Jurassic stratigraphy of the Navajo country

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synchronously with lower beds of the Morrison in southwestern Colorado.

The Morrison formation was deposited throughout Colorado and eastern Utah. It reaches a featheredge in the Kaiparowits Plateau of south-central Utah, probably as a result of increasing erosion toward the southwest prior to deposition of the Dakota sandstone of Upper Cretaceous age. The northwesterly extent of the Morrison in Utah is not known, but the formation has been reported in the vicinity of Salt Lake City and Salina in central Utah. In eastern Utah and western Colorado, the Morrison may be divided into an upper part and a lower part, but in central Colorado these units cannot be separated. The Salt Wash sandstone member occupies the lower part of the Morrison in eastern Utah and western Colorado. It consists of interstratified fluviatile sandstones and claystones. The orientation of cross-laminae and increase in thickness and coarseness indicate that the source of the Salt Wash lay southwest of south-central Utah, probably in west-central Arizona. Beds equivalent to the Salt Wash were probably deposited in central Colorado, but because of the absence of scour-fill sandstones they cannot be differentiated from the upper part of the Morrison. The upper part of the Salt Wash intertongues and grades into the Recapture shale member of the Morrison formation in southeastern Utah, south of Blanding. The Recapture is extensive in northeastern Arizona and northwestern New Mexico. The Brushy Basin shale member occupies the upper part of the Morrison formation in eastern Utah and western Colorado and consists of the variegated claystones with minor lenticular sandstones, conglomerates and limestones. It is thought to represent combinations of fluviatile and playa deposits and it probably contains large contributions of volcanic ash. These deposits cannot be differentiated from the lower part of the Morrison in central Colorado. The Brushy Basin is similar to the typical Morrison of most of the western interior of the United States. In the Blanding area of southeastern Utah the Westwater Canyon sandstone member of the Morrison intertongues and grades into the lower part of the Brushy Basin member. The Westwater Canyon member is extensive in northeastern Arizona and northwestern New Mexico.

The Winsor formation of central Kane County, southwestern Utah, may occupy the stratigraphic position of part of the San Rafael group and the Morrison formation, or the Morrison formation may have been removed by pre-Dakota erosion in this area.

Lower Cretaceous formations overlie the Morrison in Colorado and most of eastern Utah. In places the Lower Cretaceous beds are difficult to separate from the upper part of the Morrison because of similar lithologic characteristics.

JURASSIC STRATIGRAPHY OF THE NAVAJO COUNTRY*

J. W. Harshbarger, C. A. Repenning, R. L. Jackson **

Introduction

At the request of the office of Indian Affairs, the Ground Water Branch of the United States Geological Survey is making an investigation of the ground-water resources of the Navajo country. It became apparent, early in this investigation, that a study of regional stratigraphic relationships was essential. Certain phases of such a study are now being carried on. This paper is a preliminary report on the Jurassic stratigraphy of the Navajo country.

The Navajo country comprises parts of northeastern Arizona, southeastern Utah and northwestern New Mexico (pl. 1). The Jurassic rocks of the Black Mesa basin and the southwestern part of the San Juan Basin are discussed in this paper.

Intertonguing, lateral gradation and facies changes in the formations considered to be Jurassic and Jurassic (?) obscure the regional correlations. This paper presents only preliminary conclusions as to correlations among the strata.

The nomenclature used in this paper follows closely that recommended by Baker, Dane and Reeside (1936, p. 37; 1947) and Gregory's subdivision (1938, p. 58) of

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the Morrison formation. The Cow Springs sandstone is a new term that has been used as a field name by the writers for several years. This unit is defined later in the paper. Plate 2 shows the physical relationships, including lateral gradation, intertonguing and the sedimentary and erosional pinch outs of several of the formations. The datum plane is the upper boundary of the diagram and corresponds to the erosional unconformity that separates the Jurassic rocks from the overlying rocks of Cretaceous age. The base of the diagram represents the contact between the Wingate sandstone and the underlying Triassic Chinle formation.

