Moenkopi and Chinle Formations of Black Mesa and adjacent areas

J. P Akers, M. E. Cooley, and C. A. Repenning
1958, pp. 88-94. https://doi.org/10.56577/FFC-9.88

in:

Black Mesa Basin (Northeastern Arizona), Anderson, R. Y.; Harshbarger, J. W.; [eds.], New Mexico Geological Society 9th Annual Fall Field Conference Guidebook, 205 p. https://doi.org/10.56577/FFC-9

This page is intentionally left blank to maintain order of facing pages.

MOENKOPI AND CHINLE FORMATIONS OF BLACK MESA AND ADJACENT AREAS[1]

by J. P. AKERS, M. E. COOLEY, and C. A. REPENNING

The varicolored Chinle and Moenkopi formations are exposed over large areas in northeastern Arizona, including Black Mesa basin, the Defiance uplift and Chinle Valley, the peripheral part of the Monument Valley upwarp, and along Echo Cliffs (fig. 1). The total thickness of these Triassic formations ranges from 1,100 feet in the Four Corners area to more than 1,700 feet near the Little Colorado River.

PRE-TRIASSIC UNCONFORMITY

In northeastern Arizona the unconformity at the base of the Moenkopi formation represents a period of erosion which extended throughout late Permian and part of Early Triassic time. The period of erosion was shortest in the Lees Ferry area, where the Lower and Middle (?) Triassic Moenkopi formation lies on the Kaibab limestone of Leonard age. A longer period of erosion is indicated in the vicinity of the Defiance uplift, as the Kaibab limestone is absent and only the youngest part of the Moenkopi formation is present. The Moenkopi formation is absent in the northern part of the Defiance uplift, and the Upper Triassic Chinle formation rests on the DeChelly sandstone. South of the Defiance uplift, the Moenkopi formation and Kaibab limestone extend into the St. Johns area, and in the Zuni Mountains the Moenkopi rests on the San Andres formation. In summary, the hiatus represented by this unconformity becomes progressively greater eastward across northeastern Arizona and northwestern New Mexico.

The lower boundary of the Triassic is not very conspicuous in northeastern Arizona. No angular discordance has been observed in the unconformity; however, local irregularities of relief, caused by small channels, occur in the Lees Ferry area. Also, the development of karst topography in the underlying limestone near St. Johns and in the Zuni Mountains causes a marked relief at the boundary.

Channels as deep as 15 feet have been cut into the underlying Kaibab limestone in the Lees Ferry area. They are filled with reworked angular chert and limestone fragments, ranging from a quarter of an inch to 8 inches in diameter, and numerous partly rounded sandstone boulders up to 3 feet in diameter. Southward from Lees Ferry along Echo Cliffs the lower boundary of the Triassic is marked by a thin zone of greenish-yellow shaly mudstone. Lenses containing limestone pebbles and fragments of angular chert up to 2 inches in diameter occur locally in shallow depressions at the base of the Moenkopi formation along Echo Cliffs and in most of the lower part of the valley of the Little Colorado River. Near Winslow the pre-Moenkopi unconformity is nearly flat, the local relief being only 1 to 3 feet. The erosion surface parallels the bedding of the Kaibab limestone, with no noticeable angularity. To the east, as the Kaibab limestone thins eastward toward the Defiance uplift, the contact appears to be depositional. However, in the vicinity of Holbrook, pre-Moenkopi erosion may have removed a considerable part of the Kaibab limestone, as the unconformity is cut partly on the Coconino sandstone. To the southeast, near St. Johns, the Kaibab limestone is more than 250 feet thick.

Development of a karst topography on the Kaibab limestone near St. Johns accounts for a relief of 20 feet. In this area a medium- to coarse-grained basal sandstone of the Holbrook member of the Moenkopi rests unconformably on 10 to 25 feet of rubble breccia. The rubble is an aggregate of limestone blocks and some sandstone which has been deposited between the blocks and is firmly cemented by calcareous materials.

Where the Moenkopi formation is preserved in the southern part of the Defiance uplift area, the pre-Moenkopi unconformity is largely obscured by colluvium and residual material. However, several good exposures show a relief of 1 or 2 feet at the unconformity near Black Creek. In general, the erosion surface is believed to be less flat in the Defiance uplift area than it is farther west in the Winslow-Holbrook area, as it is formed by many small channels filled by sediments of the Holbrook member. Near Ganado the Moenkopi is absent, and the Shinarump member of the Chinle formation also is absent locally, so that the lower red member of the Chinle overlies Permian rocks.

