Zeigler, K.E., Heckert, A.B., and Lucas, S.G., eds., 2003, Paleontology and Geology of the Snyder Quarry, New Mexico Museum of Natural History and Science Bulletin No. 24.

UPPER TRIASSIC STRATIGRAPHY AND BIOSTRATIGRAPHY, CHAMA BASIN, NORTH-CENTRAL NEW MEXICO

SPENCER G. LUCAS, KATE E. ZEIGLER, ANDREW B. HECKERT and ADRIAN P. HUNT

New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, NM 87104-1375

Abstract—Triassic strata in the Chama basin of Rio Arriba County, New Mexico, pertain to the Upper Triassic Chinle Group (in ascending order, the Zuni Mountains, Shinarump, Salitral, Poleo, Petrified Forest and Rock Point formations). The local base of the Chinle Group is the Zuni Mountains Formation (formerly "mottled strata"), a pedogenic weathering profile as much as 7 m thick, developed in the top of the Pennsylvanian-Permian Cutler Group. Where the Zuni Mountains Formation is absent, the base of the Chinle Group is the Shinarump Formation, which also locally overlies the Zuni Mountains Formation. In the Chama basin, the Shinarump Formation (= Agua Zarca Formation of previous usage) is as much as 13 m thick and consists mostly of trough-crossbedded, quartzose sandstone and siliceous conglomerate. The overlying Salitral Formation is as much as 31 m of mostly greenish and reddish brown, smectitic mudstone. We divide the Salitral Formation into two members named here: a lower, Piedra Lumbre Member of greenish mudstone with a peristent sandstone bed (the El Cerrito Bed, also named here) at its top, and an upper, Youngsville Member, mostly reddish-brown mudstone. The Poleo Formation is up to 41 m thick and is mostly grayish yellow, trough-crossbedded litharenitic and subarkosic sandstone with minor amounts of both intrabasinal and siliceous conglomerate. Above the Poleo Formation, as much as 200 m of strata, dominated by reddish brown, smectitic mudstone, constitute the Petrified Forest Formation. In the Chama basin, the Petrified Forest Formation consists of two members, the lower Mesa Montosa Member (named here), up to 24 m of thin-bedded sandstone, siltstone and mudstone, which is overlain by up to 176 m of the mudstone-dominated Painted Desert Member. The Rock Point Formation in the Chama basin is as much as 70 m thick and mostly laterally persistent, repetitive beds of reddish brown and grayish red siltstone and ripple-laminar sandstone that disconformably overlie the Petrified Forest Formation.

In the Chama basin, unionid bivalves from the Petrified Forest Formation suggest a Revueltian age, and palynomorphs from the Rock Point Formation are of Norian age. Three formations of the Chinle Group in the Chama basin contain biochronologically important vertebrate fossils, notably the aetosaur *Desmatosuchus haplocerus* (Adamanian) in the Salitral Formation, the aetosaurs *Typothorax coccinarum* and *Desmatosuchus chamaensis* and the phytosaur *Pseudopalatus* (Revueltian) in the Petrified Forest Formation, and the phytosaur *Redondasaurus* (Apachean) in the Rock Point Formation. These fossils and lithostratigraphy allow precise correlation of the Chinle Group strata exposed in north-central New Mexico with other Upper Triassic strata in New Mexico.

Keywords: Upper Triassic, Chinle Group, lithostratigraphy, Chama basin, New Mexico

INTRODUCTION

The Chama basin of north-central New Mexico is a physiographic basin formed by the Chama River and its tributaries, especially the Rio Gallinas (Fig. 1). Located on the eastern edge of the Colorado Plateau, the Chama basin lies between the eastern margin of the structural San Juan Basin and the western edge of the Rio Grande rift. Outcrops in the Chama basin are a thick, nearly flat-lying section of Permian and Mesozoic sedimentary rocks overlain in some areas by late Cenozoic basalts and other volcanic rocks. A significant portion of this section is nonmarine red-bed siliciclastics of Late Triassic age. These are strata of the Chinle Group, and this article reviews the lithostratigraphy and biostratigraphy of Chinle Group strata in the Chama basin.

PREVIOUS STUDIES

Scientific study of the Triassic strata in the Chama basin began with the work of Edward Drinker Cope (1840-1897), who traversed part of the basin in 1874 as a member of the Wheeler Survey of the U.S. Army (Simpson, 1951). Near Gallina (Fig. 1), Cope collected the first Upper Triassic vertebrate fossils discovered in the American West (including the type material of the aetosaur *Typothorax coccinarum* Cope), as well as the type specimens of the bivalves Meek (1875) named *Unio cristonensis*, *U. gallinensis* and *U. terraerubrae* (Lucas and Hunt, 1992; Hunt and Lucas, 1993; Heckert and Lucas, 2002). Cope (1875, 1877) simply referred to the rocks that contained the fossils as Triassic, making no lithostratigraphic assignment. Several years later, a professional fossil collector hired by Cope, David Baldwin, collected additional vertebrate fossils from the Triassic of north-central New Mexico, including the type specimens of the phytosaur *Belodon buceros* and the dinosaur *Coelophysis* (Cope, 1881, 1887a,b, 1889; Huene, 1915; Colbert, 1989; Sullivan et al., 1996; Heckert and Lucas, 2002; Lucas et al., 2002).

In an effort to follow up on the discoveries of Cope and Baldwin, E.C. Case, S.W. Williston and F. von Huene explored the Permian and Triassic in north-central New Mexico in 1910 (Case and Williston, 1912). Based on this expedition, Huene (1911) published a short article in which he described the Permian-Cretaceous section at "Mesa Poleo" (Mesa Montosa, just north of Arroyo del Agua of current maps). He coined the name "Poleo-top-sandstone" for the Triassic sandstone that caps the mesa (Lucas and Hunt, 1992, fig. 7), and thus introduced the first lithostratigraphic name for Triassic rocks in north-central New Mexico. Huene (1915) incorrectly correlated the "Poleo-top sandstone" to the "Shinarump Conglomerate," but correctly inferred that post-Poleo strata in the Chama basin are of Late Triassic age.

Wood and Northrop (1946) mapped the Triassic and adjacent strata in much of north-central New Mexico and assigned the Triassic rocks to the Chinle Formation of Gregory (1917). They named two new strati-

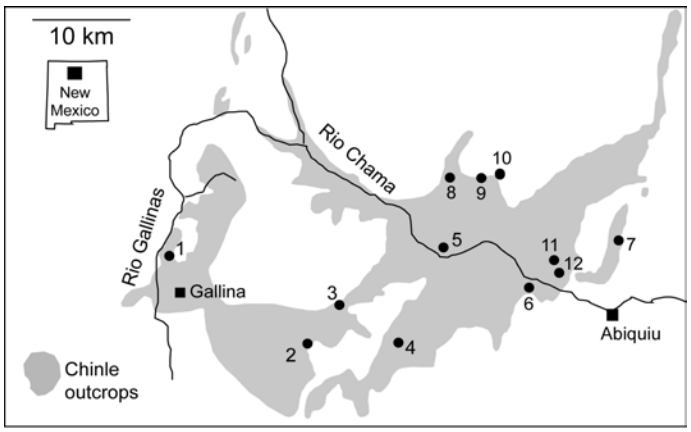


FIGURE 1. Map of the distribution of Chinle Group strata in the Chama basin of north-central New Mexico (after Dane and Bachman, 1965) showing the locations of measured sections in this article. Locations are: 1 = Cerro Blanco, 2 = Mesa Montosa (type Agua Zarca, Salitral and Poleo formations, Mesa Montosa A and B sections), 3 = Coyote amphitheater, 4 = Youngsville landfill; 5 = Piedra Lumbre, 6 = Abiquiu Dam, 7 = Minas de Pedro, 8 = Snyder quarry, 9 = Canjilon quarry, 10 = Ghost Ranch *Coelophysis* quarry, 11 = Orphan Mesa, 12 = Rest Stop. The section at Chaves Box (Fig. 5) is located north of the map area. Appendix 1 gives precise map coordinates for all of the measured sections.

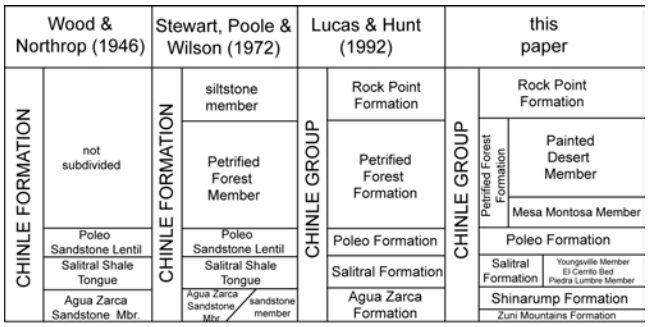


FIGURE 2. Development of lithostratigraphic nomenclature of Upper Triassic strata in the Chama basin.

graphic units for strata below Huene's (1911) Poleo, the "Agua Zarca sandstone member" and "Salitral shale tongue" of the Chinle Formation. They referred to the stratigraphic unit named by Huene (1911) as the "Poleo sandstone lentil" of the Chinle. The nomenclature introduced by Wood and Northrop (1946) was formally accepted by the U.S. Geological Survey (Keroher et al., 1966) and followed by subsequent authors, with recognition of two Chinle members above the Poleo: Petrified Forest Member overlain locally by the "siltstone member" (Smith et al., 1961; Stewart et al., 1972; O'Sullivan, 1974; Dubiel, 1989) (Fig. 2).

Kurtz (1978; see also Kurtz and Anderson, 1980) and Dubiel (1989) undertook sedimentological studies of the Triassic strata of north-central New Mexico. The discovery of the dinosaur quarry at Ghost Ranch (Colbert, 1947, 1950, 1964, 1974, 1989) and the nearby Canjilon phytosaur quarry (Camp, 1930; Lawler, 1976; Ballew, 1986, 1989; Hunt and Lucas, 1989; Long et al., 1989; Hunt and Downs, 2002) demonstrated the great paleontological potential of the strata first collected by Cope and Baldwin. More recent publications on the paleontology of the Triassic in north-central New Mexico include Ash (1974), Litwin (1986), Padian (1986), Colbert (1989), Hunt and Lucas (1989, 1991, 1993), Litwin et al. (1991), Berman and Reisz (1992), Lucas and Hunt (1992), Sullivan et al. (1996), Heckert et al. (1999a, b, 2000), Heckert and Lucas (2002), Martz (2002a,b), Lucas et al. (2002), Zeigler (2002), and Zeigler et al. (2002a, b).

Lucas and Hunt (1992; Lucas, 1993; Hunt and Lucas, 1993; Sullivan et al., 1996) revised the Upper Triassic lithostratigraphy in the Chama basin. They assigned the section to the Chinle Group divided into the (ascending order) Agua Zarca, Salitral, Poleo, Petrified Forest and Rock Point formations. Here, we modify and further subdivide this lithostratigraphy (Fig. 2).

LITHOSTRATIGRAPHY

We assign all Upper Triassic strata in the Chama basin to six formations of the Chinle Group (in ascending order): Zuni Mountains, Shinarump, Salitral, Poleo, Petrified Forest and Rock Point formations (Figs. 2-8).

Zuni Mountains Formation

In the Chama basin, strata formerly termed "mottled strata" (Stewart et al., 1972; Lucas and Hunt, 1992; Hunt and Lucas, 1993) are here assigned to the Zuni Mountains Formation of Heckert and Lucas (2003). These strata are pedogenically modified siltstone, mudstone and sandstone beneath the Shinarump Formation. On the Colorado Plateau, they represent a paleoweathering profile developed on pre-Chinle Permian or Triassic strata, and Heckert and Lucas (2003) formally designated the "mottled strata" of prior usage the Zuni Mountains Formation, with a type section in the Zuni Mountains of west-central New Mexico, southwest of the Chama basin.

In the Chama basin, the Zuni Mountains Formation is relatively thin, as much as 7 m thick, and usually absent (Fig. 3); at most places the Shinarump Formation rests disconformably on the underlying Pennsylvanian-Permian Cutler Group. Where locally present, such as at Mesa Montosa (Fig. 3), the Zuni Mountains Formation is sandy mudstone, siltstone and sandstone that is color mottled various shades of purple, orange, gray, yellow, green and brown (Lucas and Hunt, 1992). These color-mottled strata grade downward into Cutler red beds. Thus, Zuni Mountains strata in the Chama basin are genetically Cutler strata, subsequently modified pedogenically and mapped with Chinle Group strata. They are the product of a weathering profile developed during the Tr-3 unconformity (Lucas, 1993), and are widespread across the Colorado Plateau (e.g., Stewart et al., 1972; Lucas, 1993; Heckert and Lucas, 2003), so the presence of the Zuni Mountains Formation in the Chama basin is not surprising.

Shinarump Formation

Above local outcrops of the pedogenic profile termed Zuni Mountains Formation, the base of the Chinle Group in the Chama basin is a pervasive sheet of quartzose sandstone, conglomeratic sandstone and siliceous, extraformational conglomerate. Wood and Northrop (1946) named this unit the Agua Zarca sandstone member of the Chinle formation, and subsequent workers (e.g., Smith et al., 1961; Stewart et al., 1972; O'Sullivan, 1974; Dubiel, 1989; Lucas and Hunt, 1992; Hunt and Lucas, 1993; Lucas, 1993) have continued to use that name. However, we abandon the name Agua Zarca and replace it with the older name Shinarump Formation. Shinarump is used as a formation name in west-central New Mexico, and in eastern Arizona and southwestern Utah (e.g., Stewart et al., 1972), and the unit called Shinarump in these regions clearly is correlative to the Agua Zarca of the Chama basin (Stewart et al., 1972; Lucas, 1993). Furthermore, both units are of identical lithotypes (quartzose sandstone, conglomeratic sandstone, and silica-pebble conglomerate). It thus serves no useful purpose to perpetuate the name Agua Zarca; it is an unnecessary local synonym of Shinarump.

In the Chama basin, the Shinarump Formation is as much as 13 m thick (Fig. 3). Trough crossbeds are the dominant bedform, and sand-

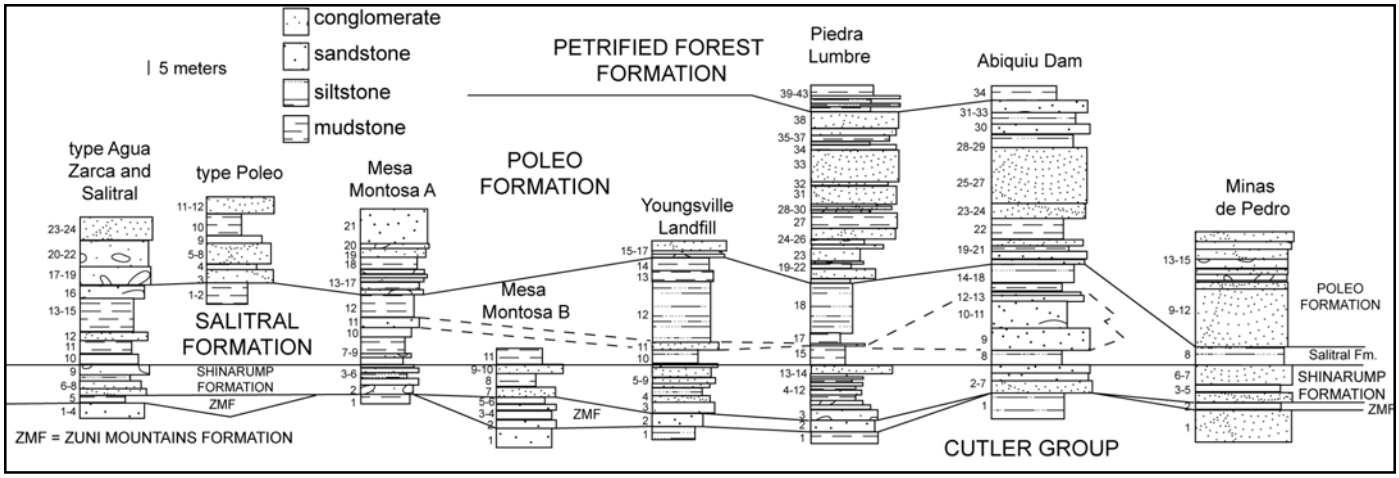


FIGURE 3. Measured stratigraphic sections of the lower Chinle Group (Zuni Mountains, Shinarump, Salitral and Poleo formations) in the Chama basin. See Appendix 1 for description of numbered lithologic units.

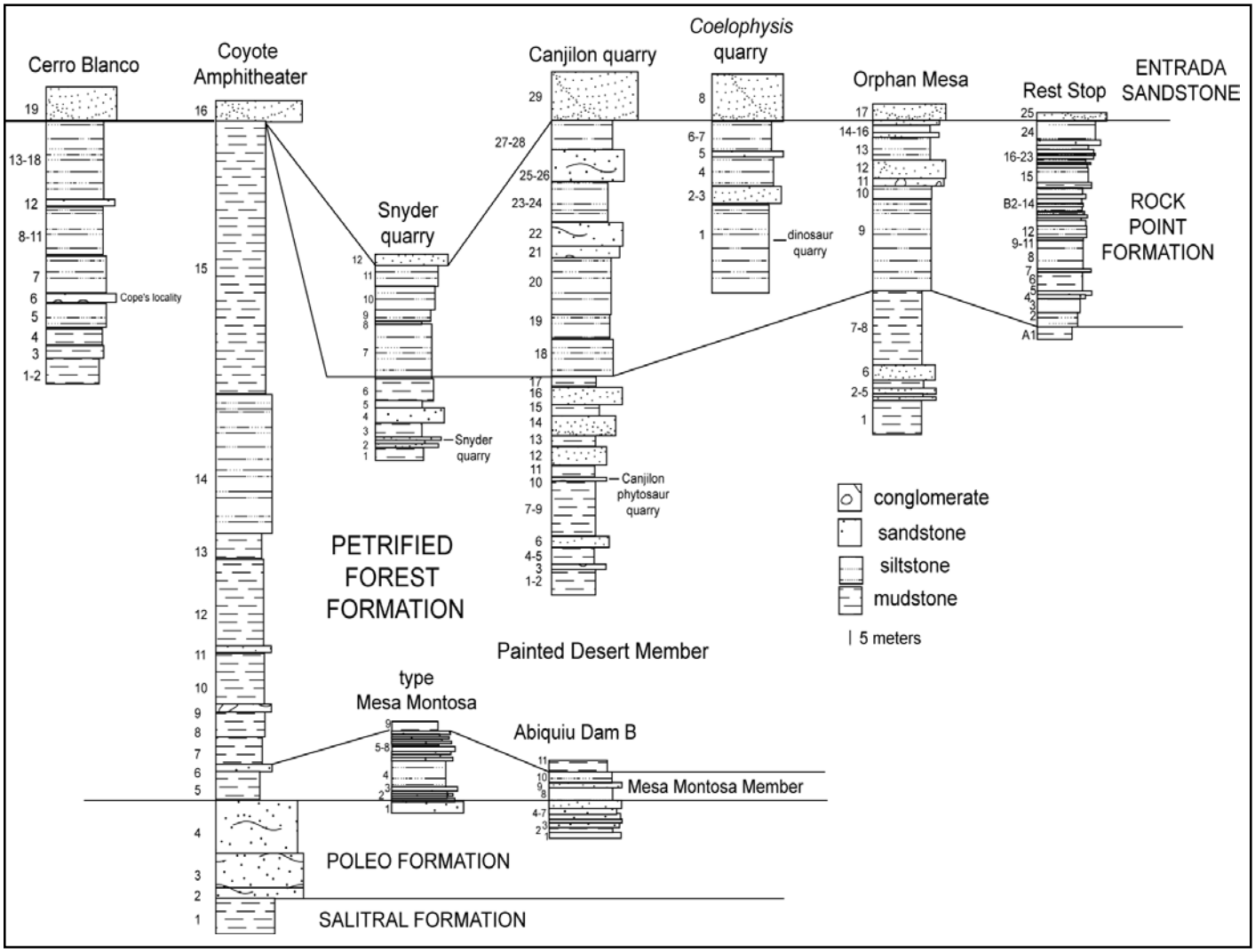


FIGURE 4. Measured stratigraphic sections of the upper Chinle Group (Petrified Forest and Rock Point formations) in the Chama basin. See Appendix 1 for description of numbered lithologic units.

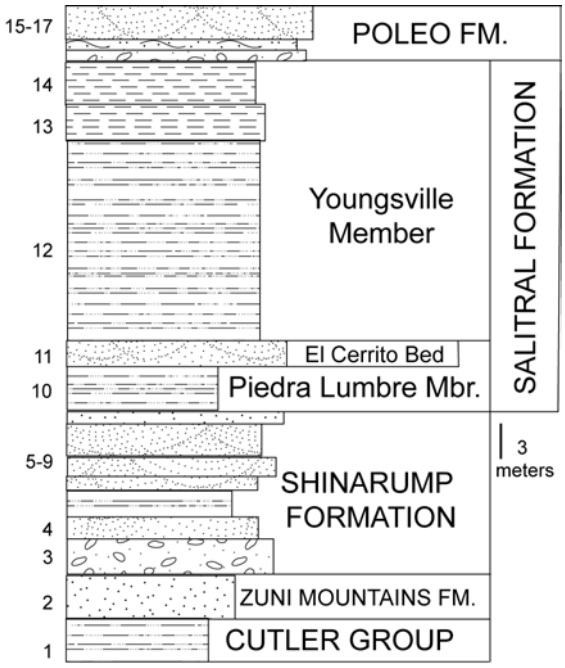


FIGURE 5. Youngsville landfill section, the type section of the Piedra Lumbre Member, El Cerrito Bed and Youngsville Member of the Salitral Formation. See Appendix 1 for description of numbered lithologic units. Legend as in Figures 3-4.

stone petrology is mature (quartzose). Colors are mostly greenish gray and grayish yellow, but in some locations (such as our Youngsville landfill and Piedra Lumbre sections), pale red, pale orange and moderate brown colors are also present. This color variation mostly reflects local mineralization (copper, uranium) that produces colors that range from black to yellow to green. Indeed, stratiform copper was mined long ago on a small scale from the Shinarump Formation in El Cobre Canyon (Newberry, 1876). In the Chama basin, petrified logs and other pieces of silicified wood are locally common in the Shinarump Formation.

The Shinarump Formation across the Chama basin forms a light-colored ledge, bench or cliff at the base of the Chinle Group. Its basal contact is a sharp, erosional scour on underlying finer grained strata of the Zuni Mountains Formation or of the Cutler Group. However, at Chaves Box (Fig. 6), the Shinarump rests on Precambrian basement or a thin interval of marine Pennsylvanian strata (Muehlberger, 1967). This is one of the most profound expressions of the Tr-3 unconformity at the base of the Chinle Group (Pipiringos and O'Sullivan, 1978; Lucas, 1993). The upper contact of the Shinarump Formation is fairly sharp as well, where mudstone at the base of the Salitral Formation rests directly on sandstone or conglomeratic sandstone of the Shinarump Formation. Whether or not this upper contact of the Shinarump Formation is a substantial disconformity cannot be determined without additional age data.

