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TRIASSIC STRATIGRAPHY IN THE STATE LINE REGION OF WEST-CENTRAL NEW MEXICO AND EAST-CENTRAL ARIZONA

By
MAURICE E. COOLEY[1]

The Triassic rocks—Moenkopi, Chinle, and Wingate formations—have been superbly carved by stream and rill action into intricately dissected "painted deserts", badlands, and buttes which outline the valleys of the Little Colorado River, Rio Puerco, and the Zuni River (fig. 1). These units, forming subparallel lines of cuestas and strike valleys, border the Zuni Mountains and the Defiance Plateau and underlie many areas covered by Cenozoic volcanic flows and sedimentary deposits. A general correlation chart of the Triassic rocks in the Arizona-New Mexico region is shown in figure 2.

Unconformity Between Permian and Triassic Rocks

In the State line region the unconformity between Permian and Triassic rocks represents a long period of erosion that lasted from about middle Permian to Lower and perhaps Upper Triassic time. The shortest period of erosion occurred in the Winslow area where the Wupatki member of the Moenkopi formation of Lower Triassic age (Wells, 1947) lies on the Kaibab limestone of Leonard age (McKee, 1938, p. 169-172). Longer periods of erosion are indicated on the Defiance Plateau and in the St. Johns area where the Holbrook member of Lower or Middle(?) Triassic age (Wells, 1947, p. 286) overlies the DeChelly sandstone of Leonard age (Read, 1951, p. 83) and the Kaibab limestone. In the Zuni Mountains the upper Moenkopi(?) sediments of probable Upper Triassic age were deposited on the San Andres limestone which is considered to be of lower Guadalupian age (Newell, and others, 1953, p. 15). The hiatus represented by the unconformity becomes progressively greater eastward across northeastern Arizona and northwestern New Mexico.

Near Winslow the pre-Moenkopi unconformity is essentially a flat surface with a local relief of one to three feet. Here the erosion surface parallels the bedding of the Kaibab limestone with no noticeable angularity, suggesting that only a moderate amount of stripping had occurred before deposition of the Moenkopi formation. To the east in the vicinity of Holbrook, much of the Kaibab may have been stripped because the unconformity is cut partly on the underlying Coconino sandstone. Near St. Johns a karst topography that has a relief of 25 feet was developed on the Kaibab limestone during pre-Moenkopi erosion. The basal sandstone of the Holbrook member of the Moenkopi rests on a zone of rubble breccia derived from the Kaibab. The unconformity is exposed poorly on the Defiance Plateau and, in the northern part, it has been removed by post-Moenkopi erosion. However, in the southern part of the Defiance Plateau near Black Creek the unconformity has a local relief of one or two feet cut on the DeChelly sandstone (Akers, Cooley, and Repenning, 1958, p. 88).

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Pre-Moenkopi erosion in the Zuni Mountains was more vigorous than that which formed the pre-Moenkopi surface in the region to the west. In places, well-defined channels about 50 feet deep were cut through the San Andres limestone and into the Glorieta sandstone. One such channel can be observed a few miles south of Fort Wingate. In the area between Fort Wingate and Grants the upper Moenkopi(?) sediments were deposited on a karst topography developed on the San Andres limestone (Smith, 1954; Cooley, 1957) with channeling subordinate to the formation of karst. The local relief ranges upwards to about 30 feet. Near Bluewater Lake the "lows" filled by siltstone and silty sandstone or rubble breccia have been cemented by impure calcareous and siliceous materials. In one exposure south of Thoreau a silty and sandy deposit, containing petrified logs, appears to have been a cave filling in the karst zone (Cooley, 1959).

Moenkopi formation

The Moenkopi formation of Lower and Middle(?) Triassic age (Wells, 1947, p. 286) was named by Ward (1901, p. 17) for a sequence of brownish-red siltstones and silty sandstones exposed at the mouth of Moenkopi Wash near Cameron, Arizona. McKee (1954, p. 19) has divided the Moenkopi formation in the Little Colorado River area into three members — the Wupatki, Moqui, and Holbrook members. The Holbrook member was previously named the Holbrook sandstone member by Hager (1922, p. 73).

Wupatki member

The Wupatki member can be subdivided into two mappable units — a lower silty slope-forming unit and an upper ledge-forming sandstone. McKee (1954) refers to this sandstone informally, as the "lower massive" sandstone, and indicates that it is an excellent marker bed in the Little Colorado River area.

