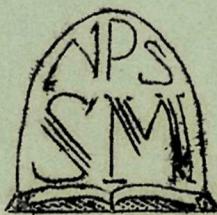


# SOUTHWESTERN MONUMENTS

## SPECIAL REPORT

NO. 20

GEOLOGIC REPORT  
CANYON DE CHELLY  
NATIONAL MONUMENT



BY

VINCENT W. VANDIVER

DEPARTMENT OF THE INTERIOR  
NATIONAL PARK  
SERVICE

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# GEOLOGIC REPORT, CANYON DE CHELLEY

By Vincent W. Vandiver, Associate Regional Geologist

## INTRODUCTION AND LOCATION

This report is intended to supply the main geologic facts regarding one of the most important Monuments of the Southwestern group, Canyon de Chelly, pronounced "shay". The Monument is situated in northeastern Arizona, near the center of the large Navajo Reservation, and consists of approximately 83,840 acres. It was established by Presidential Proclamation on February 14, 1931, and the description of the lands was amended by a Second Proclamation on March 3, 1933. The latter Proclamation defines the boundaries as follows:

"All land in Del Muerto, de Chelly, and Monument Canyons, and the canyons tributary thereto, and the lands within one-half mile of the rims of the said canyons, situated in unsurveyed Townships 4 and 5 North, Range 7 West; Townships 4, 5 and 6 North, Range 8 West; Townships 4 and 5 North, Range 9 West; and in surveyed Townships 4 and 5 North, Range 6 West; Townships 3, 6, and 7 North, Range 7 West; Township 6 North, Range 9 West; and Township 5 North, Range 10 West; all of the Navajo meridian in Arizona."

Existing approach roads to Canyon de Chelly are as follows: (1) Gallup to Chinle via St. Michaels and Ganado: 101 miles. (2) - Gallup to Canyon de Chelly via Ft. Defiance: 76 miles. (3) - Winslow via Hopi Indian Villages to Canyon de Chelly: approximately 128 miles. (4) - Shiprock to Chinle, via Redrock, Lukachukai, and Greasewood: 70 miles. (5) - Kayenta to Chinle via Rough Rock: 80 miles.

The settlement of Chinle, near the mouth of Canyon de Chelly, was so named by the Navajos meaning "a place where water flows out of a canyon." Here the Custodian has a splendid Pueblo style residence with a more or less separate office to contact visitors. There is a large Indian Day School in the village and two trading posts. One of the trading posts has been operated for years by Cozy McSparron and is known as the Thunderbird Dude Ranch. In certain seasons arrangements may be made at this ranch to secure cars for trips into the canyons and horses may likewise be procured during most of the year. Visitors at the Monument during the year ending September, 1936, numbered 1,091.

Much of the enchantment of the area lies in the primitive and picturesque background. In order to properly assimilate this setting it is preferable to spend several days at the Monument, to view the canyons from the rim, and then to take trips along the floor of the canyons and observe the towering cliff buttes, obelisks, pinnacles, not to mention the numerous arches and alcoves where the ruins of many Pueblo settlements

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## CANYON DE CHELLY GEOLOGICAL REPORT (CONT.)

are located. Many Navajos are living in the canyons at the present time. The Monument therefore offers to the visitor the rather unique experience of observing the ruins of the Pueblos and at the same time seeing the modern Navajo in his daily routine. It is with due regard to this glorious natural background, as well as the wishes of the present inhabitants of the canyons, that the Park Service has always endeavored to keep this area as nearly as possible in its original primitive state. Only the very limited and absolutely necessary development is contemplated.

### HISTORY

Records remain of the cliff-dwelling habitation of the canyons by the Basket Makers and later by the Pueblos. The most important ruins are the White House, which has been dated by the tree ring method at 1050-1300 A.D., Antelope House and Mummy Cave at 1200-1300 A.D. Archeological expeditions were made by the Mindeleff's in 1894 (8) and by Earl Morris of the American Museum of Natural History in 1923 (9).