Salitral Formation

Wood and Northrop (1946) introduced the term "Salitral shale tongue" for strata between the Shinarump and Poleo formations in the Chama basin. We continue to use this name as Salitral Formation, following Lucas and Hunt (1992), but propose formal subdivisions of the Salitral here.

In terms of regional Chinle Group stratigraphy, the Salitral Formation occupies the same stratigraphic interval as the Bluewater Creek Formation and the Blue Mesa Member of the Petrified Forest Formation in west-central New Mexico, and the Monitor Butte Formation and Blue Mesa Member of the Petrified Forest Formation in southeastern Utah (Lucas et al., 1997, 1999; Heckert and Lucas, 2002, 2003). This homotaxis suggests that the Salitral is equivalent to one or more of these units, but it is not a synonym of one of these units. This is because the Salitral Formation is a much thinner unit than its equivalents and preserves a succession of lithotypes — green mudstone, overlain by persistent sandstone capped by red mudstone — different from its homotaxial equivalents. The Salitral Formation in the Chama basin thus remains a distinctive, mappable lithofacies of the lower Chinle Group that also crops out along the southern flank of the Nacimiento uplift and as far east as the Hagan basin-Placitas area near Albuquerque (Lucas and Heckert, 1995, 1996; Lucas et al. 1999; Van Hart, 1999).

Detailed lithostratigraphy of the Salitral Formation in the Chama basin indicates it can be divided into three units, two members and a bed, each of which we formally define here (Fig. 5).

Piedra Lumbre Member

The lower part of the Salitral Formation is olive gray and brown sandstone and silty mudstone. This interval, up to 5 m thick at the type section (units 9-11 of the Youngsville landfill section: Fig. 5), forms a prominent "green" slope or hill shoulder immediately above the Shinarump Formation. We name this interval the Piedra Lumbre Member for the Piedra Lumbre Land Grant, near the type section. The upper bed of the Piedra Lumbre Member is a distinctive brown-to-yellow bench of intraformational conglomerate, as much as 1.6 m thick (unit 11 of the Youngsville landfill section: Fig. 5). We name this the El Cerrito Bed of the Piedra Lumbre Member (Fig. 3, 5). El Cerrito is a small hill just south of the type section.

Youngsville Member

Most of the upper part of the Salitral Formation is reddish brown, smectitic mudstone. It forms a prominent red-to-purple slope and is as much as 26 m thick below the overlying bench- or cliff-forming Poleo Formation. We name this unit the Youngsville Member of the Salitral Formation for the village of that name near the type section (Figs. 3, 5). The type section is units 12-14 of the Youngsville landfill section (Fig. 5).

Discussion

Throughout the Chama basin, the Salitral Formation forms a mudstone-dominated slope between the cliff/ledge-forming Shinarump (below) and Poleo (above) formations. Salitral sections are dominantly green, purple and red smectitic mudstone with calcrete nodules; conglomerate and sandstone, other than the locally persistent El Cerrito Bed, are minor lithotypes.

The two members of the Salitral Formation named here can be traced over much of the Youngsville, Arroyo del Agua and Echo Amphitheater 7.5-minute quadrangles. In some other parts of the Chama basin, however, this member-level subdivision in not clear, largely because the Salitral Formation usually forms covered or deeply weathered slopes (Fig. 3).

The Salitral Formation contact with the underlying Shinarump Formation, as noted above, is a sharp surface where mudstone rests directly on sandstone or conglomeratic sandstone. Nevertheless, sandstone beds in the lower Salitral lithologically resemble Shinarump sandstones. This suggests that the Shinarump-Salitral contact may be conformable.

The Poleo Formation contact on the Salitral Formation is a sharp, scoured surface where conglomerate/sandstone at the base of the Poleo is incised into underlying Salitral mudstone/siltstone (Fig. 3). This is the Tr-4 unconformity of Lucas (1993). Dubiel's (1989, fig. 17) schematic depiction of interfingering of the Poleo and underlying Salitral thus lacks a factual basis, as everywhere that the two units crop out the Poleo base is a sharp, scoured surface into the underlying Salitral.

Poleo Formation

The distinctive, medial sandstone unit of the Chinle Group in the Chama basin is the Poleo Formation of Huene (1911). This unit is

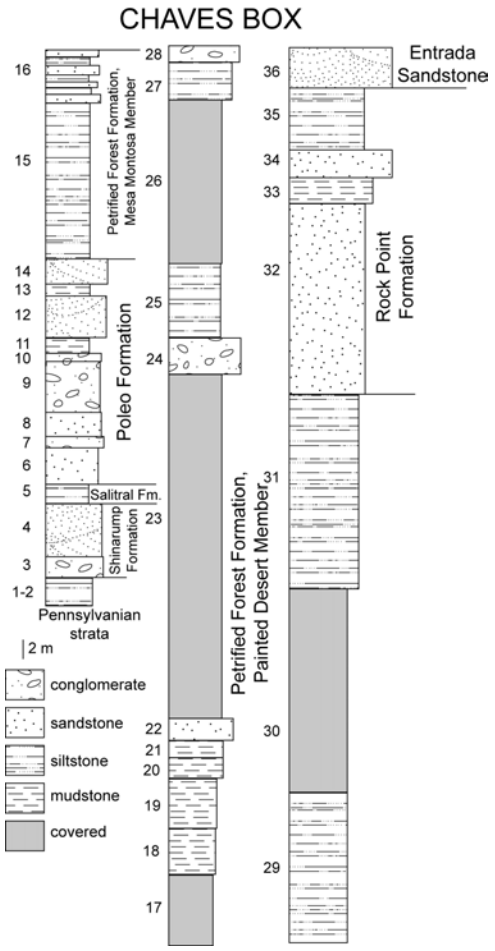


FIGURE 6. Chinle Group section at Chaves Box. See Appendix 1 for description of numbered lithologic units.

homotaxial to the other extensive medial sandstone sheets of the Chinle Group – the Trujillo Formation of West Texas and eastern New Mexico, the Sonsela Member of the Petrified Forest Formation in west-central New Mexico and northeastern Arizona and the Moss Back Formation of southern Utah and southwestern Colorado (Lucas, 1993; Lucas et al., 1997, 1999, 2001). The Poleo Formation is exposed throughout the Chama physiographic basin, along the flanks of the Nacimiento Mountains and in the Jemez Mountains of north-central New Mexico (Lucas and Hunt, 1992; Lucas and Heckert, 1995, 1996). Its relatively great local thickness, grayish yellow coloration, micaceous litharenite petrography and mixed conglomerate-clast lithotypes (both intrabasinal sedimentary clasts and extrabasinal siliceous clasts) serve to distinguish the Poleo Formation from its homotaxial equivalents.

The Poleo Formation in the Chama basin is as much as 41 m thick, and the unit is almost exclusively composed of sandstone, conglomeratic sandstone and conglomerate (Figs. 3, 4, 7C, 8D-E). Poleo sandstones are micaceous litharenites and are typically grayish yellow in color. Conglomerates are either intrabasinal (composed of siltstone and nodular calcrete clasts) or extrabasinal (chert and quartzite clasts).

The Poleo has a sharp, scoured contact on the underlying Salitral Formation, as noted above. It grades upward into the overlying Petrified Forest Formation. Throughout the Chama basin, the Poleo Formation forms a light-colored bench, ledge or cliff. Most striking is the Poleo outcrop at Abiquiu Dam (Figs. 3, 7C, 8E, 9), where the complex internal stratigraphy of the Poleo Formation is well revealed by the engineering geological profile at the dam abutment (Fig. 8).

The Poleo also has an inverse thickness relationship with the underlying Salitral Formation. Where the Poleo Formation is relatively thick, the Salitral Formation is relatively thin and vice versa. We interpret this to indicate that relatively thick Poleo sections are valley fills cut into the underlying Salitral during the development of the Tr-4 unconformity.

Petrified Forest Formation

The thickest formation of the Chinle Group in the Chama basin is the Petrified Forest Formation. As much as 200 m thick, this unit is dominantly reddish-brown smectitic mudstone that forms extensive slopes and dissected badland areas where exposed. Here, we divide the Petrified Forest Formation in the Chama basin into two members, a lower, Mesa Montosa Member (named here) and an upper, Painted Desert Member, a unit that has long been recognized on the Colorado Plateau.

Mesa Montosa Member

The lower part of the Petrified Forest Formation in the Chama basin is a sandstone-dominated unit here named the Mesa Montosa Member for the mesa of that name near the type section. At the type section, the Mesa Montosa Member is 22 m thick and mostly sandstone (44% of the measured section) and mudstone (35% of the section), with a lesser proportion of siltstone (20% of the section) (Fig. 4). These lithotypes range in color from reddish brown to moderate brown, and sandstone beds are typically ripple laminated to laminated and thin bedded. The Mesa Montosa Member thus forms a ribbed slope, 4 to 24 m thick, between coarser-grained Poleo Formation sandstone below, and slope-forming mudstone of the Painted Desert Member of the Petrified Forest Formation above (Fig. 4).

The Mesa Montosa Member is widely distributed in the Chama basin. We have measured sections of this unit from its type section near Coyote to the Piedra Lumbre Land Grant and Abiquiu Dam to the east, and to Chaves Box to the north (Figs. 4, 6).

Painted Desert Member

We apply the name Painted Desert Member to the upper, mudstone-dominated portion of the Petrified Forest Formation in the Chama basin. In the Chama basin, the Painted Desert Member is as much as 176 m thick and mostly reddish brown smectitic mudstone. Lucas (1993) introduced the name Painted Desert Member of the Petrified Forest Formation for the post-Sonsela portion of the formation in the Petrified Forest National Park in eastern Arizona.

Subsequent work has demonstrated the lithostratigraphic and biostratigraphic basis for recognition of the Painted Desert Member in west-central and central New Mexico, and throughout the Four Corners area (e.g., Lucas et al., 1997a, b, 1999). Similarly, strata here assigned to the Painted Desert Member in the Chama basin: (1) occupy the same stratigraphic position as the type Painted Desert Member; (2) are lithologically similar to the type Painted Desert Member; and (3) like the type Painted Desert Member, yield tetrapod fossils of Revueltian age and palynomorphs deemed Norian (see below). Therefore, extension of the term Painted Desert Member into the Chama basin is fully justified.

The Painted Desert Member comprises the bulk of the Petrified Forest Formation in the Chama basin. Its base is a thick mudstone bed above the highest sandstone/siltstone ledge of the Mesa Montosa Member. Its top is a sharp contact with siltstone/sandstone of the Rock Point Formation, or locally, sandstone of the Jurassic Entrada Sandstone rests directly on the Painted Desert Member (Fig. 4). The Petrified Forest-Rock Point contact is marked by the change from mudstone to overlying siltstone/sandstone and the change from bentonitic strata to overlying strata that lack significant volcanic detritus.

Rock Point Formation

The stratigraphically highest unit of Triassic age in the Chama basin is the Rock Point Formation. Rock Point strata are as much as 70

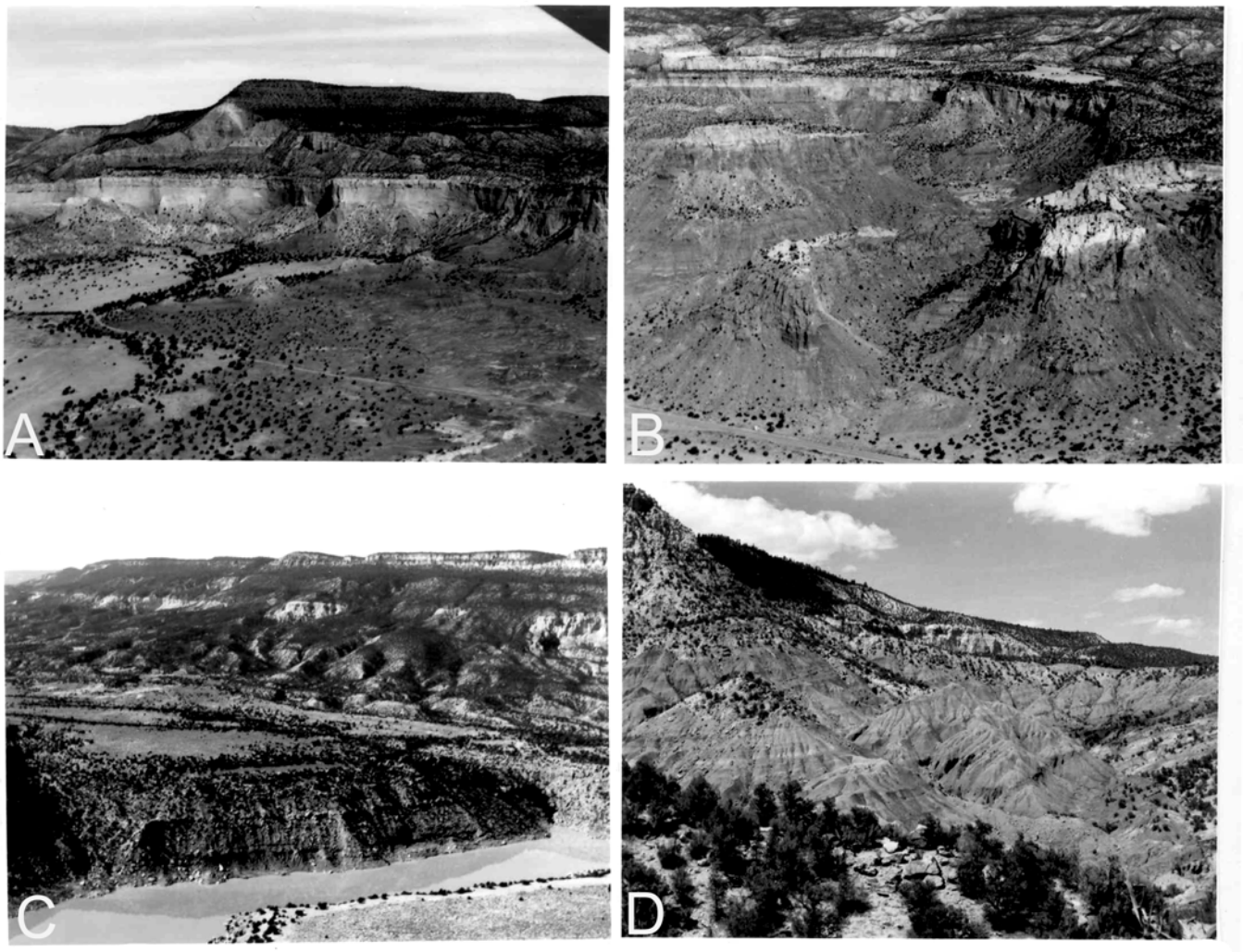


FIGURE 7. Selected Chinle Group outcrops in the Chama basin. **A,** Painted Desert Member badlands below Rock Point Formation slopes capped by prominent, light-colored cliffs of Entrada Sandstone (in turn, overlain by Jurassic slopes up to Cretaceous Dakota Sandstone summit) at Ghost Ranch. **B,** Painted Desert Member badlands below Rock Point Formation slopes capped by prominent, light-colored cliffs of Entrada Sandstone at Orphan Mesa. **C,** Thick section of Poleo Formation in lower left at Abiquiu Reservoir. **D,** Badland slopes of Painted Desert Member capped by light-colored cliffs of Jurassic Entrada Sandstone at Coyote amphitheater.

m thick and consist mostly of reddish brown and grayish red beds of massive siltstone and fine sandstone. The thinly interbedded sandstone and siltstone beds form a ribbed cliff where the Rock Point outcrop is not deeply weathered (Fig. 8F). Where weathered, the Rock Point Formation is an orange slope.

The Rock Point base is the first persistent bed of sandstone above slope-forming mudstone of the Painted Desert Member of the Petrified Forest Formation. The top of the Rock Point is a sharp contact with overlying eolian sandstone of the Slick Rock Member of the Jurassic Entrada Sandstone (Lucas and Anderson, 1998).

Identification of the Rock Point Formation in the Chama basin is well supported because: (1) it closely resembles the type Rock Point strata in the Four Corners region; (2) Rock Point strata in the Chama basin are at the top of the Chinle Group, as they are elsewhere; and (3) Rock Point strata at Ghost Ranch yield Apachean-age vertebrate fossils. Stewart et al. (1972) recognized this correlation, equating the "siltstone member" (our Rock Point Formation) and the Rock Point Formation elsewhere. Dubiel (1989), however, assigned these strata to the Owl Rock Formation (Member) as a lake margin facies of that unit. Lucas and Hunt (1992, p. 158) presented a detailed refutation of Dubiel's assignment, and subsequent work on Owl Rock sedimentology (Tanner, 2000) has rejected the sedimentological model of Owl Rock deposition advocated by Dubiel (1989).

Despite this, Goldstein and colleagues, in a series of largely redundant abstracts (Goldstein et al., 1996; Hargrave et al., 1996; Trinh et al., 1996), continued to assign uppermost Chinle Group strata in the Ghost Ranch area to the Owl Rock Formation. Our reading of these abstracts and discussion with B. Goldstein indicate that they are based on a lack of knowledge of regional Chinle Group stratigraphy and biostratigraphy, an inability to discriminate lithotypes accurately and a basic inability to trace beds laterally in the flat-lying badland exposures in and around Ghost Ranch (also see Sullivan et al., 1996). Thus, the work of Goldstein and colleagues does not contribute to an understanding of Chinle Group stratigraphy in the Chama basin.

BIOSTRATIGRAPHY

Fossil plants, invertebrates and vertebrates have been collected from Chinle Group strata in the Chama basin since the 1800s. Here, we review the stratigraphic distribution of fossils from the Chinle Group in the Chama basin.

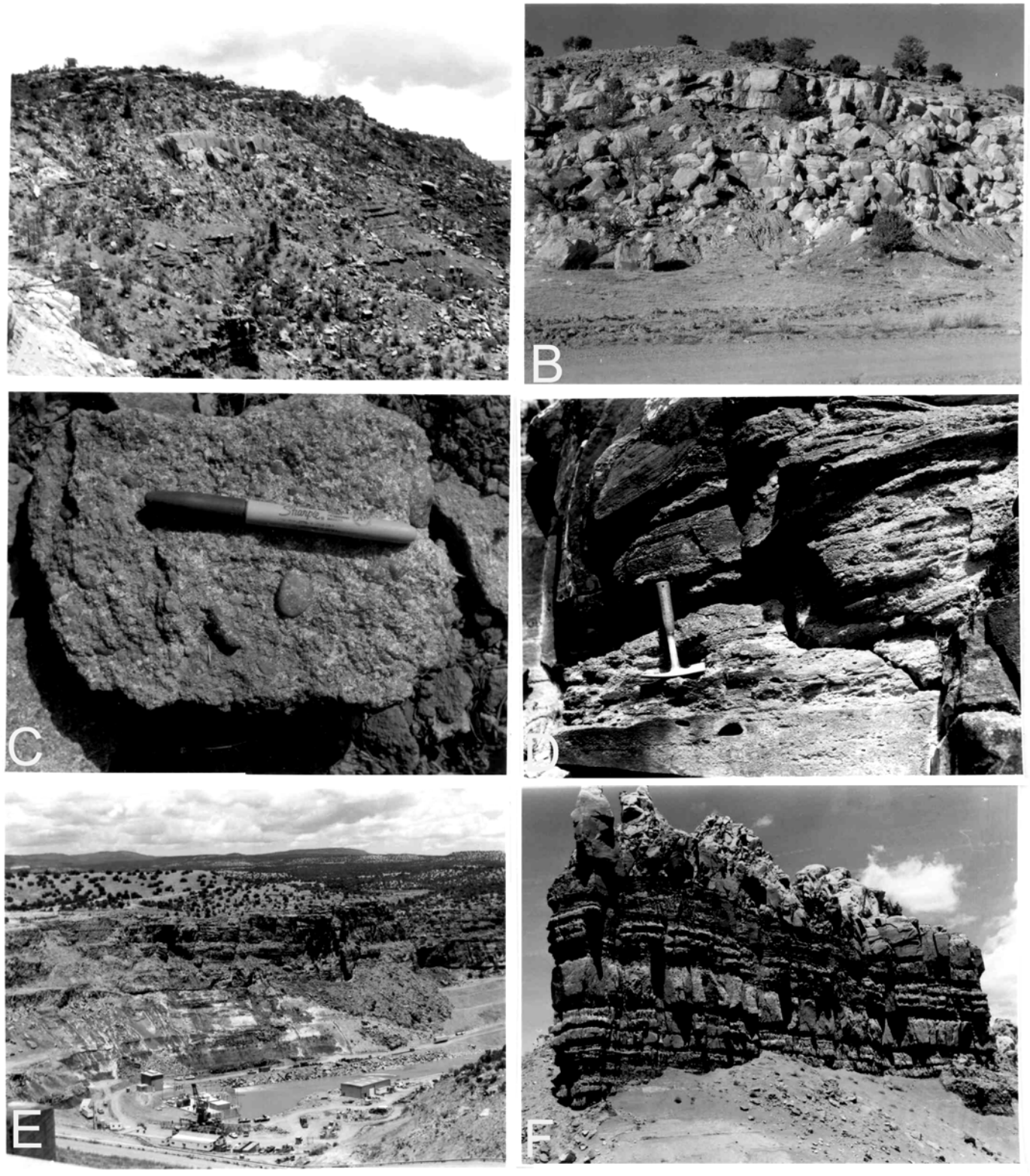


FIGURE 8. Selected Chinle Group outcrops in the Chama basin. **A,** View at Mesa Montosa of dark slopes of Cutler Group, overlain by light colored and lenticular Shinarump cliff, short slope of Salitral and capping sandstone of Poleo Formation. **B,** Shinarump Formation at Youngsville landfill section. **C,** Characteristic extraformational (siliceous) conglomerate in Shinarump Formation at Youngsville landfill section. **D,** Characteristic intraformational conglomerate of Poleo Formation at Poleo type section. **E,** Spillway at Abiquiu Dam shows thick cliff of Poleo Formation. **F,** Ribbed Rock Point Formation at Rest Stop section.