STRATIGRAPHY

The contact between the Triassic and Jurassic (?) rocks, on the basis of information at present available, is considered to be at an irregular erosional surface, overlain by a thin granule-pebble conglomerate between Gregory's "A" and "B" members of the Chinle formation at some places and at the base of the Glen Canyon group. This boundary is lower than that commonly drawn at some localities and at these places the Wingate includes the uppermost beds long assigned to the Chinle formation.

Glen Canyon Group

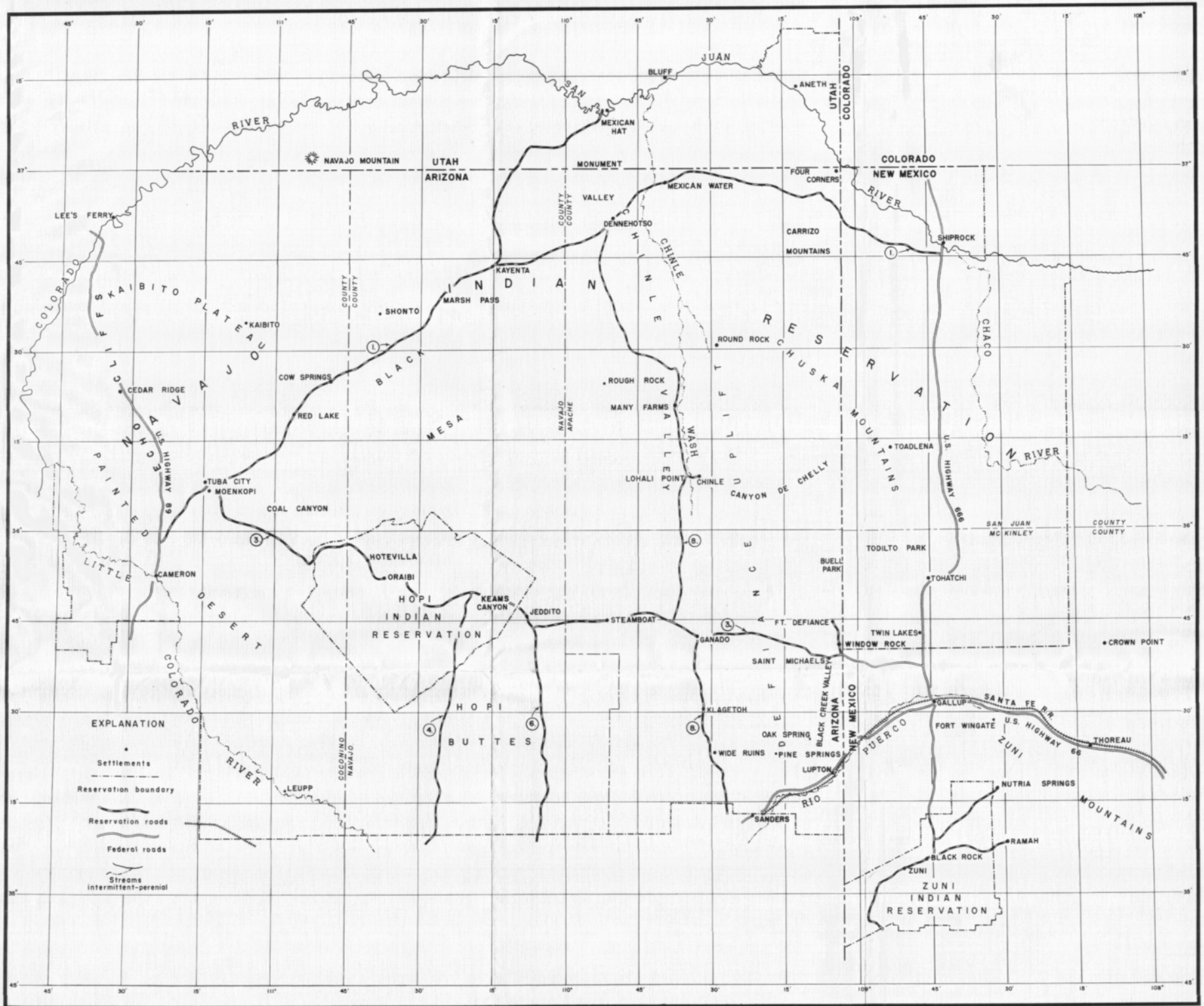
The Glen Canyon group is classed as Jurassic (?) in age (Baker, Dane and Reeside 1936 table 4.) The oldest formation of the group is the Wingate sandstone. In the Navajo country the Wingate comprises two mappable facies. The lower unit, a subaqueous facies, consists of reddish-orange siltstone and sandstone beds which are thinly bedded, are parallel- and cross-stratified and contain minor beds of claystone. The thickness of the lower unit increases southward from 350 feet at Kayenta to 700 feet in the Hopi Buttes country. The unit thins eastward to 195 feet near Lupton, Arizona and pinches out between Lupton and Fort Wingate, N. Mex. The lower unit is correlated by the authors with the "A" member of the Chinle formation as defined by Gregory (1917, p. 42); it is not present at Fort Wingate, New Mexico. The upper unit of the Wingate sandstone is an eolian facies and is the part commonly called Wingate at many localities. It consists of reddish-brown fine-grained sandstone, cross-stratified on a large scale and it commonly forms nearly vertical, massive cliffs. The unit thins southeastward from Kayenta where it is 305 feet thick and pinches out near Lupton, Arizona. Also, it thins eastward from Kayenta and is only 90 feet thick near Thoreau, N. Mex. where it forms low hills below the "Wingate sandstone" as originally defined by Dutton (1885). The Wingate sandstone of present usage exposed along U.S. Highway 66 east of Gallup, N. Mex., consists only of this upper unit. The eolian facies intertongues southward with the subaqueous facies, as seen in exposures at Lukachukai (Hoover, 1950, fig. 1), at Ganado and at Hopi Buttes.

