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STRATIGRAPHIC NOMENCLATURE AND CORRELATION OF TRIASSIC ROCKS OF EAST-CENTRAL NEW MEXICO: A PRELIMINARY REPORT

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INTRODUCTION

Triassic rocks of east-central New Mexico (Fig. 1) are sediments of continental (fluvial and lacustrine) origin that are divided into two formations, Santa Rosa and Chinle (Fig. 2). The term Dockum Group, originally based on Triassic rocks in western Texas (Cummins, 1890), has also been applied by some workers to Triassic rocks in east-central New Mexico. Indeed, the Triassic rocks of east-central New Mexico are located between the classic Chinle terrane of northeastern Arizona and northwestern New Mexico (Colorado Plateau) and the classic Dockum terrane of western Texas. This makes a better understanding of the stratigraphy and correlation of the Triassic of east-central New Mexico key to understanding the stratigraphic and age relationships between the Chinle and the Dockum. This paper is a preliminary attempt to achieve a better understanding of the stratigraphy and age relationships

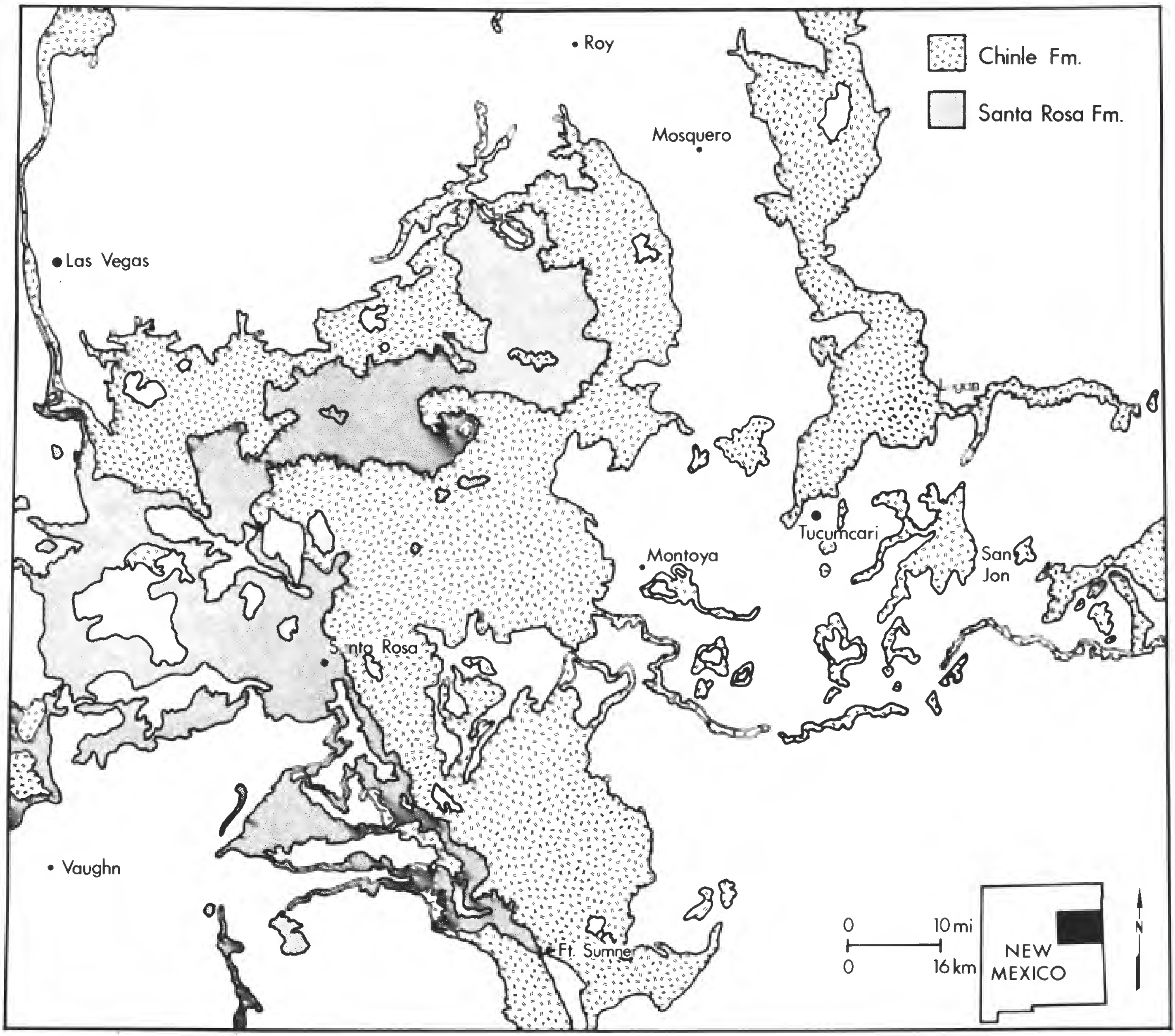

FIGURE 1. Distribution of the Triassic Santa Rosa and Chinle Formations in east-central New Mexico (modified from Dane and Bachman, 1965).

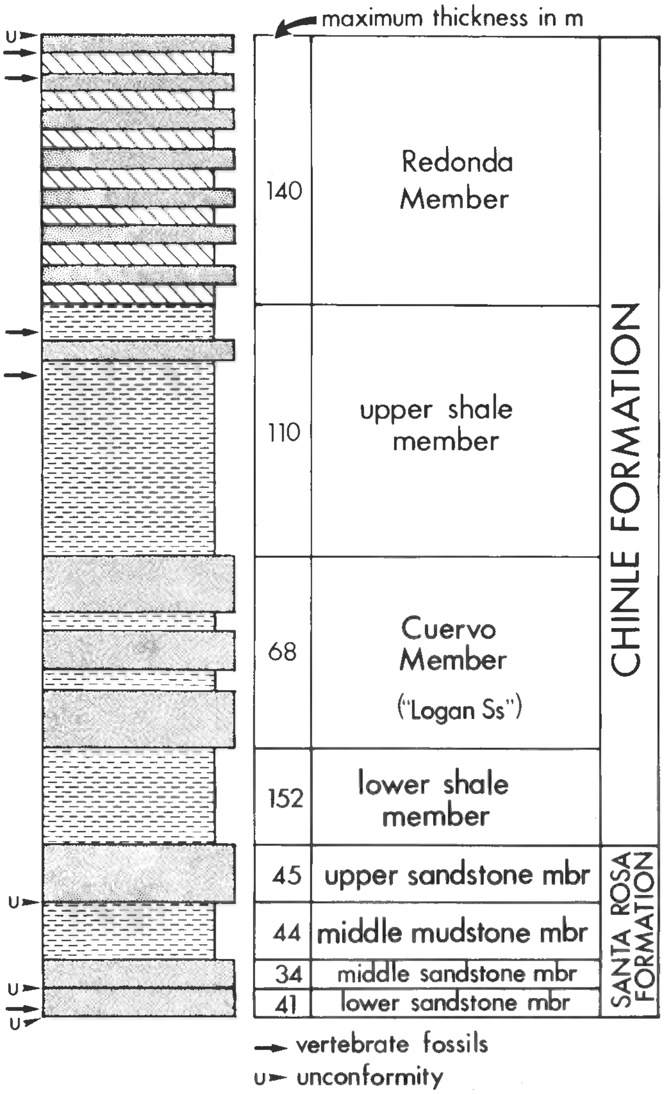

FIGURE 2. Stratigraphic nomenclature of Triassic rocks in east-central New Mexico advocated in this paper.

of the Triassic strata of east-central New Mexico. Its goals are to clarify stratigraphic nomenclature and to present a preliminary correlation chart of the Triassic of east-central New Mexico with the Triassic of other parts of New Mexico, northeastern Arizona, southeastern Utah, southwestern Colorado and western Texas.

TRIASSIC STRATIGRAPHIC NOMENCLATURE IN EAST-CENTRAL NEW MEXICO

Santa Rosa Formation

Definition and distribution

The oldest Triassic strata in east-central New Mexico pertain to the Santa Rosa Formation (Santa Rosa Sandstone of earlier workers). Wilmarth (1957, p. 831) attributed the name Santa Rosa Sandstone to an unpublished report by D. Hager and A. E. Robitaille titled "Geologic report on oil possibilities in eastern New Mexico." However, the first published use of the term Santa Rosa Sandstone was by Rich (1921). Rich was mainly concerned with correcting the work of Baker (1920), who mistakenly assigned the basal sandstones of the Triassic in Guadalupe County to the Glorieta Sandstone of Keyes (1915). Thus, although Rich (1921, p. 295) described the Santa Rosa as 50 to 100 ft (15.2 to 30.5 m) of "coarse gray sandstone, conglomeratic at base," and noted its outcrops at Santa Rosa, Puerto de Luna and along the Pecos Valley as far north as "Estaritos [sic] Dome," he did not designate a type section nor did he present a detailed description of the Santa Rosa Sandstone.

Soon after Rich's (1921) paper appeared, Darton (1922, p. 183) "named" the Santa Rosa Sandstone:

> . . . east of Glorieta Mesa and the Hills of Pedernal, the strata overlying the Chupadera formation [Permian Yeso, Glorieta and San Andres Formations] consist of 800 feet or more of red shales and sandstones representing the Dockum group, including near the bottom a resistant massive sandstone which is prominent in the mesas of Guadalupe County and along Pecos River at Santa Rosa. This sandstone appears to occur at about the horizon of the Shinarump conglomerate, but no definite correlation is possible, and I here propose for it, tentatively at least, the name Santa Rosa Sandstone.

