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# GEOLOGY OF NAVAJO NATIONAL MONUMENT

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## INTRODUCTION

The purpose of my trip to the Navajo National Monument was to ascertain the geological features in the vicinity of the ruins in order to prepare a formal report on the area. The Monument was reserved on the basis of the archeological interest. It is considered important however that the Park Service staff be informed on the geological aspects since numerous visitors ask to be advised on these questions and since such features have had a direct bearing on the presence of the Pueblo cliff dwellers in the area.

## LOCATION

Navajo National Monument is situated in the northwestern part of the Navajo Indian Reservation, in northeastern Arizona. It is composed of three units, - Betatakin Ruin, Koet Seel Ruin and Inscription House Ruin. These areas comprise a total of 360 acres and were reserved by the Government in 1909 and 1912 as a means of preservation of some of the most important remains of Pueblo cliff-dwellings thus far discovered. The maximum distance between the three units of the Monument is about 20 miles although this distance by trail or road due to the necessity of circuitous routes is much farther.

Betatakin Ruins and Koet Seel Ruins may be approached from the southwest from Shonto and from the east via Kayenta. The road leads to the top of the mesa above Betatakin and a trail for horse trips has been constructed into the canyon, distance of about a mile, to this point. A rough horse trail is available to Koet Seel from Betatakin which is approximately eight miles in length. The route to Inscription House Ruin turns north along the Rainbow Natural Bridge road about midway between Tuba City and Kayenta. Travel may then be made by car westward for a distance of about two miles from the Inscription House trading Post at which point the rim of Navajo Canyon is reached. A horse trail has been constructed into the canyon and the ruins are located about four miles distant from the rim.

Mr. John Wetherill of Kayenta, Arizona, is custodian for the Monument. Mr. Milton Wetherill is the acting ranger in charge and is stationed at the Betatakin Ruin.

## CLIMATE

The climate of this section of the Navajo country is arid. The rainfall average for eleven years to 1927 at Kayenta, with an elevation of 5,800 feet, amounted to 8.80 inches per year. The minimum temperature

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## GEOLOGY OF NAVAJO NATIONAL MONUMENT (CONT.)

during this period was  $-18^{\circ}$  F. with a maximum of  $104^{\circ}$  F. The average annual range at this point is between  $-8^{\circ}$  F. and  $101^{\circ}$  F.

### HISTORY

There are over three hundred cliff-dwelling ruins in the Tsegie Canyon drainage system north of Marsh Pass and while I have visited only a few of them, besides those included in the Monument, it is understood that they are all constructed in alcoves of the Navajo sandstone. There are times when a geologist may map outcrop of a formation from the surface vegetation and here from the association of the number of ruins with the Navajo formation it would seem almost possible to use this criterion.

#### Betatakin

This ruin is located in a magnificent arch of Navajo sandstone, on the west side of Tsegie Canyon, about one and one-half miles below the junction with Dogoszhe Beco Canyon. Betatakin was so named from the Navajos which means "Side Hill House." The enormous archway in which the cliff-dwellings were constructed is 425 feet in height to the crown, has a span of 370 feet, and reaches a maximum depth of 155 feet. It is difficult to realize the proportions of the arch or window until one has stood in its recesses and looked outward across the canyon. The great Rainbow Natural Bridge could be placed inside of the archway with room to spare. The dwellings consist of some 135 rooms and they rank fourth in size of those discovered thus far. From tree ring data it has been discovered that the ruins were inhabited from 1242 to 1277 A. D. One of the best springs in the country flows out of the sandstone cliff at the base of the arch with a flow of one and one-half gallons per minute. Betatakin was first known in 1907. In 1909 Mr. John Wetherill conducted Professor Byron Cummings to the site just prior to the First Rainbow Bridge expedition. In 1917 Mr. Neil Judd cleaned and repaired certain portions of the Betatakin ruins.

#### Keet Seel

This ruin derived its name from the Navajo term Keet Seel or "Broken Pottery" and it is located in the canyon of the same name, some eight miles by trail above the Betatakin ruins. It contains 152 rooms and is the second largest Pueblo cliff-dwelling known and ranks second to the largest ruins located at Mesa Verde National Park. Discovery was made by Richard Wetherill in 1894 who was accompanied by Mr. Charles Mason. They revisited the site in 1897. Some restoration and cleaning was carried on with CWA funds in 1934. The dwellings are indeed spectacular and one would not need to be an archeologist to enjoy spending considerable time at the site. They are also located in a huge archway in the Navajo sandstone. Slabs of Kayenta sandstone were carried from some distance below in Keet Seel Canyon for certain parts of their

## GEOLOGY OF NAVAJO NATIONAL MONUMENT (CONT.)

construction. The site was inhabited by Pueblos from 1116 to 1284 A.D. and it is considered that these peoples together with those of Betatakin migrated to Canyon del Muerto (Canyon de Chelly) because of drought conditions.

