Principal Reference Section for the Santa Rosa Formation of Middle and Late Triassic Age, Guadalupe County, New Mexico

U.S. GEOLOGICAL SURVEY BULLETIN 1804

Principal Reference Section for the Santa Rosa Formation of Middle and Late Triassic Age, Guadalupe County, New Mexico

Edited by WARREN I. FINCH

This bulletin is published as chapters A through C.
These chapters are not available separately.

U.S. GEOLOGICAL SURVEY BULLETIN 1804

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, *Secretary*

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1988

For sale by the Branch of Distribution
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, CO 80225

Library of Congress Cataloging-in-Publication Data

Principal reference section for the Santa Rosa formation of middle and late Triassic age, Guadalupe County, New Mexico.

(U.S. Geological Survey bulletin ; 1804)
Bibliography: p.
Supt. of Docs. no.: I 19.3:1804A-C
1. Sandstone—New Mexico—Guadalupe County. 2. Geology, Stratigraphic—Triassic. 3. Santa Rosa Formation (N.M. and Tex.) I. Finch, Warren Irvin, 1924- II. Series.
QE75.B9 no. 1804 557.3 s [551.7'62'0978925] 87-600312
[QE471.15.S25]

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By WARREN I. FINCH

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By SCOTT C. REEVE

U.S. GEOLOGICAL SURVEY BULLETIN 1804

PRINCIPAL REFERENCE SECTION FOR THE SANTA ROSA FORMATION OF MIDDLE AND LATE TRIASSIC AGE, GUADALUPE COUNTY, NEW MEXICO

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Description of the Principal Reference Section for the Santa Rosa Formation

By Warren I. Finch

Abstract

Because the type section for the Santa Rosa Formation is incomplete and the upper contact of the section is not exposed, a principal reference section is herein established at a more accessible location. The principal reference section is exposed in the cuts of the railroad grade at the east edge of the town of Santa Rosa and continues along the banks of El Rito Creek and into nearby slopes. The principal reference section is 228 ft thick and consists of four informal members, in ascending order: lower sandstone member, middle sandstone member, mudstone member, and upper sandstone member. These members can be traced over a large part of Guadalupe County, and some can be recognized farther to the east and south. The basal contact with Permian rocks is erosional. Collapse of underlying Permian salt influenced the deposition of the three lower members. The upper contact with the Chinle Formation is marked by a slight erosional disconformity and an abrupt change in lithology. Each member has distinct sedimentary structures and lithologic characteristics.

INTRODUCTION

The Santa Rosa Formation of Middle and Late Triassic age is the basal formation of the Dockum Group in the central part of eastern New Mexico (table 1). The Santa Rosa Formation consists chiefly of thick sandstone beds that crop out over large areas in Guadalupe, San Miguel, Quay, and De Baca Counties, and small areas in some adjacent counties (fig. 1). The Santa Rosa extends eastward along the Canadian River into Oldham County, Tex., where in the Trujillo 7.5-minute quadrangle, reconnaissance mapping in 1972 revealed its probable pinchout (Finch and others, 1976). The recognition of the Santa Rosa along the Canadian River east of Tucumcari and its extension into Texas is controversial (Trauger and others, 1972) and is not shown on the geologic map of the Tucumcari Sheet (Barnes, 1983). More recent work by Lucas and others (1985) concludes that outcrops of sandstone of the Santa Rosa along the Canadian River are too limited to map at a scale of 1:500,000, and they have modified the map of Dane and Bachman (1965) to show only the Chinle Formation. Dane and Bachman (1965) were unable to map the Santa Rosa at 1:500,000 scale south of the 34th parallel because of poor, small outcrops and southward thinning and probable pinching out of the Santa Rosa. The name "Santa Rosa Sandstone" has been used for isolated outcrops of basal Dockum sandstone and conglomerate in Eddy County, N. Mex., by Hendrickson and Jones (1952), Vine (1963), and Barnes (1976), and in Mitchell County, Tex., by Roberts (1941). These extensions of the Santa Rosa beyond its clearly recognized outcrop area shown by Dane and Bachman (1965) in central eastern New Mexico are questionable. The nature of the sandstone and conglomerate beds at and near the base of Dockum appear to be analogous to the Shinarump Member of the Chinle Formation and other units at and near the base of the Upper Triassic section in the Colorado Plateau region. Early work on the Colorado Plateau led to the idea of a widespread occurrence of a single thin sheet of Shinarump over the entire Plateau and even beyond; whereas later detailed work showed that the Shinarump was not a single widespread unit but rather consisted of several distinct stratigraphic units each having their own separate source areas and directions of sediment transport (Stewart, 1957; Finch, 1959; Stewart and others, 1972; McGowen and others, 1979, fig. 4). My studies of sedimentary structures and pebble distribution and my reconnaissance mapping indicate that the Santa Rosa ought to be restricted to the vicinity of the outcrop pattern shown by Dane and Bachman (1965).

When the "Santa Rosa Sandstone" was first introduced by Rich (1921) and described by Darton (1922), no type section was established, a common practice in early days. In 1971, I measured a section in the Santa Rosa area with the intention of establishing a type section. Later in 1972, I discovered that Vincent C. Kelley, University of New Mexico, had at about the same time measured a section nearby, which was established as the type section (Kelley, 1972). Examination of his section revealed that the mudstone member, which is intermittent, was absent, and that the top of the section was not exposed. Therefore, the purpose of this report is to designate a principal reference section that is complete, well exposed between the Permian Artesia Group and the Triassic Chinle Formation, and quite accessible.

Table 1. Stratigraphy of the Dockum Group in the Santa Rosa area, New Mexico.

Age	Group	Formation	Member
Late Triassic	Dockum Group	Redonda Formation	
		Chinle Formation	Upper shale member
			Middle sandstone member[1]
			Lower shale member
		Santa Rosa Formation	Upper sandstone member
			Mudstone member
			Middle sandstone member
Middle Triassic			Lower sandstone member

[1]Cuervo Sandstone Member of Kelley (1972)

The results of the studies reported in this bulletin are outgrowths of a broader study of the uranium potential in Triassic rocks of the southern High Plains, mainly in eastern New Mexico and West Texas, made by J. C. Wright 1967–1968 and continued by me 1968–1972. Robert Lupe made special studies of the sedimentary environment of the principal section in 1971, and Sidney R. Ash studied the plant fossils in 1971; the results of these studies are given in chapters B and C of this bulletin, respectively. A study was made of the paleomagnetic character of rocks in the section by Scott C. Reeve (1975); a brief summary of that study as it relates to the lower contact of the Santa Rosa with Permian rocks is presented at the end of this chapter. Measurements of length, distance, thickness, elevation, and size are given in each chapter in either the English or metric system, whichever was used in the original measurement.

HISTORICAL REVIEW OF NOMENCLATURE

The original reference to the "Santa Rosa Sandstone" was in 1919 by Dorsey Hager and A. E. Robitaille (1919), who list it in their correlation table for a report on oil possibilities in eastern New Mexico. The "Santa Rosa Sandstone" was described by Rich (1921) as "a very definite unit exposed at Santa Rosa" and elsewhere along the Pecos River. The name "Santa Rosa Sandstone" was adopted by the U.S. Geological Survey for N. H. Darton's report of July, 1919, but his report was not published until 1922. Darton (1922) defined the "Santa Rosa Sandstone" as resistant massive sandstone near the bottom of the Dockum Group that crops out prominently in mesas of Guadalupe County and along the Pecos River at Santa Rosa. He stated that "This sandstone appears to occur at about the horizon of the Shinarump conglomerate, but no definite correlation is possible . . .".

The "Santa Rosa Sandstone" was mapped in central eastern New Mexico by later workers, such as Gorman and Robeck (1946), Lang (1947), Bachman (1953), Wanek (1962), and Johnson (1969), but none of these authors established a type locality. Vincent C. Kelley, University of New Mexico, in connection with mapping the Fort Sumner Sheet, set up a type section located along the steep walls of the Pecos River in SW¼ sec. 35, T. 9 N., R. 21 E., about a mile north of downtown Santa Rosa (fig. 2; Kelley, 1972, p. 21–22). Because a type section has been established, the section described herein must be referred to as the principal reference section for the "Santa Rosa Sandstone."

Lucas and others (1985) renamed the "Santa Rosa Sandstone" the Santa Rosa Formation because it contains significant amounts of conglomerate and mudstone. Even though the Santa Rosa is most distinctive as a continuous sandstone unit, this renaming as Santa Rosa Formation seems appropriate and is adopted for this bulletin. Future work outside the present known distribution of the Santa Rosa may reveal time correlative deposits whose lithology is not sandstone. This would allow the extension of the Santa Rosa Formation nomenclature throughout the Dockum Basin.

PRINCIPAL REFERENCE SECTION OF SANTA ROSA FORMATION

The principal reference section of the Santa Rosa Formation is adjacent to and northeast of the city of Santa Rosa. The section was measured along an

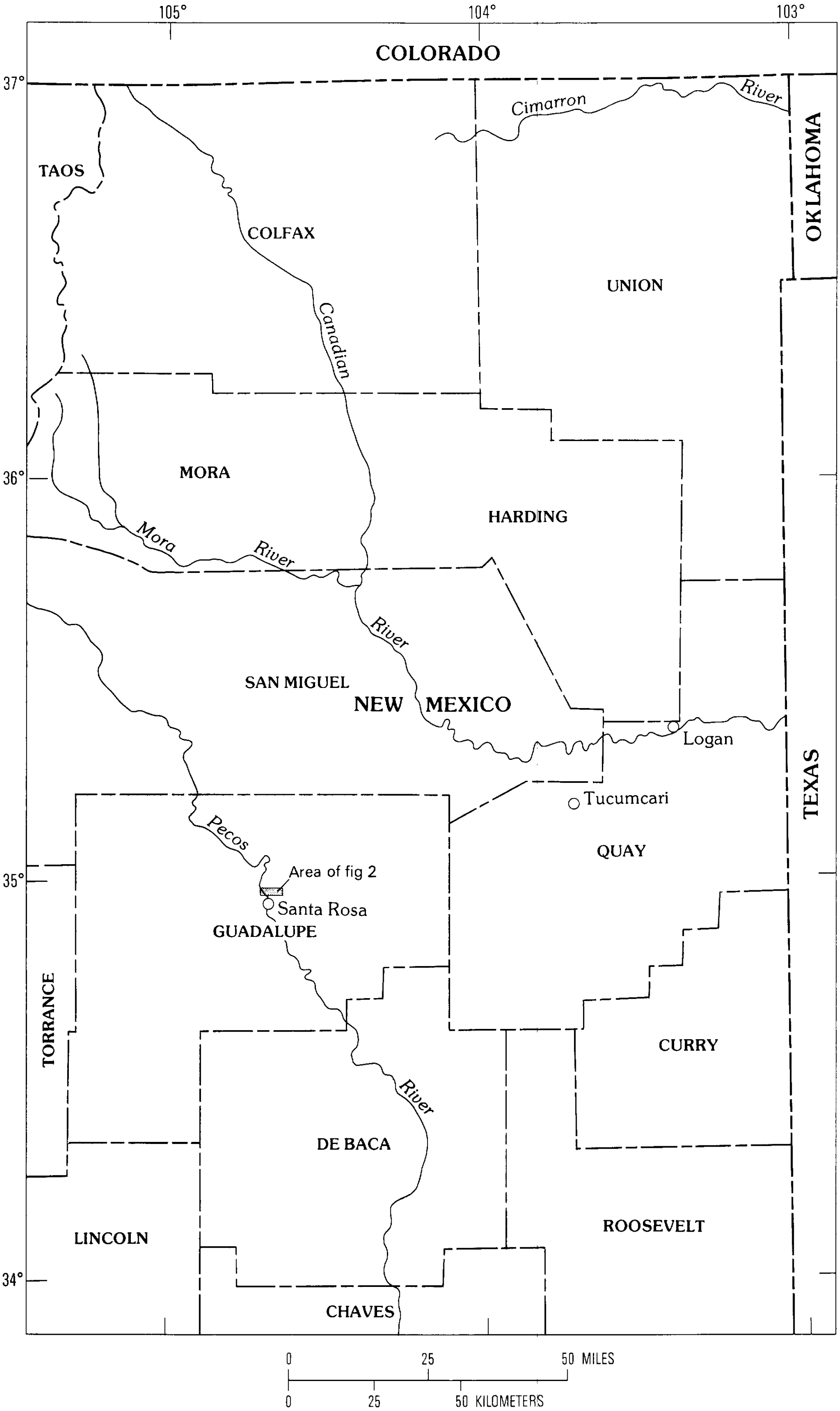

Figure 1. Map of northeastern New Mexico showing the location of the Santa Rosa area.

approximately 1-mi-long, east-trending traverse through the railroad cuts of the Chicago Rock Island and Pacific-Southern Pacific Railroad adjacent to the banks of El Rito Creek and onto the gentle slopes north of the westernmost lake of Tres Lagunas in N½ sec. 1, T. 8 N., R. 21 E., and SE¼ sec. 36, T. 9 N., R. 22 E. (fig. 2). This site was chosen because of its accessibility, nearly perfect exposures, well-defined members, and exposed basal and top contacts of the Santa Rosa with the Permian Artesia Group and the Chinle Formation, respectively. No other complete, well-exposed single exposure of the Santa Rosa is known to me. Early workers such as Dorsey Hager, A. E. Robitaille, J. L. Rich, and N. H. Darton undoubtedly used the railroad as their chief means of travel to Santa Rosa. The Santa Rosa depot is only a mile from the base of the principal reference section, and these early workers very likely examined the section. One can drive to within a hundred yards of the base of the section.

