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TRIASSIC ROCKS OF NORTHEAST ARIZONA AND ADJACENT AREAS *

by

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INTRODUCTION

The following description of Triassic rocks is based on work done by the U.S. Geological Survey on behalf of the U.S. Bureau of Indian Affairs in cooperation with the Navajo Tribe.

Triassic rocks are extensively exposed in northeastern Arizona (fig. 1) and consist of in ascending order, the Moenkopi Formation, Chinle Formation and Glen Canyon Group (which is thought to include Jurassic rocks). In the field conference area, Triassic rocks are 1,500-2,500 feet thick (fig. 3A), and are bounded at the base and top by regional unconformities. The unconformity at the base separates Triassic rocks from Lower Permian rocks. The unconformity at the top of the Glen Canyon is marked by chert pebbles in basal beds of the overlying Jurassic rocks. The following description of Triassic rocks is, of necessity, brief with emphasis on new findings, but fuller information may be found in the references cited.

Moenkopi Formation

The Moenkopi Formation pinches out eastward (fig. 3B) in the Four Corners area and is Triassic(?) and Early and Middle(?) Triassic in age. Along Comb Ridge, where U.S. 163 crosses the outcrop, the Moenkopi is about 250 feet thick and consists of interbedded sandstone and siltstone. The reddish-brown siltstone beds are thin and evenly bedded, and the outcrops have a finely ruled appearance. The white and brown sandstone beds are fine to medium-grained and contain abundant ripple marks. The formation is discussed in detail by McKee (1954), Repenning, Cooley and Akers (1969), and Stewart, Poole and Wilson (1972b). The petrology of the Moenkopi Formation is described by Cadigan (1971).

Chinle Formation

Along the route of the field conference, the Chinle Formation consists of several members and other units of lesser rank (fig. 2). The Chinle is as much as 1,200 feet thick in northeast Arizona and is Late Triassic in age. The fossils and nomenclature have recently been summarized by Breed and Breed (1972).

Shinarump Member

The Shinarump Member is very light gray, light tan and brown, and is composed of fluviatile, coarse-grained sandstone, conglomerate and minor mudstone beds. The basal contact on underlying rocks is marked by deep scours and channels as much as 75 feet deep. The Shinarump Member averages 80 feet in thickness but is as much as 200 feet thick in northeast Arizona. In the field conference area the member has an erratic distribution (fig. 3C).

Monitor Butte and Mesa Redondo Members

The Monitor Butte and Mesa Redondo members constitute a sequence of continental deposits of reddish-purple to grayish-red mudstones and siltstones intermixed with lighter colored sandstones and conglomerates resting conformably on the Shinarump Member. The Monitor Butte Member is further characterized by numerous intraformational slumps, folds and faults formed before consolidation. The Monitor Butte Member is as much as 350 feet thick on the Defiance Plateau; only the northern wedge edge of the Mesa Redondo is present in the field conference area (fig. 3C).

Petrified Forest Member

The Petrified Forest Member is as much as 900 feet thick along the route of the field conference. The member is composed of variegated blue, gray, red, brown and purple fluviatile mudstone and siltstone. Montmorillonite of volcanic origin is abundant throughout the member. Over a wide area of northeast Arizona, the Petrified Forest Member is split into upper and lower parts by the Sonsela Sandstone Bed (fig. 2 and 3C).

Owl Rock Member

The Owl Rock Member consists mainly of pink and red shale spotted light greenish gray. The shale is generally silty and calcareous and forms slopes. Interspersed with the shale are several ledge-forming beds of cherty limestone, sandstone and siltstone. Between Bluff and Lupton, the Owl Rock Member ranges in thickness from 166 to 414 feet (fig. 2).

