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NOTES ON UPPER PERMIAN AND LOWER TRIASSIC STRATA AND STRUCTURES IN EAST-CENTRAL AND CENTRAL NEW MEXICO

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Abstract.—The Middle Triassic Anton Chico Member of the Moenkopi Formation accumulated in east-central and central New Mexico, for the most part, on a very low relief Permian surface that had not been previously deformed. This conclusion is indicated by a general lack of basal coarse-grained facies within the Anton Chico, shallow or no Triassic scouring below this horizon, and Middle Permian sandstone and stromatolite marker beds that can be traced laterally for over 150 km. Post-Triassic deformation appears to have followed preexisting trends, including a reactivated thrust belt. A regional oxidation-reduction front was discovered. Lineaments control the distribution and areas of sinks in east-central and central New Mexico, and one linea-ment zone can be correlated with those of the west-central United States. The degrees of thermal alteration of organic material in Middle Permian and Middle Triassic strata suggest they were once covered by thick deposits.

INTRODUCTION

Studies of Middle Permian and Middle Triassic strata in east-central and central New Mexico, as well as analyses of structures in these regions, have resulted in anumber of new findings and the compilation of an updated structure-contour map of the Permian-Triassic boundary in Guadalupe County (Fig. 1) and adjacent areas.

PREVIOUS WORK

Middle Permian stratigraphy in east-central and central New Mexico

Tait et al. (1962) correlated Middle Permian strata from the Permian Basin south-east of the study area in southeastern New Mexico to north-central New Mexico using well logs and outcrops. They showed that the relatively thin and clastic Bernal Formation gave way to predominantly evaporitic, thicker beds of the Artesia Group to the southeast. This was corroborated by Kelley (1972b) (Fig. 2). Both suggested that the Bernal Formation was equivalent in age to lower Artesia Group formations so that there was overstepping by overlying Triassic beds toward the northwest (Fig. 2). Lucas and Hayden (1991) proposed that "Artesia Formation" be used instead of "Bernal Formation" because of the relationships indicated by Tait et al. (1962). Stromatolite and sandstone marker beds were traced by Maier et al. (1986) in the upper Bernal (or Artesia) Formation and upper Artesia Group for several km (Fig. 2), suggesting that there was little or no uplift of Permian deposits prior to Triassic deposition. This will be discussed in more detail below.

Lower Triassic stratigraphy in east-central and central New Mexico

Gorman and Robeck (1946) separated the lower part of the Triassic section in north-central Guadalupe County into 4 units, a lower "purplish-red" sandstone, followed upward by a gray sandstone, then a shale unit, and above that by another gray sandstone bed (Fig. 3).

Stewart et al. (1972a, b) tentatively correlated the lowermost Triassic Moenkopi Formation across the Rio Grande from the

FIGURE 1. Location map.

Colorado Plateau to the west to the Sevilleta Grant, about 16 km northeast of Socorro. At this location they assigned the beds overlying the "Moenkopi (?)" to the Petrified Forest Member of the Chinle Formation, also extending the nomenclature from the west. Maier et al. (1986) stated that "Moenkopi-type" strata occur southeast of Socorro.

Based on a Middle Triassic (Anisian) amphibian fossil found in the lower sandstone unit of Gorman and Robeck (1946), Lucas and Morales (1985) and Lucas et al. (1985) correlated this interval with the Moenkopi Formation. Later, Lucas and Hunt (1987) named this lower sandstone the Anton Chico Member of the Moenkopi Formation and Lucas (1991) proposed that the unit extends across west-central, south-central, and east-central New