However, Darton (1922) designated no type section nor did he then, or later (Darton, 1928a, b), map the distribution of the Santa Rosa Sandstone in east-central New Mexico. Indeed, at several places in east-central New Mexico, Darton (1928a) confused the Santa Rosa and the medial sandstone complex of the overlying Chinle ("Dockum" of Darton). Thus, for example, in a cross section of the upper Pecos Valley east of Anton Chico (Darton, 1928a, fig. 127), the "middle sandstone member" of the "Dockum" actually is the Santa Rosa Formation above Bernal (Permian) mudrock. And, Darton (1928a, p. 297) states that "just west of Montoya a low anticline brings up the top of the lower sandstone of the Dockum group, which yields phytosaur bones. This is the Santa Rosa Sandstone" (also see Darton, 1928a, fig. 140). In fact, the fossiliferous sandstone exposed in the Montoya area is the Cuervo Member of the Chinle (Kelley, 1972b, fig. 1), the "middle sandstone member" of Darton's "Dockum."

Recognition that the Santa Rosa Sandstone crops out principally in the upper Pecos Valley from Anton Chico to Fort Sumner appears not to have occurred until just after the Second World War. At that time, the mapping of Gorman and Robeck (1946) in north-central Guadalupe County and Dobrovolny et at. (1946) in northwestern Quay County was published. These maps indicated that, in general, the Santa Rosa Sandstone was covered by younger Triassic rocks east of the Pecos, and thus rectified some of Darton's (1928a) errors noted above. Northrop et al. (1946) and Bachman (1953), at essentially the same time, identified the Santa Rosa Sandstone along the east flank of the Sangre de Cristo Mountains as far north as Ocate in northwestern Mora County. Soon thereafter, Griggs and Hendrickson (1951) mapped the Santa Rosa as a unit separate from the overlying Triassic, which they termed Chinle Formation, throughout San Miguel County.

By 1962, Bachman and Dane had essentially determined the outcrop distribution of the Santa Rosa in east-central New Mexico, a distribution later documented at a 1:500,000 scale on their geologic map of New Mexico (Dane and Bachman, 1965). A significant addition to the distribution of the Santa Rosa Sandstone in east-central New Mexico, its surface exposure in the Canadian River valley east of Logan, also appeared on these maps. This addition came from field mapping by Zane Spiegel, published by Bachman and Dane (1962), Dane and Bachman (1965) and Berkstresser and Mourant (1966). The problems for the correlation of the Santa Rosa Formation raised by its recognition east of Logan, in the Canadian River valley, will be discussed later.

Kelley (1972a, pp. 21–23), about half a century after introduction of the term Santa Rosa Sandstone, designated a type section of the Santa Rosa Sandstone north of Santa Rosa (SW1/4 sec. 35, T9N, R21E). Kelley (1972a) also described two other measured sections of the Santa Rosa and mapped its distribution from Santa Rosa to Fort Sumner.

Subdivisions

No formal subdivisions of the Santa Rosa Formation have been proposed, although two, three or four informal subdivisions of the formation have been recognized by different workers (Fig. 3).

Gorman and Robeck (1946) first attempted to subdivide the Santa Rosa by recognizing four informal members in north-central Guadalupe County. Their lower sandstone member is a "friable, purplish red, 'salt-and-pepper' textured, fine-grained, platey to thin-bedded, micaceous, silty sandstone" (Gorman and Robeck, 1946). Gorman and Robeck

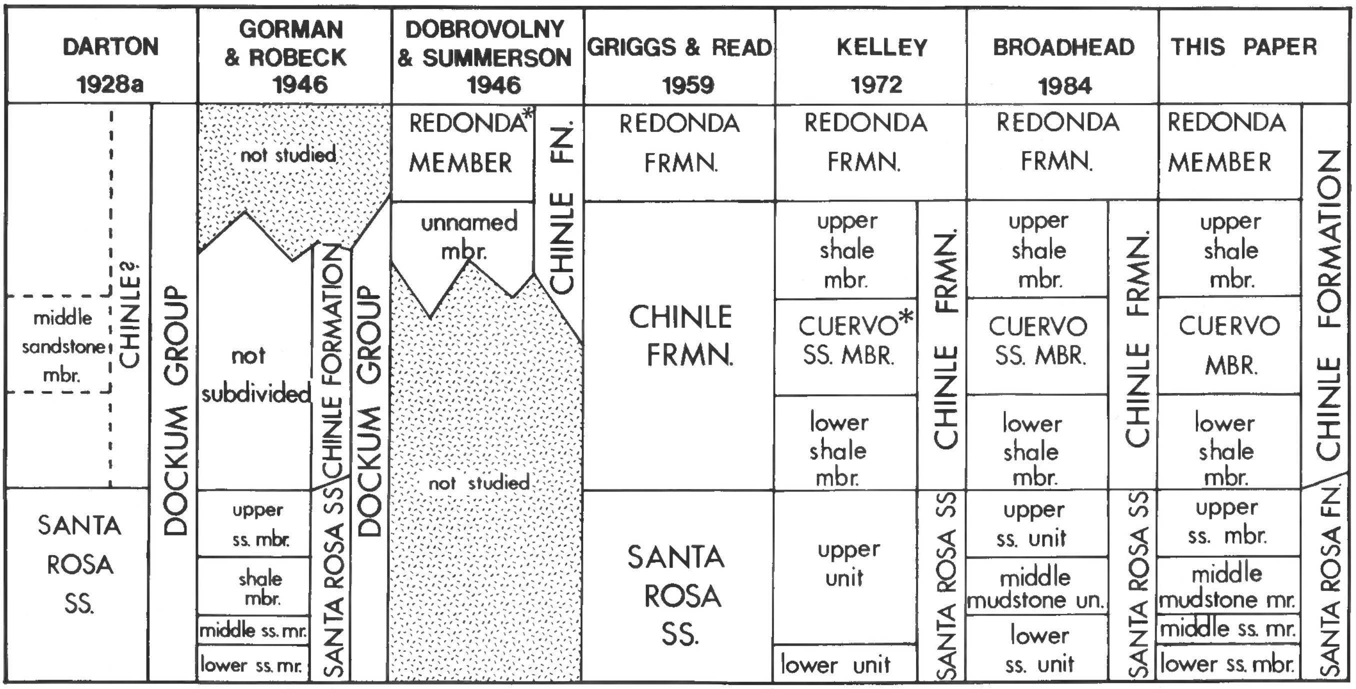

FIGURE 3. Comparison of the stratigraphic nomenclature of Triassic rocks in east-central New Mexico of some earlier workers with that advocated in this paper.

(1946) also noted that this unit "weathers into rounded and exfoliated boulder-like ledges, and occasionally contains bone fragments." It also contains local beds of mudrock, is absent locally, attains a maximum thickness of 34 m and unconformably overlies the Permian San Andres Formation.

The overlying middle sandstone member of Gorman and Robeck (1946) is "a gray to brown, medium- to coarse-grained, platey to massive-bedded sandstone that weathers into fretted blocks." This unit also contains isolated, subrounded quartz pebbles about 1 cm in diameter and a basal conglomerate of quartz, limestone and petrified-wood fragments. It is up to 41 m thick.

The shale member of Gorman and Robeck (1946) overlies their middle sandstone member, has a maximum thickness of 15 m and is absent locally. It is a "red to gray shale that frequently is arenaceous in its basal portion" (Gorman and Robeck, 1946).

The uppermost unit of the Santa Rosa Sandstone recognized by Gorman and Robeck (1946), their upper sandstone member, is "a brown to gray, dense, fine-grained, calcareous, platy to massive sandstone that weathers into rounded surfaces with ribbed cupholes." According to Gorman and Robeck (1946), it ranges in thickness from 3.3 to 35 m.

A fourfold subdivision of the Santa Rosa was subsequently endorsed by Finch et al. (1976), Lupe (1977), Granata (1981), Finch and Wright (1983) and McGowen et al. (1983). Indeed, some of these workers (Finch et al., 1976; Granata, 1981; Finch and Wright, 1983) extended the distribution of these members outside of the area originally mapped by Gorman and Robeck (1946). Furthermore, McGowen et al. (1979, p. 9) stated that "four members of the Santa Rosa Formation . . . are genetic as well as descriptive." Following Lupe (1977), they assigned the following depositional environments to the four members of Gorman and Robeck (1946): lower sandstone member = alluvial fan or fan delta, middle sandstone member = coarse-grained meanderbelt, shale member = lacustrine and prodelta–delta front and upper sandstone member = fan delta.

Nevertheless, Kelley (1972a, p. 23) only recognized two informal units (separated by an erosional unconformity) of the Santa Rosa Formation in the Santa Rosa area. His lower unit is a sandstone of "lavender to purplish-brown color and more conglomerate, whereas the upper unit is generally buff with massive, well-cemented sandstone in the lower part, with less conglomerate except probably at the base" (Kelley, 1972a, p. 23). Kelley (1972a) noted that his lower unit is equivalent to the lower sandstone member of Gorman and Robeck (1946), and their upper three members equal his upper unit. Kelley (1972a, p. 20) also reported that Read et al., in a 1943 personal communication to him, recognized three sandstone members of the Santa Rosa Formation in the Guadalupe mining district (sec. 6, T7N, R20E).

Most recently, Broadhead (1984) recognized three informal subdivisions of the Santa Rosa Formation in east-central New Mexico based on subsurface studies using gamma-ray borehole logs. His lower sandstone unit encompasses the lower and middle sandstone members of Gorman and Robeck (1946); his middle mudstone unit is equivalent to their shale member; and the upper sandstone unit of Broadhead equals the upper sandstone member of Gorman and Robeck (1946).

Discussion

From the above, it is clear that the Santa Rosa Formation is the lowermost Triassic stratigraphic unit throughout east-central New Mexico. Since this unit contains significant amounts of conglomerate and mudstone ("shale"), the use of the suffix "Sandstone" seems inappropriate. Therefore, we advocate and employ the term Santa Rosa *Formation,* instead of the term Santa Rosa *Sandstone* of earlier workers.

The surface distribution of the Santa Rosa Formation in the vicinity of the upper Pecos Valley from Anton Chico to Fort Sumner is well established. Its presence as an essentially unbroken "blanket" in the subsurface throughout the remainder of east-central New Mexico also seems beyond question. However, its putative outcrops in the Canadian River valley east of Logan include strata that arguably should be included in the Chinle Formation, as indicated in the later discussion of the "Logan Sandstone."