Reddish-orange Siltstone Member and Mule Ear Ledge

Along Comb Ridge, the upper part of the Chinle Formation locally includes the reddish-orange siltstone member overlain by the Mule Ear ledge of local usage. The reddish-orange siltstone member, composed mainly of coarse, silt-size quartz grains, grades southward into the upper part of the Owl Rock Member (fig. 2). The Mule Ear ledge is a reddish-orange, massive, very fine grained sandstone that is commonly stained with a black manganese coating. The ledge is thickest (130 feet) near its southern end.

The reddish-orange siltstone member, together with the Mule Ear ledge, is a southward-extending tongue of a thicker unit that is widespread in southeast Utah, and is assigned to the Church Rock Member (Stewart and others, 1972a, p. 42). The grain-size distribution, clay mineralogy and regional relations show that the reddish-orange siltstone member is unlike the type Church Rock Member in Arizona (O'Sullivan, 1970).

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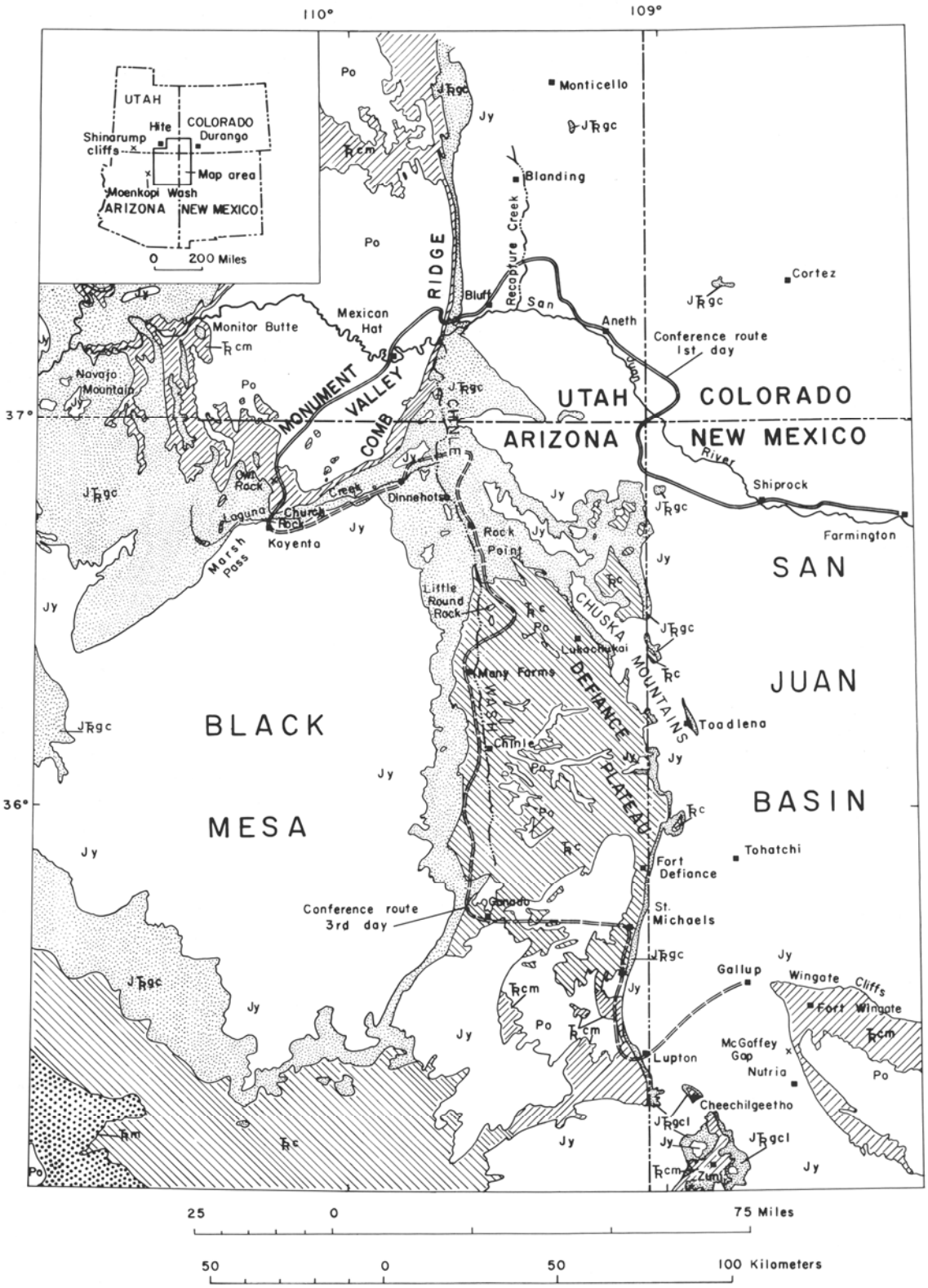

