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Triassic stratigraphy in the Lucero uplift, Cibola, Valencia and Socorro Counties, New Mexico

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1994, pp. 241-254. https://doi.org/10.56577/FFC-45.241

in:

Mogollon Slope (West-Central New Mexico and East-Central Arizona), Chamberlin, R. M.; Kues, B. S.; Cather, S. M.; Barker, J. M.; McIntosh, W. C.; [eds.], New Mexico Geological Society 45th Annual Fall Field Conference Guidebook, 335 p. https://doi.org/10.56577/FFC-45

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TRIASSIC STRATIGRAPHY IN THE LUCERO UPLIFT, CIBOLA, VALENCIA AND SOCORRO COUNTIES, NEW MEXICO

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Abstract—Triassic strata exposed in the Lucero uplift of Cibola, Valencia and Socorro Counties are nonmarine red beds of the Moenkopi Formation and Chinle Group. Moenkopi Formation strata disconformably overlie Middle Permian (Guadalupian) limestones and dolomites of the San Andres Formation and are mostly grayish red, trough-crossbedded and ripple-laminated micaceous litharenites intercalated with beds of intraformational conglomerate and grayish red, micaceous siltstone and mudstone. Charophytes, ostracods and capitosauroid amphibians indicate the Moenkopi Formation in the Lucero uplift is of Middle Triassic (early Anisian) age. Overlying Chinle Group strata consist of (ascending) the Shinarump, Bluewater Creek, Petrified Forest, Owl Rock and Rock Point Formations. In the Lucero uplift, strata of the San Pedro Arroyo Formation laterally replace Bluewater Creek Formation strata south of the Rio Salado. Shinarump Formation strata are extrabasinal conglomerates (mostly Paleozoic limestone clasts) and sandstones as much as 17 m thick that disconformably overlie Moenkopi strata. Locally, pedogenically modified sandstones, conglomerates and siltstones - the "mottled strata" - laterally replace Shinarump conglomerates and sandstones. Bluewater Creek Formation strata are at least 70 m thick and are mostly reddish brown siltstones, mudstones and ripple-laminated sandstones The distinctive McGaffey Member - 5-6 m of mostly ripple-laminated sandstone - is present in the upper half of the Bluewater Creek Formation in the northern part of the Lucero uplift. Below the McGaffey Member, the Bluewater Creek Formation contains an Adamanian (late Carnian) tetrapod fauna that includes cf. Buettneria, indeterminate phytosaurs and Stagonolepis. The base of the Petrified Forest Formation in the Lucero uplift is the Sonsela Member; evidently the Blue Mesa Member has been removed by erosion at the pre-Sonsela unconformity. Sonsela strata are as much as 15 m thick and are mostly trough-crossbedded micaceous litharenite and intrabasinal calcrete-pebble conglomerate. Overlying Painted Desert Member strata are mostly reddish-brown bentonitic mudstone at least 100 m thick. Owl Rock and Rock Point strata are only exposed in the Petaca Pinta area (SW 1/4 T6N, R6W and SE 1/4 T6N, R7W). The Owl Rock is mostly grayish-red and very pale green, calcareous mudstone and grayish-red purple bioturbated sandy siltstone and is up to 37 m thick. Rock Point strata are up to 70 m thick and consist of laterally extensive beds of massive, moderate-reddish brown sandy siltstone and laminar to trough-crossbedded moderate reddish brown quartzose sandstone. Middle Jurassic (Entrada) to Upper Cretaceous (Dakota) strata disconformably overlie Upper Triassic Chinle Group rocks in the Lucero uplift.

INTRODUCTION

Nonmarine Triassic red beds exposed in the Lucero uplift of Cibola, Valencia and Socorro Counties, New Mexico, represent one of the largest single outcrop belts of Triassic strata in the state (Fig. 1). Yet, beyond basic mapping by Kelley and Wood (1946), Tonking (1957) and Jicha (1958), little study has been undertaken of these rocks. Here, we present a comprehensive lithostratigraphy of Triassic strata in the Lucero uplift and correlate them to nearby Triassic rocks.

PREVIOUS STUDIES

Early geological fieldworkers in central New Mexico recognized that Triassic strata are exposed throughout the Lucero uplift. Thus, Darton (1910, p. 49-50) summarized earlier observations by J.S. Newberry, C.L. Herrick and H.N. Herrick. Darton (1910, pl. 1) mapped the Triassic strata in the Lucero uplift as "near 500 feet" of "undifferentiated Triassic." Darton (1928, p. 124, pl. 30) subsequently identified these strata as "Triassic red shales" (Fig. 2).

Kelley and Wood (1946) first attempted to subdivide and apply formal nomenclature to the Triassic strata exposed in the Lucero uplift (Fig. 2). They assigned them to the Shinarump Conglomerate overlain by the Chinle Formation. Kelley and Wood (1946) inferred a maximum thickness of about 400 ft and stated that "little or no conglomerate is present in the Lucero area, and the formation more nearly resembles the possibly equivalent Santa Rosa sandstone east of the Rio Grande Valley than the Shinarump conglomerate of western New Mexico." They described the Shinarump conglomerate as "red-brown shale, siltstone, and sandstone, locally contains limestone-conglomerate lenses, 300 ± feet thick".



FIGURE 1. Distribution of Triassic strata in New Mexico, showing location of Lucero uplift Triassic outcrops.

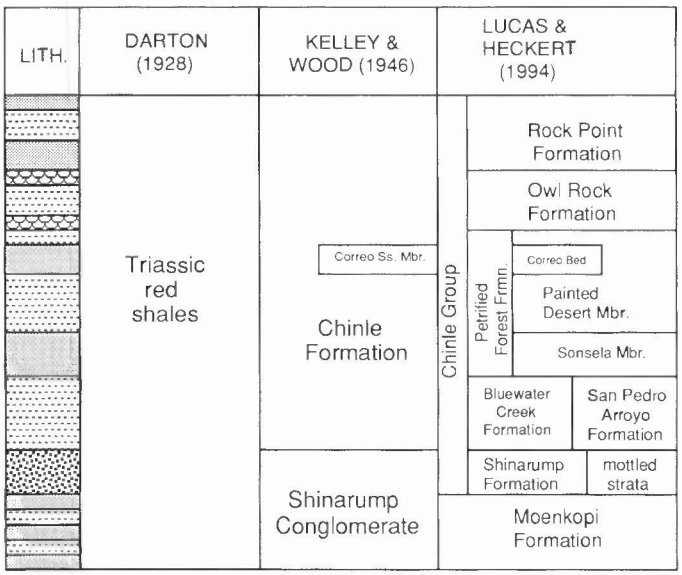


FIGURE 2. Summary of development of stratigraphic nomenclature applied to Triassic strata in the Lucero uplift.

Kelley and Wood (1946) divided strata they termed Chinle Formation in the Lucero uplift into two members, a red shale member overlain by the Correo Sandstone Member. They described the red shale member as "red-brown soft shale, 1000 ± feet thick; the basal part is not exposed." The Correo Sandstone Member was described as "dark-brown and buff, medium to massive, cross-bedded sandstone, 90-120 feet thick" that only crops out "along the lower bench at the south edge of Mesa Gigante."

Subsequent geologic mapping and study of the southern part of the Lucero uplift by Tonking (1957) used the Triassic nomenclature of Kelley and Wood (1946). Jicha (1958), mapping in the northern part of the uplift, essentially followed suit, but did not separate the Shinarump from the Chinle.

Apparently no work was undertaken on Triassic strata in the Lucero uplift for about 30 years. Mapping along the western edge of the uplift by Maxwell (1988a, b) identified the Triassic strata as Chinle Formation overlain by the Rock Point Member of the Wingate Sandstone. Hunt et al. (1989), Lucas and Hayden (1989), and Hayden and Lucas (1989) presented some observations on the Triassic strata exposed in the Lucero uplift. They assigned these rocks to the Moenkopi Formation overlain by the Chinle Formation, consisting of the Shinarump and Petrified Forest Members. Lucas and Hunt (1990) identified the Owl Rock and Rock Point Members of the Chinle Formation at Petaca Pinta on the northwestern edge of the uplift. Recently, Lucas (1993) revised the nomenclature of the Upper Triassic strata in the American Southwest, elevating the Chinle to group status and recognizing the following units in west-central New Mexico: Shinarump Formation, Bluewater Creek Formation, Petrified Forest Formation, (including Blue Mesa, Sonsela and Painted Desert Members) and the Owl Rock and Rock Point Formations.

STRATIGRAPHY

Our study of the Triassic stratigraphy of the Lucero uplift is based on several measured stratigraphic sections and a few fossil localities (Fig. 3).

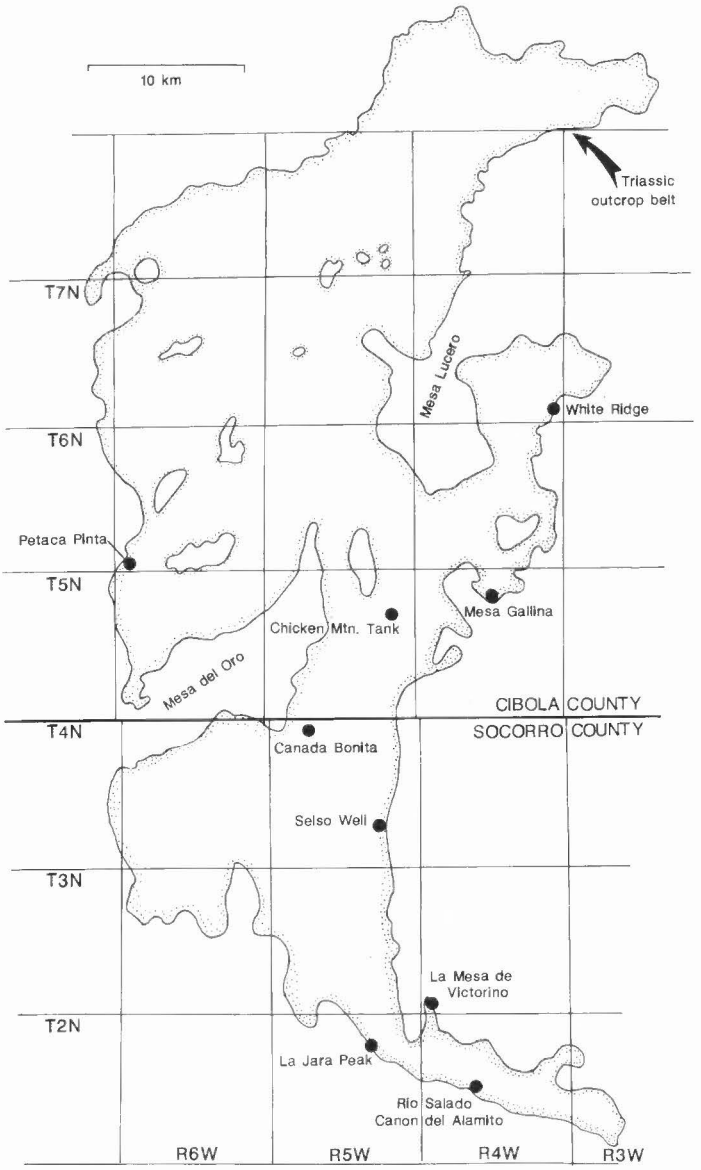


FIGURE 3. Distribution of Triassic strata in the Lucero uplift (after Dane and Bachman, 1965) and location of measured stratigraphic sections and fossil localities of this study.