Formal subdivision of the Santa Rosa obviously is feasible, but has not been attempted. The informal subdivisions advocated here are those of Gorman and Robeck (1946) using terminology essentially identical to that of Broadhead (1984) (Figs. 2, 3). It is clear that more detailed stratigraphic study of the Santa Rosa Formation, particularly mapping of its already recognized subdivisions, needs to be undertaken.

Chinle Formation

Introduction

All Triassic strata in east-central New Mexico above the Santa Rosa Formation are here assigned to the Chinle Formation which is divided into four members (three informal, one formal) following Dobrovolny et al. (1946) and Kelley (1972a) (Fig. 3). Extension of Gregory's (1915, 1917) name Chinle Formation from the Colorado Plateau into east-central New Mexico seems to have been first undertaken by Bates (1942, p. 151), although Adams (1929, p. 1045) earlier used the term Chinle in southeastern New Mexico and western Texas. Subdivision of the Chinle ("Dockum") of east-central New Mexico into three members—a lower shale, middle sandstone and an upper shale—already was evident in the work of Darton (1928a, fig. 143). Mapping by Northrop et al. (1946), Dobrovolny et al. (1946), Griggs and Hendrickson (1951), Wanek (1962) and Trauger and Bushman (1964), among others, subsequently endorsed the concept of at least a tripartite subdivision of the Chinle in east-central New Mexico. However, it was Kelley (1972a) who first established three informal members of the Chinle and mapped (Kelley, 1972b) their distribution throughout much of east-central New Mexico. Much earlier, Dobrovolny et al. (1946) established the uppermost Redonda Member of the Chinle in east-central New Mexico.

Lower shale member

Kelley (1972a) stated that the lower shale member of the Chinle is up to 122–152 m of predominately red "shale" that principally occupies the first bench east of the Pecos River near Santa Rosa. Kelley (1972a) further noted that the Santa Rosa Formation–lower shale member contact is conformable. Kelley (1972b) mapped the distribution of the lower shale member throughout much of east-central New Mexico, and Broadhead (1984) noted that it attains a maximum thickness of 76 m, considerably less than that reported by Kelley (1972a). Broadhead (1984, p. 13) described the lower shale member as follows:

> It is composed primarily of moderate reddish-brown (10 R 4/6) to moderate reddish-orange (10 R 6/6), argillaceous, calcareous mudstone. It also contains minor amounts of greenish-gray to bluish-gray mudstone and some laterally discontinuous beds of fine- to very fine-grained sandstone. Casts of plant stems are common in the red mudstones.

Granata (1981) and McGowen et al. (1983, fig. 9) characterized the lower shale member as "lacustrine and prodelta mudstone." However, this conclusion is at best a generalization, as Granata (1981, p. 56) revealed by stating "the lower and upper shale members of the Chinle . . . are considered in general to be lacustrine mudstones." No detailed sedimentological analysis of the lower shale member of the Chinle in east-central New Mexico has been undertaken. In addition, no stratigraphic or paleontologic studies of this unit have been attempted.

Cuervo Member

Kelley (1972a) named the Cuervo Sandstone Member for exposures along Cuervo Creek and the town of Cuervo (Spanish for "crow"). He designated and described a type section in sec. 4, T12N, R25E in a roadcut of New Mexico Highway 104. At its type section, the Cuervo is 68 m thick and consists of a lower sandstone (5.8 m) overlain by mudstone (18.3 m) and an upper sandstone/conglomerate/siltstone (44 m) (Kelley, 1972a). The thickness of the Cuervo at its type section reported by Kelley (1972a) is the maximum thickness reported for this unit (Broadhead, 1984).

The Cuervo Sandstone Member of Kelley (1972a) has been mapped and/or recognized in the subsurface throughout much of Guadalupe, San Miguel and Quay Counties, in many cases in its former guise as a middle sandstone "member" or "interval" of the Chinle Formation (e.g., Northrop et al., 1946; Wanek, 1962; Foster et al., 1972; Kelley, 1972b; Broadhead, 1984). Sedimentological study of the Cuervo (Granata, 1981; McGowen et al., 1983) envisions it as sand bodies and mudrock that represent multiple, thin deltas overlain by fluvial–deltaic sand and mudrock.

The above studies indicate that the name Cuervo refers to a laterally persistent complex of sand bodies and intercalated mudrock in the middle part of the Chinle Formation throughout east-central New Mexico. They also indicate that, in addition to sandstone, significant amounts of mudstone, conglomerate and silstone are included in the Cuervo. For this reason we believe the term Cuervo *Sandstone* Member is somewhat inappropriate, and we drop the lithologic descriptor, shortening the name to Cuervo Member. No serious paleontological study of the Cuervo Member has been attempted.

Upper shale member

Kelley (1972a) described the upper shale member as largely shale except for reddish-brown sandstone in the lower part. Broadhead (1984, p. 13) provided a more detailed description:

> It is chiefly mudstone, with only minor, lenticular sandstone beds. Mudstones in the upper shale member are mostly moderate reddish brown (10 R 4/6) to moderate reddish orange (10 R 6/6) to grayish red (10 R 4/2) and commonly contain casts of plant stems. A trace amount of [the] mudstone is very light gray (N8) to light gray (N7). The mudstones are silty to argillaceous and most are calcareous. Sandstones are moderate reddish orange (10 R 6/6) to grayish red (10 R 4/2) to moderate reddish brown (10 R 4/6), fine- to very fine-grained, silty, moderately to well-sorted, and generally somewhat calcareous. Some sandstones in the upper shale member are white (N9) to light gray (N7), but are otherwise similar to the red sandstones.

Detailed study of the upper shale member of the Chinle Formation at Bull Canyon, eastern Guadalupe County, reveals, however, that it also contains medium- and coarse-grained sandstone as well as conglomerate, and that casts of plant stems are rare in the mudstones (Lucas et al., in prep.).

A maximum thickness of 110 m has been reported for the upper shale member (Broadhead, 1984). Granata (1981) and McGowen et al. (1983, fig. 9) interpreted the upper shale member as "lacustrine and prodelta mudstone." However, there are fluvial sandstones throughout the upper shale member at Bull Canyon (Lucas et al., in prep.). Granata (1981) and McGowen et al. (1983, fig. 9) also indicated that a "soil horizon" is present at the top of the upper shale member, and therefore concluded that the upper shale member–Redonda Member contact is an unconformity. We have observed no evidence of a significant soil horizon and therefore no unconformity between the upper shale and Redonda at Bull Canyon or in other sections in east-central New Mexico we have studied (e.g., Mesa Redonda) (see Lucas et al., in prep., and Figure 4).

Most of the fossil invertebrates and vertebrates known from the Chinle Formation in east-central New Mexico are from the upper shale member (see later discussion).

Redonda Member

Dobrovolny and Summerson (in Dobrovolny et al., 1946) named the Redonda Member of the Chinle Formation for "25 to 425 feet of variegated and red shale, purplish-red or gray, argillaceous limestone, and red or buff sandstone and siltstone." Although no type section was designated or described, the type area of the Redonda Member is Mesa Redonda (Quay County) and includes the northern and northwestern edges of the mesa (measured stratigraphic sections 8 and 9 of Dobrovolny et al., 1946).

Griggs and Read (1959, p. 2006) raised the Redonda to formational rank because "of its distinct lithology, its presence as a readily mappable unit over a wide area of northeastern New Mexico, and its apparent equivalence to beds of Glen Canyon age." Despite this, no subsequent workers, except Wanek (1962) and Kelley (1972b), mapped the Redonda as a unit separate from the Chinle (e.g., Bachman and Dane, 1962; Trauger and Bushman, 1964; Dane and Bachman, 1965; Berkstresser and Mourant, 1966; Kelley, 1972a; Dinwiddie and Clebsch, 1973; Bureau of Economic Geology, 1977). In addition, fossil vertebrates from the Redonda (Lucas et al., 1985a) and its lithology suggest that it is older than the Glen Canyon Group. Furthermore, the "Chinle–Redonda" contact in at least one area we have studied in detail, Bull Canyon in eastern Guadalupe County, is gradational (Lucas et al., in press). For these reasons, we reject formational status for the Redonda and recognize it as a member of the Chinle (Figs. 2, 3). We also note that the Owl Rock and Church Rock Members of the Chinle Formation in the Colorado Plateau are homotaxial with, lithologically similar to and arguably correlative with the Redonda of east-central New Mexico (see later discussion). These units are recognized as *members* of the Chinle Formation (Stewart et al., 1972a), and a consistent stratigraphic

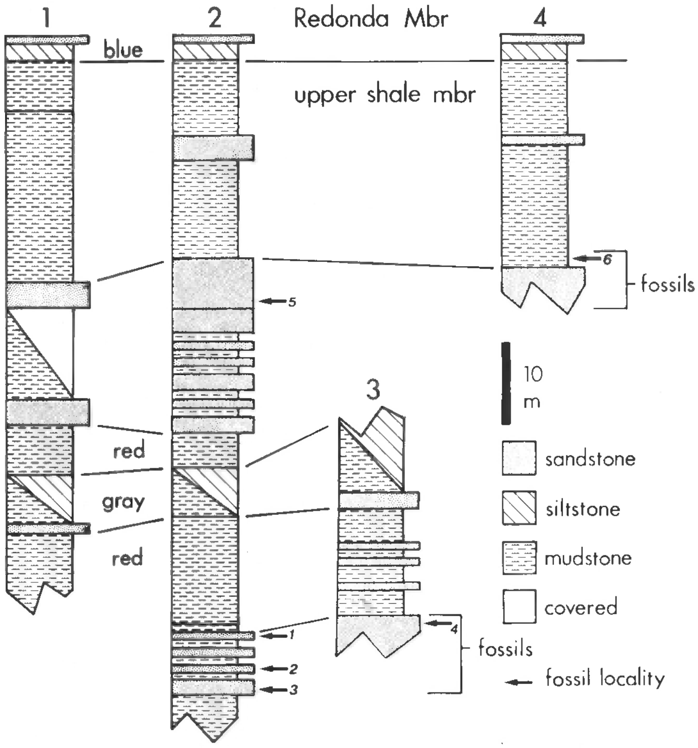

FIGURE 4. Measured stratigraphic sections of part of the Chinle Formation at Bull Canyon, eastern Guadalupe County. Locations of sections: 1 – NE¹/₄, NW¹/₄ and NW¹/₄, NE¹/₄ sec. 28, T9N, R26E; 2 – NE¹/₄, NW¹/₄ and NW¹/₄, NE¹/₄ sec. 29, T9N, R26E; 3 – SW¹/₄, SW¹/₄ sec. 21, T9N, R26E; 4 – SE¹/₄ SW¹/₄ sec. 28, T9N, R26E. Fossil localities are: *1 – Rutiodon* cf. *R. adamanensis; 2, 3, 4 – Unio* and other invertebrates; *5* – Phytosaurs; *6* – UNM locality V-601 (see Lucas et al., 1985c).

nomenclature dictates recognition of the Redonda as a member of the Chinle Formation, not as a separate formation.