The lower unit of the Wupatki member in the type area at Wupatki Pueblo is composed of approximately 95 feet of reddish-brown siltstone containing thin beds of silty sandstone. Beds containing abundant ripple marks

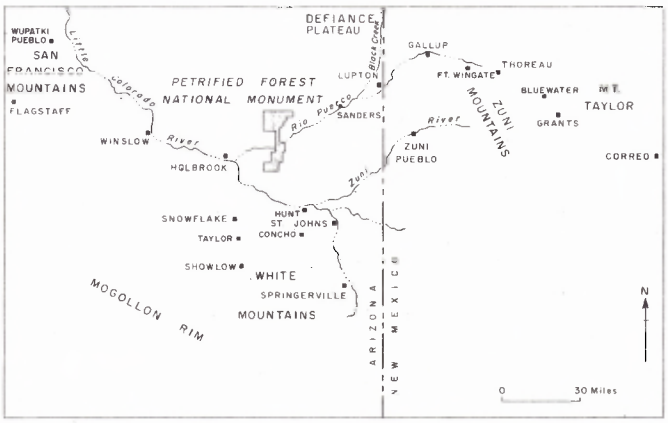

Figure 1. — Index Map

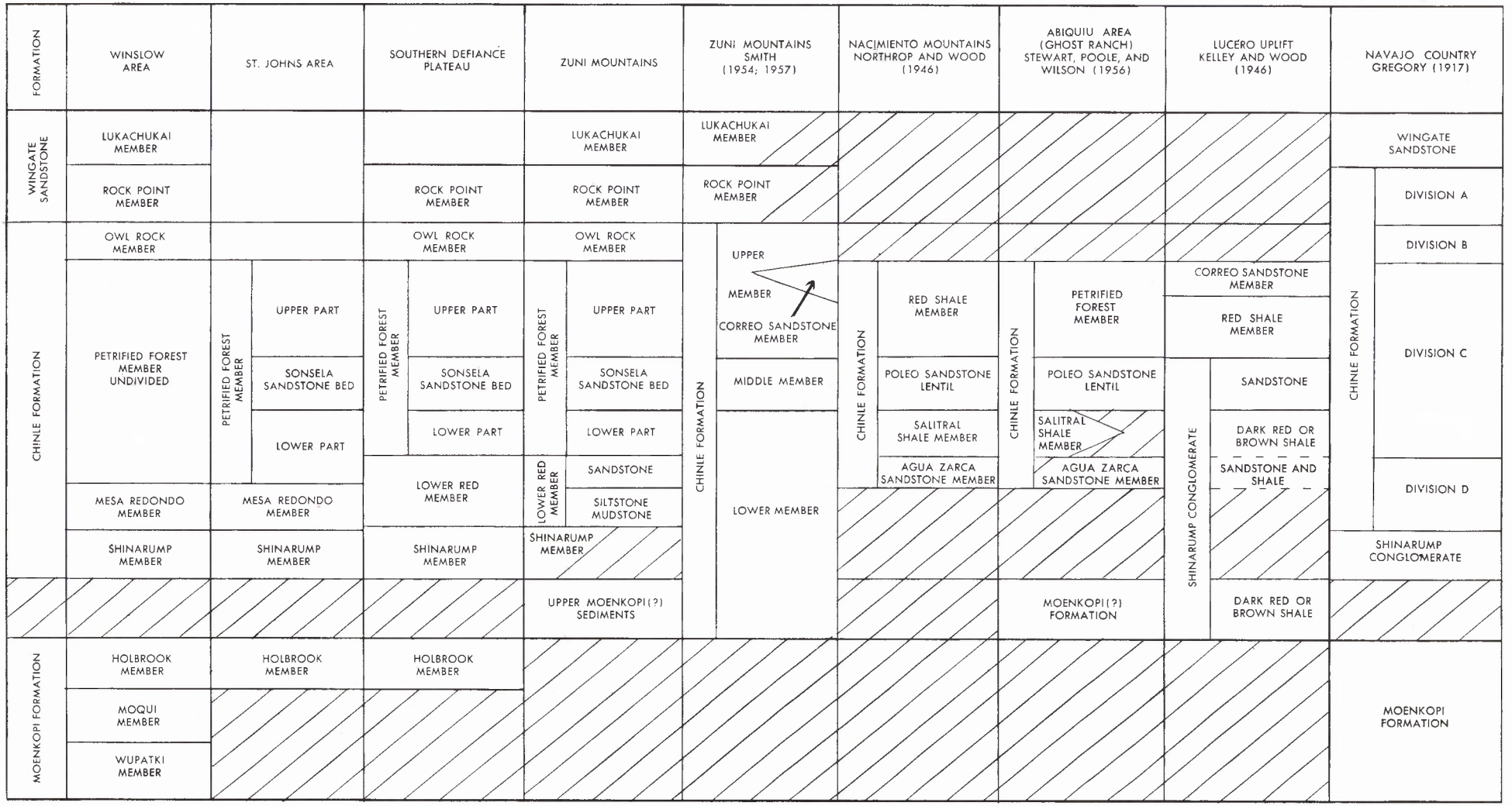

FIG. 2.—CORRELATION CHART OF TRIASSIC ROCKS IN EAST-CENTRAL NEW MEXICO AND WEST-CENTRAL ARIZONA.

