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National Park Service
Natural Resource Stewardship and Science Directorate
Geologic Resources Division

Yucca House National Monument

GRI Ancillary Map Information Document

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

yuho_geology.pdf

Version: 7/18/2012

Geologic Resources Inventory Map Document for Yucca House National Monument

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Geologic Resources Inventory Map Document

Yucca House National Monument, Colorado

Document to Accompany Digital Geologic-GIS Data

yuho_geology.pdf

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This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Yucca House National Monument, Colorado (YUHO).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

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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.

Map Unit List

The geologic units present in the digital geologic-GIS data produced for Yucca House National Monument, Colorado (YUHO) 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 Geologic Unit Information (YUHOUNIT) table included with the GRI geology-GIS data.

Recent and Pleistocene

Qal - Alluvium (Qal)
Qs - Eolian sand and silt (Qs)
Qt - Talus (Qt)
Ql - Landslide deposits (Ql)
Qb - Block rubble (Qb)
Qfg - Fanglomerate (Qfg)
Qpg - Pediment deposits (Qpg)
Qsw - Slopewash (Qsw)

Tertiary or Upper Cretaceous

TKdp - Diorite porphyry (TKdp)

Upper Cretaceous

Kch - Cliff House Sandstone (Kch)
Kme - Menefee Formation (Kme)
Kpl - Point Lookout Formation (Kpl)
Km - Mancos Formation, undifferentiated (Km)
Kmc - Mancos Formation, Cortez Member (Kmc)
Kms - Mancos Formation, Smoky Hill Member (Kms)
Kmv - Mancos Formation, Montezuma Valley Member (Kmv)
Kmj - Mancos Formation, Juana Lopez Member (Kmj)
Kmlm - Mancos Formation, Lower Mancos (Kmlm)
Kd - Dakota Sandstone (Kd)

Lower Cretaceous

Kbc - Burro Canyon Formation (Kbc)

Upper Jurassic

Jmb - Morrison Formation, Brushy Basin Shale Member (Jmb)
Jmw - Morrison Formation, Westwater Canyon Sandstone Member (Jmw)
Jms - Morrison Formation, Salt Wash Sandstone Member (Jms)
Jjc - Junction Creek Sandstone (Jjc)
Js - Summerville Formation (Js)
Je - Entrada Sandstone (Je)

Jurassic

Jn - Navajo Sandstone (Jn)

Map Unit Descriptions

Descriptions of all geologic map units, generally listed from youngest to oldest, are presented below.

Qal - Alluvium (Recent and Pleistocene)

Qal - Alluvium (Pleistocene and Recent)

Unconsolidated sands, silts, and gravels deposited mainly in stream beds and flood plains. (*GRI Source Map ID 978*). (Griffitts, 1999).

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. (*GRI Source Map ID 105).* (I-629).

Qs - Eolian sand and silt (Recent and Pleistocene)

No additional unit description available. (*GRI Source Map ID 94*). (MF-217).

Qt - Talus (Recent and Pleistocene)

No additional unit description available. (*GRI Source Map ID 94*). (MF-217).

Ql - Landslide deposits (Recent and Pleistocene)

No additional unit description available. (*GRI Source Map ID 94*). (MF-217).

Qb - Block rubble (Recent and Pleistocene)

Chiefly porphyry blocks lying on unevenly eroded surfaces; forms hummocky topography the Threemile. (*GRI Source Map ID 94*). (MF-217).

Qfg - Fanglomerate (Recent and Pleistocene)

Mainly cobbles and boulders from the Point Lookout sandstone of the Mesaverde group of Cretaceous age. (*GRI Source Map ID 94*). (MF-217).

Qpg - Pediment deposits (Recent and Pleistocene)

Qpg - Pediment deposits (Pleistocene and Recent)

Predominantly pebbles, cobbles, and boulders of igneous rocks lying on erosion surfaces that extend

radially from the mountain area. (*GRI Source Map ID 94*). (MF-217).

Qap - Pediment Gravels (Pleistocene and Holocene)

Poorly sorted angular to well-rounded sand, pebbles, and boulders; mostly diorite porphyry; in thin partly dissected deposits near the Abajo and Sleeping Ute Mountains. (*GRI Source Map ID 105).* (I-629).

Qsw - Slopewash (Holocene and Pleistocene)

Qc - Colluvial deposits (Pleistocene and Holocene)
Talus, slope wash, block rubble rock glaciers, and, in some high cirques in the San Miguel Mountains, young glacial till. (*GRI Source Map ID 105).* (I-629).

Qcl - Landslide deposits (Pleistocene and Holocene)
Unsorted material, commonly in large displaced blocks with characteristic arcuate hummocky surfaces. (*GRI Source Map ID 105).* (I-629).

Qct - Talus deposits (Pleistocene and Holocene)
Accumulations of angular blocks fallen from cliffs and outcrops of resistant rock. (*GRI Source Map ID 105).* (I-629).

TKdp - Diorite porphyry (Tertiary or Upper Cretaceous)

Medium gray diorite porphyry; phenocrysts of hornblende and andesine; forms laccoliths in extreme southwest part of quadrangle. (*GRI Source Map ID 94*). (MF-217).

Kch - Cliff House Sandstone (Upper Cretaceous)

No unit description available. (*GRI Source Map ID 978*). (Griffitts, 1999).

Kme - Menefee Formation (Upper Cretaceous)

No unit description available. (*GRI Source Map ID 978*). (Griffitts, 1999).

Kpl - Point Lookout Formation (Upper Cretaceous)

No unit description available. (*GRI Source Map ID 978*). (Griffitts, 1999).

Km - Mancos Formation, undifferentiated (Upper Cretaceous)

Predominantly gray to black shaly mudstone. A medium- to coarse-grained glauconitic sandstone and sandy fossiliferous limestone (10-50 feet thick), about 475 feet above base, is mapped separately as Kms. This unit may be equivalent in part to the Juana Lopez sandstone member (of the Carlile shale)of Rankin (1944). (*GRI Source Map ID 94*). (MF-217).

Marine light to dark gray thin bedded shales and siltstones with well developed faunal zones. 2000 feet (at Mesa Verde National Park). (*GRI Source Map ID 978*). (Griffitts, 1999).

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. (*GRI Source Map ID 105).* (I-629).

Kmc - Mancos Formation, Cortez Member (Upper Cretaceous)

No unit description available (see Mancos Shale (Km) for undifferentiated unit description). (*GRI Source Map ID 978*). (Griffitts, 1999).

Kms - Mancos Formation, Smoky Hill Member (Upper Cretaceous)

Predominantly gray to black shaly mudstone. A medium- to coarse-grained glauconitic sandstone and sandy fossiliferous limestone (10-50 feet thick), about 475 feet above base, is mapped separately as Kms. This unit may be equivalent in part to the Juana Lopez sandstone member (of the Carlile shale)of Rankin (1944). (*GRI Source Map ID 94*). (MF-217).

No unit description available (see Mancos Shale (Km) for undifferentiated unit description). (*GRI Source Map ID 978*). (Griffitts, 1999).

Kmv - Mancos Formation, Montezuma Valley Member (Upper Cretaceous)

No unit description available (see Mancos Shale (Km) for undifferentiated unit description). (*GRI Source Map ID 978*). (Griffitts, 1999).

Kmj - Mancos Formation, Juana Lopez Member (Upper Cretaceous)

No unit description available (see Mancos Shale (Km) for undifferentiated unit description). (*GRI Source Map ID 978*). (Griffitts, 1999).

Kmlm - Mancos Formation, Lower Mancos (Upper Cretaceous)

No unit description available (see Mancos Shale (Km) for undifferentiated unit description). (*GRI Source Map ID 978*). (Griffitts, 1999).

Kd - Dakota Sandstone (Upper Cretaceous)

Yellowish lenticular sandstone and conglomerate with interbedded carbonaceous shale and impure coal. Average thickness about 125 feet. (*GRI Source Map ID 94*). (MF-217).

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. (*GRI Source Map ID 94*). (MF-217).

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

150 to 300 feet thick, consists of varicolored bentonitic mudstone with a few conglomeratic sandstone lenses. Adjacent members intertongue and inter-grade to such an extent that in many places the contacts are arbitrary. (*GRI Source Map ID 94*). (MF-217).

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

75 to 100 feet thick, consists of pale yellow-brown fine-to medium-grained sandstone interbedded with green bentonitic mudstone. Adjacent members intertongue and inter-grade to such an extent that in many places the contacts are arbitrary. (*GRI Source Map ID 94*). (MF-217).

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

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 on the Colorado Plateau but no deposits are known in this quadrangle. Adjacent members intertongue and inter-grade to such an extent that in many places the contacts are arbitrary. (*GRI Source Map ID 94*). (MF-217).

Jjc - 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, 3C to 50 feet thick, has the same general lithology as the middle unit, but with low-angle cross-stratification and numerous horizontal truncations. Thickness is 230 to 280 feet; contact with underlying Summerville formation is gradational. Correlates with the Bluff sandstone of Utah and Arizona. (*GRI Source Map ID 94*). (MF-217).

Js - Summerville Formation (Upper Jurassic)

Brick-red mudstone and pink to red-brown argillaceous fine-grained well-sorted sandstone, 120 to 130feet thick. (*GRI Source Map ID 94*). (MF-217).

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 to35 feet thick, is argillaceous very fine grained brick-red sandstone. (*GRI Source Map ID 94*). (MF-217).

Jn - Navajo Sandstone (Jurassic)

Orange fine-grained eolian sandstone containing numerous prominent horizontal truncations. (*GRI Source Map ID 94*). (MF-217).

GRI Source Map Citations

The digital geologic-GIS maps for Yucca House National Monument, Colorado (YUHO) were compiled from the following sources:

Carrarra, Paul, 2009, Yucca House Geologic Map, U.S. Geological Survey, unpublished map, 1:12,000 scale. (*GRI Source Map ID 75483*). (Carrarra, 2009).