The regional dip of the rocks in the area of the section is about one degree eastward. This dip is interrupted locally by gentle to moderately steep folds a hundred feet to as much as a half mile across. These folds represent deformation into sinkholes formed by the dissolution of salts in the underlying Permian rocks. The dips of the lower members of the Santa Rosa and exposed Permian beds are more affected by this dissolution than are the uppermost member of the Santa Rosa and the overlying Chinle Formation. Thinning and thickening of the lower members of the Santa Rosa are evident depositional responses to the dissolution of salt. The line of the measured section crosses one fold at the place where the mudstone member is exposed. Kelley (1972) mapped a fault through the section at this point but I observed no offset in measuring the section. Other folds can be examined along the railroad cut west of the base of the section. Large sinks and depressions occur in the region surrounding the area of the section.

Principal reference section of the Santa Rosa Formation, Dockum Group of Middle and Late Triassic age

[The section was measured in the cuts of the Chicago Rock Island and Pacific-Southern Pacific Railroad, along the north banks of El Rito Creek, and on the northern slopes of the westernmost lake of Tres Lagunas in the Santa Rosa 7.5-minute quadrangle (figs. 1 and 2). Approximate altitude of base of section is 4,630 ft. This section was measured by W. I. Finch, October 26–27, 1971]

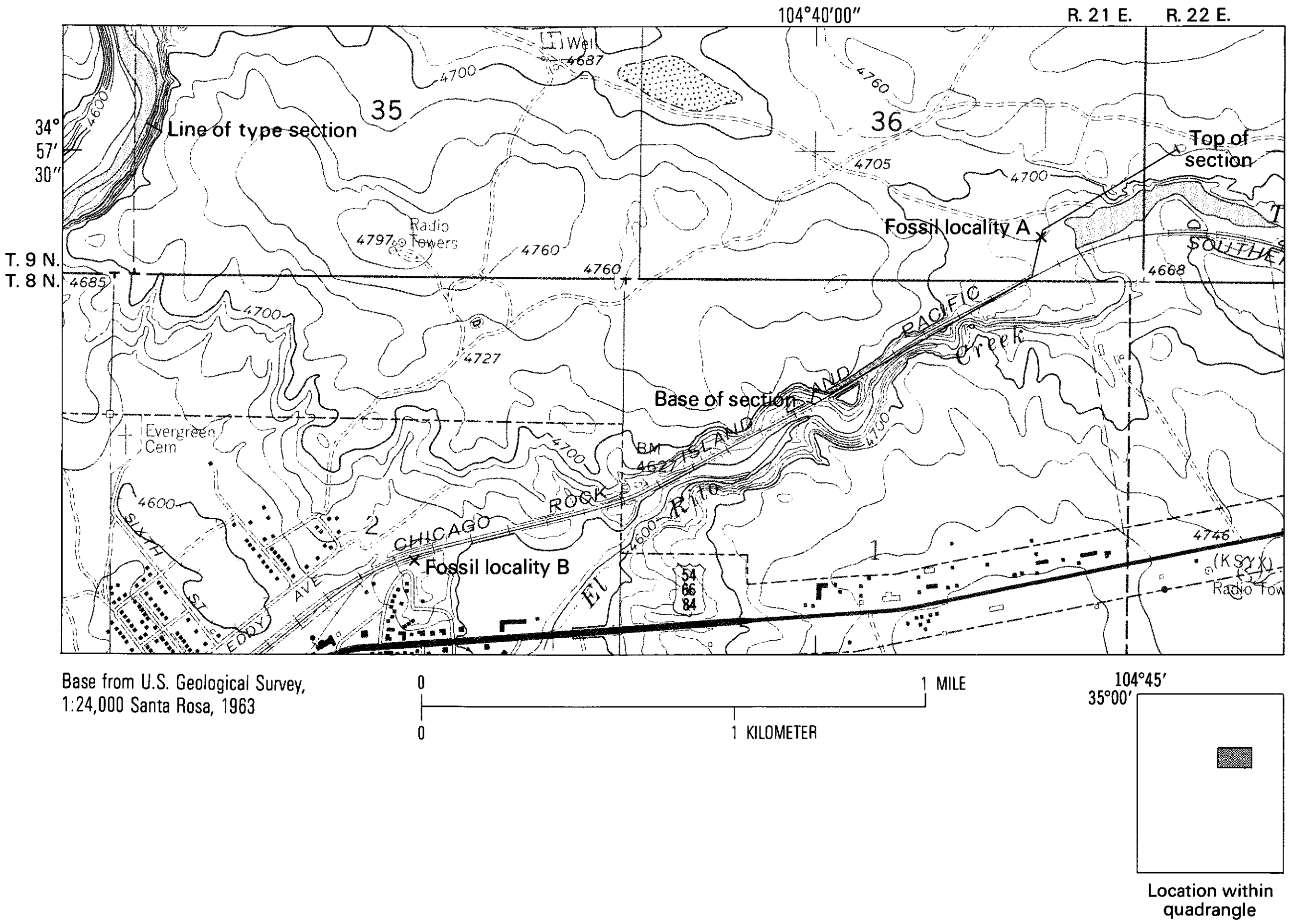

Figure 2. Map showing the location of the line of measurement of the principal reference section of the Santa Rosa Formation, the type section of Kelley (1972), and fossil plant localities in the Santa Rosa 7.5-minute topographic quadrangle, Guadalupe County, N. Mex.

Thickness Feet

Dockum Group (Triassic).

Chinle Formation (lower shale member, incomplete):

8. Siltstone, pale-red (5*R* 6/2), weathers light-red, sparse very fine grained quartz, calcareous, micaceous (colorless) along bedding planes; hard; thin wavy laminations due to pervasive ripple marks, which cause irregularly lined surface; most forms weak ledge; interfingers with upper 5 ft of unit 7 .... 3.0
7. Claystone and siltstone, intermixed, grayish-red (10*R* 4/2), calcareous, micaceous (colorless), thinly laminated to indistinctly bedded; soft, shaly; most forms a covered slope 16.0

Total Chinle Formation (incomplete) 19.0

Santa Rosa Formation (member terminology is that of Gorman and Robeck, 1946, except their shale member is here designated the mudstone member):

Upper sandstone member:

6. Sandstone, brown and yellowish-brown (due to limonite stain), speckled white and pale-gray, most weathers light-brown, minor pale-red (5*R* 6/2); very fine grained clear quartz, silty and clayey, micaceous (muscovite and biotite) along bedding planes, calcareous; shaly zone from 10 to 20 ft below top; upper part of zone is grayish- and yellowish-green claystone; zone extends 100 yd to the north where it lenses out; strongly crossbedded in upper 5 ft of unit, which is well-displayed on dip slope between top of unit and first outcrop of unit 7 about 700 ft to east; lower part thin-bedded, ripple-marked, and flat-bedded; unit forms two 5 ft ledges separated by steep slope; large rounded to angular blocks of lower ledge 3–40 ft across lie on slopes of unit 5 (fig. 8).

Total upper sandstone member 30.0

Mudstone member:

5. Claystone, grayish-red (10*R* 4/2), calcareous, soft, weakly bedded; forms covered slope shore of lake; base marked by irregular 6- to 12-in.-thick brown-weathering siltstone bed that dips about 25° eastward 45.0
4. Claystone, light-olive-gray (5*Y* 6/1) to yellowish-gray (5*Y* 7/2), calcareous; contains carbonized leaf and twig fossils that are locally abundant; soft, shaly; contains sporadic, irregular, thin (1- to 6-in.-thick) brown siltstone layers that mark edges and bottoms of local channel-fills within unit; basal part lies on undulatory beds of unit 3; unit interpreted to be lacustrine or backswamp fillings of depressions formed by dissolution of Permian salts at depth; 12 ft well exposed in canal and 8 ft exposed at railroad cut (fig. 7), ground between is disturbed by fill and covered partly by colluvium .... ≈25.0

Total mudstone member (unit variable in thickness regionally and absent in places) .... ≈70.0

Thickness Feet

Middle sandstone member:

3. Sandstone, yellowish-brown, speckled white and light-gray, weathers light-brown to brown, black desert varnish on weathered surfaces; well-sorted beds of medium- to coarse-grained clear quartz; upper and basal beds are silty to fine grained, contain inconspicuous dark grains, calcareous, white interstitial clay common, hard to friable; iron-oxide-replaced and flattened fossil wood pieces and impressions on bedding planes throughout; beds tend to be thick (3–15 ft), crossbedded, undulatory (undulations caused by local subsidence), and continuous (extending for hundreds of feet); 5–10 ft above base is continuous zone 5–10 ft thick of quartz-chert-limestone pebble conglomerate and greenish-gray (commonly pebbly) claystone; zone interfingers with adjacent sandstone beds; zone contains carbonized and limonitized wood fragments and logs; greenish-gray claystone and mudstone splits common in upper 20 ft; unit forms nearly continuous ledge; lies with erosional unconformity on unit 2; unit is distinctive and recognizable throughout Guadalupe, San Miguel, and Quay Counties, N. Mex.

Total middle sandstone member ≈60.0

Lower sandstone member:

2. Sandstone, pale-red (5*R* 6/2), speckled white, weathers brown to reddish brown; very fine grained to fine-grained brown-stained and clear quartz, interstitial white clay, calcareous, dirty looking, dense, hard; few thin (1-ft-thick) limestone-granule (1/12 to 1/6 in. diameter) conglomerate beds scattered throughout; massive, flat-bedded and crossbedded, one festoon about 50 ft across noted near base; beds range from about 2 in. to 8 ft thick, evenly thick to lenticular, 3/4 in.-thick shaly breaks common; weathers as steep slope, partly covered, some 1- to 3-ft-thick rounded ledges; slight erosional unconformity at base; bedding more or less parallel to that of underlying Permian rocks.

Total lower sandstone member . ≈68.0

Total Santa Rosa Formation ... ≈228.0

Total measured Dockum Group ≈247.0

Artesia Group (Permian).

Queen and Grayburg Formations, undivided:

1. Siltstone, moderate-reddish-orange (10*R* 6/6), calcareous, massive, lamination suggests ripple marks; soft zone a few inches thick about 5 ft below top; upper surface modified by dissolution and deposition of carbonate and is grayish orange (10 *YR* 7/4); forms smooth, irregular, and indurated ledge; measured and described within 150 ft of east end of railroad fill where thickness of unit 2 measured; Permian exposed south of tracks

	Thickness Feet
Artesia Group (Permian)—Continued	
Queen and Grayburg Formations, undivided—Continued	
is about 25 ft thick where the beds roll upward to form small anticlinal structure; here individual beds are about 5 ft thick, separated by shaly breaks, and show flat parallel bedding	8.0+
Total measured Queen and Grayburg Formations (incomplete)	8.0+

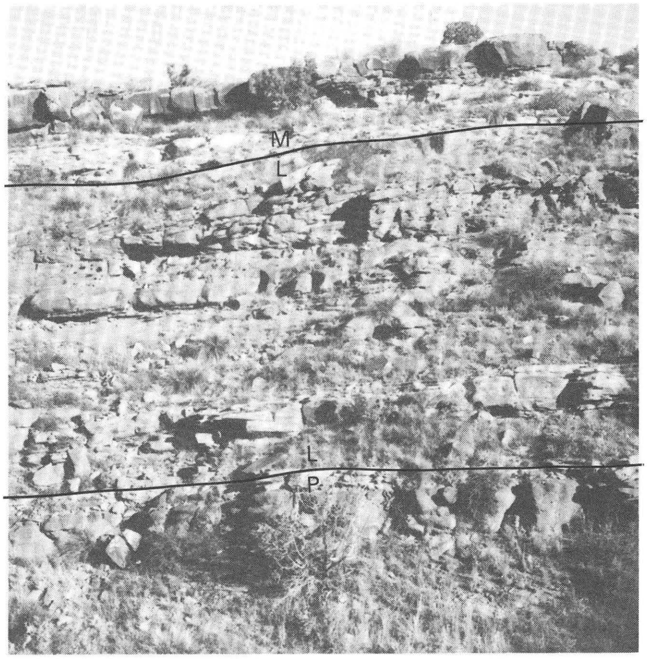

Figure 3. Photograph of the outcrop of the lower part of the principal reference section of the Santa Rosa Formation showing the weathering characteristics of measured lower sandstone member (L) and its contacts with Permian rocks (P) and the middle sandstone member (M).

