



Triassic stratigraphy in southeastern New Mexico and southwestern Texas

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TRIASSIC STRATIGRAPHY IN SOUTHEASTERN NEW MEXICO AND SOUTHWESTERN TEXAS

SPENCER G. LUCAS¹ and ORIN J. ANDERSON²

¹New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104;

²New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico 87801

Abstract—Upper Triassic strata exposed in southeastern New Mexico and southwestern Texas are assigned to the Santa Rosa, San Pedro Arroyo and Dockum Formations of the Chinle Group. In southeastern New Mexico (Chaves, Eddy and Lea Counties) the Santa Rosa Formation is as much as 25 m thick and is mostly trough-crossbedded extraformational conglomerate and sandstone with minor beds of mudstone or siltstone. It disconformably overlies Upper Permian (Artesia Group or Quartermaster Formation) strata. The San Pedro Arroyo Formation conformably (?) overlies the Santa Rosa Formation and is at least 50 m of variegated smectitic mudstone and minor sandstone/conglomerate. Regional geologic maps have greatly overstated the extent of Upper Triassic exposures in southeastern New Mexico. In southwestern Texas (area from Pecos to Mitchell Counties) the Dockum Formation consists of the basal Camp Springs Member and overlying strata here assigned to a new stratigraphic unit, the Iatan Member. The Camp Springs Member is at least 15 m thick and is dominantly extraformational, siliceous conglomerate. It disconformably overlies the Upper Permian Quartermaster (= Dewey Lake) Formation and is conformably(?) overlain by the Iatan Member, which is 80-100 m thick and characterized by intercalated, persistent intervals of red smectitic mudstone and trough-crossbedded micaceous sandstone. Fossil vertebrates indicate the Camp Springs and Iatan Members are of late Carnian (Tuvanian) age. Physical stratigraphy and lithology suggest correlation of the Santa Rosa Formation with the Camp Springs Member and the San Pedro Arroyo Formation with the Iatan Member.

INTRODUCTION

Triassic strata exposed in southeastern New Mexico (Chaves, Eddy and Lea Counties) and southwestern Texas (area from Pecos to Mitchell I Counties) are nonmarine red beds of Late Triassic (late Carnian) age (Lucas and Anderson, 1992, 1993). These strata (Fig. 1) have been studied relatively little. Here, we present a comprehensive lithostratigraphy and correlation of the Upper Triassic strata of southeastern New Mexico and southwestern Texas based on outcrop data.

PREVIOUS STUDIES

Hoots (1925, p. 91-93) provided the first detailed descriptions of Triassic strata in the Pecos River Valley of southeastern New Mexico. In particular, he measured sections at Custer ("Cluster") Mountain in Lea County and Maroon Cliffs ("Red Hills") in Eddy County. Lang (1935, 1947) subsequently assigned the lower, sandstone-dominated Triassic strata in southeastern New Mexico to the Santa Rosa Sandstone. Lang also, however, included some Upper Permian strata of the Quartermaster (= Dewey Lake, = Pierce Canyon Formation) in the Triassic, as did Miller (1955) and Vine (1963). Schiel (1988) corrected this error in the Maroon Cliffs area. Lucas and Anderson (1992) presented the first attempt at a comprehensive stratigraphy of Upper Triassic strata

in southeastern New Mexico. They assigned these strata to the Santa Rosa and San Pedro Arroyo Formations of the Chinle Group.

Drake (1892, pl. 5) provided the first detailed information on Upper Triassic strata in southwestern Texas, though his correlation of this strata with Upper Triassic strata in the Texas panhandle was in error. Hoots (1925, p. 87-90, pl. 10) described in detail and mapped the distribution of Upper Triassic strata in southwestern Texas. He concluded that "the Dockum group in this region is divisible into two more or less distinct formations—a lower one with a maximum thickness of 275 feet, characterized by red clay and numerous beds of massive gray cross-bedded sandstone [= Camp Springs and Iatan Members of Dockum Formation of this paper] and an upper one with a maximum thickness of 175 feet or more consisting almost entirely of red clay [= Tecovas Member of Dockum Formation]" (Hoots, 1925, p. 89). Adams (1929) subsequently assigned Hoots' (1925) lower formation to the Santa Rosa Sandstone and the upper one to the Chinle Formation (also see Adkins, 1932; Page and Adams, 1940).