Ekren, E.B. and Houser, F.N., 1959, Preliminary Geologic Map of the Cortez SW Quadrangle, Montezuma County, Colorado, U.S. Geological Survey, Mineral Investigations Field Studies Map MF-217, 1:24,000 scale. (*GRI Source Map ID 94*). (MF-217).

Griffitts, Mary O., 2001, Bedrock Geology and Paleontology of Yucca House National Monument Area, Colorado, unpublished, 1:62,500 scale. (*GRI Source Map ID 1341*). (Griffitts, 2001).

Griffitts, Mary O., 1999, Mesa Verde National Park Geology: National Park Service, 1:24,000 scale. (*GRI Source Map ID 978*). (Griffitts, 1999)

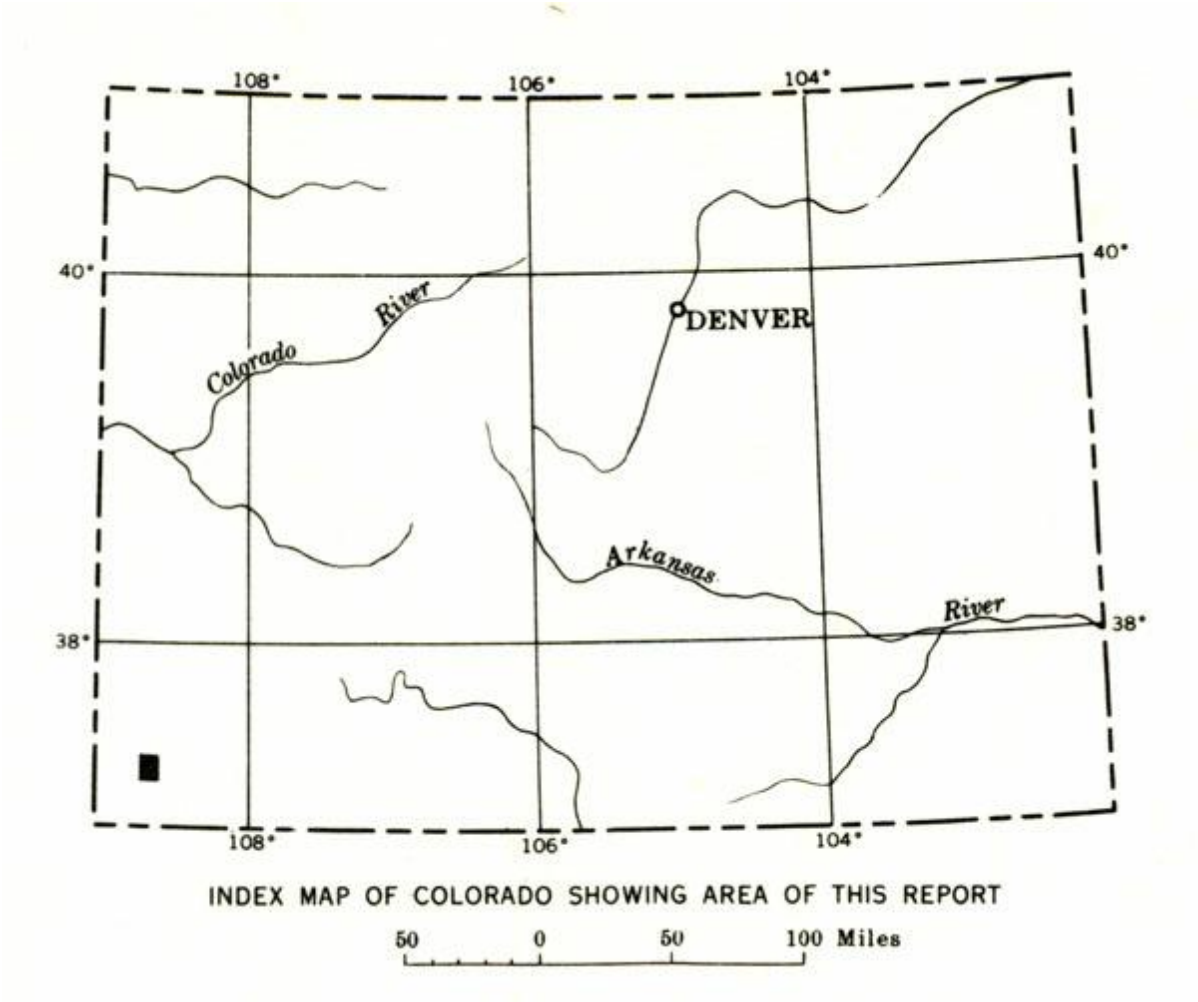
Haynes, D.D., Vogel, J.D., and Wyant, D.G., 1972, Geology, Structure, and Uranium Deposits of the Cortez Quadrangle, Colorado and Utah, U.S. Geological Survey, Miscellaneous Geologic Investigations Map I-629, 1:250,000 scale. (*GRI Source Map ID 105*). (I-629).

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

MF-217

Ekren, E.B. and Houser, F.N., 1959, Preliminary Geologic Map of the Cortez SW Quadrangle, Montezuma County, Colorado, U.S. Geological Survey, Mineral Investigations Field Studies Map, MF-217, 1:24000 scale. (*GRI Source Map ID 94*).

Index Map



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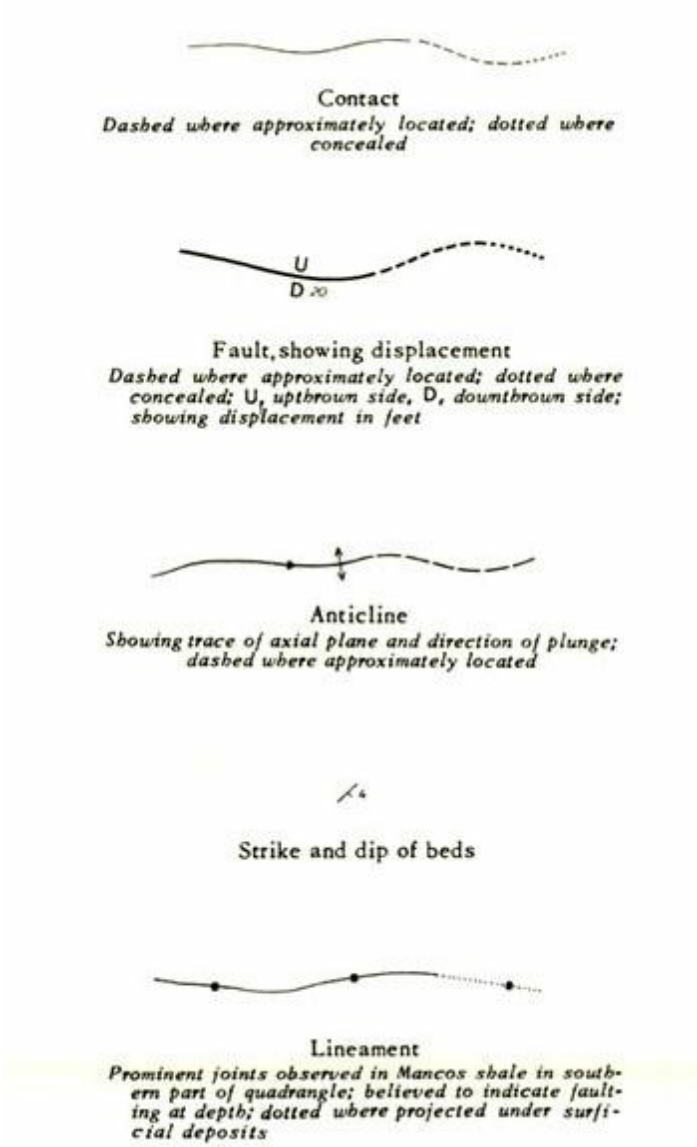
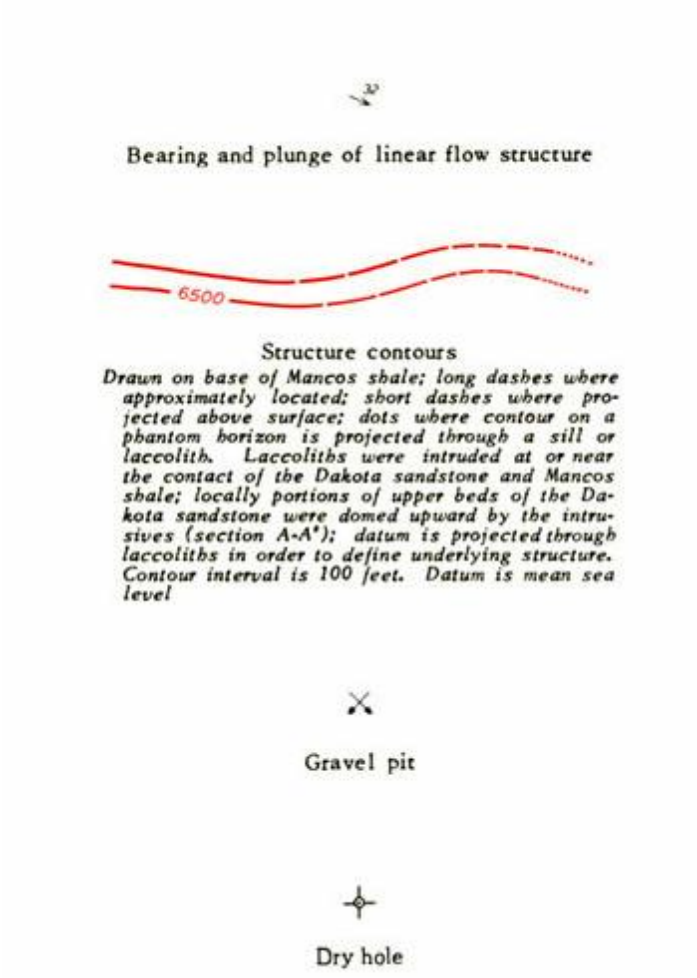
Legend Figure





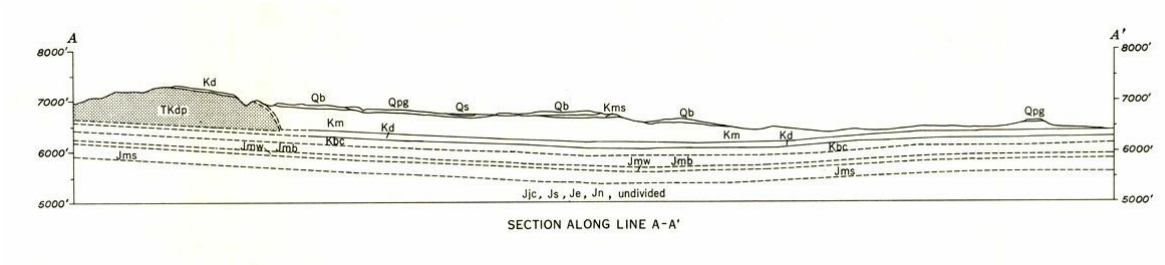
Extracted from: (MF-217).