We herein designate a type section of the Redonda Member in the SW¹/₄, SW¹/₄, SW¹/₄ sec. 18, T9N, R31E, the SE¹/₄, SE¹/₄ sec. 13, T9N, R30E and the NE¹/₄, NE¹/₄ sec. 24, T9N, R30E (Fig. 4). This section runs along the western flank of Spikes Canyon at the northwestern tip of Mesa Redonda and is between measured stratigraphic sections 8 and 9 of Dobrovolny et al. (1946).

At its type section, the Redonda is 123.6 m of mudstone, fine-grained sandstone, limestone, siltstone and a single bed of gravelly sandstone (conglomerate). Here, the Redonda is distinguished from the underlying upper shale member of the Chinle by its lack of numerous, thin sandstones and its moderate red-brown color (10 R 4/6: Goddard et al., 1979) which contrasts with the grayish red-purple (5 R 4/2) upper shale member. The lower two-thirds of the Redonda Member at its type section are mudstone and thin, lenticular sandstone. Two laterally continuous horizons of mottled mudstone are present about 25 to 35 m above the base of the Redonda. The upper horizon can be traced for at least 500 m. It contains subhorizons that are pale red-purple (5 RP 6/2) and a bed of calcium-carbonate nodules, possibly of pedogenic origin.

The upper third of the Redonda type section is dominated by sandstone and limestone with subordinate amounts of mudstone and siltstone. The sandstone is fine-grained, moderate red-brown (10 R 4/6), and individual beds are laterally continuous for thousands of meters. These sandstones often are intensively bioturbated. The limestone is yellowish gray (5 Y 8/1) and displays fine, sinuous lamination. This lithology forms laterally extensive cliffs and often contains an abundance of burrows.

The uppermost 10 m of the Redonda at its type section are mainly mudstone similar to that at the base of the unit. The Redonda Member here is overlain disconformably by a cliff-forming, probably eolian, sandstone that weathers dark yellow-orange (10 YR 6/6). This sandstone is assigned here to the Entrada Sandstone ("Wingate(?)" of Dobrovolny et al., 1946).

Naranjo Formation

Bachman (1953), in a map of the Ocate area of northwestern Mora County, named the Naranjo Formation for "a sequence of interbedded brownish-red sandstone, siltstone, and shale" and some limestone. Bachman's Naranjo conformably overlies what he termed Chinle Formation and is disconformably overlain by his Ocate Sandstone (= Entrada Sandstone). Bachman (1953) also noted the "distinctly light brownish red" color of the Naranjo, distinguishing it from the underlying Chinle. Stratigraphic position and lithology strongly support the idea that Bachman's (1953) Naranjo Formation is the same rock-stratigraphic unit as Dobrovolny et al.'s (1946) Redonda Member of the Chinle Formation. Therefore, we recommend that use of the term Naranjo Formation be discontinued.

"Logan Sandstone" problem

Trauger et al. (1972) attached the name "Logan Sandstone" to the light- to medium-gray, massive to crossbedded sandstone in which Ute Dam, near Logan, is anchored. As they put it:

> . . . this thick unit was first called the Logan Sandstone by Kottlowski; it is a proper term that will be used without quotes in further discussions. Its stratigraphic position is in contention (Trauger et al., 1972, p. 14).

Despite this, no type section of the "Logan Sandstone" was described or designated, and no formal introduction of the name was presented in the literature. For this reason, and for reasons discussed below, we reject usage of the name "Logan Sandstone."

When the name "Logan Sandstone" was introduced by Trauger et al. (1972), two divergent opinions about its stratigraphic position were expressed. Finch and Dane and Bachman (1965) equated the Logan with the Santa Rosa Sandstone. On the other hand, Trauger and Spiegel considered the Logan equivalent to the "middle sandstone member" (Cuervo Member) of the Chinle farther west and an equivalent of the Trujillo Formation (opinion of Spiegel, 1972) or upper part of the Tecovas and lower part of the Trujillo Formations (opinion of Trauger) farther east in Texas. Recently published mapping by the Bureau of Economic Geology (1977) supports Spiegel's (1972) opinion by extending the Trujillo Formation from its type area in Oldham County, Texas, westward to Ute Dam in New Mexico. However, on the west side of the dam, this map merely identifies the Triassic rocks as Chinle Formation. In contrast, the recently published Geologic Highway Map of New Mexico (Clemons, 1982) still follows Dane and Bachman (1965) by identifying the Santa Rosa Sandstone in the Canadian River valley both east and west of Ute Dam.

The solution to this contradiction, what we here call the "Logan Sandstone problem," lies in the work of Finch et al. (1976) and Finch and Wright (1983). The physical stratigraphy of these workers clearly indicates that the stratigraphically highest sandstones in the Ute Dam area are the "middle sandstone" (Cuervo Member) of the Chinle, and that these sandstones are equivalent to the Trujillo Formation in Texas. Nevertheless, stratigraphically lower sandstones in the Ute Dam area were identified by Finch et al. (1976) and Finch and Wright (1983) as the upper and middle sandstone members of the Santa Rosa Formation (*sensu* Gorman and Robeck, 1946). Finch et al. (1976) correlated these sandstones with the lower part of the Tecovas Formation in Texas.

Since no type section of the "Logan Sandstone" was designated, it is unclear whether it was meant to include the stratigraphically low sandstones in the Ute Dam area identified as Santa Rosa by Finch et al. (1976) and Finch and Wright (1983). However, photographs of the "Logan Sandstone" published by Trauger et al. (1972, pp. 14–16) are of the stratigraphically high, Cuervo/Trujillo equivalent sandstones. Therefore, we consider the "Logan" to be an invalid stratigraphic name that not only was never defined properly, but clearly refers to sandstones that would be called either Cuervo or Trujillo. It also is clear that, although there are some outcrops of Santa Rosa Formation east of Ute Dam, the majority of the bedrock in the Canadian River valley east of the dam, and immediately to the west, is Cuervo/Trujillo. This correction of the map of Dane and Bachman (1965) is shown here in Figure 1.

Use of the term Dockum in east-central New Mexico

The term Dockum Beds was first used by Cummins (1890, p. 189) for Triassic strata in the vicinity of Dockum, Dickens County, Texas. Although early workers (e.g., Cope, 1903; Gould, 1907; Case, 1914) recognized that Triassic rocks are present in east-central New Mexico, Darton (1922, p. 183) first explicitly applied the name Dockum to these rocks, the "red beds" between his "Chupadera Formation" and his "Wingate Sandstone" [Entrada Sandstone]. Darton (1928a, p. 270) also first applied the term "Chinle?" to the "bright red-shale" of Triassic age overlying the Santa Rosa "Sandstone" in east-central New Mexico. Bates (1942) subsequently applied the name Chinle to Triassic rocks above the Santa Rosa "Sandstone" in eastern San Miguel County. Bachman and Dane (1962) and Dane and Bachman (1965) later referred all Triassic strata in east-central New Mexico above the Santa Rosa to the Chinle.

Since Darton, most workers have continued to apply the term Dockum Group to include the Santa Rosa and Chinle Formations in east-central New Mexico (Fig. 3). Indeed, the term Dockum Group has been applied to Triassic rocks throughout northeastern, east-central, southeastern and south-central New Mexico, as well as in western Texas, Oklahoma, Kansas and southeastern Colorado (e.g., King et al., 1942; Hendrickson and Jones, 1952; Baldwin and Muehlberger, 1959; Jewett, 1959; McGowen et al., 1979, 1983; Fagrelius, 1982).

We recommend discontinuation of the name Dockum for Triassic rocks in east-central New Mexico for two reasons:

1. The term Dockum Group has been so widely applied, and in specific areas encompasses strata formally divided into formations and/or members, that it no longer seems a meaningful stratigraphic term. In effect, the term Dockum lacks specificity and refers to rocks that represent variable amounts of Triassic time.
2. As demonstrated below, the Triassic sequence in east-central New Mexico includes strata both older and younger than the Dockum Group of western Texas.

The main argument against this is that the Triassic strata of east-central New Mexico were deposited in the same basin as the Dockum Group and thus are genetically related to, and, in some cases, lithologically continuous with, units of the Dockum Group in western Texas (McGowen et al., 1979, 1983; Granata, 1981). Spiegel (1972) well reflected a logical outgrowth of this argument by suggesting that not only the term Dockum Group, but the terms Tecovas and Trujillo, be extended from western Texas into east-central New Mexico. Kelley 1972a, b), on the other hand, preferred to use the name Chinle in east-central New Mexico.

Finch and Wright (1983, p. 1), who also used the name Chinle in east-central New Mexico, made the following observations:

> The Dockum basin of eastern New Mexico, West Texas, and the Oklahoma Panhandle is a distinct basin (McKee and others, 1959, pl. 4) and is separated from the Colorado Plateau Chinle basin to the west by absence of outcrops in a belt 25 to 50 miles wide marked by the Rio Grande trough. Correlation of rock units across this gap has not been done in any detail. For this reason extension of the name Chinle across into the Dockum basin is only provisional.