Figure 1.

Map of northeastern Arizona and adjacent areas showing approximate outcrop distribution of Triassic rocks. All intrusive igneous rocks are omitted. The Triassic Dolores Formation, equivalent of the Chinle Formation, is not shown in northeast part of map area. Mapped units and related rocks are: JTRgc, Glen Canyon Group; JTRgcl, "beds at Lupton"; TRc, Chinle Formation; TRm, Moenkopi Formation; TRcm, Chinle and Moenkopi formations; Jy, overlying Jurassic and younger rocks; Po, Permian and older rocks. Compiled in part from Andrews and Hunt (1948); Cooley, Harshbarger, Akers and Hardt (1969); Dane and Bachman (1957); Haynes, Vogel and Wyant (1972); and Wilson, Moore and Cooper (1969). Base from U.S. Geological Survey 1:1,000,000 State base maps.

Hite Bed of the Church Rock Member

The Hite Bed in the uppermost part of the Chinle (Stewart and others, 1972a, p. 43) is about 50 feet thick and is composed mostly of a uniformly pale-red, very fine grained cross-bedded sandstone. Along Comb Ridge, the Hite Bed is split into upper and lower parts by an intervening sequence of reddish-orange siltstone that represents the northward-thinning wedge of the Church Rock Member (fig. 2).

Unconformity at the Base of the Hite Bed

An extensive unconformity is at the base of the Hite Bed throughout wide areas of southeastern Utah and northernmost Arizona. At a point in Utah 8 miles south of the San Juan River the unconformity truncates the Mule Ear ledge and the Hite Bed overlies the Owl Rock Member. From that point to the Utah-Arizona state line the unconformity is characterized by channels as much as 70 feet deep cut into the Owl Rock Member and by pebbles of chert and limestone in the base of the Hite Bed. South of the Utah-Arizona state line for 5 miles the unconformity rests on, or cuts into, (or through) a conspicuous hackly-weathering limestone, which contains nodules of black chert. Farther south the unconformity gradually becomes less conspicuous and the contact between the hackly-weathered cherty limestone and overlying beds is not marked by channeling or conglomerate.

Church Rock Member of the Chinle Formation and Rock Point Member of the Wingate Sandstone

A sequence of siltstone and sandstone at the top of the Chinle Formation is assigned to the Church Rock Member north of Laguna Creek (Witkind and Thaden, 1963, p. 22); south of Laguna Creek the same beds are assigned to the Rock Point Member of the Wingate (Harshbarger and others, 1957, pl. 2). Although two different names are used, there appears to be no dispute about the correlation across Laguna Creek, and the two members are here discussed together.

The Church Rock and Rock Point members consist of reddish-orange and reddish-brown siltstone and very fine grained sandstone that is spotted light greenish gray. Beds in the two members are as much as 20 feet thick and form a series of ledges and slopes. The Church Rock Member is about 250 feet thick and grades northward along Comb Ridge into the Hite Bed (fig. 2). The Rock Point Member thins southeastward from 344 feet at Little Round Rock to 100 feet at Fort Defiance. South of Fort Defiance the Rock Point Member is very poorly exposed and at a locality about 15 miles north of Lupton it appears to be absent and may have been truncated by overlying Jurassic rocks. A line drawn through this locality, roughly parallels to lines of truncation of other Glen Canyon units, shows a questionable eastern limit to the Rock Point Member (fig. 3D).