References

Rankin, C.H., 1944, Stratigraphy of the Colorado Group, Upper Cretaceous in northern New Mexico: N. Mex. School of Mines Bull. 20, 27 p.

Extracted from: (MF-217).

Geologic Cross Section A-A'



Extracted from: (MF-217).

Griffitts, 2001

Griffitts, Mary O., 2001, Bedrock Geology and Paleontology of Yucca House National Monument Area, Unpublished, 1:62,500 scale. (*GRI Source Map ID 1341*).

Report

INTRODUCTION

A detailed study of the bed rock geology in the area presently owned by Mrs Hallie Ismay, surroundingthe established Yucca House National Monument, Montezuma County, Colorado was initiated by MesaVerde National Park in May, 2000. The area of study (figure 1) includes portions of Montezuma Valley in the Mud Creek and Towaoc Quadrangles, extending approximately from the Aztec Divide on the north to the "Old Southern Ute Indian Reservation Boundary" on the south, and from about 1/2 mile west of the Ute Mountain Ute Reservation Boundary to the west edge of the Mesa Verde on the east.

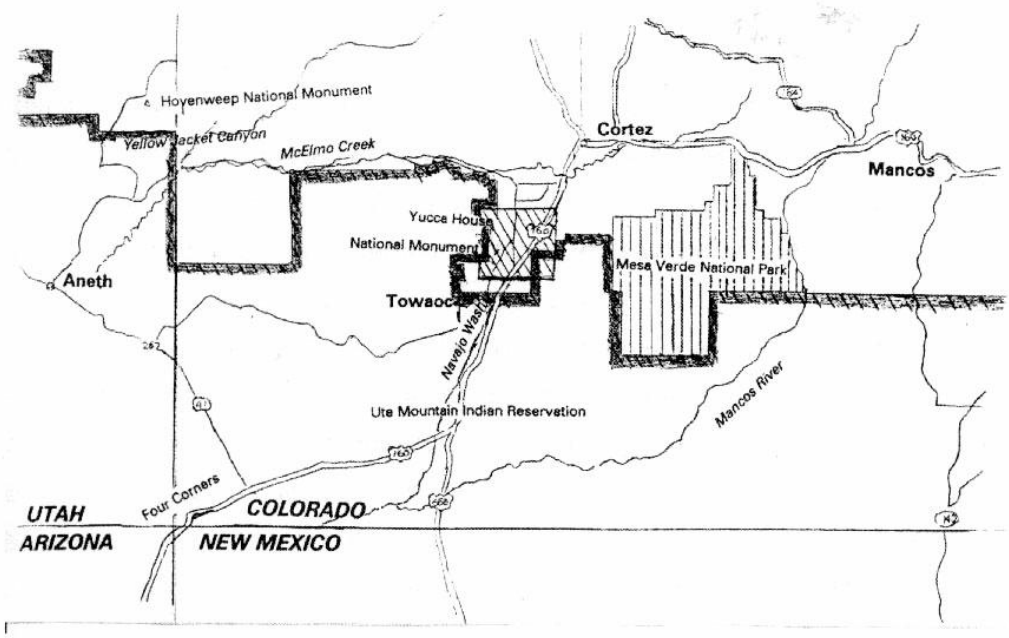


Figure 1. Location of Yucca House National Monument study area (diagonal ruling) within Towaoc and Mud Creek Quadrangles, in southwest Colorado. Ute Mountain Ute Reservation boundary south of shaded bar.

Existing geologic maps of the area were compiled, aerial photographs reviewed and a fieldreconnaissance was made to map the faunal horizons and surface outcrops. A composite aerialphotographic base map was provided by Allan Loy of the Mesa Verde staff. Although much of this are ahas been mapped in some detail by E.B. Ekren and F.N. Hauser (1965), paleontologic zones were not studied at that time. Mud Creek and Towaoc Quadrangles were remapped to determine the distribution of possible sources of building material used in the Yucca House site. The paleontology is of major significance in the Yucca House archeology. The maps generated in this study include portions on the west edge of the Mesa Verde which were taken from A.A. Wanek's 1959 map of the Mesa Verde area.

SETTING

Montezuma Valley lies to the east of the Ute Mountains and west of the Mesa Verde scarp. A broad, relatively flat area, it is largely covered by alluvial deposits and has been heavily cultivated for manyyears. There are few bed rock outcrops. Much of the surface is covered by Quaternary deposits, the upper layers of which have been plowed and reworked for generations. Along the east border, and inplaces along the west side of the study area, bed rock crops out.Numerous early surveys of the Four Corners area include some discussion of the Yucca House vicinity. The earliest recorded is the description by W.H. Holmes during his 1875-76 field excursions tothe Aztec Springs Ruins, as the locality was then known. He made a quite detailed sketch map of themound as it then appeared or as he envisioned it, and noted the "Stone used is chiefly the fossiliferous limestone that outcrops along the

base of the Mesa Verde a mile or more away" (Holmes, 1878, p399-400). The most comprehensive report is the "Geology and Petrology of the Ute Mountains Area,Colorado" by Ekren and Hauser (1965) which details the laccolithic intrusives of the Ute Mountains and includes the northern part of the present field study. Detailed discussions of the stratigraphy of the Four Corners region were published in 1997 in the report of the New Mexico Geological Society Forty Eighth Field Conference.

SEDIMENTARY HISTORY

The Yucca House National Monument and the Ismay property surveyed is underlain by sedimentaryrocks, deposited in the great Late Cretaceous inland seaway. Older rocks crop out to the north in theMcElmo Valley and to the west along the Ute Mountain front. Pre Cretaceous rocks, Jurassic Morrison and older, are well exposed in the McElmo Canyon. Although they are not found in place on the surface in the area of study, material from these older rocks may be found in the archeological record and in the superficial Cenozoic deposits The Burro Canyon Formation (Buckhorn), of controversial age, either very late Jurassic or early Cretaceous, which lies between the Morrison and the Dakota Formations, has many silicic pebbles which were used by the early Puebloan people for tool making.The Jurassic Morrison Formation has numerous beds of chert, quartzite and other highly silicic material which are commonly found in artifacts throughout the archeological sites.

The Cretaceous history begins with the deposition of the Dakota Formation. This very widespread sandstone formation is recognized throughout the Western Interior. It represents the first invasion of the Late Cretaceous seas this far inland, and generally consists of light brown fine- to coarse-grained sandstone. In this area, many of the sand grains are subround to angular and mostly poorly sorted.There is much carbonaceous material present and mineable coal beds occur a short distance west of Towaoc. These mines are no longer worked, but some of the seams were two to four feet thick where observed. The brown sandstones and muddy sandstones were deposited in shallow water, in lagoons and near the shore of the transgressing sea. The Dakota is conformably overlain by the marine Mancos Formation.

Only the very thick Mancos Formation is exposed within most of the Ismay holdings and the existing Yucca House National Monument and in the Towaoc and Mud Creek Quadrangles. The closest exposures of the underlying Dakota Sandstone are about 2 1/2 miles to the west in Ute land and about2'/2 miles north in the Mud Spring area. Although the Dakota Sandstone is solid enough to make good building material, no blocks in the exposed rubble mounds of the prehistoric structures were recognizably Dakota material. It is very possible that future excavation of the site will reveal Dakota building blocks.

As the sea slowly encroached, this area became more and more distant from the shore line. During aperiod of 13 million years the fluctuating transgressions of the inland sea deposited more than 2000feet of Mancos Formation. A measured section at the type locality near Mesa Verde National Park (Leckie, et al 1997) has been divided into eight members. The members as established by Leckie are from the oldest: the Graneros shale, the Bridge Creek Limestone, Fairport shale, Blue Hill shale, the Juana Lopez shale and calcarenite, Montezuma Valley shale , Smoky Hill shale and limestone, and the Cortez sandy shale. The lowest unit, the Graneros, is dated by its invertebrate fauna as upper Cenomanian age (approximately 94 Ma) and the top of the Mancos Cortez unit is dated Campanian in age (approximately 81 Ma). A detailed discussion of regional correlation is available in the 1997 paper by Leckie, et al. Only the upper four members including the Juana Lopez, Montezuma Valley, Smoky Hill and Cortez crop out in the expanded Yucca House study area. The Graneros Shale and Bridge Creek Limestone are recognizable in T35N, R17W Sec.20, about 2 1/2 miles west of the proposed monument boundary. The Graneros Shale is a soft, very dark gray shale and silty shale with a characteristic and easily recognizable fauna including small oysters Pycnodonte newberryi (figure12A-B) which are quite resistant to weathering and accumulate in stream washes. The Bridge Creek Limestone (Greenhorn Limestone) has several relatively massive, solid limestone layers up to 3 feet in thickness which make well defined outcrops with sparse vegetation. The limestone is solid enough thatit might have been used for building

stone, but no blocks were seen in the presently exposed prehistoric mounds. Even if it had been used, the limestone blocks tend to split along relatively thin bedding planes after being exposed to weathering, and would probably not have been preserved onthe surface to the present. Again, future excavation may reveal the use of this rock in some parts of the site. The Fairport and Blue Hill Members are without doubt present also between the Bridge Creekand the prominent Juana Lopez, but both are soft shaly deposits, poorly resistant to erosion and are not easily recognized in small outcrops and are generally covered in gullies.