MOENKOPI FORMATION

The Moenkopi formation, which includes the oldest Triassic strata of northeastern Arizona, is present throughout the area except on the summit of the Kaibab Plateau; it is present also along the southwestern border of the Navajo Indian Reservation, on the central and northern parts of the Defiance uplift, in the Carrizo Mountains, and in parts of Monument Valley. It is of Early and Middle (?) Triassic age.

The Moenkopi formation ranges in thickness from about 500 feet at Lees Ferry to an irregular wedge-edge on the Defiance uplift and in other areas adjacent to the San Juan basin (fig. 2). It ranges in thickness from 300 to 350 feet in the Cameron-Leupp-Hopi Buttes area, from 0 to 200 feet on the Defiance uplift, and from 150 to 250 feet in the area adjacent to the Petrified Forest National Monument.

In the Little Colorado River valley the Moenkopi formation has been subdivided into three members (McKee, 1954): the basal Wupatki member, the medial Moqui member, and the upper Holbrook member. The Wupatki member, exposed along Echo Cliffs and southeast of the Little Colorado River in the Cameron-Leupp area, comprises a lower slope unit of lenticular very thin- and thin-bedded layers of reddish-brown siltstone, sandy siltstone, and silty very fine-grained sandstone. This unit is 475 feet thick near Lees Ferry and 95 feet thick in the type area near Wupatki Pueblo; it thins to the southeast, is less than 5 feet thick in the Winslow-Holbrook area, and is not recognizable southeast of Holbrook. Ripple marks and a few salt casts are characteristic of the silty sandstone beds. The upper unit of the Wupatki member, informally called the "lower massive" sandstone by McKee (1954), is a poor- to fair-sorted silty very fine- to fine-grained sand. It is siltier in the upper part and grades upward into the Moqui member. The sandstone ranges from 20 to 40 feet in thickness and is lenticularly bedded. It is commonly crossbedded with low-angle small- to medium-scale crossbeds of the trough type. The base is sharp and has a relief of 1 or 2 feet, but in places small, narrow channels are exposed.

[1] Publication authorized by the Director, U. S. Geological Survey.

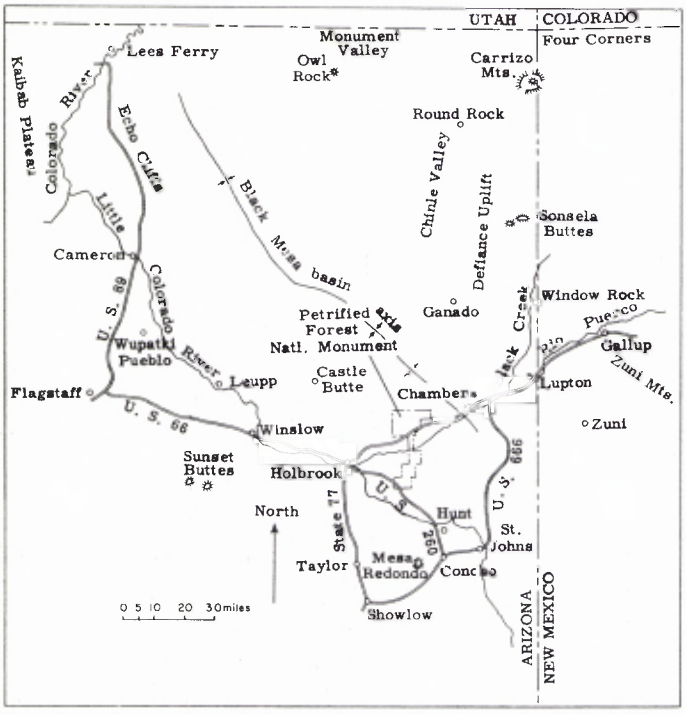

Figure 1.--Index map of Black Mesa basin and adjacent areas.

The Moqui member consists of thin flat-bedded to lenticular pale-brown gypsiferous siltstone and mudstone alternating with thin- and thick-bedded greenish-white gypsum. Lenticular and nodular beds of gypsum ranging in thickness from one-eighth of an inch to 20 feet occur within the Moqui member and may total one-fourth of the member by volume. Eastward and southward from Winslow the gypsiferous beds grade into, or are replaced by, siltstone and silty sandstone units. Many channels within the member are filled by silty sandstone and exhibit large-scale very low- and low-angle crossbeds.