In western Guadalupe County, the Santa Rosa Formation is divisible into four informal members: lower sandstone member, middle sandstone member, mudstone member (locally absent), and upper sandstone member (Gorman and Robeck, 1946). The name *shale* member of Gorman and Robeck is herein changed to *mudstone* member because the rocks lack fissility. All of the members are noticeably calcareous. These members were mapped in north-central Guadalupe County adjacent to the north edge of the Santa Rosa 7.5-minute quadrangle by Gorman and Robeck (1946). In the vicinity of the Guadalupe (Pastura) copper-mining district about 15 mi southwest of Santa Rosa, the three sandstone members are well developed, but the mudstone member is present only locally. The middle sandstone member appears to be the most continuous and prominent member and crops out over wide areas. It extends northward into San Miguel County and is exposed where State Highway 65 crosses the Canadian River south of Sabinosa. Eastward in Quay County, a sandstone that has lithology and bedding characteristics identical to those of the middle sandstone member at Santa Rosa crops out where State Highway 39 crosses the Canadian River at Logan (fig. 1).

Lower Sandstone Member

The lower sandstone member consists of a series of thin to thick beds of sandstone separated by paper-thin to a-few-inch-thick shale partings (fig. 3). Thicker beds form poorly developed to well-developed rounded boulder-like ledges (fig. 4). Gorman and Robeck (1946) noted several feet of "chocolate-red" shale in the upper part of this member in the Esterito Dome area about 10 mi to the north, and C. B. Read and R. D. Sample (written commun., 1943) noted sandy claystone in the Pastura area about 15 mi to the southwest. A few thin limestone-pebble conglomerate layers are scattered throughout the member. The sandstone beds are characteristically red and speckled white on fresh surfaces and dark-reddish and purplish shades of brown on weathered surfaces. The sandstone ranges from very fine grained to fine grained in individual beds. Iron-stained to clear quartz is the chief component; interstitial white clay gives much of the sandstone a salt-and-pepper appearance. The sandstone contains enough dark grains to give it a dirty appearance. It is generally well cemented with calcium carbonate and

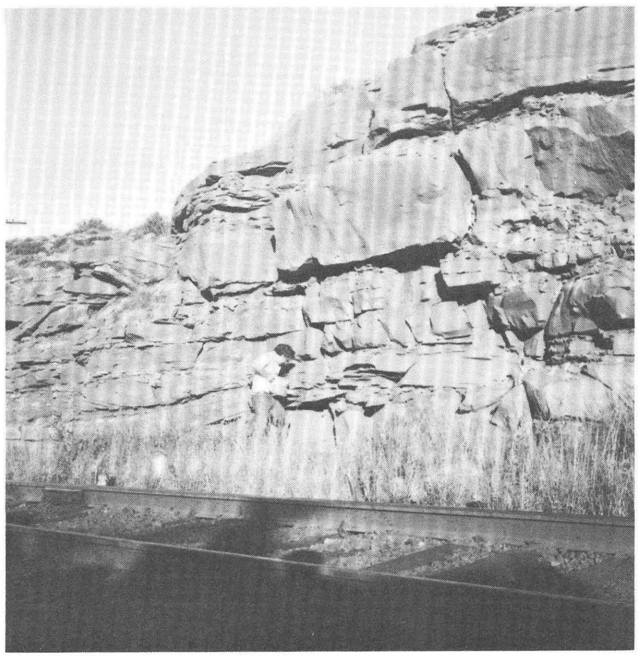

Figure 4. Photograph of lower sandstone member in railroad cut. Sample for paleomagnetic study being taken by Scott C. Reeve.

in most places is hard and brittle. Gorman and Robeck (1946) described the sandstone as friable in the area to the north.

Fossils are very rare in the member. Gorman and Robeck (1946) report bone fragments northwest of Santa Rosa. Recently, Lucas and Morales (1985) described an incomplete amphibian skull of Middle Triassic (Anisian) age collected from the lower sandstone member at a locality southeast of Dilia, Guadalupe County, in the area Gorman and Robeck worked. The skull was collected from conglomerate, mostly of sandstone and limestone fragments in a matrix of medium- to coarse-grained quartzose sand. The possibility of the skull's having been reworked from Middle Triassic beds in Late Triassic time is not addressed by Lucas and Morales, but its character does not appear to be that of a reworked fossil. More recent work has disclosed more Middle Triassic amphibians (S.G. Lucas, written commun., 1986).

The lower member is 68 ft thick in the principal reference section. Gorman and Robeck (1946) report as much as 112 ft and found the member to be extremely variable in thickness and locally absent. Variations in thickness reflect subsidence due to dissolution of underlying Permian salt during sedimentation. The lower member lies with local erosional unconformity on the clastic beds of Permian age.

Figure 5. Photograph of middle sandstone member showing angular blocks of mudstone, one on left (arrow) is 18 in. long.

Middle Sandstone Member

The middle sandstone member is characteristically yellowish-brown, speckled white to light gray on fresh surfaces, and weathers light brown. Thick, continuous beds of sandstone consist of well-sorted, generally medium to coarse quartz grains and of scattered quartz pebbles averaging ½ in. in diameter, and iron-stained fossil-wood compressions. Angular blocks of mudstone were observed within the sandstone in the railroad cut (fig. 5). The sandstone beds are platy to massively bedded and weather into "fretted" blocks. A thin zone of quartz-chert-limestone pebble conglomerate and greenish-gray claystone occurs at or near the base of the member in most places in Guadalupe County (fig. 6). This zone locally contains fossil wood fragments, some of which contain uranium (Finch, 1972). The red-bed copper deposit at Pastura is in this member. The thickness of this member is about 60 ft in the measured section and varies regionally, but not as much as the other members; it ranges from about 15 to 135 ft thick (Gorman and Robeck, 1946). It lies with erosional unconformity on the lower sandstone member and locally on the Lower Permian San Andres Limestone.

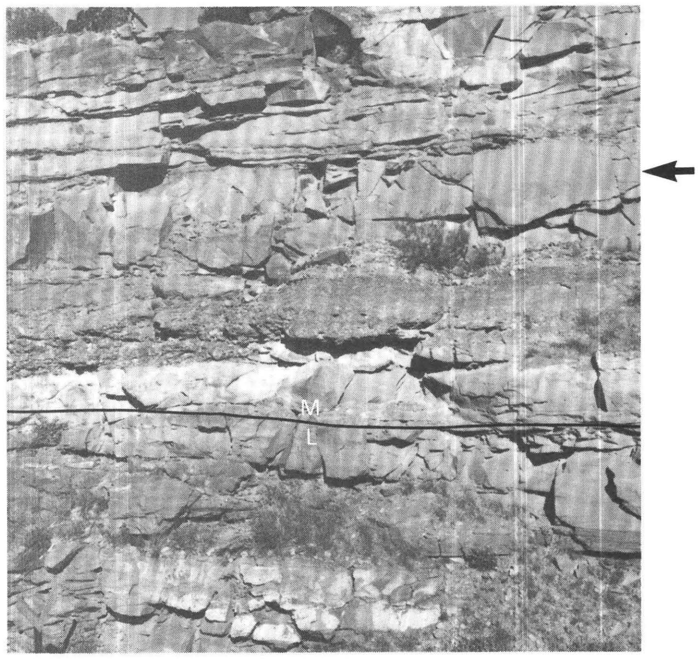

Figure 6. Photograph of the conglomerate zone (arrow) near the base of the middle sandstone member (M) and its contact with the lower sandstone member (L).

Mudstone Member

The mudstone member is red to gray, more commonly gray, soft claystone, locally silty, commonly arenaceous in basal sections, and locally leaf bearing in gray parts (see chapter C). The member is discontinuous; for example, it is absent in the type section of Kelly (1972) about 1 mi to the northwest. The mudstone fills depressions in undulatory beds of the underlying middle sandstone member (fig. 7). Its thickness is extremely variable, ranging from 0 to 70 ft. The upper contact is planar with the overlying upper sandstone member.

Upper Sandstone Member

The upper sandstone member consists of a prominent ledge of sandstone and locally thin claystone lenses and conglomerate channel fillings. The sandstone is generally brown, locally gray, micaceous, calcareous, very fine grained to fine-grained quartz, and commonly silty and clayey. It is platy to massive, and weathered surfaces are rounded and commonly have ribbed cupholes. The lower part is ripple-laminated and the upper part is strongly crossbedded. Crossbeds dip 10°–20° N. 45°–80° E. in the line of section. Characteristically, the sandstone weathers into large blocks (fig. 8). The claystone lenses are gray to green. Thin limestone-pebble conglomerate beds occur at and near the base of the member north of the principal reference section (Gorman and Robeck, 1946). The member is 30 ft thick in the principal reference section and regionally is variable, ranging from 11 to 115 ft (Gorman and Robeck, 1946). The upper contact with the overlying Chinle is disconformable. The red claystone and siltstone of the Chinle contrasts sharply with the brown sandstone of this member. Only 3 ft of the Chinle is exposed here, but 75–100 ft of dominantly claystone and siltstone and some thin sandstone and limestone-pebble conglomerate beds of the Chinle are poorly exposed in the valley to the southeast towards Sunshine Mesa (see Sunshine Mesa measured section in Finch and Wright, 1983).

Figure 7. Photograph showing nature of the basal contact of the mudstone member (MU) with the underlying middle sandstone member (M) along the line of measured section.

PALEOMAGNETIC CHARACTER OF THE SANTA ROSA-PERMIAN CONTACT
By Scott C. Reeve[1]

Paleomagnetic declinations, inclinations, and intensities across the Permian-Late Triassic unconformity in the principal reference section of the Santa Rosa were measured by Scott C. Reeve (1975) (figs. 1, 4). Above the unconformity is a reversed-normal-reversed-normal polarity sequence in the basal 9 m of the Santa Rosa Formation (fig. 9). The numerous polarity changes in the rapidly deposited braided stream bedforms suggest variations in secondary magnetization relative to varying permeability and grain composition. Magnetization directions, even though scattered, are consistent with the Triassic field (Pechersky and Khramov, 1973). The upper 2 m of the Queen and Grayburg Formations, undivided, are magnetized normally. These Permian rocks either record a period of normal magnetic field directions during Guadalupian time or were almost totally remagnetized to a depth of at least 2 m below the unconformity, most likely before deposition of the lower sandstone member.