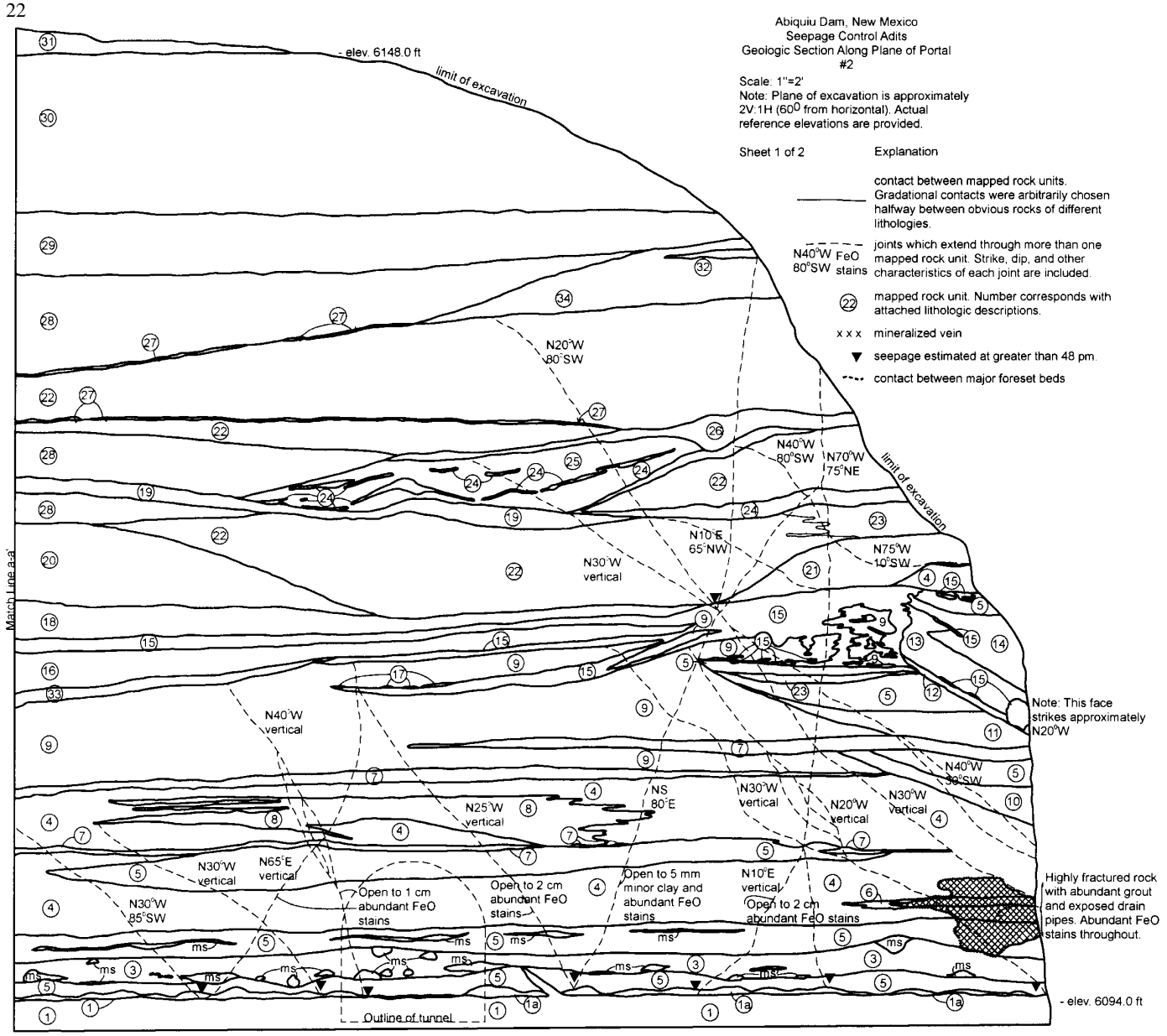


FIGURE 9. Geologic section of Poleo Formation at Abiquiu Dam (based on a chart provided by the U. S. Army Corps of Engineers). See Appendix 2 for description of numbered lithologic units.

Shinarump Formation

The only fossils known from the Shinarump Formation in the Chama basin are fossil plants originally reported by Newberry (1876) and reviewed by Ash (1974). These are from abandoned copper mines (Minas de Pedro and Las Minas Jimmie) in El Cobre Canyon. Ash (1974) listed the flora as *Brachyphyllum* sp., *Pagiophyllum newberryi*, *Araucarioxylon arizonicum*, *Otozamites macombi*, *O. powelli* and *Zamites occidentalis*. These plants belong to the *Dinophyton* floral zone of Ash (1980), which occurs in strata of Otischalkian-Adamanian age throughout the Chinle Group (Lucas, 1997).

Salitral Formation

Lucas and Hunt (1992) and Hunt and Lucas (1993) documented a small assemblage of tetrapod fossils from the Salitral Formation at its type section. Besides coprolites and indeterminate metoposaurid and phytosaur remains, these fossils include a paramedian scute (Fig. 10G-H) that they assigned to the aetosaur *Longosuchus* (Hunt and Lucas, 1990, fig. 3I-J) and a theropod dinosaur vertebra (Heckert et al., 2000b, fig. 3A-C) (Table 1). The presence of *Longosuchus* suggests an Otischalkian age, but we conclude that the specimen is better assigned to *Desmatosuchus* as *D. haplocerus*. This suggests an Adamanian age (cf. Heckert et al., 2003)

Recent collecting by us in the Salitral Formation revealed fragmentary fossils of phytosaurs, aetosaurs and metoposaurids. The metoposaurid specimens include shoulder girdle specimens diagnostic of *Buettneria* (Fig. 10C) (cf. Hunt, 1993). A large fragment has characteristic deep pits and grooves on the external surface. Two *Apachesaurus* vertebral centra (centra longer than wide) have also been recovered (Fig. 10D-E). Two osteoderm fragments with long, parallel ridges and grooves on their external surfaces (Fig. 10B, F) pertain to a new aetosaur taxon under study by us, which is also known from Adamanian strata in central New Mexico and West Texas.

TABLE 1. Biostratigraphically significant tetrapod faunas of the Chinle Group in the Chama basin.

Salitral Formation:	
Amphibians: Metoposaurs	*Buettneria*
Archosaurs: Phytosaurs	Indet.
Archosaurs: Aetosaurs	*Desmatosuchus*
	new genus
Dinosaurs	Theropoda indet.
Petrified Forest Formation:	
Amphibians	Metoposauridae indet.
Archosaurs: Phytosaurs	*Pseudopalatus buceros*
Archosaurs: Aetosaurs	*Typothorax coccinarum*
	Desmatosuchus chamaensis
Rauisuchians	*Postosuchus sp.*
Dinosaurs: Theropod	*Eucoelophysis baldwini*
Reptilia: Procolophonid	*Hypsognathus?*
Archosaur	*Dolabrosaurus*
Rock Point Formation:	
Archosaurs: Phytosaurs	*Redondasaurus*
Archosauromorphs	*Vancleavea*
	megalancosaurid
Rauisuchian	*Postosuchus kirkpatricki*
Dinosaurs: Theropods	*Coelophysis bauri*
Sphenosuchian	*Hesperosuchus*

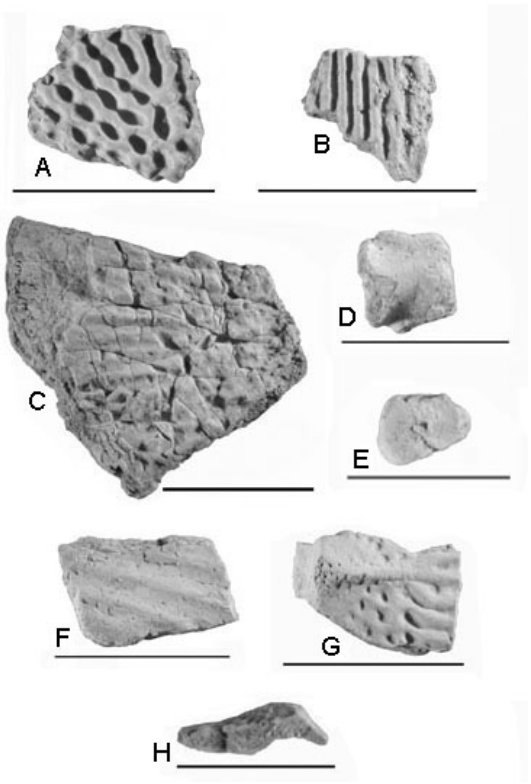


FIGURE 10. Selected vertebrate fossil material from the Salitral Formation. **A,** metoposaur skull fragment (NMMNH P-28302); **B,** *Desmatosuchus* scute fragment (NMMNH P-28303); **C,** *Buettneria* interclavicle fragment (NMMNH P-39230); **D-E,** *Apachesaurus* centrum (NMMNH P-28301) in D, dorsal view, and E, anterior view; **F,** new aetosaur genus scute fragment (NMMNH P-28304); **G-H,** *Desmatosuchus haplocerus* scute fragment (NMMNH P-11005) in G, lateral view, and H,= dorsal view. Scale bars = 5 cm.

Poleo Formation

Abundant pieces of petrified wood, mostly oxidized, are present in the Poleo Formation. Fragments of vertebrate bone, mostly unidentifiable, are also present in some conglomerate beds of the Poleo. Thus, no biostratigraphically useful fossils are yet known from the Poleo Formation in the Chama basin.

Petrified Forest Formation

In the Chama basin, the unionid bivalves from the Painted Desert Member of the Petrified Forest Formation (Meek, 1875; Good, 1998; Lucas et al., 2003) are of some biostratigraphic significance. Good (1993a,b, 1998) proposed a molluscan zonation of the Chinle Group consisting of two zones: the *Antediplodon graciliratus* zone of early Revueltian age, and the *A. thomasi* zone of late Revueltian age.

Unionids originally described by Meek (1875) from the Painted Desert Member of the Petrified Forest Formation near Gallina in the Chama basin (Lucas and Hunt, 1992) pertain to taxa found elsewhere in Revueltian strata of the Chinle Group in New Mexico, Arizona and Utah (Good, 1998). So, the Painted Desert Member unionids from the Chama basin are consistent with a Revueltian age based on vertebrate biostratigraphy.

A small, fragmentary vertebrate fossil assemblage was collected by us from the Mesa Montosa Member in its type area. It includes the Revueltian index fossil *Typothorax coccinarum*, as well as specimens that may be *Desmatosuchus*, metoposaurid fragments (*Apachesaurus* and *Buettneria*?) and large phytosaur fragments.

A much more extensive Revueltian-age vertebrate fossil assemblage is present in the upper part of the Painted Desert Member at several locations. Especially significant are: (1) Cope and Baldwin's localities near Gallina (Cope, 1875, 1877, 1881, 1887a,b, 1889; Lucas and Hunt, 1992; Hunt and Lucas, 1993); (2) the Snyder quarry near Ghost Ranch (Heckert et al., 2000; Zeigler, 2002; Zeigler et al., 2002a, b, also see several articles in this volume); (3) the Canjilon phytosaur quarry (Camp, 1930; Lawler, 1976; Long et al., 1989; Martz, 2002; Hunt and Downs, 2002); and (4) the Orphan Mesa area (Sullivan et al., 1996; Sullivan and Lucas, 1999). The tetrapod fauna of the Painted Desert Member (Table 1) includes *Pseudopalatus* and *Typothorax coccinarum*, index taxa of the Revueltian.

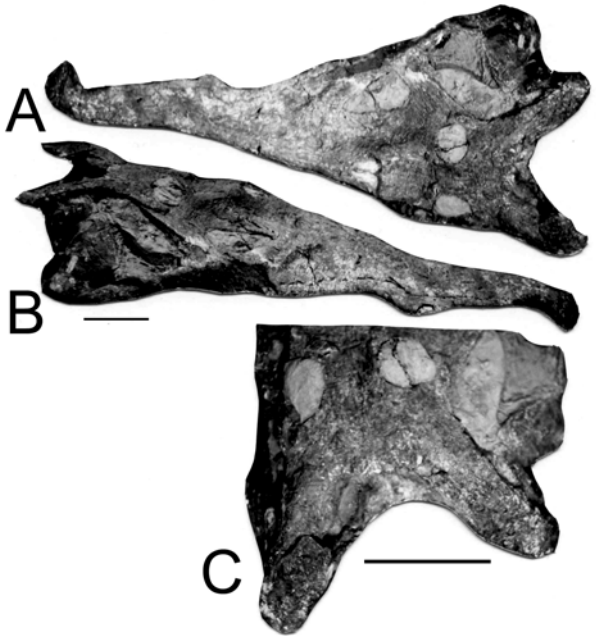


FIGURE 11. The holotype skull of the phytosaur *Redondasaurus bermani* in **A,** dorsal, and **B,** right lateral views; **C,** close-up dorsal view of squamosal region of skull. Scale bars = 10 cm.

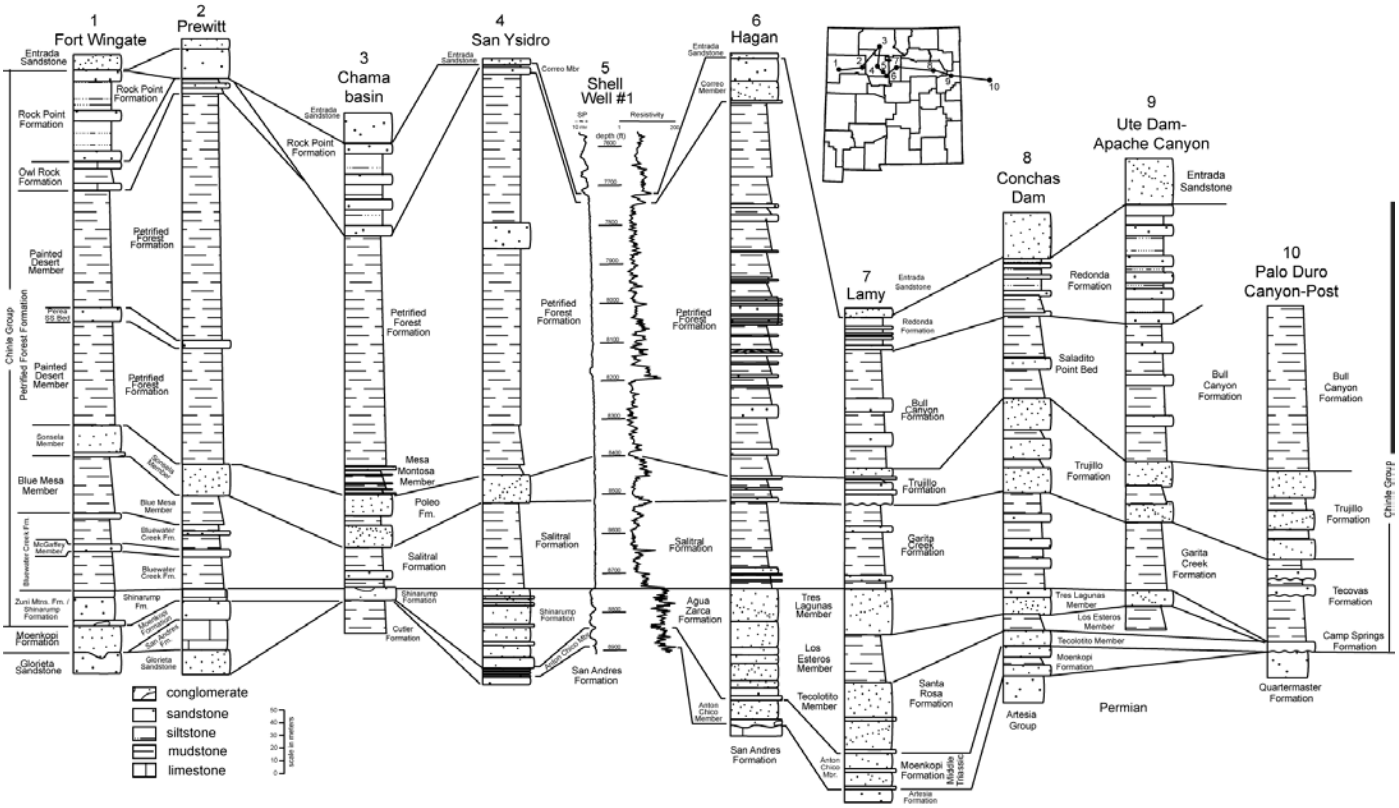


FIGURE 12. Correlation of the Chinle Group along a west-east transect across New Mexico (modified from Lucas et al., 1999, 2001).

Rock Point Formation

Pollen from the Rock Point Formation is considered to be of Norian age (Litwin, 1986; Litwin et al., 1991). The vertebrate fossil assemblage (Table 1) from the Whitaker quarry at Ghost Ranch includes *Redondasaurus* (Fig. 11), an index taxon of the Apachean land-vertebrate faunachron (Hunt and Lucas, 1993; Lucas et al., 1997).

CORRELATION

Regional correlation of the Chinle Group section in the Chama basin can be made primarily on lithostratigraphy, and is supported by biostratigraphy (Fig. 12). In west-central New Mexico, the Zuni Mountains and Shinarump formations are thin units generally lumped together (Stewart et al., 1972; Lucas, 1993; Heckert and Lucas, 2002, 2003). Across west-central and north-central New Mexico, the Shinarump Formation is laterally continuous and thickens substantially to the east of the Chama basin, where it is correlative with the Santa Rosa Formation, and becomes divisible into three members (Fig. 12) (Lucas et al., 1999). The Santa Rosa Formation then thins dramatically eastward, so that at Palo Duro Canyon in West Texas it is represented by a relatively thin unit, the Camp Springs Formation (Lucas et al., 2001). It is likely that there is a depositional center focused near Lamy and Tucumcari during deposition of the Shinarump and Santa Rosa formations.

The Salitral Formation is equivalent to the Bluewater Creek Formation and the Blue Mesa Member of the lower Petrified Forest Formation to the west (Heckert and Lucas, 2002, 2003) and the Garita Creek and Tecovas formations to the east (Lucas et al., 1999, 2001) (Fig. 12). This stratigraphic interval is relatively uniform in its thickness and is thinnest in the Chama basin section. Sandstones are more prevalent to the west and to the east, while the central sections are either composed entirely of mudstone, or have very thin, sporadic sandstone beds present. In general, the Piedra Lumbre Member most resembles basal Bluewater Creek strata (west). The El Cerrito Bed occupies a similar stratigraphic position to the McGaffey Member of the Bluewater Creek Formation (Anderson and Lucas, 1993; Heckert and Lucas, 2002, 2003), but we cannot demonstrate a direct correlation. The Youngsville Member most closely resembles upper Bluewater Creek strata (west).

Equivalent to the Sonsela Member of the Petrified Forest Formation to the west and to the Trujillo Formation to the east, the Poleo Formation and its equivalents are variable in thickness, though generally thicker to the east (Fig. 12). To the west, the Poleo and its equivalents are thick, multistoried sandstones, whereas to the east, this interval contains relatively thick mudstone units.

The Petrified Forest Formation is the thickest of all of the Upper Triassic units in the Chama basin and is equivalent to the Painted Desert Member of the Petrified Forest Formation to the west (Lucas et al., 1997; Heckert and Lucas, 2003) and the Bull Canyon Formation to the east (Lucas et al., 2001). This interval is moderately variable in thickness and becomes sandier to the east across New Mexico towards Ute Dam-Apache Canyon (Lucas et al., 2001). Farther east, the uppermost part of the Petrified Forest Formation and overlying Redonda Formation were eroded during the Neogene, so that the total thickness of the unit is not preserved in West Texas.

The Owl Rock Formation is present only to the west of the Chama basin. The overlying Rock Point Formation is also not laterally continuous and varies substantially in thickness. It is apparently equivalent to the Redonda Formation to the east. The Rock Point Formation is not present at San Ysidro or in the Hagan basin, despite its thickness in the neighboring Chama basin.

ACKNOWLEDGMENTS

Vin Morgan and Justin Spielmann provided valuable field assistance. Jim Mundy generously granted access to his land at Chaves Box. Alex Downs and the Ghost Ranch Conference Center granted access to the Ghost Ranch. Ron Morgan piloted the small aircraft used for aerial photography.

REFERENCES

Anderson, O. J. and Lucas, S. G., 1993, McGaffey Member of Upper Triassic Bluewater Creek Formation, west-central New Mexico: New Mexico Museum of Natural History and Science, Bulletin 3, p. G30.

Ash, S.R., 1974, Upper Triassic plants of Cañon del Cobre, New Mexico: New Mexico Geological Society, Guidebook 25, p. 179-184.

Ash, S. R., 1980, Upper Triassic floral zones of North America; *in* Dilcher, D. L. and Taylor, T. N., eds., Biostratigraphy of fossil plants: Stroudsburg, Dowden, Hutchinson & Ross, p. 153-170.

Ballew, K.L., 1986, A phylogenetic analysis of Phytosauria (Reptilia: Archosauria) from the Late Triassic of the western United States [M.S. thesis]: Berkeley, University of California, 75 p.

Ballew, K.L., 1989, A phylogenetic analysis of Phytosauria from the Late Triassic of the western United States; *in* Lucas, S.G. and Hunt, A.P., eds., Dawn of the age of the dinosaurs in the American Southwest: Albuquerque, New Mexico Museum of Natural History, p. 309-339.

Berman, D.S. and Reisz, R.R., 1992, *Dolabrosaurus aquatilis*, a small lepidosauromorph reptile from the Upper Triassic Chinle Formation of north-central New Mexico: Journal of Paleontology, v. 66, p. 1001-1009.

Camp, C.L., 1930, A study of the phytosaurs with description of new material from western North America: Memoirs of the University of California, v. 10, 175 p.

Case, E.C. and Williston, S.W., 1912, The Permo-Carboniferous of northern New Mexico: Journal of Geology, v. 20, p. 1-12.

Colbert, E.H., 1947, Little dinosaurs of Ghost Ranch: Natural History, v. 56, no. 9, p. 392-399.

Colbert, E.H., 1950, Mesozoic vertebrate faunas and formations of northern New Mexico: Guidebook for the Fourth Conference of the Society of Vertebrate Paleontology, p. 57-72.

Colbert, E.H., 1964, The Triassic dinosaur genera *Podokesaurus* and *Coelophysis*: American Museum Novitates, no. 2168, 12 p.

Colbert, E.H., 1974, The Triassic paleontology of Ghost Ranch: New Mexico Geological Society, Guidebook 25, p. 175-178.

Colbert, E.H., 1989, The Triassic dinosaur *Coelophysis*: Bulletin of the Museum of Northern Arizona, v. 57, 174 p.

Cope, E.D., 1875, Report on the geology of that part of New Mexico examined during the field season of 1875: Annual Report of the Wheeler Survey, p. 61-116.

Cope, E.D., 1877, Report on the extinct Vertebrata obtained in New Mexico by parties of the expedition of 1874: Report of the Geographical Survey West of the 100th Meridian by Lieutenant G. M. Wheeler, v. 4, no. 2, p. 1-365.