Lower Contact of Church Rock and Rock Point Members

O'Sullivan (1970) described a conspicuous unconformity at the base of the Hite Bed along Comb Ridge in Utah. Traced into Arizona the unconformity locally underlies the Church Rock Member. On the basis of regional thickness trends, channeling, and conglomerate reported to be at the base of the Church Rock and Rock Point elsewhere in northeast Arizona, O'Sullivan (1970, p. 13-17) concluded that the base of the Church Rock and Rock Point was probably everywhere an unconformity. However, the base of the Rock Point and Church Rock was carefully examined by the writers, accompanied by G. N. Pipiringos, along the line of outcrops from Lupton to Toadlena and Little Round Rock to the southern part of Monument Valley, and the contact at all localities was

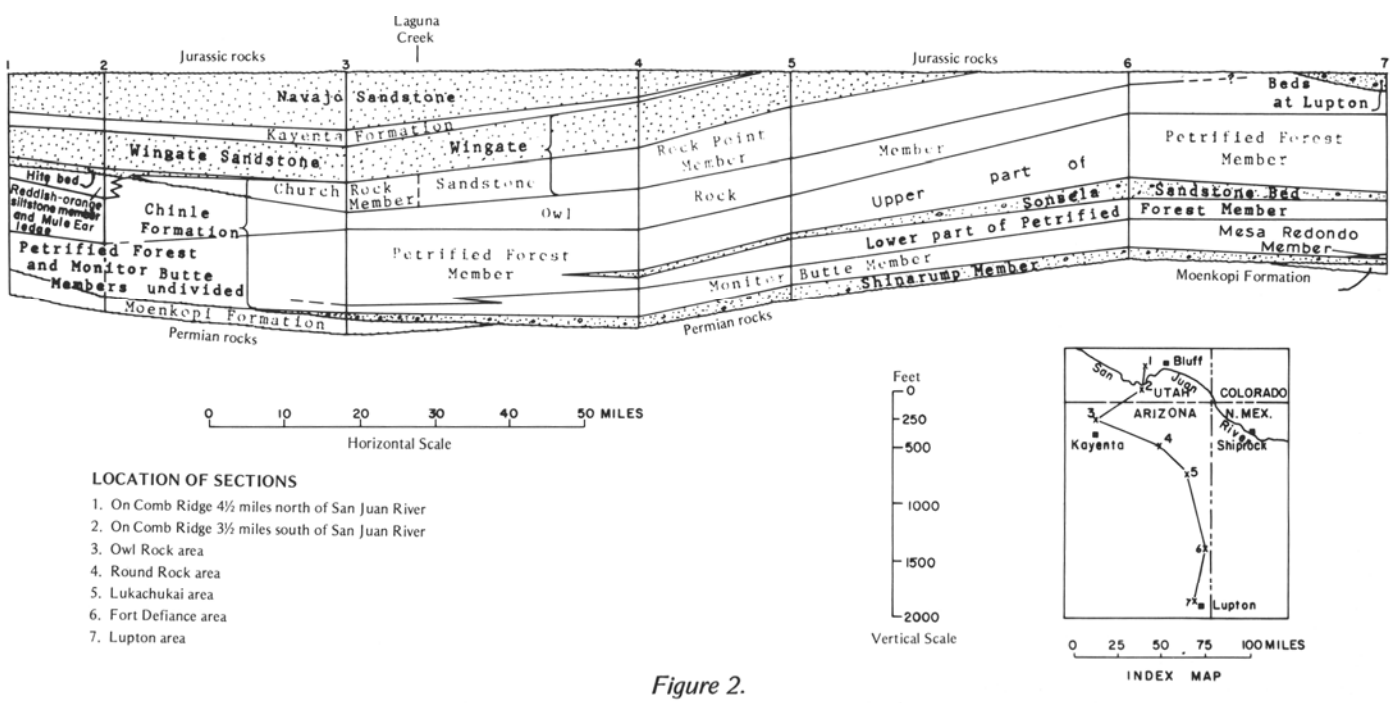

Figure 2.

