at top is radioactive near faults in the north-central part of quadrangle (Battle Rock 7.5 minute quadrangle, CO, a.k.a. Moqui SE). (Ekren and Houser, 1959c)

Summerville Formation (Upper and Middle Jurassic)

Alternating thin beds of brick-red, blocky, laminated, sandy shale and fine-grained white to red sandstone. Thickness (feet) 80. (Finley, 1951).

Jwe – Wanakah Formation and Entrada Sandstone (Upper Jurassic)

Wanakah Formation (lateral equivalent of the Summerville Formation) is 25 to 100 feet thick and consists of 3 members (in descending order): marl member, greenish-gray to red-brown friable limy

sandy siltstone; Bilk Creek Sandstone Member, light-colored friable fine-grained quartz sandstone in thin even beds with a distinctive red chalcedony zone at the top; Pony Express Limestone Member, dark-gray fetid bituminous thin-bedded limestone generally about 10 feet thick, but thins westward to 0 feet within a few miles of the east edge of map (Cortez 1x2 degree quadrangle). (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Sandstone and bench-forming mudstone of the Wanakah Formation, Sand Canyon, Colorado. The contact between the top of the Wanakah and the lowermost unit of the Junction Creek Sandstone is gradational. (Photograph by Anne Poole, 2000).

Je - Entrada Sandstone (Middle Jurassic)

San Rafael Group

Je – Entrada Sandstone (Middle Jurassic)

Divided into two parts; not mapped separately. Slick Rock Member is white, pinkish-orange, and reddish-orange, very fine to fine-grained sandstone of eolian dune and interdune origin; consists of alternating medium- to thick-bedded sets of flatbedded and crossbedded strata; lower part is slightly more argillaceous than upper part and weathers into large alcoves. Thickness of Slick Rock is 70-80 ft (21-24 m) (Ekren and Houser, 1965, p. 8). Dewey Bridge Member is dark reddish-orange, argillaceous, very fine grained, flat-bedded sandstone of sabkha origin. Unconformably overlies Glen Canyon Group. Thickness of Dewey Bridge is 25-35 ft (8-11 m) (Ekren and Houser, 1965, p. 8). (Condon, 1991).

Je – Entrada Sandstone (Upper Jurassic)

The Entrada Sandstone (Gilluly and Reeside, 1928, p. 76) consists of two units in McElmo Canyon and its tributaries. The two units have been named the Dewey Bridge Member and the Slick Rock Member by Wright, Shawe, and Lohman (1962, p. 2057). The type locality of the Dewey Bridge Member is at Dewey Bridge, Grand County, Utah, and the type locality of the Slick Rock Member is at Slick Rock, San Miguel County, Colo., about 30 miles north of the Ute Mountains area. The Dewey Bridge Member (lower unit) is red hoodoo-weathering sandstone that forms a bench over the resistant Navajo Sandstone. The Dewey Bridge Member formerly was thought to correlate with the Carmel Formation. The upper unit of the Entrada, the Slick Rock Member, is white to orange clean sandstone that weathers to a nearly vertical rounded cliff or "slickrim".

The two sandstone units are conspicuous in the McElmo Canyon area. The Dewey Bridge Member, which is 25 to 35 feet thick, is composed of brick red argillaceous and silty, very fine grained sandstone. The Slick Rock Member is 70 to 80 feet thick; it is orange to light pink in the lower part and grades to white and pale brown in the upper part. It is fine grained, is composed of subangular clear quartz and abundant well-rounded medium to medium-coarse quartz "berries," and is cross-stratified at medium angles. The cross-strata commonly are truncated by planar surfaces erosion that underlie horizontal laminae. The Slick Rock Member includes a 6-foot thick ledge at the top that may correspond to the lower part of the Bilk Creek Sandstone Member of the Wanakah Formation.