Cope, E.D., 1881, *Belodon* in New Mexico, American Naturalist, v. 15, p. 922-923.

Cope, E.D., 1887a, The dinosaurian genus *Coelurus*: American Naturalist, v. 21, p. 367-369.

Cope, E.D., 1887b, A contribution to the history of the Vertebrata of the Trias of North America: Proceedings of the American Philosophical Society, v. 24, p. 209-228.

Cope, E.D. 1889, On a new genus of Triassic Dinosauria: American Naturalist, v. 23, p. 626.

Dane, C.H. and Bachman, G.O., 1965, Geologic map of New Mexico: Denver, U.S. Geological Survey, scale 1:500,000.

Dubiel, R.F., 1989, Depositional environments of the Upper Triassic Chinle Formation in the eastern San Juan Basin and vicinity, New Mexico: U.S. Geological Survey, Bulletin 1808B, p. 1-22.

Goddard, E.N., Trask, P.D., DeFord, R.K., Rove, O.N., Singewald, J.T. Jr. and Overbeck, R.M., 1984, Rock-color chart: Boulder, Geological Society of America.

Goldstein, B. S., Trinh, T., Hargrave, E. and Demko, T. M., 1996, Geologic and stratigraphic setting of the *Coelophysis* quarry, Ghost Ranch, northern New Mexico: A reassessment: Geological Society of America Abstracts with Programs, v. 28, p. 9.

Good, S. C., 1993a, Molluscan paleobiology of the Upper Triassic Chinle Formation, Arizona and Utah [Ph.D. dissertation]: Boulder, University of Colorado, 276 p.

Good, S. C., 1993b, Stratigraphic distribution of the mollusc fauna of the Chinle Formation and molluscan biostratigraphic zonation: New Mexico Museum of Natural History and Science, Bulletin 3, p. 155-159.

Good, S. C. 1998. Freshwater bivalve fauna of the Late Triassic (Carnian-Norian) Chinle, Dockum, and Dolores formations of the southwest United States; *in* Johnston, P. A. and Haggart, J. W., eds., Bivalves: An eon of evolution: Calgary, University of Calgary Press, p. 223-249.

Gregory, H.E., 1917, Geology of the Navajo Country, a reconnaissance of parts of Arizona, New Mexico and Utah: U. S. Geological Survey, Professional Paper 93, 161 p.

Hargrave, E. V., Goldstein, B. S., Trinh, T. and Trinh, T., 1996, Paleomagnetism of the Chinle Formation at Ghost Ranch, New Mexico: Age constraints for *Coelophysis* bauri: Geological Society of America Abstracts with Programs, v. 28, p. 72.

Harris, J. D. and Downs, A., 2002, A drepanosaurid pectoral girdle from the Ghost Ranch (Whitaker) *Coelophysis* quarry (Chinle Group, Rock Point Formation, Rhaetian), New Mexico: Journal of Vertebrate Paleontology, v. 22, p. 70-75.

Heckert, A.B. and Lucas, S.G., 2002, Lower Chinle Group (Upper Triassic: Carnian) stratigraphy in the Zuni Mountains, west-central New Mexico: New Mexico Museum of Natural History and Science, Bulletin 21, p. 51-72.

Heckert, A.B. and Lucas, S.G., 2003, Triassic stratigraphy in west-central New Mexico: New Mexico Geological Society, Guidebook 54, in press.

Heckert, A. B., Lucas, S. G. and Rinehart, L. F., 1999a, From decapods to dinosaurs: A diverse new fauna from a bonebed in the Upper Triassic (Norian) Petrified Forest Formation: Journal of Vertebrate Paleontology, v. 19, supplement to no. 3, p. 50A.

Heckert, A. B., Zeigler, K. E. and Lucas, S. G., 2003, Aetosaurs (Archosauria: Stagonolepididae) from the Upper Triassic (Revueltian) Snyder quarry, New Mexico: New Mexico Museum of Natural History and Science, Bulletin 24, p. 115-126.

Heckert, A. B., Rinehart, L. F., Lucas, S. G., Downs, A., Estep, J. W., Harris, J. D., Reser, P. K. and Snyder, M., 1999b, A diverse new Triassic fossil assemblage from the Petrified Forest Formation (Revueltian: early-mid Norian) near Abiquiu, New Mexico. New Mexico Geology, v. 21, p. 42.

Heckert, A. B., Zeigler, K. E., Lucas, S. G., Rinehart, L. F. and Harris, J. D., 2000, Preliminary description of coelophysoids (Dinosauria: Theropoda) from the Upper Triassic (Revuletian: early-mid Norian) Snyder quarry, north-central New Mexico: New Mexico Museum of Natural History and Science, Bulletin 17, p. 27-32.

Huene, F. von, 1911, Kurze Mitteilung über Perm, Trias, und Jura in New Mexico: Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie, v. 32, p. 730-739.

Huene, F. von, 1915, On reptiles of the New Mexico Trias in the Cope collection: American Museum of Natural History Bulletin, v. 34, p. 485-507.

Hunt, A.P., 1993, A revision of the Metoposauridae (Amphibia: Temnospondyli) of the Late Triassic and description of a new genus from western North America: Museum of Arizona, Bulletin 59, p. 67-97.

Hunt, A.P. and Downs, A., 2002, Taphonomy of the Late Triassic Canjilon quarry (Petrified Forest Formation: Chinle Group), north-central New Mexico: Data from new excavations: New Mexico Museum of Natural History and Science, Bulletin 21, p. 291-296.

Hunt, A.P. and Lucas, S.G., 1989, Late Triassic vertebrate localities in New Mexico; *in* Lucas, S.G. and Hunt, A.P., eds., Dawn of the Age of Dinosaurs in the American Southwest: Albuquerque, New Mexico Museum of Natural History, p. 71-101.

Hunt, A.P. and Lucas, S.G., 1991, *Rioarribasaurus*, a new name for a Late Triassic dinosaur from New Mexico (USA): Paläontologische Zeitschrift, v. 65, p. 191-198.

Hunt, A.P. and Lucas, S.G., 1993, Triassic vertebrate paleontology and biochronology of New Mexico: New Mexico Museum of Natural History and Science Bulletin 2, p. 49-60.

Keroher, G. C. et al., 1966, Lexicon of geologic names of the United States for 1936-1960: U. S. Geological Survey, Bulletin 1200, 4341 p.

Kurtz, D.D., 1978, Sedimentology and stratigraphy of the Triassic Chinle Formation, eastern San Juan Basin, New Mexico [M.S. thesis]: Houston, Rice University, 185 p.

Kurtz, D.D. and Anderson, J.B., 1980, Depositional environments and paleocurrents of Chinle Formation (Triassic), eastern San Juan Basin, New Mexico: New Mexico Geology, v. 2, p. 22-27.

Lawler, D. A., 1976, Osteological variation in the phytosaur *Rutiodon tenuis* from Ghost Ranch, New Mexico [M.S. thesis]: Berkeley, University of California, 137 p.

Litwin, R. J., 1986, The palynostratigraphy and age of the Chinle and Moenave formations, southwestern USA [Ph.D. dissertation]: College Park, The Pennsylvania State University, 265 p.

Litwin, R.J., Traverse, A. and Ash, S.R., 1991, Preliminary palynological zonations of the Chinle Formation, southwestern U.S.A., and its correlation to the Newark Supergroup (eastern U.S.A.): Review of Palaeobotany and Palynology, v. 68, p. 269-287.

Long, R.A., Lucas, S.G., Hunt, A.P. and McCrae, R.T., 1989, Charles Camp: collecting Late Triassic vertebrates in the American Southwest during the 1920's and 1930's: *in* Lucas, S.G. and Hunt, A.P., eds., Dawn of the Age of the Dinosaurs in the American Southwest: Albuquerque, New Mexico Museum of Natural History, p. 65-71.

Lucas, S.G., 1993, The Chinle Group: Revised stratigraphy and biochronology of Upper Triassic strata in the western United States: Museum of Northern Arizona, Bulletin, v. 59, p. 27-50.

Lucas, S. G., 1997, Upper Triassic Chinle Group, western United States: A nonmarine standard for Late Triassic time; in Dickins, J. M., Yang, Z., Yin, H., Lucas, S. G. and Acharyya, S. K., eds., Late Palaeozoic and early Mesozoic circum-Pacific events and their global correlation: Cambridge, Cambridge Univerity Press, p. 209-228.

Lucas, S.G. and Anderson, O.J., 1998, Jurassic stratigraphy and correlation in New Mexico: New Mexico Geology, v. 20, p. 97-104.

Lucas, S.G. and Heckert, A.B., 1995, Triassic stratigraphy around the Sandia uplift, central New Mexico: New Mexico Geological Society, Guidebook 46, p. 233-241.

Lucas, S.G. and Heckert, A.B., 1996, Stratigraphy and correlation of Triassic strata around the Nacimiento and Jemez uplifts, northern New Mexico: New Mexico Geological Society, Guidebook 47, p. 199-204.

Lucas, S.G., and Hunt, A.P., 1992, Triassic stratigraphy and paleontology, Chama basin and adjacent areas, north-central New Mexico: New Mexico Geological Society, Guidebook 43, p. 151-167.

Lucas, S.G., Heckert, A.B. and Estep, J.W., 1999, Correlation of Triassic strata across the Rio Grande rift, north-central New Mexico: New Mexico Geological Society, Guidebook 50, p. 305-310.

Lucas, S. G., Heckert, A. B. and Hunt, A. P., 2001, Triassic stratigraphy, biostratigraphy and correlation in east-central New Mexico: New Mexico Geological Society, Guidebook 52, p. 85-102.

Lucas, S. G., Zeigler, K. E. and Heckert, A. B., 2003, Invertebrate paleontology of the Upper Triassic Snyder quarry, north-central New Mexico: New Mexico Museum of Natural History and Science Bulletin 24, p. 63-65.

Lucas, S.G., Heckert, A.B., Estep, J.W., and Anderson, O.J., 1997, Stratigraphy of the Upper Triassic Chinle Group, Four Corners Region: New Mexico Geological Society Guidebook 48, p. 81-107.

Lucas, S.G., Heckert, A.B., Zeigler, K.E., and Hunt, A.P., 2002, The type locality of *Belodon buceros* Cope, 1881, a phytosaur (Archosauria: Parasuchidae) from the Upper Triassic of north-central New Mexico: New Mexico Museum of Natural History and Science, Bulletin 21, p. 189-192.

Martz, J.W., 2002, A new map for the Late Triassic Canjillon quarry (Petrified Forest Member, Chinle Formation), and the ontogeny of *Typothorax coccinarum* (Archosauria, Stagonolepididae): Journal of Vertebrate Paleontology, v. 22, supplement to no. 3, p. 84A.

Meek, F. B. 1875. Descriptions of three new species of Triassic *Unio* from the Gallinas Range, New Mexico: Geographical Surveys West of the 100th Meridian [Wheeler Survey], Annual Report for 1875, p. 61-97.

Muehlberger, W. A., 1967, Geology of Chama quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 89, 114 p.

Newberry, J.S., 1876, Geological report: *in* Macomb, J.N., Report of the exploring expedition from Santa Fe … in 1859: Washington, D.C., U.S. Army, Engineer Department, p. 135-148.

O'Sullivan, R.B., 1974, The Upper Triassic Chinle Formation in north-central New Mexico: New Mexico Geological Society, Guidebook 25, p. 171-178.

Padian, K., 1986, On the type material of *Coelophysis* Cope (Saurischia: Theropoda) and a new specimen from the Petrified Forest of Arizona (Late Triassic Chinle Formation): *in* Padian, K., ed., The beginning of the age of dinosaurs: Faunal change across the Triassic-Jurassic boundary: Cambridge, Cambridge University Press, p. 45-60.

Pipiringos, G.N. and O'Sullivan, R.B., 1978, Principal unconformities in Triassic and Jurassic rocks, Western Interior United States – a preliminary survey: U.S. Geological Survey, Professional Paper 1035A, 29 p.

Simpson, G.G., 1951, Hayden, Cope, and the Eocene of New Mexico: Academy of Natural Sciences Philadelphia Proceedings, v. 103, p. 1-21.

Smith, C. T., Budding, A. J. and Pitrat, C. W., 1961, Geology of the southeastern part of the Chama basin: New Mexico Bureau of Mines and Mineral Resources, Bulletin 75, 57 p.

Stewart, J.H., Poole, F.G. and Wilson, R.F., 1972, Stratigraphy and origin of the Chinle Formation and related Upper Triassic strata of the Colorado Plateau region: U.S. Geological Survey Professional Paper 690, 336 p.

Sullivan, R.M., and Lucas, S.G., 1999, *Eucoelophysis baldwini*, a new theropod dinosaur from the Upper Triassic of New Mexico, and the status of the original types of *Coelophysis*: Journal of Vertebrate Paleontology, v. 19, p. 81-90.

Sullivan, R.M., Lucas, S.G., Heckert, A.B., and Hunt, A.P., 1996, The type locality of *Coelophysis*, a Late Triassic dinosaur from north-central New Mexico (U.S.A): Paläontologische Zeitschrift, v. 70, p. 245-255.

Tanner, L.H., 2000, Palustrine-lacustrine and alluvial facies of the (Norian) Owl Rock Formation (Chinle Group) Four Corners region, southwestern U.S.A: Implications for Late Triassic paleoclimate: Journal of Sedimentary Research, v. 70, p. 1280-1289.

Trinh, T. A., Trinh, T. A., Goldstein, B. S. and Demko, T. M., 1996, Sedimentology, stratigraphy, and paleontology of the Chinle Formation, Ghost Ranch, New Mexico: Paleoenvironmental interpretation: Geological Society of America, Abstracts with Programs, v. 28, p. 118-119.

Van Hart, D., 1999, Geology of Mesozoic sedimentary rocks in the Juan Tabó area, northwest Sandia Mountains, Bernalillo County, New Mexico: New Mexico Geology, v. 21, p. 104-111.

Wood, G.H. and Northrop, S.A., 1946, Geology of the Nacimiento Mountains, San Pedro Mountain, and adjacent plateaus in parts of Sandoval and Rio Arriba Counties, New Mexico: U.S. Geological Survey, Oil and Gas Investigations Map OM-57.

Zeigler, K.E., 2002, A taphonomic analysis of a fire-related Upper Triassic fossil assemblage [M.S. thesis]: Albuquerque, University of New Mexico, 124 p.

Zeigler, K. E., Heckert, A. B. and Lucas, S. G., 2002a, A new species of *Desmatosuchus* (Archosauria: Aetosauria) from the Upper Triassic of the Chama basin, north-central New Mexico: New Mexico Museum of Natural History and Science, Bulletin 21, p. 215-219.

Zeigler, K. E., Lucas, S. G. and Heckert, A. B., 2002b, The late Triassic Canjilon quarry (upper Chinle Group, New Mexico) phytosaur skulls: Evidence of sexual dimorphism in phytosaurs: New Mexico Museum of Natural History and Science, Bulletin 21, p. 179-188.

APPENDIX 1 – MEASURED STRATIGRAPHIC SECTIONS

This Appendix describes the numbered lithologic units in the measured sections in Figures 3-6. Rock colors are those of Goddard et al. (1984).

Minas de Pedro

Measured in the SE 1/4 SW1/4 sec. 18 (unsurveyed), T24N, R6E, Rio Arriba County.

unit	lithology	thickness (m)
	Chinle Group:	
	Poleo Formation:	
15	Sandstone with conglomeratic beds: sandstone is light olive brown (5 Y 5/6), very fine grained, subangular-subrounded, moderately sorted, noncalcareous, micaceous litharenitic; conglomerate is light greenish gray (5 GY 8/1) and composed of siltstone and nodular calcrete clasts; laminar and planar crossbedded with conglomerate concentrated at scour bases.	11.3
14	Conglomerate: matrix is pale olive (10 Y 6/2), very fine-coarse grained, subangular quartzose sandstone; clasts are brown, white and red chert up to 1 cm in diameter; trough crossbedded.	1.6
13	Sandstone: yellowish gray (5 Y 7/2); very fine-fine grained; subrounded; moderately sorted; micaceous subarkosic; very calcareous; laminar.	2.2
12	Sandstone: yellowish gray (5 Y 7/2); very fine-fine grained; subangular-subrounded; moderately sorted; micaceous quartzarenitic; very calcareous; trough crossbedded; multi-storied with pebbly beds at scour bases.	10.3
11	Sandstone: pale greenish yellow (10 Y 8/2), weathers moderate yellowish brown (10 Y 5/4); fine grained; subrounded; well sorted; quartzarenitic; noncalcareous; trough cross-bedded.	2.0
10	Sandstone: grayish orange (10 YR 7/4); very fine grained; subrounded; well sorted; arkosic litharenite; calcareous; some cover.	1.3
9	Conglomeratic sandstone: sandstone is dusky yellow (5 Y 6/ 4), very fine-fine grained, subangular, moderately sorted, micaceous litharenitic, calcareous; pebbles are light gray, black, white quartzite and petrified wood; trough cross-bedded; scour base with 0.3-0.6 m of relief.	3.0
	unconformity (Tr-4 unconformity of Lucas, 1993)	
	Salitral Formation:	
8	Sandy mudstone and muddy sandstone: sandy mudstone is mottled grayish red purple (5 RP 4/2) and yellowish gray (5 Y 7/2), bentonitic and very calcareous; muddy sandstone is medium light gray (N 6), fine grained, subangular, poorly sorted, lithic wacke; trough crossbedded ledges with mud-stone partings.	5.5
	Shinarump Formation:	
7	Sandstone: pale greenish yellow (10 Y 8/2); fine-medium grained; subrounded; moderately sorted; quartzose; slightly calcareous; trough cross bedded; some siliceous pebbles.	3.0
6	Sandstone: yellowish gray (5 Y 7/2); very fine-medium grained; subrounded; poorly sorted; feldspathic litharenitic; noncalcareous; trough crossbedded; contains some siliceous pebbles; upper half of unit thinner bedded with some mudstone partings.	3.1
5	Sandy mudstone: pale reddish purple (5 RP 6/2); noncalcareous.	1.5
4	Sandstone: yellowish gray (5 Y 7/2); fine-medium grained; subrounded; moderately sorted; micaceous feldspathic litharenitic; calcareous; trough crossbedded; some dispersed siliceous pebbles.	2.8
3	Conglomerate: matrix is pale green (5 G 7/2), fine-medium grained, subangular, poorly sorted quartzose sandstone; clasts are greenish black (5 G 2/1) chert and white quartzite up to 15 cm in diameter; trough crossbedded.	0.5
	unconformity (Tr-3 unconformity of Pipiringos and O'Sullivan, 1978)	
	Zuni Mountains Formation:	
2	Siltstone: mottled grayish yellow green (5 GY 7/2) and dark reddish brown (10 R 3/4); bioturbated and massive.	1.2-1.4
	Cutler Group:	
1	Sandstone: moderate reddish brown (10 R 4/6); very fine-fine grained; subangular; moderately sorted; micaceous lithic wacke; noncalcareous; trough crossbedded.	2.0+

Coelophysis quarry

Measured in the SW1/4 SE1/4 sec. 1, T24N, R4E, Rio Arriba County.

unit	lithology	thickness (m)
	San Rafael Group:	
	Entrada Sandstone:	
8	Sandstone: moderate reddish orange (10 R 6/6); very fine-fine grained; subrounded; well sorted; quartzarenitic; noncalcareous; trough crossbedded; forms a cliff.	not measured
	unconformity	
	Chinle Group:	
	Rock Point Formation:	
7	Covered.	5.5
6	Siltstone: grayish red (l0 R 4/2) with very pale green (l0 G 8/2) reduction spots; very calcareous; slope.	4.5
5	Siltstone: same colors and lithology as unit 2.	0.8
4	Siltstone: moderate reddish orange (10 R 6/6) with pale yellowish green (10 GY 7/2) reduction spots; very calcareous.	8.0
3	Sandstone: pale red (l0 R 6/2); very fine grained; subrounded and well sorted; micaceous litharenitic; calcareous; trough crossbedded grading upward to laminar; forms a ledge.	3.8
2	Siltstone: moderate reddish orange (10 R 6/6) with very pale green (10 G 8/2) reduction spots; noncalcareous; laminar and ripple laminar with much horizontal bioturbation.	0.5-1.5
1	Silty mudstone: moderate reddish brown (10 R 4/6) with very pale green (10 G 8/2) reduction spots; very calcareous; some secondary gypsum in veins that cut across bedding; *Coelophysis* quarry is 9.0 m above base of unit; correlates with unit 20 of Canjilon quarry section.	20.5

Canjilon quarry

Measured in the SW1/4, sec. 2, T24N, R4E, Rio Arriba County.

unit	lithology	thickness (m)
	San Rafael Group:	
	Entrada Sandstone:	
29	Sandstone: pale greenish yellow (10 Y 8/2); very fine-fine grained; subrounded; moderately sorted; quartzarenitic; not calcareous; trough crossbedded; forms a cliff.	not measured
	unconformity (J-0-J-2 unconformity)	
	Chinle Group:	
	Rock Point Formation:	
28	Muddy siltstone: grayish red (10 R 4/2) with pale yellowish green (10 GY 7/2) mottles; calcareous.	2.4
27	Siltstone: mottled pale red (5 R 6/2) and very pale green (10 G 8/2); very calcareous.	7.3
26	Siltstone: same colors and lithology as unit 25, except forms a slope.	4.5
25	Siltstone: moderate reddish brown (10 R 4/6) with very pale green (10 G 8/2) veinlets; very calcareous; ripple laminar ledges.	3.2
24	Silty mudstone and siltstone: mottled moderate red (5 R 5/ 4) and very pale green (10 G 8/2); very calcareous; bioturbated ledge (paleosol?).	2.5
23	Silty mudstone: pale reddish brown (10 R 5/4) and very pale green (10 G 8/2); very calcareous.	9.0
22	Silty mudstone: pale reddish brown (10 R 5/4); very calcareous; some thin sandstone ledges of unit 21 lithology with extensive bioturbation and ripple laminae.	7.5
21	Sandstone and sandy siltstone: sandstone is pale green (5 G 7/2),	

fine-medium grained, subangular, moderately sorted, clayey, quartzose and laminar; sandy siltstone is very pale green (10 G 8/2) and pale reddish brown (10 R 5/4), very calcareous. 2.0

20 Muddy siltstone with thin sandstone and conglomerate lenses: muddy siltstone is moderate reddish brown (10 R 4/6), slightly calcareous and has gypsiferous veins that are yellowish gray (5 Y 7/2); sandstone is moderate reddish orange (10 R 616), very fine grained, subrounded, well sorted, quartzarenitic; conglomerate is light olive gray (5 Y 5/2) and composed of very calcareous clasts of nodular calcrete. 18.5