According to Colton (5), Canyon de Chelly was first explored by Americans in 1849, when it was found not to be the impregnable Navajo stronghold that had been reported. He further states that "By 1858 the Navajos had occupied Arizona east of the Hopi country, but had progressed very little farther. By 1863, because the U. S. troops had been withdrawn on account of the Civil War, the depredations of the Navajos had become serious. In that year a special expedition under Col. Kit Carson was sent against them. He rounded them up in Canyon de Chelly, captured about 8000 from all over the whole reservation and deported them to a reservation called Bosque Redondo near Fort Sumner in New Mexico. They were not all captured and the bands scattered. Some took refuge in the maze of canyons in the Rainbow Plateau and others invaded the Coconino Basin near the Grand Canyon. In 1868 the 8000 were returned from Bosque Redondo to their old desert home. Here they increased rapidly until their great reservation is now overpopulated. Spreading north of the Utah line and west to the Little Colorado River, the Navajos, estimated at 50,000 souls, occupy the largest Indian Reservation in the United States - a great area of 25,000 square miles. On the vast plains and juniper-covered mesas they tend their flocks of sheep and goats. They may be truly called "The Arabs of the American Desert."

At present there are from 350 to 400 Navajos living along the 60 miles of canyon floors within the Monument. Water may be secured from pit holes in the sandy flood plain at depths of 3 to 4 feet. The higher portions of this plain are utilized for their homes ("hogans") built of earth and logs, and adjacent plots of land are being farmed in much the same way as they were centuries ago.

### GEOGRAPHY

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## CANYON DE CHELLY GEOLOGICAL REPORT (CONT.)

### Land Forms

Canyon de Chelly lies in the south-central portion of the Colorado Plateau Province. The rocks of this section of the province are in the main horizontal or gently folded, in some instances they are sharply folded and faulted. Vegetation is scant and streams have cut deeply into the surface with the controlling factors generally conforming to the attitude or structure of the beds and to the relative resistance of the various strata. The soft shale members form broad valleys and slopes, with the hard sandstone layers forming steep walled canyons and cap rocks of the many escarpments or mesas. These briefly mentioned land forms are in evidence at Chinle, where to the west may be observed the enormous Black Mesa, containing some 2,400 square miles, capped largely by competent Upper Cretaceous sandstones; also in this same direction the broad Chinle valley composed of soft shales or "marls"; and to the east the west flank of the Defiance uplift where streams have been given added gradient to carve deep canyons in resistant strata.

### Drainage

Canyon del Muerto drainage has its headwaters in Spruce Brook, to the northeast in the Lukachukai Mountains, and Canyon de Chelly in the Cushka Mountains proper to the eastward. Both canyons drain into Chinle creek and the waters ultimately reach the master stream of the province, the Colorado River, through the tributary San Juan. South of the Monument, drainage from the west flank of the Defiance uplift, reaches the Colorado River via the Little Colorado. Streams in the general area are mainly intermittent though some in their lower drainage and near their sources, at higher elevations, are perennial. The stream occupying Canyon de Chelly flows for a distance of some 15 miles as a permanent stream. The large valley of Chinle creek, of which de Chelly and del Muerto are tributaries, drains an area of approximately 4,800 square miles.

### Climate

Topography is the prime factor as regards to climate in the Navajo country. The cliff-dwellers were aware of this fact and gave consideration of this feature in the establishment of their settlements along the canyon walls. Rainfall averages approximately 10 inches per year at Canyon de Chelly with around two-fifths of the precipitation generally falling in July, August, and September. Temperatures of  $-24^{\circ}$  have been recorded at Ft. Defiance and highs of over  $100^{\circ}$  are not uncommon during the summer months. The prevailing winds are from the southwest.

Dr. Gregory (1) expresses these points regarding Navajo climate, - "The keynote of the climate of the Navajo country is variability, marked by sudden changes in temperature and wide fluctuation in rainfall. An intensely hot summer day may be followed by a chilly night; sunlight is

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## CANYON DE CHELLY GEOLOGICAL REPORT (CONT.)

synonymous with heat, shade with cold. The high temperature of the forenoon may be lowered by a cold rain or by a hailstorm, only to become re-established within an hour. When storms come the country is flooded; at other times the task of finding water for man or beast taxes the skill of the most experienced explorer.

### GEOLOGY

#### General

Only sedimentary rocks are exposed at the surface on the Monument. The geology of the area is shown on the attached sketch map. It will be recalled that the boundaries define lands within one-half mile of the rims of Canyon de Chelly, del Muerto and Monument canyon as well as their tributaries.