The Moqui member is 55 feet thick at Winslow, 85 feet thick at Holbrook, and about 50 feet thick at Hunt. This variation is due to the definition of the upper contact as the base of the lowest sandstone bed that has a lithology similar to the overlying Holbrook member, rather than to a regional trend in deposition. The Moqui member thins east and southeast from Holbrook and cannot be recognized on the Defiance uplift or southeast of Hunt.

Sandstone beds of the Holbrook member of the Moenkopi formation form an irregular line of bluffs north of the Little Colorado River between Holbrook and Black Falls, or covered slopes on the Defiance uplift. The Holbrook member is present either at the surface or in the subsurface in the Little Colorado River area west of the Arizona-New Mexico State line. The member ranges in thickness from 48 feet at Holbrook to about 160 feet near Taylor and from 100 to 200 feet on the southern part of the Defiance uplift.

In the area southeast of Cameron, the Holbrook member was deposited on a prominent erosion surface. Northwest of Cameron, however, the unconformity is not recognized, as sandstone units of the Holbrook member intertongue with the silty Moqui member. Near the highland areas, such as the Defiance uplift and the Triassic Mogollon highlands, erosion was more severe and the Holbrook member was deposited directly on Permian rocks.

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

MOENKOPI-CHINLE UNCONFORMITY

Because the Moenkopi formation in northeastern Arizona may contain beds as young as Middle(?) Triassic, the hiatus represented by the unconformity between the Moenkopi and the Upper Triassic Chinle formation may be shorter than was formerly supposed. The break in deposition represents a greater time interval to the northeast in the San Juan basin where the Moenkopi formation is absent than it does in most places within the area. The unconformity is represented as far west as the marine sequence of west-central Nevada (Muller and Ferguson, 1939, p. 1594).

In the Black Mesa basin area the pre-Chinle unconformity is marked by a channeled surface of moderate relief. Over most of the area relief of the surface averages about 30 feet; however, in the southern and southeastern part of the area the surface cuts the Moenkopi and Permian strata, and has a gross relief of about 200 feet between the valleys and the divide areas. Superimposed on these broad valleys are local channels averaging about 30 feet deep.

CHINLE FORMATION

In the Navajo country Gregory (1917) recognized four divisions of the Chinle formation which he called informally, in descending order, divisions A, B, C, and D. "Division A," the youngest unit, consists of an "orange-red" silty flat-bedded sandstone that is now named the Rock Point member of the Wingate sandstone (Harshbarger, Repenning, and Irwin, 1957) throughout most of northeastern Arizona and northwestern New Mexico. "Division B," named the Owl Rock member of the Chinle by Stewart (1957, p. 458), is composed of alternating calcareous siltstone and cherty fresh-water limestone. Gregory (1950) renamed "Division C" the Petrified Forest member of the Chinle formation for the Petrified Forest National Monument where the member is well exposed. In the eastern and southeastern parts of the Black Mesa basin area, the Petrified Forest member is subdivided into an upper and a lower part separated by a prominent sandstone bed or group of beds referred to as the Sonsela sandstone bed (fig. 3). "Division D" of Gregory is informally referred to as the lower red member in this paper. This unit forms ledges of silty sandstone and slopes of calcareous mudstone and is transitional between the Petrified Forest and Shinarump members in the eastern part of the Navajo country.

The Shinarump conglomerate was first described by Gilbert (1875) in Kane County, Utah. It is composed chiefly of crossbedded sandstone and conglomerate and interbedded mudstone and siltstone. Stewart (1957) has assigned it, as the Shinarump member, to the Chinle formation.