Fossil vertebrates were first discovered in Upper Triassic strata near Otis Chalk in Howard County during the 1920s. Subsequent collecting has produced a substantial and diverse vertebrate fauna of late Carnian age (see Lucas et al., this volume).

Grover (1984) presented a detailed but informal attempt to further subdivide Upper Triassic strata in Howard and Mitchell Counties by recognizing the persistence of certain sandstone beds. Subsequently, Lucas and Anderson (1992, 1993) recognized basal Upper Triassic strata in this area as the Camp Springs Member of the Dockum Formation. Overlying strata of Hoots' (1925) "lower formation" were termed "unnamed member" of the Dockum Formation by Lucas and Anderson (1992, 1993).

LITHOSTRATIGRAPHY Southeastern New Mexico

Triassic strata are not well exposed in southeastern New Mexico; their outcrop distribution is greatly overstated on regional geologic maps (see below). The best exposures are at Mesa Diablo (sec. 7, T10S, R27E, Chaves County), Maroon Cliffs (sec. I, T21S, R29E and sec. 35, T20S, R29E, Eddy County) and Custer Mountain (sec. 12, T25S, R35E, Lea County) (Figs. 1, 2). Other smaller outcrops preserve less thick Upper Triassic sections and are discussed below. In southeastern New Mexico, we assign exposed Upper Triassic strata to the Santa Rosa and San Pedro Arroyo Formations (Lucas and Anderson, 1992).

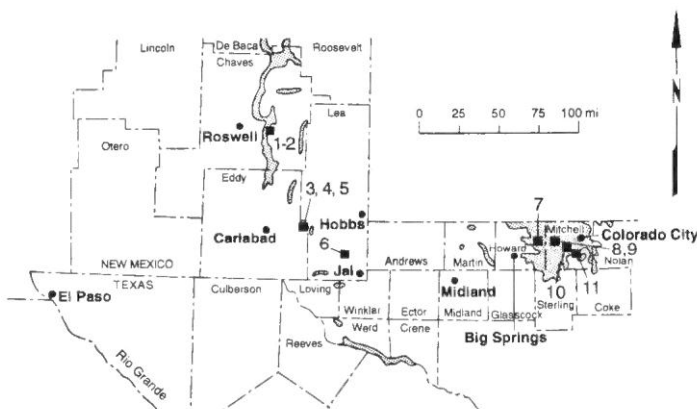


FIGURE 1. Map of Triassic outcrops (shaded) in southeastern New Mexico and southwestern Texas indicating location of measured stratigraphic sections in Fig. 2.

