



Jurassic stratigraphy of the north flank of the Zuni Mountains

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JURASSIC STRATIGRAPHY OF THE NORTH FLANK OF THE ZUNI MOUNTAINS

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INTRODUCTION

The Zuni Mountains are an asymmetrical anticline which is generally taken as the southern margin of the San Juan Basin. Precambrian rocks are exposed in the central portion of the mass and are overlain by sediments which range in age from Pennsylvanian(?) to Recent. Repeated uplift and subsidence, of both the present mountain block and the surrounding regions, has alternately provided barriers and depositional basins for many formational units. Much of the depositional sequence is non-marine and sparsely fossiliferous, and correlation is difficult. Jurassic sedimentation was strongly influenced by a large positive element (called the Navajo Highland by Smith (1951) and the Mogollon Highland by Harshbarger, Repenning, and Irwin (1957)) which developed in late Triassic time to the south and west of the Zuni Mountains.

Dutton (1885) first described the Jurassic section of the Zuni Mountains from exposures near Fort Wingate, New Mexico, as two units, the Wingate Sandstone below and the Zuni Sandstone above. The Wingate Sandstone included all the beds from the nodular limestone beds of the upper Chinle Formation (Lower Trias of Dutton) to the thin limestone beds overlying the massive red cliffs north of Fort Wingate; the Zuni Sandstone included all the beds from the thin limestone beds at the top of the massive Wingate cliff to the upper Cretaceous Dakota Sandstone capping. The intervening thin limestone beds between the two units were later correlated with the Todilto Limestone by Gregory (1917).

Subsequent work by Baker, Dane, and Reeside (1936, 1947), and Harshbarger, Repenning, and Irwin (1957) has resulted in major revisions of Dutton's original concepts; a marked break in the section separates Dutton's original Wingate Sandstone into two distinct time units, a lower correlative of the Wingate Sandstone of the Glen Canyon section in Arizona, and an upper correlative of the Entrada Sandstone of Utah and Colorado. Harshbarger, Repenning, and Irwin (1957) also demonstrate that the restricted Wingate Sandstone is Triassic in age and has little relation to the overlying Jurassic sediments.

The author wishes to thank Harold L. James of the New Mexico State Highway Dept. for providing the two excellent photographs used in Figures 1 and 2.

STRATIGRAPHY

ENTRADA SANDSTONE

The Entrada Sandstone was named by Gilluly and

Reeside (1928) from exposures in the northern part of the San Rafael Swell in Utah. Eastward from the type locality two facies are recognized: A lower silty sandstone and mudstone unit typical of the exposures of the type locality, and an upper well-sorted, cross-bedded, medium-grained sandstone unit. Harshbarger, Repenning, and Irwin (1957) describe, in the western part of the Navajo Reservation, a lower sandstone facies below the silty sandstone and mudstone of the typical Entrada. Thus, three members of the Entrada have been recognized, the lower sandy member, the medial silty member, and the upper sandy member. Along the north flank of the Zuni Mountains only the medial silty member and the upper sandy member are present (figure 1).

The medial silty member of the Entrada Sandstone is fine-grained, massive (3- to 4-foot beds), mottled red and white, silty sandstone. The red color is chiefly a surficial staining derived from the weathering and leaching of interlayered red siltstone and mudstone partings (3- to 12-inches thick). These thin beds combined with a prominent vertical jointing yield the rectangular weathered blocks with rounded corners to which the name "hoodoo" or "rock baby" has so often been applied. The medial silty member is between 40 and 50 feet thick and is prominently exposed at the base of the massive red cliffs north of U.S. Highway 66 between Grants and Gallup. It rests on the underlying Wingate Sandstone with slight erosional disconformity and a relief of about 6 inches. The contact with the upper sandy member is gradational; often a white bleached zone on the cliff is selected as the top of the medial silty member.

The upper sandy member of the Entrada Sandstone is massive, orange-red to pale buff or white, friable, composite bedded, medium- to coarse-grained, well-sorted sandstone. Two grain sizes occur; the coarser grains are concentrated along the foreset surfaces of the cross-strata sets. In those places where planar cross-stratification sets are replaced by horizontally bedded sets some horizontally bedded strata are ripple laminated in several directions.

The upper 35 feet of the upper sandy member is finer grained, and limy, and locally, near the top of the unit, lenses of sandy limestone 1- to 3-inches thick occur. As the sandy limestone thickens and the interbedded sandstone thins, the Entrada grades into the overlying Todilto Limestone. Elsewhere the limestone beds of the Todilto sharply truncate the cross-stratification of the upper sandy member of the Entrada Sandstone.