An additional member of the Chinle formation, the

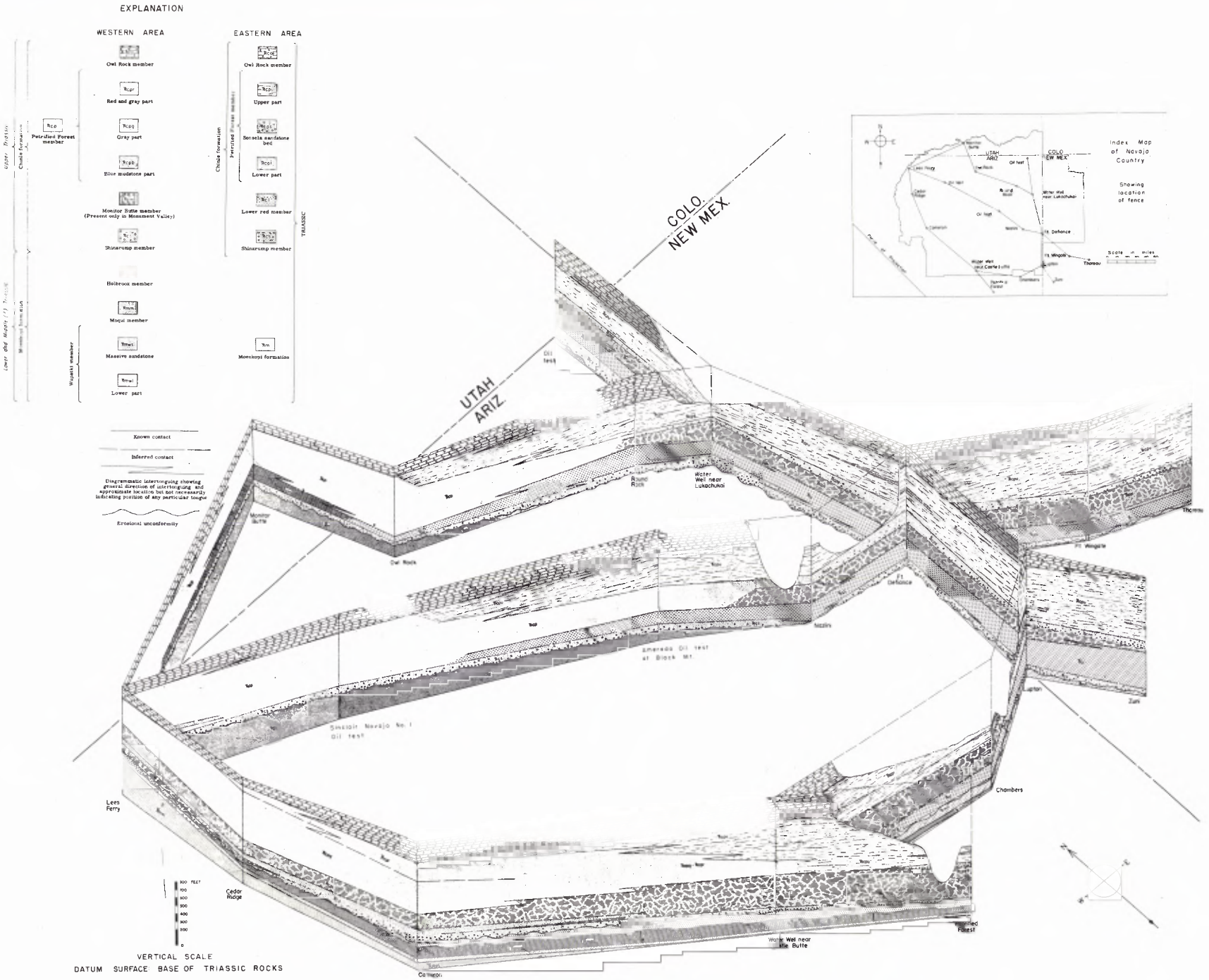

Figure 2.--Fence diagram of the Moenkopi and Chinle formations of Black Mesa basin and adjacent areas.

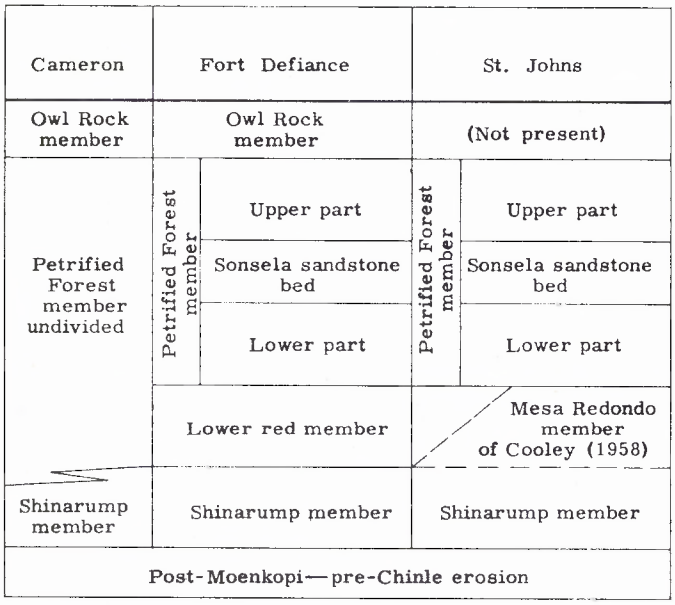

Figure 3.--Chart showing stratigraphy of the Chinle formation in the Black Mesa basin area.