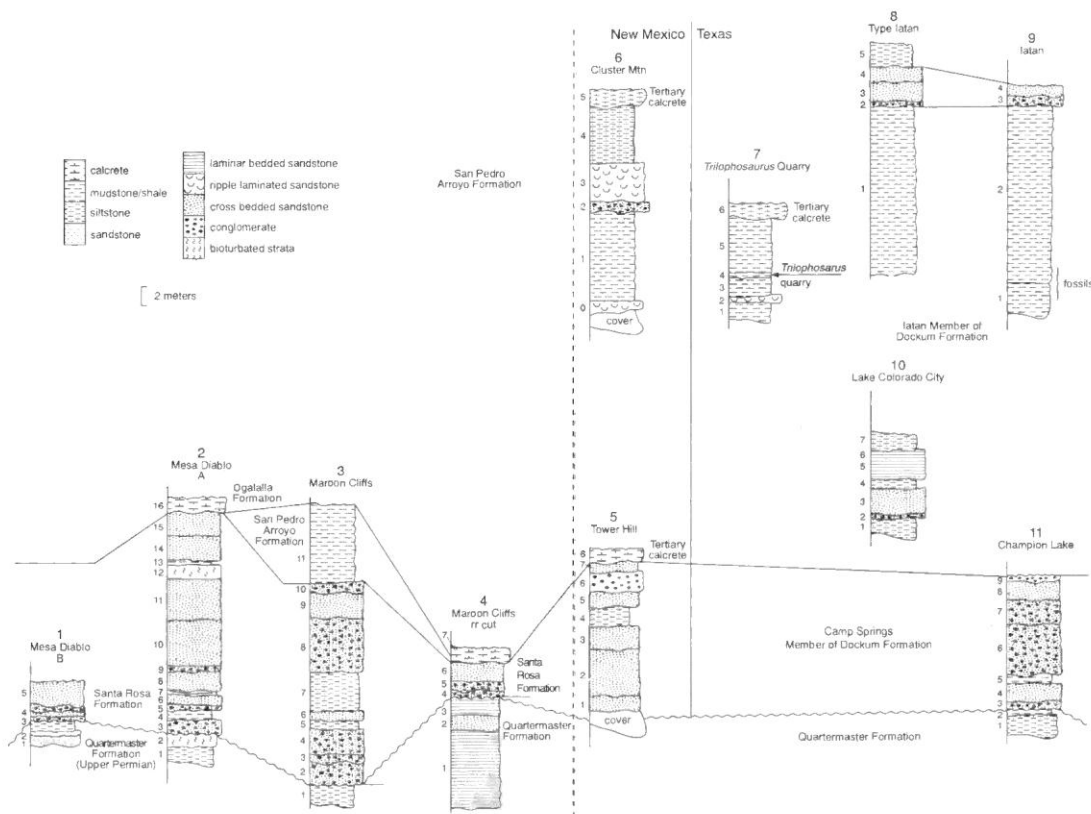


FIGURE 2. Measured stratigraphic sections of Upper Triassic strata in southeastern New Mexico and southwestern Texas. Numbered lithologic units in sections 3 and 8 are described in the Appendix.

Santa Rosa Formation

We assign the basal sandstones and conglomerates of the Upper Triassic section in southeastern New Mexico to the Santa Rosa Formation, as did Lang (1935) and subsequent workers. The Santa Rosa is as much as 25 m thick and is mostly trough-cross-bedded extraformational conglomerate and sandstone with minor beds of mudstone or siltstone. Typical colors are grayish red (10 R 4/2) and pale reddish brown (10 R 5/4) for the sandstones, siltstones and mudstones, whereas conglomerate beds are mostly yellowish gray (5 Y 8/1) to light greenish gray (5G Y 8/1). Sandstones are micaceous subarkoses or litharenites. Conglomerate clasts typically are rip-ups of underlying Permian red beds (Artesia Group or Quartermaster Formation) at the base of the Santa Rosa Formation. Some quartzite clasts (usually in the very coarse to pebbly size range) also are present in basal Santa Rosa conglomerates. Conglomerates higher in the unit contain reworked Triassic siltstone and sandstone clasts.

The base of the Santa Rosa Formation is a disconformity above Permian red beds. Permian strata are finer grained, more texturally and mineralogically mature, gypsiferous, more evenly bedded and a different color (mostly moderate reddish brown) than the Santa Rosa Formation. Despite these differences, in southeastern New Mexico both Miller (1955) and Vine (1963) incorrectly included uppermost sandstones of the Quartermaster Formation in the Santa Rosa Formation (Schiel, 1988; Lucas and Anderson, this volume).

The top of the Santa Rosa Formation in southeastern New Mexico is visible only at Maroon Cliffs. Here, variegated moderate reddish brown (10 R 4/6) and grayish red purple (5 RP 4/2) mudstone of the San Pedro Arroyo Formation rests directly (conformably?) on the uppermost conglomerate bed of the Santa Rosa Formation (Fig. 2).

Other than unidentifiable fragments of petrified wood, bone and coprolites, no fossils have been collected in the Santa Rosa Formation in southeastern New Mexico. Nevertheless, regional correlation suggests this unit is of Late Triassic (late Carnian) age (see below).