It is known from the records of wells drilled along the Defiance uplift that there is a granite ridge which forms the core of this structural feature. The granite occurs at relatively shallow depths, around 600 feet at Nazlini canyon, 18 miles southeast of Chinle. This pre-Cambrian ridge was probably an old land mass throughout most of the Paleozoic, until the Permian, when it was buried by the Supai red beds. Overlying the Supai formation is the de Chelly sandstone, most recently considered to have been deposited at the same time interval as the Coconino sandstone to the west and southwest, but the material as will be explained later was probably derived from different sources. Both the de Chelly sandstone and the Coconino sandstone are now generally recognized to be mainly dunes deposited by the winds, or principally eolian in origin. Triassic and Jurassic formations have in turn been deposited over the de Chelly sandstones and we have every reason to believe from regional criteria that Cretaceous sediments once covered the area of the Monument to depths of several thousands of feet, however, these strata have since been removed by erosion.

#### Stratigraphy

The stratigraphy of the general area is shown on the table, page 59 following. Brief description of the various formations are listed on this table which includes the oldest rocks known up to and including those most recently deposited.

Interesting features in the stratigraphy of the Defiance uplift are the absence of the Kaibab limestone (Permian) and the thinning out of the Moenkopi formation (Triassic) in the central portion along the east flank. The Kaibab limestone, which caps large areas west and south of Black Mesa, and likewise forms the rim rock at Grand Canyon, thins out in the vicinity of Holbrook and is absent on the uplift, where in the southern portion the Moenkopi formation rests directly on de Chelly sandstone. The Moenkopi in turn thins out not far north of Ft. Defiance,

GENERALIZED STRATIGRAPHIC TABLE

ERA	PERIOD	FORMATION	THICKNESS (FEET)	LITHOLOGY	
CENOZOIC	QUATERNARY			Alluvium, gravel and eolian deposits.	
		Mesa Verde		Grey, yellow, brown sandstone and blue grey to iron grey shales.	
	CRETACEOUS	Mancos Shale	2500 /	Contain coal, Conglomerate.	
		Unconformity: Dakota ss.		Buff to grey and pink sandstone. Variable in thickness. Contains reptilian remains, non-marine invertebrates, silicified wood. Formerly McElmo Formation.	
	JURASSIC	Morrison	200 /	Usually buff to grey, white and red, massive, intricately cross-bedded sandstone. Contains quartz with some feldspar poorly cemented by lime and silica.	
		Unconformity:		Reddish irregularly bedded sandstone with grits and fine conglomerates. Minor shales and impure limestone. Contains dinosaur tracks, pelecypods, and plant remains. Formerly Todilto.	
	MESOZOIC	JURASSIC (?) (Glen Canyon Group)*	Kayenta	40	Massive cross-bedded cliff forming, pale red to light buff sandstone; mainly quartz grains poorly cemented with lime and silica.
			Unconformity:		Non-marine varicolored marls, thin sandstone and limestone conglomerate. Contains vertebrate, fresh water invertebrate fossils and silicified wood.
		TRIASSIC	Wingate ss.	275	Coarse sandstone, irregularly conglomeratic, grey in color. Fragments of petrified wood.
			Unconformity:		Chocolate, red and grey sandstone and alternating red shale. Partially marine to westward.
TRIASSIC		Shinarump	20-60	Chocolate, red and grey sandstone and alternating red shale. Partially marine to westward.	
		Unconformity:		Chocolate, red and grey sandstone and alternating red shale. Partially marine to westward.	
TRIASSIC	Moenkopi	50	Chocolate, red and grey sandstone and alternating red shale. Partially marine to westward.		
	Unconformity:		Chocolate, red and grey sandstone and alternating red shale. Partially marine to westward.		
PALEOZOIC	PERMIAN	De Chelly ss.	825	Reddish cross-bedded sandstone. Composed variable sized grains white and red grains quartz with kaolin. Calcareous and iron cement. Cliff forming.	
		Unconformity:		Reddish cross-bedded sandstone. Composed variable sized grains white and red grains quartz with kaolin. Calcareous and iron cement. Cliff forming.	
PROTERZOIC	PRE-CAMBRIAN	Supai	600 /	Red sandstone and shales, uniformly bedded. Fossil plants.	
		Unconformity:		Massive and bedded grey quartzite. Granite.	