Mesa Redondo member of Cooley (1958), was named for the brownish-red mudstone-siltstone and conglomeratic sandstone south and southeast of the Petrified Forest National Monument. The Mesa Redondo member occurs between the Petrified Forest member or the lower red member and the Shinarump member.

The Chinle formation in Black Mesa basin and adjacent areas thickens southeastward. At Lees Ferry it is 848 feet thick, at well 17T-354 northwest of Ganado it is 1,270 feet thick, and at Zuni it is 1,500 feet thick (fig. 4).

Shinarump Member

The Shinarump member ranges from sandstone to conglomerate and is composed of quartz, jasper, and quartzite particles embedded in a matrix of fine- to very coarse-grained sand. Thin, lenticular beds of mudstone are interbedded with the conglomeratic sandstone. Most beds of the conglomeratic sandstone of the member have low- to high-angle medium- to large-scale trough crossbedding.

The Shinarump member is a blanket deposit in most of the Black Mesa basin area but in the southeastern part it occurs as scattered lenticular channel deposits. It is absent in a small area near Ganado and is locally absent in the area near the Petrified Forest National Monument. In the area south and southwest of the Petrified Forest the Shinarump member occurs only in isolated deposits which rarely attain a thickness of more than 30 feet. Throughout the area the Shinarump member varies greatly in thickness. It has a maximum thickness of 250 feet on the northern and central parts of the Defiance uplift and is 100 feet thick near Chambers, 35 feet at Holbrook, and 30 to 100 feet in the Cameron area.

The Shinarump member grades upward into and intertongues laterally with the lower red and Mesa Redondo members. Work by several persons in the past decade has revealed considerable information indicating that the Shinarump does not always represent one unit; it represents similar units which are stratigraphically in sequence and which, with the overlap of the Chinle formation toward its margins of deposition, consecutively form the basal conglomeratic unit of the Chinle (Stewart, 1957).

Mesa Redondo Member

The Mesa Redondo member (Cooley 1958) of the Chinle formation occurs in the southern part of the Black Mesa basin area. It has a maximum thickness, near St. Johns, of 159 feet. It thins to the north and northwest, having a thickness of about 100 feet near Hunt and less than 50 feet in exposures on the Sunset Buttes southwest of Winslow. The Mesa Redondo member intertongues with the Shinarump member and underlies and intertongues with the lower red and Petrified Forest members.

The Mesa Redondo member in the Hunt-St. Johns area generally consists of lower and upper mudstone and siltstone slope-forming units separated by a conglomeratic sandstone. The mudstone and siltstone units are brownish gray and grayish red purple and contain some silty very fine-grained sandstone. The bedding is flat to lenticular, individual beds having maximum thicknesses of 15 feet. The silty sandstone layers are less than 2 feet thick.

The medial ledge-forming unit, a mottled pale-red-purple and pale-pink conglomerate and sandstone, lies unconformably on the lower mudstone and siltstone. The unit is made up of channel-type deposits which have crossbedding of the lenticular and the wedge, low- to medium-angle, medium- to large-scale trough types. The lower contact has a local relief of 20 feet. The conglomerate is concentrated chiefly in the lower part of the unit. The matrix ranges from very fine- to coarse-grained sand, fine to medium grains predominating. The pebbles range mostly from five-eighths inch to an inch, and a few cobbles have a maximum diameter of 6 inches. The conglomerate and sandstone grade upward into the upper mudstone and siltstone unit.

Lower Red Member

The lower red member of the Chinle formation, Gregory's "Division D," consists of interstratified mudstone, sandstone, and conglomerate. The member weathers into irregular ledges and slopes and frequently forms low buttes. Mudstone makes up most of the member and is a dusky red to grayish red with subordinate hues of blue and gray. In most places the member contains discontinuous thin lenses of sandstone and limestone pebble conglomerate. The mudstone units are as much as 100 feet thick and weather into slopes. The sandstone units are 1 to 25 feet thick and are composed of very fine- to medium-grained angular to well-rounded clear and stained quartz intermixed with mica and argillaceous material, all of which is weakly to firmly bonded with calcareous cement. Many of the sandstone units contain overlapping lenses of sandstone, mudstone, and conglomerate. The sandstone is lenticular and thin to thick bedded and commonly exhibits crossbedding of the planar and trough types, with small- to medium-scale crossbeds deposited at a low angle. One of the most prominent bedding features of the sandier parts of the lower red member is the development of pseudo-crossbedding formed by the rhythmic advance of ripple marks.