San Pedro Arroyo Formation

In southeastern New Mexico, Upper Triassic strata above the Santa Rosa Formation are mudstone dominated and very poorly exposed. The most extensive outcrops are around Custer Mountain in Lea County where as much as 22 m of strata are exposed. These strata are mostly pale reddish brown (10 R 5/4) and yellowish gray (5 Y 7/2), slope-forming smectitic mudstone and siltstone. Some minor ledges of yellowish gray (5 Y 7/2) micaceous quartzarenite sandstone also are present.

We assign these upper, mudstone-dominated strata in southeastern New Mexico to the San Pedro Arroyo Formation of Lucas (1991), which overlies the Santa Rosa Formation directly to the northwest in Lincoln and Socorro Counties. No fossils are known from the San Pedro Arroyo Formation in southeastern New Mexico. However, in Lincoln and Socorro Counties, this unit yields fossils of Late Triassic (late Carnian–early Norian?) age. Tertiary calcretes overlie the San Pedro Arroyo Formation on outcrop in southeastern New Mexico.

Actual outcrop distribution

Geologic maps of southeastern New Mexico by Dane and Bachman (1965), Barnes (1974, 1976a) and Clemons (1982) greatly exaggerate the extent of Upper Triassic outcrops in southeastern New Mexico. Here, we list and briefly describe these exaggerated or misidentified Upper Triassic outcrops:

I. Mescalero Ridge, Chaves County—Dane and Bachman's (1965; also see Clemons, 1982) most extensive Triassic outcrop in southeastern New Mexico is at Mescalero Ridge, along and to the south of U.S. Highway 380 (also see Barnes, 1974). These maps greatly exaggerate the extent of intermittent exposures of the San Pedro Arroyo Formation underneath the Ogallala Formation here along the western edge of the Llano Estacado. Nye (1932, p. 236-238) provided detailed observations of these outcrops, which expose as much as 50 m of strata dominated by reddish brown and yellowish gray mudstones, especially in the

SW¹/₄ sec. 3, SW¹/₄ sec. 16 and the W¹/₂ sec. 28, T1 IS, R31E and the SE¹/₄ sec. 21, T125, R31E.

2. Loco Hills, Eddy County-the Triassic outcrop shown by Barnes (1976a) just south of Loco Hills along NM Highway 360 (secs. 15-16, T195, R29E and vicinity) does not exist.

3. Maroon Cliffs and vicinity, Lea County-Triassic strata just north of Maroon Cliffs (secs. 5-6, T21S, R30E) mapped by Barnes (1976a) are uppermost sandstones of the Quartermaster Formation (Schiel, 1988; the mapping error followed Miller's [1965] incorrect placement of the Permian-Triassic boundary). Furthermore, Barnes' (1976a) map exaggerates the extent of the Triassic outcrop belt along the escarpment east of Maroon Cliffs; Triassic strata are exposed here only in the SE¹/₄ sec. 36, T205, R3 IE (our Tower Hill section: Fig. 2).

4. East of the Pecos River north of Red Bluff Reservoir, Eddy County-Triassic strata mapped here by Barnes (1976a) are light-colored fanglomerates, sedimentary breccias and calcretes, of Tertiary age (Gatuña Formation). These outcrops are in the NW¹/₄ sec. 34 and NW¹/₄ sec. 35, T26S, R29E.

5. Paduca Breaks, Lea County-This is a very large outcrop according to Dane and Bachman (1965), Barnes (1976a) and Clemons (1982). However, the Triassic outcrop across the highway in secs. 9-10, T26S, R32E on Barnes' (1976a) map does not exist. Generalized outcrop patterns on all maps refer to isolated, patchy outcrops in sec. 12, T26S, R32E and the NE¹/₄ sec. 7-NW¹/₄ sec. 8, T26S, R33E, a few kilometers to the east. The basal Santa Rosa Formation is exposed here at the BTA Oil Producers Mesa B well in the NE¹/₄ NE¹/₄ sec. 7, T26S, R33E. Santa Rosa strata are siliceous conglomerates and very micaceous litharenites that are mostly pale reddish brown (10 R 5/4) and display trough crossbeds and ripple laminations.