This observation overlooks the fact that there are Triassic rocks exposed in the Rio Grande rift (Harrison, 1949; Kelley and Northrop, 1975; Fagrelius, 1982). Indeed, in the Hagan basin of north-central New Mexico these rocks have been assigned to the Santa Rosa and the Chinle Formations (Kelley and Northrop, 1975). It thus is not clear how discontinuous deposition was between the Colorado Plateau and the Dockum basin during the Late Triassic. Apparently an apron of Upper Triassic rocks was deposited south of the Uncompaghre uplift between these two areas.

It is also clear that stratigraphic nomenclature of Upper Triassic rocks currently employed in the American Southwest emphasizes localized nomenclature (Stewart et al., 1972a), even when physical-stratigraphic and biostratigraphic data indicate continuity of a unit receiving separate names in different areas (compare, for example, the Dolores Formation of southwestern Colorado with the Chinle Formation of adjacent areas). This supports the idea that the Dockum Group may, as a stratigraphic term, best be restricted to western Texas, where its use is unambiguous.

TRIASSIC BIOSTRATIGRAPHY OF EAST-CENTRAL NEW MEXICO

Santa Rosa Formation

Until recently, no age-diagnostic fossils were known from the Santa Rosa Formation. The first mention of fossils from this unit was by Darton (1922, p. 183):

> Case[16] [Case, 1914] has found in it [the Santa Rosa Formation], as well as in overlying strata, bone of Triassic age. I found supposed Unios[17] [determined by T. W. Stanton] in beds immediately above it 1 mile north of Santa Rosa. The underlying shales are of undetermined age and may be either Triassic or Permian.

Darton (1928a) essentially repeated these observations. However, a careful reading of Case (1914) indicates that the Triassic vertebrate fossils he collected could not have come from the Santa Rosa. Case (1914) only collected at Bull Canyon and in areas south and east of Tucumcari where the Santa Rosa Formation is not exposed.

Berkstresser and Mourant (1966, p. 11) mentioned "clam" shells from a black-clay interbed of the Santa Rosa Formation in De Baca County (sec. 15, T13N, R36E). Presumably these are unionids, but, nonetheless, Triassic fresh-water clams from the American Southwest are so little studied that their biostratigraphic potential cannot be realized (Kues, 1985).

Ash (1972) documented some megafossil plants from the Santa Rosa Formation in east-central New Mexico. These plants were collected from the mudstone member of the Santa Rosa and represent the following taxa: *Otozamites powelli* (a cycadeoid also known from the Tecovas and Trujillo Formations of the Dockum Group, the Newark Supergroup of the eastern United States and the ?Petrified Forest Member of the Chinle Formation), *Cynepteris lasiophora* (a fern also known from the ?Petrified Forest Member of the Chinle Formation and the Newark Supergroup of North Carolina) and *Dinophyton spinosus* (a gymnosperm also known from the Tecovas Formation and the ?Petrified Forest Member of the Chinle Formation) (S. R. Ash, oral comm. 1985). These taxa are of Norian aspect according to S. R. Ash (oral comm. 1985), and thus suggest the mudstone and upper sandstone members of the Santa Rosa are of Late Triassic age.

The only vertebrate fossil known from the Santa Rosa Formation is the capitosaurid labyrinthodont *Eocyclotosaurus* sp. (Table 1) from the lower sandstone member (Lucas and Morales, 1985). *Eocyclotosaurus* occurs in units of well-established Anisian (Middle Triassic) age in western Europe (Heyler, 1969, 1976; Ortlam, 1970; Kamphausen and Morales, 1981). These include the Voltzia Sandstone of France, assigned an early Anisian age by Gall (1971) and the Röt (= uppermost Buntsandstein) of West Germany (Wild, 1980). In North America, the occurrence of *Eocyclotosaurus* in the Holbrook Member of the Moenkopi Formation of northeastern Arizona supports assignment of an Anisian age to this unit. *Eocyclotosaurus* is not known from the Upper Triassic (Carnian–Norian) Chinle Formation or Dockum Group (*sensu stricto*) of the American Southwest.

The presence of *Eocyclotosaurus* in the lowermost Santa Rosa Formation provides strong evidence that this part of the Santa Rosa is Anisian. Fossil plants suggest the mudstone and upper sandstone members of the Santa Rosa are Late Triassic, Carnian or Norian, in age. There are no biostratigraphic data with which to evaluate directly the age of the middle sandstone member of the Santa Rosa.

Chinle Formation

Lower shale member

Darton (1922, p. 183), quoted above, mentioned fossils of *Unio* from strata just above the Santa Rosa Formation about 1.6 km north of Santa Rosa. Apparently these fossils were derived from the lower shale member of the Chinle, but, as noted above, *Unio* has no established biostratigraphic value in Triassic correlations.

Broadhead (1984, p. 13), also quoted earlier, mentioned "casts of plant stems" in mudstones of the lower shale member. Some of the megafossil plants from the Triassic of east-central New Mexico described by Ash (1972), especially *Otozamites powelli,* may have come from the lower shale member, but Ash (1972) provided no specific stratigraphic data. Clearly, megafossil plants are present in the lower shale member, but have not been studied, and thus are of no biostratigraphic value at present.

No fossil vertebrates are known from the lower shale member (Table 1), probably because no attempt has been made to collect them. Thus, at present there are no biostratigraphically useful fossils known from the lower shale member of the Chinle in east-central New Mexico.

Cuervo Member

Other than unstudied petrified wood, we know of no megafossil plants, and also of no fossil invertebrates, from the Cuervo Member of the Chinle in east-central New Mexico. Apparently, Case (1914, p. 254) collected "phytosaur bones" from the Cuervo near Montoya, but otherwise no vertebrate fossils have been reported from the Cuervo Member (Table 1). Phytosaur remains indicate a Late Triassic (Carnian–

TABLE 1. Triassic vertebrates from east-central New Mexico. Sources: Mehl (1922), Darton (1928a), Gregory (1972), Carpenter and Parrish (1985), Lucas and Morales (1985) and Lucas et al. (1985a, c).

SANTA ROSA FORMATION (LOWER SS MBR):

- Class AMPHIBIA
  - Subclass LABYRINTHODONTIA
    - Order STEREOSPONDYLI
      - Family CAPITOSAURIDAE
        - *Eocyclotosaurus* sp.

CUERVO MEMBER, CHINLE FORMATION:

- Class REPTILIA
  - Subclass ARCHOSAURIA
    - Suborder PHYTOSAURIA
      - Family PHYTOSAURIDAE
        - genus indeterminate

UPPER SHALE MEMBER, CHINLE FORMATION:

- Class OSTEICHTHYES
  - Subclass ACTINOPTERYGII
    - Order PALAEONISCIFORMES
      - Suborder PTYCHOLEPOIDEI
        - Family PTYCHOLEPIDAE
          - cf. *Ptycholepis* sp.
      - Suborder REDFIELDOIDEI
        - Family REDFIELDIIDAE
          - genus indeterminate
- Class AMPHIBIA
  - Subclass LABYRINTHODONTIA
    - Order TEMNOSPONDYLI
      - Family METOPOSAURIDAE
        - cf. *Eupelor* sp.
        - genus indeterminate
    - Order INDETERMINATE
      - Family INDETERMINATE
        - large species
        - small species
- Class REPTILIA
  - Subclass ARCHOSAURIA
    - Order THECODONTIA
      - Suborder PSEUDOSUCHIA
        - Family RAUISUCHIDAE
          - *Poposaurus* sp.
        - Family STAGONOLEPIDAE
          - *Desmatosuchus* sp.
          - *Typothorax* sp.
      - Suborder PHYTOSAURIA
        - Family PHYTOSAURIDAE
          - *Rutiodon andersoni*
          - *Nicrosaurus gregorii*
          - *Rutiodon* cf. *R. adamenensis*
          - *Rutiodon* sp.
          - *Nicrosaurus* sp.
          - genus indeterminate
    - Order SAURISCHIA
      - Suborder THEROPODA
        - Family PODOKESAURIDAE
          - cf. *Coelophysis* sp.
        - Family INDETERMINATE
          - new genus and species
          - genus indeterminate
    - Order ORNITHISCHIA
      - Suborder ORNITHOPODA
        - Family FABROSAURIDAE
          - genus indeterminate
  - Subclass SYNAPSIDA
    - Infraorder CYNODONTIA
      - genus indeterminate
    - ?Infraorder ICTIDOSAURIA
      - genus indeterminate

REDONDA MEMBER, CHINLE FORMATION:

- Class OSTEICHTHYES
  - Subclass ACTINOPTERYGII
    - Order PALAEONISCIFORMES
      - genus indeterminate
  - Subclass SARCOPTERYGII
    - Order DIPNOI
      - genus indeterminate
- Class AMPHIBIA
  - Subclass LABYRINTHODONTIA
    - Order TEMNOSPONDYLI
      - Family METOPOSAURIDAE
        - *Anaschisma* new species
- Class REPTILIA
  - Subclass ARCHOSAURIA
    - Suborder PSEUDOSUCHIA
      - Family STAGONOLEPIDAE
        - *Typothorax* sp.
        - genus indeterminate
    - Suborder PHYTOSAURIA
      - Family PHYTOSAURIDAE
        - *Rutiodon* sp.
        - *Nicrosaurus gregorii*
        - genus indeterminate
    - Order SAURISCHIA or ORNITHISCHIA
      - genus indeterminate

Norian) age for the Cuervo Member, but more biostratigraphic data are needed to make a more precise age assignment.

Upper shale member

The upper shale member of the Chinle Formation in east-central New Mexico is the most fossiliferous portion of the Triassic section in this part of the state. Most fossils from the upper shale member apparently come from the upper part of the unit. Detailed stratigraphic study of the distribution of fossils in the upper shale member at Bull Canyon (Fig. 5) supports this statement; here, two fossiliferous intervals are present in the upper 65 m of the upper shale member.