The Kayenta formation, which overlies the Wingate sandstone in the western part of the Navajo country, consists of alternating beds of medium-brown sandstone and siltstone. In general, the lithologic composition of the Kayenta formation is very similar to that of the lower unit of the Wingate sandstone, although to the southwest the Kayenta increases in clay content. At the type locality, Kayenta, Ariz. the formation is about 150 feet thick, but it pinches out approximately 50 miles to the east and southeast. The Kayenta formation thickens to the west and southwest from the type locality and is 349 feet thick near Tuba City, Arizona.

The uppermost formation of the Glen Canyon group is the Navajo sandstone, which is pinkish gray, fine grained and generally cross-stratified on a large scale. The formation is remarkably homogeneous and the lithology changes very little from place to place throughout the Navajo country, which Gregory has designated as the type locality. There is general agreement that this sandstone is mainly a product of eolian sedimentation. The Navajo sandstone is nearly 1,200 feet thick in the northwestern part of the Navajo country. The formation decreases in thickness to the east and is not present in the southeast part of the region(pl. 2).

San Rafael Group

The San Rafael group overlies the Glen Canyon group and in southeastern Utah it contains marine rocks of definite Jurassic age (Baker, Dane and Reeside 1936 p. 58). Nearly everywhere in the Navajo country the boundary between these two groups is an erosional unconformity. The amount of relief shown on the surface of the older formations is usually less than 10 feet and the basal beds of the overlying rocks generally consist, in part, of reworked Navajo sandstone, or of Wingate sandstone where the Navajo and Kayenta are



Base Compiled from Office of Indian Affairs Map 1937

MAP OF NAVAJO COUNTRY

ARIZONA, NEW MEXICO, UTAH, and COLORADO

Scale in miles

0 1 2 4 6 8 10 12

not present. The lowest division of the San Rafael group is the Carmel formation, which in the Navajo country consists of alternating beds of multicolored sandstone, siltstone and claystone. In most places the Carmel contains numerous large mud cracks filled with resistant sandstone. Ripple marks are developed over wide areas. This earthy facies probably represents the southeastward extension of the Carmel basin, and it is considered to be a coastal-plain deposit with intercalated fluviatile deposits. In the northwest part of the area the Carmel formation is about 300 feet thick. The formation decreases in thickness toward the southeast and is believed to pinch out in the vicinity of Nutria Springs and Black Rock. (pl. 1). In the Fort Wingate-Thoreau area a reddish-orange siltstone unit occupies the stratigraphic position of the Carmel formation and forms the lower part of Dutton's type "Wingate sandstone". This unit has been considered equivalent to the Carmel formation (Baker, Dane and Reeside, 1947 p.1666) and is shown on plate 2 as Carmel (?).