Moenkopi Formation

Strata of the Moenkopi Formation (Anton Chico Member) in the Lucero uplift consist of 20 to 70 m of interbedded conglomerates, sandstones, siltstones and mudstones that are disconformably bounded by the San Andres Formation (below) and the Chinle Group (above) (Fig. 4). The Moenkopi Formation is exposed throughout the Lucero uplift both west and east of the San Andres Formation axis. Basal Moenkopi strata rest on dramatically eroded surfaces of the San Andres Formation, including both incised channels (Lucas and Hayden, 1989) and paleokarst topography (Stewart et al., 1972). The uppermost Moenkopi is covered by either "mottled strata" or sandstones and conglomerates of the Shinarump Formation (Fig. 4). In addition to the measured sections reported by Lucas and Hayden, we document two complete sections at La Mesa de Victorino and Selso Well (Fig. 3).

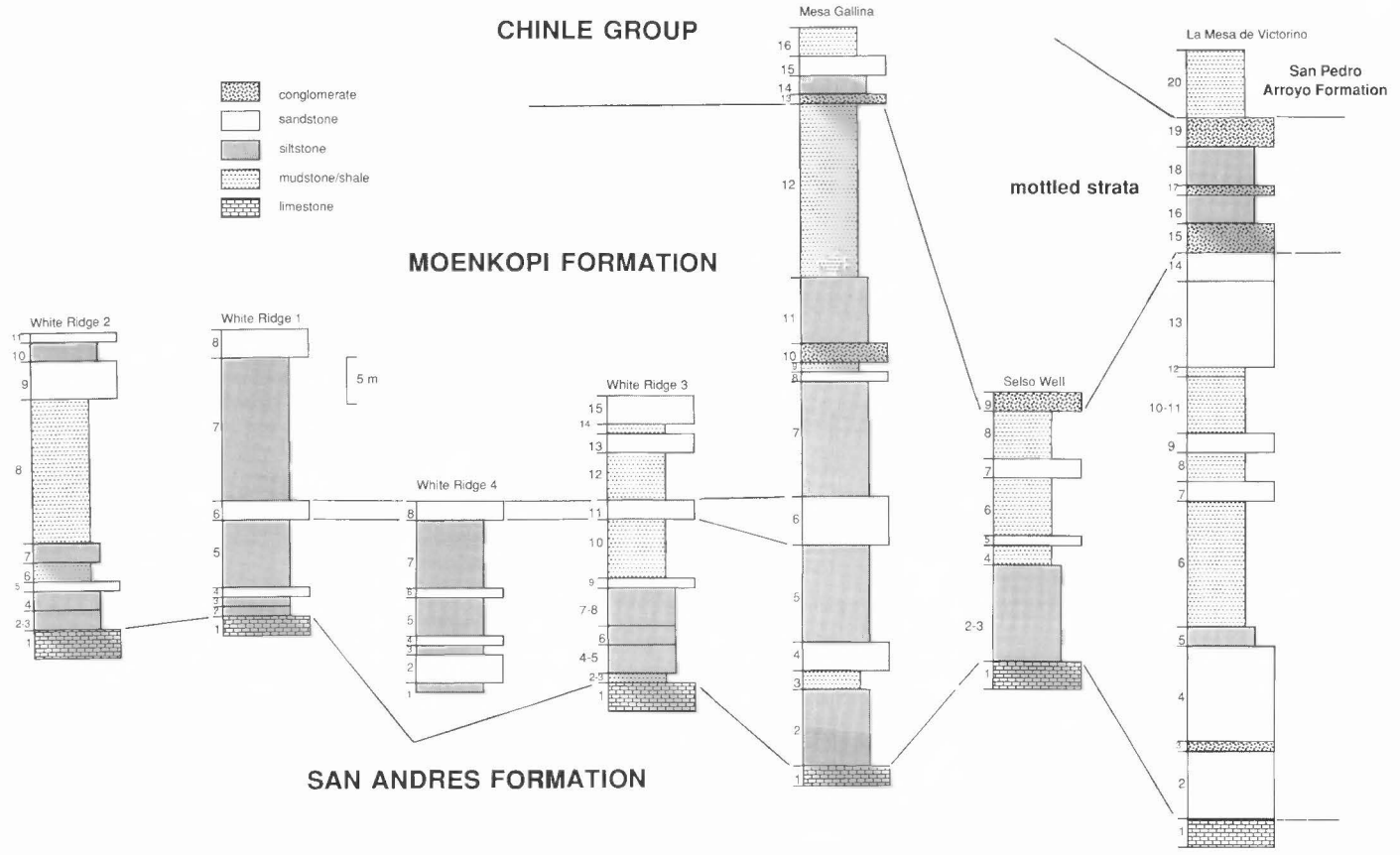


FIGURE 4. Measured stratigraphic sections of the Moenkopi Formation in the Lucero uplift.

The basal contact of the Moenkopi Formation is typically an interbedded series of white to yellowish gray mudstones, siltstones and sandstones. Lucas and Hayden (1989) referred to this lowermost interval of the Moenkopi in the Lucero uplift as a bleached zone of mudstones and siltstones. At La Mesa de Victorino (the section measured by Tonking, 1957) we place the San Andres-Moenkopi contact at the change from yellowish gray micritic dolomite of the San Andres Formation to yellowish gray to grayish orange sandstones and siltstones of the Moenkopi Formation (Fig. 4). This is approximately 12.4 m below the base of the Triassic described by Tonking (1957). Likewise, at Selso Well north of Puertecito, yellow to yellowish gray siltstones mark this lowermost bleached horizon in the Moenkopi.

Above these strata, the Moenkopi Formation is dominated by poorly sorted reddish brown to reddish gray mudstones, siltstones, sandstones and conglomerates. Mudstones are typically silty with some interbeds of siltstone, whereas siltstones are typically muddy and calcareous. Sandstones are poorly sorted litharenites typically displaying either ripple laminae or, more frequently, trough crossbeds (Fig. 5B). Some sandstones are conglomeratic, with clasts consisting of intraformational mudstone rip-ups. Conglomerates in the Moenkopi are also trough crossbedded and characterized by intraformational clasts of siltstone, mudstone and calcrete up to 2 cm in diameter.

Thickness of the Anton Chico Member of the Moenkopi Formation varies considerably due to unconformities that bound the unit. In the extreme eastern side of the uplift, closely spaced measured sections show that Moenkopi thicknesses average approximately 30 m (Lucas and Hayden, 1989). Farther west the section varies from a low of approximately 25 m at our measured section at Selso Well to almost 70 m at Mesa Gallina (Lucas and Hayden, 1989). In the southern portion of the uplift we measured 51 m of Moenkopi at La Mesa de Victorino. Sections capped by mottled strata generally appear to be thicker than those capped by the Shinarump, indicating a greater amount of erosion associated with pre- and syn-Shinarump deposition.

Chinle Group

The Chinle Group in the Lucero uplift consists of (in ascending order) the Shinarump, Bluewater Creek, San Pedro Arroyo, Petrified Forest, Owl Rock and Rock Point Formations (Fig. 6). Mottled strata, as originally described by Stewart et al. (1972) are also locally present throughout the Lucero uplift at the base of the Chinle Group. Near the Rio Salado, strata of the Bluewater Creek Formation grade into those of the San Pedro Arroyo Formation. Thus, rocks identified by us as Bluewater Creek Formation are present throughout most of the uplift, whereas the San Pedro Arroyo Formation is the equivalent unit south of the Rio Salado. These rocks are disconformably overlain by the Sonsela Member of the Petrified Forest Formation, which in turn is overlain by the Painted Desert Member. There are no strata of the Blue Mesa Member of the Petrified Forest Formation in the Lucero uplift; evidently these rocks were eroded during the pre-Sonsela unconformity. In the area of Petaca Pinta the Chinle succession is capped by the Owl Rock and Rock Point Formations.

Shinarump Formation/"mottled strata"

Both the Shinarump Formation and the correlative "mottled strata" are present in the Lucero uplift to varying extents. We identify conglomerates (25%) and conglomeratic sandstones (75%) of the Shinarump Formation in the north near Chicken Mountain, and at Selso Well farther south (Fig. 6). Mottled strata were first reported from the Lucero uplift by Stewart et al. (1972) and are evident at Mesa Gallina (Lucas and Hayden, 1989), at La Mesa de Victorino, and just south of the Rio Salado (Fig. 6).

Strata identified by us as Shinarump consist of light olive-gray to brownish gray extrabasinal conglomerate and conglomeratic sandstones (Figs. 7A-B). Bedding is trough- to wedge-planar crossbedded,

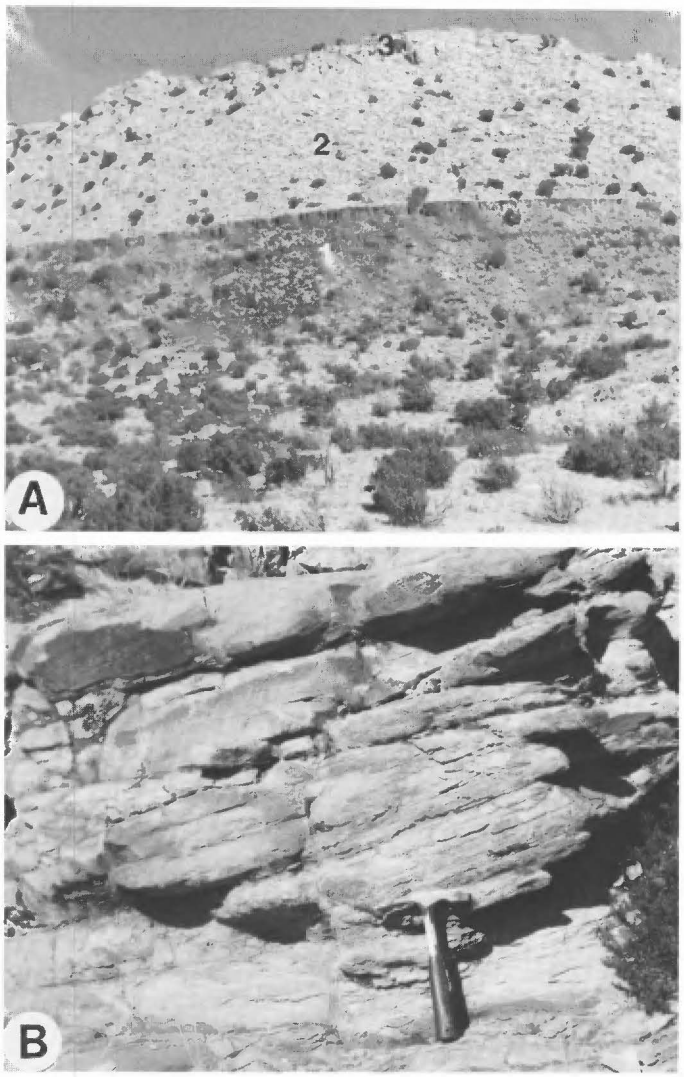


FIGURE 5. Photographs of selected Moenkopi outcrops in the Lucero uplift. A, Overview of La Mesa de Victorino section showing Moenkopi Formation (1) overlain by San Pedro Arroyo Formation (2) followed by Quaternary travertine (3). B, Typical cross-bedded Moenkopi litharenite, unit 9 of La Mesa de Victorino section.

with much scouring of underlying strata (Fig. 7B). At Selso Well, conglomerate clasts consist primarily of Paleozoic limestones with a few chert and jasper pebbles. Similar lithologies predominate at Chicken Mountain Tank, where the Shinarump also crops out (Fig. 7A). Due to structural complexities the entire unit could not be measured at either locality, so known thickness is a minimum of 10 m.