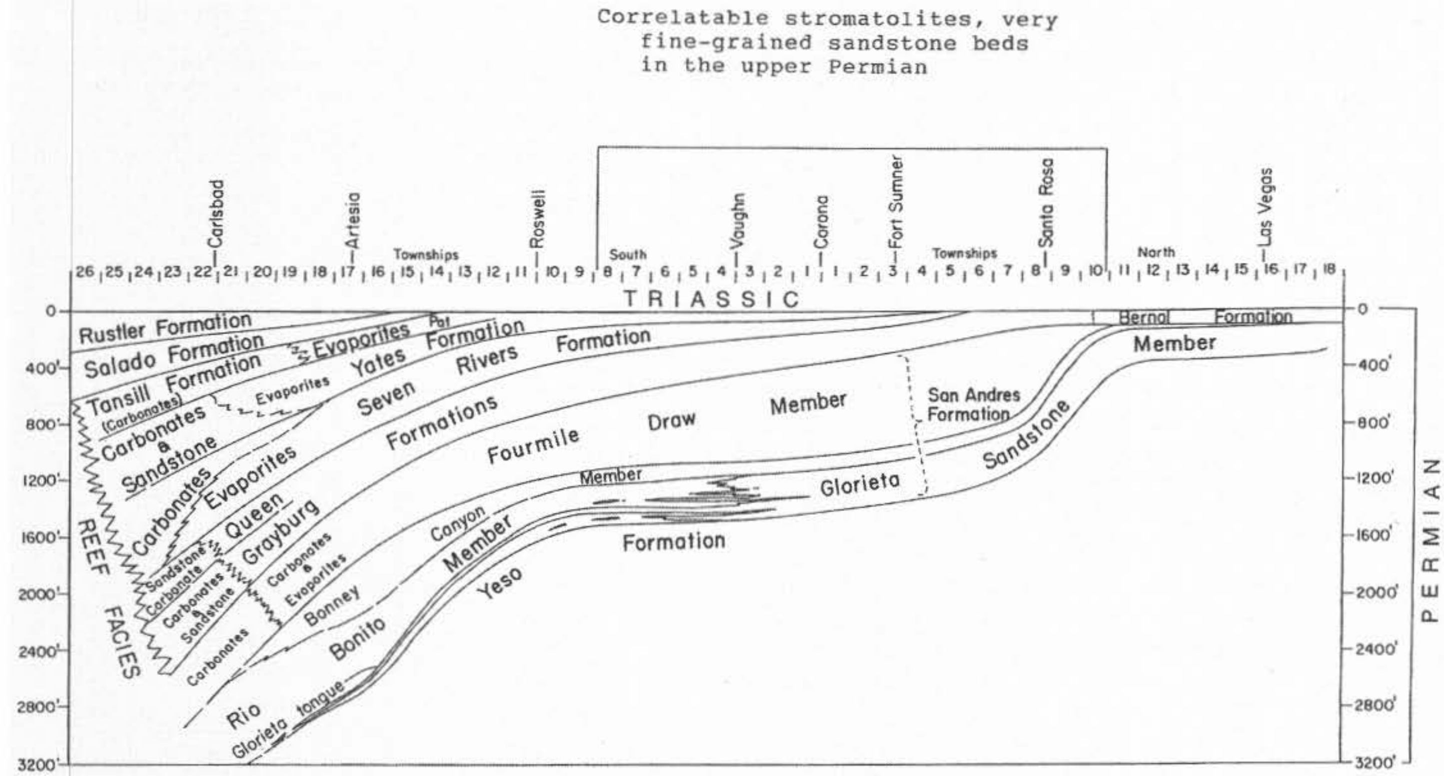

FIGURE 2. Cross section from Kelley (1972b).

Mexico (Fig. 3) because of lithology, stratigraphic position, and another Anisian amphibian fossil discovered approximately 25 km southeast of Socorro.

Permian-Triassic boundary surface

Foster et al. (1972) and Broadhead (1984) mapped the structure on the Permian-Triassic boundary surface in Guadalupe County. They used broader-based data than this study, which incorporates some of Broadhead's gamma-ray picks of the boundary, especially in eastern Guadalupe County.

Other regional structure data

Kelley (1972a) mapped surface structures in east-central New Mexico and concluded that they follow preexisting Pennsylvanian-Permian features, the north-south Pedernal high and the northeast-trending Sierra Grande arch (Fig. 4).

Maughan and Perry (1988) showed that within the west-central United States there are prominent northeast-southwest oriented lineaments, some extending to the north-central U.S. This study uncovered another long lineament in east-central and central New-Mexico that parallels those found by Maughan and Perry (1988).

In 1986, Maier et al. said that northeast-trending lineaments in east-central and central New Mexico control the areas of sinks and that Middle Permian and Middle Triassic beds were once covered by thick sedimentary deposits, as determined from thermal alteration values.

METHODS AND OBJECTIVES

Twenty-five stratigraphic sections of Middle Permian and Middle Triassic rocks were measured and described in the field in east-central and central New Mexico (Fig. 5). Cores from 8 drill holes in central northern Guadalupe County of the same interval were also documented. The purposes were to correlate Permian and Triassic strata in east-central and central New Mexico and to note any lateral differences in these beds.

The Permian-Triassic boundary was surveyed for 100 km in east-central New Mexico. This data set plus log (lithologic, radioactive, and electric) picks of this surface were used to construct a structure-contour map of the boundary in Guadalupe County and adjacent areas (Fig. 6). Seismic sections were studied from Guadalupe County for the purpose of integrating surface manifestations with subsurface structures.