Most of the taxa of megafossil plants from the Triassic of east-central New Mexico reported by Ash (1972) apparently are present in the upper shale member, although Ash (1972) presented no specific stratigraphic data. The calamite *Neocalamites* also is present in the upper shale member at Bull Canyon (Lucas et al., 1985b). Apparently the upper shale member paleoflora is of Late Triassic (Carnian–Norian) aspect, but little more can be said about its biostratigraphic significance at present.

Nonmarine invertebrates, mostly unionids and gastropods, from the upper shale member have been described by Kues (1985). Spirorbid worm shells and ostracodes from the upper shale member are presently under study by B. S. Kues and K. K. Kietzke of the University of New Mexico. The unionids and gastropods definitely identified by Kues (1985)—*Antediplodon* (= *Unio*) *dockumensis* and *Triasamnicola pilsbryi*—have been reported from the upper part of the Chinle Formation of northeastern Arizona (upper Petrified Forest Member and Owl Rock Member: Stewart et al., 1972a). This could be used to support correlation of the upper shale member of the Chinle in east-central New Mexico with the upper part of the Chinle in northeastern Arizona. However, Late Triassic fossil invertebrates from the American Southwest are so poorly studied (Kues, 1985) that we hesitate to draw biostratigraphic conclusions from them.

Fossil vertebrates from the upper shale member (Table 1) have been described by Gregory (1953, 1962, 1972, 1980), Lucas et al. (1985a, c) and Carpenter and Parrish (1985). This fauna lacks the primitive phytosaurs characteristic of Carnian time and contains *Nicrosaurus*, a phytosaur that first appears in the Norian (Westphal, 1976). Correlation with the upper part of the Petrified Forest Member of the Chinle in northeastern Arizona and the upper shale unit of the Dockum Group in western Texas is not contradicted by any elements of the fauna of the upper shale member of the Chinle in east-central New Mexico. However, more detailed study of this fauna is needed before this conclusion can be termed incontrovertible.

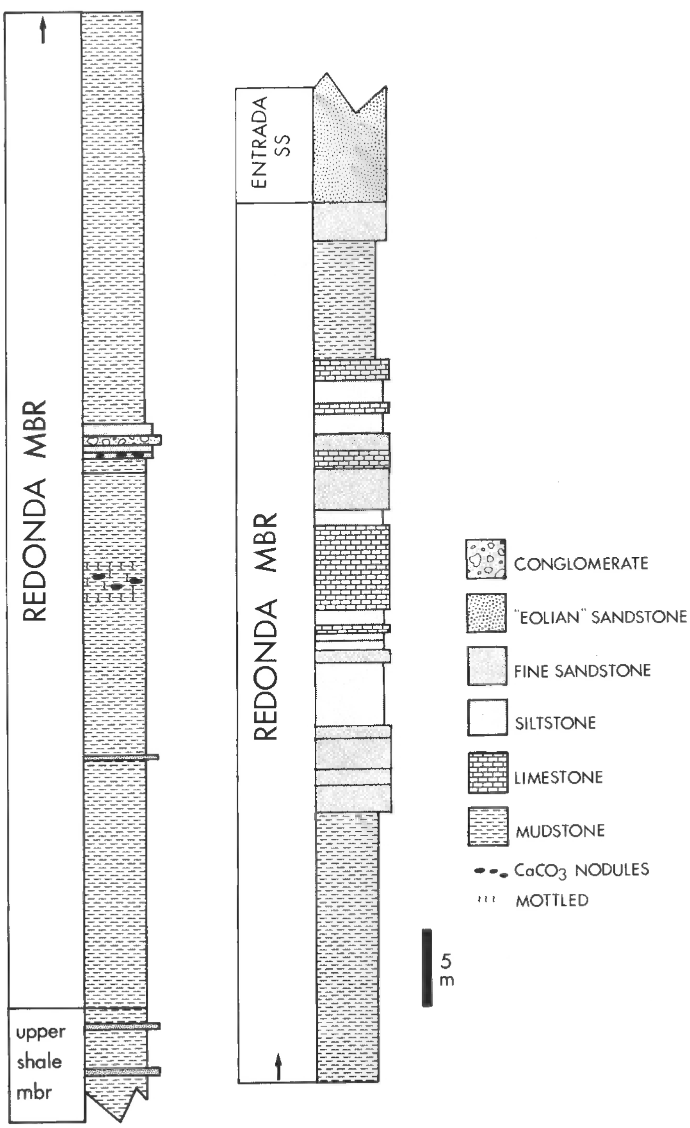

FIGURE 5. Type section of the Redonda Member of the Chinle Formation. See text for location of this section and discussion.

Redonda Member

To our knowledge, no fossil plants other than *Neocalamites* (Gregory, 1972) have been reported from the Redonda Member of the Chinle Formation in east-central New Mexico. Fossil invertebrates (unionids, conchostracans and ostracodes) are present in this unit (Gregory, 1972), but have not been studied. Fossil vertebrates from the Redonda Member (Table 1) include a new species of the metoposaurid labyrinthodont *Anaschisma*, the pseudosuchian *Typothorax* and the phytosaurs *Rutiodon* sp. and *Nicrosaurus gregorii*. The Norian age of the Redonda thus is beyond question. Its more precise biostratigraphic correlation with other Triassic strata of the American Southwest is based primarily on an undescribed species of putatively advanced phytosaur. This species apparently is more advanced than those found in the Petrified Forest Member of the Chinle Formation in northeastern Arizona and closely resembles the phytosaur skull from the Sloan Canyon Formation of northeastern New Mexico described by Stovall and Savage (1939) (Gregory, 1957, 1962, 1972; Colbert and Gregory, 1957; Lucas et al., 1985a). However, a revision of the species-level taxonomy of phytosaurs will be needed before this correlation can be accepted without question.

CORRELATION OF THE TRIASSIC OF EAST-CENTRAL NEW MEXICO

Introduction

Physical stratigraphy and the biostratigraphic data just discussed allow a preliminary correlation of the Triassic of east-central New Mexico with Triassic strata in other parts of New Mexico and in portions of Arizona, Utah, Colorado and Texas (Fig. 6). To present this correlation, we discuss each column in Figure 6 and its correlation with the Triassic section in east-central New Mexico.

Northeastern Arizona

Upper Triassic stratigraphic nomenclature in northeastern Arizona employed here (Fig. 6, column 1) is essentially that used by Stewart et al. (1972a, fig. 1). Correlation with the Triassic time scale is essentially that of Colbert and Gregory (1957) and Gregory (1957) revised in light of better age determinations for the Keuper in West Germany (see Chatterjee, in press, table 2) and unpublished information provided by R. Long (oral comm. 1985) of the University of California at Berkeley. The age of the Moenave Formation remains problematical (either Late Triassic or Early Jurassic), as it was in 1957 (Reeside et al., 1957).

Correlation with the Triassic section in east-central New Mexico is based on the following considerations:

1. In a broad overview, the Upper Triassic strata of the American Southwest display striking homotaxis. The lowermost Upper Triassic

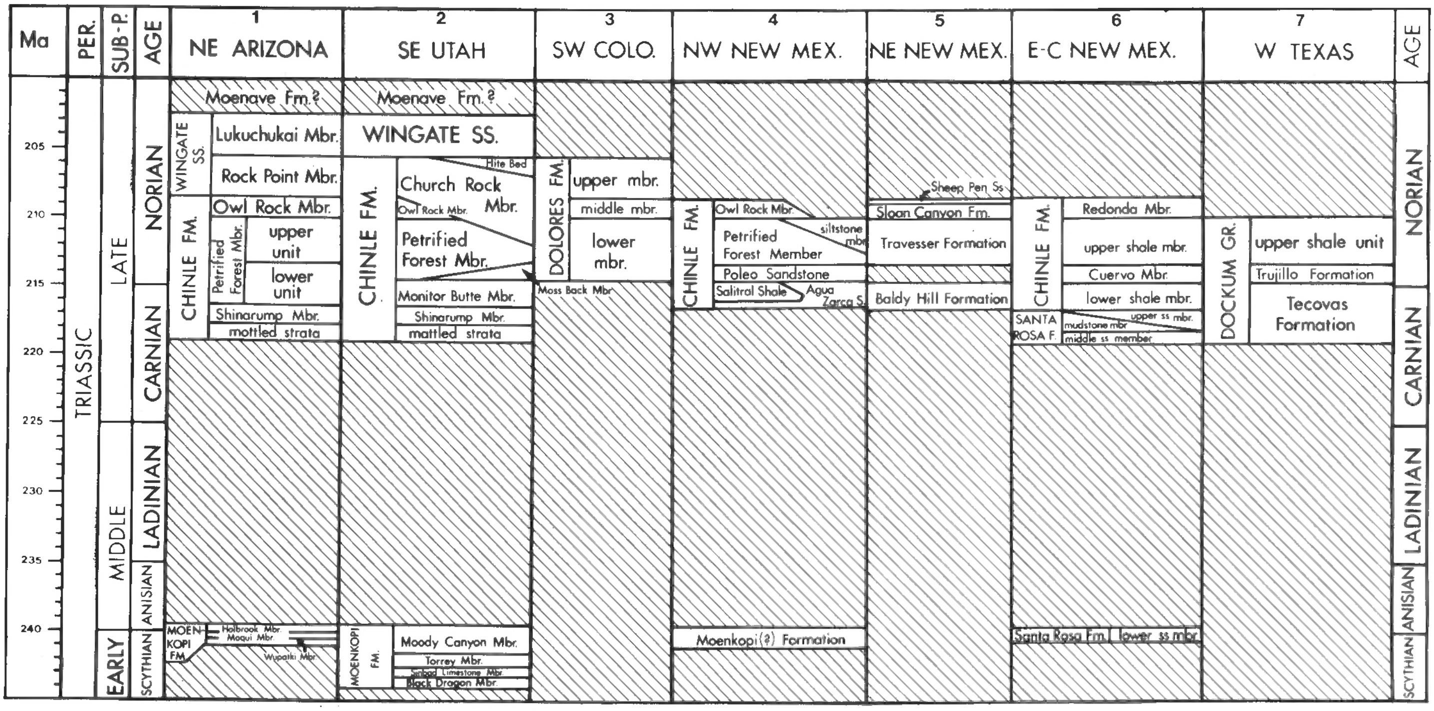

FIGURE 6. Preliminary correlation of the Triassic strata of east-central New Mexico with selected Triassic strata of the American Southwest. Geochronometric and chronostratigraphic scales from Webb (1981).