"Mottled strata" are identified from numerous localities in the Lucero uplift. These pedogenically altered siltstones, mudstones and conglomerates have been inferred to represent a paleoweathering surface that developed either during the Tr-3 unconformity of Pipiringos and O'Sullivan (1978) and/or contemporaneously with Shinarump deposition (e.g. Lucas and Hayden, 1989; Lucas, 1991). In the southern portion of the Lucero uplift "mottled strata" are widely distributed, with particularly informative outcrops at La Mesa de Victorino, in the section originally measured by Tonking (1957) (Fig. 7C), and at our Rio Salado section to the south and east of Tonking's section (Fig. 7D).

At La Mesa de Victorino, "mottled strata" consist of nearly 15 m of mud pellet conglomerates (70%) and muddy sandy siltstones (30%) (Fig. 7C). Mud-pellet conglomerates are pale to grayish red with mottles of reddish orange, reddish brown, and dark gray. Clasts are rip-ups of Moenkopi mudstone. Siltstones are pale to grayish red, calcareous and extensively pedogenically altered. In contrast, within sight of this section, at Rio Salado "mottled strata" consist of a thin mixture of calcrete and silcrete less than a meter thick (Fig. 7D). Mottles are dark gray, grayish purple, light gray and pale red. Conglomeratic clasts include quartzite and jasper pebbles up to 2.0 cm in diameter.

Bluewater Creek Formation

The Bluewater Creek Formation in the Lucero uplift is typified by at least 70 m of ripple-laminated sandstones, muddy siltstones, and silty mudstones (Fig. 6). Strata of the Bluewater Creek Formation crop out in extensive, structurally complex badlands in the vicinity of Chicken Mountain Tank, where they rest with apparent disconformity on strata of the Shinarump Formation. In this region the McGaffey Member crops out as 5 m of ripple-laminated litharenite near the top of the measured section. Elsewhere in the uplift, Bluewater Creek strata are often preserved as several meters of bentonitic mudstone red beds underlying hogbacks of the Sonsela Member of the Petrified Forest Formation. In the southernmost portion of the uplift, rocks of the Bluewater Creek Formation grade into strata assigned by us to the San Pedro Arroyo Formation.

At Chicken Mountain, basal Bluewater Creek strata consist of approximately 20 m of olive-gray, ripple-laminated micaceous quartzarenites. Some minor trough crossbedding is evident. Sandstones are typically fine to very fine grained. Above these strata the Bluewater Creek Formation is typified by bentonitic mudstones (63%) with minor crossbedded sands and clays (37%) (Fig. 7E). Approximately 30% of the mudstones display varying degrees of calcrete nodule development.

Due to structural deformation and cover in the Lucero uplift, we were not able to locate a single, complete section of the Bluewater Creek Formation. Above the mudstones at Chicken Mountain Tank, the McGaffey Member of Anderson and Lucas (1993) is present. In other localities, including Cañada Bonita and numerous other localities, trough crossbedded sandstones of the Sonsela Member of the Petrified Forest Formation rest disconformably on the Bluewater Creek Formation. These uppermost Bluewater Creek sediments are "red beds" of trough-crossbedded quartzarenites and bentonitic mudstones.

McGaffey Member

To the north and west of Chicken Mountain, sandstones of the McGaffey Member crop out in a prominent bench near the road (Fig. 6). These strata are hummocky-bedded and ripple laminated sandstones at least 5 m thick. We identify this ledgy sand as the McGaffey Member on the basis of lithology, thickness, outcrop pattern and nature of the contact with underlying strata. These sandstones are micaceous, lithic arenites that are regionally persistent and form a distinct bench. As in the type section of the McGaffey Member (Anderson and Lucas, 1993), the unit is approximately 5-7 m thick. The presence of "redbeds" of fine sandstones and siltstones beneath these rocks indicates that they are not basal Bluewater Creek Formation sandstones. For all of these reasons we believe this sandy unit is the first identified outcrop of the McGaffey Member in the Lucero uplift. Hunt et al. (1989) earlier misidentified this outcrop as Sonsela.

San Pedro Arroyo Formation

Near the southern terminus of the Lucero uplift, strata pertaining to the San Pedro Arroyo Formation (Lucas, 1991) grade into muddier Bluewater Creek Formation sediments (Fig. 6). We identify the San Pedro Arroyo Formation in the Lucero uplift as a series of mudstones (89%) interrupted by numerous thin, persistent ledges of sandstone (7%), conglomerate (1%), and very minor siltstone and calcrete (Fig. 7F). Mudstones are dominantly bentonitic, calcareous and grayish red purple with light gray mottles. Sandstones and conglomerates typically crop out as thin, 0.5 to 2.0 m thick, laterally extensive sheets. The sandstones are laminated, micaceous litharenites, whereas conglomerates are typified by intraformational calcrete and mudstone clasts. This sequence of strata is approximately 90 m thick in the vicinity of our Rio Salado section, and represents a complete section from the underlying mottled strata to the base of the Sonsela Member (Fig. 6).

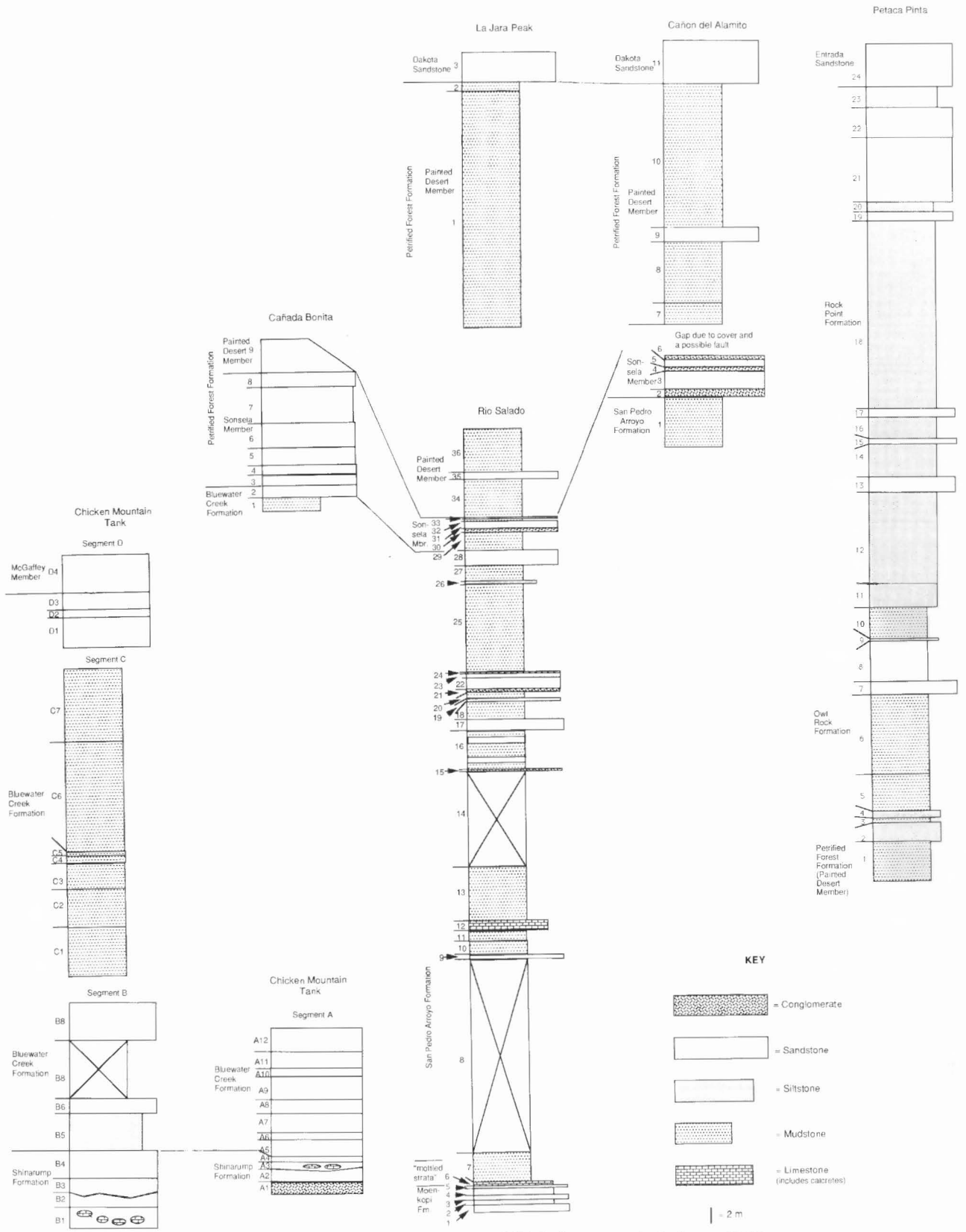


FIGURE 6. Measured stratigraphic sections of Chinle Group strata in the Lucero Uplift.