The conglomeratic units of the lower red member range from shades of red to brown, but they commonly are brownish gray or light olive gray. They are composed predominantly of limestone pebbles with subordinate amounts of petrified-wood fragments, flattened mud pellets, and bone scraps all bound together in a matrix of calcareous silt and sand. The conglomerate units form irregular ledges up to 12 feet in thickness.

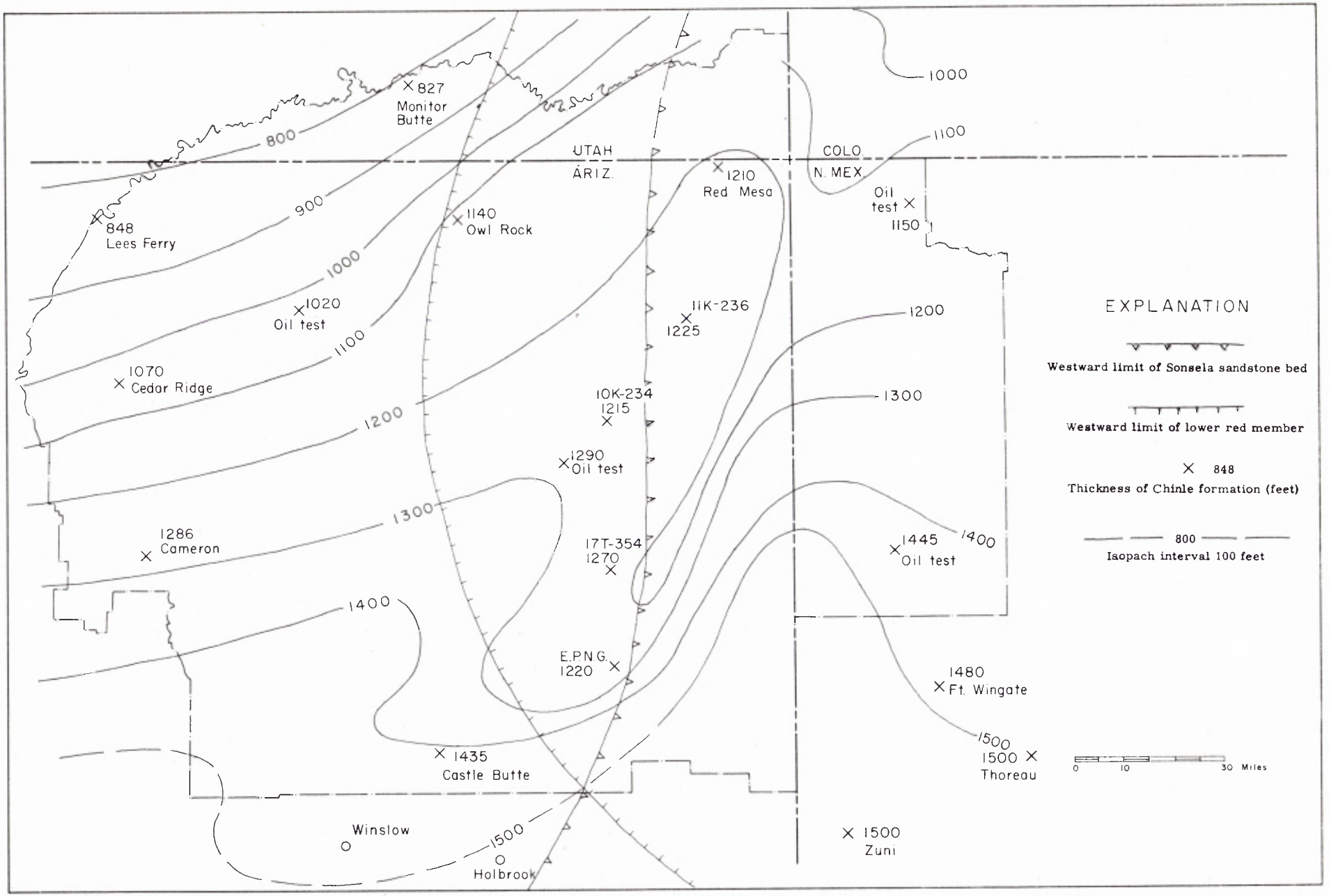

Figure 4.-- Generalized isopach map of the Chinle formation in Black Mesa basin area.