Lineaments and circles were traced from black and white and color satellite images (black and white Landsat band 4 and Heat Capacity Mapping Mission (HCMM) thermal infrared images and Landsat false-color composite) of east-central and central New Mexico. The main objectives were to correlate sinks with lineaments and to show the spatial association of lineaments with those of the larger region (Western Interior U.S.).

Thermal alteration indices (TAI'S) were calculated from organic constituents of outcrops and core samples of Middle Permian and Middle Triassic strata in east-central and central New Mexico. The purpose was to estimate the former thickness ofrocks (that then captured heat) once covering these beds.

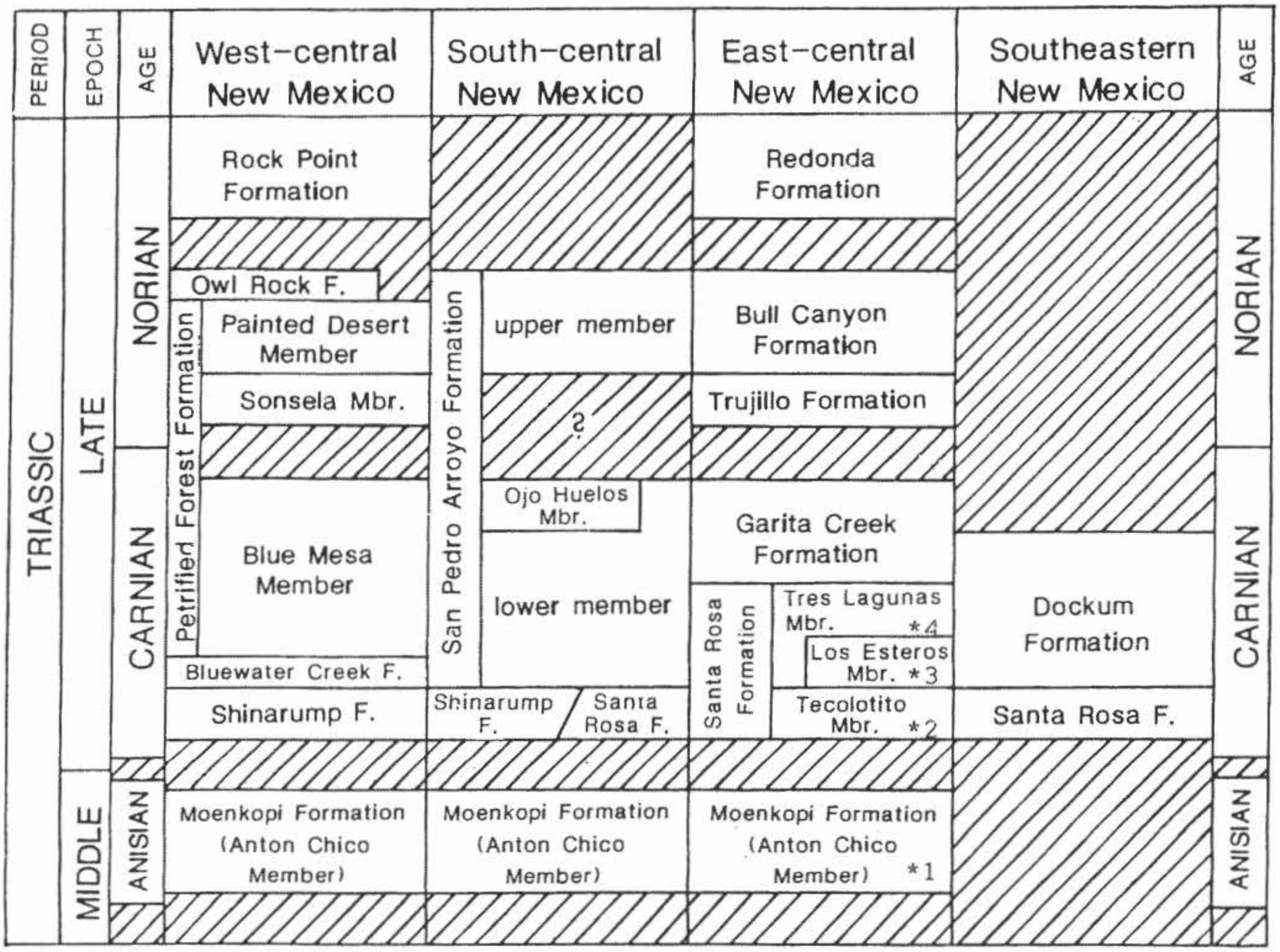

FIGURE 3. Triassic formation chart from Lucas (1991). * Unit numbers from Gorman and Robeck (1946).