The overlying Entrada sandstone is composed of reddish-brown fine-grained sandstone beds and minor beds of siltstone. It contains a heterogeneous mixture of cross- and parallel-stratified sedimentary structures. A study of these structures suggests an environment of alternating subaqueous and subaerial deposition resulting from oscillatory shallow floods over a large plain of low relief. In southeastern Utah the Entrada sandstone is 80 feet thick (Gregory, 1938 p. 75), near Marsh Pass it is 300 feet thick and in the Gallup area it attains a thickness of 240 feet (pl. 2) and forms the upper part of Dutton's type "Wingate sandstone".

The Todilto limestone overlies the Entrada sandstone in the eastern part of the area. It consists of thinly bedded, platy impure limestone and is about 14 feet thick at Todilto Park, the type locality. The authors have not found the Todilto limestone west of the Defiance uplift. In some places, notably in northwestern New Mexico, it is associated with bedded gypsum deposits.

The Summerville formation, the uppermost unit of the San Rafael group, is represented by an assemblage of flat-lying siltstone and claystone beds in the northeastern part of the area. These rocks weather to a characteristic horizontally ribbed outcrop. Toward the south and southwest the formation becomes more arenaceous and grades laterally into the lower part of the massive Cow Springs sandstone (pl. 2). Farther south and southwest near Steamboat, Arizona, Lupton, Arizona and Black Rock, New Mexico a lithologic unit correlative to the Summerville formation cannot separately be recognized.

Cow Springs Sandstone

Several Upper Jurassic units in the area grade laterally southwestward into a distinct sand facies. These include the Summerville formation, the overlying Bluff sandstone member and the Recapture shale member of the Morrison formation. The name Cow Springs sandstone is proposed for this sand unit, which attains optimum development near Cow Springs, Ariz. The type locality is in a cliff along the north face of Black Mesa, four miles east of Cow Springs along Reservation Highway 3. The type section is 1-1/4 miles west of long. 110° 45' and 6 miles south of lat. 36° 30' (see appendix). From a distance the exposure appears as a massive grayish-white rounded cliff about 300 feet high. It consists of greenish-gray to light yellowish-gray fine-grained well-sorted cross-stratified firmly cemented sandstone. The sandstone is composed predominantly of subrounded quartz grains, but grains of magnetite, garnet, tourmaline and staurolite totaling less than one percent are present. The stratification is one of the most distinctive characteristics of this sandstone. The major part consists of large scale asymmetrical festoon and compound types of cross-stratification (McKee, 1948, p.1378). Parallel stratification commonly occurs in zones throughout the section and some such zones can be traced for several miles.

At the type locality the Cow Springs sandstone is 342 feet thick. It is separated from the overlying Dakota sandstone by an erosional unconformity. The underlying Entrada sandstone is distinguishable from the Cow Springs sandstone by differences in grain size, color, sedimentary structures and topographic expression. Southward from the type locality the Cow Springs thins to 112 feet at Coal Canyon and it remains relatively thin eastward into the Hopi Buttes area (pl.1). It is 420 feet thick near Steamboat, Ariz., and decreases in thickness southeastward toward Lupton, Arizona where its thickness is 240 feet. Southward from Lupton in the Black Rock area, the contact between the Cow Springs and the Entrada sandstone becomes practically unidentifiable.