The upper sandy member varies in thickness from over 200 feet near Gallup to less than 150 feet east of Grants. It thins rapidly southward and southeastward being absent



FIGURE 1

Exposures of lower part of Jurassic section—slopes at base of cliffs are Triassic Chinle overlain by Lukuchukai Member of the Triassic Wingate Formation. Well-jointed lower part of cliff below the prominent white band is the medial silty member of the Jurassic Entrada Sandstone. Main massive cliff is upper sandy member of the Entrada capped by thin slabby Todilto Limestone.

Photograph by H. L. James

on the south flank of the Zuni Mountains at El Morro and points farther east. The unit is widespread on the Colorado Plateau and is recognized in New Mexico as far east as Tucumcari where it forms the sheer, white cliffs of Tucumcari Mountain.

TODILTO LIMESTONE

The Todilto Limestone was named by Gregory (1917) from exposures in Todilto Park, New Mexico. Similarities to other scattered limestone units throughout the Colorado Plateau region have led to considerable confusion concerning the stratigraphic position of the Todilto. Most workers now concur with the correlation of Baker, Dane and Reeside (1947) making the Todilto equivalent to the lower portion of the Curtis-Summerville sequence in the upper part of the San Rafael Group.

The Todilto Limestone is a very thin- to thin-bedded

(1- to 6-inches) dark-gray, dense, fine-grained rock. In places it contains fish scales, ostracod remains, and other microfossils but it is not abundantly fossiliferous. Alternating light and dark layers which weather to thin slabby plates have been shown by Anderson and Kirkland (1960) to be semi-annual varve-like layers. These are particularly abundant in the lower limy layers of the formation. Lenses of calcareous or gypsiferous sandstone and siltstone are interbedded with the limestone particularly near the base and top of the formation. The Todilto grades upward into the overlying Thoreau Formation as the limestone layers gradually thin and interfinger with siltstone and sandstone lenses. The top of the Todilto Limestone usually is placed at the top of the last continuous limestone layer. The formation ranges in thickness from 7 to 30 feet depending in part upon the selection of basal and top contacts. The north flank of the Zuni Mountains is practically the

southern margin if the Todilto depositional basin and the unit does not extend southward.

THOREAU FORMATION

The Thoreau Formation was named by Smith (1954) from exposures along the north flank of the Zuni Mountains. These beds have been variously interpreted as Summerville Formation, Bluff Sandstone, Cow Springs Sandstone, or several combinations of these units. Facies changes along the north flank of the Zuni Mountains permit local subdivision, but these cannot be recognized elsewhere.

At Fort Wingate and Thoreau, New Mexico, Harshbarger, Repenning, and Irwin (1957) interpret the interval of the Thoreau Sandstone as Summerville below and a tongue of the Cow Springs Sandstone above. Freeman and Hilpert (1956) correlate the upper Thoreau with the Bluff Sandstone of Utah and ignore the facies changes to the south and west which make the extension of such local terminology of doubtful validity.

The lower part of the Thoreau Formation is alternating poorly sorted, thin-bedded, brown, red, and white siltstone and sandstone beds, with thin (1- to 6-inch) mudstone layers near the base; local limestone lenses and limy siltstone mark the gradation between Thoreau Sandstone and the underlying Todilto Limestone. The lower beds of the formation grade upward into well-sorted, medium- to fine-grained sandstone containing sparse siltstone and mudstone inter-beds and partings; cross-stratified sets alternating with horizontally bedded sets are common. The upper contact of the lower member has been placed at the point where cross-stratification becomes predominant; the lower member averages slightly more than 200 feet thick along the north flank of the mountains.

The upper part of the Thoreau Formation consists of sets of medium-grained, poorly sorted, cross-stratified beds from 5 to 11 feet thick alternating with even-bedded sets of similar sandstone from 2 to 5 feet thick. Many of the layers contain abundant red, black, and brown chert fragments; mottled red and greenish staining and local concretionary weathering are common. The total thickness of the Thoreau Formation is slightly less than 400 feet and the upper member is from 185 feet to 200 feet in thickness depending upon where the lower contact is picked.

MORRISON FORMATION

Rocks correlated with the Morrison Formation are well-exposed along the north flank of the Zuni Mountains; farther to the south and east they were either not deposited or have been removed by pre-Dakota(?) erosion. The Morrison Formation originally was defined by Eldridge (Emmons, Cross, and Eldridge, 1896) from rocks near Morrison, Colorado, which have since been shown to include Lower Cretaceous beds. Waldschmidt and Loery (1944) described a new type section, which is much better exposed than the earlier localities, but subdivision into members, so common farther west, is not possible.