strata (Shinarump in the Colorado Plateau, upper Santa Rosa in east-central New Mexico and basal Tecovas [Camp Springs] in western Texas) are sandy to conglomeratic. Overlying strata (lower Petrified Forest and Monitor Butte Members in the Colorado Plateau, lower shale member in east-central New Mexico and upper Tecovas in western Texas) are predominately mudrock. Another sandy interval follows (Sonsela and Poleo in the Colorado Plateau, Cuervo in east-central New Mexico and Trujillo in western Texas). A second mudrock interval overlies this sandy interval (upper Petrified Forest Member in the Colorado Plateau, upper shale member in east-central New Mexico and upper shale unit in western Texas). Finally, cyclical lacustrine deposits overlie this mudrock interval (Owl Rock and lower Church Rock in the Colorado Plateau, Redonda in east-central New Mexico, but no apparent equivalent in western Texas). This homotaxis does not imply exact synchroneity of the units involved, but it does support their broad correlation. It also implies that regional tectonism and/or climatic fluctuation controlled Late Triassic sedimentation in a regular way throughout the Southwest.

2. The vertebrate fauna of the upper part of the Petrified Forest Member in northeastern Arizona is arguably correlative with the faunas of the Chinle upper shale member in east-central New Mexico and the Dockum upper shale unit in western Texas (Colbert and Gregory, 1957; Lucas et al., 1985a; Chatterjee, in press).

3. The Owl Rock Member of the Chinle Formation in northeastern Arizona (Kiersch, 1956) is up to 152 m of "pale-red and pale-reddish-brown coarse siltstone interstratified with pale-red and light-greenish-gray limestone beds" and "locally contains beds of horizontally laminated and ripple-laminated siltstone and sandstone, cross-stratified sandstone, and limestone and siltstone conglomerate" (Stewart et al., 1972a, pp. 38–39). In thickness, lithology and stratigraphic position it corresponds remarkably well with the Redonda Member of the Chinle Formation in east-central New Mexico. This correlation (Fig. 6) is supported slightly by fragmentary phytosaurs from the Owl Rock that indicate it is of Norian age.

Subdivisions of the Moenkopi Formation (Ward, 1901) are those used by Stewart et al. (1972b, fig. 2)—Wupatki Member (McKee, 1954), Moqui Member (McKee, 1954) and Holbrook Member (Hager, 1922)—except that their "lower massive sandstone" is included here in the Wupatki Member following Blakey (1974). These three units clearly were deposited after the marine transgression that produced the Virgin Limestone Member of the Moenkopi in southern Nevada, southwestern Utah and northwestern Arizona (Stewart et al., 1972b, fig. 10). The Virgin Limestone in southwestern Utah is of middle Spathian (late Scythian) age (Carr and Paull, 1983). Fossil vertebrates and reptilian trackways from the Wupatki Member in northeastern Arizona suggest an Early Triassic age (Camp et al., 1947; Peabody, 1948). In considering the vertebrate fauna of the Holbrook Member, Welles (1947, p. 286) noted that "it seems best that we refer it to the Lower Triassic, bearing in mind the possibility that the Moenkopi may extend at least into the Middle Triassic." Nevertheless, the occurrence of the capitosaurid amphibian *Eocyclotosaurus* in the Holbrook Member of the Moenkopi, and in the lower sandstone member of the Santa Rosa Formation in east-central New Mexico, supports correlation of these units and their identification as Anisian (see earlier discussion).

Southeastern Utah

Stratigraphic nomenclature of the Upper Triassic strata of southeastern Utah employed here (Fig. 6, column 2) is that of Stewart et al. (1972a, fig. 1). Its correlation with the Upper Triassic sequence in northeastern Arizona is securely based on physical stratigraphy, to some extent supported by biostratigraphic data (Stewart et al., 1972a). Correlation with the Triassic sequence in east-central New Mexico thus is indirect, being based on the correlation of the northeastern Arizona sequence with the New Mexican sequence.

The Church Rock Member of the Chinle Formation in southeastern Utah (Stewart, 1957) is primarily "pale-reddish-brown, reddish-orange, and light-brown fine to coarse siltstone that is structureless or in thin to thick horizontal beds" (Stewart et al., 1972a, p. 42). It is in part laterally equivalent to the Owl Rock Member of the Chinle in northeastern Arizona (Stewart et al., 1972a). Therefore, we consider it to be equivalent in part to the Redonda Member of the Chinle in east-central New Mexico. However, the upper part of the Church Rock Member and its lateral equivalent in northeastern Arizona, the Rock Point Member of the Wingate Sandstone, are not as similar lithologically to the Redonda Member as is the Owl Rock Member. Although these units have produced phytosaurs, and thus are of Norian age, we believe they are younger than the Redonda Member (Fig. 6). This differs from the correlation of Gregory (1957, fig. 2), who equated the Redonda with the Owl Rock, the entire Wingate Sandstone and the Moenave Formation.

In southeastern Utah, four members of the Moenkopi are recognized: Black Dragon Member (Blakey, 1974), Sinbad Limestone Member (Gilluly and Reeside, 1928), Torrey Member (Blakey, 1974) and Moody Canyon Member (Blakey, 1974). The Black Dragon Member is older than any part of the Moenkopi Formation in northeastern Arizona (McKee, 1954; Stewart et al., 1972b), and it has produced Early Triassic conodonts (Orgill, 1971). The overlying Sinbad Limestone Member intertongues with the Black Dragon Member. It contains ammonites of the *Meekoceras* and *Anasiberites* zones (Stewart et al., 1972b) which are zones of Smithian (early late Scythian) age (Silberling and Tozer, 1968). The Torrey Member apparently is older than the Moenkopi in its type area in northeastern Arizona (Blakey, 1974). Its suggested equivalence with the Virgin Limestone Member of the Moenkopi in north-central Arizona and with part of the Thaynes Formation of west-central Utah and other areas (Blakey, 1974) suggests assignment to the *Columbites–Tirolites* ammonite zone of early Spathian (late Scythian) age (Silberling and Tozer, 1968).

No fossils that are biostratigraphically useful have been identified from the Moody Canyon Member, and its correlation with the section in northeastern Arizona is based solely on stratigraphic and lithologic criteria (Blakey, 1974). This suggests that the Moody Canyon Member, which conformably overlies the Torrey Member (Blakey, 1974), transgresses the Scythian–Anisian boundary.

Southwestern Colorado

Informal subdivision of the Dolores Formation (Cross, 1899; Cross and Howe, 1905) in the southern San Juan Mountains of southwestern Colorado into lower, middle and upper members (Fig. 6, column 3) follows Stewart et al. (1972a). The lower member includes ledge-forming sandstones clearly correlative with the Moss Back Member of the Chinle Formation in southeastern Utah (Stewart et al., 1972a, fig. 15). Physical stratigraphy and understudied fossil plants and vertebrates support correlation of the Dolores with the upper Chinle and lower Wingate (Rock Point Member) in northeastern Arizona (Baker et al., 1936, pp. 34, 39; Reeside et al., 1957, pl. 1, p. 1481; Stewart et al., 1972a, fig. 15). However, this conclusion needs further support, especially biostratigraphic, and there is no direct way to correlate the Dolores with the Triassic sequence in east-central New Mexico.

Northwestern New Mexico

Upper Triassic stratigraphic nomenclature in northwestern New Mexico (Fig. 6, column 4) employed here follows Stewart et al. (1972a, fig. 1). This nomenclature applies specifically to the eastern San Juan Basin; to the north the nomenclature is the same as that used in southwestern Colorado, and to the west it is the same as the northeastern Arizona nomenclature (O'Sullivan, 1977).

The Agua Zarca Sandstone Member (Wood and Northrop, 1946) and laterally equivalent Salitral Shale Tongue (Wood and Northrop, 1946) are correlated with the lower part of the Petrified Forest Member of the Chinle in northeastern Arizona (Stewart et al., 1972a; O'Sullivan, 1977). The Poleo Sandstone Lentil (Huene, 1911) is a coarse-grained facies homotaxial with the Sonsela Sandstone Bed in northeastern Arizona (Stewart et al., 1972a; O'Sullivan, 1977). The vertebrate fauna from the overlying Petrified Forest Member and "siltstone member" in northwestern New Mexico includes the classic *Coelophysis* quarry at Ghost Ranch (Colbert, 1974). This fauna resembles that from the upper part of the Petrified Forest Member in northeastern Arizona, supporting correlation of these units (Colbert and Gregory, 1957), a correlation possible solely on the basis of physical stratigraphy (Stewart et al., 1972a; O'Sullivan, 1977). The Owl Rock Member has been traced from northeastern Arizona into the San Juan Basin (O'Sullivan, 1977).

Although Darton (1910, 1922, 1928a) referred basal Triassic rocks in northwestern, north-central and south-central New Mexico to the Moenkopi Formation, most of these rocks pertain to the Chinle Formation, as was first noted by Bates (1942). A thin sequence in west-central New Mexico, however, probably does pertain to the Moenkopi Formation (Bates, 1942; McKee, 1954; Cooley, 1957; Stewart et al., 1972b). These rocks, here identified as Moenkopi(?) Formation, are mostly red siltstone and sandstone with occasional conglomerates composed of chert, quartz and quartzite cobbles (O'Sullivan, 1977). They are up to 65 m thick and are present locally in and directly east of the Zuni Mountains. Lithology supports correlation of the New Mexican Moenkopi(?) Formation with the Moenkopi in northeastern Arizona and the Moody Canyon Member of the Moenkopi in southeastern Utah (Blakey, 1974; O'Sullivan, 1977). However, fossil evidence is lacking to support this correlation, and Read and Wanek (1961) have assigned strata in New Mexico termed Moenkopi(?) to the Chinle Formation.