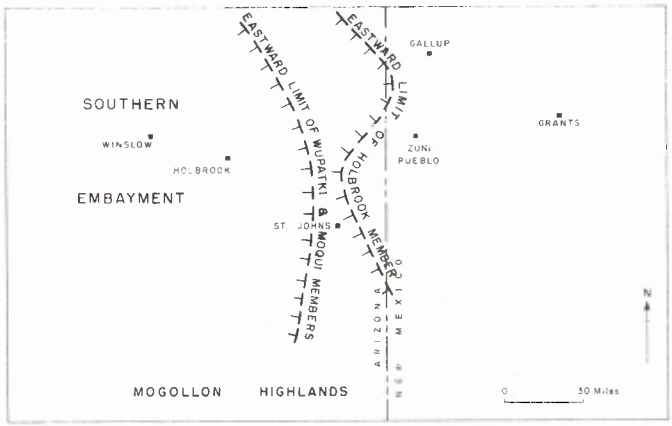

Figure 3. — Distribution of Moenkopi

and a few salt casts are common in this area. The upper sandstone is a light reddish-gray, very fine to fine-grained sandstone locally having minor amounts of silt. The sandstone is about 20 feet thick and is commonly crossbedded with low-angle, small- to medium-scale crossbeds of simple and trough types.

From the type area the lower siltstone unit gradually thins to the southeast. Ten miles west of Winslow, the upper sandstone unit is separated from the base of the Moenkopi formation by less than five feet of siltstone and in the Holbrook area the upper sandstone lies unconformably on the Coconino sandstone and Kaibab limestone. Southeast of Holbrook the Wupatki member is not (fig. 3) exposed on the surface and it cannot be recognized in logs of drilled wells.

Moqui member

The Moqui member is a thin to thick, flat-bedded, lenticular series of pale brown gypsiferous siltstone, mudstone, gypsum, and crossbedded silty sandstones. Eastward and southward from Winslow the gypsiferous beds grade into, or intertongue with siltstone and sandstone units. East and southeast of Holbrook the Moqui member thins and it cannot be recognized on the Defiance Plateau or at St. Johns. The member ranges from 50 to 85 feet in thickness.

Holbrook member

Unless eroded away, the Holbrook member of the Moenkopi is present either at the surface or in the subsurface west of the Arizona-New Mexico State line. It ranges in thickness from 48 feet at Holbrook and 60 feet at St. Johns to about 150 feet near Taylor and as much as 200 feet on the Defiance Plateau. The Holbrook member unconformably overlies the Moqui member.

In the type area at Holbrook the member consists of pale red, thin- to thick-bedded channel deposits of sandstone and some thin-bedded siltstone units. The sandstone is composed of poorly sorted, very fine to medium-grained sand, and it contains considerable silt. The beds are lenticular and wedge shaped and have small- to medium-scale, low- to medium-angle, through-type crossbedding. Lenses of limestone and mudstone pellet conglomerate which grade laterally into sandstone are common in the member.

Near St. Johns the Holbrook member consists of a basal zone of rubble breccia which is an aggregate of blocks derived from the Kaibab limestone with some sandstone deposited in the intervening fractures. Unconformably overlying the rubble is a sandstone, 5 to 20 feet thick, composed of a silty, fine- to coarse-grained sand. The sandstone shows lateral changes from flat thinly bedded layers into large-scale lenticular and tabular very low angle crossbeds. Ripple marks as much as four inches from crest to crest and some pseudo crossbedding are present. Above the sandstone and comprising a rather indefinite zone about 20 feet thick, is a series of very fine to coarse-grained lenticular crossbedded sandstone beds which alternate with flat-bedded mudstone units. The sandstone beds contain a few chert pebbles with maximum diameters of 3/8 inch. The remainder of the member ranges from 30 to 40 feet in thickness and is primarily mudstone with minor amounts of sandstone.

In the area southwest of the Little Colorado River ledge-forming sandstone beds of the Holbrook member are prominent. A large channel, two miles north of Shumway, is about 75 feet thick in the deepest part. It is filled with fine- to medium-grained sandstone containing lenses of coarse-grained sand, all of which are crossbedded with small- to medium-scale low-angle trough and planar types. East of Taylor the member consists of 150 feet of an alternating crossbedded sandstone and silty sandstone sequence. Near Hunt a few quartz-jasper pebbles, about ¼ inch in diameter are scattered in a sandstone bed in the lower part of the Holbrook member.

On the Defiance Plateau the Holbrook member contains a greater proportion of siltstone and mudstone. In this area the member consists of siltstone units, having a maximum thickness of 50 feet, and silty sandstone and sandstone, chiefly very fine to fine-grained, which have thicknesses of less than 15 feet. They are crossbedded with small- to medium-scale trough types of cross-stratification.

Upper Moenkopi(?) sediments

Within the Zuni Mountains are several lithologic units which are not typical of any Triassic units exposed to the west near the Little Colorado River or on the Defiance Plateau. These sediments have been included as part of the Moenkopi formation by past investigators but they are referred to informally in this report as the upper Moenkopi(?) sediments. These sediments occur between the channeled unconformity underlying the Chinle formation and the karst topography eroded on the top of the San Andres limestone. Because of the relationships to these two unconformities, the thickness is very irregular and generally is less than 75 feet, but in several exposures the formation is more than 100 feet thick.