6. Custer Mountain-Baldy Hill, Lea County-Triassic strata of the San Pedro Arroyo Formation are exposed at Custer ("Cluster" on some maps) Mountain (sec. 12, T25S, R35E) and Old Baldy (sec. 8, T25S, R36E) near NM-128 just west of Jal. (Clemons, 1982, failed to show the Custer Mountain outcrop). However, the Triassic outcrops west of Custer Mountain on Barnes' (1976a) map in secs. 2-3, T25S, R35E do not exist.

7. San Simon Sink, Lea County-Dane and Bachman (1965), Barnes (1976a) and Clemons (1982) mapped a Triassic outcrop along the northeastern edge of the San Simon Sink in secs. 5 and 8, T23S, R35E. These "red beds" are Cenozoic dune sands similar to the Blackwater Draw Formation of the Llano Estacado.

Southwestern Texas

In southwestern Texas, Upper Triassic strata are extensively exposed in the low badlands and escarpments of Howard and Mitchell Counties between Big Spring and Champion Creek Lake (Fig. 1). Mapped Triassic outcrops to the west, in Martin, Ward, Winkler, Loving and Crane Counties, are small and isolated (Barnes, 1976b). Some of these outcrops are not Triassic (see below).

We assign Triassic strata in southwestern Texas to the Dockum Formation. Two members are present, the basal Camp Springs Member of Beede and Christner (1926) and the overlying Iatan Member, a new unit defined here.

Camp Springs Member

The base of the Dockum Formation throughout west Texas is conglomerate and sandstone of the Camp Springs Member (Lucas and Anderson, 1992, 1993, this volume). In southwestern Texas, the Camp Springs Member is best exposed along the southeastern shore of Champion Creek Lake south of Colorado City in Mitchell County (UTM 3572950N, 326000E, zone 14 and vicinity). Here, the Camp Springs Member is at least 13 m thick and is mostly clast-supported silica-pebble conglomerate. This conglomerate is mostly trough crossbedded and most clasts are gray, pink, orange or white quartzite or black novaculite chert up to 2.5 cm in diameter. Silicified wood and oxidized stem impressions are also present. Roth (1984) presented a detailed description of the mineralogy of Camp Springs conglomerates in this area.

At Champion Creek Lake the Camp Springs Member disconformably overlies moderate reddish brown (10 R 4/6) and light olive gray (5 Y 6/1) siltstone and silty mudstone of the Quartermaster (= Dewey Lake) Formation. The top of the Camp Springs Member, however, is weathered, so its maximum thickness is not known. But, to the north in Scurry County, the Camp Springs is as much as 15 m thick and probably is as thick in Mitchell County.

Mudstone of the Iatan Member rests directly (conformably?) on the Camp Springs Member in Mitchell County. The late Carnian (Tuvalian) phytosaur *Paleorhinus* was collected in the Camp Springs Member in Scurry County (Hunt and Lucas, 1991) and we apply this age to the Camp Springs Member in Mitchell County.

Iatan Member

The name Iatan Member here is coined for the defunct railroad siding of Iatan (UTM 3579360N, 299420E, zone 14) in Mitchell County, Texas about 32 km east of Big Spring. This is the unnamed member of the Dockum Formation of Lucas and Anderson (1992, 1993). The type section of the Iatan Member is along the railroad tracks at Rattlesnake Gap 7 km west of Iatan (UTM 3577780N, 292440E to 3577620N, 291940E, zone 14, Howard County, Iatan 7.5-minute quadrangle, 1951 [photorevised 1978]). Because of subdued relief and intermittent exposures, however, no single complete section of the Iatan Member could be measured. Instead, the type section is a representative section that displays characteristic lithologies of the member.