Magnetic remanence in the Middle Triassic lower sandstone member is carried by detrital specular hematite and martized magnetite and by red hematite pigment. The

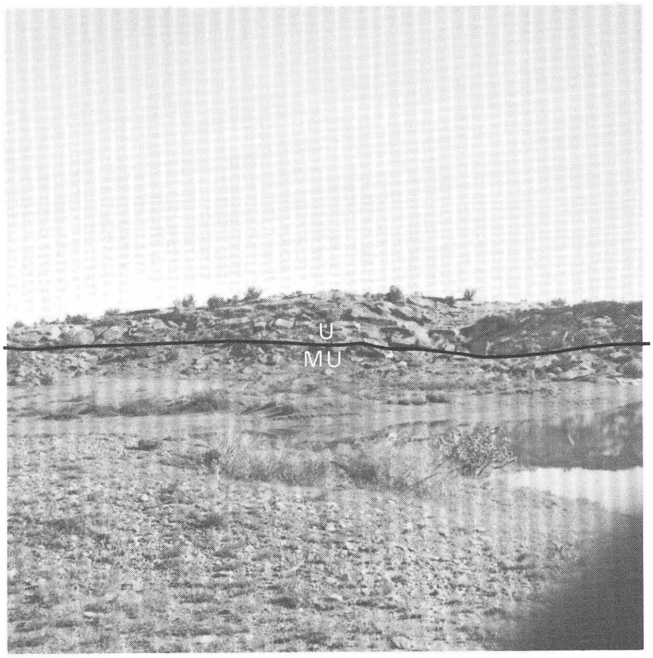

Figure 8. Photograph of the upper sandstone member (U) weathered into blocks as much as 25 ft across and the upper part of the mudstone member (MU) near the edge of the westernmost lake of Tres Laguna.

agreement in polarity of a portion of the detrital fraction with the thermally stable fraction of the pigment is consistent with a nearly contemporaneous acquisition of the magnetism. Unfortunately, the agreement is also due in

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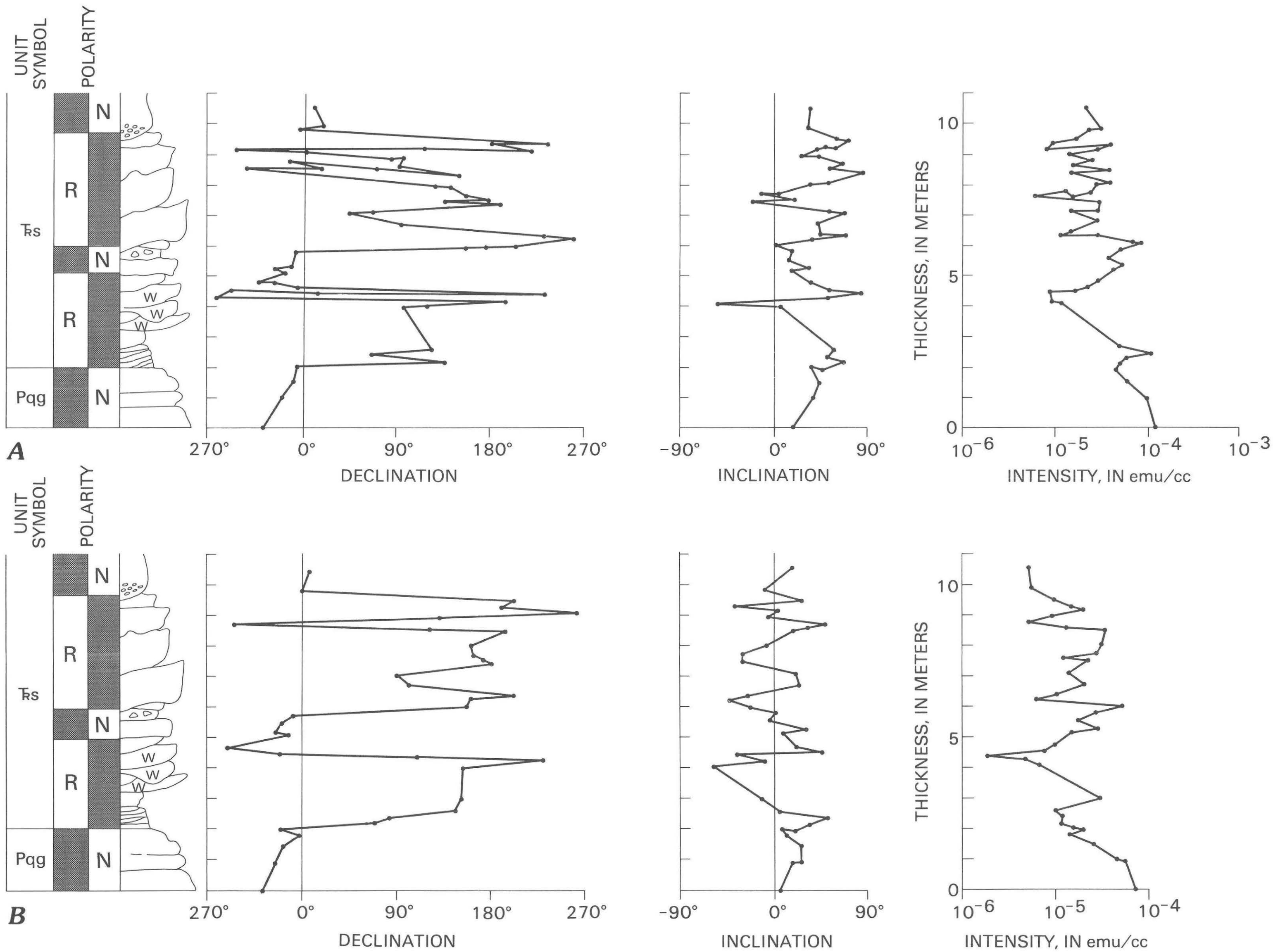

Figure 9. Paleomagnetic declination, inclination, and intensity of the basal 9 m of the lower sandstone member (₨s) and the upper 2 m of the Queen and Grayburg Formations, undivided (Pqg) (modified from Reeve, 1975). *A*, natural remanent magnetism (NRM): *B*, magnetism after demagnetism at 621°–635°C. Beds marked with W are leached of all or portions of their red hematite pigment. N, normal polarity; R, reversed polarity.

part to further oxidation of the original magnetite portion of the detrital fraction during the pigment's growth and could have occurred long after deposition. Attempts at chemical demagnetization were only partly successful. These results suggest that the detrital fraction, in addition to carrying Triassic field directions, also carries a steeply dipping normal-field, chemical-remanent magnetization component of Cretaceous or Holocene age in some grains and some multidomain viscous magnetizations as well.

REFERENCES CITED

Bachman, G.O., 1953, Geology of a portion of northwestern Mora County, New Mexico: U.S. Geological Survey Oil and Gas Investigations Map OM-137, scale about 1 in. to 1¼ mi.

Barnes, V.E., project director, 1976, Geologic Atlas of Texas, Hobbs Sheet: The University of Texas at Austin, Bureau of Economic Geology Map, scale 1:250,000.

Barnes, V.E., project director, 1983, Geologic Atlas of Texas, Tucumcari Sheet: The University of Texas at Austin, Bureau of Economic Geology Map, scale 1:250,000.

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

Darton, N.H., 1922, Geologic structure of parts of New Mexico: U.S. Geological Survey Bulletin 726-E, p. 173-275.

Finch, W.I., 1959, Geology of uranium deposits in Triassic rocks of the Colorado Plateau region: U.S. Geological Survey Bulletin 1074-D, p.125-164.

Finch, W.I., 1972, Uranium in eastern New Mexico, *in* Kelley, V.C., and Trauger, F.D., eds., Guidebook of east-central New Mexico: New Mexico Geological Society Guidebook, Twenty-third Field Conference, East-central New Mexico, September 28-30, 1972, p. 172-175.

Finch, W.I., and Wright, J.C., 1983, Measured stratigraphic sections of uranium-bearing Upper Triassic rocks of the Dockum Basin, eastern New Mexico, West Texas, and the Oklahoma Panhandle, with brief discussion of stratigraphic problems: U.S. Geological Survey Open-File Report 83-701, 118 p.

Finch, W.I., Wright, J.C., and Davis, B.O., 1976, Unevaluated preliminary geologic cross section of uranium-bearing Upper Triassic rocks extending from Ute Reservoir, New Mexico to Palo Duro Canyon, Texas: U.S. Geological Survey Open-File Report 76-205, 1 sheet.

Gorman, J.M., and Robeck, R.C., 1946, Geology and asphalt deposits of north-central Guadalupe County, New Mexico: U.S. Geological Survey Oil and Gas Investigations Preliminary Map 44, scale approximately 1 inch=1 mile.

Hager, Dorsey, and Robitaille, A.E., 1919, Geological report on oil possibilities in eastern New Mexico: 15 p. [unpublished pamphlet; copy available in U.S. Geological Survey Library, Reston, Va.]

Hendrickson, G.E., and Jones, R.S., 1952, Geology and groundwater resources of Eddy County, New Mexico: New Mexico Bureau of Mines and Mineral Resources Ground-Water Report 3, 169 p.

Johnson, R.B., 1969, Geologic map of the Villanueva quadrangle, San Miguel County, New Mexico: U.S. Geological Survey Geologic Quadrangle Map GQ-869, scale 1:24,000.

Kelley, V.C., 1972, Geology of the Fort Sumner sheet, New Mexico: New Mexico State Bureau of Mines and Mineral Resources Bulletin 98, 55 p.

Lang, W.T.B., 1947, Triassic deposits of Pecos Valley, southeastern New Mexico: American Association of Petroleum Geologists Bulletin, v. 31, no. 9, p. 1673-1674.

Lucas, S.G., Hunt, A.P., and Morales, Michael, 1985, Stratigraphic nomenclature and correlation of Triassic rocks of east-central New Mexico: A preliminary report, *in* Lucas, S.G., ed., Santa Rosa-Tucumcari region: New Mexico Geological Society Guidebook, Thirty-sixth Annual Field Conference, September 26-28, 1985, p. 171-184.

Lucas, S.G., and Morales, Michael, 1985, Middle Triassic amphibian from basal Santa Rosa Formation, east-central New Mexico, *in* Lucas, S.G., ed., Santa Rosa-Tucumcari region: New Mexico Geological Society Guidebook, Thirty-sixth Annual Field Conference, September 26-28, 1985, p. 56-58.

McGowen, J.H., Granata, G.E., and Seri, S.J., 1979, Depositional framework of the lower Dockum Group (Triassic), Texas panhandle: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations no. 97-1979, 60 p.

Pechersky, D.M., and Khramov, A.N., 1973, Mesozoic paleomagnetic scale of the USSR: Nature, v. 244, p. 499-500.

Reeve, S.C., 1975, Magnetization of the basal (Upper Triassic) Santa Rosa Sandstone, and underlying Permian Greyburg-Queen Formation, Santa Rosa, N.M., *in* Paleomagnetic studies of sedimentary rocks of Cambrian and Triassic age: The University of Texas at Dallas, unpublished Ph.D. dissertation, p. 130-162.

Rich, J.L., 1921, The stratigraphy of eastern New Mexico—a correction: American Journal of Science, 5th series, v. 2, p. 295-298.

Roberts, M.E., 1941, Measurement of composite section, *in* Scott, Gayle, and others, Spring field trip, Fort Worth to Midland, Texas, on Highway 80 along the T & P, May 10-11, 1941: [Midland, Texas] West Texas Geological Society [Guidebook], p. 57-58.

Stewart, J.H., 1957, Proposed nomenclature of part of Upper Triassic strata in southeastern Utah: American Association of Petroleum Geologists Bulletin, v. 41, no. 3, p. 441-465.

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

Trauger, F.D., Mankin, C.J., and Brand, J.P., 1972, Road log of Tucumari, Mosquero, and San Jon country, *in* Kelley, V.C., and Trauger, F.D., eds., Guidebook of east-central New Mexico: New Mexico Geological Society Guidebook, Twenty-third Field Conference, East-central New Mexico, September 28-30, 1972, p. 12-45.

Vine, J.D., 1963, Surface geology of the Nash Draw quadrangle, Eddy County, New Mexico: U.S. Geological Survey Bulletin 1141-B, 46 p.

Wanek, A.A., 1962, Reconnaissance geologic map of parts of Harding, San Miguel, and Mora Counties, New Mexico: U.S. Geological Survey Oil and Gas Investigations Map OM-208, scale 1:96,000.

Chapter B

Interpretive Depositional History of the Santa Rosa Formation at the Principal Reference Section

By ROBERT LUPE

U.S. GEOLOGICAL SURVEY BULLETIN 1804

PRINCIPAL REFERENCE SECTION FOR THE SANTA ROSA FORMATION OF MIDDLE AND LATE TRIASSIC AGE, GUADALUPE COUNTY, NEW MEXICO

CONTENTS

FIGURES

Interpretive Depositional History of the Santa Rosa Formation at the Principal Reference Section

By Robert Lupe[1]

Abstract

The Santa Rosa Formation at the principal reference section consists of continental sediments, primarily sandstone and less claystone, siltstone, and limestone-clast conglomerate. The formation is divided into lower sandstone, middle sandstone, mudstone, and upper sandstone members. The three sandstone members are interpreted to have been deposited as alluvial sheets by braided streams, and the mudstone member was deposited as discontinuous strata in small lakes.