The Juana Lopez member of the Mancos Formation is exposed on a dip slope (figure 2) over much of the western part of the Mud Creek and Towaoc Quadrangles. The very low angle of dip of the bed rock allows a relatively thin lithologic unit to be exposed over a very large surface area. The dip is so low, 3to 5 degrees where measurable, that bedding plane irregularities mask minor structural anomalies.The Juana Lopez is a distinctive and widespread member of the Mancos Formation. With a very abundant late Turonian invertebrate fauna, it is correlated with widely distributed rocks throughout the Western Interior of North America. Originally described by Dane and others (1966) on the east side of the San Juan Basin, the type section was measured "on the Mesita Juana Lopez Grant, six miles northwest of Cerrillos, Santa Fe County, New Mexico."(Rankin, 1944 p. 19). Later studies by Kaufman(in Dane and others 1966), and Hook and Cobban (1980) revised details of location and provide a more comprehensive type section measuring 106 foot thickness. At Mesa Verde a detailed section (Leckie, et al 1997) of the measured thickness of the Juana Lopez totaled approximately 140 feet. Dueto the poor exposures it is not practical to measure a detailed section at Yucca House, but it is unlikely to differ seriously from the Mesa Verde section 15 miles to the northeast.

Figure 2. Thin bedded calcarenite of the Juana Lopez (zone 3) exposed on the dip slope west of Yucca House.

The Juana Lopez member of the Mancos Formation is relatively resistant to weathering and frequently forms low terraces and irregular hills because of the numerous layers of solid calcarenite. Calcareniteis a granular rock similar in appearance to sandstone, but composed almost entirely of calcium carbonate. Solution of pieces of this calcarenite in hydrochloric acid left only a very small residue of silt and fine clay. Much of the calcarenite is thin bedded, (figure 2) and could not be used as building stone. But some of the beds are locally more than six inches in thickness (figure 3). The calcarenite is often a

dense, dark colored solid rock which weathers to a rusty brown color. It naturally breaks into building blocks along bedding planes and joints (figure 4). Most of the slabs show at least fragmental fossils, and many excellent ammonite and bivalve fossils are found. In the exposed prehistoric walls of the present mounds, many of the building stones are made of the brown, fossiliferous calcarenite of the Juana Lopez Member of the Mancos Formation (figure 5). The fossils are diagnostic and many are easily recognized even when fragmental. Although the Juana Lopez Member of the Mancos underlies the area, Quaternary terrace gravels, pediment deposits, alluvium, and loess soil cover much of the surface, and some of the boulders from these deposits were also used as building stone. Outcrops of the Juana Lopez typical building stone are not found nearer the archeologic sites of Yucca House than about 1/2 mile (map distance) to the west.

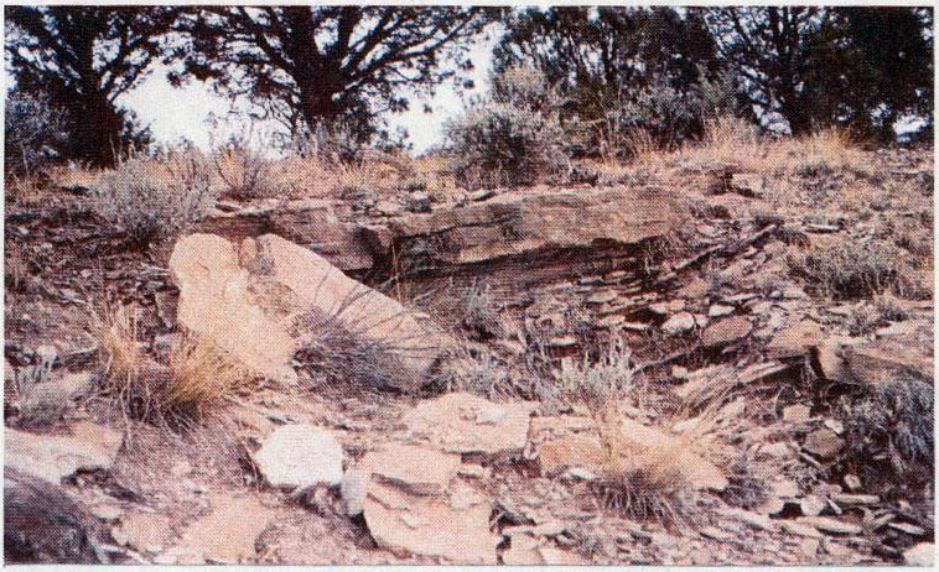


Figure 3. Thick solid beds of calcarenite in gully about ½ mile southwest of Yucca House mound.

Figure 4. Calcarenite beds in gully southwest of Yucca House mound, showing ready made building blocks shaped by bedding planes and joints.

Figure 5. Building block in Yucca House mound, surface covered with *Lopha lugubris* shells from the Juana Lopez zone 2 calcarenite.

Although much of the Juana Lopez is silty shale, there are several consistent calcarenite beds of varying

thicknesses. The paleontologic zones which can be recognized in these calcarenite beds should be useful to archeologists during any future excavation. Although alluvial and other Quaternary sediments cover most of the broad flats of the area, in some places deep gullies, ditches and roadcuts expose the bed rock. Leckie (1997) recognized and described four calcarenite zones in the Mesa Verde section, each with a distinctive fauna. Hook and Cobban (1980) recognized the same faunal sequence in the type section in New Mexico. In the Yucca House area, the two uppermost paleontologic zones of the Juana Lopez are recognizable over quite a large area, mainly because the calcarenites are thicker, more resistant to weathering and form long, low ridges trending northeast/southwest. The calcarenite layers are quite solid, frequently very dark and dense. Although some of them look very sandy, most have very little quartz sand, and will dissolve in hydrochloric acidleaving only a residue of fine silt. Both of these zones have distinct enough faunas to be recognizable not only when they occur in place but also when found as building stones. Many of the blocks are made up of almost solid molluscan fossils, both fragmental and entire. The thickest calcarenite beds in the Mesa Verde section occur near the top of the Juana Lopez Member, where they total about 9 feet,though the individual beds are usually less than a foot thick and most are one to six inches in thickness. Some of the material used for building stone comes from this zone (referred to hereafter inthis report as "zone 4"). About 30-35 feet lower in the section is another group of calcarenites with a somewhat different fauna. This will be referred to as "zone 3" and is the most widespread zone exposed in the Yucca House environs. The most diagnostic fossils are the ammonite assemblages.The upper (zone 4) calcarenites contain Prionocyclus novimexicanus (Marcou)(figures 11 C-D) and Scaphites whitfieldi Cobban (figure 10A). Zone 3 contains Prionocyclus wyomingensis Meek (figures11A-B, 18) and Scaphites warreni Meek and Hayden (figure 10A) in addition to Inoceramus perplexus Whitfield (figure 15). About 30 feet lower a calcarenite unit (unit 2) contains a much more limitedfauna mostly of Lopha lugubris (Conrad) (figure 13) and Inoceramus dimidius White (figures 14 A-B). Astill lower calcarenite unit has been recognized in the Mesa Verde section, characterized by the presence of Prionocyclus macombi Meek , but was not found at Yucca House, probably due to poor exposures.

Figure 6. *Prionocyclus wyomingensis* Meek (zone 3) in place in gully bed rock.

Outcrops of the more solid calcarenite which would make good building stone, similar to building blocks in the mounds, are found in the gullies mainly to the west and southwest of the present Yucca House

National Monument. The same faunal beds are present to the north, but mostly in thin-bedded layers. Good solid building stone was not found capping the tops of the mesas. Although Quaternary deposits and vegetation cover much of the area, the three distinctive faunal units were found and recorded as well as possible from the limited exposures along a reasonably continuous trend (figure7).