These lithologies are smectitic, noncalcareous mudstone that is mostly dark reddish brown (10 R 3/4) to grayish red (5 R 4/2) and mottled yellowish gray (5 Y 7/2); and (2) trough crossbedded sandstone that is very pale orange (10 YR 8/2) to pale yellowish brown (10 YE 6/2), micaceous and subarkosic. The alternation of these lithologies is characteristic of the Iatan Member. It consists of four persistent beds of sandstone (some clay-ball conglomerates are present at sandstone-channel bases) intercalated with four persistent slope-forming intervals of mudstone (Fig. 3).

Grover (1984) first described briefly the nature of the Iatan Member, numbering the persistent sandstones 1 through 4 (Fig. 3). However, his sandstone 1 is the Camp Springs Member of our usage. Also, the sandstone immediately below mud and limestone of the Lower Cretaceous Walnut and Edwards Formations at Signal Peak southeast of Big Spring (UTM 3564620N, 282630E, zone 14, Moss Creek Lake, 7.5-minute quadrangle, 1971) is not Trinity Cretaceous, as Hoots (1925) indicated. This micaceous sandstone is Triassic (see Drake, 1892) and represents a fifth sandstone not recognized by Grover (1984).

Although low relief prevents measurements of a single complete section of the Iatan Member, its stratigraphy and approximate thickness can be deduced in an approximately 40 km traverse from Champion Creek Lake in Mitchell County to Signal Peak in Howard County via Lake Colorado City, Westbrook, Rattlesnake Gap and the Snyder Oil Field. The Camp Springs Member is exposed around Champion Creek Lake. At Lake Colorado City to the northwest sandstone 2 is exposed. The bluffs just east of Westbrook (including Clay Smith Peak) are defended by sandstone 3. The escarpment above Iatan Flats is capped by sandstone 4, as are low bluffs in the Snyder Oil Field. The late Carnian fossil vertebrates collected north of Otis Chalk at localities in the Snyder Oil Field (Lucas et al., this volume) thus are from the mudstone interval between sandstones 3 and 4. Only at Signal Peak is sandstone 5 preserved. Across this traverse, the Iatan Member is estimated to be 80-100 m thick.

The Iatan Member is of Late Triassic (late Carnian) age based on its vertebrate fossils (Lucas et al., this volume). The presence of *Paleorhinus* as high as the mudstone interval between sandstones 3 and 4 suggests that most of the Iatan Member is older than the Tecovas Member of the Dockum Formation to the north.

Other outcrops

We have not examined all isolated Dockum outcrops mapped by Barnes (1974, 1976b) west of Howard and Mitchell Counties in southwestern Texas. However, we offer the following observations on Dockum