Stratigraphic diagram showing correlation of Triassic rocks from near Bluff, Utah, to near Lupton, Ariz. In part from Harshbarger, Repenning and Irwin (1957); Repenning, Cooley and Akers (1969); and Sears (1956). Chinle and Moenkopi formations at section 1 measured by L. C. Craig and T. E. Mullens, 1951.

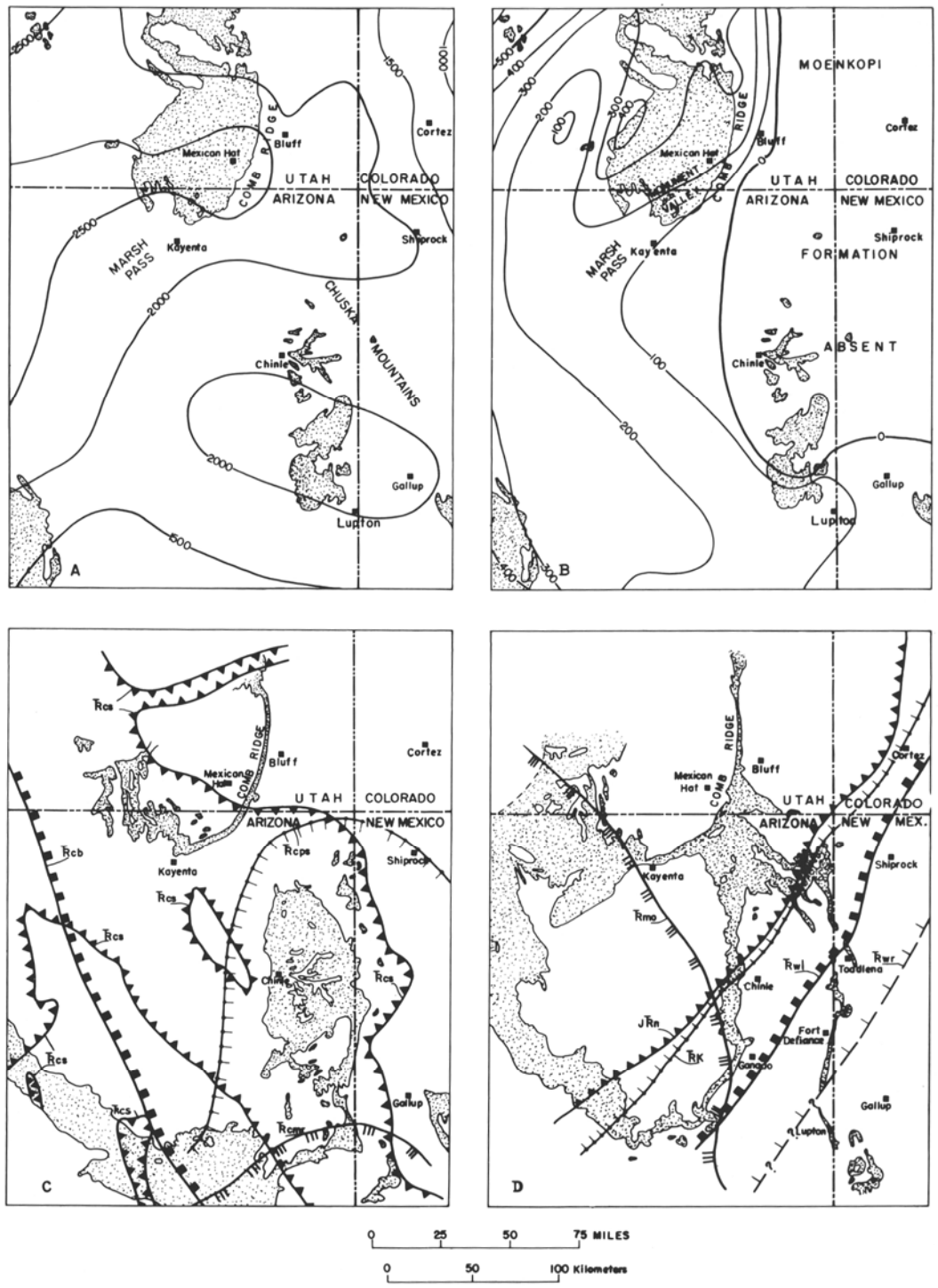

Figure 3.

Maps showing distribution and thickness of some Triassic formations in northeast Arizona and adjacent areas.

A Total thickness of Triassic rocks. Isopach interval 500 feet. Stippling indicates exposure of pre-Triassic rocks. Compiled in part from McKee and others (1956 and 1959).

B Thickness of Moenkopi Formation. Isopach interval 100 feet. Stippling indicates exposures of pre-Triassic rocks. Compiled in part from Stewart, Poole and Wilson (1972b).

C Limits of some units of the Chinle Formation: TRcs, Shinarump Member; TRcb, Monitor Butte Member: TRcmr, Mesa Redondo Member; TRcps, Sonsela Sandstone bed of Petrified Forest Member. Units are present on ornamented sides of lines. Stippling shows approximate outcrop distribution of Chinle Formation. Compiled in part from Stewart, Poole and Wilson (1972a), and Repenning, Cooley and Akers (1969).

D Eastern limit of units of the Glen Canyon Group: JTRn, Navajo Sandstone; TRmo, Moenave Formation; TRk, Kayenta Formation; TRwl, Lukachukai Member of Wingate Sandstone; TRsr, Rock Point Member of Wingate Sandstone. Stippling shows outcrop distribution of Glen Canyon Group. Compiled in part from Harshbarger, Repenning and Irwin (1957).