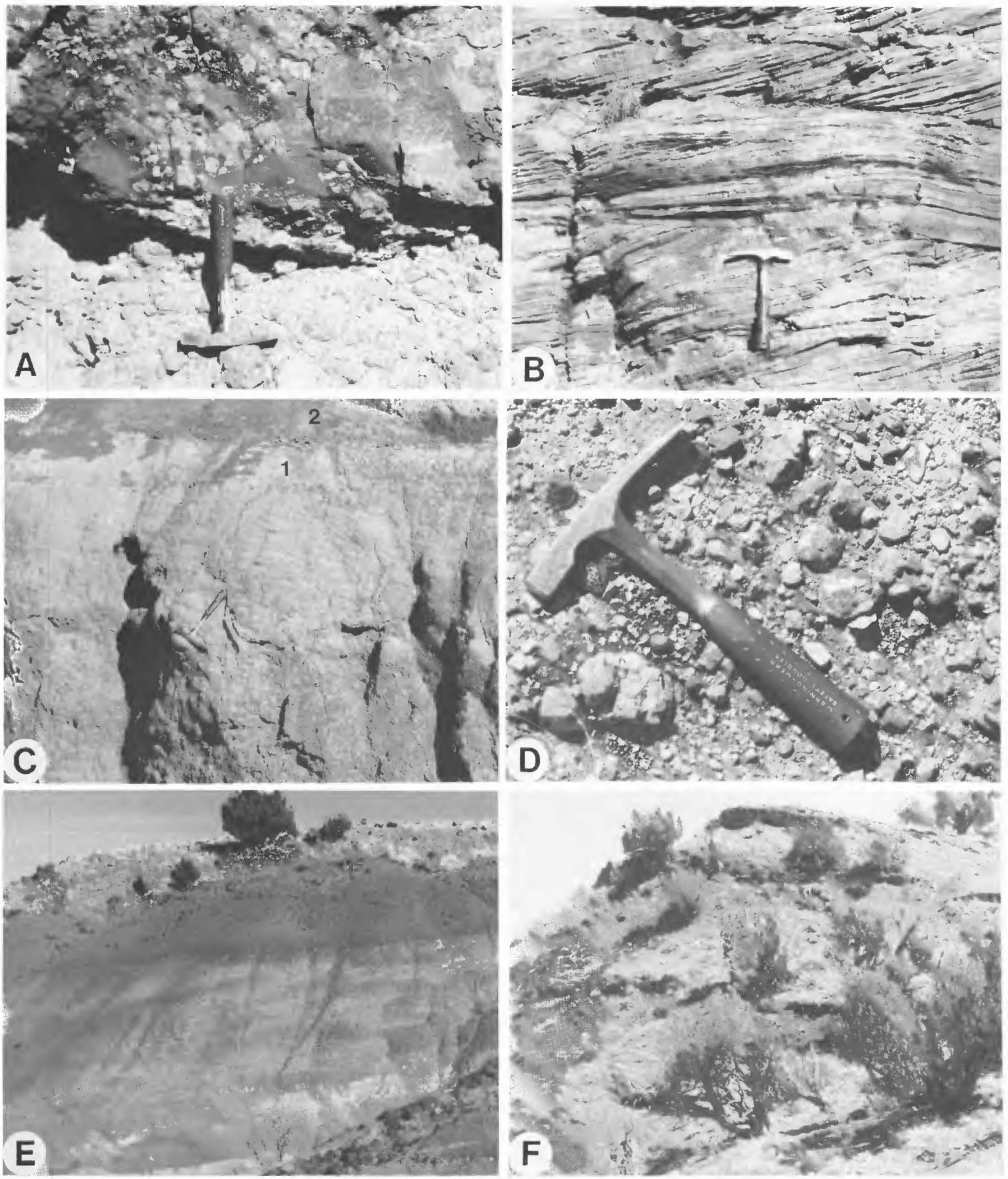


FIGURE 7. Photographs of selected Chinle Group outcrops in the Lucero uplift. A, Paleozoic limestone cobble conglomerate of Shinarump Formation, unit A1 of Chicken Mountain Tank section. B, Planar and crossbedded sandstones and conglomeratic sandstones of the Shinarump Formation near the Chicken Mountain Tank section. C, Base of the Chinle Group at the La Mesa de Victorino section shows mottled strata (1=unit 19 of measured section) overlain by mudstone (2=unit 20 of measured section) at the base of the San Pedro Arroyo Formation. D, Calcrete and silcrete nodules of the mottled strata at the Rio Salado section (unit 6). E, Mudstones and heterolithic cross strata of the Bluewater Creek Formation in the Chicken Mountain Tank section (unit C6). F, Typical mudstones, sandstones and conglomerates of the San Pedro Arroyo Formation, units 20-28 of the Rio Salado section.

Petrified Forest Formation

Lucas (1993) subdivided the Petrified Forest Formation into the Blue Mesa, Sonsela and Painted Desert members. We recognize only strata pertaining to the Sonsela and Painted Desert Members in the Lucero uplift. The Blue Mesa Member appears to have been eroded during the pre-Sonsela unconformity. The Sonsela Member thus rests disconformably on the Bluewater Creek Formation or laterally equivalent sediments of the San Pedro Arroyo Formation.

Sonsela Member

The lowest unit of the Petrified Forest Formation in the Lucero uplift north of the Rio Salado is the Sonsela Member. It rests directly on the Bluewater Creek Formation and is overlain by the Painted Desert Member (Fig. 6). South of the Rio Salado, the Sonsela Member separates the San Pedro Arroyo Formation (below) from the Painted Desert Member (above). Excellent outcrops of the Sonsela Member are present throughout the Lucero uplift, especially: (1) around Cañada Bonita and Cerro Pelon in secs. 5,6,8,20 and 29, T4N, R5W; (2) near Paint Tank in secs. 4 and 5, T3N, R5W; (3) in Cañada Bonita near Bill Dobbs Well in sec. 8, T3N, R5W; and (4) south of the Rio Salado near Cañon del Alamito in secs. 16 and 17, T2N, R4W.

Two measured sections, one to the north, the other to the south, well encompass the lithologic variation of the Sonsela Member in the Lucero uplift. To the north, at Cañada Bonita, the Sonsela Member is 15.3 m thick. It is almost entirely sandstone with a conglomeratic sandstone at its base (Figs. 6, 8A-C). This conglomerate mostly consists of mudstone clasts, but a few siliceous and Paleozoic limestone clasts are present. The sandstones are feldspathic litharenites that are either laminated or trough crossbedded. Grayish red and grayish pink color banding is characteristic (Fig. 8C). At Cañada Bonita, the Sonsela forms a resistant bench between redbed mudstone-dominated slopes, the Bluewater Creek Formation below and Painted Desert Member above (Fig. 8A).

To the south, along Cañon del Alamito near Riley, the Sonsela Member is thinner, about 5 m thick. Conglomerates are much more prominent in the Sonsela here and their clasts are almost exclusively calcrete rip-ups. Laminar and trough crossbedded sandstones are also litharenites and grayish purple and olive gray color banding is common.

Painted Desert Member

The Painted Desert Member conformably overlies the Sonsela Member throughout the Lucero uplift (Fig. 6). In the Petaca Pinta area, the Owl Rock Formation of the Chinle Group conformably overlies the Painted Desert Member (Fig. 8D). At Mesa Gigante, Middle Jurassic strata (Entrada Sandstone) disconformably overlie the Painted Desert Member. Throughout the rest of the Lucero uplift, the Cretaceous Dakota Group rests disconformably on the Painted Desert Member. This Cretaceous-Triassic disconformity is particularly well exposed from the unnamed mesa just northwest of Puertecito in secs. 18, 19 and 30 of T3N, R5W to the southeast at Cañon del Alamito in secs. 16, 20, and 21, T2N, R4W.

In the Lucero uplift, as is the case elsewhere on the Colorado Plateau (Lucas, 1993), the Painted Desert Member is mostly reddish brown and grayish red bentonitic mudstones (Fig. 8D). Typical lithologies are described here (see La Jara Peak and Cañon del Alamito sections).

Because it is not a resistant unit, the Painted Desert Member is not well exposed in the Lucero uplift. It typically forms broad valleys or slopes much mantled by soil or covered with colluvial debris. Because of this, we were not able to measure a single, completely exposed section of the member in the Lucero uplift. The closest we came to this is Cañon del Alamito where the measured 34.7 m is only a few meters less than the total thickness of the Painted Desert Member, which we estimate as about 40 m thick here. Just northwest of Puertecito, between the Sonsela Member outcrops in sec. 8, T3N, R5W at the road crossing of Cañada Bonita, the Painted Desert Member is nearly flat lying to its contact with the Dakota in sec. 18, T3N, R5W over an elevation gain of about 73 m. This suggests a thickening of the Painted Desert Member from south to north across the Lucero uplift.

In the northern part of the Lucero uplift, at Mesa Gigante, the upper part of the Painted Desert Member contains the Correo Bed, about 26 m of cliff-forming sandstone and conglomerate (Kelley and Wood, 1946; Stewart et al., 1972; Lucas et al., 1987). Correo Bed conglomerates are intrabasinal, being composed of siltstone and limestone clasts, and the sandstones are quartzose. In the Lucero uplift, the Correo Bed crops out only in its type area along the southern flank of Mesa Gigante.

Owl Rock Formation

The Owl Rock Formation rests conformably on the Painted Desert Member in the vicinity of Petaca Pinta (Fig. 6). In the Lucero uplift, its outcrops are limited to the Petaca Pinta area in T6N, R6W. To the south and southeast, where Cretaceous Dakota Group strata rest disconformably on the Chinle Group, no Owl Rock (or overlying Rock Point) strata are preserved. At the northern edge of the Lucero uplift, at Mesa Gigante, the Entrada Sandstone rests disconformably on the Painted Desert Member, so here too Owl Rock and Rock Point strata are missing.

At Petaca Pinta, we measured a 35.4-m-thick section of the Owl Rock Formation. Here, the Owl Rock is mostly mudstone (78% of the measured section) with much less siltstone (17% of the section) and minor silty sandstone (5% of the section). The mudstones are variegated hues of red, purple and pale green. They are bentonitic and typically contain numerous calcrete nodules (Fig. 8E). The siltstones are brown and purple and very bioturbated, as is the one ledge-forming sandstone near the middle of the formation. At Petaca Pinta, as elsewhere on the Colorado Plateau (Lucas, 1993), the Owl Rock Formation conformably overlies the Painted Desert Member of the Petrified Forest Formation and is disconformably overlain by the Rock Point Formation.

Rock Point Formation

Like the Owl Rock Formation, the Rock Point Formation is only present on the western fringe of the Lucero uplift at Petaca Pinta (Fig. 6), and its distribution in the Lucero uplift is identical to that of the Owl Rock Formation. We measured 69.1 m of Rock Point Formation at Petaca Pinta.

At Petaca Pinta the Rock Point Formation is repetitively interbedded, laterally persistent sandy siltstone (71% of the measured section) and silty sandstone (29% of the section) (Fig. 8F). These strata are mostly reddish brown. The siltstones are massive, ledgy, and not bentonitic. The sandstones are mostly laminated, ripple laminated or massive micaceous quartzarenites. The Middle Jurassic Entrada Sandstone overlies the Rock Point Formation disconformably at Petaca Pinta.

PALEONTOLOGY

No systematic effort has been undertaken to recover fossils from the extensive Triassic exposures in the Lucero uplift, but a few biochronologically significant fossils are known. These are mostly from the Moenkopi Formation and lower part of the Chinle Group.

Kietzke (1988, 1989) reported charophytes and ostracods from the lower part of the Moenkopi Formation at White Ridge, in the northern part of the Lucero uplift. These fossils indicate an Early or Middle Triassic age. From Mesa Gallina, also in the northern part of the Lucero uplift, Lucas and Hayden (1989) described bones of a capitosauroid amphibian and an indeterminate archosaur from the Moenkopi Formation. Capitosauroids (*Eocyclotosaurus*) from elsewhere in the Anton Chico Member of the Moenkopi Formation indicate an early Middle Triassic (early Anisian) age (Lucas and Morales, 1985; Lucas and Hunt, 1987; Morales, 1987; Ochev and Shishkin, 1989; Hunt and Lucas, 1993).