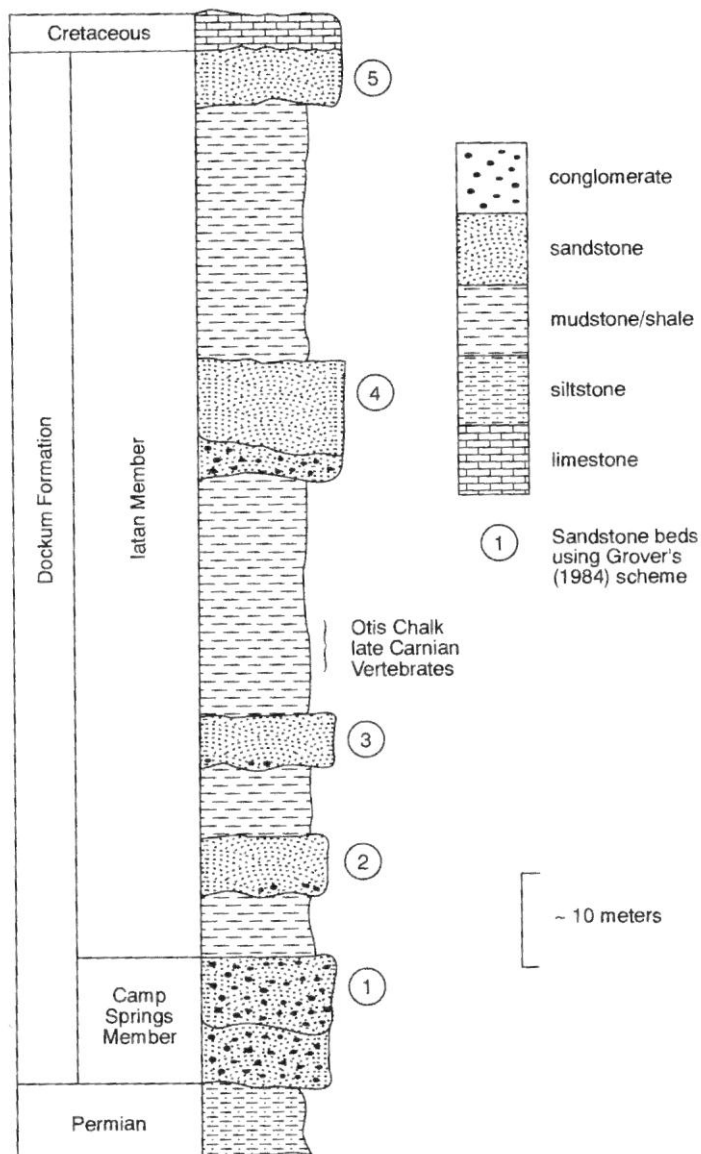


FIGURE 3. Generalized stratigraphic section and approximate thickness of Camp Springs and Iatan Members of the Dockum Formation in Mitchell and Howard Counties, Texas.

outcrops we have examined, some of which have been misidentified: (1) At Sterling City, Sterling County, just south of Highway 163 to Ozona just southeast of the Concho River, are intermittent mudstone outcrops of the Iatan Member. (2) Triassic outcrops mapped by Barnes (1976b) in Loving County just east and southeast of Red Bluff Reservoir on the Pecos River either are Quartermaster Formation or Cenozoic deposits. (3) Outcrops on Texas Highway 1053 just north of Imperial, Texas on the north bank of the Pecos River in Crane County mapped as Dockum by Barnes (1976b) actually are Upper Permian Quartermaster Formation. (4) Just east of Barstow in Pecos County along Interstate 80, Triassic sandstones are exposed that may pertain to the upper part of the Iatan Member.

CORRELATION

Lithostratigraphy and vertebrate biochronology support correlation of the Camp Springs Member of the Dockum Formation in southwestern Texas and the Santa Rosa Formation of southeastern New Mexico (Fig. 4). These late Carnian strata are overlain by correlative strata of the Iatan Member and lower San Pedro Arroyo

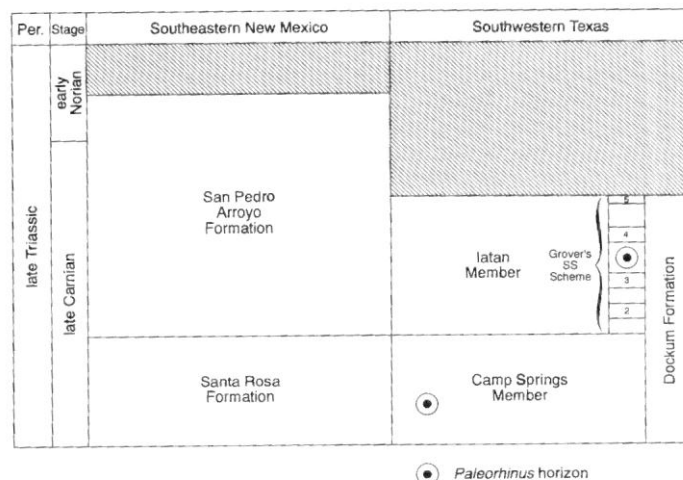


FIGURE 4. Correlation of Upper Triassic strata in southeastern New Mexico and southwestern Texas.

Formation. However, upper strata of the San Pedro Arroyo Formation may be younger than those of the Iatan Member (Fig. 4).