RESULTS OF STUDY

Middle Permian stratigraphy

Stromatolites near the top of the Permian Bernal Formation-Artesia Group were found southward 160 km from the Aurora stratigraphic section location to the Fort Stanton outcrop. They extend eastward from the Barnham exposure about 100 km to near the Salado outcrop.

A continuous very fine-grained sandstone bed under the stromatolites can be traced along outcrops eastward from Aurora 40 km to the east of Colonias in the Pecos River canyon. The same sequence can be seen in the Pintada drainage, west of Santa Rosa, for 40 km, and at the West Salado measured section, 32 km southwest of Santa Rosa. The same sandstone unit was tentatively identified, although stromatolites were missing above it, in the Pecos River exposures southeast of Santa Rosa 10 km to the Puerta de Luna measured section. Other upper, very fine-grained sandstone beds were observed in local outcrops to the west and south but are less reliable markers.

Middle Triassic stratigraphy

As proposed by Lucas (1991), Unit 1 of Gorman and Robeck (1946) (his Anton Chico Member of the Moenkopi Formation) can be found in the entire study area. I also agree that the base of the Anton Chico is usually the first gray-red sandstone overlying the typically red-brown, finer-grained Bernal Formation, except where the latter is missing at Tejon.

However, I would place the upper limit of the Anton Chico below the first chert-bearing conglomerate, apparently occurring everywhere in the study area except at his Sevilleta Grant section and at the Derramadero outcrop of my study. It took some lateral tracing at the Sevilleta outcrop, located 8 km south of his section, to find chert clasts in what was the "usual" gray-red conglomerate of the Anton Chico. His unit 10 conglomerate of the Anton Chico occurs upsection from the Bernal at approximately the same level (within 6 m) as at my Sevilleta section and may correlate. This would reduce his measured thickness of the Anton Chico to 31 m, more typical of the member in central and east-central New Mexico. If the lowest chert conglomerate in the Bull Gap N sec-

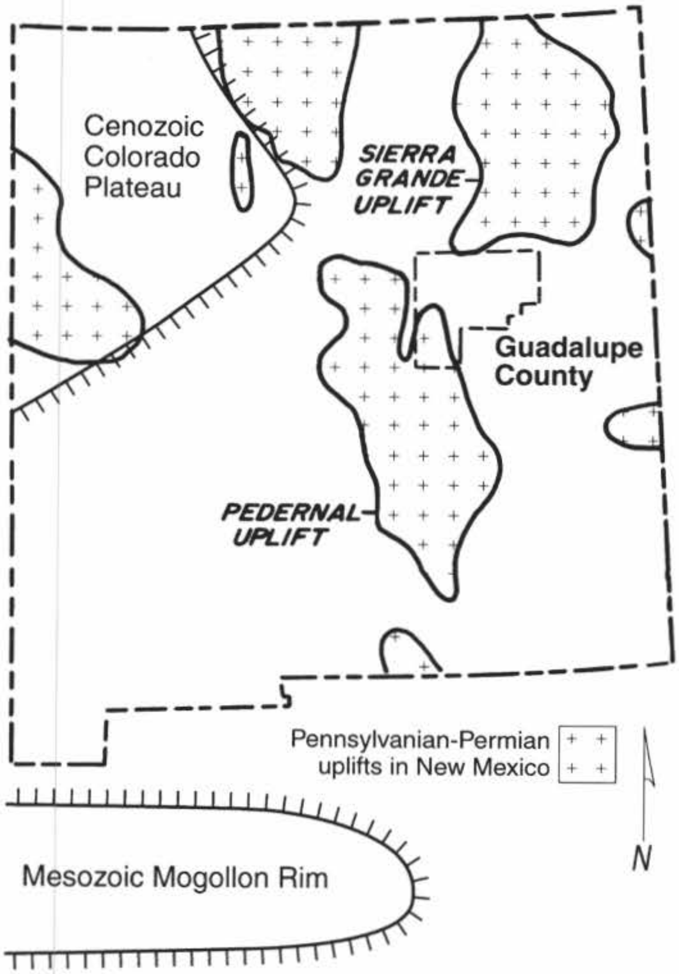

FIGURE 4. Selected tectonic features in and south of New Mexico.