Stratification in the Dewey Bridge Member (red silty facies) in the McElmo Canyon area is inconspicuous. Most of the visible stratification is flat. The sparseness of cross-stratification of either eolian or fluvial type together with fair sorting of the grains suggests deposition in a lacustrine or marine environment.

The most conspicuous feature of the stratification of the Slick Rock Member of the Entrada Sandstone of the McElmo Canyon area is the large number of horizontal (planar) surfaces of erosion that are continuous over long distances. These surfaces commonly separate wedge-stratified beds from horizontal laminae. The alternating stratification suggests subaqueous and subaerial deposition.

Several alcoves have been weathered into the Slick Rock Member of the Entrada Sandstone in the McElmo Canyon area. These alcoves were used by ancient Indians as building sites for cliff houses. The cliff houses are most numerous and are best preserved in the Sand Creek area.

The contact of the Slick Rock Member with the overlying siltstones and mudstones of the Summerville Formation (Wanakah) is sharp in McElmo Canyon, but beds of sandstone similar to those in Entrada occur in the lower part of the Summerville Formation, and the two formations may intertongue. (Ekren and Houser, 1965).

Je – Entrada Sandstone (Upper Jurassic)

Consists of two units. Upper unit is sandstone, 70 to 80 feet thick, pale brown and light pink at top grading to white and finally to orange red in lower part; weathers to a "slick rim". The lower unit, 25 to 35 feet thick, is argillaceous, very fine grained brick-red sandstone. (Ekren and Houser, 1959c).

Entrada sandstone (Upper and Middle Jurassic)

Largely tan to reddish-brown, fine- to medium-grained, hard, friable, tight to porous, rounded to subrounded granular sandstone and a few thin layers of purplish-brown, fine-grained sandy shale. Thickness (feet) 230. (Finley, 1951).

Je – Entrada Sandstone (Upper Jurassic)

In western and central part of map (Cortez 1x2 degree quadrangle) includes (descending order): Moab Member, white medium-grained crossbedded or flat-bedded well sorted sandstone; Slick Rock Member, white or reddish- or yellowish-orange thick massive fine- to medium-grained eolian

crossbedded quartz sandstone that erodes to prominent rounded cliffs; Dewey Bridge Member, reddish-brown flat-bedded locally contorted earthy siltstone and some flat-bedded white sandstone. In northeast part of map and on the southeast side of the La Plata Mountains, pale- to greenish-gray massive sandstone contains large low-grade vanadium-uranium deposits. Averages about 150 feet thick, but ranges in thickness from 70 to 440 feet. (Haynes, Vogel, and Wyant, 1972).



Photograph Caption: Cliff dwelling in the Entrada Sandstone, Sand Canyon, Canyons of the Ancients National Monument, Colorado. Ancestral Puebloans in this area built structures in the alcoves that formed between the softer Dewey Bridge Member (lower siltstone unit), and the harder Slick Rock Member (upper sandstone unit). (Photograph by Anne Poole, 2000).

GRI Ancillary Source Map Information

Dakota Sandstone (Kd) and Cultural Resources at Hovenweep

Square Tower at Hovenweep National Monument was built on a slump block of Dakota Sandstone. The weathering and erosion of this rock has been a cause for some concern, particularly on the east and south sides of the block which are adjacent to an intermittent stream bed. Much of the block is also very porous, poorly cemented, and badly honeycombed with solution hollows along bedding planes. Between 1991 and 1994 study was undertaken by a geology and archaeology researchers to find a method of stabilizing the slump block, slowing further erosion and thereby preserving the cultural resource above. Some success was achieved with the product Conservare OH, a solution of ethyl silicate and methyl ethyl ketone, which is absorbed into the pores of the rock and forms a silica gel cement. This process strengthens the bond between sand grains but does not completely fill the spaces between them, allowing water to continue to flow through the rock – an important factor, because water trapped behind an impervious surface might cause spalling. Another advantage is that the consolidant did not alter the appearance of the rock in several scientific trials on sample specimens. Unfortunately, the presence of groundwater in sample boulders treated in the field seemed to inhibit the absorption of the consolidant. It was determined however that repeated applications to the Square Tower slump block after a long dry spell might be beneficial in strengthening the rock without harming it aesthetically. (Summarized from Griffiths, 1994).