Northeastern New Mexico

Baldwin and Muehlberger (1959) recognized four Triassic formations in northeastern New Mexico (Union County) (Fig. 6, column 5) that they included in the Dockum Group:

1. Approximately 35 m of purple-mottled mudstone, the Baldy Hill Formation (Foster, 1956), represent the oldest Triassic rocks in Union County. Other than "questionable plant fragments" (Baldwin and Muehlberger, 1959, p. 38), no fossils have been reported from the Baldy Hill Formation.
2. Clayey siltstone and very fine-grained sandstone, up to 168 m thick, overlie the Baldy Hill Formation in Union County, and were named the Travesser Formation by Baldwin and Muehlberger (1959, p. 38). Baldwin and Muehlberger (1959) suggested a possible angular unconformity at the Baldy Hill–Travesser contact. No fossils are known from the Travesser Formation.
3. The Sloan Canyon Formation (Parker, 1933) conformably overlies the Travesser Formation and consists of up to 46 m of variegated shale and siltstone and minor beds of mudstone, sandstone and conglomerate. Fossils from the Sloan Canyon Formation are a phytosaur skull (Stovall and Savage, 1939) and reptilian trackways (Baird, 1964).
4. Parker's (1933) Sheep Pen Sandstone is up to 33 m of thin-bedded to massive, tan to buff sandstone that conformably overlies the Sloan Canyon Formation.

There is no good evidence for correlating the Baldy Hill and Travesser Formations and the Triassic sequence in east-central New Mexico. The Sloan Canyon Formation is a probable correlative of the Redonda Member of the Chinle Formation in east-central New Mexico (see below). This suggests that the Travesser is equivalent to at least the upper part of the Chinle upper shale member farther south (Fig. 6). The possible angular unconformity between the Baldy Hill and Travesser Formations may reflect rising of the Sierra Grande uplift and Bravo dome in northeastern New Mexico and southeastern Colorado. At this time, the Cuervo Member of the Chinle Formation and its correlative, the Trujillo Formation of the Dockum Group, were deposited south and east of the uplifted area (Granata, 1981; McGowen et al., 1983). The predominately fine-grained Baldy Hill Formation, older than this time of uplift, may thus be equivalent to all or part of the Chinle lower shale member in east-central New Mexico (Fig. 6). The speculative nature of this correlation, however, should be underscored.

The phytosaur skull from the Sloan Canyon Formation described by Stovall and Savage (1939) and the reptilian footprints from this unit (Baird, 1964) support, in a preliminary way, correlation of the Sloan Canyon with the Redonda Member of the Chinle Formation in east-central New Mexico (Colbert and Gregory, 1957; Gregory, 1957, 1962; Lucas et al., 1985a).

Western Texas

Three divisions of the Dockum Group (Cummins, 1890) are recognized in western Texas (Fig. 6, column 7): upper shale unit (Drake, 1892), Trujillo Formation (Gould, 1907) and Tecovas Formation (Gould, 1907). The Camp Springs Conglomerate (Christner in Beede and Christner, 1926) is here included in the Tecovas Formation. Dunay (1972) and Chatterjee (in press) have reduced the rank of the Dockum from group to formation, and Chatterjee (in press) has formally named the "upper shale unit" of Drake (1892). However, we here follow traditional stratigraphic terminology by conferring group status to the Dockum and formational status to its subdivisions. Application of the name Chinle to Drake's (1892) upper shale unit, advocated by Adams (1929), Green (1954) and Kiatta (1960), is rejected (Chatterjee, in press). As McKee (in Reeside et al., 1957, p. 1476) put it:

> The extension of this name [Chinle] from the west and its restriction to the uppermost unit of the Triassic in this area [western Texas] is unfortunate, for here the name connotes a meaning different from that in the type locality.

Correlation of the Triassic sequence in western Texas with the chronostratigraphic scale has been presented by Chatterjee (in press). He argues that the Tecovas vertebrate fauna (principally described by Case, 1922, 1932; Case and White, 1934; Langston, 1949; and Colbert and Imbrie, 1956) corresponds well to the German lower Keuper fauna (Rotewand and Schilfsandstein) and is of middle–late Carnian age. No fossil vertebrates are known from the Trujillo, but the overlying upper shale unit has a diverse vertebrate fauna (e.g., Chatterjee, 1983, 1984, in press) that corresponds well to the fauna of the German Stubensandstein, and thus is of early Norian age (Chatterjee, in press). This correlation relies principally on the stratigraphic distribution of parasuchid (phytosaur) genera in Germany: *Parasuchus* is restricted to the Carnian, *Nicrosaurus* to the early Norian, and *Rutiodon* is found throughout the Norian (*sensu lato*, i.e., including the "Rhaetian") (Westphal, 1976).

Correlation of the western Texas Triassic sequence with the Triassic sequence in east-central New Mexico is based on the blending of physical stratigraphy (Finch et al., 1976; Finch and Wright, 1983) and biostratigraphy. No Anisian vertebrates are present in the Triassic of west Texas, so the lower sandstone member of the Santa Rosa Formation in east-central New Mexico apparently antedates any part of the Triassic sequence in western Texas.

Physical stratigraphy and homotaxis support correlation of the middle sandstone, mudstone and upper sandstone members of the Santa Rosa Formation and the lower shale member of the Chinle Formation in east-central New Mexico with the Tecovas Formation of the Dockum Group in western Texas (Finch et al., 1976; Finch and Wright, 1983). Megafossil plants of Late Triassic aspect from the mudstone member of the Santa Rosa support this correlation. This suggests that the unconformity at the base of the middle sandstone member of the Santa Rosa Formation is of great temporal significance; it probably represents about 20 million years of Triassic time (Fig. 6).

Physical stratigraphy and homotaxis, and the solution to the "Logan Sandstone problem" proposed above, support correlation of the Cuervo Member of the Chinle in east-central New Mexico with the Trujillo Formation of the Dockum Group (Finch et al., 1976; Finch and Wright, 1983).

From this it follows that the upper shale member of the Chinle in east-central New Mexico is equivalent to the upper shale unit of the Dockum in western Texas (Fig. 6). Fossil vertebrates from both units are consistent with this correlation, although the vertebrates from the upper shale member in east-central New Mexico need further study before they can be used to support this correlation conclusively.

The cyclic, lacustrine Redonda Member of the Chinle in east-central New Mexico (Granata, 1981; McGowen et al., 1983) has no lithological/depositional counterpart in the Dockum Group of western Texas. It also has produced a phytosaur that is putatively more advanced than any Dockum phytosaur. For these reasons, we consider the Redonda to be younger than any part of the Dockum in western Texas (Fig. 6).

Magnetostratigraphy

There is no standard magnetic-polarity zonation of the Triassic and the "polarity bias superchron" (Harland et al., 1982) of the period is recognized as mixed, i.e., a mixture of normal and reversed polarity (Irving and Pullaiah, 1976). Reeve and Helsley (1972) reported a magnetic-reversal sequence for the uppermost upper shale member and the Redonda Member of the Chinle Formation in east-central New Mexico. This polarity sequence is mixed and should, on biostratigraphic grounds, be of Norian age. This suggests correlation with the mixed-polarity interval of the Passaic Formation of the Newark basin of New Jersey (McIntosh et al., 1985, fig. 2). McIntosh et al. (1985, fig. 10) incorrectly correlated the Redonda magnetic-polarity sequence with the lower normal interval of the Newark basin (lowermost Passaic Formation and Lockatong Formation) based on the biostratigraphy of Olsen et al. (1982), which they accepted as a basis for assigning the Redonda a late Carnian age.

CONCLUSIONS

Based on the data and discussion presented in this paper, the following conclusions are offered:

1. Triassic strata in east-central New Mexico pertain to the Santa Rosa Formation and overlying Chinle Formation. The term Dockum Group should not be applied to Triassic strata in east-central New Mexico.
2. Four informal members of the Santa Rosa Formation can be recognized: lower sandstone member, middle sandstone member, mudstone member and upper sandstone member. Intraformational unconformities are present at the bases of the middle and upper sandstone members. Formal subdivision of the Santa Rosa Formation is feasible and should be undertaken.
3. All Triassic strata above the Santa Rosa Formation in east-central New Mexico are referred to the Chinle Formation which is divided into four members: lower shale member, Cuervo Member, upper shale member and Redonda Member (= Naranjo Formation).
4. The capitosaurid amphibian *Eocyclotosaurus* from the lower sandstone member of the Santa Rosa Formation indicates a Middle Triassic (Anisian) age. The lower sandstone member thus is a correlative of the Holbrook Member of the Moenkopi Formation in northeastern Arizona. It apparently is older than any part of the Dockum Group in western Texas.
5. Megafossil plants and physical stratigraphy indicate that the middle sandstone, mudstone and upper sandstone members of the Santa Rosa Formation are correlatives of the lower–middle part of the Tecovas Formation of the Dockum Group in western Texas. These units are of Late Triassic, probably late Carnian, age.
6. Physical stratigraphy indicates that the lower shale member of the Chinle is a correlative of the upper part of the Tecovas Formation of the Dockum Group in western Texas.
7. The Cuervo Member and the Trujillo Formation of the Dockum Group in western Texas are correlated on the basis of physical stratigraphy. The term "Logan Sandstone" refers to strata of the Cuervo–Trujillo and should be abandoned.
8. Fossil vertebrates of the upper shale member support correlation with the upper shale unit of the Dockum Group in western Texas and the upper part of the Petrified Forest Member of the Chinle in northeastern Arizona. The upper shale member thus is of early Norian age.
9. The Redonda Member contains Norian vertebrates and is remarkably similar in lithology to the Owl Rock Member of the Chinle Formation in the Colorado Plateau. This supports correlation of the Redonda with the Owl Rock and suggests that the Redonda is younger than any part of the Dockum Group in western Texas.

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