In the Colorado Plateau region Craig (Craig et al., 1955) grouped the various units assigned to the Morrison For-

mation into four members showing considerable facies variation, but reasonably consistent throughout. However, considerable confusion still exists, even among U.S. Geological Survey personnel, as to where boundaries between members should be drawn. For example, at Laguna, New Mexico, Craig's (Craig et al., 1955, p. 155, fig. 29) isopach map of the Brushy Basin Member of the Morrison Formation indicates 50 feet of Brushy Basin; Freeman and Hilpert (1956, p. 320-321) report a measured section of the Brushy Basin Member 372.3 feet thick at the same locality. Chenoweth (1953) correlated units of the Morrison Formation between Laguna and Mesa Gigante and concluded that the variegated member (Kelley and Wood 1946) in the Mesa Gigante area which superficially resembled the Brush Basin Member (Gregory, 1938) was actually low in the section and that no Brushy Basin is present in the Laguna-Mesa Gigante area.

Three subdivisions of the Morrison Formation are recognized readily along the north flank of the Zuni Mountains and Harshbarger, Repenning, and Irwin, (1957) distinguish a fourth unit near Fort Wingate. Because of the confusion noted above, local names defined by Smith (1954) are used herein, and a new name is suggested for the rocks previously correlated with the Brushy Basin Member (Smith, 1954).

The lowest member of the Morrison formation is the Chavez Member (Smith, 1954) consisting of alternating greenish siltstone, purplish to reddish, sandy mudstone, and white to buff, coarse-grained, conglomeratic sandstone. The sandstone layers are cross-bedded, exhibiting either planar or trough cross-stratification on a small to medium scale. The sandstone beds are from 3 to 6 feet thick, siltstones from 1 to 3 feet thick, and mudstone intervals from 3 inches to 2 feet thick. Chert and chalky clay (derived from feldspar?) particles are common particularly in the upper part of the member.

The Chavez Member rests disconformably on the Thoreau Formation with local relief of as much as 2 to 5 feet. Individual beds in the Chavez Member vary in thickness and the upper part of the member intertongues with and is scoured by the overlying Prewitt Member (Smith, 1954), so that thicknesses ranging from less than 100 feet to over 200 feet have been measured at various points. The average thickness over most of the north flank of the mountains is between 150 and 200 feet.

Lithologically the Chavez Member resembles the Recapture Member of the Morrison Formation (Gregory, 1938) in exposures northwest of Todilto Park, New Mexico. However, it also is similar to the Salt Wash Member (Lupton, 1914) particularly where the Salt Wash intertongues with the Recapture. The Chavez Member occupies a similar stratigraphic position and may be equivalent to one or both of them wholly or in part. Locally, variations within a unit are greater than variations between units so that correlations based on vague lithologic similarities or relative stratigraphic position are certainly not justified.

The Prewitt Member of the Morrison Formation (Smith, 1954) locally overlies the Chavez Member along a scour surface with as much as 4 to 5 feet of relief. In

other places the two members intertongue and selection of a basal contact for the Prewitt Member is arbitrary. The Prewitt Member is a brown-weathering, massive, coarse-grained, light pinkish-red, conglomeratic sandstone. Tabular or wedge-shaped, planar or trough cross-stratification is common. Poor sorting and coarseness, the occurrence of small (5 millimeter) green mud balls, and the bedding suggest a nearby sedimentary source. Purplish siltstone layers very similar to beds in the underlying Chavez Member occur in the lower and central portions of the exposures. Above the central siltstone layer the sandstone is much coarser with the coarsest material concentrated along the foreset planes of the cross-stratification. The beds average between 175 and 200 feet in thickness.

Part of the stratigraphic interval occupied by the Westwater Canyon Member (Gregory 1938) of the Morrison Formation in southeast Utah probably coincides with the position of the Prewitt Member along the north flank of the Zuni Mountains. However, the nature of the Prewitt sediments suggest a local source and makes exact correlation doubtful.

The uppermost member of the Morrison Formation along the north flank of the Zuni Mountains is herein named the Casamero Member (Table 1). It is the only unit which closely resembles the type Morrison Formation of eastern Colorado. Pre-Dakota(?) erosion has removed recognizable units of the Morrison Formation to the south but the rapid facies changes which occur along the north flank of the Zunis suggest that the limits of deposition could not have been far south of the present southern flank of the mountains.