Hunt et al. (1989) reported a vertebrate fossil assemblage from the Bluewater Creek Formation near Chicken Mountain Tank in the northern Lucero uplift. Taxa represented are cf. *Buettneria* sp. (= *Metoposaurus* sp. of Hunt et al., 1989, here revised after Hunt, 1993), *Apachesaurus* sp. (="*Anaschisma* n. sp." of Hunt et al., 1989, here revised after Hunt, 1993), *Stagonolepis* sp. (=*Calyptosuchus* sp. of Hunt et al, 1989, here revised after Hunt and Lucas, 1993) and

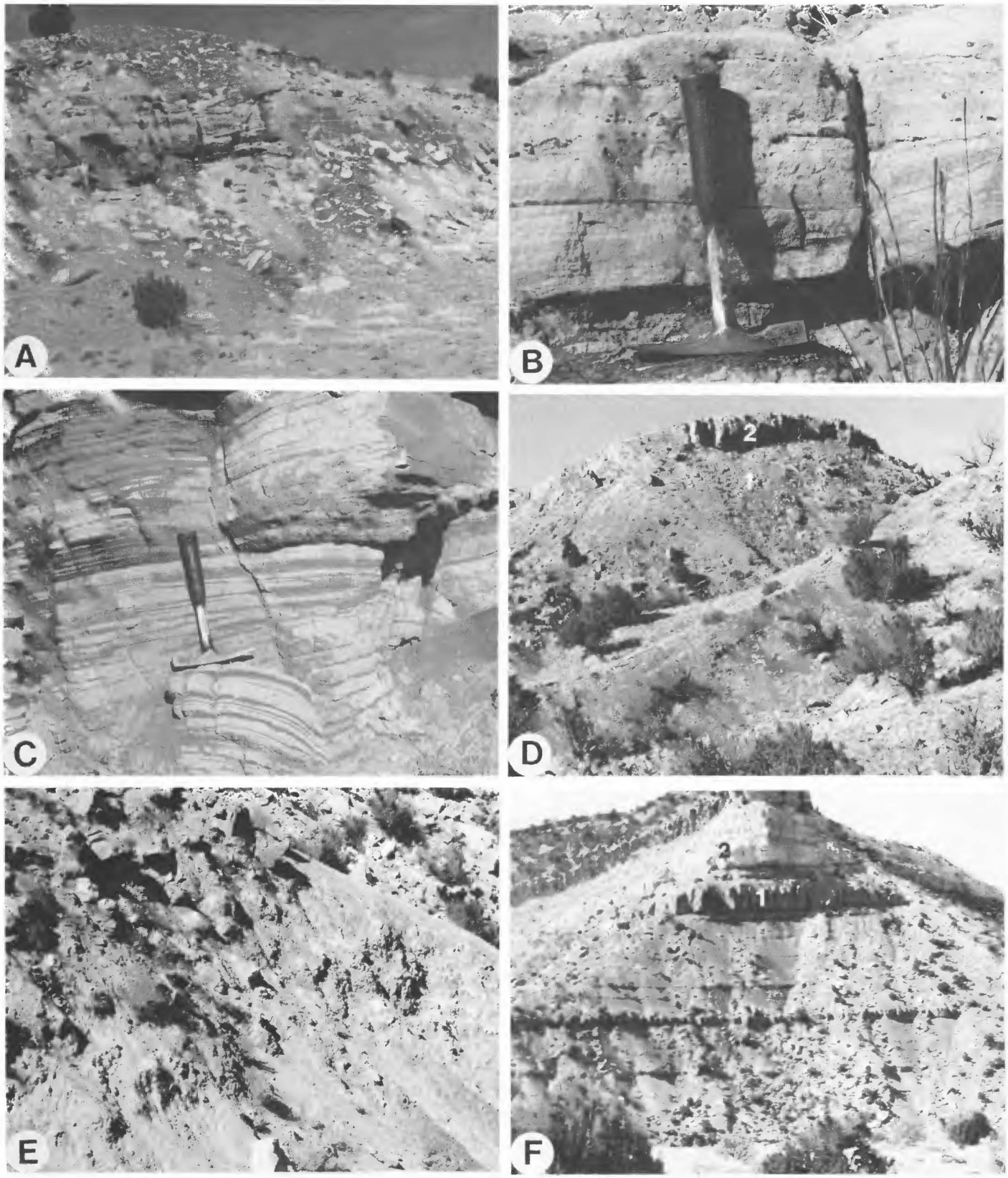


FIGURE 8. Photographs of selected Chinle Group outcrops in the Lucero uplift. A, Sonsela Member forming bench between red-bed mudstones of the Bluewater Creek Formation (below) and the Painted Desert Member (above) in the Cañada Bonita section. B, Close-up of basal conglomeratic sandstone of Sonsela Member, unit 3 of Cañada Bonita section. C, Typical color-banded crossbeds of Sonsela Member, unit 4 of Cañada Bonita section. D, Overview of La Jara Peak section, showing red-bed mudstone slope of Painted Desert Member of Petrified Forest Formation (1) overlain by bench-forming sandstone and conglomerate of Dakota Sandstone (2). E, Pedogenically altered, variegated mudstone of Owl Rock Formation, unit 5 of Petaca Pinta section. F, Overview of upper part of Petaca Pinta section, showing evenly bedded and intercalated slope-forming sandstones and siltstones of the Rock Point Formation (1=top of formation) overlain by Middle Jurassic eolianites of the Entrada Sandstone (2).



FIGURE 9. NMMNH P-22297, part of the paramedian scute of *Desmatosuchus* sp. from NMMNH locality 2810 in the San Pedro Arroyo Formation. A, Dorsal view. B, Edge view. Bar scale = 2 cm.

Phytosauridae. Unionid bivalves also are present with the vertebrate fossils (Hunt et al., 1989). The presence of *Stagonolepis* indicates an Adamanian (late Carnian) age for the Bluewater Creek Formation at Chicken Mountain Tank (Lucas, 1993; Lucas and Hunt, 1993).

We document here another Adamanian vertebrate fossil occurrence in the Lucero uplift. This is a partial paramedian scute of *Desmatosuchus* sp. (Fig. 9) from NMMNH locality 2810 in the San Pedro Arroyo Formation near our Rio Salado section (Fig. 6). The ornamentation of this scute fragment consists of large, deep oblong pits that are arranged randomly and lack a radial pattern. A raised marginal lamina is evident along the preserved margins of this scute. These features strongly support identification of NMMNH P-22297 as *Desmatosuchus* (Case, 1922; Long and Ballew, 1985). This indicates an Adamanian age (Lucas and Hunt, 1993).

The youngest Triassic fossils reported from the Lucero uplift are petrified wood, water-worn fragments of phytosaur bone and nonmarine gastropods. Lucas et al., (1987, p. 88, 93) reported these fossils from the upper part of the Painted Desert member of the Petrified Forest Formation, including the Correo Bed, at the Correo type section on the south flank of Mesa Gigante. These fossils indicate a Late Triassic age, but are not a more precise age indicator.

CORRELATION

A fence diagram (Fig. 10) depicts our interpretation of stratigraphic correlation of Triassic strata across the Lucero uplift and with nearby Triassic outcrops. The diagram correlates four composite sections: (1) Bluewater Creek - Thoreau, T12-13-14 N, R 11-12-13 W, Cibola County, based on data in Stewart et al. (1972) and Lucas and Hayden (1989); (2) Northern Lucero uplift, T6-7-8-9, R 4-5-6, Cibola County, based on data presented here; (3) southern Lucero uplift, T 2-3 N, R 3-4-5 W, Valencia and Socorro Counties, based on data presented here; and (4) Carthage area, T4-5 S, R 2 E, Socorro County based on data in Lucas (1991).

Correlation of the Bluewater Creek-Thoreau composite section with the section in the northern Lucero uplift is very direct because all Triassic stratigraphic units in west-central New Mexico, except the

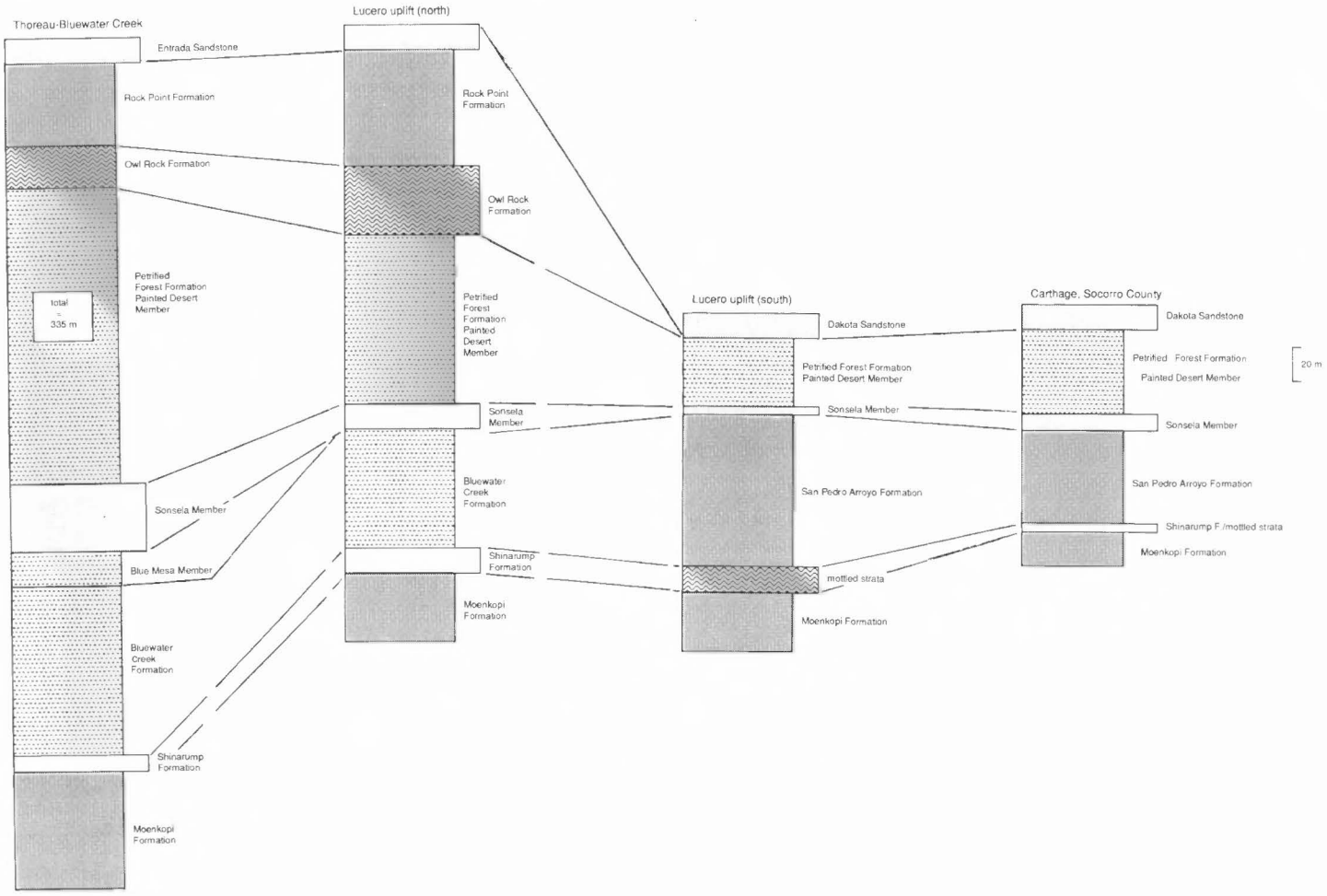


FIGURE 10. Correlation of Triassic strata in the Lucero uplift and nearby areas.