On the basis of measured sections and field observations the Cow Springs sandstone occupies a considerable interval in the stratigraphic section. The lower part of the unit is undoubtedly equivalent to the Summerville formation and the upper part is equivalent to the Bluff and Recapture members of the Morrison formation. The Summerville grades laterally into rocks typical of the lower part of the Cow Springs and intertonguing occurs between the members of the Morrison and the upper part of the Cow Springs. It is believed that the Cow Springs sandstone was laid down as an eolian deposit with intercalated shallow-water deposition, probably a reworking of the eolian sands. Everywhere the term Cow Springs sandstone is used, it is being applied to a homogeneous lithologic unit having distinctive characteristics as described in this paper.

Morrison formation

The Morrison formation overlies the San Rafael group with no apparent unconformity. In the northeastern part of the Navajo country where the Bluff sandstone member of the Morrison formation is present, there is a definite lithologic difference; thus providing a distinct contact. To the south and southwest the contact is not readily discernible. The boundary is usually a gradational zone and the divisions are made on the basis of lithologic differences in gross aspect only.

The Morrison formation, the youngest of the Jurassic units, is represented by four members in the Navajo country. The basal member, the Bluff sandstone member, is composed of a lower unit of light-gray fine-grained sandstone cross-stratified on a large scale, overlain by poorly sorted sandstone beds with lenses of granule conglomerate*. Locally it contains a cliff-forming unit, as at its type locality, Bluff, Utah. This member is present in the northeastern part of the area and pinches out to the south near Toadlena, N. Mex., and to the west in the Marsh Pass locality. The upper unit of the member is considered to be chiefly a fluviatile deposit (Weir, 1951), though the cliff-forming part may be a tongue of the Cow Springs sandstone.

*The authors have been applying a field term "Salt Wash sandstone member" to this upper fluviatile unit.

The overlying Recapture shale member, in the northeastern part of the area, consists of intercalated beds of pink and white claystone, siltstone and weakly cemented argillaceous sandstone. Along the east flank of the Defiance uplift the Recapture shale member grades into a granule-conglomerate facies. Southward from Rough Rock, Ariz., it intertongues with the Cow Springs sandstone phase near Lohali Point, Ariz., and attains maximum intertonguing near Lupton, Ariz., (pl.2). Along the west and south sides of the Navajo country the Recapture loses its identity as a lithologic unit and intertongues with the Cow Springs.