\*No diagnostic fossils discovered. Compiled from various USGS reports by Vincent W. Vandiver, NPS, Santa Fe, N.M.

is absent on the north end of the uplift. It can be observed everywhere in the vicinity of the Monument that the Shinarump conglomerate (Triassic) rests unconformably on the de Chelly sandstones.

#### Pre-Cambrian

The oldest rocks on the Defiance uplift are quartzites, probably pre-Cambrian in age. They occur in Quartzite canyon, northwest of Ft. Defiance. Moenkopi sandy shales overlie the quartzite unconformably but the underlying strata are not exposed. Darton (2) states that the quartzite which occurs along the axis of the Defiance uplift is an old ridge which extends northwest from the Zuni mountain uplift in New Mexico and apparently persisted through a large part of Paleozoic time, since Permian rocks now abut against it. From well records we know that granite forms the core of the Defiance uplift.

#### Permian

##### Supai Formation

The type locality for the Supai formation, which consists of red sandstones and shales, is in Havasu canyon and adjacent portions of Grand Canyon. Here it consists of 100 to 1200 feet of red beds. A well drilled 18 miles southeast of Chinle, on the west flank of the Defiance uplift, encountered granite at 806 feet. In this well which started in the de Chelly sandstone, the Supai red beds were reached at 210 feet. Supai strata may be observed in Canyon de Chelly east of the junction with Monument canyon where the beds are composed of red sandy shales and fine grained sandstones. Supai red beds overlap on granite on the Defiance uplift. Darton (2) observed a short distance west of Ft. Defiance that there is a fairly strong break between the Supai formation and the overlying cross-bedded sandstones. He states that to the northward the distinction is lost somewhat by the development of coarser and lighter beds in the upper part of the Supai; suggesting transition. Fossil plants have been found in this formation three miles west of Ft. Defiance and they have been determined by paleobotanists (1) to be Permian in age.

##### De Chelly Sandstone

Conformably overlying the Supai formation in Canyon de Chelly are the vermilion, highly cross-bedded sandstones, which have been termed the De Chelly sandstones by Gregory (1). Edwin D. McKee, park naturalist at Grand Canyon National Park, has written a very interesting paper (4) on the De Chelly sandstone and its relation to the Coconino and other cross-bedded Permian sandstones of the southern portion of the Colorado plateau. The writer of this paper has taken the liberty to use portions of this reference by McKee.

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CANYON DE CHELLY NATIONAL MONUMENT GEOLOGICAL REPORT (CONT.)

Sandstones comprising the vertical walls of Canyon de Chelly were originally considered to be the equivalent of the Vermilion Cliff or Wingate sandstone of the Mesozoic by early geologists. As above stated they were termed the De Chelly sandstone in 1917 by Gregory and assigned to the Permian due to their stratigraphic position unconformably beneath the Shinarump conglomerate of the Triassic, and conformably above the Supai red beds containing a Permian flora. They have since been considered by Darton (2) and by Baker and Reeside (10) to be a continuation of the Coconino sandstone found to the west and southwest. McKee, in the more recent paper mentioned above, states that the De Chelly sandstones of Canyon de Chelly are a well defined formation composed principally of red cross-bedded sandstones which are different from the Coconino in the type of cross-bedding, variety of grain size, mineral composition and kind of cement. He concludes that the upper De Chelly sandstone and the Coconino sandstone were formed contemporaneously, but under different conditions of deposition and from materials derived from different sources. The source of the Coconino is regarded by McKee (3), in another paper, to be from the south and to have been deposited in the main as dune sands by the winds. The De Chelly was at the same time being formed from sands of a different source, probably from the north, as suggested by the remarkable uniformity of dip in the opposite direction. Most of the De Chelly section contains cross-bedding indicative of wind deposition, however, some portions especially in the upper part are deposited or at least reworked by water, as shown by the non-cross-bedded layers of shaly sand.

McKee finds that where the entire thickness of the De Chelly sandstone is obtained that there appears to be two well defined units separated by some horizontally bedded layers of very fine-grained, red, argillaceous sandstone. Also that by the color, type of cross-bedding and erosional behavior, the upper and lower sandstone members may be readily distinguished, but that in mineral composition they are similar in most places. The upper member generally forms bright red vertical cliffs while the lower member is reddish brown in color and usually weathers into rounded slopes containing many alcoves and cavities. Cross-bedding in the lower member shows dips in nearly every direction, whereas in the upper portion the beds are much longer and the slope is remarkably constant, ranging from southwest to southeast and suggesting that the source of the latter beds must have been from the north.