In the Fort Wingate area the upper Moenkopi(?) is divided into a lower slope unit about 75 feet thick and a capping ledge-forming unit 25 feet thick. The slope unit is composed principally of a grayish-red to blackish-red flat-bedded sandy siltstone and silty fine-grained sandstone, but also includes many channels filled with sandstone. The largest of these channels observed is 30 feet deep and about 150 feet wide. The capping unit is a sandstone and conglomerate. The matrix is a fine- to very coarse-grained sand and the gravel consists of pebbles having a maximum diameter of about 3½ inches. The gravel is concentrated in the lower part of the unit. The unit contains medium- to low-angle, small- to large-scale crossbedding of the trough type.

In the area of Bluewater Lake ten miles southeast of Grants the upper Moenkopi(?) consists generally of five units. The lowest unit, comprising a weathered or bleached zone, is a greenish- or yellowish-white, slope-formnig siltstone and mudstone that attains a maximum thickness of 40

feet. The basal part of the lowest unit commonly contains lenticular limestone breccia cemented by chert, and many small beds of conglomerate composed of quartz and jasper pebbles. This grades upward into a reddish-brown slope-forming, thinly flat-bedded, mudstone, siltstone, and silty sandstone, 25 to 40 feet in thickness which constitutes most of the lowest unit. Overlying the lowest unit is a conglomeratic sandstone which varies in thickness from 5 to 15 feet, and lies between 25 and 50 feet above the base of the formation. The matrix is a very fine to medium-grained sandstone. Pebbles, chiefly of rounded quartz and jasper, have a maximum diameter of about two inches. Overlying the conglomeratic sandstone is a reddish-brown slope-forming unit 30 to 50 feet thick; it is lithologically similar to the lower slope-forming unit. The uppermost unit of the upper Moenkopi(?) is ledge-forming, mottled pale yellowish-brown to very pale orange sandstone. It is a very fine to fine-grained sand with minor amounts of medium-grained sand — all of angular clear quartz. The sandstone has low- to medium-angle, medium- to large-scale trough type crossbedding. Locally, the crossbeds grade into channel deposits containing pseudo-crossbedding features, ripple marks, and a few shrinkage cracks. It contains numerous limestone pebbles possibly derived from the San Andres limestone. The lower contact is sharp and irregular with a relief less than three feet.

The upper Moenkopi(?) is composed of sediments somewhat different from those considered typical of the Chinle or Moenkopi formations. These sediments are not related to Chinle deposition because field relationships indicate that the upper Moenkopi(?) underlies the pre-Chinle erosion surface. The upper Moenkopi(?) is believed to be unrelated to the Moenkopi formation in northeastern Arizona for the following reasons: (1) coarse conglomeratic units containing quartz-jasper pebbles are not present within the Holbrook member on the Defiance Plateau, only 25 miles away; (2) limestone conglomerate typical of the Holbrook member in the Holbrook-Defiance Plateau area, is not present in the upper Moenkopi(?) sediments; (3) petrified wood occurs within the upper Moenkopi(?) sediments, but no petrified wood has been reported or described from the Moenkopi formation to the west; (4) if the extensive development of karst topography, the most pronounced in the southern Colorado Plateau, is a time criterion, then the time involved from the cessation of deposition of the Permian limestones to the beginning of deposition of the upper Moenkopi(?) sediments is greater than that for the Holbrook member.

Pre-Chinle unconformity

In the Little Colorado River area, pre-Chinle erosion carved a surface of considerable relief on the top of the Moenkopi formation and the DeChelly sandstone. Buried ridges and hills as high as 200 feet formed the divide areas of the pre-Chinle drainage. Conglomeratic layers of the Shinarump member of the Chinle formation were laid down in the intervening valleys, but in the highland areas finer grained sediments of the lower red and Mesa Redondo members rest on the Moenkopi formation. Channels, ranging from about 15 to more than 50 feet in depth, are superimposed on the larger physiographic features. The valleys, filled with Shinarump member sediments, were fairly large features and are present at Holbrook, about 10 miles northwest of Concho, near St. Johns, and in the Sanders area.

In the Zuni Mountains the pre-Chinle unconformity is not as well exposed as in other parts of the Colorado Plateau. The unconformity has a local relief of over 50 feet and several deep narrow channels have been cut through the underlying upper Moenkopi(?) sediments into the San Andres limestone.

Chinle formation

In the Navajo country Gregory (1917) recognized and described four divisions of the Chinle formation which he called informally, in descending order "divisions A, B, C, and D." Since his time the divisions have been named and are, respectively, the Rock Point member of the Wingate sandstone (Harshbarger, Repenning, and Irwin, 1957), and Owl Rock (Stewart, 1957, p. 458), Petrified Forest (Gregory, 1950), and lower red (Akers, Cooley, and Repenning, 1958) members of the Chinle formation. The Shinarump member assigned by Stewart (1957) to the Chinle formation was first described by Gilbert (1875) in Kane County, Utah. The Mesa Redondo member (Cooley, 1958) lies between the Shinarump and Petrified Forest members in the Winslow-St. Johns area. Contacts of all of the members of the Chinle formation are intertonguing and gradational. Figure 4 (in pocket) is an isometric fence diagram of the Chinle formation showing detailed correlation of the various units of the formation.