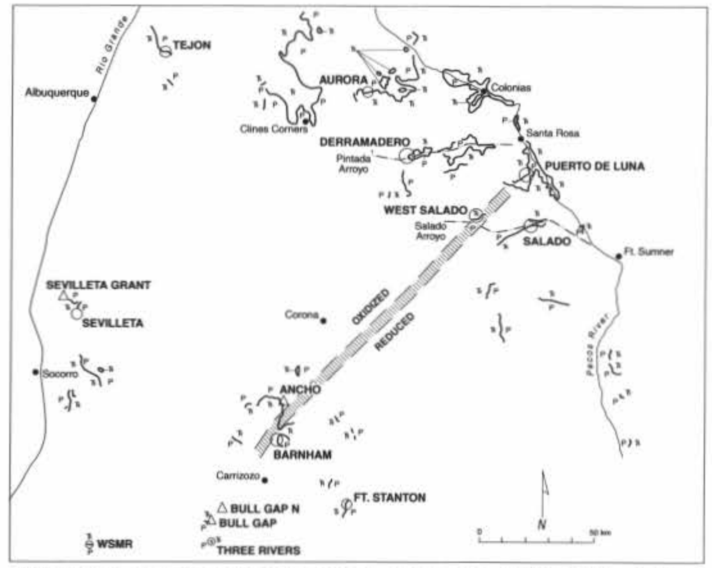

FIGURE 5. Permian-Triassic contact exposures, stratigraphic sections mentioned in this report. Triangles- Lucas (1991). Circles- this study.

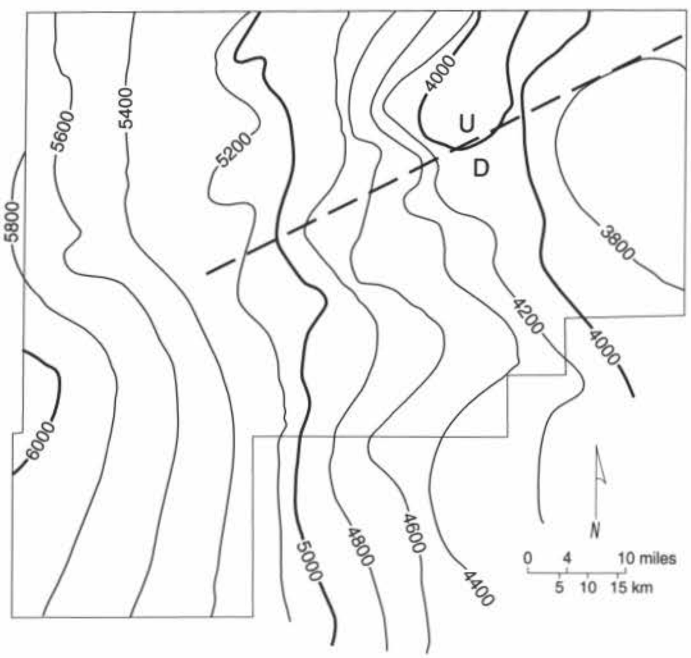

FIGURE 6. Structure-contour map of the Permian-Triassic contact in Guadalupe County and adjacent areas. Contour interval 200 feet (61 m).

tion is used as the same marker, it would make Lucas' Anton Chico 62 m thick, much more reasonable than the 101 m measured. The only other explanations would be a nearby active fault or sinkhole during Anton Chico deposition.

The chert conglomerate marks the base of Unit 2 of Gorman and Robeck (1946), which Lucas (1991) called the Tecolotito Member of the Santa Rosa Formation in east-central New Mexico and which he correlated with the Shinarump Formation to the west. I agree with this deignation and think that the term "Shinarump" should be used throughout the region for the lower chert conglomerate. My southernmost sections, WSMR, Three Rivers, and Fort Stanton, had by far the largest chert clast sizes, indicating a southerly source. I do not understand how 8 cm clasts got to Lucas' (1991) Ancho location.

A notable point is that the Anton Chico does not vary much in thickness throughout east-central and central New Mexico, roughly averaging 24 m. The maximum is at Lucas' (1991) Bull Gap N and Bull Gap (50 m at the latter) sections. The thinnest is at WSMR (3 m) and Three Rivers (6 m). This suggests that the Shinarump was deposited on a fairly level surface in the study area.

The Unit 3 shale of Gorman and Robeck (1946) (Los Esteros Member of the Santa Rosa Formation (Lucas 1991)) can be identified in all of east-central and central New Mexico where outcrop or drill hole data are available. The characteristic features are local mottling, calcareous nodules, bentonite, gypsum, and thin limestone interbeds. It is also varicolored and can contain a considerable amount of sandstone. Lucas' (1991) correlations of the Los Esteros and Tres Lagunas (Unit 4 of Gorman and Robeck (1946)) Members of the Santa Rosa Formation in east-central New Mexico westward with the lower San Pedro Formation then the lower Petrified Forest Formation are beyond the scope of this paper.