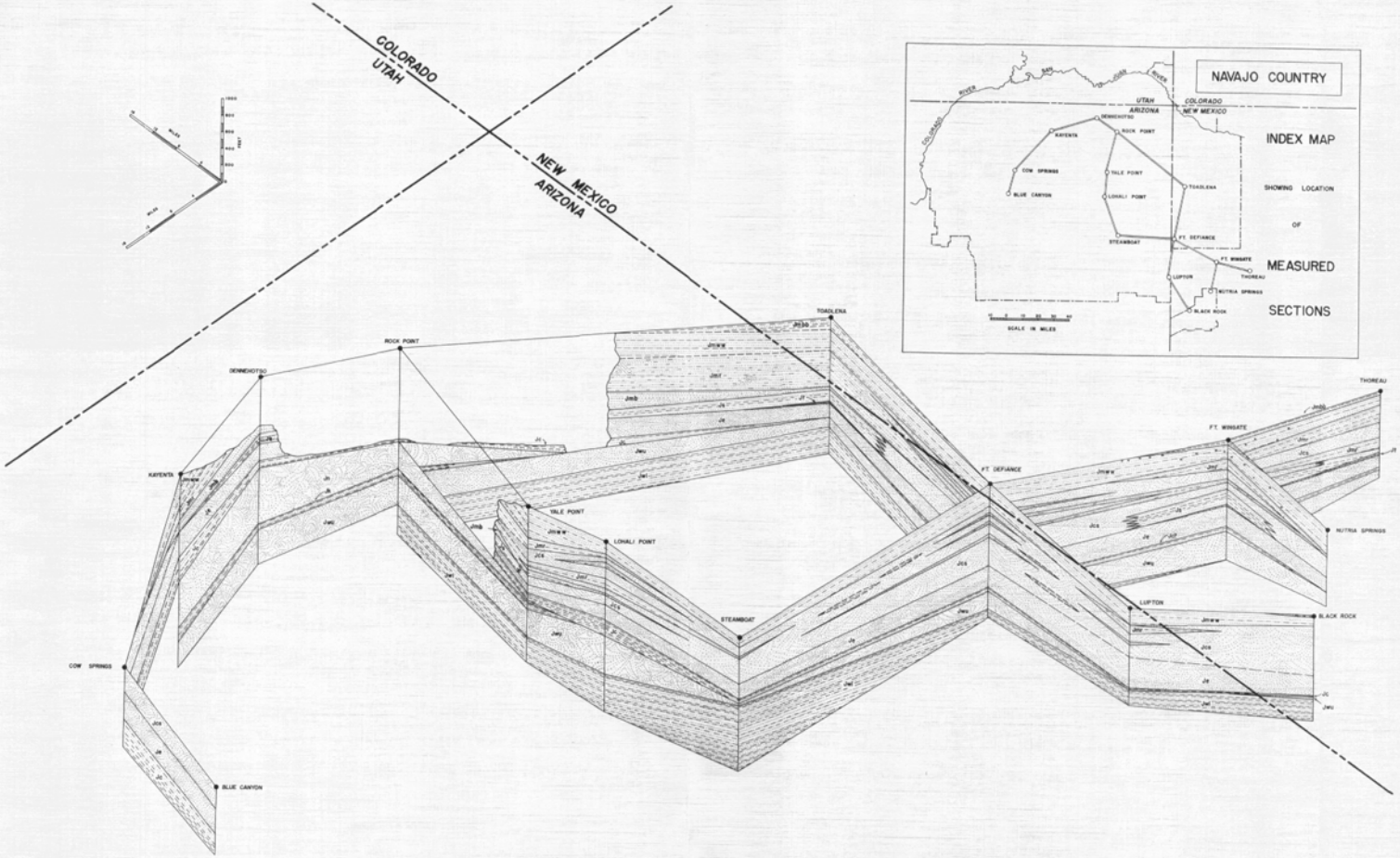
The Westwater Canyon sandstone member lies above the Recapture shale member. This unit consists of yellowish-gray sandstone with conglomeratic lenses and minor dark reddish-brown siltstone and claystone beds. The member is about 155 feet thick at Kayenta, Ariz., but decreases in thickness to the south and is not present in the Hopi Buttes area. This pinch-out is due to pre-Dakota erosion rather than to nondeposition.

The uppermost member of the Morrison formation in the Navajo country is the Brushy Basin shale member. It consists of intercalated green, purple and gray claystone and siltstone beds and a few sandstone lenses. This member is present only in the eastern part of the area (pl. 2). It may originally have extended over an area to the west, but it was apparently removed by erosion during the pre-Dakota erosion interval.

The boundary between the Jurassic and Cretaceous rocks is delineated by an erosional unconformity of moderate to low relief, which cuts across progressively older Jurassic rocks southward and southwestward. The unconformity lies at the base of the Dakota sandstone.

Conclusions

The rocks definitely and tentatively included in the Jurassic of the Navajo country represent a complex environmental history. A better understanding of the lateral gradation and intertonguing of these sedimentary rocks is dependent upon the recognition of contemporaneous eolian and subaqueous environments. The authors believe that, upon the collection of additional detailed data and with the aid of criticism of these preliminary relationships, it will be possible



EXPLANATION

- Jmbb — Brushy Basin shale member
- Jmww — West Water Canyon sandstone member
- Jbr — Recapture shale member (Intertongues with upper part of Cow Springs sandstone)
- Jmb — Bluff sandstone member (Intertongues with upper part of Cow Springs sandstone)
- Js — Summerville formation (Grades laterally into lower part of Cow Springs sandstone)
- Jcs — Cow Springs sandstone
- Jt — Todilto limestone
- Je — Entrada sandstone
- Jc — Carmel formation
- Jn — Navajo sandstone
- Jk — Kayenta formation
- Jwu — Wingate sandstone (Jwu - upper unit; Jwl - lower unit)

Upper Jurassic: Morrison formation; San Rafael group; Glen Canyon group

Jurassic; Jurassic (?)