Shinarump member

The Shinarump member of the Chinle formation does not form a blanket deposit in the State line region, but occurs as scattered channel-type deposits (fig. 5). The Shinarump varies greatly, both regionally and locally, and ranges from a coarse conglomerate to a sandy siltstone or mudstone with a few lenses of conglomerate sandstone.

The Shinarump member has maximum thickness of 35 feet in the Holbrook-St. Johns area, 75 feet in the southern part of the Defiance Plateau, 60 feet in a water well at Zuni Pueblo, and 25 feet at Fort Wingate. It is a sandstone or conglomerate and is composed of siliceous gravel embedded in a matrix of fine- to very coarse grained sand. Lenticular beds of mudstone are interbedded with the conglomeratic sandstone. Most of the conglomeratic beds have low- to high-angle, medium- to large-scale trough cross bedding. Conglomerate or conglomeratic sandstone is present in all areas except in the Zuni Mountains where the member contains only a few scattered pebbles.

The gravel within the Shinarump consists of subrounded pebbles and cobbles composed of quartzite, quartz, jasper, and chert. Locally, chert or quartzite make up as much as 50 percent of the gravel. In most areas near the Little Colorado River the chert contains Permian(?) invertebrate fossils. The gravel is coarser in the St. Johns and Snowflake areas where cobbles attain a maximum diameter of eight inches.

Mesa Redondo member

The Mesa Redondo member occurs only in the upper Little Colorado River drainage and south of the Defiance Plateau. It has a maximum thickness of 159 feet near St. Johns and thins to the north and northeast to 100 feet at Hunt and about 25 feet on the Sunset Buttes southwest of Winslow. It is not present on the surface east of the Arizona-New Mexico State line, but it is believed to be present in water wells at Zuni Pueblo.

In the St. Johns-Hunt area the member can be divided into upper and lower mudstone-siltstone, slope-forming units which are separated by a conglomeratic sandstone. The mudstone and siltstone units are brownish-gray to

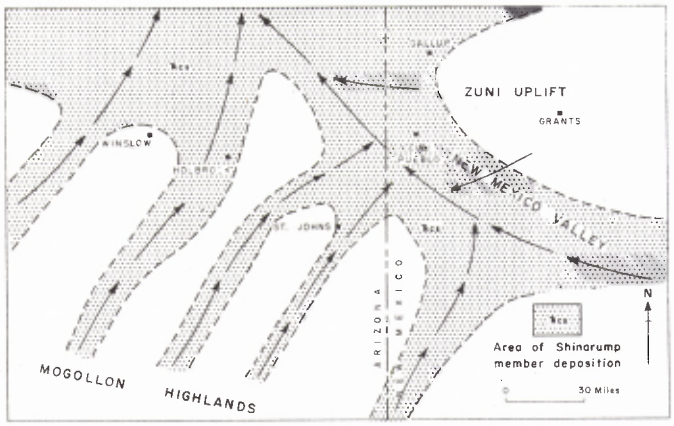

Figure 5. — Drainage map of the Shinarump

grayish red-purple and include some silty very fine-grained sandstone beds. The bedding is flat and lenticular, and individual beds are as much as 15 feet thick.

The conglomeratic sandstone is a mottled pale reddish-purple and pale pink unit that lies unconformably on the lower mudstone-siltstone unit. The surface of unconformity has a relief of 20 feet. The unit has crossbedding of the lenticular and wedge, low- to medium-angle, medium- to large-scale trough types. The gravel is concentrated mostly in the lower part of the unit, and ranges in size to a maximum diameter of six inches. The matrix is very fine to coarse-grained sand with fine and medium grains predominating.

Lower red member

The lower red member is composed of siltstone-mudstone units alternating with tongues of conglomeratic sandstone. The member lies between the conglomeratic Shinarump member and the "muddy" Petrified Forest member. The member is approximately 200 feet thick in the southern Defiance Plateau area and on the northeast flank of the Zuni Mountains. It may be as much as 300 feet thick near Zuni Pueblo as indicated from the log of the Zuni Town No. 1 well. Near the Little Colorado River the member is less than 50 feet thick.

In the Lupton area the lower red member consists of ledge-forming sandstone beds, ranging in thickness from 10 to 40 feet, and slope-forming mudstone-siltstone units, between 20 and 75 feet in thickness. In general four lithologic types are present in the Lupton area. These are: (1) crossbedded sandstones that contain quartz-jasper pebbles less than one inch in size; (2) ripple-laminated, very fine to fine-grained sandstone that contains abundant mica; (3) limestone conglomerate; and (4) mudstone-siltstone units that are flat and lenticular bedded and are composed of material ranging from mudstone to a silty sandstone. The limestone conglomerate grades laterally into the sandstone units and consists principally of limestone pebbles, but it also includes a heterogeneous assortment of sandstone fragments, flattened mudstone pebbles, quartz-jasper pebbles, bone scrap, and teeth of phytosaurs and amphibians.