Photograph Caption: Square Tower, at Hovenweep National Monument. The tower was built on a slump block of Dakota Sandstone which is eroding due to the presence of a nearby stream. The stabilizing wall below the boulder was built by the National Park Service in 1960. (Photograph by Anne Poole, 2000).

Hovenweep Geology - NPS Brochure

Note: From Hovenweep Geology: National Park Service brochure (author and date unknown).

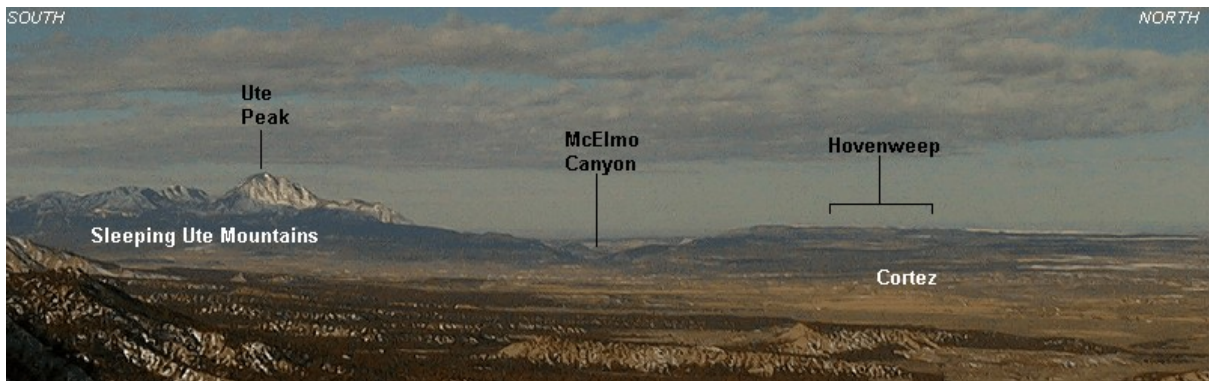
There are only two geologic strata easily visible within the monument. These are the Burro Canyon and Dakota Formations. The Burro Canyon was laid down as river or lake deposits in the early Cretaceous period between 100 and 135 million years ago. It is composed of white conglomeratic sandstone layers with interspersed pebbles and cobbles of chert, silicified limestone, and quartzite. This conglomerate is easily seen at the Cutthroat Castle site and below Stronghold House at the Square Tower Group.

The Dakota Sandstone lies atop the Burro Canyon Formation. It makes up most of the cliffs and ledges on Cajon Mesa. It was deposited during the late Cretaceous. An unconformity exists between these two layers. An unconformity means that one or several layers of rock are missing from the geologic record due to erosion. The Dakota is composed of yellow sandstones, grey mudstones, and a few thin beds of coal. Look for coal deposits along the trail to Twin Towers and beyond. Springs and seeps occur where Dakota sandstone lies atop the Burro Canyon shale. Water percolates slowly through the porous sandstone where it meets the relatively impermeable shale layer and drips or flows out.

During the Miocene, 10-25 million years ago, masses of molten trachyte (fine-grained, light colored, extrusive igneous rock) intruded all the way up into the Mancos Shale (a layer of rock which lies atop the Dakota sandstone and has since been eroded away in this area). This molten rock never reached the surface and hence cooled slowly forming crystalline igneous rocks which make up the Abajo Mountains and the Sleeping Ute Mountain. In the Pliocene epoch the Cretaceous and Tertiary beds of rock were eroded away exposing the Ute and Abajo Mountains. (Note: No igneous rocks have been found in the Hovenweep quadrangles of interest and thus do not appear on the digital geologic map, although they can be seen in the Sleeping Ute Mountains south of McElmo Canyon.)