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CANYON DE CHELLY GEOLOGICAL REPORT (CONT.)

The following section was measured by McKee near the mouth of Monument Canyon:

	Feet
<u>Shinarump Conglomerate</u>	
<u>Unconformity</u>	
<u>De Chelly Sandstone</u>	
1. Sandstone, fine grained, Vermilion red, cliff-forming. Cross-bedded. Composed in vertical section of a series of similar units, each with long, sloping, nearly parallel laminae which curve at their bases tangential to flat-lying, brown, shaly sandstone layers 6" to 3' thick, that separate the units. Twelve to twenty units ranging in thickness from four to eighty feet constitute this member. Sand grains of two sizes . . . . .	.569.5
2. Sandstone, argillaceous. Deep red, very fine-grained, non-cross-bedded, Rests on truncated surface of underlying sandstone. Some traces of sand of type found in upper and lower members . . . . .	36.0
3. Sandstone, fine-grained; Red-brown, weathers to rounded surfaces. Cross-bedded with short curving surfaces forming irregular wedges, truncated at bases. Sand grains of two sizes . . . . .	<u>.219.0</u>
Total . . . . .	624.5 ft.

Red Permian shales and flat-lying beds of sandstone.

Many geologists have observed the formation of arches, alcoves, and caves in the cross-bedded sandstones of the southern part of the Colorado Plateau, and numerous explanations have been offered as to their origin. These features are so constant in some sections that it would almost seem that one could chart a formation by spotting the cliff dwellings on a map, for almost invariably the Pueblo people have utilized these alcoves at one time or another for their settlements. These erosional features have been observed by the writer throughout southern Utah, northern Arizona and southwestern Colorado and it is concluded that they are the result of several factors, the most important of which are the structure and porous nature of the rocks in which they occur. The tangential cross-bedding permits ready access of the surface waters along the angular bedding planes in the porous sandstone. Such waters percolate into the face of the cliff and thus at first small units are weakened as the loose cement is dissolved and the shell-like forms are carried down by gravity.

These processes are repeated over long periods of time, the curved laminae being removed on an increasing larger scale, until the shells have cut back into the cliff to form alcoves large enough to house whole settlements of Pueblo people. The jointing is generally of lesser importance than the tangential cross-bedding in this process although in some instances it is a major factor. For many of the larger alcoves especially in Navajo Canyon, at Mesa Verde, and at Zion Park it is a common occurrence to observe a concentration of surface water at the top of a cliff directly over the alcove, giving a funnel effect, with the result that there is a concentration of water above the cave site. Alcoves and recesses may be observed in all stages of formation. In some cases the shells are so loose that they might seemingly be expected to crash to the floor at any minute, as in the alcoves in Navajo Canyon.

Near the head of the trail leading from the rim of Canyon de Chelly to the White House ruins are some minute erosion forms in the De Chelly sandstone which have been termed as worm borings by some and to the work of the wind by others. It appears that the wind has played only a very minor part in the formation of such features and that they may be attributed to normal processes of surface water carrying away the softer, less resistant, and more poorly cemented material to form the fine holes along the face of the cliff.

### Triassic

#### Moenkopi Formation

This formation consists of chocolate, red and grey sandstone with alternating red shales. The Moenkopi does not occur in the vicinity of the Monument but is mentioned for completeness since it is present on the southern portion of the Defiance uplift. In this section, with the Kaibab limestone absent, the Moenkopi rests directly on De Chelly sandstone, and thins out just north of Ft. Defiance.

#### Shinarump Conglomerate

The Shinarump consists of coarse grey sandstone and conglomerate. It occupies much of the surface over the northern sector of the Defiance uplift and forms a resistant cap as may be noted from contacts along the rim of the canyons within the Monument boundaries. The conglomerate is unconformable with the underlying De Chelly sandstone and that there was a considerable period of erosion in post-De Chelly time and prior to the deposition of the Shinarump is attested from the very irregular contact, with numerous ancient valleys carved in the sandstone, and now filled with Shinarump conglomerate. Fragments of petrified wood are common in the Shinarump.