19 Sandy mudstone: pale yellowish green (10 GY 7/2); slightly calcareous. 6.3

18 Mudstone intercalated with thin beds of ripple-laminar siltstone: mudstone is moderate reddish brown (10 R 4/6) and very calcareous; siltstone is very pale green (10 G 8/2), weathers moderate reddish brown (10 R 4/6) and is moderately calcareous. 13.0

unconformity (Tr-5 unconformity of Lucas, 1993)

Petrified Forest Formation:

Painted Desert Member:

17 Mudstone: moderate reddish brown (10 R 4/6); very calcareous. 3.0

16 Muddy siltstone, siltstone and conglomerate: grayish yellow green (5 GY 7/2); very calcareous; same lithology and bed forms as unit 12. 5.0

15 Silty mudstone: same color and lithology as unit 13. 3.0

14 Muddy siltstone, siltstone and conglomerate: same colors and lithology as unit 12. 6.5

13 Silty mudstone: pale reddish brown (10 R 5/4); very calcareous. 4.0

12 Muddy siltstone, siltstone and conglomerate: muddy siltstone is grayish purple (5 P 4/2) and very calcareous; siltstone is pale olive (10 R 6/2), very calcareous and ripple laminar; conglomerate is light olive gray (5 Y 5/2), very calcareous and has same clast composition as unit 3 (clasts up to 1.5 cm in diameter); siltstone and conglomerate are interlaced with muddy siltstone in trough-form "arroyo-fill facies." 5.3

11 Muddy siltstone with interbeds of ripple-laminar siltstone: moderate reddish brown (10 R 4/6); very calcareous. 4.0

10 Conglomerate: pale red (10 R 6/2); same lithology as unit 3; Canjilon phytosaur quarry. 0.1

9 Mudstone: moderate reddish brown (10 R 4/6) with pale green (5 GY 7/2) mottles; noncalcareous. 8.3

8 Mudstone: grayish red purple (5 RP 4/2); noncalcareous. 1.7

7 Silty mudstone: grayish red (10 R 4/2); very calcareous. 6.0

6 Mudstone, siltstone and conglomerate: mudstone is greenish gray (5 G 8/1) and very calcareous; siltstone is light greenish gray (5 G 8/1) and very calcareous; conglomerate is greenish gray (5 G 6/1) and same lithology as unit 3; mudstone, siltstone and conglomerate form trough beds ("arroyo-fill facies"); calcareous concretions (nodular calcrete) are light greenish gray (5 G 8/1), and up to 5 cm in diameter. 1.5

5 Mudstone: moderate reddish brown (10 G 8/2) reduction spots; very calcareous; slightly sandy; nodular calcrete up to 3 cm in diameter. 2.5

4 Mudstone with thin beds of ripple-laminar siltstone: grayish red (10 R 4/2); very calcareous. 4.0

3 Conglomerate: very pale green (10 G 8/2); clasts are coarse-very coarse pebbles of limestone (calcrete); matrix is mudstone; very calcareous. 0.6

2 Mudstone: grayish red (10 R 4/2); moderately calcareous. 1.9

1 Muddy siltstone: pale reddish brown (10 R 5/4); calcareous. 4.5+

Abiquiu Dam

Measured in the N1/2 sec. 8, T23N, R4E, Rio Arriba County.

unit lithology thickness (m)

Chinle Group:

Petrified Forest Formation:

Mesa Montosa Member:

34 Mudstone: grayish red purple (5 RP 4/2) and pale green (5 G 7/2); calcareous. 5.0

Poleo Formation:

33 Mudstone and interbedded sandstone: mudstone is same color and lithology as unit 22; sandstone is same color and lithology as unit 30. 3.8

32 Sandstone: same color and lithology as unit 30. 8.5

31 Siltstone: grayish red (10 R 4/2) and pale yellow green (10 GY 7/2); noncalcareous. 3.8

30 Sandstone: mottled grayish red (10 R 4/2) and moderate yellow green (5 GY 7/4); very fine grained; subrounded; well sorted; quartzose; ripples; planar bedding. 3.0

29 Siltstone: grayish red (10 R 4/2); slightly calcareous; platy; inclined heterolithic stratification. 1.1

28 Muddy siltstone: grayish red (10 R 4/2); noncalcareous; laterally is cut out by unit 29. 1.6

27 Sandstone: dusky yellow (5 Y 6/4); very fine grained; sub-angular; well sorted; quartzose; noncalcareous; planar cross-beds. 0.3

26 Sandstone: yellowish gray (5 Y 7/2); very fine grained; sub-angular; well sorted; quartzose; noncalcareous; massive. 2.0

25 Sandstone: pale olive (10 Y 6/2); very fine grained; subangular; well sorted; quartzose; very calcareous; planar and trough cross-beds; inclined heterolithic stratification. 14.2

24 Sandstone: grayish green (10 GY 5/2) and mottled dusky blue (5 PB 3/2); very fine grained; subrounded; well sorted; quartzose; very calcareous. 0.9

23 Sandstone: pale yellowish green (10 GY 7/2); very fine-fine grained; subrounded; poorly sorted; litharenitic; very calcareous; planar crossbeds; inclined heterolithic stratification. 3.2

22 Mudstone: pale red (10 R 6/2); calcareous. 6.0

21 Sandstone: grayish yellow green (5 GY 7/2); fine grained; subrounded; well sorted; hematitic quartzose; calcareous; planar crossbeds; inclined heterolithic stratification. 1.5

20 Mudstone: pale red (5 R 6/2); noncalcareous. 0.7

19 Sandstone and conglomerate: yellowish gray (5 Y 7/2); sandstone is very coarse, subrounded, poorly sorted, quartzose; clasts are black, red, gray quartzite up to 2 cm in diameter; planar bedded. 2.7

unconformity (Tr-4 unconformity of Lucas, 1993)

Salitral Formation:

18 Mudstone: grayish yellow green (5 GY 7/2); noncalcareous. 1.0

17 Siltstone: moderate reddish brown (10 R 4/6); noncalcareous. 5.8

16 Sandstone: pale olive (10 Y 6/2); very fine grained; sub-rounded; well sorted; micaceous litharenitic; noncalcareous; ripple laminar. 02

15 Mudstone with floating sand grains: greenish gray (5 GY 6/1); pink and white sand grains up to 4 mm in diameter. 1.1

14 Mudstone: medium gray (N 5) with mottling of light greenish gray (5 G 8/1). 0.9

13 Sandstone: pale yellowish green (10 GY 7/2) and grayish orange (10 YR 7/2) and pale red purple (5 RP 6/2); very fine grained; subangular; moderately sorted; litharenitic. 1.0

12 Muddy sandstone: pale yellowish green (10 GY 7/2); very fine-medium grained; subrounded; poorly sorted; quartzose; noncalcareous. 1.3

11 Siltstone: very dusky red purple (5 RP 2/2) and very pale green (10 G 8/2); calcareous. 1.3

10 Silty mudstone: very dusky red purple (5 RP 2/2) and very pale green (10 G 8/2); noncalcareous; forms ledge. 6.0

9 Sandstone: lower 2.0 m is light bluish gray (5 B 7/1) and upper portion is pale greenish yellow (10 Y 8/2); fines up from medium-coarse grained at base to fine-medium grained; subrounded; moderately sorted; quartzose; noncalcareous. 5.7

8 Silty mudstone: pale red (5 R 6/2); noncalcareous. 5.5

Shinarump Formation:

7 Muddy sandstone: gray orange pink (5 YR 7/2); very fine grained; subrounded; well sorted; litharenitic; very calcareous; poorly developed low angle crossbeds. 3.0

6 Sandstone: very light gray (N 8); medium-coarse grained; subrounded; well sorted; quartzose; noncalcareous; horizontal

lamination; unit thins laterally. 0.5
5 Conglomerate and sandstone: light gray (N 8); sandstone is fine-medium grained, subrounded. moderately sorted. quartzose; clasts are yellow, pink quartzite up to 6 cm in diameter. 1.5
4 Conglomerate and sandstone: light greenish gray (5 GY 8/ 1); sandstone is fine-medium grained. subrounded, moderately sorted, quartzose; clasts are yellow and pink quartzite up to 5 cm in diameter; unit thins laterally. 0.2
3 Sandstone: very light gray (N 8); very fine-fine grained; subrounded; well sorted; quartzose; noncalcareous. 0.3
2 Conglomeratic sandstone: grayish green (10 GY 5/2); very fine-coarse grained; subangular; poorly sorted; subarkosic; noncalcareous; clasts of quartzite up to 6 cm in diameter. 1.1
unconformity (Tr-3 unconformity of Pipiringos and O'Sullivan, 1978)
Cutler Group:
1 Sandy mudstone: grayish red (10 R 4/2) with reduction spots of pale green (5 G 7/2); noncalcareous. 2.9+

Type Agua Zarca and Salitral Formations

Measured in the SE1/4, sec. 36, T23N, R2E. Strata dip 12° to due west.

unit lithology thickness (m)

Chinle Group:
Poleo Formation:
24 Sandstone: yellowish gray (5 Y 7/2), weathers grayish olive green (5 GY 3/2); fine grained; subrounded; well sorted; calcareous; trough crossbedded; forms a cliff; top of unit a stripped surface here. 5.6
23 Sandstone: grayish yellow (5 Y 8/4); very fine grained; subrounded; well sorted; sublitharenitic; very calcareous; platy with small trough crossbeds; liesegang bands. 1.2
22 Conglomerate: same colors and lithology as unit 18. 2.3
21 Sandstone and conglomerate: sandstone is pale olive (10 Y 6/2); weathers dark yellowish brown (10 YR 4/2); very fine-fine grained; subrounded; well sorted; litharenitic; very calcareous; conglomerate is same colors and lithology as unit 18; in graded trough beds with sandstone at top. 3.0
20 Conglomerate: same colors and lithology as unit 18. 1.7
19 Sandstone: dusky yellow (5 Y 6/4); very fine-fine grained; subrounded; well sorted; litharenitic; noncalcareous; trough crossbedded. 0.2
18 Conglomerate: matrix is pale olive (10 Y 6/2); very fine-medium grained, angular-subangular; poorly sorted, very calcareous, subarkosic; clasts are red, white, pink and black chert; faint trough crossbeds. 1.1
17 Sandstone and conglomerate: sandstone is yellowish gray (5 Y 7/2), very fine grained, subrounded, well sorted, very calcareous, micaceous litharenitic; conglomerate consists of pale olive (10 Y 6/2) clasts of nodular calcrete up to 15 cm in diameter; conglomerate forms base of scours in trough-crossbedded sandstone. 1.5
unconformity (Tr-4 unconformity of Lucas, 1993)
Salitral Formation:
Youngsville Member:
16 Muddy sandstone: light greenish gray (5 GY 8/1); very fine-fine grained; subarkosic; subrounded; moderately sorted; litharenitic; massive. 3.6
15 Mudstone: same color and lithology as unit 13. 5.6
14 Mudstone: grayish red (5 R 4/2); noncalcareous. 3.0
13 Mudstone: grayish red purple (5 RP 4/2); noncalcareous. 2.4
Piedra Lumbre Member:
12 Sandstone (El Cerrito Bed): grayish red purple (5 RP 4/2); fine-medium grained; subrounded; moderately sorted; litharenitic; noncalcareous; small trough crossbeds. 1.2
11 Mudstone: grayish purple (5 P 4/2); noncalcareous. 3.6
10 Siltstone: mottled pale reddish purple (5 RP 6/2) and grayish yellow green (5 GY 7/2); paleosol. 0.8
Shinarump Formation:
9 Conglomeratic sandstone: very light gray (N 8); sandstone matrix same lithology as unit 8; clasts are black, pink and white quartzite pebbles up to 2 cm in diameter; trough cross-bedded; forms a bench. 3.4
8 Conglomeratic sandstone: light greenish gray (5 G 8/1); coarse-very coarse grained; subangular-subrounded; moderately sorted; quartzose; trough crossbedded; noncalcareous; 60 m to NW this unit is totally scoured out by unit 9. 0.7
7 Siltstone: grayish yellow (5 Y 7/2); noncalcareous; thin secondary gypsum platelets. 0.7
6 Sandstone: light greenish gray (5 GY 8/1); very fine-medium grained; subrounded; moderately sorted; quartzose; noncalcareous; trough crossbedded; forms a mottled ledge. 1.1
Zuni Mountains Formation:
5 Sandy siltstone: mottled grayish purple (5 P 4/2) and pale greenish yellow (10 Y 8/2); this unit locally cut out by unit 6. 1.5
unconformity (Tr-3 unconformity of Pipiringos and O'Sullivan, 1978)
Cutler Group:
4 Sandy mudstone: pale reddish brown (10 R 5/4); noncalcareous. 0.8
3 Conglomeratic sandstone: pale olive (10 Y 6/2); fine-coarse grained; subangular; poorly sorted; quartzose; noncalcareous; clasts are pale olive (10 Y 6/2) and grayish red purple (5 RP 4/2) mudstone and siltstone up to 1 cm in diameter. 0.7
2 Sandstone: grayish red purple (5 RP 4/2) with pale greenish yellow (10 Y 8/2) mottles; very fine-fine grained; subrounded; moderately sorted; subarkosic; massive. 1.8
1 Sandstone: grayish red (10 R 4/2) with moderate yellowish green (5 GY 7/4) mottles; fine-coarse grained; subangular to poorly sorted; subarkosic; massive. not measured.

Type section of Poleo Formation

Measured in the NW1/4 NW1/4 sec. 36, T23N, R2E, Rio Arriba County. Strata dip 3-5° to N20°E.

unit lithology thickness (m)

Chinle Group:
Poleo Formation:
12 Sandstone: pale olive (10 Y 6/2); very fine-fine grained; subangular and moderately sorted; micaceous litharenitic; very calcareous; trough cross bedded; caps ridges in this area. 1.7+
11 Conglomerate: pale yellowish brown (10 YR 6/2); siltstone and limestone (nodular calcrete) pebbles up to 7 mm in diameter; calcareous; trough crossbedded; contains bone fragments. 0.7
10 Mudstone: light brownish gray (5 YR 6/1); calcareous. 7.3
9 Muddy siltstone: dusky yellow (5 Y 6/4); calcareous. 2.4
8 Sandstone: dusky yellow (5 Y 6/4); very fine grained; subrounded and well sorted; micaceous subarkosic; noncalcareous; laminar and ripple laminar in shallow troughs; weathers flaggy. 1.7
7 Sandstone: same color and lithology as unit 6, but weathers flaggy. 1.2
6 Sandstone: dusky yellow (5 Y 6/4); very fine-fine grained; subrounded and moderately sorted; micaceous subarkosic; noncalcareous; lateral accretion crossbeds; liesegang bands. 2.7
5 Sandstone: grayish yellow (5 Y 8/4) and yellowish gray (5 Y 7/2); very fine grained; subangular-subrounded; well sorted; micaceous litharenitic; calcareous; lower 0.9 m are massive, upper 0.7 m trough crossbedded. 1.6
4 Silty mudstone and sandstone: mudstone is greenish gray (5 GY 6/1) and noncalcareous; sandstone is yellowish gray (5 Y 7/2) with dusky blue (5 PB 3/2) and dark yellowish orange (10 YR 6/6) mottles; very fine grained; subangular; well sorted; noncalcareous; micaceous litharenitic; black plant debris is up to 1x 3 cm; unit is a trough bottom of low angle trough-crossbedded sandstone with mudstone

and carbonaceous plant debris; base of unit is prominent scour. 0.5
3 Sandstone: yellowish gray (5 Y 7/2); very fine-fine grained; subrounded-subangular; moderately sorted; micaceous lith-arenitic; calcareous; trough crossbedded; trough bottoms are pebbly; forms a cliff. 2.6

unconformity (Tr-4 unconformity of Lucas, 1993)
Salitral Formation:
Youngsville Member:
2 Silty mudstone: grayish yellow green (5 GY 7/2); calcareous. 0.3-0.6
1 Silty mudstone: grayish red purple (5 RP4/2); noncalcareous. 3.0+

Coyote Amphitheater

Measured in the NW1/4 sec. 21, T23N, R3E. Strata dip 10° to N50°W.

unit lithology thickness (m)

San Rafael Group:
Entrada Sandstone:
16 Sandstone: pale reddish brown (10 R 5/4); very fine-fine grained; subrounded; moderately sorted; quartzarenitic; calcareous; trough crossbedded. not measured

unconformity (J-0-J-2 unconformities of Pipiringos and O'Sullivan, 1978)
Chinle Group:
Petrified Forest Formation:
Painted Desert Member:
15 Mudstone, sandstone and sandy mudstone: mudstone is moderate reddish brown (10 R 4/6) with very pale green (10 G 8/8) reduction spots, noncalcareous, bentonitic, some cover; sandstone is pale green (5 G 7/2), very fine grained, subangular/subrounded, well sorted, micaceous litharenitic; sandy mudstone is moderate reddish orange (10 R 6/6) and pale reddish purple (5 RP 6/2); some gravelly scour-and-fill structures with bone fragments. 84.0
14 Siltstone: moderate reddish brown (10 R 4/6) with very pale green (10 G 8/2) reduction spots; contains some medium-coarse grained sandstone beds that fill scours and contain bone fragments. 42.0
13 Mudstone: same colors and lithology as unit 8. 8.0
12 Silty mudstone: same colors and lithology as unit 7. 26.5
11 Conglomeratic sandstone: same colors and lithology as unit 9; very persistent laterally. 0.8
10 Silty mudstone: same colors and lithology as unit 7. 16.8
9 Conglomeratic sandstone: pale reddish brown (10 R 5/4) and pale green (5 G 7/2); medium-very coarse grained; sub-rounded; poorly sorted; litharenitic; larger clasts are lime-stone (nodular calcrete); trough crossbeds. 1.0
8 Mudstone: pale reddish brown (10 R 5/4) with very pale green (10 G 8/2) streaks; contains numerous concretions of nodular calcrete; trough fill. 8.0
7 Silty mudstone: moderate reddish brown (10 R 4/6) with pale yellowish green (10 GY 7/2) reduction spots; very calcareous. 9.0
Mesa Montosa Member:
6 Muddy siltstone: moderate brown (5 YR 4/2) with pale green (5 G 7/2) mottles; very calcareous. 1.8
5 Siltstone and conglomerate: siltstone is moderate brown (5 YR 4/4), very calcareous and ripple laminar; conglomerate is brownish gray (5 YR 4/1) with clasts of mudstone and siltstone up to 1 cm in diameter; ledges of siltstone are intercalated with pebbly beds; NMMNH locality 911, *Pseudopalatus* and *Typothorax*. 10.5
Poleo Formation:
4 Sandstone with thin beds of mudstone: sandstone is light greenish gray (5 G 8/1), ripple laminar and same lithology as unit 2; mudstone is moderate brown (5 YR 4/4); units 4 and 5 represent a transitional interval between the Poleo and Petrified Forest Formations. 15.0
3 Sandstone: light greenish gray (5 G 8/1), weathers to grayish brown (5 YR 3/2); same lithology as sandstone in unit 2; noncalcareous; low angle crossbeds and ripple laminations; scour surfaces about 1.5 m apart; top 2 m very ripple laminar; forms cliff. 10.5
2 Sandstone: grayish yellow green (5 GY 7/2); very fine grained; subrounded; well sorted; micaceous litharenitic; noncalcareous; ripple laminated. 2.5

unconformity (Tr-4 unconformity of Lucas, 1993)
Salitral Formation:
Youngsville Member:
1 Mudstone and muddy sandstone: pale olive (10 Y 6/2); sand-stone is very fine grained, subrounded-subangular, poorly sorted mic-aceous litharenitic; moderately calcareous; forms a slope above purple bentonitic mudstone. 3.5

Cerro Blanco

Measured in the NE1/4, sec. 4, T23N, R1E, Rio Arriba County.

unit lithology thickness (m)

San Rafael Group:
Entrada Sandstone:
21 Sandstone: pale green yellow (10 Y 8/2); fine grained; sub-rounded; well sorted; noncalcareous; trough crossbedded; cliff former. not measured

unconformity (J-0-J-2 unconformities of Pipiringos and O'Sullivan, 1978)
Chinle Group:
Petrified Forest Formation:
Painted Desert Member:
18 Mudstone: pale blue (5 B 5/6); calcareous. 4.6
17 Silty mudstone: same lithology and color as unit 11. 5.9
16 Mudstone: grayish red purple (5 RP 4/2) and grayish yellow green (5 GY 7/2); slightly silty; very calcareous. 0.6
15 Silty mudstone: same lithology and color as unit 11. 11.4
14 Silty mudstone: mottled moderate reddish brown (10 R 4/6) and grayish yellow green (5 GY 7/2); moderately calcareous. 0.35
13 Silty mudstone: same lithology and color as unit 11. 2.9
12 Silty sandstone: moderate reddish brown (10 R 4/6); very fine grained; subangular to subrounded; well sorted; quartzose; much hematite; noncalcareous. 0.6
11 Silty mudstone: same lithology and color as unit 9. 4.9
10 Muddy sandstone: moderate reddish brown (5 R 5/4) and pale green (5 G 7/2); very fine grained; subangular; well sorted; quartzose; platy and lenticular. 1.8
9 Silty mudstone: pale reddish brown (10 R 5/4); very calcareous. 4.9
8 Mudstone, grades up to sandy siltstone: mudstone is grayish red purple (5 RP 4/2) and noncalcareous; sandy siltstone is grayish red purple (5 RP 4/2) to grayish yellow green (5 GY 7/2); sand is medium grained, subrounded, quartzose and very calcareous. 3.4
7 Siltstone: pale reddish brown (10 R 5/4); very calcareous. 11.9
6 Sandstone and clay-pebble conglomerate: dusky red (5 R 3/4) to moderate yellow green (5 GY 7/4); sandstone is same lithology as unit 3; very calcareous; conglomerate clasts are calcrete, highly calcareous; conglomerate has crude trough crossbeds; sandstone is 15-cm-thick laminar bed 1 m from base; unit 8 is laterally discon-tinuous and pinches out 10 m laterally; NMMNH locality 918, type locality of *Typothorax coccinarum*, is in conglomerate. 2.0
5 Muddy siltstone, grades up to silty mudstone: muddy silt-stone is pale olive (10 Y 6/2) and highly calcareous; silty mudstone is pale reddish brown (10 R 5/4) and noncalcareous. 8.1
4 Mudstone: same lithology and color as unit 2. 5.6
3 Siltstone and sandstone: dark reddish brown (10 R 3/4); sand-stone is very fine grained, quartzose, with mica flakes; slightly calcareous. 3.4
2 Mudstone: pale red purple (5 RP 6/2) with some mottling of

grayish yellow green (5 GY 7/2); slightly silty; very calcareous. 1.4

1 Mudstone: yellowish gray (5 GY 7/2) and pale reddish brown (10 R 5/4); bentonitic; very calcareous. 5.0

Mesa Montosa B

Measured in the NW1/4 SE1/4. sec. 36, T23N, R2E, Rio Arriba County.