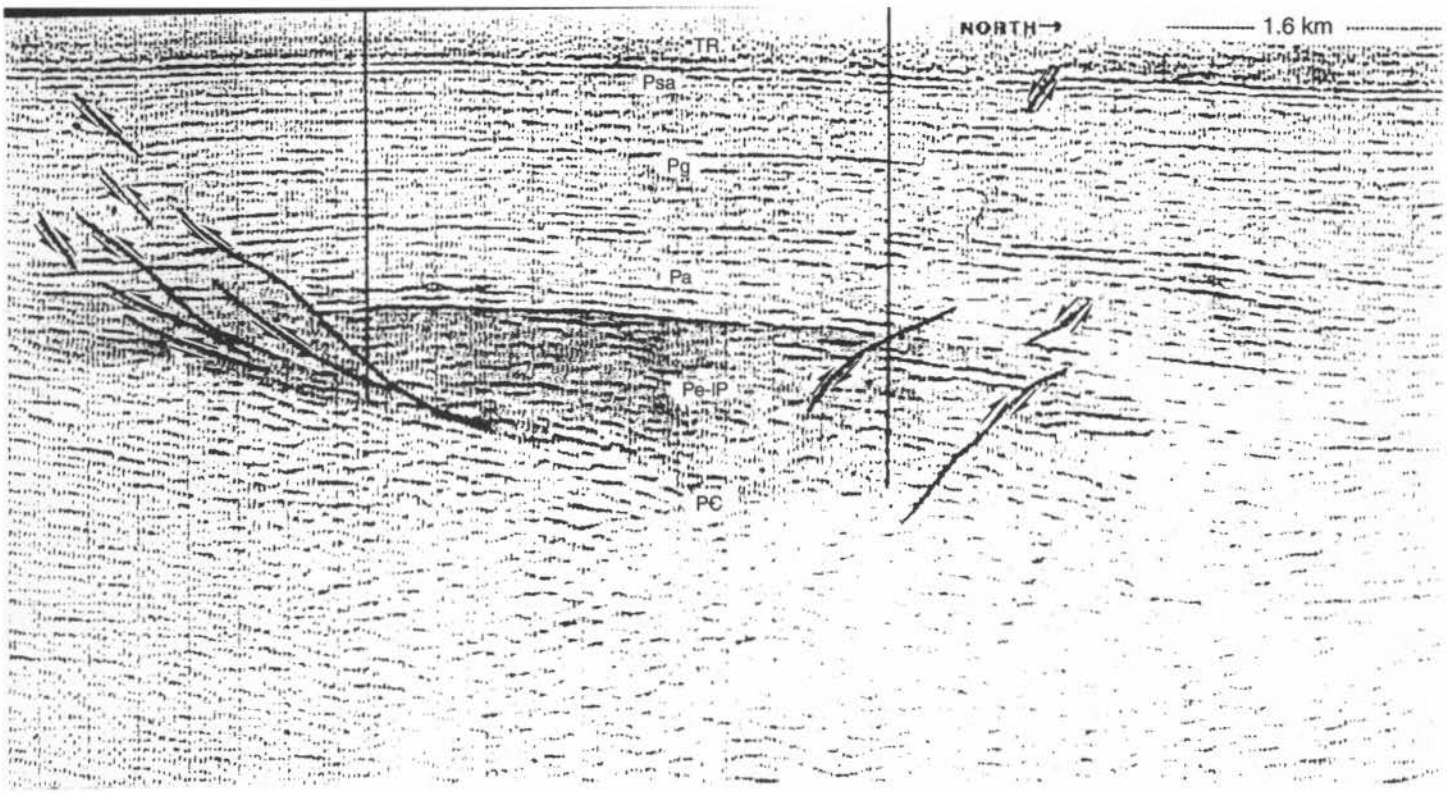

FIGURE 7. Seismic section of thrust faults in Guadalupe County. TR- Triassic; Psa- San Andres Formation; Pg- Glorieta Sandstone; Pa- Abo Formation; Pe-lP- Pennsylvanian-lower Permian. PC- Precambrian.

Oxidation-reduction front

Middle Permian and Middle Triassic strata are generally oxidized in east-central and central New Mexico. Exceptions occur at various southeasterly locations in the study area where the Bernal Formation and the Anton Chico are reduced. A northeast-southwest bar (Fig. 5) denotes where this front is projected. In Salado Arroyo just west of the West Salado section the lateral change from oxidized to the northwest to reduced to the southeast is exposed.