Blue Mesa Member of the Petrified Forest Formation are present in the Lucero uplift. The Blue Mesa Member shows a regional trend of thinning from west to east; in the Petrified Forest National Park of Apache County, Arizona, it is at least 83 m thick but in McKinley County, west-central New Mexico it is 20-40 m thick and in the Lucero uplift it is absent. Over a similar traverse, the Bluewater Creek Formation thickens from about 50 m in McKinley County to more than 70 m in the northern Lucero uplift. This thickening is not, however, as great as the thinning of the Blue Mesa member, so it cannot be argued that the Blue Mesa Member is simply grading eastward into red beds of the upper Bluewater Creek Formation. Clearly, erosion associated with the pre-Sonsela unconformity (Tr-4 unconformity of Lucas, 1993) must account for some (or perhaps all) of the eastward thinning and disappearance of the Blue Mesa Member across the southern Colorado Plateau.

Correlation of the composite sections in the northern and southern Lucero uplifts relies on the persistence of the Moenkopi Formation, Shinarump Formation/mottled strata, Sonsela Member and Painted Desert Member across the Rio Salado (Fig. 10). Strata below the Sonsela Member south of the Rio Salado differ strikingly from the Bluewater Creek Formation in being sandier, having beds of conglomerate and including significant thicknesses of grayish purple mudstones. These strata south of the Rio Salado are lithologically identical to the lower part of the San Pedro Arroyo Formation to the southeast across the Rio Grande at Carthage (Lucas, 1991). For this reason we assign strata between the mottled strata and Sonsela Member in the southern Lucero uplift to the San Pedro Arroyo Formation. These strata occupy the same stratigraphic position as the Bluewater Creek Formation to the north and Adamanian-age aetosaurs also support correlation of the Bluewater Creek and San Pedro Arroyo Formation across the Lucero uplift. Strata above the Sonsela Member in the southern Lucero uplift are red-bed mudstones of the Painted Desert Member identical to Painted Desert Member strata to the north.

Identification and correlation of the San Pedro Arroyo Formation resolves the problems encountered when correlating this unit in its type area at Carthage, Socorro County, discussed by Lucas (1991). Resolution of these problems and a redefinition of the San Pedro Arroyo Formation in its type area are embodied in our fence diagram (Fig. 10). We correlate the pre-Sonsela San Pedro Arroyo Formation strata of the southern Lucero uplift with only the lower part (actually units 2-9) of the San Pedro Arroyo Formation type section. In other words, we limit the San Pedro Arroyo Formation to units 2-9 of Lucas' (1991) original type section, and we identify his unit 10 as Sonsela Member and his units 11-18 as Painted Desert Member. This redefinition recognizes the southeastward continuity of the Sonsela and Painted Desert members from the southern Lucero uplift eastward across the Rio Grande rift to Carthage.

Limited biostratigraphic data and magnetostratigraphy further support these correlations. The Bluewater Creek and lower part of the original San Pedro Arroyo Formation produce some Adamanian-age vertebrates, as does the Santa Rosa and Garita Creek Formation of east-central New Mexico (Lucas, 1993; Hunt and Lucas, 1993). Magnetostratigraphically, the lower San Pedro Arroyo Formation also has the same sequence of magnetic polarity as the Santa Rosa Formation, normal-reversed-normal (Molina-Garza et al., 1993),and this supports correlation of the two units.

What emerges is a much clearer correlation of Chinle Group strata in central New Mexico than was available to previous workers. The redefined San Pedro Arroyo Formation is an Adamanian (upper Carnian) unit that extends from the Lucero uplift across the Rio Grande to as far east as Lincoln County (Lucas, 1991). In Socorro County, the Sonsela Member, followed by the Painted Desert Member (both Petrified Forest Formation) overlie the San Pedro Formation. What the precise equivalents of these upper Chinle Group strata are to the east, in Lincoln County, will have to be resolved with data not now available.

ACKNOWLEDGMENTS

The New Mexico Museum of Natural History and Science supported this research. Adrian Hunt provided some field assistance. Orin Anderson and John Lorenz reviewed an earlier version of this manuscript.

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APPENDIX–STRATIGRAPHIC SECTIONS

Petaca Pinta

Section measured in the SW 1/4 SW1/4 NW 1/4 sec. 31, T6N, R6W, Cibola County by S.G. Lucas and A.P. Hunt, 14 October 1989. Strata are flat-lying

unit	lithology	thickness (m)
	Entrada Sandstone:	
24.	Silty sandstone; grayish yellow (5Y8/4) and moderate reddish brown (10R4/6); quartzarenite; very fine grained; subrounded; moderately sorted; moderately calcareous; trough crossbedded; forms a cliff.	not measured
	unconformity (J-2 unconformity of Pipiringos and O'Sullivan, 1978).	
	Chinle Group:	
	Rock Point Formation:	
23.	Sandy siltstone; grayish red (10R4/2); very calcareous.	2.7
22.	Silty sandstone; moderate reddish brown (10R4/6); quartzarenite; very fine grained; subangular-subrounded; well sorted; slightly micaceous; very calcareous; trough crossbedded and ripple laminated.	5.2
21.	Silty sandstone; moderate reddish brown (10R4/6) and pale reddish brown (10R5/4); micaceous quartzarenite; very fine to fine grained; subrounded; moderately sorted; very calcareous; lower 3 m massive, next 1.5 m trough crossbedded, remainder laminated	9.1
20.	Sandy siltstone; moderate reddish brown (10R4/6); moderately calcareous; climbing ripple laminations.	1.3
19.	Silty sandstone; moderate reddish brown (10R4/6); micaceous quartzarenite; very fine grained; subangular-subrounded; well sorted; very calcareous; massive; forms a persistent ledge.	1.5
18.	Sandy siltstone; pale reddish brown (10R5/4); a few resistant ledges 0.3-0.6 m thick every 3-5 m.	25.1
17.	Silty sandstone; yellowish gray (5Y7/2); quartzarenite; very fine grained; subrounded; well sorted; moderately calcareous; massive; forms a prominent ledge.	1.2
16.	Sandy siltstone, same color and lithology as units 12 and 14.	3.0
15.	Silty sandstone; very pale green (10G8/2) with moderate reddish brown (10R4/6) spots; same lithology as unit 19; massive and blocky; forms a prominent ledge.	0.8
14.	Sandy siltstone; same color and lithology as unit 12.	4.7
13.	Silty sandstone; same color and lithology as unit 15; massive and blocky; top of unit bioturbated; forms a prominent ledge.	2.1
12.	Sandy siltstone; moderate reddish brown (10R4/6) with yellowish gray (5Y7/2) mottles; very calcareous; forms a slope with some thin ledges	13.1
	Total thickness of Rock Point Formation:	69.8
	unconformity (Tr-5 unconformity of Lucas, 1991, 1993).	
	Owl Rock Formation:	
11.	Sandy siltstone; pale reddish brown (10R5/4); very calcareous; much more poorly sorted than overlying units; very bioturbated and blocky	3.3
10.	Silty mudstone; same color and lithology as unit 8.	4.3
9.	Siltstone; grayish red purple (5RP5/2); very calcareous; blocky and mottled ledge.	0.3
8.	Silty mudstone; variegated grayish red purple (5RP4/2) and pale greenish yellow (10Y8/2); calcite veins; approximately in middle of unit is 1.3 m-thick nodular calcrete zone.	5.6
7.	Silty sandstone; mottled grayish red purple (5RP4/2) and very pale green (10G8/2); quartzarenite; very fine to medium grained; subrounded; poorly sorted; very calcareous; bioturbated; forms a blocky ledge.	1.7
6.	Mudstone; variegated very pale green (10G8/2) and grayish red (10R4/2); very calcareous	11.1
5.	Mudstone; variegated grayish red (10R4/2) and very pale green (10G8/2); very calcareous; very bentonitic; contains grayish red (10R4/2) calcrete nodules.	6.1
4.	Sandy siltstone and sandstone; Grayish red purple (5RP4/2), mottles of very pale green (10G8/2); sandstone is very fine to fine grained; poorly sorted; subangular.	1.1
3.	Mudstone; grayish purple (5P4/2); slightly calcareous.	0.6
2.	Sandy siltstone and clay-pebble conglomerate; grayish red purple (5RP4/2) and pale yellowish green (10GY7/2); very calcareous, fills fissures and scours in underlying unit.	2.4
	Thickness of Owl Rock Formation:	36.5
	Petrified Forest Formation:	
	Painted Desert Member:	
1.	Mudstone; dark reddish brown (10R3/4) with moderate yellowish green (5GY7/4) spots; not calcareous; blocky.	not measured

Chicken Mountain Tank

Composite section consisting of four partial sections. These are segments A-D, in ascending order.

Segment D measured at UTM 3830751N, 13285105E. Strata dip 12° to the NW.

unit	lithology	thickness (m)
	Chinle Group:	
	Bluewater Creek Formation:	
	McGaffey Member:	
D4	Fine-grained sandstone; hummocky bedded and ripple laminated; fresh material is yellow gray (5Y7/2) weathering to grayish brown (5YR3/2); some mostly yellow gray (5Y7/2) iron- or magnesium-rich beds; forms persistent, extensive benches 0.5m between scours. Top is a stripped surface.	5.2
	Bluewater Creek Formation:	
D3	Same color and lithology as unit D1.	2.6
D2	Sandstone; hummocky bedded, ripple laminated, bench-forming litharenite; grayish orange pink (5YR7/2) fresh; weathering light brownish gray (5YR6/1); well-sorted, subrounded to subangular very fine grained; calcareous.	1.0
D1	Silty sandstone; very fine light olive gray (5Y6/1) ; well-sorted, subrounded-subangular micaceous litharenite; calcareous.	4.5 +

Segment C measured from UTM 3838867N, 13286397E to 3828809N, 13286065E, where basaltic rubble caps section. Apparent dip of strata is 10° to N 70°W.