The boundary between the Casamero Member and the underlying Prewitt Member may be represented by a sharp lithologic break or may be gradational. At the type locality of the member (SW ¼, NW ¼, sec 4, T14N, R12W) the contact is gradational and is placed where the friable, clean, pink-white sandstone of the Prewitt grades into a rusty, yellowish-brown to greenish zone in which clay-size particles are the principal cement, and the average grain size decreases from ½ millimeter to about 1/16 millimeter. The finer-grained portions of the Casamero Member generally are more evenly bedded than the intricate cross bedding patterns exhibited by the Prewitt Member.

The Casamero Member exhibits rapid alternations between very fine-grained sandstone and mudstone and gritty to conglomeratic sandstone and conglomerate. Typically, the lower part of the unit is variegated chocolate- to reddish-brown to green to gray mudstone interbedded with fine sandstone and siltstone. Nodular weathering layers (calcareous cement) less than 6 inches in thickness are occasionally prominent. Individual beds are from 1-3-feet thick although each bed is made up of many laminae of all types, i.e., mudstone, siltstone, fine sandstone.

The upper part of the Casamero is massive, cliff-forming, medium- to coarse-grained (1 millimeter to 1/10 millimeter) poorly sorted, quartz sandstone. The sandstone is intricately cross-bedded in laminae ranging in thickness from 5 millimeters to 5 centimeters; scour and fill type festoon layering is predominant. Near the top of

the upper sandstone the layers are more evenly bedded and the upper 2 to 3 feet is bleached suggesting weathering prior to the deposition of the overlying Dakota(?) Sandstone.

Local conglomeratic lenses with small pebbles of quartzite from 2 millimeters to 10 millimeters in diameter crop out irregularly along the strike and attain thicknesses of as much as 10 feet.

Except for the massive, cliff-forming sandstone at the top of the unit the Casamero Member is characterized by soft, friable outcrops which generally weather to a covered slope between the prominent cliffs of the Prewitt Member below and the Dakota(?) above.

Measured sections of the Casamero Member average

TABLE 1

Lithology of the Casamero Member at the type locality
(SW ¼, NW ¼, Sec. 4, T14N, R12W, NMBM)

Dakota Formation	
	Massive, cliff-forming, buff-brown, arkosic sandstone with carbonaceous fragments; partly conglomeratic and with thin carbonaceous shale partings. Local lenses of coal.
Morrison Formation	
Casamero Member	
Interval	
58'-80'	Massive, cliff-forming, medium- to coarse-grained, (1 millimeter-1/10 millimeter), poorly sorted quartz sandstone. Weathers buff to pale brown, yellowish white to white on fresh surface. Intricately cross-bedded in laminae ranging from 5 millimeters to 5 centimeters in thickness. The basal ten feet is predominately scour and fill festoon layers grading upward into more evenly bedded layers and somewhat finer grained. The upper 2 to 3 feet is bleached white suggesting a weathered zone. The upper surface is scoured but the relief is less than 6 inches.
48'-58'	Covered; slightly variegated greenish gray siltstone and mudstone with a few pinkish layers.
38'-48'	Gritty to pebbly (2 millimeters-10 millimeters) conglomerate; greenish-buff to yellowish-buff weathering gray. Pebbles are mostly quartzite with chalky feldspar grains, arkosic with claystone fragment. Calcareous cement. Conglomerate grades upward into soft, friable, greenish-buff, evenly bedded sandstone (2 centimeters-5 centimeters thick) layers. Sandstone grades upward into greenish-buff siltstone and mudstone.
4'-38'	Variegated chocolate- to reddish brown, green, and gray mudstone; becomes sandy in places and locally nodular zones with calcareous cement; at 20' beds grade into fine-grained sandstone and siltstone; individual layers (1- to 3-feet thick). Upper part of unit is mostly greenish-gray to gray and exhibits less variegation than the lower layers.
0'- 4'	At base rusty yellowish-brown to greenish sandstone with abundant clay cement for 3 inches grading into blue to gray weathering, chocolate brown on fresh surface, medium to fine-grained (½ millimeter to 1/64 millimeter) sandstone with hematite stained clay-size cement. Sandstone is poorly sorted and grades upward into mudstone with increase in the amount of clay-size cement. Basal contact is gradational.
Morrison Formation	
Prewitt Member	
	Massive, coarse- to medium-grained (1 millimeter to ¼ millimeter) poorly sorted, pinkish-white conglomeratic sandstone. Some grains are frosted, although mostly sub-rounded. Intricate cross-bedding in 1 millimeter to 3 millimeter laminae. Some chalky feldspar grains and unit as a whole is slightly arkosic.