Permian-Triassic boundary surface

The main influences on the Permian-Triassic boundary in Guadalupe County (Fig. 6) are the resurgent north-south trending Pedernal arch to the west and northeast-oriented Sierra Grande arch to the north. A suspected fault was deduced from converging contours and follows the margin of the Sierra Grande arch.

Thrust faults

The fault mentioned just above is situated in the vicinity of a northeast-southwest belt of thrust faults that can be seen on seismic sections (Fig. 7) (Maier, 1987). They are southeast-vergent, and appear to be products of Laramide compression from the west that reactivated basement-cored faults.

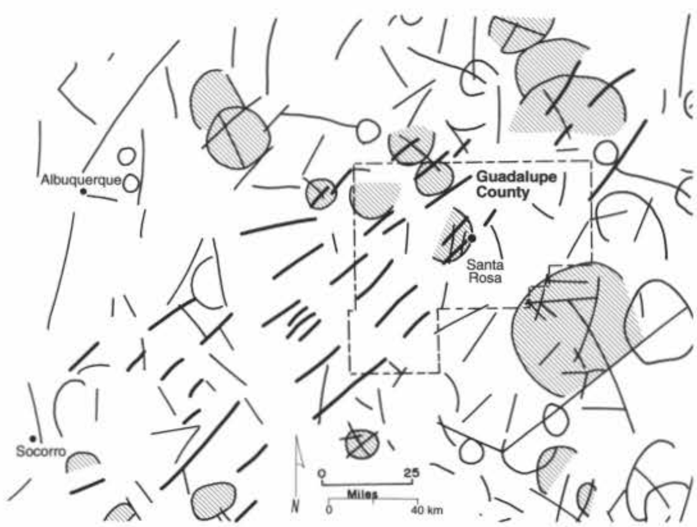

FIGURE 8. Lineaments and circular features from HCMM image. Darkened lines show prominent northeast-trending lineament zone. Hachures show sinks areally controlled by northeast-oriented lineaments.

Lineaments and circles

Recognizing regional-scale lineaments was best achieved by using relatively low resolution HCMM thermal infrared imagery. A major lineament extends northeast-southwest for 250 km across the study area (Fig. 8), paralleling other west-central U.S. long lineaments (Fig. 9). It is in an n=2 zone, described by the formula

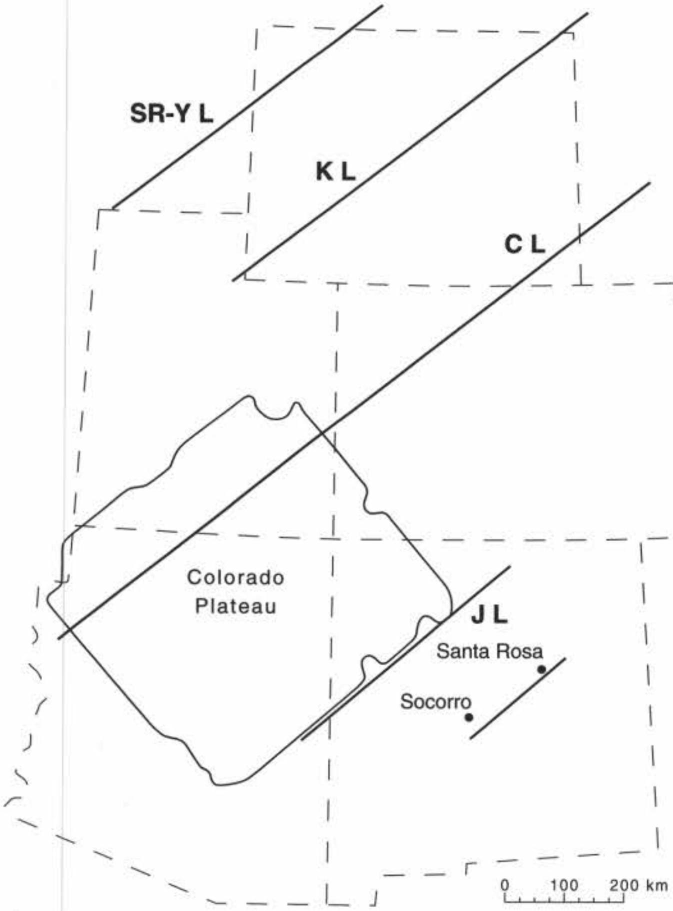

FIGURE 9. Mapped northeast-oriented lineaments in west-central U.S. from Maughan and Perry (1988) and Aldrich et al. (1986) (Jemez Lineament). Paralleling HCMM lineament zone in east-central and central New Mexico. SR-Y L- Snake River-Yellowstone Lineament; K L-Kaycee Lineament; C L- Colorado Lineament; J L- Jemez Lineament.

x/2 with x being 500 km for North America (Maier, 1993).