unit lithology thickness (m)

Chinle Group:
Salitral Formation:
Piedra Lumbre Member:

11 Sandy mudstone: light greenish gray (5 G 8/1); noncalcareous. 1.5

Shinarump Formation:

10 Sandstone: light greenish gray (5 GY 8/1); fine-medium grained; subrounded; moderately sorted; sublitharenitic; noncalcareous; ripple laminar and bioturbated; caps ledge. 0.1

9 Sandstone: grayish blue (5 PB 5/2); fine-coarse grained; subrounded; poorly sorted; litharenitic; noncalcareous; trough crossbedded. 1.7

8 Mudstone: mottled grayish red purple (5 RP 4/2) and dusky yellow (5 Y 6/4); noncalcareous. 2.7

7 Sandstone: grayish red purple (5 RP 4/2); fine-medium grained; subrounded; moderately sorted; micaceous litharenitic; trough crossbedded; some angular pebbles of chert and quartzite. 2.0

Zuni Mountains Formation:

6 Sandy mudstone and siltstone: mottled very dusky red purple (5 RP 2/2) and moderate reddish orange (10 R 6/6); secondary gypsum platelets; forms a slope. 2.4

5 Sandstone: grayish red purple (5 RP 4/2); medium grained; subrounded; well sorted; lithic wacke; noncalcareous; bioturbated with a hint of trough crossbeds; some quartzite-pebble gravels; forms a ledge. 0.8

4 Siltstone: mottled very dusky purple (5 P 2/2) and light olive gray (5 Y 5/2); noncalcareous. 1.7

3 Sandy mudstone and siltstone: mottled grayish purple (5 P 4/2) and dusky yellow (5 Y 6/4); sandy nodules are grayish yellow green (5 GY 7/2) and light brown (5 GY 5/6); noncalcareous. 1.4

2 Silty sandstone: mottled very dusky red purple (5 RP 2/2), dusky yellow (5 Y 6/4), moderate reddish brown (10 R 4/ 6) and pale greenish yellow (10 Y 8/2); very fine-fine grained; subrounded-subangular; moderately sorted; arkosic; noncalcareous; massive; ledge former. 0.8

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

1 Muddy sandstone: moderate reddish brown (10 R 4/6) with pale greenish yellow (10 Y 8/2) reduction spots; fine-medium grained; subrounded; poorly sorted; arkosic; noncalcareous; massive. not measured

Snyder Quarry

Section measured up a northwest-trending tributary of Arroyo Seco. Section begins at UTM zone 13S, 036937E, 4022522N and ends at UTM zone 13S, 0362982E, 4022951N.

unit lithology thickness (m)

San Rafael Group:
Entrada Sandstone:

12 Sandstone, very pale orange (10 YR 8/2) to grayish orange (10 YR 7/4), weathers to light brown (5 YR 6/4), fine- to medium-grained, subangular to subrounded, well-sorted quartz-arenite, trough crossbedded and forms a pale green/gray cliff; very calcareous. Not measured

unconformity (J-0-J-2 unconformity of Pipiringos and O'Sullivan, 1978)
Chinle Group:
Rock Point Formation:

11 Siltstone, mottled moderate brown (5 YR 4/4), moderate brownish yellow (10 YR 5/4) to yellowish gray (5 Y 8/1) and light greenish gray (5 GY 8/1); very calcareous, blocky, forms a cliff. 7.2

10 Siltstone with rare clay rip-ups, light brown (5 YR 5/6) to moderate brown (5 YR 4/4); moderately calcareous, forms a slope. 6.7

9 Siltstone and silty mudstone, light brown (5 YR 5/6) to light brown (5 YR 6/4) with mottles of light greenish gray (5 GY 8/1); moderately calcareous (green mottles are very calcareous); green is muddy clay; blocky, bleachouts on joint exposure. 4.0

8 Prominent "white" silty mudstone stripe, mostly greenish gray (5 GY 8/1); not calcareous. 0.6

7 Siltstone, mottled yellowish gray (5 Y 8/1) and light brown (both 5 YR 6/4 and 5 YR 5/6), moderately calcareous, laminated, also a blocky tan mudstone, light brown (5 YR 5/6), calcareous, referred to as 7A; marks a pronounced color and lithological change from dark red bentonitic mudstone with popcorn weathering (below) to non-bentonitic slick slopes with less crumbly and more blocky lithologies. 17.1

unconformity (Tr-5 unconformity of Lucas, 1993)
Petrified Forest Formation:
Painted Desert Member:

6 Bentonitic mudstone, pale reddish brown (10 R 5/4) with mottles of light greenish gray (5 GY 8/1), not particularly silty, calcareous, mottles are confined to irregular lenses, weathers darker than underlying unit. 6.3

5 Mudstone, pale reddish brown (10 R 5/4), bentonitic, calcareous, finely laminated, slightly silty. 2.7

4 Muddy sandstone to sandy mudstone, grayish red (10 R 4/2), very fine grained, subrounded, well-sorted, subarkosic wacke, some low angle trough crossbeds, forms a heterolithic slope, slightly micaceous with both biotite and muscovite, very weakly calcareous. 4.2

3 Silty mudstone, pale red purple (5 RP 6/2) to grayish red purple (5 RP 4/2) with lens that are pale green (5 G 7/2) to light greenish gray (5 GY 8/1), micaceous with biotite, moderately calcareous, thin sandstone is very fine grained, subrounded, moderately well sorted, quartzwacke, very calcareous. 4.8

2 Siltstone and sandstone with lenses of intraformational conglomerate, greenish gray (5 GY 6/1) with some mudstone rip-ups, plant debris, fish scales, moderately calcareous; mudstone is light olive gray (5 Y 6/1), silty, calcareous; conglomerate is greenish gray (5 GY 6/1) with matrix of very coarse grained, rounded to well rounded chert clasts, wacke when sandy, clast-supported when conglomerate; stratigraphic level of the Snyder quarry (NMMNH L-3845). 3.0

1 Muddy claystone, pale red purple (5 RP 6/2) to grayish red purple (5 RP 4/2), some rare coarser clasts, very bentonitic, calcareous, top purple bed above the quarry level. 3.8

Mesa Montosa Member Type Section

Measured in Coyote amphitheater. Base of section at UTM zone 13, 353291E, 4009034N, NAD 27, top at 353321E, 4009100N. Strata dip 8° to N50°W.

unit lithology thickness (m)

Chinle Group:
Petrified Forest Formation:
Painted Desert Member:

9 Mudstone: moderate brown (5 YR 3/4-4/4) with pale olive (10 Y 6/2) mottles; very calcareous. Not measured

Mesa Montosa Member (type section):

8 Muddy siltstone: moderate reddish brown (10 R 4/6); very calcareous; micaceous; thin ledges of lithic sandstone; cross-laminated. 4.5

7 Sandstone and silty mudstone: sandstone is pale brown (5 YR 5/2),

very fine-fine grained, subangular, moderately sorted, clayey, quartzose, laminated and calcareous; silty mudstone is moderate brown (5 YR 4/4), very calcareous, laminated, slope former. 2.2

6 Sandstone and mudstone; same lithologies as unit 7 but with more sandstone. 2.4

5 Sandstone: moderate brown (5 YR 4/4) to pale brown (5 YR 5/2); very fine-fine grained; subrounded; well sorted; clayey and quartzose; calcareous; ripple laminated; forms bench. 0.8

4 Muddy siltstone: pale brown (5 YR 5/2); calcareous; laminated. 7.8

3 Sandstone: pale yellowish brown (10 YR 6/2); very fine grained; subrounded; moderately sorted; clayey and quartzose, some clay rip-up clasts; very calcareous; cross-bedded with climbing ripples; forms ledge. 1.0

2 Sandstone and mudstone: sandstone is pale olive (10 Y 6/2), moderately rounded, moderately sorted, clayey and quartzose, slightly calcareous, micaceous, faint laminations, lenses; mudstone is mottled pale olive (10 Y 6/2) and moderate brown (5 YR 4/4), very calcareous, nodular, bentonitic. 3.5

Poleo Formation:

1 Sandstone: pale olive (10 Y 6/2); very fine grained; subrounded; well sorted; clayey and quartzose; moderately calcareous; micaceous; ripple laminated. 2.0+

Youngsville Landfill

Base of section at UTM zone 13, 357453E, 4005948N, NAD 27, top at 357764E, 4005353N. Strata are ~ flat lying.

unit lithology thickness (m)

Chinle Group:

Poleo Formation:

17 Sandstone: very pale orange (10 YR 8/2); medium grained; subrounded; well sorted; quartz arenite; moderately calcareous; low-angle trough crossbeds; rounded weathering. 3.0+

16 Sandstone: grayish orange (10 YR 7/4) to pale yellowish orange (10 YR 8/6); fine-medium grained; subangular to subrounded; well sorted; quartz arenite; noncalcareous; faint ripple laminations; plant debris. 0.9

15 Pebble sandstone: yellowish gray (5Y 7/2); medium grained; subrounded; moderately sorted; clayey and quartzose; calcareous; rare mudclasts (0.5 mm diameter); oxidized stem fragments; thick bedded. 0.7

Salitral Formation:

Youngsville Member (type section):

14 Mudstone: pale reddish brown (10R 5/4); bentonitic; very calcareous. 4.1

13 Mudstone like unit 14 with lenses of pebbly sandstone: moderate reddish brown (10R4/6) and pale greenish yellow (10Y 8/2); medium grained; subrounded; poorly sorted; heterolithic; very calcareous; clasts are mud pebbles; nodular; forms slopes. 3.4

12 Silty mudstone: moderate brown (5 YR 4/4); bentonitic; noncalcareous. 18.6

Piedra Lumbre Member (type section):

11 Sandstone (type El Cerrito Bed): yellowish gray (5 Y 8/1); medium to coarse grained; subangular to rounded; moderately sorted; clayey and quartzose; slightly calcareous; trough crossbeds; horizontal burrow traces on bedding planes. 1.6

10 Mudstone: light olive gray (5 Y 5/2) and moderate brown (5 YR 3/4); with lenses of sandstone that are coarse grained; rounded; moderately sorted; quartz and mud pebbles; clayey; noncalcareous; massive; slope former. 4.8

Shinarump Formation:

9 Sandstone: light gray (N 7); medium to very coarse; subangular to subrounded; moderately sorted; quartz, large hematitic concretions, goethite; calcareous; pedogenically modified. 0.7

8 Sandy siltstone and sandstone; sandy siltstone is pale red (10 R 6/2), heterolithic, noncalcaerous, faintly laminated; sandstone is yellowish gray (5 Y 8/1), medium to very coarse grained, angular to subrounded, moderately sorted, quartz with clay, slightly calcareous, laminated, trough crossbedded. 2.7

7 Sandstone: mottled colors include pale red (5 R 6/2), pale red (10 R 6/2), very pale orange (10 YR 8/2), grayish brown concretions (5 YR 3/2); fine-medium grained; subangular to subrounded; poorly sorted; quartzose; noncalcareous; massive. 1.6

6 Sandstone: grayish brown (5 YR 3/2); coarse-very coarse grained; subangular; moderately sorted; quartz and clay; calcareous; petrified log fragments; carnotite. 1.0

5 Sandy siltstone; mottled colors include light brown (5 YR 5/6), light brown (5 YR 6/4), dark yellowish orange (10 YR 6/6); quartzose; noncalcareous; forms slope. 2.7

4 Sandstone: mottled colors include pale red (5 R 6/2), pale red (10 R 6/2), very pale orange (10 YR 8/2), very light gray N8; fine-medium grained; subangular to subrounded; poorly sorted; quartzose; noncalcareous; massive. 1.5

3 Conglomerate: matrix is yellowish gray (5 Y 8/1), very pale orange (20 YR 8/2) and moderate brown (5 YR 3/4), medium-coarse grained, angular to subrounded sandstone; clasts are quartz and feldspar up to 1.5 mm in diameter; noncalcareous; scour base with up to 0.5 m relief. 2.9

Zuni Mountains Formation:

2 Sandstone: mottled pinkish gray (5 YR 8/1), dark yellowish orange (10 YR 6/6) and grayish red (5 R 4/2); fine-medium grained; subrounded; moderately sorted; quartz, hematite-coated quartz and clay; noncalcareous. 4.2

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

Cutler Group:

1 Sandy siltstone: moderate brown (5 YR 3/4); quartzose; noncalcareous; unconsolidated; faint laminations. not measured

Abiquiu Dam B

Measured in the highway cut above Abiquiu Dam at UTM zone 13, 372001E, 4010777N, NAD 27. Strata are ~ flat lying.

unit lithology thickness (m)

Chinle Group:

Petrified Forest Formation:

Painted Desert Member:

11 Mudstone: moderate brown (5 YR 3/4); calcareous. not measured

Petrified Forest Formation:

Mesa Montosa Member:

10 Muddy claystone and siltstone: claystone is moderate brown (5 YR 4/4), very calcareous, pockets of siltstone chips; siltstone is light greenish gray (5 GY 8/1), moderately calcareous, ripple laminated, micaceous; forms slopes. 2.9

9 Sandstone: grayish orange pink (5 YR 7/2) to light brown (5 YR 6/4); very fine grained; angular; well sorted; subarkosic; calcareous; faint laminations (differing composition); trough crossbeds; rare siltstone interbeds in upper part. 1.4

8 Muddy siltstone: moderate brown (5 YR 3/4); very calcareous; ripple laminated; some soft sediment deformation. 3.8

Poleo Formation:

7 Sandstone: grayish orange (10 YR 7/4) with weathering rind of pale reddish brown (10 R 5/4); fine grained; subangular to subrounded; very well sorted; quartzose; calcareous; trough crossbedded; scour base. 2.3

6 Sandstone: pale brown (5 YR 5/2); quartz and feldspar; slightly calcareous; trough crossbeds with climbing ripples; grades laterally into lithology similar to unit 5. 2.1

5 Sandstone: moderate brown (5 YR 4/4); very calcareous; ripple laminated. 1.5

4 Sandstone: same lithology and color as unit 3; forms ledge with unit 3. 0.7

3 Sandstone: yellowish gray (5 Y 7/2) with weathering rind of light

brown (5 YR 5/6); calcareous in laminated areas; occasional laminations; micaceous; low angle crossbeds. 1.8
2 Muddy siltstone: pale brown (5 YR 5/2); moderately calcareous; ripple laminated, thin bedded. 1.2
1 Sandstone: dark yellowish orange (10 YR 6/6); quartzose; noncalcareous; color banding; trough crossbeds. not measured

Mesa Montosa Section A

Base at UTM zone 13, 353270E, 4005537N, NAD 27, top at 353110E, 4005611N. Strata are ~ flat lying.

unit lithology thickness (m)

Chinle Group:
Poleo Formation:
21 Sandstone: very pale orange (10 YR 8/2); quartzose; subrounded; well sorted; calcareous; faint laminations; trough crossbedded; cliff. 10.5+
20 Conglomerate: matrix is grayish orange (10 YR 7/4), weathered olive gray (5 Y 4/1) to brownish gray (5 YR 4/1), medium grained, subrounded, well sorted quartz arenite; clasts are chert, jasper, quartzite, calcrete rip-ups; calcareous. 1.2
19 Sandstone: very pale orange (10 YR 8/2); fine-medium grained; subrounded; well sorted; quartz arenite; calcareous; trough crossbedded, some overturned crossbeds. 2.6
18 Mudstone: mottled pale olive (10 Y 6/2) and moderate brown (5 YR 4/4); calcareous. 4.0
17 Conglomerate: matrix is very light gray (N 8), weathered pale brown (5 YR 5/2), medium-grained, subangular to rounded, moderately sorted, quartz arenite; clasts are mud pebbles, calcrete nodules, quartzite, quartz, feldspar; calcareous; unstratified. 1.3
16 Sandstone: very pale orange (10 YR 8/2) with weathering rind of moderate brown (5 YR 4/4); very fine-fine grained; subangular; well sorted; noncalcareous. 0.6
15 Sandstone: very pale orange (10 YR 8/2) with weathering rind of moderate brown (5 YR 4/4); very fine-fine grained; subangular; well sorted; trough crossbedded; noncalcareous. 1.4
14 Siltstone: yellowish gray (5 Y 7/2); quartzose; slightly calcareous; ripple laminated to thin bedded (wavy). 2.3
13 Silty sandstone: very pale orange (10 YR 8/2); very calcareous; rare mud pebbles; trough crossbeds; sharp scour surface. 1.1
unconformity (Tr-4 unconformity of Lucas, 1993)
Salitral Formation:
Youngsville Member:
12 Siltstone and silty mudstone: Siltstone is pale olive (10 Y 6/2), micaceous, noncalcareous; silty mudstone is pale olive (10 Y 6/2), quartzose, micaceous, noncalcareous, ripple laminated, thin bedded; forms slope. 6.7
Piedra Lumbre Member:
11 Sandstone (El Cerrito Bed): grayish orange (10 YR 7/4); very fine-fine grained; subangular to subrounded; well sorted; quartzose; rare mud pebbles; noncalcareous; large trough crossbeds; multistoried. 2.9
10 Muddy siltstone: dark yellowish brown (10 YR 4/2); quartzose; noncalcareous; blocky; thin sandstone lenses locally. 3.1
9 Mudstone: mottled pale yellowish brown (10 YR 6/2) and moderate brown (5 YR 3/4); noncalcareous; blocky to nodular; forms slope. 4.8
8 Conglomeratic sandstone and sandstone: conglomeratic sandstone is light olive gray (5 Y 5/2), weathers to grayish orange (10 YR 7/4), medium-coarse grained, subrounded, moderately sorted, quartzose, mud pebbles, moderately calcareous; sandstone is pale olive (10 Y 6/2) to grayish olive (10 Y 4/2), fine grained, subrounded, well sorted, quartzose, noncalcareous; forms bench. 0.5
7 Mudstone with sandstone lenses: sandstone is pale red (5 R 6/2), medium-coarse grained, subangular to subrounded, well sorted, noncalcareous, thin bedded; siltstone is pale red (5 R 6/2), dark reddish brown (10 R 3/4) and pinkish gray (5 YR 8/1), noncalcareous, nodular. 2.2
Shinarump Formation:
6 Sandstone: pale red (10 R 8/2) to grayish orange pink (10 R 8/2); coarse-very coarse grained; angular to subrounded; poorly sorted; quartz and clay; noncalcareous. 1.1
5 Sandstone: very pale orange (10 YR 8/2), weathered light brown (5 YR 5/6); fine-coarse grained; subangular to subrounded; moderately sorted; quartz and mud pebbles; slightly calcareous; trough crossbeds; scour base with up to 1 m relief. 2.0
4 Sandy siltstone: mottled dark reddish brown (10 R 3/4) and yellowish gray (5 Y 8/1); quartzose; noncalcareous; blocky; faint laminations in coarser material. 1.5
3 Conglomeratic sandstone: grayish pink (5 R 8/2), weathers moderate orange pink (10 R 7/4); medium-very coarse grained; subangular to subrounded; poorly sorted; quartzose; noncalcareous; crossbeds. 2.0
2 Conglomeratic sandstone: grayish pink (5 R 8/2) and moderate brown (5 YR 3/4); coarse grained; subangular to subrounded; moderately sorted; quartz, layers of clay and hematite-coated quartz; noncalcareous; quartzite pebbles up to 6 cm diameter; thickly laminar. 3.5
unconformity (Tr-3 unconformity of Pipiringos and O'Sullivan, 1978)
Cutler Group:
1 Silty mudstone: grayish red (10 R 4/2) to very dusky red (10 R 2/2); noncalcareous; micaceous. not measured

Piedra Lumbre Section

Base at UTM zone 13S, 362132E, 4012656N, NAD 27. Top at UTM zone 13S, 361906E, 4012811N. Strata are ~flat lying.

unit lithology thickness (m)

Chinle Group:
Petrified Forest Formation:
Painted Desert Member:
43 Covered slope. not measured
Mesa Montosa Member:
42 Conglomerate and sandstone: conglomerate is pale red (10 R 6/2) with matrix that is fine grained, subangular to subrounded, well sorted, quartz arenite, clasts are mud pebbles and calcrete nodules, very calcareous; sandstone is pale orange (10 YR 8/2) and weathered light brown (5 YR 6/4), medium grained, subangular to subrounded, moderately sorted, quartzose, very calcareous, ripple laminated. 0.5
41 Mudstone: same lithology and color as unit 39. 1.4
40 Sandy siltstone: pale brown (5 YR 5/2), weathered moderate brown (5 YR 4/4); quartz; micaceous; calcareous; trough crossbeds; thin bedded. 0.7
39 Mudstone: moderate brown (5 YR 3/4); micaceous; calcareous; ripple laminated; forms slope. 1.1
Poleo Formation:
38 Sandstone: grayish orange pink (5 YR 7/2); very fine-fine grained; subrounded; well sorted; heterolithic; moderately calcareous; ripple laminations; trough crossbeds; thin bedded. 4.2
37 Sandstone: same lithology and color as unit 31; trough crossbed foresets dip to the east; rounded weathering. 1.8
36 Mudstone: grayish red (10 R 4/2); calcareous; ripple laminated; forms slope. 2.3
35 Sandy siltstone: pale yellowish brown (10 YR 6/2); quartzose; very calcareous; ripple laminated; forms bench. 0.9
34 Sandy siltstone: pale yellowish brown (10 YR 6/2); quartzose; moderately calcareous; climbing ripple laminations; very thin bedded. 1.6
33 Sandstone: same lithology and color as unit 31; rounded weathering; oxidized plant debris. 8.9