FIGURE 2

Sandy facies of Morrison Formation at Kit Carson cave. Rounded pinnacle in foreground and white cliffs in upper right background are Prewitt Member (Jmp). Thin bedded layers at base of pinnacle are Chavez Member (Jmc); massive sandstone in between has been interpreted as a tongue of the Cow Springs Sandstone (Jcs) by Harshbarger, Repenning, and Irwin (1957). Boundaries become less distinct westward and in other outcrops in this area.

Photograph by H. L. James

about 80 feet in thickness, although the member may be quite variable because of variations in the basal contact and the pre-Dakota(?) beveling which has occurred. Locally, the upper contact has less than 6 inches of relief although scour and fill structures can be identified with ease. In other places a few feet of relief may be present, and a regional unconformity exists, although angularity between layers is not visible in individual outcrops.

Interpretations of sections at Fort Wingate, Thoreau, Laguna, and Mesa Redonda have marked discrepancies and inconsistencies. Chenoweth (1953) asserts that the variegated member of the Morrison of Kelley and Wood (1946) is equivalent to the Chavez Member of Smith

(1954) and that most of the higher members of the Morrison Formation have been removed by pre-Dakota(?) erosion in the Mesa Redonda area.

Thick local sandstone lenses make interpretation of the Laguna section difficult, and the three fold subdivision recognizable farther west is not readily apparent. Units containing uranium mineralization such as the Jackpile Sandstone or the Poison Canyon Sandstone are probably higher in the section than the Prewitt Member, although other local sandstone lenses may be essentially equivalent. Outcrop irregularities and pre-Dakota(?) beveling may prevent a final resolution of the problem of equivalence of the various members. (See figure 2)

A total of from 400 to 450 feet of Morrison Formation is exposed in the north flank of the Zuni Mountains. The Morrison thins rapidly southward both from non-deposition and pre-Dakota(?) erosion, and the edge of the Morrison depositional basin probably did not extend any appreciable distance south of the latitude of the present range. The abundance of fluviatile sand and gravel and the lack of fossils other than a few bone fragments suggests a moderately energetic environment of a non-marine nature.

DEPOSITIONAL ENVIRONMENTS

The medial silty member of the Entrada Sandstone is the earliest Jurassic unit along the north flank of the Zuni Mountains. Harshbarger, Repenning, and Irwin (1957) consider this member to be marine although no evidence exists in the Zuni Mountains area for this conclusion. The alternating evenly bedded sands and silts, generally with good sorting, indicate an environment with minor changes in energy and uniform conditions. A shallow marine estuary or restricted bay could fulfill such requirements.

The upper sandy member of the Entrada Sandstone contains beds indicative of eolian, fluvial, and shallow marine environments. A slight rejuvenation of the source area provided more sand and less silt and forced a retreat of the sea allowing sand dunes to be built northward across the underlying medial silty member. Streams flowing northward across the newly exposed area provided additional sand and reworked the dune materials. The final stages of deposition included local undrained depressions where some dessication allowed the deposition of limestone and gypsum.

The Todilto Limestone is remarkably uniform over a very large area and apparently represents a toxic restricted marine basin with sufficient addition of fresh water to prevent complete dessication. The seasonal varves described by Anderson and Kirkland (1960) indicate a long cycle of uniform depositional patterns. The pinch-out of the formation to the south marks the edge of the basin. The variations in thickness apparently reflect relief on the underlying Entrada Sandstone.

A repetition of the spreading of sand dunes and fluvial deposits occurred during the deposition of the Thorcau Formation. The mudstone and siltstone in the lower part of the formation indicate some quiet water deposition, but the upper parts of the deposits are nearly all eolian or torrential fluviatile types. Harshbarger, Repenning and Irwin (1957) suggest that the Curtis-Summerville sequence in southeastern Utah represents a continuous depositional interval during a marine transgression and regression. If the correlations have been correctly inferred the Todilto would represent the transgressive facies and the Thorcau the regressive facies.

The Morrison Formation has long been an environmental problem because of the extent of the fine-grained terrestrial units. On the north flank of the Zuni Mountains the formation is predominately fluviatile and appar-

ently represents deposition on an upland slope without much chance for the accumulation of fine material. Some of the mudstones contain bentonitic clays indicative of volcanic ash deposition although no volcanism has been identified within the outcrop area of the Morrison Formation.

The Prewitt Member accumulated as an alluvial fan partially developed into a bajada. The similarities between the Chavez and the Casamero Members suggest that the Prewitt may represent a slight rejuvenation of the source area to the south or a slight increase in moisture and runoff rather than any marked change in depositional environment. The close of Morrison time saw long-continued erosion and some structural dislocation before the region was submerged by the early upper Cretaceous seas.

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