The landscape and canyons of Cajon Mesa continued to erode to the late Pleistocene and Early Recent times. Valleys filled in and streams meandered. Early people, the Archaic, wandered through this area in search of game. They utilized caves and overhangs for shelter, and igneous rocks to make points and hammers. The Dakota sandstone was used to make dwellings, and manos and metates to grind corn in ancestral Puebloan times.

The soil at Hovenweep is composed of fine-grained sandstone with a reddish coating of iron oxide. Most of it was deposited by wind in Recent Times. This soil grew crops of corn, beans and squash for hundreds of years, and supported large numbers of peoples over the Four Corners area.



Photograph Caption: View of the Hovenweep region, looking west from Montezuma Valley Overlook at Mesa Verde National Park, Colorado. Photograph from park brochure, date unknown).

Structural Features

Note: The GRI digital geologic-GIS data contains structure contour lines (HOVECNI feature class) drawn on the base of the Dakota Sandstone (Kd). These lines have a vertical accuracy within 125 feet or greater. Contour interval is 250 feet. These features were digitized by the GRI from USGS I-629 (Haynes, Vogel, and Wyant, 1972), which is a 1:250,000 scale map. Use caution when comparing these features with all 1:24,000 scale data.

McElmo Dome (and Related Folds)

The largest structural features in the Ute Mountains area are Ute dome, the result of igneous intrusion, and McElmo dome, which may be partly of igneous origin.

McElmo structural dome is just north of the Ute Mountains, and only the southern half of it lies within the mapped area (USGS Prof. Paper 481, Plate 1, southeast of the Hovenweep map area.) Its structure is well exposed in McElmo Canyon, which cuts through the southern flank.

The central part of the dome is nearly star-shaped in outline and has a flat top. The dome is asymmetric, its steepest side being on the south where the maximum dip is about $9\frac{1}{2}$. Except for the south side, the flanks of the dome pass into a series of five anticlines. A northwest-trending anticline that lies north of the mapped area is 7 miles long (Coffin, 1920). An east-trending anticline near the northern border of the mapped area extends more than 12 miles from the east side of McElmo dome and passes through the city of Cortez, Colo. A moderately sharp anticline plunges southeastward from McElmo dome in the vicinity of Ute Peak. It is asymmetric with a steeply dipping southwest side. Because of the uncertainties in recognizing stratigraphic levels in the poorly exposed Mancos Shale, the structural saddle between this anticline and Ute Peak may be considerably higher or lower than shown on plate 1 (Prof. Paper 481).

A poorly defined anticline extends southwest from McElmo dome about 4 miles, almost parallel to a graben that lies to the north. The fifth anticline of the series (not shown on pl.1) extends northeast of McElmo dome and can be traced for approximately 6 miles.

The total area affected by McElmo Dome and its satellitic anticlines is about 20 miles east to west and 10 miles north to south. If the configuration of the south-east-trending anticline in the vicinity of Ute Peak is correctly shown on plate 1, the McElmo structure has about 500 feet of closure; the 6,600-foot contour is the lowest closing contour.

The origin of McElmo Dome and its relation to Ute dome is uncertain. The proximity of the two domes suggests that McElmo dome may also be underlain by an igneous mass. The two domes are of about the same areal extent, and appear to have about the same structural relief. McElmo dome differs from Ute dome mainly in the configuration of its satellitic folds. The McElmo structure is characterized by long, relatively narrow anticlines that plunge radially away from the central structure, whereas Ute dome is characterized by broad flexures that lose definition at short distances from the central structure. Anticlines similar to those around McElmo dome occur only on the western flank of Ute dome and, as previously mentioned, may not be genetically related to the Ute structure.