FENCE DIAGRAM - JURASSIC (?) AND JURASSIC ROCKS - NAVAJO COUNTRY

to arrive at a satisfactory correlation of the Jurassic rocks of the Navajo country and a satisfactory interpretation of their environmental history.

PROBLEMS OF JURASSIC STRATIGRAPHY OF THE COLORADO PLATEAU AND ADJOINING REGIONS.

Clay T. Smith *

Stratigraphic problems in the Jurassic section of the Colorado Plateau and surrounding regions can be grouped into three closely related categories: the first type of problems are those which are concerned with the areal distribution of the various rock units and their correlations. A second type of problem is paleogeographic in nature: the delineation of source areas for the complex sedimentary series which have already been defined and whose distribution is at least partly known. A third type of problem is more detailed; it involves the recognition of facies changes within the units and interpretation of sedimentary environments. Solutions for all these problems have become critical because of the extensive distribution of uranium ore in the Jurassic system. Extensive and continuing revision of correlations and nomenclature has often contributed to confusion and misunderstanding, even among those who are most familiar with the area.

Several facts regarding this rock sequence bear repeating: The section is composed almost entirely of clastic sediments with considerably more than half the accumulation being silt or coarser sized. Cross bedding of all types is the general rule and evenly or parallel bedded sediments comprise a subordinate part of the assemblage. Fossils are so rare as to be essentially non-existent and age assignments are based upon either over-extended lithologic correlations or upon broader relationships with overlying and underlying sediments. Volcanic rocks or intrusive igneous masses which characterize the Jurassic rocks farther west are absent; a considerable proportion of some of the claystone sequences contain ash beds. Mineralogically the sediments are monotonous, and heavy minerals which might be of considerable assistance in correlation are sparse.

The classic three-fold division of the Jurassic rock units on the Colorado Plateau is utilized to illustrate the broad features of the distribution patterns of these rocks. The isopach and facies maps (See Figures 1-4) which are used include little data other than surface sections because of the great difficulty in separating many of the group sequences in well logs. In southwestern Colorado and adjacent parts of Utah, the Dolores formation contains equivalents of both the Chinle formation and the Glen Canyon Group throughout much of its extent. Other units which have variously been included with both the Morrison formation or with parts of the San Rafael Group have been placed where most of the present day workers in the area believe they belong.

McKee (1951, p. 488) has suggested that during Paleozoic time there were two consistently postive areas in Arizona; one occupying roughly the position of the Defiance uplift in northeastern Arizona and the other in southwestern Arizona. The Uncompahgre and Front Range positive elements and the Sierra Grande Arch were also well-defined structural highs in Colorado and New Mexico. By upper Triassic time these positive elements were greatly reduced, particularly the Defiance uplift. The Chinle formation was a very widespread formation accumulating material from multiple sources (See figure 1).

A marked change from earlier time in the distribution of positive areas accompanied the transition to Glen Canyon time; these changes exerted continuing controls over all of Jurassic sedimentation. The Defiance positive element was reduced to the extent that it was no longer effective in controlling sedimentation in the Four Corners area. A new positive element trending slightly north of west began to rise in central Arizona and New Mexico; it apparently restricted Chinle deposition from extending southward. This positive element might be termed the "Navajo Highland" because of its marked and continuing effects on the rocks exposed on the Navajo Reservation. Two things are noteworthy about the Navajo Highland; first, it did not contribute materially to the accumulations of Glen Canyon time, except perhaps to the fluviatile facies of the Wingate formation described by Harshbarger which may have derived some of its material from this area; second, the gradual rise of the Navajo element caused a general westward tilting of the Glen Canyon depositional basin so that its Kayenta and Navajo formations extend only a short distance eastward into New Mexico and the deepest parts of the depositional basin lie several hundred miles to the west of the New Mexico-Arizona state line.

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