The lower sandstone member is marked at the base by a high-energy depositional pulse that deposited a one-half- to one-meter-thick lag concentrate of Permian intraclasts and interbeds of trough-crossbedded, fine-grained sandstone. Lower energy fluvial channel-fills interpreted to have been deposited by a braided-stream system make up the rest of the unit.

The base of the middle sandstone member is marked by an extensive lag conglomerate of resistate clasts. Structureless, flat beds of sandstone deposited during a high-flow regime immediately overlie the conglomerate. This episode of deposition waned quickly, and the upper part of the middle sandstone member consists of planar crossbeds interpreted to be deposits of transverse bars and related low-flow sedimentary structures. This unit grades upward into the overlying mudstone member.

The mudstone member consists of claystone and minor sandstone and is interpreted to have been deposited in lakes. Intermittent desiccation is indicated by pedogenic calcrete and mudcracked surfaces. The mudstone member was apparently coursed rarely by streams that left narrow channel-fills of lag gravel, claystone, and sandstone. The claystone beds contain well-preserved organic fossil plant remains. Near the top, the mudstone member contains nonclastic limestone beds that are burrowed and display probable algal structures.

The upper sandstone member is lithologically and structurally similar to the lower and middle sandstone members and was deposited in similar environments.

Paleotransport trends within each member indicate changes in basin attitude and probable changes in sediment source area. Flow changed from dominantly northward during deposition of the lower sandstone member to southward during deposition of the middle sandstone member and back to northward during deposition of the upper sandstone member.

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INTRODUCTION

The Triassic Santa Rosa Formation is interpreted to have been deposited by braided streams and in lakes or on floodplains in the area of the principal reference section. The rocks of each member of the formation differ in their history of deposition as indicated by sedimentary structures and composition; therefore, subdivision of the formation into members is genetic as well as descriptive.

Thanks are expressed to J. A. McGowen, University of Texas at Austin, for his field introduction to fluvial depositional systems and to Carolyn Lupe for assistance in the field. Preliminary results of this study were previously reported orally (Lupe, 1977).

ENVIRONMENTS OF DEPOSITION

All members of the Santa Rosa Formation except the mudstone member were deposited as alluvial sheets by braided streams. In general, the deposits of these braided-stream systems have the following properties. The depositional packages (rock or sediment bodies that were laid down during the same depositional episode and are bounded by surfaces of erosion or nondeposition) are lenticular in cross section and vary little in grain size. They have erosional bases and the basal deposits contain intraclasts. Furthermore, the variety of sedimentary structures is small, and these structures reflect waning flow.

The basal beds of the sandstone members are characterized by flat beds and trough crossbeds as shown for the lower sandstone member in figure 1*A*. On the basis of criteria given by Harms and others (1975), these bedding features are interpreted as having formed during high flow. The upper parts of the sandstone members are characterized by current ripples and by tabular foreset beds as typified in the middle sandstone member (fig. 1*B*). On the basis of criteria given by Smith (1970), these features are interpreted as migrating transverse bars. They are similar to those in the Upper Triassic Trujillo

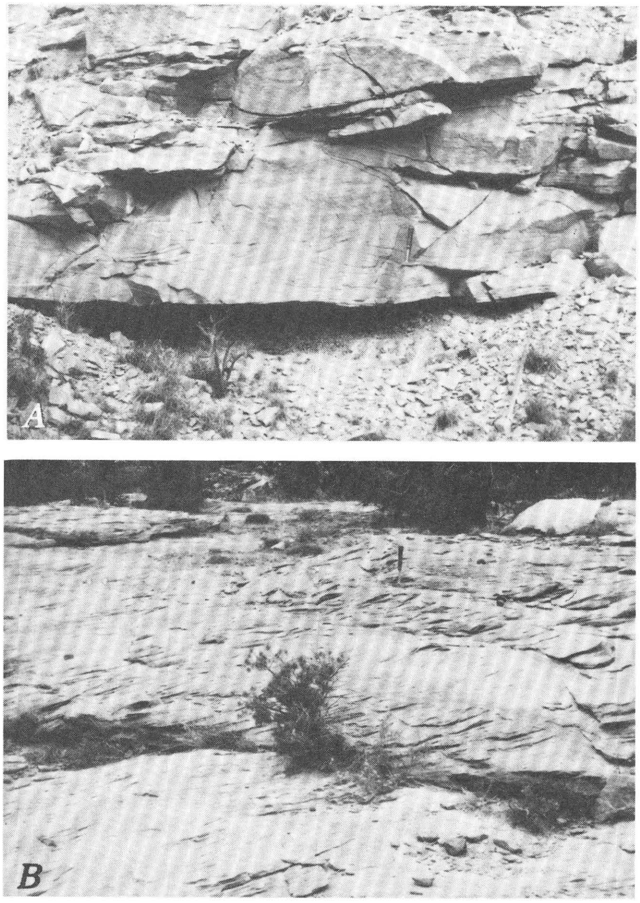

Figure 1. Photographs showing *A*, trough crossbeds and flat beds of the lower sandstone member; *B*, foreset bedding formed by migrating sand waves interpreted to be transverse bars in the middle sandstone member of the Santa Rosa Formation.

Sandstone in West Texas (Asquith and Cramer, 1975). The sedimentary rocks of each of the three sandstone members have these characteristics in common and are interpreted as braided-stream deposits; however, the typical dimensions of sedimentary structures in each is different. The dominant alluvial environment was broken after the middle sandstone episode by lacustrine deposition of the mudstone member.

The lower sandstone member of the Santa Rosa rests unconformably on the Permian Artesia Group, which has less than 1 m of local relief. At its base, the lower sandstone member contains local lag-concentrates of Permian lithic intraclasts in conglomeratic lenses less than 1 m thick. This intraconglomerate is the most widespread conglomerate in the member. During the remainder of the high-energy depositional pulse that deposited the lower sandstone member, trough-crossbedded, poorly-sorted, fine- to medium-grained, red arkosic quartz sandstone was deposited in beds 0.5–1 m thick. Strata of this initial depositional episode are approximately 3 m thick.

After this first high-energy episode of the lower member, the style of deposition changed sharply in the upper part of the member. Rock bodies deposited after this episode are thinner, repetitious, and reflect lower, but still high, depositional energy. Packages of episodically deposited foreset- and flat-bedded strata are approximately 0.5–1 m thick and 5–30 m wide. Many are separated by thin, current-rippled siltstone and mudstone laminae. These packages represent channels within a braided-stream system.

The middle sandstone member consists mainly of tan feldspathic quartz sandstone, which is more mature than the lower member. It represents a second major depositional event by braided streams. The onset of deposition was similar to, but stronger than, that of the lower sandstone member and is marked by an extensive regional unconformity measured in tens of meters of relief. Local relief on the unconformity is 1–2 m, and the lag conglomerate at the base not only is more extensive than that at the base of the underlying member, but it contains resistate clasts of quartz as large as 5 cm in diameter in addition to intraclasts of mudstone. These resistate clasts of quartz are from a source different and more distant than the source of the lithic intraclasts of the lower sandstone member. The structureless and flat beds of the rocks immediately above the conglomerate indicate deposition during high flow, as was the case with the lower sandstone member, but the beds are thicker (1–3 m) and total approximately 8 m. This high-flow depositional episode, like that of the lower sandstone member, apparently waned rapidly, for the rest of this member was deposited as transverse bars and other sedimentary structures characteristic of low-flow regimes (fig. 1*B*). Well-preserved delicate animal tracks and trails (fig. 2) attest to deposition in still water. These low-energy conditions represent the gradual transition into the lacustrine environment of the overlying mudstone member.

Regionally, the mudstone member is discontinuous and appears to have been deposited mainly in lakes developed by local subsidence caused by dissolution of Permian salt. In the principal reference section, this member consists of about 20 m of predominantly weakly bedded claystone. The lower 8 m is olive gray and contains abundant well-preserved organic fossil plant material (see chapter C), which indicates local ponding, low-energy conditions, and high water tables. The upper 15 m is dominantly red, which indicates open-water oxidizing conditions and a gradual return to the fluvial environment of the upper sandstone member.

Sparse thin lenses of siltstone and sandstone typically less than 1 m thick and 5 m wide scattered throughout the claystone indicate that the member was coursed by streams. The channels contain lag gravel of pedogenic calcareous clasts (fig. 3) overlain by current-rippled siltstone and sandstone. The surfaces of these channel

Figure 2. Photograph showing tracks and trails on the lower bedding plane of current-rippled sandstone in the middle sandstone member of the Santa Rosa Formation.

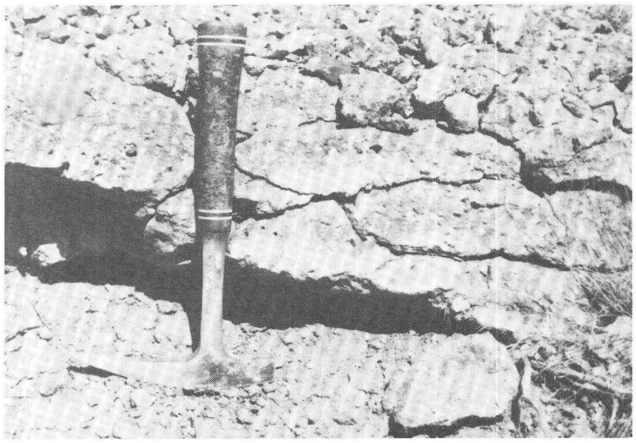

Figure 3. Photograph showing lag conglomerate of pedogenic, calcareous intraclasts deposited in small channels within the mudstone member of the Santa Rosa Formation.

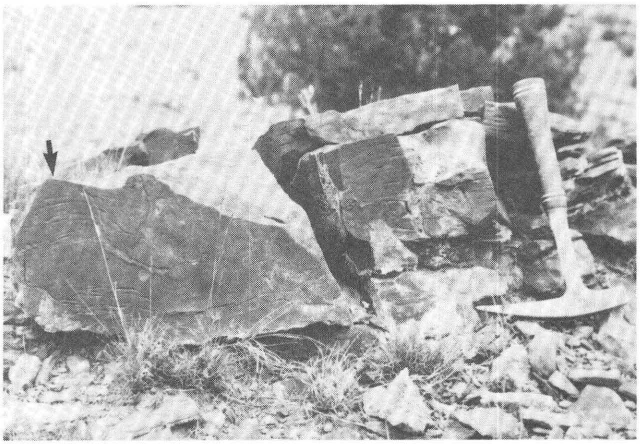

Figure 4. Photograph showing thin, possibly algal-laminated limestone (arrow) in the mudstone member of the Santa Rosa Formation.

deposits are commonly covered by oscillation ripples, tracks, and trails that attest to deposition in standing water and by mudcracks that indicate desiccation took place. These thin units are commonly burrowed.

Within the red claystone section are scattered calcrete layers less than 1 m thick containing nodules and filaments that are characteristic of desert soils described by Gile and others (1966). Underlying each calcrete layer is a zone of ochre, purple, and white alteration from the normal red that probably developed as part of the soil-forming process, a process described by Cooke and Warren (1973).

In the vicinity of the measured reference section and in the upper part of the member are minor thin nonclastic limestone beds that are burrowed and display structures of possible algal origin (fig. 4).

The upper sandstone member was deposited in depositional environments similar to those of the lower and middle sandstone members; however, the basal contact of the upper sandstone member with the mudstone member is gradational, so no significant erosional event marked the beginning of the upper sandstone depositional episode. Rather, all sediments were deposited as transverse bars and related low-flow bed forms, much as in the upper part of the middle sandstone member.