Chinle Formation

The name Chinle was proposed by Gregory (1) in 1917 to include a group of shales, "marls", thin soft sandstones and conglomerates lying above the Shinarump and below the Wingate formations. This formation although widely distributed in the Colorado Plateau province was named from the type locality in the Chinle valley, immediately west of Canyon de Chelly, where the entire section of 1,182 feet has been measured. The Chinle is usually considered to be the most beautifully colored formation in the Navajo country, certainly it is the most highly colored. These marvelous color effects may be seen in Beautiful Valley along the route north from U. S. Highway 66 to Canyon de Chelly; at Petrified Forest National Monument, east of Holbrook, Arizona; and in the vicinity of Cameron, on U. S. Highway 89, north of Flagstaff, Arizona. The rather pastel tones change with the angle of the sun but they are probably more effective at sunrise and sunset. The sediments are considered to be non-marine and to have been deposited by great shifting streams and in shallow bodies of water. During deposition there were occasional outbursts of volcanic activity in nearby areas with the result that there is considerable volcanic ash in the Chinle and some of the color variations are due to the presence of ash. Fossil vertebrates, fresh-water invertebrates, and quantities of silicified wood have been found in the Chinle which further attest to its non-marine character.

Jurassic (?)

Glen Canyon Group

This group consisting of the Wingate sandstone, Kayenta formation, and the Navajo sandstone contain no diagnostic fossils and are therefore assigned with some question to the Jurassic. They do not occur on the Defiance uplift proper and the details of the formations will therefore be omitted. A ridge of these sandstones form a prominent erosional feature on the west side of the Chinle valley. These massive sandstones are merely a remnant of a much more extensive deposit but rarely fail to attract attention of visitors. It should probably be stated that the uniformly bedded reddish sandstone which separates the Wingate and the Navajo is now called the Kayenta formation. It was formerly known in this area as the Todilto. Zion National Park is carved largely in the Navajo sandstone.

Jurassic

Morrison Formation

Unconformably overlying the Navajo sandstone is the Morrison formation. It is composed of buff, grey and pink sandstones and varies considerably in thickness. It has until recently been largely included in the McElmo formation. Important reptilian remains have been found in

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## CANYON DE CHELLY GEOLOGICAL REPORT (CONT.)

these strata, also non-marine invertebrates and considerable petrified wood. Many complete dinosaur remains have been taken from the Morrison in the vicinity of Dinosaur National Monument in northeastern Utah.

### Cretaceous

Black Mesa to the west of Canyon de Chelly is made up principally of Cretaceous formations, namely, the Dakota sandstone, Mancos shale, and the Mesa Verde group. This is a thick series of grey, yellow, and brown sandstone, and blue-grey or iron grey shale. The strata is drab in appearance and is somewhat monotonous as compared with the highly colored Jurassic and Triassic formations. Coal is mined from Cretaceous rocks on Black Mesa by the Hopis and Navajos. In the Gallup basin, in northwestern New Mexico, there is considerable coal mined for commercial purposes. These strata comprise the section at Mesa Verde National Park, in southwest Colorado, northeast of Canyon de Chelly.

### Quaternary

Recent alluvium, gravels and wind blown sands are in evidence throughout the area.

### Structure

Sedimentary strata are in most instances deposited in a horizontal position. Exceptions to this rule may be found in the walls of Canyon de Chelly where the rocks are cross-bedded and largely eolian in character deposited by the wind. Sediments after deposition are often times uplifted resulting in tilted, folded and broken or faulted strata. Their present attitude, or position, is called the geologic structure and this feature must not be confused with the land surface or the topography of the area since the sub-surface attitude of rocks does not necessarily bear any relationship to the configuration of the earth's surface.

The principal structural feature of the Monument area is, of course, the Defiance uplift. It is an anticline, with axis almost due north and south, extending from near the Santa Fe railroad almost to the Utah line, or a distance of over 100 miles. The structure is 30 miles or more in width. The attitude of the strata on the Defiance uplift are well illustrated by Darton (2) Plate 52, page 148). It will be observed that the last flank is the steeper, is faulted on the southeast, and that the beds then flatten to form the Gallup basin to rise again sharply along the Zuni mountain uplift. To the west, beds forming this flank of the uplift, dip gently at angles of 2° to 4° to form the great Black Mesa Coal Basin.