found to be conformable and to record no break in sedimentation. The base of the Rock Point is marked at places by conglomerate and channeling but these features probably have no regional significance. The unconformity at the base of the Hite Bed along Comb Ridge in Utah terminates gradually southward in Arizona.

GLEN CANYON GROUP

The Glen Canyon Group in northeast Arizona comprises, in ascending order, the Wingate Sandstone, Moenave Formation, Kayenta Formation and Navajo Sandstone. The Glen Canyon Group is Late Triassic, Triassic (?) and Jurassic in age.

Wingate Sandstone

The Wingate Sandstone in northeast Arizona now comprises two members: the lower Rock Point Member discussed previously, and the upper Lukachukai Member (Harshbarger and others, 1957, p. 8). The Lukachukai Member is a rather uniformly moderate-reddish-orange to light-brown, very fine to fine-grained sandstone and is composed of well-sorted subround to round clear and iron-stained quartz grains. Large-scale crossbedding is characteristic.

The Lukachukai Member is present on the west side of the Chuska Mountains to a point 21 miles southeast of Lukachukai. Between there and Lupton it is missing along the outcrop benath the unconformity at the base of the Tertiary rocks that make up the Chuska Mountains, or the unconformity at the base of Jurassic rocks. On the east side of the Chuska Mountains the Lukachukai Member is truncated by Jurassic rocks at a locality 3 miles northwest of Toadlena (Cooley and others, 1969, pl. 1, sheet 7). The Lukachukai Member is also truncated in the subsurface near Shiprock (J. D. Strobell, Jr., oral commun., 1967).