PALEOTRANSPORT TRENDS

Each member of the Santa Rosa has different paleotransport trends, which implies a change in basin attitude and a possible change in sediment source area. Sediment transport during the deposition of the lower

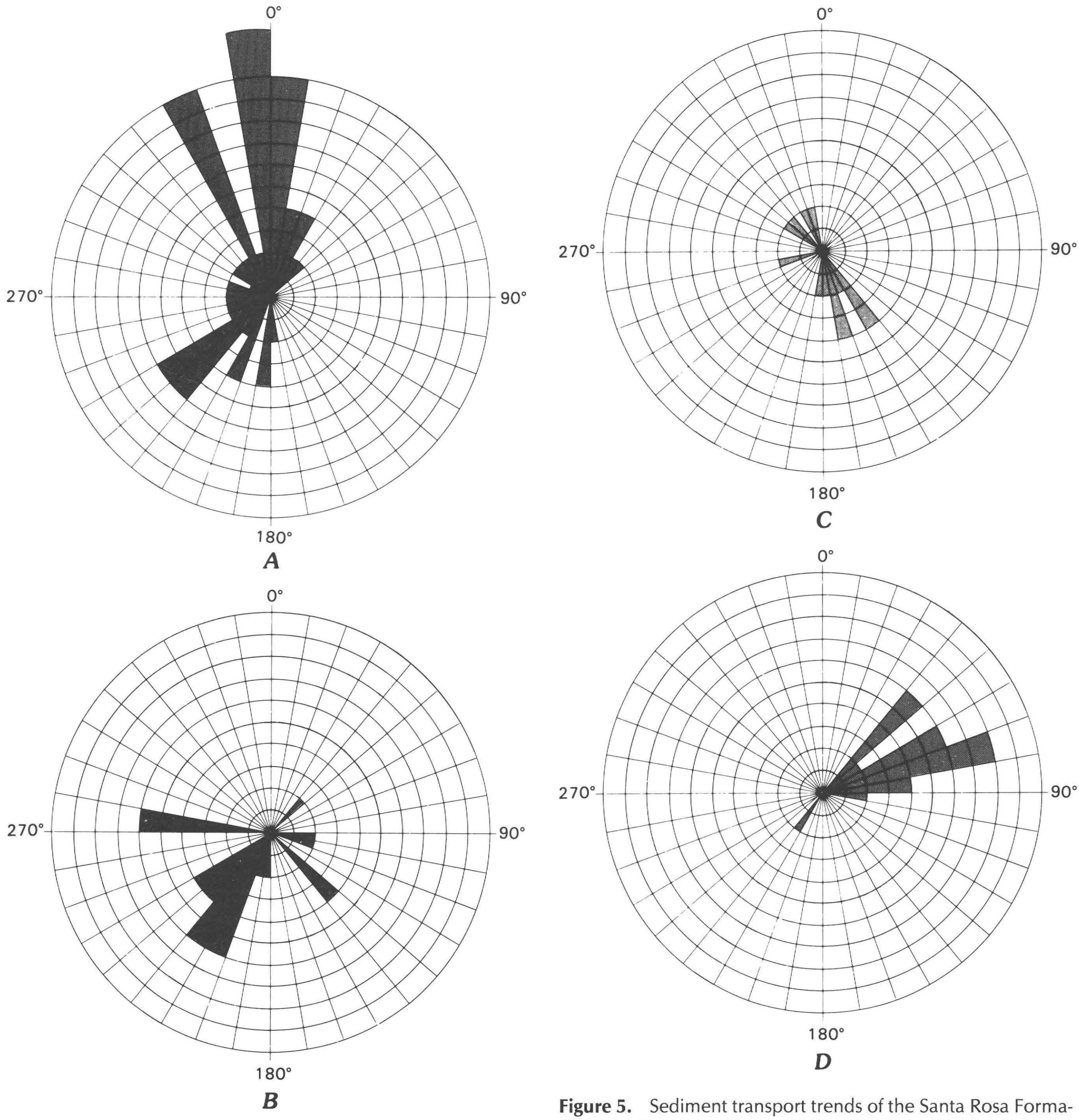

Figure 5. Sediment transport trends of the Santa Rosa Formation. *A*, lower sandstone member; *B*, middle sandstone member; *C*, mudstone member; *D*, upper sandstone member.

sandstone member was dominantly to the north (0°) as determined by measuring azimuths of trough crossbed axes, foreset bed dips, and, to a minor extent, parting lineations (fig. 5*A*). Transport direction changed sharply in the middle sandstone member to nearly the opposite direction (210°) (fig. 5*B*). Regional studies by McGowen and others (1979), done after my local studies, confirmed these changes in transport directions. Therefore, the source of sediment for the middle sandstone member must have been within the formerly more distal part of the depositional basin than the source for the lower sandstone member. This conclusion is supported by the modal analysis data given below. Early work by Cazeau (1960) before subdivision of the Santa Rosa into members showed two opposing source areas for the "Santa Rosa Sandstone."

Data on transport directions for the discontinuous mudstone member deposited mainly in lakes are inconclusive (fig. 5*C*). It appears that the intermittent channels were haphazardly coursing through flat-lying, overbank-lacustrine sediments.

Trends for the upper sandstone member, however, are restricted enough in distribution to show that unidirectional flow was to the northeast (70°) (fig. 5*D*), which contrasts to the southwest flow of the middle sandstone member. Thus, there was a final apparent change in the basin attitude.

MODAL ANALYSES

Modal analyses of 40 sandstone samples of the Santa Rosa indicate differences in composition between the red lower sandstone member and the tan middle and upper sandstone members. The differences in composition not only reflect differences in source material, but, when considered together with changes in sediment transport trends (figs. 5*A*, 5*B*, 5*D*), confirm changes in basin attitude.

The sandstone of the lower sandstone member is compositionally more immature than that of the remainder of the formation, as shown in figure 6. The sandstone of the lower member has more than 10 percent lithic fragments, more than 10 percent feldspar, and less than 70 percent quartz. In contrast, the sandstone of the remaining part of the formation generally has less than 20 percent lithic fragments, less than 10 percent feldspar, and more than 75 percent quartz. If the source material for the three sandstone members was similar, the more unstable constituents must largely have been destroyed prior to deposition of the upper two members.

Similar changes in composition are shown by comparison of abundances of heavy minerals plus micas for each member (fig. 7). Generally, the lower sandstone member has more than 2.5 percent heavy minerals plus micas, and the upper sandstone member contains less than 2.5 percent of these constituents.

SUMMARY

After the first cycle, during which immature sediments of the lower sandstone member were deposited on the Permian Artesia Group erosional surface by braided streams moving from south to north into the basin, the attitude of the basin changed. Braided streams were forced to flow in nearly the opposite direction; they eroded sediments of the lower sandstone member, which were matured in the process, picked up resistant clasts from the new source, and deposited the middle sandstone member.

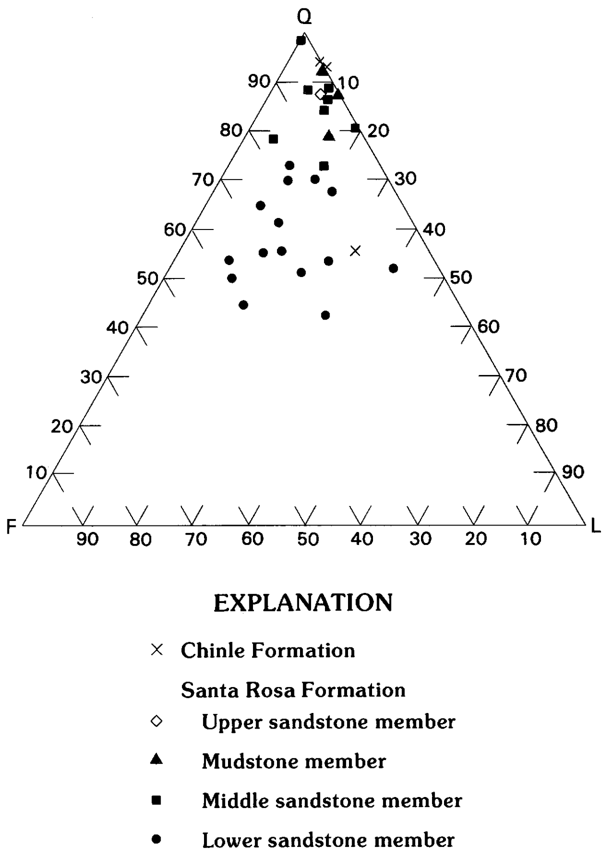

Figure 6. Ternary diagram of quartz plus chert(Q), feldspar (F), and lithic fragments (L) for Santa Rosa Formation samples.

The depositional episode of the middle member gradually subsided to lower energy levels until overbank-lacustrine sediments of the mudstone member were deposited. Under apparently stable conditions over a considerable length of time, soils developed. Intermittent streams flowing in diverse directions coursed the low-relief surface of the mudstone until finally the braided-stream sediments of the upper sandstone gradually took over deposition in the area of the principal reference section.

REFERENCES CITED

Asquith, G.B., and Cramer, S.C., 1975, Transverse braided bars in the upper Triassic Trujillo Sandstone of the Texas Panhandle: Journal of Geology, v. 83, p. 657–661.

Cazeau, C.J., 1960, Cross-bedding directions in Upper Triassic sandstones of northeastern New Mexico: American Association Petroleum Geologists Bulletin, v. 44, p. 638–640.

Cooke, R.U., and Warren, Andrew, 1973, Geomorphology in deserts: Berkeley, University of California Press, 374 p.

Gile, L.H., Peterson, F.F., and Grossman, R.B., 1966, Morphological and genetic sequences of carbonate accumulation in desert soils: Soil Science, v. 101, p. 347–360.

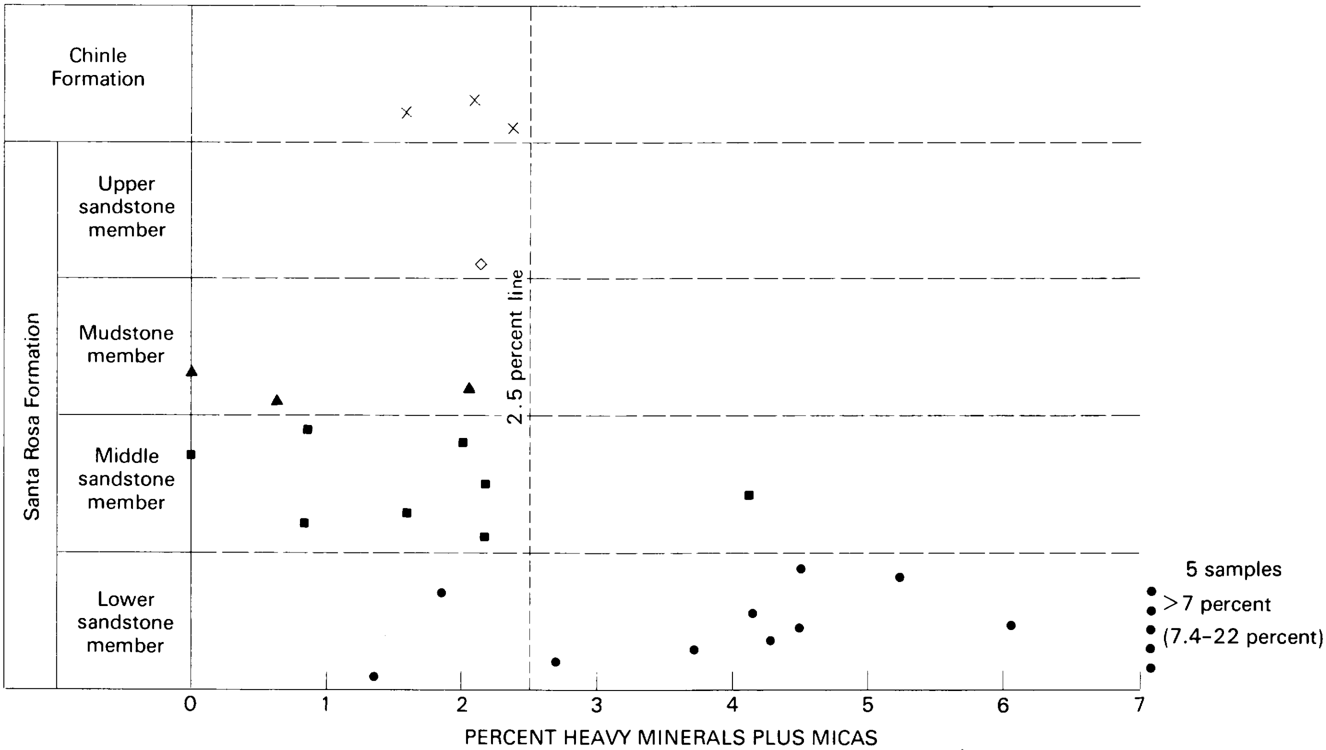

Figure 7. Abundances of heavy minerals plus micas in the framework of sandstone from various members of the Santa Rosa Formation and lower beds of the Chinle Formation. Thin sections are not located precisely in the stratigraphic section, and relative thickness of units is not shown. Symbols for samples are the same as in figure 6.