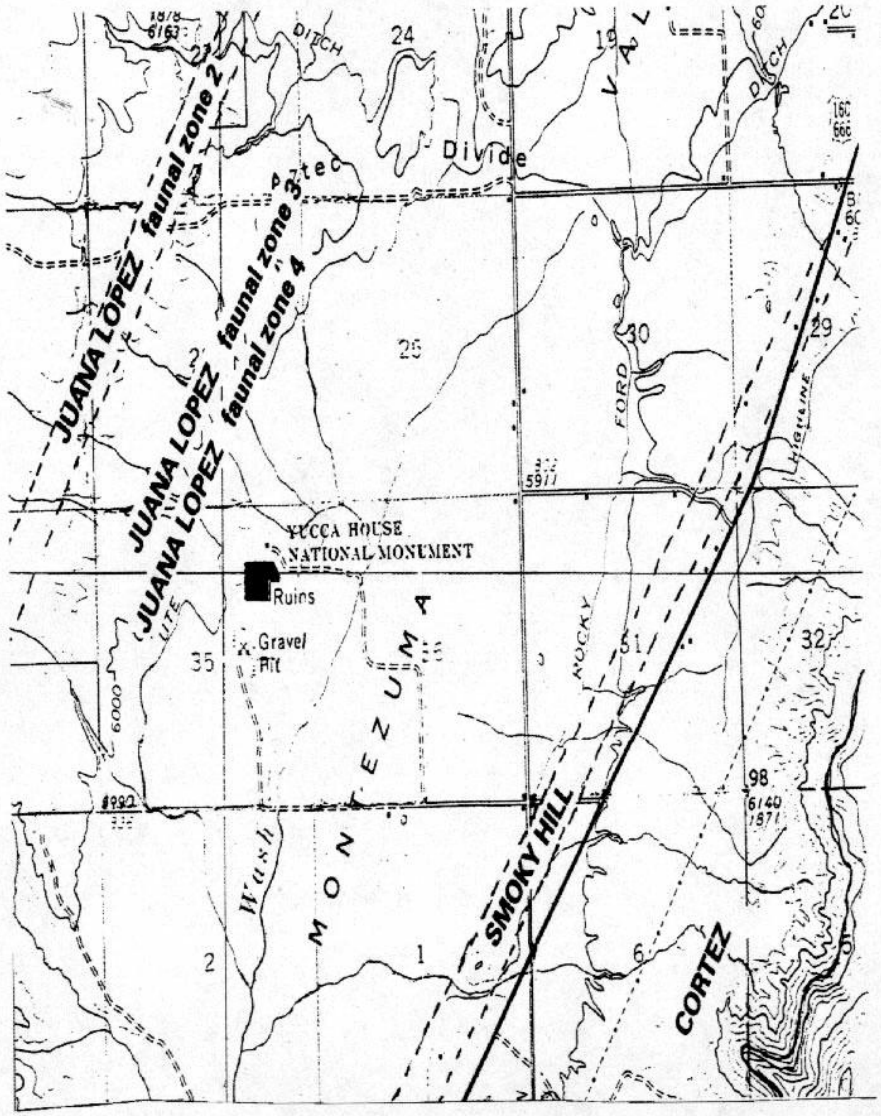


Figure 7. Approximate distribution of the faunal zones of the Mancos Formation in the vicinity of Yucca House. (Not outcrop pattern)

Identification of the zone 3 and zone 4 ammonites by field archeologists may pose some problems. Anillustrated, simplified description of each of the more important guide fossils, with its diagnostic characteristics is appended to this report. However, many other macrofossils are present in the Juana Lopez. Illustrations of some of these may be found in Kauffman, 1977 and Leckie, et al., 1997.

In fragments, it is often difficult to separate Prionocyclus novimexicanus from P. wyomingensis, but the association with the two Scaphites species is helpful. While the Lopha lugubris can occur in a much

longer range, the large accumulations are characteristic of the lower paleontologic zone. Inoceramusdimidius also has a longer range, but the faunal assemblage again will help with recognizing a zone.Many other fossils are found in the Juana Lopez, but are not as diagnostic or easily recognized as the above. Small Baculites are frequently found. Baculites undulatus (figures 10A, 18) and B. yokoyamioccur in zones 3 and 4 respectively as fragments and may be useful as guide fossils to the zones if identifiable. Inoceramids are very common, both as fragments and entire. They are frequently difficult zones.

The Juana Lopez represents a period of quiet deposition far from shore, with little clastic material being brought into the area. Although the calcarenite is largely composed of bioclastic debris such as broken shell material, some probably represents a chemical recrystallization of calcium carbonate derived from the molluscan shells.

Overlying the Juana Lopez Member are the Montezuma Valley and the Smoky Hill Members of the Mancos Formation. The Montezuma Valley Member consists primarily of soft calcareous shale and bentonitic shale and was not recognized as a mappable unit in outcrops. The overlying Smoky Hill Member of calcareous shale and fossiliferous limestone is slightly more resistant and erosion remnants were found with the characteristic Pseudoperna-Inoceramus fauna (figures 16,17). The biostromes of oysters are more resistant to erosion than the shales above and below them and are frequently preserved in isolated low hills or even as broken fragments in cultivated fields. This member does not actually crop out in the proposed monument area, but has been mapped for reference. The best outcrop of the Smoky Hill is on a small butte T34N, R17W, sec 1 (figure 8). Just to the west and south of the butte is a very deep draw with soft dark gray shale in the bottom, overlain by about 40 feet of alluvium and soil. The gray shale is probably the Montezuma Valley Member.

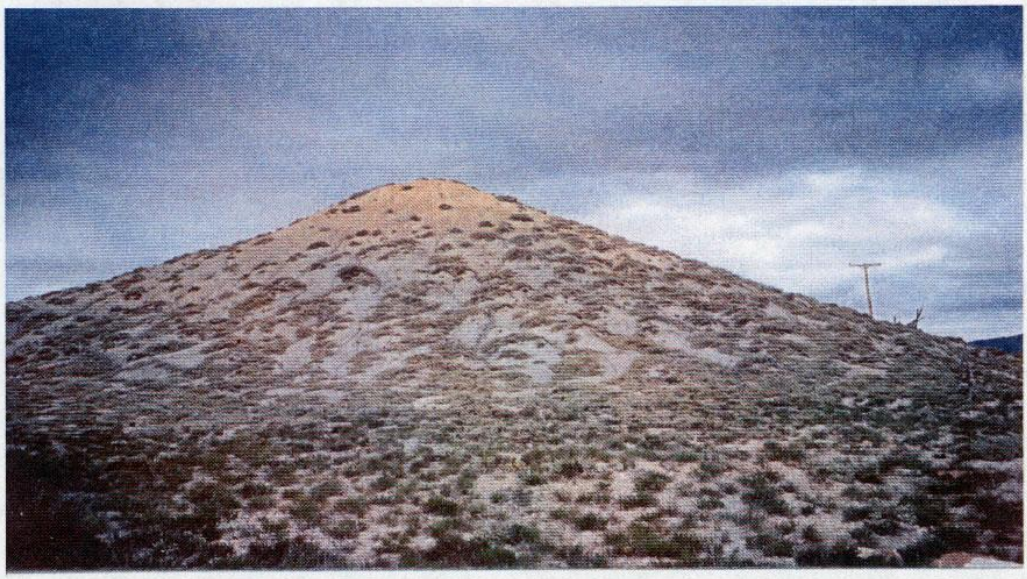


Figure 8. Smoky Hill erosion remnant capped with yellow Point Lookout Formation colluvium. *Inoceramus* fragments with *Pseudoperna* encrusting them in lower slopes of butte.

Between the Smoky Hill Member and the Point Lookout Formation, lies the very thick unit of the Cortez member, formerly referred to as the Transitional zone. Deposited at the beginning of a temporary withdrawal of the sea from this area, this soft unit consists of nearly 1200 feet of interbedded soft shale, silty to sandy shale, shaly sandstone, siltstone, and thin bedded sandstone (figure 9). The unit coarsens

upwards to grade into the Point Lookout Sandstone Formation. The soft gray slopes below the Mesa Verde are all part of the Cortez Member of the Mancos Formation. Scattered fossils are present, but not common. Although scattered fragments of Inoceramids, baculites, and trace fossils are found, fossil zones in this unit are scarce and difficult to recognize. Several beds of dense dolomitic siltstone form resistant ledges locally protecting soft shales in gullies (figure 9). Most of the deeply gullied slopes are covered with Point Lookout colluvium.

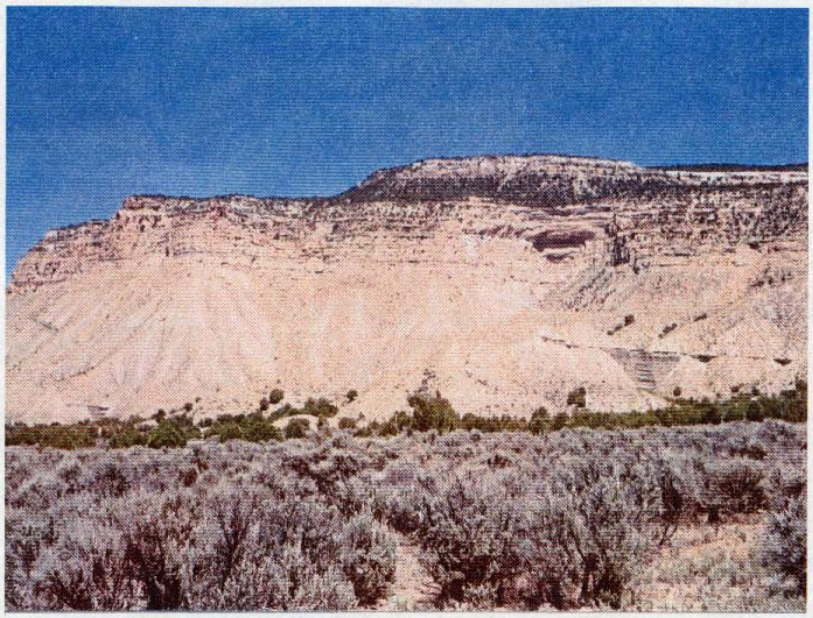


Figure 9. Soft light gray to tan sandy shales of the Cortez Member of the Mancos Formation, overlain by resistant Point Lookout Sandstone. Dolomitic siltstone layers in right gully locally protect soft shales to form small scarps.

The Point Lookout, Menefee and Cliff House Formations border the east side of the study area of theMontezuma Valley along the Mesa Verde cliffs (figure 9). The Point Lookout Formation is the basal member of the Mesaverde Group and conformably and gradationally overlies the Mancos Formation.The outcrops on the West Rim of the Mesa Verde are within Ute lands, and it was not possible to get a permit to land there with a helicopter. Presumably, the Point Lookout, Menefee and Cliff House Formations, which all crop out along the West Rim in Ute land are similar in character to those studied within Mesa Verde National Park. They do not crop out on Ismay land. The Point Lookout Formation influences the Yucca House Monument because it is found in colluvial deposits capping the top of the erosion remnants near the new eastern boundary. The yellow tops of the small hills and buttes are remnants of Point Lookout colluvium that was deposited before the hills were isolated by erosion.