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APPENDIX—MEASURED SECTIONS
Iatan Member Type Section

Measured at Rattlesnake Gap, Howard County, Texas. Section begins at UTM 3577780N, 292440E and ends at UTM 35777620N, 291940E, zone 14.

unit	lithology	thickness (m)
Chinle Group:		
Dockum Formation:		
Iatan Member:		
5	Sandy mudstone; dark reddish brown (10 R 3/4); very calcareous.	not measured
4	Sandstone; very pale orange (10 YR 8/2) to grayish orange pink (5 YR 7/2); fine to medium grained; subrounded; moderately sorted; micaceous subarkose; trough crossbedded.	1.5
3	Sandstone; very pale orange (10 YR 8/2) to grayish orange pink (5 YR 7/2), weathers pale yellowish brown (10 YR 6/2); medium to coarse grained; subrounded; moderately sorted; micaceous subarkose; trough crossbedded.	2.0
2	Sandstone; same colors and lithology as unit 4 but contains yellowish gray (5 Y 7/2) clay balls up to 1 cm in diameter; trough crossbedded.	0.6
1	Mudstone; dark reddish brown (10 R 3/4) to grayish red (5 R 4/2) with pale yellowish green (106 Y 7/2) mottles; forms a slope; base of unit not exposed.	17.0+

Maroon Cliffs

Measured in the NW^{1/4} NW^{1/4} sec. 1, T21S, R29E, Eddy County, New Mexico. Strata dip 20° to N70°E.

unit	lithology	thickness (m)
Chinle Group:		
San Pedro Arroyo Formation:		
11	Mudstone and silty mudstone; moderate reddish brown (10 R 4/6) and grayish red purple (5 RP 4/2) to grayish purple (5 P 4/2); smectitic; not calcareous; contains some lenses of sandstone that is very fine- to coarse-grained, poorly sorted, subangular, slightly micaceous, quartzose and light greenish gray (5G Y 8/1) to yellowish gray (5 Y 8/1); forms a slope.	8.0+
Santa Rosa Formation:		
10	Conglomerate; mostly yellowish gray (5 Y 8/1) to light greenish gray (5 GY 8/1); weathers pale red (10 R 6/2) and pale reddish brown (10 R 5/4); matrix is calcareous sandy siltstone; clasts are limestone and siltstone pebbles up to 0.8 cm in diameter; trough crossbedded; forms a ledge.	0.9
9	Sandstone; pale reddish brown (10 R 5/4) to pale red (10 R 6/2); very fine grained; subrounded; well sorted; micaceous quartzarenite; trough crossbedded.	2.6
8	Conglomerate; same colors and lithology as unit 10; forms a hogback; trough crossbedded; contains bone fragments and coprolites.	5.5
7	Silty sandstone; same colors and lithology as unit 6; massive; forms a slope.	3.8
6	Sandstone; pale reddish brown (10 R 6/2); very fine to fine grained; subangular to subrounded; moderately sorted; calcareous; micaceous litharenite; laminar and small trough crossbeds.	1.0
5	Sandy siltstone; pale reddish brown (10 R 5/4); calcareous; micaceous; laminar; forms a slope.	0.9
4	Sandstone and conglomeratic sandstone; grayish red (10 R 4/2) and pale reddish brown (10 R 5/4); fine to very coarse grained; poorly sorted; subangular; micaceous litharenite; calcareous; conglomeratic portions have mud chips up to 1.5 cm in diameter; trough crossbedded; top of unit is ripple laminar; units 2, 3 and 4 form a prominent hogback.	2.5
3	Conglomerate; same colors and lithology as unit 4 conglomerate; also contains clasts of quartzite and limestone; trough crossbedded to laminar.	0.7
2	Conglomerate; matrix is yellowish gray (5 Y 7/2) to pale reddish brown (10 R 5/4), very fine to medium grained, subangular, micaceous litharenite; clasts are pale reddish brown (10 R 5/4) rounded pieces of Quartermaster siltstone and sandstone up to 8 cm in diameter; trough crossbedded.	2.0
disconformity		
Quartermaster Formation:		
1	Siltstone; moderate reddish brown (10 R 4/6); calcareous.	not measured