The line of truncation (fig. 3D) connecting the points just described trends northeastward parallel to truncation lines of other units of the Glen Canyon Group. Rocks along the Wingate cliffs just east of Gallup, far southeast of the limits of the Lukachukai as herein used, were identified as the Lukachukai Member by Harshbarger, Repenning and Irwin (1957, p. 8). Recent work by Green (1971), however, suggests that these rocks should be assigned to the Entrada Sandstone.

Basal Contact of the Lukachukai Member

Along Comb Ridge in Utah the basal contact of the Wingate (here consisting only of the Lukachukai Member) generally is sharp and even, but at places it is a wavy surface with less than one-half foot of relief. The base of the Lukachukai was examined by the writers and G. N. Pipiringos at Little Round Rock and at a locality 8 miles to the north. The contact at both localities is as a change from irregularly bedded mudstone of the Rock Point to horizontally bedded, fine-grained sandstone of the Lukachukai Member. The contact is particularly emphasized because uppermost beds of the Rock Point are recessed as much as 3 feet and basal beds of the Lukachukai Member overhang the recess. The contact is further characterized by scattered coarse grains in the basal beds of the Lukachukai Member and by sand wedges extending down into the Rock Point Member. All the features at the contact in the Little Round Rock area and in Monument Valley suggest an uncomformity at the base of the Lukachukai Member. The Lukachukai supposedly intertongues extensively with the Rock Point Member elsewhere in northeast Arizona, particularly in the cliffs east of Lukachukai. Stewart, Poole and Wilson (1972, p. 43) accepted the intertonguing but questioned the degree or amount by stating that "our observations suggest that only a few of the so-called tongues actually merge with the overlying part of the Wingate, and that many may be isolated lenses in the Rock Point Member."

MOENAVE FORMATION

The Moenave Formation consists generally of many lenticular crossbedded sandstone and shale lenses of fluviatile origin. Near Marsh Pass the Moenave cannot be distinguished from the Kayenta Formation. The Moenave Formation thins eastward and is only 47 feet thick near Ganado.

The eastern distribution of the Moenave Formation (fig. 3D) for the most part marks solely the limit of recognition of the formation and trends northwest unlike that of other units of the Glen Canyon Group. The Moenave is truncated by younger beds only in the area west of Ganado.

KAYENTA FORMATION

The Kayenta Formation consists mainly of fine- to coarse-grained sandstone with minor amounts of interbedded siltstone and shale. Viewed from a distance the Kayenta stands out as a zone of thin and irregularly bedded ledges that are pale red tinged with purple. The Kayenta Formation is 100-150 feet thick along Comb Ridge. It thins gradually eastward and is truncated by younger rocks (fig. 3D).

NAVAJO SANDSTONE

The Navajo Sandstone is grayish orange to pale reddish brown. It is composed of very fine to fine-grained, well-sorted, subrounded, generally clear quartz grains. The formation is conspicuously and extensively characterized by high-angle and large-scale crossbeds. Here and there, the upper part of the Navajo Sandstone contains beds of light-gray cherty limestone as much as 3 feet thick.

At Kayenta the Navajo Sandstone is 740 feet thick (Beaumont and Dixon, 1965, p. 8). The Navajo thins to 252 feet at a locality 5 miles southwest of Rock Point. Eastward the Navajo is uncomformably truncated by younder beds (fig. 3D).

The Navajo Sandstone at present is considered to be Jurassic and Triassic(?) in age. Galton described in some detail the fossils from the Navajo Sandstone and related rocks elsewhere and concluded (Galton, 1971, p. 793): "However, on the basis of sound biostratigraphic practice I consider that the Kayenta Formation and most of the Navajo Sandstone should be assigned to the Late Triassic." The Navajo is considered to be partly Jurassic because of reported intertonguing between the Navajo and the overlying Carmel Formation of Middle and Late Jurassic age (Wright and Dickey, 1962). The area of this reported intertonguing has been mapped in great detail by Fred Peterson, who reported (oral commun., 1972) that he found no evidence of intertonguing; instead the Navajo Sandstone is everywhere separated from Jurassic rocks by an unconformity. Until the evidence is documented more fully, however, the age of the Navajo remains Jurassic and Triassic(?).