The Point Lookout Formation includes about 300 feet of light colored, resistant sandstone and shaly sandstone. In this area two massive units of sandstone make up the bulk of the formation thickness,with relatively thin shaly sandstone breaks. The contact between the Mancos Formation Cortez member and the Point Lookout Sandstone is gradational, and difficult to mark, and the base of the Point Lookout Formation is generally placed where the sandstone layers become non argillaceous and are more numerous than the muddy layers. The Point Lookout Formation represents a regressive interval in the sedimentary history and was deposited as shore face and strand plain sand. Recent studies by Wright--Dunbar, Zech, and others have shown that some of the deposits are deltaic and lagoonal as well. Here the well cemented sandstones form high cliffs protecting the soft Mancos shales. Although the solid

sandstone blocks would be good building stone, none is visible in the unexcavated mounds of Yucca House. Presumably it would have been impractical to transport so far when there was good building material much closer. If there are prehistoric dwelling sites on the eastside of the Montezuma Valley, they will probably include material from the Point Lookout Sandstone,rather than from the Juana Lopez calcarenites.

Overlying the Point Lookout Formation is the nonmarine Menefee Formation. This unit of sediments is composed mostly of relatively soft shales, woody shales, coal and irregular soft sandstones. It forms the slopes above the Point Lookout cliffs and below the overlying Cliff House Sandstone cliffs high above the Montezuma Valley. The Menefee Formation was deposited on land on the low relief former sea bottom. Low interstream areas developed soil and vegetation, giving rise to carbonaceous shales.The stream sandstones within the Menefee Formation are discontinuous and not well enough indurated in most places to be utilized for building material. In the Yucca House archeological collection are pendants made of red burnt shale. Well above the Point Lookout Sandstone, bright red burnt shale is visible, presumably the result of the burning of a coal bed in the Menefee Formation. The overlying shales are baked and the iron content gives a red color. These burned beds are found in many locations along the mesa edges and are very common along the Mancos River to the south, so the exact source of the carved burnt shale artifacts cannot be determined. Coal beds within the Menefee have been mined in this area in historic times, but prehistoric use of coal has not been documented at this locality.

Overlying the Menefee Formation is the top member of the Mesaverde Group, the Cliff House Formation deposited in the readvancing seaway. The Cliff House Formation consists of two massive sandstone units separated by shaly sandstones in Mesa Verde National Park. The formation was not examined at this locality. It is the source for much of the prehistoric building stone in Mesa Verde National Park and in the Ute Mountain Tribal Park to the south, but no building blocks of Cliff House Sandstone were recognized at the Yucca House mounds. If there are prehistoric building sites on the east side of the valley, nearer the Mesa Verde, they will very likely be found to be built using the local Point Lookout and Cliff House sandstones. .

Because most of the valley has been cultivated over the years, and alluvial soils and crops cover much of the surface, bed rocks crop out only in the deepest gullies, along ditches and other excavations and in a few low hills on the extreme west and on the east below the Mesa Verde cliffs. Sediments of Quaternary terraces, pediments, and alluvium bury the bed rock to at least 40 feet depth in some places. Therefore in many parts of the map the contacts of underlying sediments have had to be approximated.

STRUCTURE

The Cretaceous sedimentary beds underlying the Yucca House Monument area are along the northern part of the San Juan structural basin. The gentle southeast dip toward the basin is interrupted by the structural dome resulting from the laccolithic intrusives of the Ute Mountains, but there is very little effect of this doming visible within the study area. The tectonic setting of the Four Corners region has been recently summarized by Woodward, Anderson and Lucas (1997).Most of the sediments in the study area are very gently dipping to the southeast generally at less than5 degrees, with a strike about N60E. Dips are gentle and many bedding planes are so irregular due to burrowing and reworking of surfaces during deposition that an accurate dip is difficult to measure.Exposures are poor, mainly in the gully bottoms, where the gully has been eroded through the Quaternary overburden to bed rock and follows down along the gentle dip slope. No faults are visible inthe bed rock of the valley, but small faults are visible along the mesa rim, though not within the area covered by a detailed map. The faults shown on the west edge of the Mesa Verde, were located from aerial photographs and Wanek's (1959) map. There is so much soil and overburden on top of the bedrock in the Montezuma Valley, that minor structures are hidden. No stratigraphic anomalies were noted which would require structural explanation.

IGNEOUS HISTORY

Although no igneous rocks crop out in the Ismay-Yucca House holdings, igneous rocks are very common, both as loose cobbles and pebbles, and in building blocks in the prehistoric structures. The Ute Mountain laccoliths and other intrusive bodies crop out less than three miles to the west. These igneous rocks are dated as of Laramide age - very late Cretaceous or very early Tertiary. They were intruded through and between layers of old sedimentary rocks as stocks, laccolithic bodies, dikes and sills. Although there is variation from one intrusive to another, most are light to dark gray, fine- to medium-grained, porphyritic, plagioclase rich rocks. Most of the fine grained gabbro is very dark grayto almost black. The crystalline structure of the ground mass is very fine, but visible to the naked eye.

Mineralogically the ground mass is mostly composed of plagioclase and chlorite with phenocrysts of augite or hornblende (Ekren and Houser,p. 28) More common than the fine grained gabbro, are diorite porphyry, granodiorite porphyry and monzonite porphyry. All of the igneous intrusives examined were porphyritic, and the phenocrysts are usually plagioclase, hornblende or augite. These rocks are found as hammer stones and other artifacts, as well as building stones.

SUMMARY

The bed rocks of the Izmay holdings surveyed are entirely of Upper Cretaceous age. Most of the area is underlain by Mancos Formation sediments. The Point Lookout, Menefee and Cliff House Formations crop out only along the Mesa Verde scarp on the east border of the surveyed area. Igneous rocks from the Ute Mountain intrusives do not crop out in the area. but are abundantly present as pebbles to large boulders in stream beds, and as alluvial and terrace deposits.Yucca House building blocks as seen in the present rubble mounds were derived from two main sources. Many of the blocks are debris from the laccolithic masses to the west which were brought down to the valley in streams and landslides. What appears at this time to be the majority of the building material was derived from the upper two units of calcarenite from the Juana Lopez member of the Mancos Formation. These crop out in several gullies about 1/2 mile west of the Yucca House mounds. When this site is eventually excavated, it may disclose use of some of the earlier Juana Lopez layers or even Dakota Sandstone. Holmes (1878, p. 399-400) assumption that the "stone used is chiefly the fossiliferous limestone that outcrops along the base of the Mesa Verde" was erroneous.There is no limestone cropping out at the base of the Mesa Verde. The diagnostic fossiliferous limestone (calcarenite) crops out to the west of the building site. No sandstone blocks of the Point Lookout or Cliff House Formations were seen in the mounds, and it certainly is unlikely that the early Puebloans would have carried in heavy building blocks from the east side of the valley, when the localstone was so readily available.

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Extracted from: (Griffitts, 2001)

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Extracted from: (Griffitts, 2001)

Appendix

The fossils collected during this study are catalogued and stored in the Mesa Verde National Parkmuseum collection.

DESCRIPTIVE PALEONTOLOGY OF GUIDE FOSSILS

AMMONITES

Scaphites warreni Meek and Hayden (see Figure 10A)

Scaphites are a group of ammonites which have involute early coils, followed by a living chamber that is loosely coiled or almost straight. Scaphites warreni averages 35 mm length, subovate in cross section, stout with small umbilicus. The living chamber is distinctly free from coiled portion. The early whorls are smooth. Adult forms show primary ribs which bend slightly where crossing the flank and at the ventrolateral margin swell into rounded nodes and divide into secondary ribs which extend straight across the venter. A second form of this species (dimorphic) is more slender, less ovate in cross section and smaller, but has similar ornamentation.This species of Scaphite is found in unit 3 of the Juana Lopez Member of the Mancos Formation, and is a very good guide fossil for this horizon.

Scaphites whitfieldi Cobban (see Figure 10B)

Scaphite similar in size to *S. warreni*, but more slender and distinctly quadrangular in cross section. Ornamentation on adult form is more dense and has more evenly spaced ribs on the venter, and this ornamentation combined with the slender, compressed, quadrangular cross section easily separates *S. whitfieldi* from *S. warreni*. This species also has two forms- a macroconch or female which is morerobust and has a characteristic umbilical swelling on the living chamber, and a slender smaller male form.

This species of Scaphite is found in unit 4 of the Juana Lopez Member of the Mancos Formation, and is a very good guide fossil for this horizon.

Prionocyclus wyomingensis Meek (see Figures 11A-B)

A moderately large evolute ammonite with a somewhat rectangular whorl cross section, a broad venter and a continuous serrate keel. The inner whorls are more compressed and have finer ribs, much closer together, and with less prominent nodes. On the outer whorls of larger specimens, 7 cm in diameter and larger, the whorl section begins to show slight convexity between the umbilical and ventrolateral nodes. The ribs are strong with the primary ribs usually bearing umbilical nodes.Secondary ribs in some cases branch from the primaries and in other cases are intercalated between the primaries. As the ribs approach the ventrolateral shoulder, another node is formed on the primaries. At that point, the rib bends abruptly forward toward the keel, disappearing just before contact, so that a slight depression exists on either side of the strong median keel. The keel shows moderately strong serrations.

The diagnostic characteristics of this species is the ovoid rectangular whorl section, the strong clearribs, and the double row of ventrolateral nodes.

The faunal association with *Scaphites warreni* and *Inoceramus dimidius* with *Prionocyclus wyomingensis* helps separate the two common *Prionocyclids*. This faunal group is found in unit 3 of the Juana Lopez Member of the Mancos Formation.

Prionocyclus novimexicanus (Marcou) (see Figures 11C-D)

Similar in many characteristics to *P. wyomingensis*, in fact was originally described as *P.wyomingensis var. elegans. P. novimexicanus* has only a single row of ventrolateral tubercles instead of the double row of *P. wyomingensis* and has a low ventral ridge bordering a smooth ventral furrow .Haas (1946, p. 200-201) observed that it also has a more compressed whorl section and more distinctly ribbed juvenile whorls. In the field, the most obvious difference is the more compressed,rectangular cross section of the whorl and lack of seration on the keel.