An oil well (The Three States Natural Gas Co. (Byrd-Frost) MacIntosh 1) drilled into the central part of the McElmo structure cuts igneous rock from a depth of 4,600 feet to the bottom of the hole at 4,965 feet. According to Zabel (1955, p. 135) the igneous rock from 4,600 to 4,715 feet was identified as either a dellenite or a latite, and the rock from 4,715 to 4,965 feet as a porphyritic hornblende monzonite. Such rocks could be related to those of the Ute Mountains. The igneous rocks apparently were intruded into the Paradox formation of Pennsylvanian age at a point 90 feet below the highest anhydrite. In contrast, two gas wells drilled farther north, the Schmidt 1 and the Dudley 1, which bottomed in Devonian and Cambrian strata, respectively, did not cut igneous rock. Similarly, no intrusive rocks were found above

the granite of Precambrian age in the Gulf Oil Co. Fulks 1, on the northeast flank of McElmo dome, 6 miles northeast of Goodman Point. (Note: Here, the name "Goodman Point" refers to a promontory in McElmo Canyon, not the unit of Hovenweep National Monument.) The possibility exists, therefore, that the igneous rock in the MacIntosh 1 is part of a laccolithic body extending northward from the Ute igneous centers. Most of the structural relief of McElmo dome and its satellitic folds may be a result of basement uplift related to Late Cretaceous or early Tertiary folding such as recognized elsewhere on the Colorado Plateau (Hunt, 1956, p. 57-58). The possibility also exists that part of the relief is due to movement of salt. According to Zabel (1955, p. 134), the thickness of the salt section in the Paradox varies considerably in the McElmo area. The salt is 1,500 feet thick in the Three States Schmidt 1; 1,350 feet thick in the Gulf Fulks 1. There is an overall thinning of 345 feet from the Schmidt 1 on the highest part of McElmo dome to the Fulks 1 on the northeast flank. (Ekren and Houser, 1965).

Faults in the Ute Mountains area

Steeply dipping normal faults occur in the Ute Mountains area on the south, southwest, and northwest flanks of Ute dome, on the southwest flank of McElmo dome, in the central part of McElmo dome, and along the anticline trending eastward from McElmo dome. Faults are conspicuously absent on the steeply dipping east flank of Ute dome.

The greatest concentration of faults is on the northwest flank of Ute dome. Two sets of faults appear to have formed in this vicinity; one set strikes nearly west, the other set northeast. The west-striking faults parallel west-trending folds and have displacements that rarely exceed 30 feet.