32 Sandstone: yellowish gray (5 Y 7/2); medium-coarse grained; subrounded to rounded; moderately well sorted; quartzose; very calcareous; thin trough and ripple crossbeds, forms notch. 0.6
31 Sandstone: yellowish gray (5 Y 8/1); medium grained; subrounded to well rounded; well sorted; quartz arenite; very calcareous; trough crossbed foresets dip northeast; multistoried. 5.5
30 Pebbly sandstone: very pale orange (10 YR 8/2); medium-coarse grained; subrounded to rounded; poorly sorted; quartzose with calcrete pebbles; very calcareous; trough crossbeds. 0.4
29 Sandstone: yellowish gray (5 Y 7/2), weathered moderate brown (5 YR 4/4); very fine-fine grained; subangular to subrounded; moderately well sorted; very calcareous; trough crossbeds. 0.7
28 Conglomeratic siltstone: grayish orange (10 YR 7/4); quartzose; clasts are calcrete pebbles; calcareous; trough crossbeds; oxidized plant debris. 0.9
27 Muddy claystone: pale brown (5 YR 5/2); moderately micaceous; slightly calcareous; blocky to spheroidal with laminations. 4.7
26 Sandstone: very pale orange (10 YR 8/2); fine-medium grained; subrounded to rounded; well sorted; calcareous; ripple laminations at top; trough crossbeds; rounded weathering. 3.4
25 Sandstone and conglomerate: sandstone is dusky yellow (5 Y 6/4), fine grained, subangular to subrounded, well sorted, quartz arenite, moderately calcareous, trough crossbeds; conglomerate matrix is yellowish gray (5 Y 7/2), fine-medium grained, subangular to subrounded, moderately well sorted, quartz arenite with aligned pale olive (10 Y 6/2) clasts that are 3-4 mm in diameter, very calcareous, conglomerate in lower 0.5 m; bone fragments. 1.6
24 Sandstone: dusky yellow (5 Y 6/4); fine-medium grained; subrounded; well sorted; quartz; micaceous; very calcareous; trough crossbeds; large scour at base with calcrete conglomerate lag. 1.1
23 Sandstone: yellowish gray (5 Y 7/2) with weathering rind pinkish gray (5 YR 8/1); fine-medium grained; subrounded; moderately well sorted; quartz and clay; calcareous; weathering rind is noncalcareous clay-rich siltstone; trough crossbeds; multistoried; basal calcrete conglomerate lag. 3.8
22 Conglomeratic sandstone: pale brown (5 YR 5/2) and weathered dark yellowish brown (10 YR 4/2); fine grained; subrounded; poorly sorted; quartz; mud pebbles; very calcareous; trough crossbeds. 0.6
21 Sandy mudstone: pale yellowish brown (10 YR 6/2); calcareous; thinly laminated; forms notch. 1.4
20 Sandstone: very pale orange (10 YR 8/2), weathered dusky yellow (5 Y 6/4); fine-medium grained; subrounded to rounded; well sorted; quartz arenite; very calcareous; trough crossbeds with foreset dip to southwest; multistoried. 2.9
19 Conglomerate: matrix is pale brown (5 YR 5/2) to pale yellowish brown (10 YR 6/2), fine grained, rounded, moderately well sorted, quartz arenite; clasts are mud and calcrete pebbles; calcareous; fine-grained areas are hematite-stained; trough crossbeds; sharp scour base; interfingers with unit 20. 1.0

unconformity (Tr-4 unconformity of Lucas, 1993)

Salitral Formation:

Youngsville Member:

18 Muddy claystone: grayish red (10 R 4/2), weathered grayish red (5 R 4/2) with mottles of grayish orange (10 R 7/4); noncalcareous; blocky. 14.6
17 Muddy claystone: mottled grayish red (5 R 4/2), grayish orange (10 YR 7/4) and very pale orange (10 YR 8/2); noncalcareous; waxy; blocky. 3.0

Piedra Lumbre Member:

16 Sandstone (El Cerrito Bed): pinkish gray (5 YR 8/1), weathered pale red (10 R 6/2); medium grained; angular to subrounded; moderately well sorted; arkosic; noncalcareous; small trough crossbeds; hummocky bedding. 0.2
15 Sandy mudstone: mottled grayish orange pink (10 R 8/2) and grayish red (10 R 4/2); irregularly shaped mud-chips; noncalcareous; bentonitic; blocky; forms slope. 4.3

Shinarump Formation:

14 Sandstone: very pale orange (10 YR 8/2), weathered light brown (5 YR 6/4), hematite-coated areas grayish brown (5 YR 3/2); medium-coarse grained; subangular to subrounded; moderately sorted; quartzose with clay-rich areas, arenitic areas; noncalcareous; faint ripple laminations; intensely pedoturbated; iron-replaced calcrete top. 1.1
13 Sandstone and conglomerate: sandstone is pinkish gray (5 YR 8/1), coarse-very coarse grained, subrounded, well sorted, quartz and clay, moderately calcareous; conglomerate is layered grayish red (5 R 4/2), grayish orange (10 YR 7/4) and dark yellowish orange (10 YR 6/6), clasts are quartz and mudchip granules, noncalcareous; trough crossbeds; sharp scour base. 1.7
12 Siltstone: mottled light brown (5 YR 6/4), pale reddish brown (10 R 5/4), dark yellowish orange (10 YR 6/6) and very pale orange (10 YR 8/2); slightly calcareous; iron-oxidized calcrete nodules. 0.5
11 Sandstone: same lithology and color as unit 9. 0.8
10 Silty mudstone: same lithology and color as unit 6. 0.6
9 Sandstone: banded light gray (N 7) and pinkish gray (5 YR 8/1); coarse-very coarse grained; subangular to subrounded; moderately sorted; quartzose; slightly calcareous; trough crossbeds. 0.8
8 Silty mudstone: same lithology and color as unit 6. 0.9
7 Conglomeratic sandstone: grayish pink (5 R 8/2), weathered pale red (5 R 6/2); subrounded; moderately sorted; quartz and clay; noncalcareous. 1.1
6 Silty mudstone: mottled light greenish gray (5 GY 8/1), grayish red (10 R 4/2) and moderate reddish orange (10 R 6/6); noncalcareous; ripple laminated. 1.0
5 Conglomeratic sandstone: yellowish gray (5 Y 8/1) and dark reddish brown (10 R 3/4); subangular to subrounded; moderately well sorted; hematite-stained quartz; noncalcareous; trough crossbeds. 1.1
4 Siltstone: pale reddish brown (10 R 5/4); noncalcareous; blocky. 0.9
3 Sandstone: layered white (N 9), light gray (N 7) and pale reddish brown (10 R 5/4); medium-coarse grained; subrounded; moderately well sorted; quartz and clay; hematite-stained patches; slightly calcareous; trough crossbeds; rounded weathering; sharp scour base with 0.3 m relief. 3.0

Zuni Mountains Formation:

2 Sandstone: dark reddish brown (10 R 3/4); fine-medium grained; angular to subangular; moderately well sorted; quartzose; micaceous; noncalcareous; faintly laminated. 3.3

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

Cutler Group:

1 Mudstone: moderate reddish brown (10 R 4/6); noncalcareous; blocky; calcrete nodules. not measured

Chaves Box

Base at UTM zone 13S, 369270E, 4069847N, NAD 27. Top at UTM zone 13S, 368761E, 4069759N. Strata dip 38° at S50° W.

unit lithology thickness (m)

San Rafael Group:

Entrada Sandstone:

36 Sandstone: light brown (5 YR 6/4); very fine-fine grained; subrounded; well sorted; quartz (arkosic?) and clay; calcareous; trough crossbeds. not measured

unconformity (J-0-J-2 unconformities of Pipiringos and O'Sullivan, 1978)

Chinle Group:

Rock Point Formation:

35 Siltstone: moderate brown (5 YR 4/4); quartzose; very calcareous. 7.2
34 Sandstone: mottled light brown (5 YR 6/4) and grayish orange

(10 YR 7/4); very fine-fine grained; subangular to subrounded; well sorted; quartz and clay; very calcareous; massive; forms bench. 1.9

33 Silty mudstone: moderate brown (5 YR 4/4); quartzose; very calcareous; forms slope. 3.2

32 Sandstone: light brown (5 YR 6/4); very fine-fine grained; subrounded to rounded; well sorted; hematite-stained quartz; micaceous; calcareous; ripple laminations; multistoried; forms cliff. 20.5

unconformity (Tr-5 unconformity of Lucas, 1993)

Petrified Forest Formation:

Painted Desert Member:

31 Siltstone: light brown (5 YR 5/6); very calcareous. 21.0

30 Covered interval. 23.0

29 Silty mudstone: moderate brown (5 YR 4/4); quartzose; noncalcareous; bentonitic; faint laminations; some thin sandstones. 16.3

28 Conglomeratic sandstone: mottled pale red (5 R 6/2), very pale orange (10 YR 8/2), dark yellowish orange (10 YR 6/6), grayish brown (5 YR 3/2), weathered grayish red (10 R 4/2); medium-grained; subangular to subrounded; moderately poorly sorted; quartzose; noncalcareous; pedoturbated. 1.4

27 Siltstone: pale reddish brown (10 R 5/4); slightly micaceous; noncalcareous. 3.9

26 Covered interval. 18.0

25 Mudstone: moderate reddish brown (10 R 4/6); slightly calcareous; bentonitic. 8.0

24 Conglomeratic sandstone: pale reddish brown (10 R 5/4); coarse grained; subangular to subrounded; poorly sorted; quartz, quartzite pebbles; noncalcareous. 4.0

23 Covered interval. 38.0

22 Sandstone: grayish red (5 R 4/2), pale red (5 R 6/2) and very light gray (N 8); coarse-very coarse grained; subangular to subrounded; moderately sorted; quartz and hematite-stained quartz, clay; calcareous; laminar; medium bedded interbedded with coarser, thicker beds. 2.5

21 Silty mudstone: grayish red (5 R 4/2); micaceous; noncalcareous; thinly ripple laminated. 1.6

20 Muddy claystone and mudstone: muddy claystone is grayish red (5 R 4/2) with mottles of light greenish gray (5 GY 8/1), calcareous; mudstone is yellowish gray (5 Y 8/2) and pale red (10 R 6/2), very calcareous, ripple laminated. 2.4

19 Mudstone: pale red (5 R 6/2) with spots of yellowish gray (5 Y 8/1); calcareous; sparse calcrete nodules. 5.3

18 Silty mudstone: pale red (5 R 6/2); very calcareous; thinly laminar; calcrete nodules. 5.0

17 Covered interval. 7.2

Mesa Montosa Member:

16 Sandstone and muddy siltstone: sandstone is white (N 9) with weathering rind yellowish gray (5 Y 8/1) to moderate orange pink (10 R 7/4), coarse grained, subrounded, moderately well sorted, quartz and clay, noncalcareous, trough crossbeds; muddy siltstone is grayish red (5 R 4/2), micaceous, noncalcareous, ripple laminated, lenses within sandstone. 6.0

15 Mudstone and siltstone: mudstone is grayish red (5 R 4/2), noncalcareous, blocky; siltstone is mottled grayish red purple (5 RP 4/2) and yellowish gray (5 Y 8/1), quartzose, noncalcaerous, interbedded with mudstone. 17.4

Poleo Formation:

14 Sandstone: pale red (5 R 6/2), weathered grayish red (10 R 4/2); coarse grained; subrounded; moderately poorly sorted; quartz and clay; calcareous; trough crossbeds; calcrete rip-ups. 2.5

13 Mudstone: grayish red (5 R 4/2), weathered pale reddish brown (10 R 5/4); noncalcareous; blocky. 1.2

12 Sandstone: pale reddish brown (10 R 5/4); coarse-grained; subangular to subrounded; moderately sorted; quartz and clay; noncalcareous; trough crossbeds. 4.7

11 Mudstone: grayish red (5 R 4/2); noncalcareous; blocky. 1.6

10 Conglomeratic quartzite: pale reddish brown (10 R 5/4); very coarse grained; subangular; well sorted; quartz arenite; noncalcareous. 0.9

9 Quartzite and metaconglomerate: quartzite is pale reddish brown (10 R 5/4), coarse grained (grains not very distinct), rounded, well sorted, quartz arenite, noncalcareous; metaconglomerate is pale reddish brown (10 R 5/4), matrix is quartzite (grain boundaries blurred), clasts are quartzite and siltstone pebbles, noncalcareous; thick bedded. 5.6

8 Quartzite: pale reddish brown (10 R 5/4); fine-medium grained; subrounded; well sorted; quartz arenite; noncalcareous; faint laminations. 3.2

7 Metaconglomerate: matrix is pale red purple (5 RP 6/2), weathered pale reddish brown (10 R 5/4), fine grained, subrounded to rounded, moderately sorted, quartzite; clasts are quartz and silt pebbles; noncalcareous. 0.7

6 Quartzite: same lithology and color as unit 3. 3.8

unconformity (Tr-4 unconformity of Lucas, 1993)

Salitral Formation:

5 Muddy siltstone: pale reddish brown (10 R 5/4); noncalcareous; chalky. 1.5

Shinarump Formation:

4 Quartzite: banded pale red (5 R 6/2) to moderate red (5 R 5/4); medium-coarse grained; moderately well sorted; quartz arenite; noncalcareous; trough crossbeds. 5.8

3 Conglomeratic quartzite: pale red (5 R 6/2); coarse grained; subrounded to rounded; well sorted; noncalcareous; clasts are quartzite pebbles; trough crossbeds. 1.6

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

Pennsylvanian strata:

2 Siltstone/argillite: pale reddish brown (10 R 5/4), weathered pale yellowish brown (10 YR 6/2); noncalcareous. not measured

1 Quartzite: light brown (5 YR 6/4); very coarse grained; subrounded; moderately sorted; quartz arenite; noncalcareous. not measured

Rest Stop Rock Point Section

Base at UTM zone 13S, 369733S, 4019385N, NAD 27. Top at UTM zone 13S, 370232S, 4018715N. Strata are ~flat lying.

unit lithology thickness (m)

Segment A (note unit A14=units B2-14):

Chinle Group:

Rock Point Formation:

14 Silty mudstone: moderate brown (5 YR 4/4) with mottles of light greenish gray (5 GY 8/1); mottled areas very calcareous, brown areas moderately calcareous; mottled areas blocky, brown areas ripple laminated; sandy lenses; forms slope. 12.5

13 Silty mudstone: grayish orange (10 YR 7/4); very calcareous; nodular; stage 3 calcrete. 0.2

12 Pebbly mudstone: light brown 5 YR 5/6; calcareous; blocky to nodular; moderately pedogenically modified; forms slope. 4.2

11 Mudstone: light brown (5 YR 6/4) and light greenish gray (5 GY 8/1); very calcareous; blocky to nodular; calcrete; pedogenically modified pond deposit; scour base. 0.3

10 Mudstone: light brown (5 YR 6/4) with rare spots of light greenish gray (5 GY 8/1); calcareous; blocky. 0.6

9 Muddy claystone: mottled light brown (5 YR 6/4) and yellowish gray (5 Y 8/1); calcareous; nodular to blocky; stage 4 calcrete with prismatic fabric. 0.2

8 Mudstone: light brown (5 YR 6/4) with ribbons of moderate brown (5 YR 4/4); moderately calcareous; blocky; contains stage 0-1 calcretes; forms slope. 8.8

7 Muddy siltstone: light brown (5 YR 6/4) with green nodules of light greenish gray (5 GY 8/1); moderately calcareous; nodular; stage 2-3 calcrete. 0.2

6 Mudstone: light brown (5 YR 5/6); calcareous; blocky; contains

stage 0-1 calcrete (hematized nodules). 6.0
5 Mudstone: light brown (5 YR 6/4); moderately calcareous; blocky. 0.9
4 Silty mudstone: moderate brown (5 YR 4/4); very calcareous; blocky; bio/pedoturbated; forms slope. 0.7
3 Silty mudstone: light brown (5 YR 5/6) mottled with light greenish gray (5 GY 8/1); calcareous; blocky. 3.5
2 Mudstone: light brown (5 YR 6/4) with rare spots light greenish gray (5 GY 8/1); calcareous; blocky; strings of coarser grains; forms slope. 4.5

Petrified Forest Formation:

Painted Desert Member:

1 Mudstone: light brown (5 YR 6/4); calcareous; blocky to faintly nodular; bentonitic. not measured

Segment B:

unit	lithology	thickness (m)

San Rafael Group:

Entrada Sandstone:

25 Sandstone: light brown (5 YR 5/6); fine-medium grained; rounded; well sorted; arkosic; noncalcareous; trough cross-beds; scour base. not measured

unconformity (J-0-J-2 unconformities of Pipiringos and O'Sullivan, 1978)

Chinle Group:

Rock Point Formation:

24 Pebbly siltstone: light brown (5 YR 6/4) layered with yellowish gray (5 Y 8/1); very calcareous; mud pebbles; ripple laminated; low angle crossbed sets with set breaks 0.5-1.0 m apart; scoured locally by Entrada Fm.; forms cliffs. 6.0
23 Sandstone and pebbly siltstone: sandstone is yellowish gray (5 Y 8/1) to grayish orange pink (5 YR 7/2), weathered light brown (5 YR 6/4), coarse grained, rounded, well sorted, mud and rare quartz, very calcareous, ripple laminated; pebbly siltstone is mottled pale reddish brown (10 R 5/4) and yellowish gray (5 Y 8/1), clasts are mud pebbles, very calcareous; beds are lens-shaped; multistoried; scour base with 0.5 m relief; forms cliff; contains phytosaur scute fragments. 1.2
22 Muddy siltstone: mottled pale reddish brown (10 R 5/4) and light greenish gray (5 GY 8/1); slightly calcareous; nodular; stage 2-3 calcrete; irregular base; forms notch. 0.7
21 Muddy siltstone: same lithology and color as unit 17. 1.4
20 Silty mudstone: same lithology and color as unit 18. 0.3
19 Muddy siltstone: same lithology and color as unit 17. 1.3
18 Silty mudstone: light brown (5 YR 5/6); noncalcareous; nodular to blocky; forms notch. 0.3
17 Muddy siltstone: light brown (5 YR 5/6) with mottles of yellowish gray (5 Y 8/1); calcareous; blocky; rounded and blocky weathering; forms cliff. 1.1
16 Silty mudstone and muddy siltstone: silty mudstone is moderate brown (5 YR 4/4), calcareous, blocky, forms basal 0.2 m of unit, rounded weathering; muddy siltstone is mottled moderate brown (5 YR 4/4) and light greenish gray (5 Y 8/1); calcareous; nodular. 1.6
15 Mudstone and siltstone: mudstone is mottled pale reddish brown (10 R 5/4) and light greenish gray (5 Y 8/1), very calcareous, nodular; siltstone is very light gray (N 8), calcareous, blocky; contain rhizoliths; massive; rounded weathering; forms prominent cliff. 5.0
14 Mudstone: light brown (5 YR 6/4 to 5/6); moderately calcareous; blocky; rare coarse quartz grains; common 6-10 cm diameter rhizoliths. 1.5
13 Silty mudstone: light brown (5 YR 5/6) to moderate brown (5 YR 4/4); calcareous; blocky; rounded weathering; forms prominent cliff. 2.2
12 Mudstone: light brown (5 YR 6/4 to 5/6); slightly calcareous; rare mud pebbles. 0.6
11 Mudstone: light brown (5 YR 5/6); moderately calcareous; blocky to rounded; rounded weathering; forms prominent cliff. 1.5
10 Mudstone: light brown (5 YR 6/4 to 5/6); moderately calcareous; blocky; occasional coarse sand grains; sheets of selenite 0.2 m above base. 0.7
9 Mudstone: pale reddish brown (10 R 5/4) with yellowish gray (5 Y 8/1) on planes; slightly calcareous; some pedogenesis; large rhizolith structures. 1.5
8 Pebbly siltstone: moderate reddish brown (10 R 4/6) with mud-chips of moderate orange pink (10 R 7/4); moderately calcareous, mudchips very calcareous; stage 3 calcrete; very irregular base. 0.5
7 Mudstone: pale reddish brown (10 R 5/4) with occasional mottles of light greenish gray (5 GY 8/1); slightly calcareous; blocky; truncated locally by unit 8. 0.5
6 Mudstone and pebbly mudstone: mudstone is light brown (5 YR 5/6) with mottles of yellowish gray (5 Y 8/1), moderately calcareous, blocky, possible calcrete; pebbly mudstone is light brown (5 YR 5/6) with mottles of yellowish gray (5 Y 8/1), mud pebble clasts, calcareous, blocky, stage 3 calcarete. 0.7
5 Pebbly mudstone: light brown (5 YR 6/4) with rare spots of light greenish gray (5 GY 8/1); mud pebble and chip clasts; very calcareous; blocky; scour base. 0.2
4 Mudstone: moderate brown (5 YR 4/4); moderately calcareous; nodular; contains calcrete nodules, moderate pink orange (10 R 7/4). 0.8
3 Siltstone: light brown (5 YR 6/4); slightly calcareous; blocky; large green mottles of light greenish gray (5 GY 8/1) in lower 0.5 m; some pedogenic alteration. 2.1
2 Mudstone: light brown (5 YR 5/6); calcareous; laminated. 0.15
1 Mudstone: moderate brown (5 YR 4/4) with rare spots of light greenish gray (5 GY 8/1); calcareous; blocky to nodular texture. 1.5

Orphan Mesa

Section measured at T24N, R5E, in the center of the western margin of section 18.

unit	lithology	thickness (m)

San Rafael Group:

Entrada Sandstone:

17 Sandstone; trough-cross bedded cliff with sandstone dikes into unit 16. not measured

unconformity (J-0-J-2 unconformities of Pipiringos and O'Sullivan, 1978)

Chinle Group:

Rock Point Formation:

16 Sandstone; yellowish gray (5 Y 8/1) and light greenish gray (5 GY 8/l); stained or weathered to moderate reddish orange (10 R 6/6) and moderate brown (10 R 4/6); very fine- to fine-grained, angular, well sorted quartzarenite; calcareous. 0.3
15 Siltstone; pale reddish brown (10 R 5/4) to grayish red (5R4/2); some mottles of yellowish gray (5Y7/2); laminated; not calcareous. 2.9
14 Sandstone, pale red (5 R 6/2) fresh, weathering to pale reddish brown (10 R 5/4); medium-grained, subangular, well-sorted sublitharenite; slightly micaeous; trough-crossbedded; forms a ledge; calcareous. 1.2
13 Sandy siltstone with interbeds of sandstone; siltstone is finely banded with bands of moderate red (5 R 5/4) dominating those of light greenish gray (5 GY 8/l); very micaceous; ripple laminated to small troughs/climbing ripples; both lithologies have green bands that are more calcareous than red; 0.3- to 0.5-m-thick trough cross- bedded sandstone interbeds are pale reddish brown (10 R 5/4) with white (N 9) to very light gray (N 8) flecks; weathers to moderate reddish brown.(10 R 4/6); fine- to medium-grained, subangular, moderately well-sorted sublitharenite: calcareous. 7.7
12 Sandstone; moderate orange pink (10 R 7/4) to grayish yellow green (5 GY 7/2); fine- to coarse-grained, subangular, poorly sorted sublitharenite; very micaceous; small fining-upward troughs, decreasing higher in the unit; some locally pebbly lenses; very calcareous. 5.9

11 Conglomerate; light greenish gray (5 GY 8/1) fresh, some moderate reddish orange . (10R6/6) stains, clasts are dominantly small quartz pebbles with minor lithics; base is a scour; very calcareous. 0.5-0.8

(Units 11-16 form a bold cliff below the Middle Jurassic Entrada Sandstone.)