In the Zuni Mountains the lower red member can be divided into two units which can be traced from Bluewater Lake to Fort Wingate. These units are an upper sandstone that ranges between 25 and 40 feet thick and a lower slope-forming unit that consists of an alternation of lenticular, thick and very thick bedded subunits ranging in composition from claystone to silty sandstone. Near Bluewater Lake the lower slope-forming unit rests on a channeled erosion surface, with some of the deeper channels filled primarily with a grayish-blue very fine grained silty sandstone. The upper sandstone is very fine to fine-grained and has large-scale trough type crossbedding deposited at low angles. Near Fort Wingate the sandstone contains a few quartz pebbles.

Petrified Forest member

The Petrified Forest member is the most widespread of all of the members of the Chinle formation, and within the area is about 1,000 feet thick. The member was subdivided into three units — the upper and lower parts separated by the Sonsela sandstone bed (Akers, Cooley, and Repenning, 1958). These units can be recognized throughout the State line region from Grants to Holbrook. The lower part of the member is thickest in the area between Lupton and Holbrook where it is more than 300 feet thick. It thins progressively southeastward and southward from this area to 125 feet in the eastern part of the Zuni Mountains and about 150 feet near Concho. The upper part is more than 800 feet thick in all areas and the unit thins rapidly in a northwestward direction.

In the valley of the Rio Puerco the lower part of the Petrified Forest member is composed mainly of grayish-blue mudstone with subordinate amounts of tuffaceous siltstone and sandstone. Individual units rarely exceed 20 feet in thickness and generally wedge out laterally within a distance of 100 feet. They are thinly bedded, with very large-scale crossbeds deposited at very low and low-angles and have an overall appearance of being deposited in broad channels. In sandier portions the channels are better defined and contain medium-angle, medium- to large-scale trough type crossbedding. In the finer-grained units much of the bedding is obscured by "puffy" weathering and slumping of the tuffaceous materials. The mudstones are similar in composition throughout the region, but sandstone units and tuffaceous beds are more numerous near the Little Colorado River.

The brownish-red, mudstone-siltstone units of the upper part of the Petrified Forest member are flat and lenticular bedded, with individual beds having thicknesses of more than 50 feet and exceeding a quarter of a mile in length. The upper part contains bedding that is flatter, units that can be traced farther laterally, and fewer well-defined channels than the sediments of the lower part Local variations in the lithology of the upper part occur primarily in the Little Colorado River area. Limestone beds occur throughout the upper part and limestone nodules are locally abundant. Near the Zuni River, 20 miles north of St. Johns, the upper part contains zones approximately 50 feet thick, which are flat bedded and composed of several thin limestone and nodular limestone layers alternating with calcareous mudstone. In the same area the uppermost 300 feet has considerable amounts of very fine and fine-grained silty sandstone. In the confines of the Petrified Forest National Monument a grayish-white tuff bed 30 feet thick and several gypsum beds occur within the mudstone.

Sonsela sandstone bed. The medial grayish-white Sonsela sandstone bed forms a sharp color contrast, as well as a physiographic break between the lower bluish-gray mudstone and the upper reddish-brown mudstone parts. It is a continuous bed in the Defiance Plateau, Gallup-Zuni basin, and Zuni Mountains regions, but in the border areas of deposition near the Little Colorado River, it forms lenti-

cular channel-like deposits. The Sonsela bed in most places lies unconformably on the lower part of the Petrified Forest member with the basal contact having a local relief of 15 feet.

The Sonsela bed is a light-colored, very fine- to very coarse-grained sandstone and conglomeratic sandstone, containing pebbles and small cobbles which range in size up to six inches in the long dimension. The gravel is concentrated along bedding planes and in channels which may constitute as much as 60 percent of the lower portion of the unit. The bedding is irregular and lenticular, with small- to large-scale trough crossbedding and some planar type crossbedding. Mudstone and siltstone layers occur as thin lenses througout the unit. Limestone conglomerates, locally forming "coquina" composed of **Unio** (?), have a maximum thickness of six feet and grade laterally into the sandstone.

The gravels within the Sonsela bed are principally subrounded to well-rounded pebbles composed of silicified limestone, white chert, and dark jasper, with fewer of quartz, quartzite, or pebbles of rhyolite or andesite. Near Thoreau and in parts of the Little Colorado River valley, white chert makes up as much as 75 percent of the gravel. McKee (1938) has listed marine invertebrates found in the chert from the Petrified Forest National Monument as forms from the Kaibab limestone. Cobbles having maximum dimensions of more than five inches occur in gravels in the areas of the National Monument, St. Johns, and near Thoreau. In other areas the average size and total amount of the gravel is less; therefore, it is believed that the areas having larger gravel may represent the arteries of three main northward-flowing streams which deposited most of the Sonsela sandstone bed (fig. 6).

Other sandstone beds of the Petrified Forest member. Three types of lithologies are represented by other sandstone beds within the Petrified Forest member. These are: (1) conglomeratic sandstone, "Rainbow Forest bed"; (2) light-buff fine-grained ripple-laminated sandstone, "Newspaper bed" and the "Amejo bed" (a term used by R. K. DeFord, University of Texas field party); and (3) pale red sandstones, the Taaiylone and Correo(?) sandstone beds.