### Inscription House

These ruins, located in Navajo Canyon, were named from a dim carving on the wall which has been interpreted to read "Carlos Arnais 1661". A party headed by Professor Byron Cummings discovered the ruins and the inscription several years ago. The dwellings are located more than 150 feet up on the side of a cliff of Navajo sandstone and the inhabitants were well protected. A rather large cave is present on one side. Some protection must have been desirable as other sites might have been selected which would have been more accessible. Occupation was during the Pueblo III interval. Some water is in evidence in the stream bed of the canyon which is probably fed by springs. No doubt some water could be developed in the canyon from seeps.

Besides the above mentioned ruins which have been included in the Navajo National Monument there are many others of importance in this area some of which are Swallows Nest, Rope House, Platform House, Bubbling Spring, Turkey Cave, Turkey House, Ladder House, Bat Woman, Twin Caves, Horn Basket and Spruce Tree House. They contain from 20 to 30 rooms.

## GEOLOGY

The three units of the Navajo National Monument are all located in the lower part of the Navajo sandstone formation. This massive wind blown deposit outcrops over wide areas to the northwest of Black Mesa and forms the uppermost member of the Glen Canyon group, generally recognized to be Jurassic in age. As yet no fossils have been found in the Navajo sandstone to definitely establish its age so that it should be kept in mind that this classification is tentative. The sedimentary rocks involved in the three units of the Monument and vicinity are composed of Pleistocene or Recent Lake Beds; Navajo sandstone, Kayenta formation, and Wingate sandstone of the Glen Canyon group, Jurassic (?) in age; and the Chinle formation of the Upper Triassic. A stratigraphic section indicating additional details of the above mentioned formations is included on page following.

### PLEISTOCENE TO RECENT

In recent years, possibly not more than 25 years ago, Marsh Pass as well as Tsegie ("Lakes in the Canyon") Canyon contained swamps and lakes which have since been drained by a deep arroyo. Overgrazing is generally conceived as being responsible for this now erosion cycle. There is much evidence of an extensive series of lakes in both Tsegie

## STRATIGRAPHIC SECTION, NAVAJO NATIONAL MONUMENT

AGE	FORMATION	THICKNESS (FEET)		CHARACTER OF ROCKS	
		REGIONAL	LOCAL		
RECENT TO PLEISTOCENE	LAKE BEDS		0 TO 60	Sands and gravels deposited in an old lake bed or series of lake beds which once occupied Tsegie Canyon. Several different periods may be recognized. Plant remains and several varieties of fresh water shells are present.	
JURASSIC (?)	GLEN CANYON GROUP	NAVAJO SANDSTONES	400 to 1100	900	Massive buff to grey sandstone, with spectacular cross-bedding and well developed jointing. contains local limestone lenses. Weathers various shades to brown and red. Prominent cliff maker. No determinable fossils have been discovered. Of a total of over 300 ruins in Tsegie Canyon drainage system all are in this formation. The Navajo Monument ruins occur near the base. Widespread tangential cross-bedding has made possible the huge development of arches, alcoves and caves.
		KAYENTA FORMATION	0 to 225	0 to 225	Uniformly bedded, red to buff sandstone, with interbedded shale. Weathers a grey vermilion. More slope forming than Navajo sandstone. No fossils have been found although dinosaur tracks have been located to the north of this area.
		WINGATE SANDSTONE	30 to 450	150 to 250	Buff cross-bedded sandstone which forms vertical cliffs. Cross-bedding not so highly developed perhaps as in the Navajo sandstone. Weathers deep red to black. Unfossiliferous although dinosaur tracks reported.
UPPER TRIASSIC	CHINLE FORMATION	0 to 1182	0 to 70	Variegated shale which contains silicified wood. Exposed in the lower parts of Tsegie Canyon. Supplies much of the paint in the Painted Desert area.	