10 Siltstone; moderate reddish brown (10 R 4/6); massive to bioturbated; some very light gray (N 8) flecks or mottles; very calcareous. 3.3

9 Siltstone and colluvium cover; siltstones vary from dark reddish brown (10 R 3/4) to pale reddish brown (10R5/4) and moderate reddish orange (10 R 6/6) to yellowish gray (5 Y 7/2) and pale greenish yellow (10 Y 8/2); non-red colors most frequently appear as spots, mottles or bands; some thin (<10 cm), ripple-laminated ledges; deeply weathered; forms a slope with the upper third covered by much colluvium. 28.5

unconformity (Tr-5 unconformity of Lucas, 1993) .

Petrified Forest Formation:

Painted Desert Member:

8 Mudstone; dark reddish brown (10 R 3/4); some thin yellowish gray (5 Y 7/2) sandy siltstone and silty sandstone beds; mudstone is bentonitic; both lithologies are calcareous; slope-forming unit with bottom two thirds much covered by colluvium; also some variegated bands of unit 7 color and lithology. 21.2

7 Powdery claystone; grayish red (5 R 4/2) to grayish olue (5 PB 5/2); appears variegated purple to blue-green in outcrop; bentonitic; calcareous. 0.6

6 Conglomerate and sandstone; conglomerate is olive gray (5 Y 4/1); clasts are calcrete nodules and intraformational mud- and siltstone rip-ups up to 7 mm in diameter; clast-supported; muddy fraction of matrix is bentonitic; sandstones are coarse- to very coarse-grained, well-rounded, moderately well-sorted litharenites; unit is trough crossbedded; forms a persistent, prominent thick green band: very calcareous. 4.4

5 Same colors and lithology as unit 1. 2.3

4 Sandstone and mud pellet conglomerate at base; conglomerate is light olive gray (5 Y 5/2) to greenish gray (5 GY 6/1), conglomerate clasts are almost entirely intraformational mud pellets which are dark greenish gray (5 GY 4/1) with some grayish red purple (5 RP 4/2); mud pellets are bentonitic; sandstone is greenish gray (5 GY 6/1); sandstone is coarse- to very coarse-grained, rounded, well-sorted litharenite; entire unit is very calcareous. This unit is the dinosaur-bone-producing unit. 1.0

3 Same colors and lithology as unit 1. 0.4

2 Conglomerate to coarse sandstone; light greenish gray (5 GY 8/1) to greenish gray (5 GY 6/1) fresh, weathers to olive gray (5 Y 4/1); clasts are small (3 mm or less) mudstone pebbles; subrounded; numerous calcrete nodules at this horizon; whole unit is calcareous.

1 Mudstone and silty mudstone; pale reddish brown (10 R 5/4) to grayish red (10 R 4/ 2); some ripple laminations; Units forms a red slope. not measured

APPENDIX 2 — ABIQUIU DAM ENGINEERING PROFILE

Description of engineering profile of Poleo Formation at Abiquiu Dam (Fig. 9). Courtesy of U. S. Army Corps of Engineers.

43: Overburden composed of slopewash and landslide debris.

42: Siltstone: mottled pale red (5R 6/2) and yellowish gray (5Y 8/1); very fine grained; moderately soft; slightly to moderately weathered; medium bedded; very close to close jointed; joints are generally smooth and tight with abundant FeO stains, minor $CaCO_3$, and some polishing; FeO stained throughout; moderately cemented; becomes fissile and slakes readily when exposed. (FC)

41: Siltstone: pinkish gray (5YR 8/1); very fine grained; moderately soft; medium bedded; siliceous; slightly weathered; very close to close jointed; joints are slightly rough, tight to open to 2 mm, with abundant FeO stains, some clay, and scattered slickensides; moderately cemented; becomes fissile and slakes readily when exposed. (FC)

40: Sandstone: mottled grayish red (5R 4/2), grayish pink (5R 8/2), and pale red (10R 6/2); fine to medium grained; moderately soft; composed of subrounded to subangular quartz and quartzite grains in an iron-silica cements; mottling due to variations in amount of FeO in individual beds; unweathered; laminated and cross bedded; wide jointed; joints are rough and tight.

39: Sandy mudstone: medium light gray (N6); very fine to fine grained; moderately soft; composed of 85% very fine silt and clay and 15% fine subrounded quartz grains; slightly weathered; laminated; close jointed; joints are rough and tight; moderately cemented. (FC)

38: Conglomeratic quartz sandstone: like sample #19, except no lenses of sandy siltstone.

37: Sandstone: primarily pale reddish purple (5RP 4/2); fine grained; moderately hard; composed for subrounded to subangular, fine, with scattered medium, quartzite and quartz grains in siliceous cement; unweathered; faintly laminated; wide jointed; joints moderately rough and tight; well cemented. (FC)

36: Sandstone: mottled white (N9), dark gray (N7), and pale pink (5RP 8/2); fine to medium grained, mostly fine; moderately hard; composed of subrounded to subangular quartz and quartzite grains as individual laminations resulting in mottled appearance with scattered laminations of dark to fine silt; unweathered; laminated; wide jointed; joints are rough, tight to open to 1 cm with FeO stains; moderately cemented. (FC)

35: Mudstone and silty sandstone: thinly interbedded and lenticular as in samples 15 and 17, except silty sandstone in dark gray (N3) to black (N1); similar to sample 7 except without conglomerate.

34: Quartz sandstone laminated to very thinly interbedded with sandy siltstone: 75% sandstone, 25% sandy siltstone; sandstone is mottled white (N9), grayish red purple (5RP 4/2), and dark reddish brown (10R 3/4); mottling due to variations in the FeO content of cement in individual beds; fine to medium grained, mostly medium; moderately hard; composted of 70% subangular to subrounded quartz grains; unweathered to slightly weathered; close jointed, joints are rough, tight, with minor FeO stains; well cemented; sandy siltstone is medium dark gray (N4); very fine to fine grained; moderately soft to moderately hard; composed of 75% silt and 25% fine quartz grains, unweathered, well cemented, thin beds of coarse gray sandstone and silty sandstone are scattered throughout; individual beds are laminated. (FC)

33: Sandy siltstone: mottled medium gray (N5) and minor very dark red (5R 2/6); very fine to fine grained; moderately soft; composed of 70% silt and 30% very fine to fine subrounded quartz and quartzite grains in siliceous cement; slightly weathered; laminated to slightly fissile; close jointed; joints are rough, tight, and coated with minor FeO; moderately to well cemented. (FC)

32: Quartz sandstone: mottled grayish red (10R 4/2) and white (N9) with minor FeO stains throughout; medium to coarse grained, mostly coarse; moderately soft; composed of subrounded to subangular quartz and quartzite grains; slightly to moderately weathered; very thin bedded; close jointed; joints are rough, tight, and FeO stained; poorly to moderately cemented. (FC)

31: Silty sandstone: mottled grayish red (5R 4/2) and minor yellowish gray (5Y 8/2); very fine to fine grained; moderately soft; composed of 60% fine subrounded quartzite and quartz grains and 40% silt; slightly weathered; thin bedded; close jointed, joints are rough, tight, and are coated with calcite and minor FeO stains; moderately to well cemented. (FC)

30: Quartz sandstone: mottled white (N9) and minor mdium brownish gray (5YR 5/1); fine to mdium grained, mostly medium with scattered coarse grains; moderately soft to moderately hard; composed primarily of subrounded to subangular quartz grains with scatter(ed) thin beds with abundant quartzite and some lithic and mafic grains, resulting in mottled appearance; quartzite ismore abundant in bottom 1 foot; unweathered; thin to very thin bedded and crossbedded, wide to very wide jointed; joints are slightly rough to rough with FeO and minor MnO stains; moderately cemented. (FC)

29: Quartz sandstone: primarily white (N9); fine to coarse grained, mostly medium; moderately soft to moderately hard; composed of 90% subrounded to

subangular, fine to coarse, mostly medium quartz grains, 10% coarse, subangular quartzite grains; slightly weathered; thin to medium bedded and crossbedded; wide to very wide jointed; joints are rough, tight, and coated with very minor FeO stains. (FC)

28: Sandstone very thinly interbedded with laminated mudstone: sandstone is dark reddish brown (10R 3/4); fine to coarse grained, mostly coarse; moderately soft; composed of subangular quartz and quartzite grains in iron-silica cement; mudstone is medium light gray (N6); very fine grained; moderately soft; occurs as laminated irregular lenticular beds and masses within the sandstone; rock is slightly weathered, moderately close to wide jointed; joints are rough and tight; poorly to moderately cemented. (FC)

27: Quartz sandstone: white (N9); medium grained; moderately soft to moderately hard; composed of medium, with scattered fine and coarse, subrounded to subangular quartz grains; unweathered; very thin bedded; very wide jointed. (FC)

26: Quartz sandstone: as in sample #25, except also contains scattered very coarse grains to 3/8 inch and no mudstone. (FC)

25: Quartz sandstone: very light gray (N8); fine to coarse grained, mostly coarse; moderately hard; composed to 90% subrounded to subangular, fine to coarse, mostly coarse, quartz grains and 10% irregular, thin dark gray mudstone lenses; unweathered; thin bedded and cross-bedded; very wide jointed; well cemented. (FC)

24: Silty sandstone: medium dark gray (N4); very fine to fine grained; moderately soft to moderately hard; composed of 20% fine, subrounded quartz and quartzite grains and 30% very fine grains in siliceous cement; very thin bedded; interbedded with sandy siltstone: grayish red (5R 4/2); very fine to fine grained with scattered medium grained laminations; moderately soft to moderately hard; composed of 80% very fine grains and 20% subrounded fine quartzite and quartz grains in iron-silica cement; laminated; moderately closely jointed; joints are rough and tight. (FC)

23: Quartz sandstone: light gray (N7); fine to coarse grained, mostly medium; moderately soft to moderately hard; composed of subangular quartz grains with scattered quartzite gravel to 1/2 ich, moderately cemented; very thinly interbedded with sandstone; moderate brownish gray (5YR 5/1); fine grained; moderately hard; laminated; well cemented; closely jointed, joints are rough to very rough and tight. (FC)

22: Quartz sandstone: mottled grayish red (10R 4/2), white (N9), pale red (5R 6/2) and light brownish gray (5YR 6/1); fine to coarse grained, mostly medium; composed of subrounded to subangular quartz grains and minor quartzite in an iron-silica cement; mottling is due to variations in FeO content of matrix as well as bleaching along bedding planes and in irregular masses; color is extremely variable; very thin bedded to laminated; crossbedded; moderately soft; slightly weathered; wide to very wide jointed; joints are tight and rough with minor FeO stains; very minor thin mudstone laminations and lenses scattered throughout; moderately to poorly cemented. (FC)

21: Conglomeratic quartz sandstone: primarily white (N9); moderately hard to hard; fine to very coarse grained, mostly coarse; composed of 85% fine to coarse, mostly medium to coarse, subangular quartz and quartzite grains, and 15% subangular to subrounded quartz and quartzite gravel to 1 inch in siliceous cement; slightly weathered to unweathered; thin bedded; closely jointed; joints are tight with minor FeO stains; moderately cemented. (FC)

20: Sandstone: light gray (N7); fine to coarse grained, mostly medium; moderately soft to moderately hard; composed primarily of subangulae to subrounded quartzite grains with minor lithic, mafic and quartz grains in siliceous cement; unweathered; thin bedded; ver wide to wide jointed; joints are rought, tight and coated with minor $CaCO_3$; moderately cemented. (FC)

19: Conglomeratic quartz sandstone: mottled very light gray (N8) and minor dark gray (N4); very fine to very coarse grained, mostly coarse to very coarse; moderately soft to moderately hard; composed of fine to very coarse, mostly coarse to very coarse, subrounded to subangular quartz and minor quartzite grains to 3/8 inch with scattered thin lenses of sandy siltstone as in #15; unweathered; thin bedded; very wide jointed; moderately cemented. (FC)

18: Quartz sandstone: white (N9) mottled with abundant FeO stains; fine to medium grained; soft to moderately soft; composed of subrounded quartz grains; moderately weathered; very thin bedded; moderately close jointed; joints are rough, open to 1 mm, with abundant FeO stains; moderately cemented. (FC)

17: Mudstone: light greenish gray (5GY 8/1); very fine grained; soft; composed of poorly cemented very fine, slightly plastic, bentonitic fines; unweathered; laminated and slightly fissile with fine grained muscovite concentrated on bedding planes, minor FeO stains on joints and within rock. (FC)

16: Sandy mudstone: grayish red (5R 4/2) to very dark red (5R 2/6); very fine to fine grained; moderately soft; composed of 75% clay and 25% fine, subrounded quartz grains in iron-silica cement; unweathered; laminated and fissile with abundant polished surfaces; very close to close jointed; joints are smooth and tight; poorly cemented; slakes readily when exposed to air. (FC)

15: Silty sandstone: medium gray (N5) to medium dark gray (N4); moderately soft to soft; very fine to medium grained, mostly very fine to fine; composed of 20% very fine to fine with scattered medium, subrounded quartz, quartzite, and lithic grains, 30% very fine siliceous grains; slightly weathered, laminated to very thin bedded; closely jointed; joints are tight, rough, with abundant FeO stains in upper 0.5 foot; moderately cemented. (FC)

14: Quartz sandstone: mottled white (N9) and light brownish gray (5YR 6/1); fine to medium grained; moderately soft to moderately hard; composed of fine to medium, subrounded to subangular quartz grains (white) and quartzite grains (light brownish gray); unweathered; very thinly bedded as alternating quartz and quartzite beds; quartzite beds contain minor lithic grains; moderately close jointed; joints are tight with minor FeO stains. (FC)

13: Quartz conglomerate: primarily white (N9); fine to very coarse grained, mostly medium to coarse; moderately soft to moderately hard; composed of subangular to subrounded quartz and minor quartzite grains to 1/2 inch, most are medium to coarse; slightly weathered; thin to very thin bedded and crossbedded; close jointed; joints are rough, tight, and coated with very minor FeO stains; moderately cemented; slightly calcareous. (FC)

12: Quartz sandstone: very light gray (N8) mottled with minor medium light gray (N6); very hard to hard; fine to coarse grained, mostly fine to medium; composed of fine to medium subangular to subrounded quartz and minor lithic grains with scattered coarse grains in a siliceous cement; slightly weathered; laminated to very thinly bedded and crossbedded; bedding pronounced by concentrations of lithic grains; jointing nondeterminable; well cemented. (FC)

11: Quartz sandstone: very light gray (N8); moderately soft to moderately hard; fine to coarse grained; composed of fine to coarse, with scattered very coarse to 3/8 inch, subangular to subrounded quartz and quartzite grains in siliceous, slightly calcareous cement; scattered thin lenticular laminations of dark gray clay throughout; slightly weathered; laminated to very thinly bedded; very widely jointed; well cemented. (FC)

10: Quartz sandstone: as sample #9, except no very coarse grains.

9: Quartz sandstone: white (N9); fine to coarse grained with scattered very coarse grains; moderately hard; composed of fine to coarse, with scattered very coarse to 1/2 inch, subrounded quartz and minor quartzite grains; unweathered; thin bedded and crossbedded; wide jointed; joints are slightly rough, tight, and have minor FeO stains; moderately to well cemented. (FC)

8: Quartzite conglomerate: multicolored; fine to very coarse grained; moderately hard to hard; composed of 75% subrounded quartzite gravel to 3 inches in 25% matrix of fine to coarse, mostly medium, subrounded to subangular quartz grains; unweathered; thin to medium bedded; moderately close to wide jointed; joints are tight to open to 1 mm, rough, and coated with minor FeO stains; well cemented. (FC)

7: Mudstone and conglomerate: multicolored; very fine to very coarse grained; very soft to moderately hard; composed of about 60% conglomerate of subrounded to rounded quartzite gravel and scattered cobbles in quartz sand matrix; 25% irregular lenses and laminations of black silty mudstone, and 15% irregular lenses, masses, and laminations of green bentonitic mudstone, ratio of conglomerate to mudstone is highly variable; unweathered; close to moderately close jointed. (FC)

6: Quartz sandstone very thinly interbedded with sandy siltstone: Sandstone is as in sample #30; sandy siltstone is as in sample #15; ratio of sandstone to siltstone is 1:1. (FC)

5: Quartz sandstone: primarily white (N9); hard to very hard; fine to coarse grained; composed of fine to coarse, mostly medium to coarse, subangular quartz and quartzite grains with scattered subrounded gravel to 1 inch in a slightly calcareous to noncalcareous siliceous cement; slightly weathered to unweathered; very thinly to thinly bedded and crossbedded; widely jointed; joints are tight, slightly rough to rough, and coated with minor FeO stains; moderately to well cemented; scattered thin beds of mostly coarse grained.

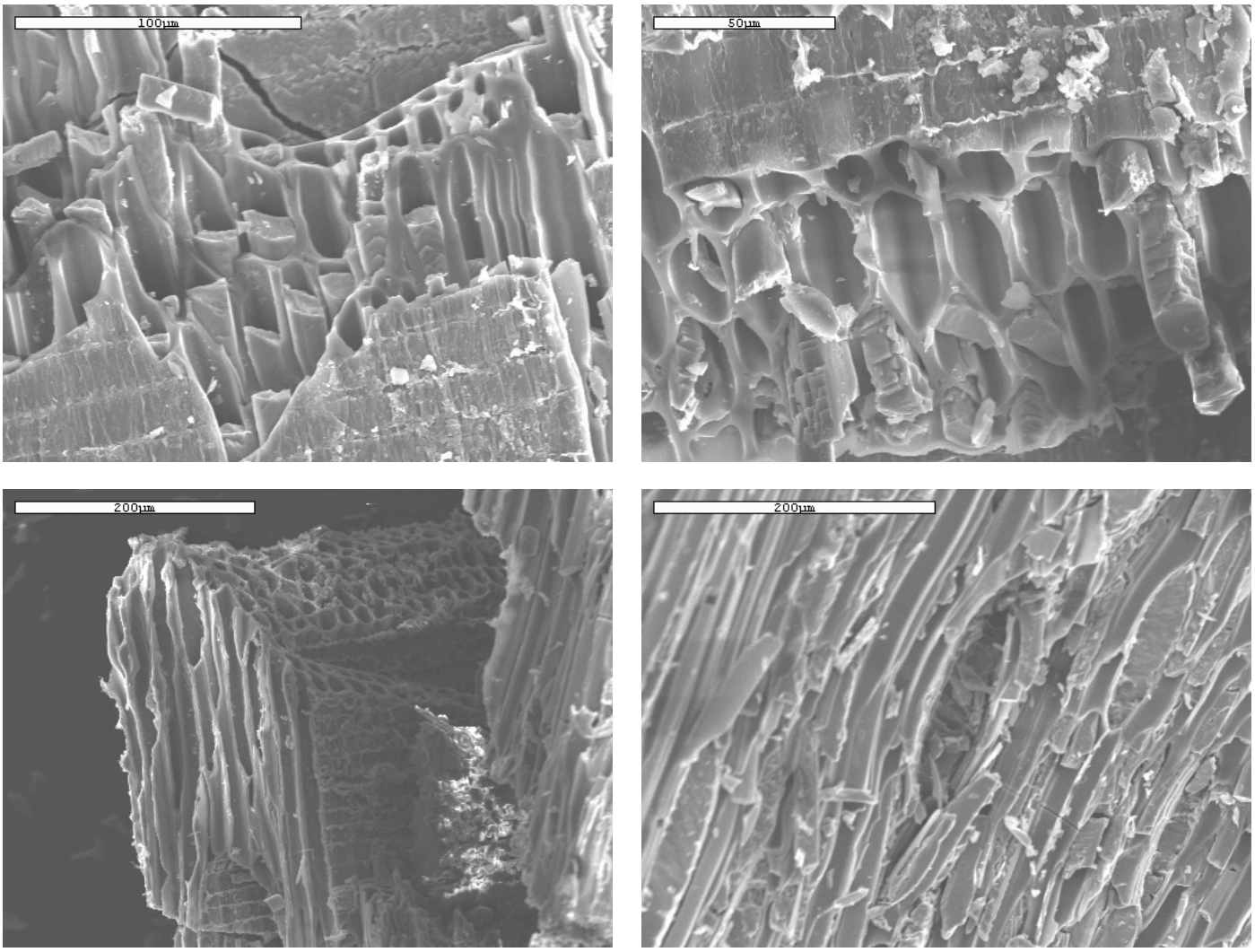
4: Calcareous conglomeratic quartz sandstone: primarily white (N9); hard to very hard; fine to very coarse grained, mostly coarse; composed of about 60% fine to coarse, mostly medium to coarse, subangular quartz and quartzite grains, and 20% subangular to subrounded quartz and quartzite gravel to 1.5 inches in a calcareous-siliceous cement; slightly weathered to unweathered; thin to medium bedded; widely jointed; joints are tight, slightly rough to rough, and coated with minor FeO stains and a trace of clay; moderately to well cemented; upper four feet is slightly to none calcareous.

3: Conglomerate: primarily white (N9) with multicolored quartzite; fine to very coarse grained; moderately hard to hard; composed of 80% subrounded quartzite gravel to 3 inches with scattered cobbles in a 20% matrix of fine to coarse grained quartz sand; thin to medium bedded and interbedded with sandstone as in sample #5, and containing scattered laminations, beds, and irregular lenses of variable dimensions of mudstone as in samples 17 and 1 and silty sandstone as in sample 15, estimate 60% conglomerate, 25% sandstone, and 15% mudstone and silty sandstone; widely jointed; joints are tight to open to 1/4 inch, slightly rough, and have abundant FeO stains and some clay; seepage rating is VI for most joints; unweathered; lower 0.1 to 0.8 foot is a nearly continuous basal unit of conglomerate and/or light greenish gray mudstone. (#1, 15, and 17 are labeled “ms”) (FC)

2: Quartz sandstone: light greenish gray (5GY 8/1): fine to medium grained; soft to moderately soft; composed of subrounded to subangular quartz grains in siliceous bentonitic cement; very thin to thin bedded; slightly weathered; wide jointed; joints are rough, open to 1 mm and contain FeO stains; moderately cemented. (FC)

1a: Lenticular interbedded #3 conglomerate and #17 mudstone.

1: Mudstone: dark reddish brown (10R 3/4); very fine grained with scattered fine grains; moderately soft to soft; unweathered; laminated and slightly fissile; scattered irregular to well rounded nodules of soft bentonitic siltstone scattered throughout; muscovite is concentrated along lamination planes; close to very close jointed; joints are smooth, tight and are slickensided and polished; in upper 1 foot, joints are coated with montmorillonite; poorly cemented; slakes readily when exposed. (FC)



Scanning electron microphotographs of charcoal samples from the Snyder quarry, showing homogenized cell wall structure.