	Chinle Group:	
	Bluewater Creek Formation:	
C7	Same color and lithology as unit C5.	10.0 +
C6	Variegated blue, purple and reddish-gray clay with some trough-bedded sandstones in heterolithic crossbeds; sandstones are very fine-grained grayish red (5R4/2) sublitharenite; micaceous; calcareous; weathers to yellow gray (5Y8/1); NMMNH locality 248 produced fossils of the unionid bivalve *Antediplodon* sp. near the middle of this unit.	15.5

C5 Mudstone; waxy grayish red (10R4/2); bentonitic. 0.5
C4 Mudstone; grayish purple (5P4/2); bentonitic; calcareous; mottled very light gray (N8). 1.1
C3 Sandy mudstone; grayish red purple (5RP4/2); bentonitic. 3.8
C2 Bentonitic mudstone; grayish purple (5P4/2); calcareous; large calcrete bed with nodules up to 10 cm in diameter in first 0.3 m of this unit. 5.0
C1 Slightly calcareous grayish purple (5P4/2) bentonitic mudstones; calcrete nodules up to 10 cm in diameter. 6.5 +

Segment B was measured WSW down Horse Mountain Draw on the west limb of the anticline measured for segment A. Strata dip 15° to due west. Section was measured from UTM 3838396N, 13286359E to 3838540N, 13286752E.

Chinle Group:
Bluewater Creek Formation:
B8 Same color, lithology, and weathering profile as unit A12. 5.3
B7 Slope; much covered by debris from B8. 8.2
B6 Sandstone; yellow gray (5Y7/2) to light olive gray (5Y5/2); lithologically identical to B2; calcareous. 2.2
B5 Sandy siltstone and silty sandstone; light olive gray (5Y6/1); micaceous. 5.0

Shinarump Formation:
B4 Same lithology as unit B; more hematized; weathers brownish gray (5YR4/1); fresh color is light to medium gray (N7-N6). 3.9
B3 Trough scour on B2; sandstone identical to unit B2; trough has relief of .5 m. 1.8
B2 Very fine-grained micaceous quartz arenite; well sorted; subrounded-subangular; calcareous; grayish yellow green (5GY7/2) weathering to pale red (5R6/2); planar to wedge planar bedded. 2.3
B1 Trough crossbedded fine- to medium-grained quartzarenite; some beds of limestone cobble conglomerate; sands are well sorted, subrounded, and slightly calcareous; very light gray (N8), weathering pale red (5R6/2); conglomerate clasts are Paleozoic limestones up to 5 cm in diameter; moderate yellow brown (5YR5/4)to pale reddish brown (10R5/4). 2.8

Segment A measured on the east limb of an anticline in the Chicken Mountain Draw/Horse Canyon area, UTM13287136E, 3838429N. Strata dip 15° to S 70°E.

Chinle Group:
Bluewater Creek Formation:
A12Very fine-grained micaceous quartz arenite; yellow gray (5Y8/1); weathers pale olive (10Y6/2) well-sorted; subrounded; calcareous. 3.2
A11 Same color and lithology as unit A7. 2.5
A10 Same color and lithology as unit A6. 1.0
A9 Much covered, same color and lithology as unit A7. 2.5
A8 Ledge-forming ripple-laminated sandstone, same lithology as unit A6. 1.8
A7 Fine-grained micaceous litharenite and grayish red (10R4/2) silty mud; sandstone is pale olive (10Y6/2); calcareous; sandstone is subangular. 2.6
A6 Very fine-grained micaceous litharenite; well-sorted; subangular; ripple laminated; interbeds of siltstone; sandstone is light olive gray (5Y6/1); calcareous. 1.0
A5 Flaggy ripple-bedded thin sandstones like A4 with very micaceous sandy mud; sandstone is light olive gray (5Y5/2); mudstone is pale olive (10Y6/2). 2.5

Shinarump Formation:
A4 Planar bedded flaggy micaceous quartzarenite with some mudballs and Paleozoic limestone clasts; light brownish gray (5YR6/1) and light olive gray (5Y6/1); hematitic; beds are .25m or thinner. 0.9
A3 Scour; conglomerate at base, trough crossbedded sandstone above; same lithology and color as unit A2. 0.8
A2 Very fine- to fine-grained quartzarenite; trough cross-bedded with some pebbly lenses like A1; olive gray (5Y3/2); calcareous. 1.5
A1 Massive, hummocky-bedded conglomerate with interbedded fine- to medium-grained quartzarenite; sandstone is pinkish gray (5YR8/1), subrounded, and calcareous; conglomerate clasts are up to 1.5 cm diameter and consist of greenish gray (5GY6/1) Paleozoic limestone pebbles and grayish red (10R4/2) Moenkopi mudchips. 1.0 +

Cañada Bonita

Section begins at UTM 3830910N, 13280990E and ends at 3830897N, 13281040E. Strata dip 20° to due north.

unit	lithology	thickness (m)
	Chinle Group:	
	Petrified Forest Formation:	
	Painted Desert Member:	
9.	Muddy sandstone; grayish red (5R4/2) with very light gray (N8) spots; very fine- to fine-grained quartzarenite; subrounded; well sorted; not calcareous; forms a slope much covered by terrace gravels.	not measured
	Sonsela Member:	
8.	Sandstone; banded grayish pink (5R8/2) and pale red (5R6/2); feldspathic litharenite; very fine grained; subrounded; well sorted; not calcareous; laminated; forms a resistant bench.	2.6
7.	Sandstone; mottled grayish red (10R4/2) and very light gray (N8); feldspathic litharenite; medium to coarse grained; subangular; moderately sorted; very calcareous; laminated; friable, forms a slope.	5.0
6.	Sandstone; very light gray (N8); some very dusky red purple bands (5RP2/2); micaceous litharenite; medium grained; subrounded; moderately sorted; slightly calcareous; trough cross-bedded.	3.2
5.	Sandstone; grayish pink (5RP 8/2); feldspathic quartzarenite; subangular; fine to medium grained; moderately sorted; not calcareous; some isolated clasts of Paleozoic limestone up to 4 cm in diameter; trough crossbedded.	2.2
4.	Sandstone; pinkish gray (5YR8/1) with bands of very dusky red purple (5RP2/2); quartzarenite; fine grained; subrounded; well sorted; not calcareous; trough crossbedded.	1.2
3.	Conglomeratic sandstone; very light gray (N8), weathers pale red (5R6/2) to grayish red (5R4/2); sandstone is same lithology as unit 2; clasts are very dusky red (10R2/2) mudstone chips, a few cherts and Paleozoic limestones; trough crossbedded.	1.3
	Thickness of Sonsela Member:	15.3
	unconformity (Tr-4 unconformity of Lucas, 1991, 1993).	
	Bluewater Creek Formation:	
2.	Sandstone; pale pink (5RP8/2); lithic quartzarenite; fine to medium grained; subrounded; moderately sorted; calcareous; some biotite; trough cross-bedded; some thin lenses of mudstone of unit 1 color and lithology	1.5
1.	Mudstone; grayish red (5R4/2) and grayish purple (5P2/3); bentonitic; not calcareous.	not measured

Selso Well

Section measured at UTM 3824229N, 13285390E. Strata dip 10° to N 80°E.

unit	lithology	thickness (m)
	Chinle Group:	
	Shinarump Formation:	
9.	Conglomerate and conglomeratic sandstone; light olive gray (5Y6/1) to brownish gray (5YR4/1); conglomerate clasts are mostly gray Paleozoic limestone up to 5 cm in diameter, but a few clasts of yellow and red chert and jasper are present; matrix is fine- to coarse-grained sandstone that is a poorly sorted, subrounded, calcareous litharenite; trough crossbedded; forms a bench.	1.2 +
	unconformity (Tr-3 unconformity of Pipiringos and O'Sullivan, 1978).	
	Moenkopi Formation:	
	Anton Chico Member:	
8.	Silty mudstone; same colors and lithology as unit 6; forms a slope.	4.8
7.	Sandstone and conglomerate; sandstone is grayish red (5R4/2) to pale reddish brown (10R5/4); very fine grained, well sorted, subrounded; non-calcareous micaceous litharenite; conglomerate is grayish red (10R4/2), matrix-supported,	

calcareous mudstone pellets up to 1 cm in diameter; trough crossbedded and ripple laminated with conglomerate in trough bases; forms the only prominent bench in the Moenkopi slope. 2.0
6. Silty mudstone; moderate reddish brown (10R4/6); calcareous; contains lenses of greenish gray (5GY6/1), calcareous, bioturbated micaceous silt-stone. 6.3
5. Sandstone; light olive gray (5Y6/1); very fine grained; well sorted; subrounded; calcareous; micaceous litharenite; trough crossbedded; forms a ledge; has some lenses of conglomerate of unit 7 lithology with unidentifiable bone fragments. 0.5
4. Silty mudstone and muddy siltstone; moderate reddish brown (10R4/6). 2.0
3. Siltstone and sandy siltstone; yellowish gray (5Y7/2) but weathers pale reddish brown (10R5/4); calcareous; ripple laminated. 0.8
2. Covered slope; probably yellow siltstone. 8.5
Thickness of Moenkopi Formation: 24.9

unconformity (Tr-1 unconformity of Pipiringos and O'Sullivan, 1978).

San Andres Formation (Permian)

1. Limestone; pale yellowish orange (10YR8/6); weathers grayish orange (10YR7/4); forms a bench. not measured

La Mesa de Victorino

Measured in the NE 1/4 SW 1/4 sec. 31, T3N, R4W, Socorro County. Section begins at UTM 3813209N, 13288841 E and ends at 3813427N, 13288823E. Strata dip 40° to N 30° W. This is the section described by Tonking (1957, p. 58-59).

unit	lithology	thickness (m)

Chinle Group:
San Pedro Arroyo Formation:
20. Silty and sandy mudstone; pale reddish brown (10R5/4); calcareous; forms a slope. 10.5 +
"mottled strata"
19. Mud-pellet conglomerate; pale red (5R6/2), weathers grayish red (10R4/2); calcareous; mottled and bioturbated; contains pale red (10R6/2) calcrete nodules; ledgy and blocky. 3.5
18. Muddy, sandy siltstone; grayish red (10R4/2) with light gray (N7) reduction spots; calcareous. 3.8
17. Mud-pellet conglomerate; pale red (5R6/2) with color mottling like unit 15; calcareous; some crude trough crossbeds. 1.3
16. Muddy sandy siltstone; pale red (5R6/2); calcareous; heavily modified pedogenically. 2.8
15. Mud-pellet conglomerate; grayish red (10R4/2) with color mottling of moderate reddish orange (10R6/6), moderate reddish brown (10R4/6), pale red (5YR6/2) and medium dark gray (N4); not calcareous; pellets up to 0.5 cm in diameter; rip-ups of Moenkopi mud-stone. 3.0
Total thickness of "mottled strata": 14.4

unconformity (Tr-3 unconformity of Pipiringos and O'Sullivan, 1978)