The Taaiylone sandstone bed occurs in the upper part of the Petrified Forest member at a stratigraphic distance between 150 and 250 feet above the Sonsela bed. This sandstone, actually composed of several lenticular beds, is in general very fine- to medium-grained and has some

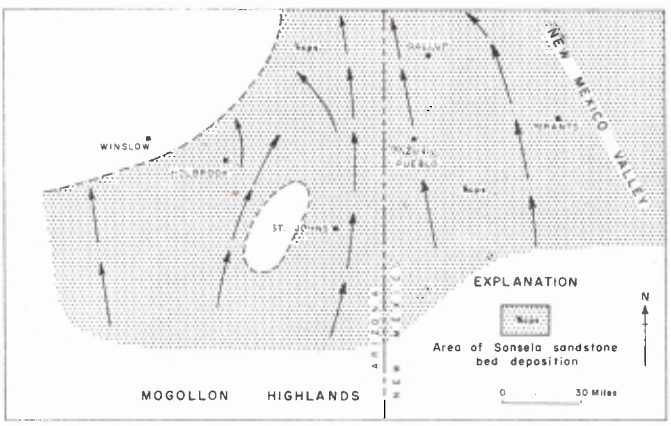

Figure 6. — Drainage Map - Sonsela Bed

brownish-gray limestone conglomerate. The sandstones are crossbedded with lenticular and wedge, low- to medium-angle, and small- to medium-scale trough types and were deposited by north-flowing streams (fig. 7). Some conglomerate composed of quartz, jasper, chert, and limestone pebbles with maximum diameters less than two inches is present near St. Johns.

The Correo(?) sandstone bed lies stratigraphically 364 feet below the top of the Chinle formation at Thoreau. It has a lithology similar to the previously described Taaiylone bed and to the Correo sandstone member of Kelly and Wood (1946) in the Lucero uplift. The bed pinches out to the west and is believed to have been deposited by west-and southwest-flowing streams (fig. 7). Smith (1954, p. 10) suggested a possible correlation of this bed with the Correo sandstone member. A covered area about 40 miles in width separates the Correo (?) bed near Thoreau from the type area of the Correo sandstone member, 30 miles west of Albuquerque. If these two sandstone units are the same then pre-Entrada erosion or the thinning of Upper Triassic units in the type area must account for about 400 feet of Chinle and Wingate sediments.

Owl Rock member

The Owl Rock member is limited to the general area between Lupton and Thoreau, as it has been eroded southwest of Lupton and was not deposited as a mappable unit south of the Zuni River either at Zuni Pueblo or in the St. Johns area (fig. 8). North of Winslow the Owl Rock member is 300 feet thick. At Lupton it is 200 feet thick. It thins to 80 feet at Fort Wingate, and is 50 feet thick at Thoreau.

The member is primarily a pale red calcareous siltstone, and light greenish-gray limestone and nodular limestone. In addition it contains some thin-bedded silty sandstone. Some of the limestone and siltstone contains medium-grained sand, and much of the limestone is siliceous and includes abundant chert.

Stratigraphic relationships

In a possible correlation of the Chinle formation from the Zuni Mountains into central New Mexico there are certain similarities between the various sandstone and mudstone units of both areas. However, a correlation is difficult because of facies changes and because the Chinle between the two areas is concealed by younger rocks. Considering these difficulties the following correlation is tentatively presented (fig. 2). The upper part of the Petrified Forest member is equivalent to the red shale member of Kelly and Wood (1946) and Northrop and Wood (1946) in the Lucero uplift and Nacimiento Mountains areas respectively. This is supported by the thinning of these sediments to the west across New Mexico and Arizona and the fact that the lithologies are similar in all areas. The Sonsela sandstone bed and the Poleo sandstone lentil (Northrop and Wood, 1946) are believed also to be equivalent sandy deposits. Correlative with the Sonsela-Poleo is the upper sandstone unit of the Shinarump conglomerate of Kelly and Wood (1946) in the Lucero uplift, and a grayish-white sandstone bed exposed a few miles north of Puertocito, New Mexico. Regional thinning of the lower part of the Petrified Forest member to the east and to the southwest and the general overlap of younger Chinle units to the east (fig. 4) suggests that the Salitral shale member (Northrop and Wood, 1946) may be generally correlative with the lower part of the Petrified Forest member. On the basis of the regional relationship and the similar lithologies of the Poleo sandstone lentil and the