Structural considerations are important in a study of the Monument area since it is due to the uplift that streams have been given increased

gradient or added power to carve the beautiful canyons of de Chelly, Del Muerto, and Monument as we see them today.

The most detailed study of the structural history of the Navajo country has been made by Gregory (1) and the following is taken from his paper:

"The dates assigned to the several epochs of faulting, folding, and peneplanation during the history of the Plateau province rest on the assumptions that the upwarps trenched by the middle Colorado date from Pliocene, Miocene or late Eocene time. There is reason to believe, however, that the first profound faulting and flexing, which built the horizontal strata into a series of domes and monoclines, occurred at the end of the Cretaceous period....."

"Among the probable events in the Tertiary and Quaternary history of the Navajo country, the following are recorded:

1. A period of widespread folding associated with regional uplift from the Cretaceous sea. The Defiance uplift was one of the major structural features developed during this period, which is believed to date from the Cretaceous-Tertiary interval.

2. A period of erosion, during which the domes and ridges of Cretaceous rock were much reduced in height and a system of subsequent streams was developed. Earliest Tertiary.

3. A second period of differential warping, perhaps associated with regional depression. On the long slopes and on the floors of the basins thus formed the Eocene beds of continental origin were laid down.

4. Post-Eocene uplift.

5. A period of extensive and long-continued erosion, interrupted by intervals of quiescence and uplifts. During this period most of the Tertiary beds were removed, the present plateau blocks were outlined, and erosion surfaces of low relief were developed.

6. A regional uplift that revived the streams of the region and provided favorable conditions for the cutting of Glen Canyon and its many companions.

7. A period of aggradation - the filling of the rock canyons with alluvium in consequence of regional downwarp or climatic change.

8. A period of degradation - the trenching of gravel floors, of canyons, and of alluvial slopes on mountains.

The filling and trenching of the rock-walled canyons are not events of great antiquity and may have been accomplished within the period of

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## CANYON DE CHELLY GEOLOGICAL REPORT (CONT.)

human occupation. The cutting of Canyon de Chelly, and other profound gorges - gigantic pieces of river sculpture - does not demand a long period of geologic time. The conditions for river erosion in this region are so favorable that even a part of Quaternary time is sufficient."

### Water Facilities

Water for the headquarters area is obtained from a well 100 feet deep. A gravel strata at from 46 to 50 supplies 25 gallons per minute with water level in the well at 20 feet from the top. The well is cased with 6" pipe. A three h.p. engine with deep well pump was installed by PWA in 1956 and supplies from ten to fifteen gallons per minute. From the well the water is pumped through a 1½" pipe line to a 5,000 gallon concrete reservoir which is buried on a hill near the Custodian's residence.

The well seems adequate to meet the requirements of present facilities.

### ROADS AND TRAILS

There is at present a low standard road, about eight miles in length, from headquarters along the rim of Canyon de Chelly to the overlook opposite White House ruins. This road should be improved to enable the hurried traveler some knowledge of the Monument, especially for those who do not go into the canyons. Modern cars could not get over this road at the time of my last visit. Parking area near the overlook has been proposed. The roads leading into the canyons all have to be taken with care and preferably under the guidance of the Custodian.

A horse trail has been constructed in recent years to enable visitors to reach White House ruins from the rim of the Canyon. This trail is about 4,000 feet in length, contains several short tunnels to pass vertical ledges, and was treated with bituminous surface in 1936. No other trails are being considered for the present and I do not see that any are needed.

### SIGNS AND MARKERS

This is one of the few Parks and Monuments that I have visited where I hesitate to recommend construction of signs to call attention of the visitors to geologic features. I feel quite sure that with the small number of visitors at Canyon de Chelly the Custodian will be able to handle the situation, at least for the present, and get across to those who seem interested the main geologic facts which I have endeavored to portray in this paper. This is especially true since I understand that a Park Service representative accompanies all parties on trail and canyon trips. A geologic map of at least the northeast portion of Arizona should be exhibited in the office.

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CANYON DE CHELLY GEOLOGICAL REPORT (CONT.)

It is also suggested that the references included in the attached bibliography be obtained for the Monument library. Those by Gregory (1), McKee (3 and 4) and Baker (6) will supply the geologic facts.

BIBLIOGRAPHY FOR CANYON DE CHELLY NATIONAL MONUMENT (Geology)

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