Moenkopi Formation:
Anton Chico Member:
14. Sandstone; same color and lithology as unit 7. 3.5
13. Sandstone; grayish red (5R4/2); micaceous litharenite; very fine grained; subrounded; well sorted; calcareous; trough-crossbedded; fines upward, grades into overlying unit. 8.8
12 Silty mudstone; same color and lithology as unit 6. 1.1
11. Sandstone; grayish red (5R4/2); very fine grained; micaceous litharenite; subangular-subrounded; well sorted; has iron-rich (goethitic) laminae that are brownish black (5YR2/1) to black (N1); wavy laminated and shallow trough crossbeds. 0.3
10. Silty mudstone; same colors and lithology as unit 6; lower 0.5 m of unit is a calcareous paleosol. 6.0
9. Sandstone; pale red (10R6/2); same lithology as unit 7; trough crossbedded; contains some pebbly beds like those of unit 7; forms a prominent bench; section is offset at top of this unit ~ 100 m to NW. 2.5
8. Silty mudstone; same colors and lithology as unit 6; top of unit is a paleosol. 3.5
7. Sandstone; grayish red (10R4/2); micaceous litharenite; fine grained; subangular-subrounded; well sorted; calcareous; trough crossbedded; has some pebbly beds of grayish red mudstone/siltstone; forms a bench. 1.8
6. Silty mudstone; grayish red (10R4/2); calcareous; has some lenses of mud-pellet conglomerate that are pale red (10R6/2) to light olive gray (5Y6/1); much pedogenic modification; forms a hackly slope; base of this unit=unit 1 of Tonking's section. 12.5
5. Muddy siltstone; yellowish gray (5Y8/1); calcareous; ripple laminated and bioturbated. 2.3
4. Sandstone; light brownish gray (5YR6/1); weathers light gray (N7); micaceous litharenite; medium grained; subrounded; well sorted; calcareous; trough crossbedded; some pebbly lenses (of unit 3 lithology) at bases of trough axes. 10.0
3. Conglomerate and conglomeratic sandstone; conglomerate is pale red (5R6/2) and light olive gray (5Y6/1) with clasts of San Andres Formation limestone up to 2 cm in diameter; sandstone is moderate reddish brown (10R4/6) and very light gray (N8) micaceous litharenite that is fine-medium grained, subangular, moderately sorted and hematitic; trough crossbedded. 0.8
2. Sandstone and siltstone; sandstone is yellowish gray (5Y8/1) and light greenish gray (5GY8/1), very fine-medium grained, poorly sorted, subangular, calcareous, micaceous litharenite; siltstone is grayish orange (10YR7/4), muddy and very calcareous; sandstone is hummocky laminated and ripple laminated. 6.5
Total thickness of Moenkopi Formation: 51.6

unconformity (Tr-1 unconformity of Pipiringos and O'Sullivan, 1978)

San Andres Formation:
1. Dolomitic limestone; yellowish gray (5Y7/2); micritic. not measured

La Jara Peak

Measured in the SE 1/4 sec. 10, T2N, R5W, Socorro County. Section begins at UTM 3810274N, 13284528E in arroyo bottom and ends at 3810365N, 13284483 E. Strata are flat-lying.

unit	lithology	thickness (m)

Dakota Sandstone:
3. Sandstone and conglomeratic sandstone; pale red (5R6/2), weathers dark yellowish orange (10YR6/6); quartzarenite, very fine to fine grained; subangular-subrounded; poorly sorted; hematitic; not calcareous; siliceous pebbles; trough crossbedded; forms a prominent cliff. not measured

unconformity

Chinle Group:
Petrified Forest Formation:
Painted Desert Member:
2. Mudstone; grayish orange (10YR7/4); not calcareous. 1.1
1. Silty and sandy mudstone; grayish red (5R4/2) with light greenish gray (5GY8/1) reduction spots; not calcareous; forms a slope much covered by colluvium. 32.8 +

Rio Salado

Section starts at UTM 2809765N, 13291284E and ends at 3809108N, 13290989E. Strata dip 7° due South.

unit	lithology	thickness (m)

Chinle Group:
Petrified Forest Formation:
Painted Desert Member:
36. Mudstone; dark reddish brown (10R3/4); bentonitic; calcareous. not measured
35. Sandstone; light brownish gray (5YR6/1); very fine grained; subrounded; well sorted; litharenite; not calcareous; trough crossbedded; forms a cuesta. 1.0

34. Mudstone; grayish red (5R8/2) and grayish pink (5R8/2); bentonitic; calcareous. 5.2

Sonsela Member:

33. Sandstone; same colors and lithology as unit 31; laminated in shallow troughs; a porphyritic dike cuts the top of this unit locally. 0.2
32. Mudstone; grayish red purple (5RP4/2); bentonitic; calcareous. 0.8
31. Sandstone; very light gray (N8); very fine grained; well sorted; subrounded; litharenite; not calcareous; trough crossbedded. 1.0
30. Conglomerate; grayish green (5G5/2); weathers grayish red purple (5RP4/2); clasts are rounded calcrete, mudstone and siltstone pebbles up to 0.5 cm in diameter; clast supported. 0.5

Total thickness of Sonsela Member: 2.5

unconformity (Tr-4 unconformity of Lucas, 1993)

San Pedro Arroyo Formation:

29. Mudstone; same color and lithology as unit 25. 2.5
28. Sandstone; grayish red purple(5RP4/2); very fine grained; micaceous litharenite; subrounded; well sorted; trough crossbedded; some pebbly beds; forms a ledge. 2.2
27. Mudstone; same color and lithology as unit 25. 3.3
26. Siltstone; light gray (N7); not calcareous; massive; very well indurated; forms a ledge. 0.5
25. Mudstone; grayish red (5R4/2); bentonitic; calcareous; contains numerous medium light gray (N6) calcrete nodules. 12.3
24. Conglomerate; pale yellowish brown; clast supported; clasts are rounded calcrete and mudstone pebbles; massive. 0.1
23. Sandstone; light gray (N7); same lithology as unit 17; planar crossbedded; forms a cuesta. 0.5
22. Sandstone; light brownish gray (5YR6/1); weathers brownish gray (5YR 4/1); very fine-fine grained; micaceous litharenite; subangular, poorly sorted; laminated. 1.5
21. Conglomerate; medium gray (N5) and bluish white (5B9/1); clasts are rounded calcrete pebbles up to 2 cm in diameter; contains *Desmatosuchus* sp. at NMMNH locality 94-18. 0.9
20. Mudstone; same color and lithology as unit 11. 0.7
19. Sandstone; same colors and lithology as unit 17 except rock is mostly light gray (N7) and weathers brownish gray (5YR4/1). 0.3
18. Mudstone; same colors and lithology as unit 11. 2.5
17. Sandstone; pale red (5R6/2); very fine grained; litharenite; well sorted; subrounded; not calcareous; laminated in shallow trough crossbeds; crest of ridge. 1.5
16. Mudstone and sandstone, interbedded; mudstone same colors and lithology as unit 11; sandstone is banded light olive gray (5Y6/1) and grayish purple(5R4/2), fine grained micaceous litharenite, subangular, moderately sorted, not calcareous, laminated. 5.5
15. Conglomerate; brownish gray (5YR4/1); clast supported; clasts are rounded calcrete pebbles up to 1 cm in diameter; some trough crossbeds. 0.3
14 Covered slope; probably same lithology as units 13 and 11. 13.2
13. Mudstone; same colors and lithology as unit 11. 7.5
12. Calcrete (limestone); massive to nodular; olive gray (5Y4/1). 1.3
11. Mudstone; grayish red purple (5RP4/2) with very light gray (N8) mottles; bentonitic; calcareous; forms a powdery slope. 1.5
10. Silty mudstone; grayish red (10R4/2) with light greenish gray (5GY8/1) mottles; some sandy lenses; not calcareous. 1.5
9. Sandstone; moderate red (5R5/4); weathers pale red (5R6/2) and moderate pink (5R7/4); very fine grained; micaceous litharenite; subangular; well sorted; calcareous; massive to ripple laminated; forms a thin ledge. 0.4
8. Covered; gully cuts show red mudstone identical to unit 7. 26.0
7. Mudstone; grayish red (10R4/2) with light greenish gray (5GY8/1) to light gray (N8) mottles; bentonitic; calcareous. 4.0

Thickness of San Pedro Arroyo Formation: 90.0

"mottled strata":

6. Calcrete (limestone) and silcrete; mottled medium dark gray (N4), grayish purple (5P4/2), light gray (N7) and pale red (10R6/2); some clasts of light olive gray quartzite up to 4 cm in diameter and moderate pink (5R7/4) to dark gray (N3) jasper up to 2 cm in diameter. 0.7

unconformity (Tr-3 unconformity of Pipiringos and O'Sullivan, 1978)

Moenkopi Formation:

Anton Chico Member:

5. Sandstone; same color and lithology as unit 1. 0.3
4. Muddy siltstone; grayish red (10R4/2); not calcareous. 1.0
3. Sandstone; same color and lithology as unit 1. 0.8
2. Muddy siltstone; grayish red (10R4/2); not calcareous. 0.5
1. Sandstone; pale reddish brown (10R5/4); weathers grayish red (10R4/2); very fine grained; subrounded; well sorted; litharenite; not calcareous; ripple laminated with small trough crossbeds; forms a ledge. 0.8

Cañon del Alamito

Start at UTM 3810190N, 13290223E, end at 3908483 N, 13291592 E. Strata are nearly flat-lying.

unit	lithology	thickness (m)

Dakota Group:

11. Sandstone; light olive gray(5Y6/1); weathers moderate orange pink (10R7/4); quartzarenite; very fine-fine grained; subrounded; poorly sorted; not calcareous; trough crossbedded; forms a bench capping the escarpment. not measured

unconformity

Chinle Group:

Petrified Forest Formation:

Painted Desert Member:

10. Mudstone; pale red (5R6/2); bentonitic; calcareous: forms a slope. 20.1
9. Silty sandstone and mudstone interbeds; grayish red (10R4/2) with some white (N9) to light greenish gray (5GY8/1) mottles; very fine grained; litharenite; poorly sorted; subangular; not calcareous; trough crossbedded and ripple laminated; thin interbedding of sandstone and mudstone beds; tops of sandstone beds are bioturbated. 2.0
8. Mudstone; dark reddish brown (10R3/4); calcareous; bentonitic; contains light gray (N7) calcrete nodules. 8.8
7. Mudstone; grayish red (10R4/2); bentonitic; calcareous; contains medium gray (N5) calcrete nodules.

[There is a stratigraphic gap due to cover and a possible fault between units 6 and 7; this gap appears at most to be 3-4 m of the lowermost Painted Desert Member]

Sonsela Member:

6. Conglomerate; same colors and lithology as unit 2; top of the unit here is not its stratigraphic top but a stripped surface. 0.2 +
5. Sandstone; same colors and lithology as unit 3; laminated and low angle trough crossbedded. 1.0
4. Conglomerate; same colors and lithology as unit 2. 0.3
3. Sandstone; pale red (5R6/2) with laminae of grayish red purple (5RP4/2); litharenite; fine grained; subangular; well sorted; not calcareous; trough and planar crossbedded; some laminated beds. 2.5
2. Conglomerate; medium light gray (N6) with grayish red purple (5RP4/2) mottles; clasts are well rounded calcrete and mudstone pebbles up to 1 cm in diameter; some crude trough crossbeds. 0.8

Thickness of Sonsela Member: 4.8

unconformity (Tr-4 unconformity of Lucas, 1993)

San Pedro Arroyo Formation:

1. Mudstone; grayish red (5R4/2); bentonitic; calcareous. 6.8 +