Again the faunal association is useful in identifying this species. It is slightly younger than *P. wyomingensis* and occurs with *Scaphites whitfieldi* and characterizes the upper unit 4 calcarenite zoneof the Juana Lopez Member of the Mancos Formation.

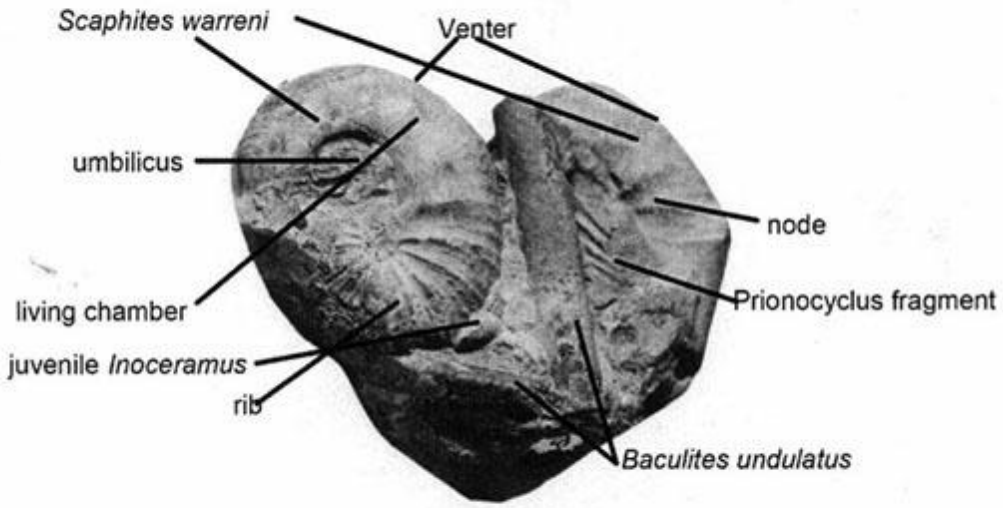
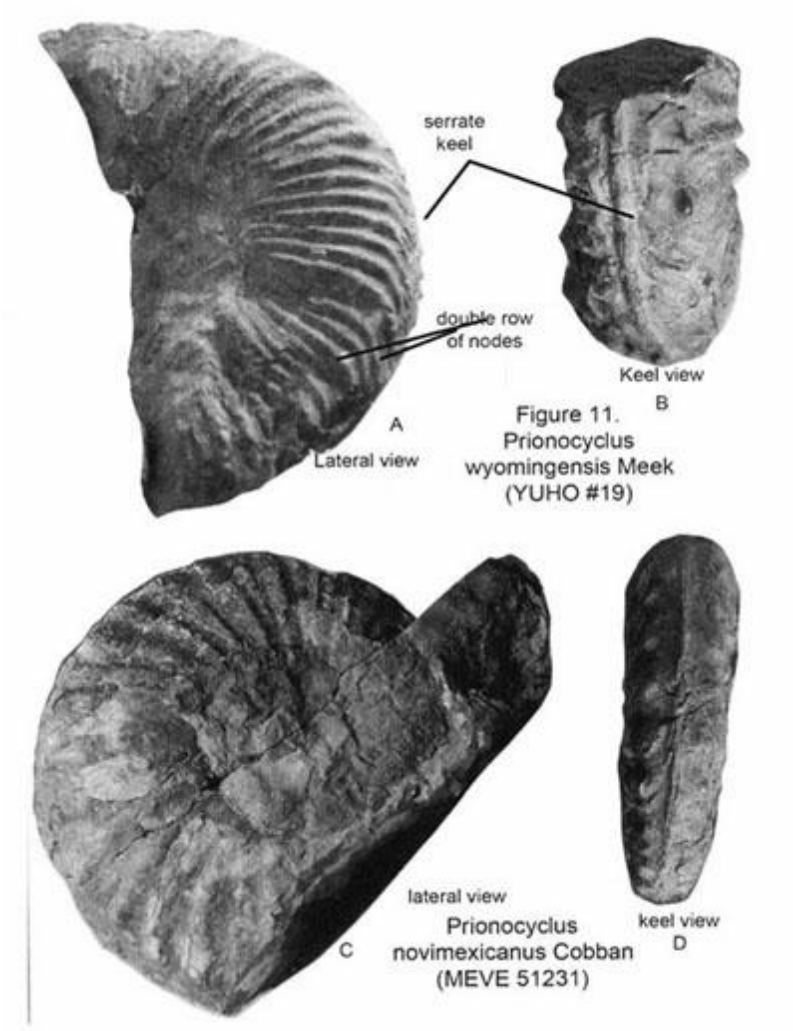


Figure 10A. ***Scaphites warreni*** Meek and Hayden, ***Baculites undulatus*** d'Orbigny, with juvenile ***Inoceramus*** and fragment of ***Prionocyclus*** on slab from Yucca House with zone 3 faunal assemblage. (YUHO # 17). X2.

Figure 10B. ***Scaphites whitfieldi*** Cobban (YUHO #98) X1



Baculites undulatus d'Orbigny (see Figure 10A, 18)

The Baculites are a group of ammonites with only a minute coil of one to two whorls before growing out into a straight or very slightly bent shaft. Associated with the Scaphites warreni -Prionocyclus wyomingensis fauna are fragments of small, straight Baculites. Most fragmental sections are less than5 cm in length and usually only about 5 to 7 mm in diameter, although some specimens measure up to12 mm in diameter. All show a rounded oval cross-section and distinctive, though rather weak, arcuate swellings along the flanks, dorsum and venter, with a slight taper visible even on short fragments.

Baculites yokoyami Tokunaga and Shimizu

Associated with the Scaphites whitfieldi-Prionocyclus novimexicanus fauna are fragments of another small, straight Baculite. These also are preserved only as fragmental sections 5 cm or less in length ,but though the venter may show closely spaced ribs, the flanks are usually relatively smooth. The cross section is oval. This Baculite is found in a longer vertical time range.

BIVALVES

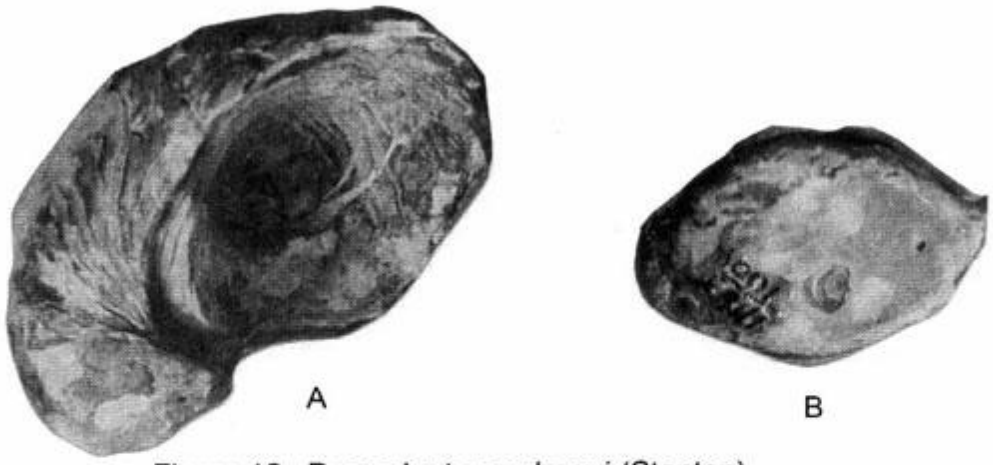


Figure 12. Pycnodonte newberryi (Stanton)
A. Convex left valve with small concave right valve in place. (MEVE #11185)
B. Right valve interior showing muscle scar (MEVE #11185)

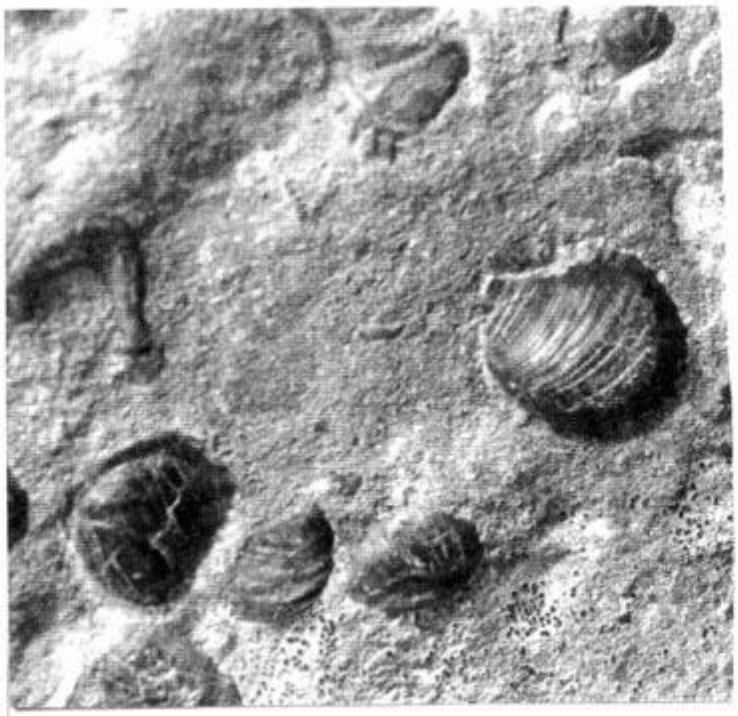


Figure 13. ***Lopha lugubris*** (Conrad) Typical slab of multiple individuals. (MEVE 7286)

Pycnodonte newberryi (Stanton) (see Figures 12A-B)

Pycnodonte newberryi (Stanton) is a small, highly inequivalve, strongly inrolled species of oyster which is very diagnostic of Graneros shale of the Mancos Formation. It has a subovate to subtriangularoverall outline. The two valves are very inequal, with the larger left valve strongly inrolled and usually with a

conspicuous radial sulcus. Ornamentation consists of irregular growth lines. The right valve is usually flat to slightly concave and ornamentation consists of concentric growth lines. The interior of each valve shows a conspicuous single muscle scar. The attachment area is usually at the apex of the left valve umbone.