The lower red member of the Chinle formation is present only in the eastern part of the Navajo country. It intertongues with the Shinarump member and also grades upward into and intertongues with the Petrified Forest member. It thins westward from a maximum of 200 to 300 feet along the Arizona-New Mexico State line to about 100 feet along a line between Monument Valley and the Petrified Forest National Monument. It is not recognized in outcrops of the Chinle formation west of Holbrook and Monument Valley. To the south it grades laterally into the Mesa Redondo member.

The Monitor Butte member, defined by Stewart (1957, p. 452-453), is present in the Monument Valley area. It extends northward and occurs throughout most of southeastern Utah. The Monitor Butte member appears to be essentially continuous with the lower red member of the Chinle formation but represents a somewhat different facies. It probably was deposited contemporaneously with the lower red member but the material came in from different source areas. The stratigraphic relationships of these two members in the Monument Valley area ar shown in figure 2.

Petrified Forest Member

In the eastern part of the Black Mesa basin and adjoining areas the Petrified Forest member of the Chinle formation is divided into a lower and an upper part by the Sonsela sandstone bed. Beneath the Sonsela sandstone bed, the lower part of the member is composed of medium-red-purple, grayish-blue, and grayish-red mudstone and minor amounts of thin, crossbedded lenses of sandstone and siltstone. Locally, petrified logs are concentrated in this unit. The blue color commonly forms a band immediately underlying the Sonsela sandstone bed. Bedding is obscured in most places by the shaly weathering of the unit. However, in many areas irregularities in the color banding show the position of large channels; and in freshly exposed rock, as in undercut banks along washes and in road cuts, the bedding of the unit is apparent. The unit consists of a large series of lenses, some of which are very thinly flat bedded and many are trough crossbedded with large-scale crossbeds deposited at low and very low angles. Both the lower and upper parts of the Petrified Forest member weather into a rough, puffy surface due to swelling of some of the contained clay, and they form rounded, barren hills and slopes typical of the painted deserts.

In many areas the upper part of the Petrified Forest member is lithologically similar to the lower part except that it contains a considerable number of red sandy siltstone beds. Several lenticular silty sandstone beds, composed of very fine- to fine-grained sand, are present on the Defiance uplift and in the Rio Puerco valley. Most of these sandstone beds lie about 250 feet stratigraphically above the Sonsela sandstone bed.

Beyond the western limits of the Sonsela sandstone bed the upper and lower parts of the Petrified Forest member cannot be differentiated with certainty. In the western part of the Navajo country near Cameron and along Echo Cliffs the member is divided into three zones, based on slight lithologic and color differences. In ascending order these are: (1) lower blue mudstone unit approximately 200 feet thick, (2) medial gray and grayish-red mudstone and sandstone unit about 400 feet thick, and (3) upper banded pale-red-purple and gray sandstone and mudstone unit about 250 feet thick which underlies the Owl Rock member of the Chinle formation.

Near Cameron the blue mudstone unit is believed to be continuous with the lower part of the Petrified Forest member where the Sonsela bed is present, and the upper two units appear to thin eastward and to grade into the zone occupied by the Sonsela sandstone bed. The upper part of the Petrified Forest member, where the Sonsela sandstone bed is present, appears on the basis of reconnaissance tracing of these color-band zones to thin westward and is not recognizable as a unit west of Leupp between the Owl Rock member and the banded pale-red-purple and gray unit (fig. 2).

Sonsela Sandstone Bed

At its type section 3½ miles north of the western Sonsela Butte on the east flank of the Defiance uplift, the Sonsela sandstone bed of the Petrified Forest member comprises two conglomeratic sandstone units separated by a siltstone unit. The lower sandstone is a 25-foot ledge-forming unit consisting of very light-gray very fine- to very coarse-grained subrounded to subangular frosted, clear, and stained quartz; fairly abundant feldspar and mica; and abundant argillaceous material. A few quartz and limestone pebbles averaging three-eighths of an inch in diameter are concentrated along the bedding planes. Scattered lenses, up to a foot thick, of quartz granules appear throughout the unit. Bedding is irregular and lenticular. Crossbedding is the trough type, with small- to medium-scale crossbeds deposited at low to medium angles. The siltstone separating the two sandstone units is light bluish gray and weathers into a slope. The upper sandstone unit forms an irregular ledge more than 60 feet high. It is similar to the lower sandstone unit except that it contains more coarse-grained sand. The threefold division of the Sonsela sandstone bed at its type section is not characteristic of the unit in all areas. In regional aspect, the Sonsela sandstone bed consists of a variable number of ledge-forming sandstone units separated by slope-forming shaly beds.