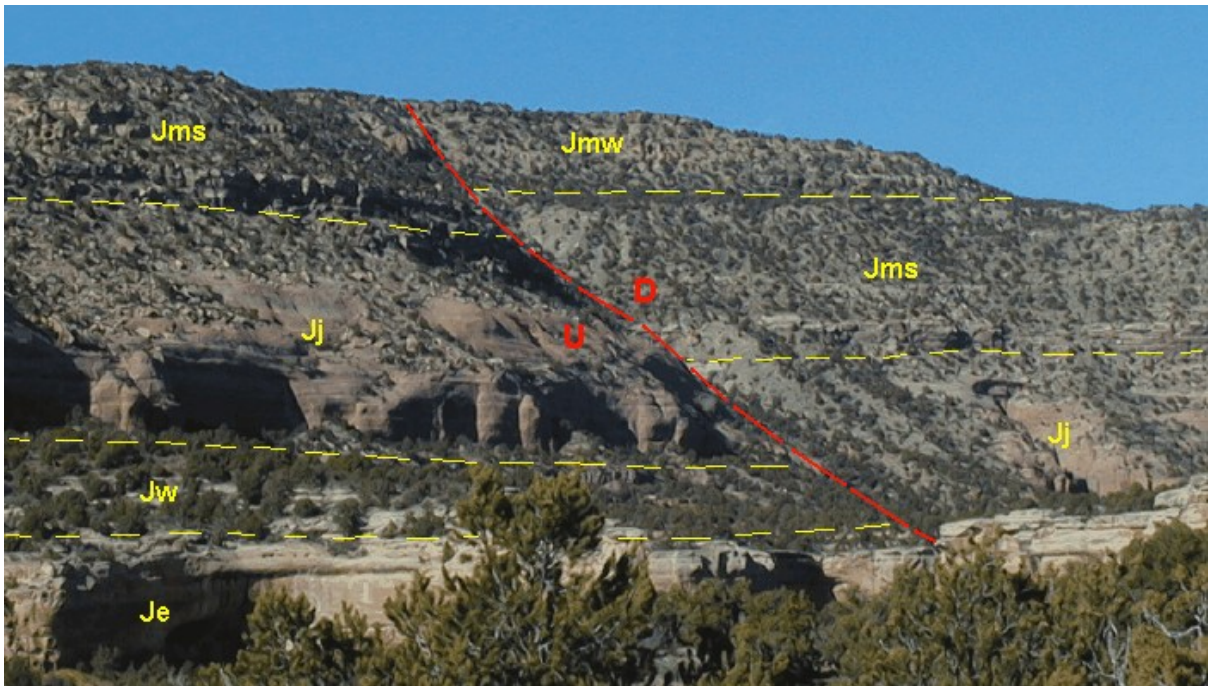
The north-east-trending faults appear to be extensions of a zone of faulting that cuts the southwest flank of McElmo dome. This zone curves to a nearly east strike in the vicinity of the Schmidt 1 gas well on McElmo dome and continues eastward beyond the map area toward Cortez, Colo. The faults along this zone form a graben on the southwest flank of McElmo dome and have displacements of as much 180 feet, the greatest known in the Ute Mountains area. Faults along the graben contain radioactive mineral deposits.

The northeast-trending faults are roughly concentric with the northern part of the Ute Mountains and may be related to the uplift of Ute dome. On the other hand, they are nearly parallel to southwest-plunging folds in the western part of the area that may predate the doming, and to inferred fracture zones that pre-date intrusion, which is the presumed cause of doming. The two largest stocks, at Black Mountain and Ute Peak, lie suggestively close to and parallel with the southwestward extension of the fracture and fault along which the Ute Creek dike was intruded. It is conceivable, therefore, that the extensive zone of northeast-trending faults lies en echelon to a zone of fracturing that localized part of the igneous activity in the Ute Mountains and also the uplift of McElmo dome. (Ekren and Houser, 1965).

Faults: House Creek Fault

Extends northeast from Hovenweep map area approximately 21 kilometers. See USGS I-629 or location map for full extent.

Only two faults were seen in the area. The fault at the southeastern corner (of USGS OM-120, which covers the area north of the Hovenweep map) has a displacement of not more than 50 feet in an area of poor exposures. (This fault, although not named in this reference, is in the same location as the House Creek Fault on I-629.) (Finley, 1951).



Photograph Caption: Normal fault in East Rock Creek canyon (red line), north of Ute Dome and southwest of Goodman Point Unit, showing offset in the Entrada Sandstone ([Je](#)), Wanakah Formation ([Jw](#)), Junction Creek Sandstone ([Jj](#)), and the Salt Wash ([Jms](#)), and Westwater Canyon ([Jmw](#)) Members of the Morrison Formation ([Jm](#)). (Photograph by Anne Poole, 2000).

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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 James Winter (Colorado State University) and Stephanie O'Meara.

The information in this document was compiled from GRI source maps, and is intended to accompany the digital geologic-GIS maps and other digital data for Hovenweep National Monument, Colorado and Utah (HOVE) developed by Anne Poole (NPS GRD) and Stephanie O'Meara (see the [GRI Digital Maps and Source Map Citations](#) section of this document for all sources used by the GRI in the completion of this document and related GRI digital geologic-GIS maps).

GRI finalization by Stephanie O'Meara

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