## GEOLOGY OF NAVAJO NATIONAL MONUMENT (CONT.)

and Keet Seel Canyons. Sands, gravels and clays have been deposited in regular beds up to 60 feet or more in thickness. The trail leading from Betatakin to Keet Seel shows a remarkable development of this formation. The remains of plants and pollen together with the presence of fresh water shells buried in these beds has led geologists to believe that lakes were depositing their sediments from the Pleistocene to Recent times. Several different stages of development or cycles may be observed in sections of the Lake Beds where the present drainage system has unfolded excellent exposures. These beds usually cover the Wingate sandstone in the lower portions of the canyon although in some instances it is the Chinle formation that is obscured.

### JURASSIC (?) - GLEN CANYON GROUP

#### Navajo Sandstone

The uppermost member of the Glen Canyon Group in this area is the Navajo sandstone formation. This formation contains the three units of Navajo National Monument and it is stated that there are some 300 other cliff-dwellings in the Tsegi Canyon drainage system which are also found in the Navajo. A superb display of cross-bedding with tangential planes a conspicuous feature and the almost total lack of horizontal bedding characterizes the formation. It is composed of sub-angular to rounded grains of quartz of medium size, which are rather loosely cemented by calcium carbonate. On fresh surfaces the color is buff to grey and upon weathering various shades of red and brown stand out. The coloring has not been so spectacularly applied to the Navajo in this area as in the Virgin River Canyon at Zion National Park. Box canyons and huge dome have been carved in this sandstone until passage on foot is treacherous and in many instances impossible. Rainbow Bridge and several other natural bridges in the area have been carved from the Navajo formation.

The Navajo sandstone is generally recognized to be of eolian origin. The rareness of horizontal bedding and the presence of cross-bedding on an enormous scale, together with the absence of silt and almost total absence of fossils tend to support this theory. There are thin lenses of limestone in the Navajo Monument area, especially in Navajo Canyon, indicating that at least some of the sediments were deposited by water. Efforts were made to locate fossils in these limestone lenses but no success was had. Brady (5) describes a small theropod which was discovered about two and one-half miles east of the Inscription House Lodge in the Navajo sandstone. The possible remains of a small dinosaur in this formation were found above Turkey Cave. The bones were located about 750 feet above the base of the sandstone in a sandy shale lense and it is stated by C. Camp of the University of California that they "show evidence of belonging to a different group from any dinosaur yet discovered." A few bone fragments are in evidence just below Keet Seel ruin but these are considered to be too fragmentary to serve for identification purposes. No fossils have been discovered thus far to actually determine the age of the sandstone.

## GEOLOGY OF NAVAJO NATIONAL MONUMENT (CONT.)

Baker (3) states that the Navajo sandstone thickens towards the west and is believed to include all of the massive Jurassic sandstone that crops out in northern Arizona and southern Utah west of a line through Less Ferry, Arizona. He also states that the source of the sediments is not definitely known but concludes from the westward thickening of the formation that the source presumably lay in this direction.

Gregory (1) describes the factors involved in the formation of the arches and alcoves in which the cliff-dweller constructed his home in excellent fashion and the following is quoted from his paper, - "The sandstone cliffs in this region are beautifully sculptured; buttresses and recesses are common, overhanging walls are characteristic, and the wide open mouths of niches and caves perched high on the canyon walls are conspicuous. These cavities, protected from the rain, from the glaring heat of the sun, and from suffocating sandstorms, were widely utilized by the ancient inhabitants as building sites - rock shelters or cavate dwellings, as the terms are used by the archeologists. The structure of these beds is favorable for the production of rock shelters. The rock composing them is porous, elaborately cross-bedded, and traversed by joint planes set far apart. The curved laminae of the cross-bedded strata, 1 inch to several feet thick, are held together by weak cement that is easily removed by percolating water. Slight undermining along zones of the more impervious rock permits the overlying laminae to fall in response to gravity. They drop to the floor as a unit or in separate slabs; the crushed fragments, with cement already removed from the spherical grains, rapidly disintegrate and make their way to the mouth of the cave. As the process continues shell after shell is removed and the arched roof cave is sunk farther and farther into the face of the cliff, until building sites 200 to 3,000 square feet in area are prepared for the cliff-dweller. All stages of the work are represented. In some caves shells of partly detached rock bridge the entrance; in others blocks on the point of falling extend downward from the roof, and the floor is piled high with fragments that crumble under the blow of the hammer; still others are free of debris, and the rock of the roof and sides is firm. The work of ground water in forming these rock shelters is evident. Some of the caves are dry or streaked with moist alkali 'bloom'; in others water oozes continuously from the wall over a wide area marked by moss and ferns; many caves contain perennial springs whose outlet is definitely localized. The conditions that permit the formation of rock shelters in massive beds of sandstone--namely, tangential cross-bedding and porosity in rock of uniform composition--also favor the production of windows and natural bridges."