It is a relatively unique, easily recognized fossil, and also is quite resistant to weathering. With itsalmost spherical shape. it rolls out of outcrops and often accumulates in large quantities in stream beds.

Lopha lugubris (Conrad) (see Figure 13)

Lopha lugubris (Conrad) is a small, inequivalve oyster whose presence in quantities is very diagnostic of the lower calcarenite unit 2 of the Juana Lopez. This oyster has a longer vertical range, found from unit 1 through unit 3 of the Juana Lopez Member of the Mancos Formation, but only in unit 2 is it the dominant species and found covering most of the slabs of calcarenite.

Lopha lugubris is easily recognized by its crenulate, subovate outline. The left valve is usually more convex than the right, and has a large attachment area. The shells of this species are attached to *Inoceramus* shells, and often have attachment areas covering half of the left valve. The right valve is flat to slightly convex. Both valves show a single conspicuous adductor muscle scar. Both valves have strongly plicate outlines which are quickly diagnostic in the field.

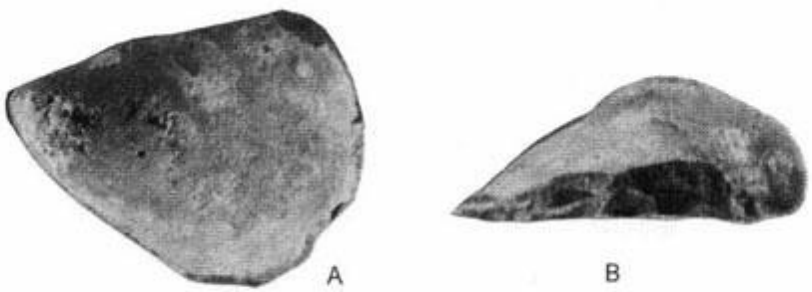


Figure 14. ***Inoceramus dimidius*** White (YUHO #151)
A. Cast of interior of left valve showing sharp change in slope of shell.
B. Profile of same specimen. X1

Inoceramus dimidius White (see Figures 14A-B)

Inoceramus dimidius White is a small, inequivalve inoceramid that occurs with *Lopha lugubris* in unit 2 and also in unit 3 with the *Scaphites warreni-Prionocyclus wyomingensis* faunas. It is easily recognized because of the major break in ornamentation between the earlier stages of growth where there are strong rugae and the later part of the shell which is almost smooth. At the juncture of the two types of ornamentation, a prominent angular change in the slope of the shell, makes an easy diagnostic characteristic.

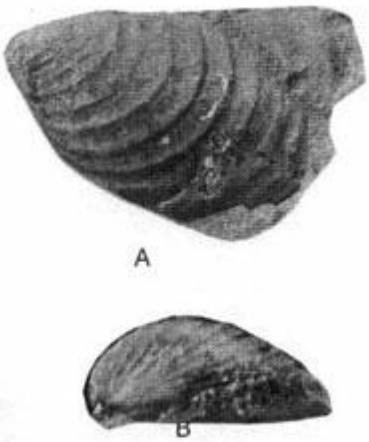


Figure 15. ***Inoceramus perplexu***Whitfield (YUHO 62) A. Cast of exterior left valve, showing regular ornamentation over entire shell.

B. Profile view of same specimen.

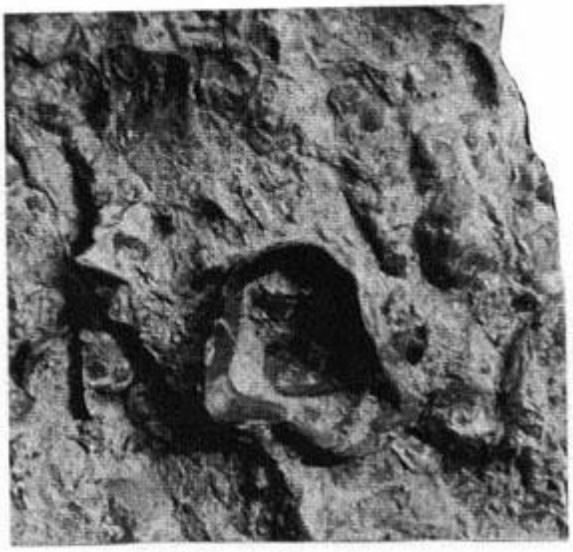


Figure 16. ***Pseudoperna congesta*** (Conrad) (YUHO 158) oysters encrusting large ***Inoceramus*** X2

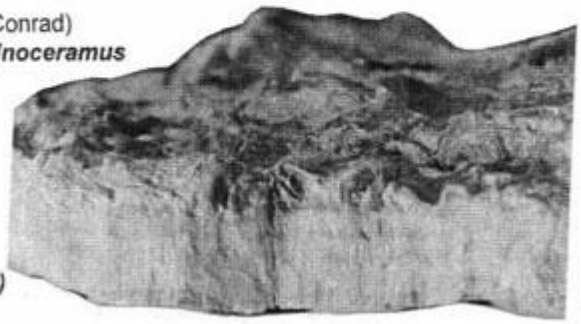


Figure 17. Side view of prismatic shell layer of large ***Inoceramus*** Upper surface encrusted with ***Pseudoperna congesta. (YUHO 158)*** X2

Inoceramus perplexus Whitfield (see Figures 15A-B)

Inoceramus perplexus Whitfield is a small inoceramid with regular, sharp, concentric growth lines throughout the shell. This species occurs in Juana Lopez unit 4 with the *Scaphites whitfieldi-Prionocyclus novimexicanus* fauna

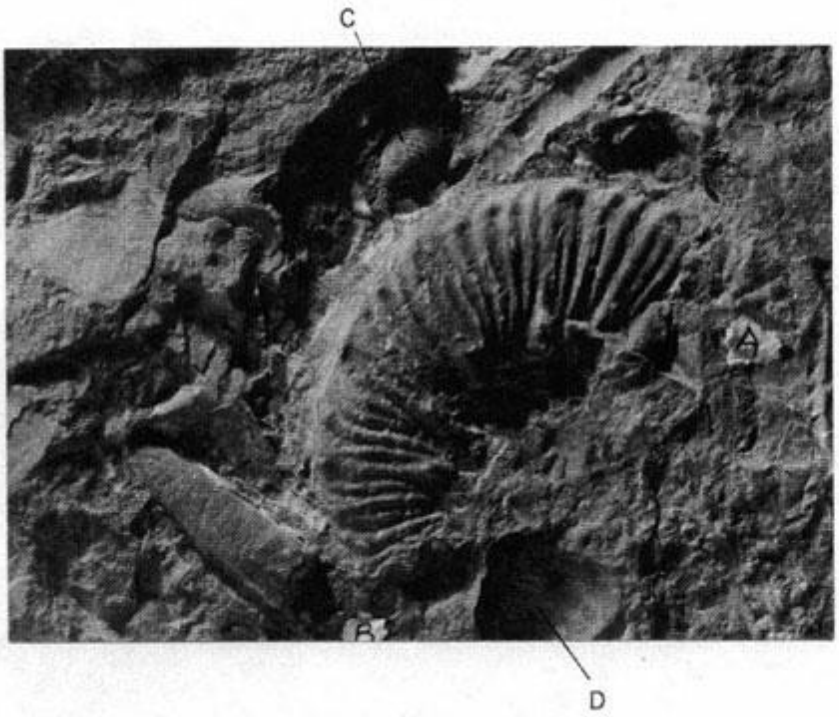
Pseudoperna congesta (Conrad) (see Figure 16)

A small irregular to ovate oyster, usually found in masses encrusting the prismatic layer of large Inoceramid such as *Inoceramus grandis*. Where crowded, develop a very irregular shape due to impingement by neighboring individuals. Where sparse population, may be nearly oval. Valves very unequal with attachment area on left (larger) valve very large. Right valve often crushed into left valve by weight of overlying sediments. The solid oyster beds are quite resistant to erosion. This is a very widespread, diagnostic species found throughout the Western Interior in Niobrara age sediments. In the Mancos section it is referred to the Smoky Hill Member. The Smoky Hill is the upper unit of the Niobrara elsewhere. The lower unit is missing in the Four Corners area.

Inoceramus (Volviceramus) grandis Conrad (see Figure 17)

A very large, irregular Inoceramid, frequently found only as cross sections of the prismatic layer of the

shell. Occasionally these cross sections are up to a meter in width. More often, they are seen only as fragments, densely encrusted by *Pseudoperna congesta*. Individually, it is rare to see a complete *I. grandis*.



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Griffitts, Mary O., 1999, Mesa Verde National Park Geology, National Park Service, 1:24,000 scale. (*GRI Source Map ID 978*).

Carrara, 2009, and Haynes et. al., 1972

Carrarra, Paul, 2009, Yucca House Geologic Map, U.S. Geological Survey, unpublished map, 1:12,000 scale. (*GRI Source Map ID 75483*).

Unit descriptions for the GRI digital geologic-GIS using this source map were taken from:
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, 1:250,000 scale. (*GRI Source Map ID 105*).

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The information contained here was compiled to accompany the digital geologic-GIS map(s) and other digital data for Yucca House National Monument, Colorado (YUHO) developed by Georgia Hybels (NPS GRD) using source data, and from GRI data previously digitized and completed by Georgia Hybels and Stephanie O'Meara. See the GRI Source Map Citations section of this document for all sources used by the GRI in the completion of this park's maps.

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