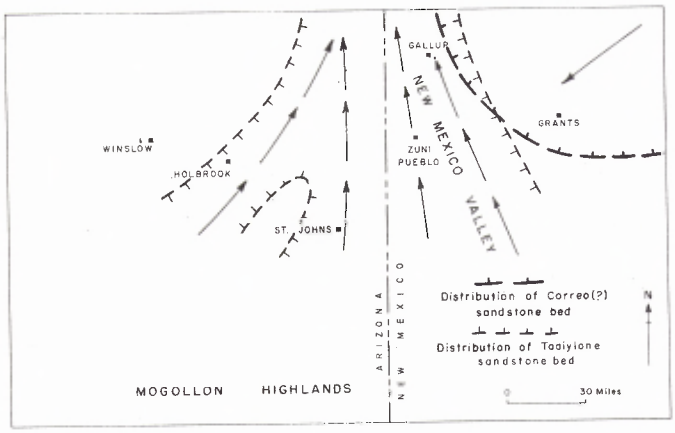

Figure 7. — Drainage Map - Taaiylone - Correo

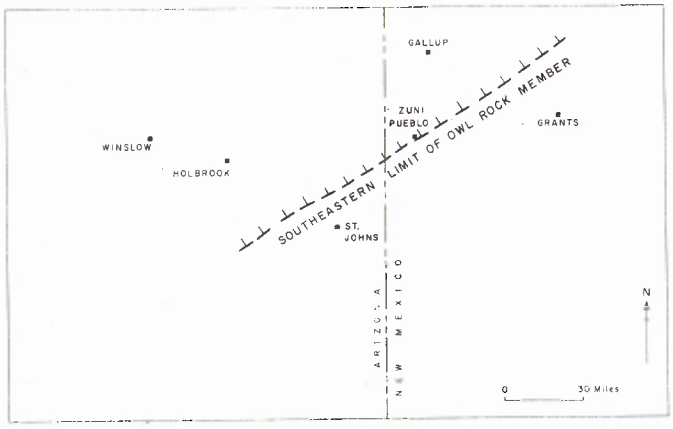

Figure 8. — Owl Rock Distribution

Agua Zarca sandstone member (Northrop and Wood, 1946; Northrop, 1950, p. 35), a possible correlation is indicated between the Agua Zarca sandstone of the Nacimiento Mountains and the lower red member in the Zuni Mountains, perhaps with the upper sandstone unit of the lower red member (fig. 4). This is the only prominent sandstone bed below the Sonsela bed in the Zuni Mountains that could be considered similar in lithology as the Sonsela-Poleo sandstone beds. Intertonguing between the Agua Zarca and Salitral members (Stewart, Poole, and Wilson, 1956) indicates the Agua Zarca should be included with the Chinle formation and that it is not an older Triassic unit. The Shinarump member is believed to be absent east of the Zuni Mountains.

Chinle-Wingate contact

Within much of northeastern Arizona the boundary between the Chinle formation and Wingate sandstone is gradational, but in places intertonguing can be observed. The intertonguing is prominently displayed near Cove, Arizona, between silty sandstones of the Rock Point member of the Wingate and the sediments of the Owl Rock member. In the Chinle Valley area the contact is flat and gradational.

To the south and southeast of Chinle Valley in the Lupton area , Zuni Mountains, and the Zuni Indian Reservation the Chinle-Wingate contact is sharp and in places irregular and channeled. At Zuni Pueblo small channels about 10 feet deep were cut into the Petrified Forest member of the Chinle and filled with thin- to thick-bedded sandstones of the Rock Point member. Small channels filled by granule conglomerate are present at the base of the Lukachukai member near Thoreau. Also, near Thoreau, an exposure of the upper contact of the Owl Rock member shows wedge-shaped shrinkage cracks that taper downward to a depth of five feet. These cracks were formed in a limy siltstone and are filled by fine-grained sandstone and grit from the base of the overlying Lukachukai member.

Wingate sandstone

The Wingate sandstone was named originally by Dutton (1885) for the orange-red cliffs that lie to the north of Fort Wingate, New Mexico, including the sediments between the Todilto limestone and limestone beds (Owl Rock member) of the Chinle formation. The cliff-forming unit was correlated with the Entrada sandstone (Baker, Dane, and Reeside, 1947) and the remaining sediments are now considered to be the Wingate sandstone (Harshbarger, Repenning, and Irwin, 1957).

The Rock Point member is exposed in the southern Defiance Plateau area, in the western part of the Zuni Mountains, near Zuni Pueblo, and it may be present in the Atarque area. It is not present at St. Johns or in the Thoreau area. The member is 950 feet thick in the Hopi Buttes, 800 feet in the northern part of the Defiance Plateau, 200 feet at Lupton, and 100 feet at Fort Wingate. At the type area the Rock Point member is a flat thin-bedded, silty very fine to fine-grained sandstone alternating with slightly thicker sandy siltstone. In the Hopi Buttes sandy siltstone predominates, but some relatively thin sandstone beds are also present. To the south of the Navajo country the member is generally thin- to very thick-bedded sandstone with medium-scale trough type of crossbedding. In the Zuni Indian Reservation some flat-bedded silty sandstone is preserved at the base. In much of the Navajo country the Rock Point member is considered a lucustrine deposit, but to the south the member is chiefly fluvial with a considerable amount of channeling exhibited.

The Lukachukai member is highly crossbedded, well-sorted, and chiefly a fine-grained sandstone of eolian origin. The crossbeds were deposited at high and medium angles and are a very large-scale trough type. The resulant dip directions of the cross-strata is to the southeast (Stewart, Poole, and Wilson, 1957). The Lukachukai member is 300 feet thick in the northern Defiance Plateau area and has a maximum thickness of 355 feet in the Zuni Mountains at Fort Wingate. It is not present elsewhere in the central Arizona-New Mexico State line region.

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