Harms, J.C., Southard, J.B., Spearing, D.R., and Walker, R.G., 1975, Depositional environments as interpreted from primary sedimentary structures and stratification sequences: Society of Economic Paleontologists and Mineralogists Short Course no. 2, Dallas, 161 p.

McGowen, J.H., Granata, G.E., and Seri, S.J., 1979, Depositional framework of the lower Dockum Group (Triassic), Texas panhandle: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations no. 97-1979, 60 p.

Lupe, Robert, 1977, Depositional history of the Triassic Santa Rosa sandstone, Santa Rosa, New Mexico [abs.]: Geological Society of America, South Central Section, 11th Annual Meeting, March 17-18, 1977, El Paso, Texas, p. 61.

Smith, N.D., 1970, The braided stream depositional environment: Comparison of the Platte River with some Silurian clastic rocks, north-central Appalachians: Geological Society of American Bulletin, v. 81, p. 2993-3014.

Chapter C

Fossil Plants from the Mudstone Member of the Santa Rosa Formation at the Principal Reference Section

By SIDNEY R. ASH

U.S. GEOLOGICAL SURVEY BULLETIN 1804

PRINCIPAL REFERENCE SECTION FOR THE SANTA ROSA FORMATION OF MIDDLE AND LATE TRIASSIC AGE, GUADALUPE COUNTY, NEW MEXICO

CONTENTS

Fossil Plants from the Mudstone Member of the Santa Rosa Formation at the Principal Reference Section

By Sidney R. Ash[1]

Abstract

Systematic descriptions are given for six species of plant megafossils from the mudstone member of the Santa Rosa Formation. They are the fern *Cynepteris lasiophora*, the bennettitalean *Zamites powellii*, the conifer *Pelourdea poleoensis*, *Dinophyton spinosus* of uncertain classification, *Samaropsis* sp, and a pithcast not assigned a name. Four of these are well known and characteristic of the Chinle Formation to the west in the Colorado Plateau region. Several of the species also occur in the Triassic part of the Newark Supergroup in eastern North America. The flora in the mudstone member of the Santa Rosa at the reference section area is typical of the floral *Dinophyton* zone.

INTRODUCTION

This report concerns seven species based on plant megafossils collected from the mudstone member of the Santa Rosa Formation. Four are from the principal reference section of the Santa Rosa Formation (fossil locality A, fig. 2, chapter A), and three were obtained from the mudstone member at a nearby locality (fossil locality B, fig. 2, chapter A). They were collected mainly by W.I. Finch, R.A. Scott, and me during the spring of 1972, although a few were found by Finch in 1971.

Most of the fossils considered here are preserved as faint iron-stained impressions, but there is a small amount of carbonaceous residue on several impressions. The impressions from the principal reference section are preserved in fairly hard, dusky yellow (5*Y* 6/4) claystone; those from the adjacent locality are in soft, yellowish-gray (5*Y* 7/2), silty, micaceous, fine-grained sandstone. One fossil from the adjacent locality is a pithcast composed of grayish-yellow (5*Y* 8/4), medium- to coarse-grained sandstone. The exterior of that fossil is iron-stained and bears traces of woody material.

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Cuticles, epidermises, and sporangia are not preserved on the Santa Rosa compressions, so data about those features in the following descriptions were taken from previous publications.

The fossils described here have been deposited in the U.S. National Museum (USNM), Washington, D. C.

SYSTEMATIC DESCRIPTIONS

Division PTERIDOPHYTA
Order FILICALES
Family CYNEPTERIDACEAE
CYNEPTERIS LASIOPHORA Ash, 1970a
Plate 1, figure 4

Description. The leaf of this fern is twice pinnate with oblong decurrent pinnules that have acute to obtuse apices and obtusely dentate to smooth margins. A strong midvein enters each pinnule and gives off several anastomosing lateral veins that form a coarse reticulum. The resulting vein meshes never contain blind vein endings. The epidermal cells on the pinnules are polygonal and have wavy to slightly sinuous anticlinal walls. The outer periclinal walls of the cells occasionally bear a simple or stellate hair. Some pinnules bear few to many solitary sporangia on the lower surface. They are more or less inversely pear shaped and have a complete apical annulus. The spores produced in the sporangia are round, each has a simple, narrow triradiate mark, and the surfaces bear low reticulations.

Remarks. Cynepteris lasiophora can be easily recognized and separated from all other ferns known in the Upper Triassic rocks of the southwestern United States. Almost all of them have simple forking venation in contrast to the present species which has reticulate venation. The only other Chinle or Dockum fern having reticulate venation is *Clathropteris walkeri*. However, it has a palmately compound leaf whereas *Cynepteris lasiophora* has a pinnately compound leaf. Also, the vein meshes of *Clathropteris walkeri* commonly contain blind vein endings (Ash, 1970a, fig. 18H, I), which are always absent in *Cynepteris lasiophora*.

Distribution. This fern has been found in the Monitor Butte Member of the Chinle Formation in western New Mexico, in the lower part of the Petrified Forest Member of the Chinle in Petrified Forest National Park (Ash, 1970a), and in the Shinarump Member of the Chinle in Utah (Ash, 1975b). It is also known from the Pekin Formation of Late Triassic age in the Newark Supergroup in North Carolina (Hope and Patterson, 1969). Otherwise it is rarely known. However, two closely related species do occur in the Santa Clara Formation in Sonora, Mexico (Reinhard Weber, Institute of Geology, Autonomous National University of Mexico, Mexico, D. F., written commun. 1984).

Material. USNM 172305, 172307, 172308.

Division CYCADOPHYTA
Order BENNETTITALES
ZAMITES POWELLII Fontaine (in Fontaine and Knowlton, 1890)
Plate 1, figures 2, 9

Description. This form has oblanceolate to elliptical leaves that are once pinnate. The pinnae are linear and have distinctly parallel sides and truncate apicies. Small, poorly developed expansions or auricles occur in the basal angles of the pinnae. The pinnae usually arise alternately from the rachis at a high angle (55°–70°), except near the leaf apex where they arise at a much lower angle and a pinnae terminates the rachis. The veins are commonly distinct in the pinnules and arise from one or two veins in the bases of the pinnae. They are generally parallel except in the pinnae bases where they diverge. Most of the veins continue to the apices of the pinnae and end in the margin there. One or two veins commonly enter each auricle where they end in the margins. The cuticle is thin and shows more or less rectangular epidermal cells with fairly sinuous side walls and wavy to straight end walls. Frequently the outer wall bears a small sac or stellate hair. The stomata are syndetocheilic and irregularly oriented and occur mainly between the veins.

Remarks. Many specimens of *Z. powellii* have been collected from the principal reference section. They range considerably in size as is usual in this species. The pinnules vary from 3 mm to 7 mm in width and from 1.5 cm to 2.5 cm in length.

The only species in the Upper Triassic flora of the southwest with which *Z. powellii* might be confused is *Otozamites macombii* Newberry (1876). Both have once pinnate leaves but they have somewhat different proportions; those of *O. macombii* are narrower than the leaves of *Z. powellii*. The pinnules also have slightly different proportions; they are usually shorter and wider in *O. macombii* than in the present species. Probably the most obvious difference is venation. In *O. macombii* the veins follow fairly straight courses from their place of origin and end in the lateral as well as the apical margins. Only a few of the veins in *Z. powellii* end in the lateral margins of the auricles. Most change their courses a short distance from their place of origin, so they come to parallel the lateral margins and continue to the apical margins, where they end.

Distribution. Zamites powellii is probably the most common leaf found in the lower part of the Dockum Group as well as in the Chinle Formation west of the Rio Grande (Ash, 1975a). The species was first described from the lower few feet of the Upper Triassic sequence in northern New Mexico by Fontaine (Fontaine and Knowlton, 1890). Since then it has been reported from the lower part of the Chinle Formation at many localities in southern Utah by Berry (1927) and Ash (1975a, 1975b), in northeastern Arizona by Daugherty (1941), and in western New Mexico by Ash (1967, 1975a), from the Tecovas and Trujillo Formations in Texas and the Chinle Formation in eastern New Mexico by Ash (1972), and from unspecified positions in the Dockum Group in Texas by Daugherty (1941). It has also been reported from the lower part of the Pekin Formation of the Newark Supergroup of Late Triassic age in North Carolina (Hope and Patterson, 1969). Except for this one occurrence, *Z. powellii* is unknown outside the southwestern United States.

Material. USNM 172299, 172300.

Division CONIFEROPHYTA
Order CORDAITALES
PELOURDEA POLEOENSIS (Daugherty) Arnold, 1964
Plate 1, figure 5

Description. This form has lanceolate to linear lanceolate leaves that have entire margins and acute to acuminate apices. The bases of the leaves narrow slightly to clasp the stems. Veins are narrow and distinct and are generally parallel, except in the left bases where they originate. The leaves are as wide as 5.2 cm and are 34 cm or more in length.

Remarks. Four fragments of finely striate, linear leaves have been obtained from the principal reference section. They fit the general concept of *Pelourdea poleoensis* and thus are tentatively referred to that taxa. I know that most of the fragments are parts of the central regions of leaves because the margins of the fossils are more or less parallel. The illustrated specimen (pl. 1, fig. 5), however, apparently comes from near the apex of a leaf because the margins converge whereas the veins remain parallel and end in the margins, which is typical of the apex of the leaf of *Pelourdea*. The other specimens vary from 1.5 cm to 3 cm in width.

Distribution. Similar fragments have been reported from the Upper Triassic Dolores Formation in southwestern Colorado by Arnold (1964), from the Upper Triassic Poleo Sandstone Lentil of the Chinle in northern New Mexico (Daugherty, 1941), from an unspecified position in the Dockum of Texas (Daugherty, 1941), and I have collected them from the upper part of the Chinle Formation in southeastern Utah, the lower part of the Chinle Formation in northern Arizona and western New Mexico, and the Tecovas Formation of the Dockum in Texas. Pelourdea leaves are not very good index fossils because similar leaves have been found in rocks that range in age from Pennsylvanian to Jurassic from many parts of the world. Some of these leaves may represent different species, but they are difficult to distinguish and little significance can be attached to their occurrence in the Santa Rosa at this time.

Material. USNM 172306, 172309.

Division uncertain
DINOPHYTON SPINOSUS Ash, 1970b
Plate 1, figures 3, 6–8

Description. The long, narrow leaves of this species are spirally arranged on a narrow stem but in the fossil are flattened into one plane. They are round in section, contain two veins, and have more or less acuminate apices. Petioles are absent and the basal attachment of the leaves is broad. Some of the axes show narrow stumps of unknown function between the leaves. The possible female reproductive organ consists of a pinwheel-like structure composed of four appendages attached at right angles to a small, hollow central cup-like body. The cuticle of this species is tough and thick and shows polygonal to rectangular epidermal cells that have curving to straight anticlinal walls. Each cell commonly bears a low papillae or unicellular hair. The stomata are haplocheilic with rectangular pores. They are typically longitudinally oriented and occur on all surfaces of the leaves, axis, and pinwheel structure.

Remarks. Five recognizable examples of the leafy shoot of *D. spinosus* have been collected from the principal reference section in addition to two specimens of the pinwheel structure. The leaves on the shoots vary from 0.3 to 1.0 mm in width and from 0.8 to 2.9 cm in length, well within the range known for the species. The two pinwheels are about 1.5 cm in diameter. The pinwheel structures and leafy shoots are attributed to the same plant on the basis of their very similar cuticles and their close association in the outcrop.

Dinophyton spinosus does not resemble any other known plant in the Upper Triassic rocks of the Southwest U.S., and there is no doubt that the specimens described here are correctly identified.

Distribution. Dinophyton spinosus is one of the most common plant fossils in the Dockum Group and the Chinle Formation west of the Rio Grande. It has been reported from the lower part of the Chinle Formation in northeastern Arizona, western New Mexico, and southeastern Utah (Ash, 1975b), and the Tecovas Formation in Texas (Ash, 1970b). *D. spinosus* has been reported from only one other place in the world, namely in the Upper Triassic New Oxford Formation of the Newark Supergroup in Pennsylvania (Cornet, 1977).

Material. USNM 177301–177304.

SAMAROPSIS SP.
Plate 1, figure 1

Description. This seed is about 8 mm by 15 mm and consists of a thick, oval central carbonaceous body surrounded by a thin membraneous wing 1–3 mm wide. The wing is wider in the basal and apical parts of the seeds than along the sides and is apparently divided into two long, narrow basal lobes.