The pebbles within the Sonsela sandstone bed are more numerous and larger in diameter in the area south of the Rio Puerco than they are in the area of the Defiance uplift. The maximum diameter of cobbles is 5 and 6 inches in the Petrified Forest National Monument and near St. Johns, respectively. The gravel decreases in amount and grain size northward into the Defiance uplift, where pebbles only 2 inches in diameter are noted. Thus, at Lupton a large part of the Sonsela is conglomerate, but near Round Rock only a few sandstone lenses or channels contain sufficient pebbles to be called a conglomerate.

In most areas the Sonsela bed consists of a main sandstone bed and numerous sandstone tongues separated by intervening mudstone units. Consequently, the thickness ranges from 50 to 200 feet, depending upon the local abundance of sandstone units. The bed is120 to 200 feet thick along the east side of the Defiance uplift and is present as a 60-foot ledge-forming conglomeratic sandstone in the Petrified Forest National Monument. North of Holbrook the position of the Sonsela sandstone bed is occupied by a poorly defined banded red and gray zone of sandy siltstone.

Owl Rock Member

At the type section, at Owl Rock in Monument Valley, the Owl Rock member of the Chinle formation, Gregory's "Division B," (Stewart, 1957, p. 458) consists of 131 feet of interbedded limestone and calcareous siltstone. The limestone is mottled very pale blue and grayish pink and

contains abundant chert nodules and mud pellets. Locally the limestone is rather silty and is made up of concretionary structures. Bedding within the siltstone units is irregular and lenticular. In contrast to this, the individual limestone beds are 1 to 5 feet thick and in Chinle Valley and the Little Colorado River valley they have been traced along continuous exposures for as much as 20 miles. However, in most areas the limestone beds are somewhat lenticular. The member as a whole weathers to form slopes and ledges.

The Owl Rock member extends over the entire Navajo country. It is about 300 feet thick along a southwest-trending line between Round Rock and Castle Butte. It thins northwestward and southeastward from this line. At Lees Ferry the Owl Rock member is 130 feet thick; in House Rock Valley, along the northern half of the east Kaibab monocline, it is absent. It is 200 feet thick at Lupton and is absent in exposures of the Chinle along the Zuni River north of St. Johns. At Cameron, in the southwestern part of the reservation, the Owl Rock member is about 270 feet thick.

In the western and southwestern parts of the Black Mesa basin area the Owl Rock member is separated from the overlying formations by an erosion surface of slight relief on which gravel, derived in part from the limestone of the Owl Rock member, accumulated. Gravel is also present at the top of the Chinle formation, locally, in the Chinle Valley area and eastward near Round Rock and Thoreau. In many areas in the central part of the Black Mesa basin there is no apparent break in deposition between the Chinle formation and the overlying Glen Canyon group.

REFERENCES

Cooley, M. E., 1958, The Mesa Redondo member of the Chinle formation, Apache and Navajo Counties, Arizona: Plateau, v. 31, no. 1, p. 7-15.

Gilbert, G. K., 1875, Report on the geology of portions of Nevada, Utah, California, and Arizona: U. S. Geol. and Geog. Surveys W. 100th Meridian, v. 3, p. 17-187.

Gregory, H. E., 1917, Geology of the Navajo country: U. S. Geol. Survey Prof. Paper 93.

....., 1950, Geology and geography of the Zion Park region, Utah and Arizona: U. S. Geol. Survey Prof. Paper 220.

Harshbarger, J. W., Repenning, C. A., and Irwin, J. H., 1957, Stratigraphy of the uppermost Triassic and the Jurassic rocks of the Navajo country: U. S. Geol. Survey Prof. Paper 291.

McKee, E. D., 1954, Stratigraphy and history of the Moenkopi formation of Triassic age: Geol. Soc. America Mem. 61.

Muller, S. W., and Ferguson, H. G., 1939, Mesozoic stratigraphy of the Hawthorn and Tonopah quadrangles, Nevada: Geol. Soc. America Bull., v. 50, no. 10, p. 1573-1624.

Stewart, John H., 1957, Proposed nomenclature of part of Upper Triassic strata in southeastern Utah: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 3, p. 441-463.