Sinks occur at the intersections of mostly northeast-trending lineaments (following generally the strike of the beds) and updip-trending lineaments to the north and northwest. Their areas are confined by the lengths of northeast-oriented lineaments and this phenomenon can be seen at variable scales, including that of aerial photography and Landsat and HCMM images (Fig. 8).

Thermal alteration indices

That thick deposits once overlaid Middle Permian and Middle Triassic strata in east-central and central New Mexico is indicated by elevated thermal alteration values that were found. The minimum thickness of these former beds can be estimated by application of formulas Pigott (1985) proposed:

$$T=164.4-19.39 \ln t$$
$$=164.4-19.39 \ln (250)$$
$$=57.54\ C$$
$$Doc=100\ ((T-Ts)/dt/dZ)$$
$$=100\ ((57.54-20)/3)$$
$$=4129 \text{ feet } (1228 \text{ m})$$

T is the threshold temperature at which organic matter will decompose to form hydrocarbons; t is the age of the bed in 10 years; Doc is the depth of the oil ceiling; Ts is the mean surface temperature; and dt/dZ is the thermal gradient.

Thermal alteration values of three or more were found in the palynological samples from east-central and central New Mexico that were processed (Dr. Cornell, personal communication) This suggests that the threshold temperatures had been reached (Waples, 1980). The Doc of 1230 m implies a major basin of deposition in this region. Presumably, this was during the Early Tertiary and/or Late Cretaceous.

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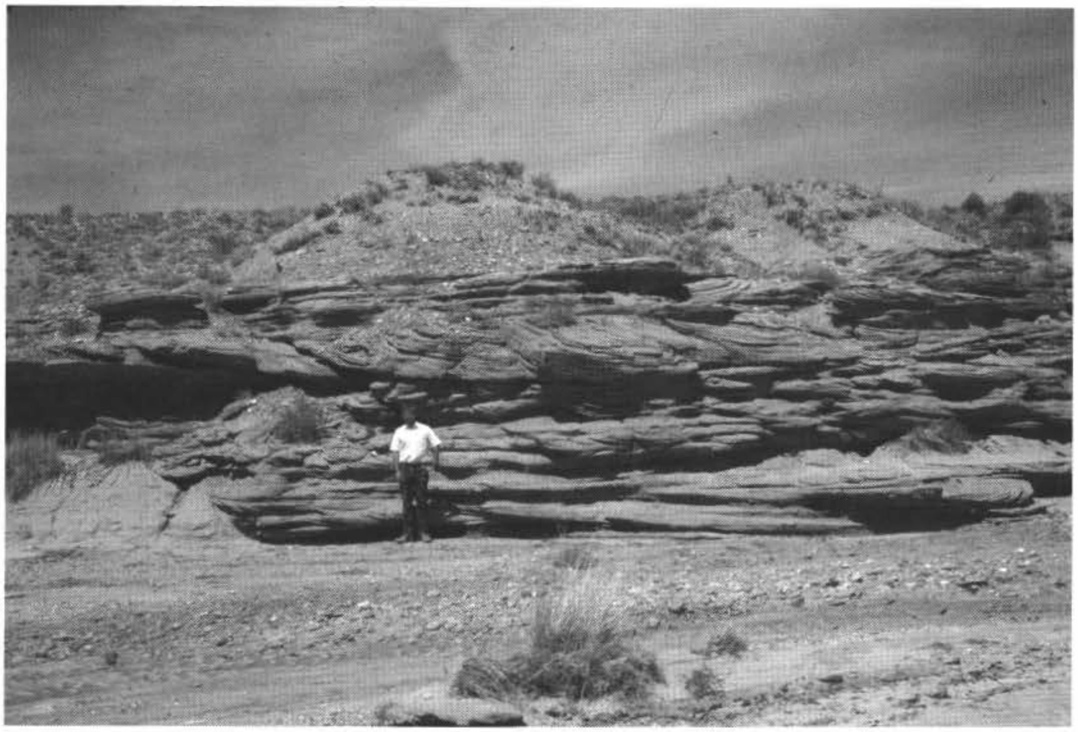

At Revuelto Creek in Quay County, New Mexico, trough-crossbedded sandstones and conglomerates of the Trujillo Formation of the Chinle Group are well exposed. Paleocurrent azimuths measured in these strata indicate westerly and northwesterly flow of large, Late Triassic rivers that crossed West Texas and New Mexico toward a Pangean shoreline that lay near the present Utah-Nevada border.