Remarks. This fossil is somewhat similar to the one Daugherty (1941) described from the Chinle Formation in Petrified Forest National Park, but it is not as well preserved. As in the case of *Pelourdea poleoensis*, this general type of fossil is also known from rocks that range in age from Pennsylvanian to Jurassic; thus, it is not judged to be an important index fossil at this time.

Material. USNM 172298a, b.

PITHCAST
(not illustrated)

Description. The pithcast is slightly flattened and is about 4.5 cm wide along the longest axis and 1.5 cm along the shortest. It is about 5 cm long. The surface bears spirally arranged, narrow, spindle-shaped raised areas that are about 5 mm wide. Some of the areas show a narrow slit at one end. As noted above, a small amount of woody material adheres to the case in places.

Remarks. Casts similar to the one described here are known from rocks of Pennsylvanian through Cretaceous age in many parts of the world. Some are thought to be cordiatean, others coniferous, and still others clearly are cycadean. They have been given a variety of names, commonly on the basis of very slight differences. According to Seward (1917, 1919), those from Pennsylvanian and Permian rocks have been called *Tylodendron* and also *Schizodendron*; those from Triassic and younger rocks have been referred to as *Voltzia*, *Endolepsis*, and *Cycadeomyelon*. Specimens from the Upper Triassic part of the Newark Supergroup in New Jersey were called *Palissya*? sp. by Newberry (1876), and some from the Newark in New Brunswick were referred to as *Voltzia coburgensis* by Holden (1913).

Because the validity of most of these names is questionable, it seems best to refrain from assigning the specimen described here to any genus at this time.

Distribution. Little stratigraphic significance can be attached to the occurrence of this pithcast in the Santa Rosa as it appears to be a wide-ranging form. Nevertheless, similar pithcasts are known from the Upper Triassic of eastern North America and also from the Upper Triassic rocks of northern New Mexico according to C. B. Read (oral commun., U.S. Geological Survey, 1964).

Material. USNM 172310

CONCLUSIONS

The mudstone member of the Santa Rosa Sandstone in the principal reference section contains a small flora consisting of six forms, four of which are well known and characteristic of the lower part of the classical Chinle Formation west of the Rio Grande (table 1). They are *Cynepteris lasiophora, Zamites powellii), Pelourdea poleoensis*, and *Dinophyton spinosus*. Two others, *Samaropsis* sp. and the pithcast, may also occur in the Chinle, but this is uncertain. No other Triassic unit in the western United States contains as many Santa Rosa species, and it is evident that the two floras correlate fairly closely. The flora in the mudstone member of the Santa Rosa Sandstone is typical of the Zone of *Dinophyton* as proposed by Ash (1980). Recent investigations indicate that the Zone of *Dinophyton* correlates with the Carnian Stage of the Upper Triassic (Ash and others, 1986).

The relation of this flora to those in the other members of the Dockum is less clear because they are so poorly known at the present time. Two and possibly three of the Santa Rosa forms occur in the Tecovas Formation, and only one is known in the Chinle Formation east of the Rio Grande and in the Trujillo Formation. The only other unit that definitely contains some of the Santa Rosa forms is the Upper Triassic part of the Newark Supergroup in eastern North America, which contains three or possibly four forms.

REFERENCES CITED

Arnold, C.A., 1964, *Cordiates*-type foliage associated with palm-like plants from the Upper Triassic of southwestern Colorado: Indian Botanical Society Journal, v. 42A, p. 4–9.

Ash, S.R., 1967, The Chinle (Upper Triassic) megaflora of the Zuni Mountains, New Mexico, *in*, Trauger, F.D., ed., Guidebook of Defiance-Zuni-Mt. Taylor region [Arizona and New Mexico]: New Mexico Geological Society, 18th Field Conference, 1967, p. 125–131.

______1970a, Ferns from the Chinle Formation (Upper Triassic) in the Fort Wingate area, New Mexico: U.S. Geological Survey Professional Paper 613-D, p. D1–D52.

______1970b, *Dinophyton*, a problematical new plant genus from the Upper Triassic of the southwestern United States: Paleontology, v. 13, p. 646–663.

______1972, Upper Triassic Dockum flora of eastern New Mexico and Texas, *in* Kelley, V.C., and Trauger, F.D., eds., Guidebook of east-central New Mexico: New Mexico Geological Society Guidebook, 23rd Field Conference, East-central New Mexico, September 28–30, 1972, p. 124–128.

______1975a, *Zamites powellii* and its distribution in the Upper Triassic of North America: Palaeontographica, pt. B, v. 149, p. 139–152.

______1975b, The Chinle (Upper Triassic) flora of southeastern Utah, *in*, Fassett, J.E., ed., Canyonlands Country: A Guidebook of the Four Corners Geological Society, 8th Field Conference, September 22–25, 1975, p. 143–147.

______1980, Upper Triassic Floral Zones of North America, *in* Dilcher, D.L., and Taylor, T.M., Biostratigraphy of fossil plants: Stroudsburg, Pa., Dowden, Hutchinson & Ross, p. 153–170.

Ash, S.R., Litwin, R.J., and Long, R.A., 1986, Biostratigraphic correlation of the Chinle Formation (Late Triassic) on the Colorado Plateau, a progress report [abs]: Geological Society of America Abstracts with Programs, v. 18, p. 338–339.

Berry, E.F., 1927, Cycads in the Shinarump conglomerate of southern Utah: Journal of the Washington Academy of Sciences, v. 27, p. 303–307.

Table 1. Summary of the known distribution of the plants from the Santa Rosa Formation in other stratigraphic units
[X, definite occurrence; ?, possible occurrence; --, absent]

Santa Rosa Formation	Chinle Formation, west of the Rio Grande	Dockum Group, New Mexico and Texas			Newark Supergroup in eastern North America
		Chinle Formation	Trujillo Formation	Tecovas Formation	
Cynepteris lasiophora	X	--	--	--	X
Zamites powellii	X	X	X	X	X
Pelourdea poleoensis	X	--	--	?	--
Dinophyton spinosus	X	--	--	X	--
Samaropsis sp.	?	--	--	--	--
pithcast	?	--	--	--	?

Cornet, Bruce, 1977, Preliminary investigations of two Late Triassic conifers from York County, Pennsylvania: Geobotany, p. 165–172.

Daugherty, L.H., 1941, The Upper Triassic flora of Arizona: Carnegie Institute of Washington Publication 526, 108 p.

Fontaine, W.M., and Knowlton, F.H., 1890, Notes on Triassic plants from New Mexico: U.S. National Museum Proceedings, v. 13, p. 281–285.

Holden, Ruth, 1913, Some fossil plants from eastern Canada: Annals of Botany, v. 27, p. 243–255.

Hope, R.C., and Patterson, O.F., III, 1969, Triassic flora from the Deep River Basin, North Carolina: North Carolina Department of Conservation and Development Special Publication 2, 12 p.

Newberry, J.S., 1876, Geological report *in* Report of exploring expedition from Santa Fe, New Mexico, to the junction of the Grand and Green Rivers of the Great Colorado of the West, in 1859, under Captain J.N. Macomb: U.S. Army Engineering Department, p. 9–118.

Seward, A.C., 1917, Fossil plants, v. III, Pteridospermeae, Cycadofilices, Cordaitales, Cycadophyta: Cambridge, England, Cambridge University Press, 656 p.

Seward, A.C., 1919, Fossil plants, v. IV, Ginkgoales, Coniferales, Gnetales: Cambridge, England, Cambridge University Press, 543 p.

PLATE 1

Fossil plants from the mudstone member, Santa Rosa Formation, near Santa Rosa and the Chinle Formation near Fort Wingate, N. Mex.

Figure 1. *Samaropsis* sp. USNM 172298a, ×1.

2,9. *Zamites powellii* (Fontaine *in* Fountaine and Knowlton, 1890). Many of the pinnules in the figures show parallel margins and truncate apices, which are so characteristic of the species. In a few pinnules, slight ear-like projections of the lamina are visible in the basal angles.

2. Apical part of a leaf. USNM 172299, ×1.
9. Middle part of a leaf. USNM 172300, ×1.

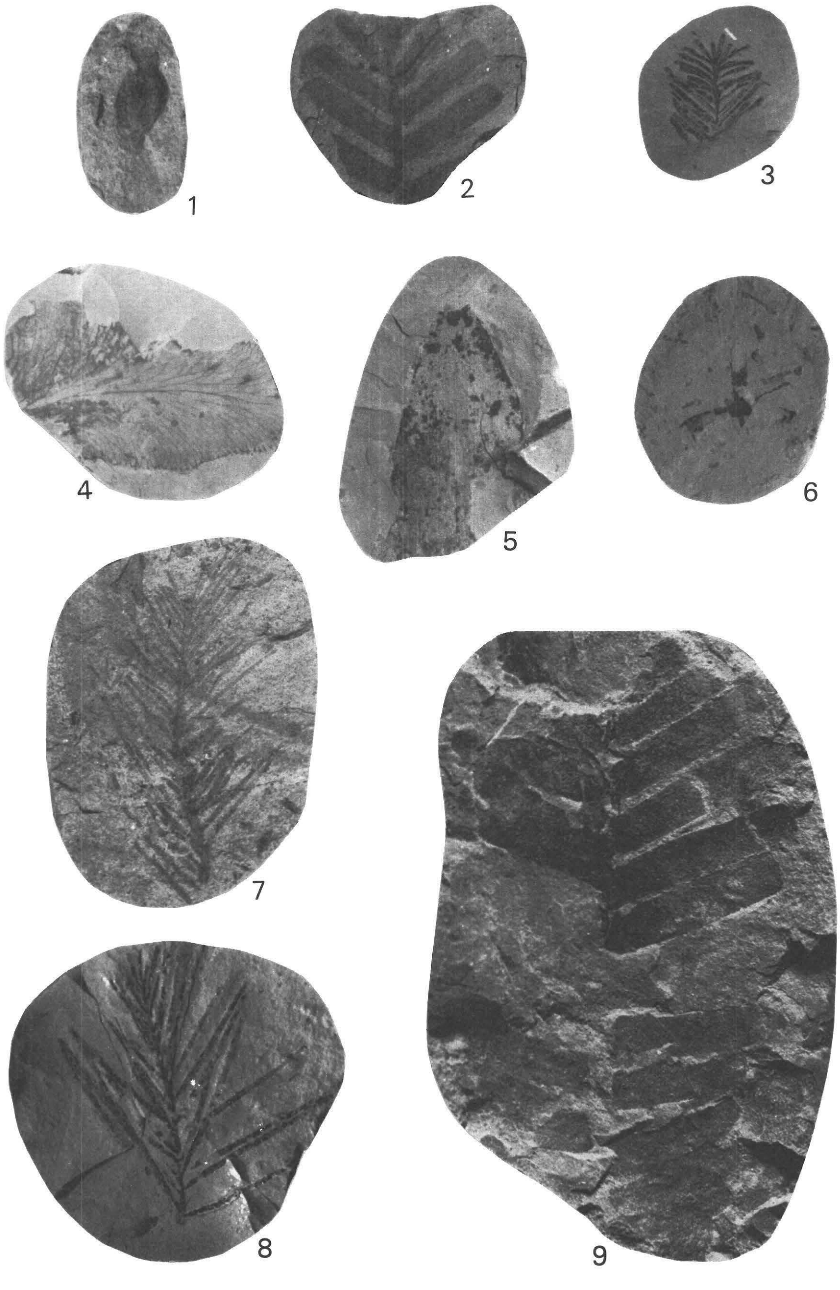
3,6–8. *Dinophyton spinosus* Ash, 1970b.

3, 7, 8. Typical leafy shoots showing the variation in size commonly noted in the species. The needle-like leaves are clearly evident in the figures. USNM 172301, 172302, 172303, all ×1.

6. Specimen from the Monitor Butte Member of the Chinle Formation near Fort Wingate, N. Mex. Example of a pinwheel-like structure attributed to the species. In this specimen parts of three of the appendages and the central cup-like body are preserved. USNM 172304, ×1.

4. *Cynepteris lasiophora* Ash, 1970a. Pinna from the upper part of a leaf showing a more or less entire margin. Reticulate venation typical of the species is visible in many places. USNM 172305, ×1.

5. *Pelourdia poleoensis* (Daugherty, 1941) Arnold, 1964. The apical part of a leaf showing the converging margins and parallel veins. USNM 172306, ×1.



FOSSIL PLANTS FROM THE MUDSTONE MEMBER, SANTA ROSA FORMATION, AND THE CHINLE FORMATION

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