### Kayenta Formation

The Kayenta formation in the vicinity of Navajo National Monument varies from 0 to 125 feet thick whereas regionally it is almost twice this thickness. It is uniform to irregularly bedded and consists mainly of sandstone with some interbedded shale and in some instances limestone and conglomerate. The character of the bedding is the main criterion

for distinguishing it from the massive cross-bedded sandstones above and below. There are cross-bedded sandstones in the Kayenta however and for this reason it is difficult at times to draw the contact with certainty. Since no fossils of significance have been collected from the Kayenta it has been the general practice to include all of these sediments which show distinct bedding within the limits of this formation. At several localities dinosaur tracks have been found but the nearest identification that has been made is that they are not older than the Triassic. Colors range from purplish red to buff and upon weathering the beds are greyish purple to reddish brown. Generally the Kayenta is darker than the overlying Navajo sandstones. The name Kayenta has recently been adopted by the U. S. Geological Survey to replace the name Todilto formation. The type locality for the former is about one mile north of Kayenta, Arizona, and it is tentatively classified as Jurassic (?). Outcrops of the Kayenta may be seen just below the Botatakin ruins and along the trail to Keet Seel ruins. The formation lenses out in the vicinity of Keet Seel and apparently the slabs of sandstone used in the construction of part of the dwellings at this site were carried a mile or more from the canyon below. These beds were laid down in fresh water by shifting streams.

#### Wingate Sandstone

The Wingate is a buff colored highly cross-bedded sandstone with rare limestone lenses and local conglomerates near the base. It has many of the characteristics of the Navajo sandstone. On weathering the Wingate acquires darker shades of red to tones almost black. It is massive forming vertical cliffs and narrow gorges with vertical joints a prominent feature. It comprises the lower formation of the Glen Canyon group and again no fossils have been found which could be used to definitely establish the age and it is tentatively classified with the Jurassic (?) along with the Kayenta and Navajo. The uniform character of the sandstone and the highly developed cross-bedding together with almost total lack of fossils (a few dinosaur tracks have been reported) is most suggestive of eolian origin. The Wingate sandstone may be observed below Botatakin ruins and in the Tsegie and Navajo Canyons en route to Keet Seel ruin. At many points along the latter trail it is obscured by the Lake Bed deposit. Nothing below the Navajo sandstone is present in Navajo Canyon along the trail to Inscription House ruin.

#### Chinle Formation

The Chine is less than 100 feet thick in Tsegie Canyon along the trail to Keet Seel. In the general region it is as much as 1182 feet in thickness. It is in the main a variegated shale and can easily be distinguished from the above mentioned Wingate sandstone. Fragments of silicified which are almost always in evidence in the Chine have been collected in Tsegie Canyon and reptilian bones have been reported from these beds in Tsegie Canyon in the direction of Marsh Pass. Vertebrate fossils have been found at many places which place the age of the





highly cross-bedded sandstones above and below.

Note: Two such signs needed for Betatakin area and Keet Seel trail.

III: WINGATE SANDSTONE  
JURASSIC (?) AGE

The uniform texture, large scale cross-bedding and lack of fossils strongly suggest that these sandstones were deposited by the wind in the form of dunes.

IV: CHINLE FORMATION  
UPPER TRIASSIC IN AGE

These variegated shales contain shells, reptilian remains, and silicified wood which have established their age. They are fresh water forms and the formation is considered to be of continental origin. Ask the Ranger to show you Petrified Wood from these beds.

Note: One sign needed to be placed along the Keel Seel trail.

V: LAKE BEDS  
PLEISTOCENE TO RECENT IN AGE

Sands, gravels and clays deposited in old lake beds which once occupied this valley. Plant remains and fresh water shells are found in abundance and the Ranger will point these out to you if you wish.

Note: One sign required to be posted along the Keet Seel trail.

CONCLUSIONS

Navajo National Monument is a most interesting area. While I am not familiar with the fundamental archeological factors the ruins were just as spectacular to me as some of those contained at Mesa Verde National Park. It is surprising that so few people living in northern Arizona know of the importance and inspirational character of this Monument. The Park Service is indeed fortunate in having Milton Wetherill on duty as Acting Ranger at Betatakin. He was most helpful to me during my recent trip and is greatly interested in all of the different angles of the Monument. He has made a study of the plants and is now working on the birds and animals.

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GEOLOGY OF NAVAJO NATIONAL MONUMENT (CONT.)

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