"Beds at Lupton" of the Glen Canyon Group

A sequence of reddish-brown sandstone beds uncomformably overlies the Chinle Formation and unconformably underlies Jurassic rocks at Lupton and are referred to as the "beds at Lupton." From Lupton to Zuni the "beds at Lupton" are 150-180 feet thick and consist of a lower, ledge-forming sequence and an upper part that tends to weather to a slope. The "beds at Lupton" thin northward from Lupton and may wedge out (fig. 2). The sandstone is both crossbedded and horizontally bedded and contains ripple marks, mud cracks and cobbles of dark-brown siltstone and shale. A wide variety of chert pebbles as much as 3 inches across are present and generally are concentrated in layers that are distributed at several levels within the "beds at Lupton" in the Zuni area. The sharp base of the "beds at Lupton" is an unconformity marked by a scour surface, chert pebbles, wedges of sand that penetrate down into the underlying Chinle and an abrupt change in lithology.

The relationship of the "beds at Lupton" to rocks farther north is not completely understood. The beds have been considered a marginal facies of the Rock Point Member of the Wingate Sandstone (Harshbarger and others, 1957, pl. 2), because they are unlike the reddish-orange siltstone that makes up the typical Rock Point Member. From Lupton southward to Zuni, the "beds at Lupton" rest either on the Owl Rock Member or on the Petrified Forest Member of the Chinle Formation, except at one locality VA miles south of Lupton. At that locality the "beds at Lupton" rest unconformably on 25 feet of reddish-orange siltstone typical of the Rock Point, and the siltstone in turn rests on the Owl Rock. Eastward, in the line of outcrops along the west side of the Zuni Mountains at Nutria and McGaffey Gap, Jurassic beds are underlain by 6-8 feet of gravel that may be a lag concentrate of the pebbles distributed through the "beds at Lupton" to the west. The gravel bed possibly representing the "beds at Lupton" is unconformably underlain by as much as 161 feet of reddish-orange siltstone assigned to the Rock Point Member, and it in turn overlies the Owl Rock Member (Cooley and others, 1964, p. 153-154). In outcrops east of Gallup reddish-orange siltstone is absent and Jurassic rocks with only a few pebbles at the base are underlain unconformably by the Owl Rock Member. If the reddish-orange siltstone at McGaffey Gap, Nutria and at the locality 11/2 miles south of Lupton is Rock Point, then the unconformably overlying "beds at Lupton" are a younger unit and the possible Rock Point line of truncation (fig. 3D) has much different configuration than is shown.

The reddish-orange siltstone is erratically distributed. It is absent in most of the Lupton-Zuni area and east of Gallup, but is more than 160 feet thick in the McGaffey Gap-Nutria area. This erratic distribution may result from local preservation in downwarps. In addition the inverse thickness relations may be significant. At Nutria and McGaffey Gap the reddish-orange siltstone is thick and the "beds at Lupton" (the gravel bed at Nutria) are thin; conversely, in the Lupton-Zuni area the siltstone is thin or absent and the "beds at Lupton" are thick. This inverse thickness relation could be explained by deposition of the thicker "beds at Lupton" in areas where erosion had removed much or all of the reddish-orange siltstone.

It is also possible that the Rock Point Member grades southward into the"beds at Lupton" in much the same manner that the upper part of the Church Rock Member grades northward into the Hite Bed along Comb Ridge (fig. 2). The writers, however, have not been able to establish this relationship in the area north of Lupton, owing to poor exposures. If the "beds at Lupton" are equivalent to the Rock Point, then the underlying reddish-orange siltstone at the locality 11/2 miles south of Lupton, and at Nutria and McGaffey Gap is another, heretofore-unrecognized member of the Chinle Formation.

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