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CORRELATION OF TRIASSIC STRATA ACROSS THE RIO GRANDE RIFT, NORTH-CENTRAL NEW MEXICO

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Abstract—Middle Triassic strata of the Moenkopi Formation and Upper Triassic strata of the Chinle Group are correlated from the Colorado Plateau eastward across the northern Rio Grande rift to the southern High Plains of eastern New Mexico. This correlation demonstrates the continuity of Middle and Late Triassic deposition across northern New Mexico and significant (tens of meters of) stratigraphic relief on the Tr-1, Tr-3, and J-2 unconformities. Relatively little regional stratigraphic relief on the Tr-4 unconformity is consistent with previous interpretations that suggest that it is an intrabasinal unconformity that represents a relatively brief temporal hiatus in deposition.

INTRODUCTION

Upper Triassic strata are exposed across northern New Mexico and are often considered to represent deposition in two separate basins, a Chinle basin to the west (Colorado Plateau) and a Dockum basin to the east (southern High Plains) (e.g., Finch and Wright, 1983; Lehman, 1994). Furthermore, it was long believed that no older Middle or Lower Triassic strata were present in the state (McKee, 1954). Recent studies, however, demonstrate that these two concepts are incorrect—there was continuity of deposition of Middle and of Upper Triassic strata across northern New Mexico (Lucas, 1991, 1993, 1995). Here, we present a correlation of Triassic strata across the northern part of the state (Figs. 1–2) and discuss its implications for the identification and interpretation of regional Triassic unconformities.

FORT WINGATE

Triassic strata in the Fort Wingate area of McKinley County (T14N, R16W) have been most recently described by Lucas and Hayden (1989), Heckert and Lucas (1996), and Lucas et al. (1997). With one exception, the Triassic section here well represents the Triassic strata exposed across southern McKinley and Cibola counties, from Gallup to Grants (also see Repenning et al., 1969; Stewart et al., 1972).

Triassic strata on the Fort Wingate quadrangle (Fig. 2) are (ascending): (1) Anton Chico Member of Moenkopi Formation, as much as 20 m of dominantly grayish-red, trough-crossbedded litharenite that rests with marked disconformity on the Permian San Andres or Glorieta formations; (2) "mottled strata" and Shinarump Formation, as much as 22 m of biogenically and pedogenically modified siltstones, sandstones and conglomerates ("mottled strata") or about 4 m of yellowish-gray, trough- and planar-crossbedded quartzose sandstone and silica-pebble (mostly quartzite and jasper) conglomerate (Shinarump Formation); (3) Bluewater Creek Formation, as much as 60 m of red-bed sandstone, siltstone and mudstone; a 4- to 12-m-thick persistent bed of sandstone in the middle of the Bluewater Creek Formation is the McGaffey Member (Anderson and Lucas, 1993); (4) Blue Mesa Member of Petrified Forest Formation, as much as 43 m of mostly purple and greenish-gray smectitic mudstone; (5) Sonsela Member of Petrified Forest Formation, as much as 24 m of light-gray to yellowish-brown, fine-grained-to-conglomeratic, crossbedded sandstone with locally abundant fossil logs; (6) Painted Desert Member of Petrified Forest Formation, as much as 180 m thick and mostly reddish-brown and grayish red, smectitic mudstone with minor beds of resistant, laminated or crossbedded micaceous litharenite; a persistent, 4-m-thick sandstone interval in about the middle of the unit is the Perea Sandstone Bed of Cooley (1957; formalized by Lucas et al., 1997); and (7) Owl Rock Formation, as much as 22 m of laterally persistent beds of pale-red and pale-reddish-brown calcareous siltstone, and light-greenish-gray limestone and nodular limestone, disconformably overlain by the Middle Jurassic Entrada Sandstone.

The one exception to the Triassic section at Fort Wingate represening the Triassic section across much of west-central New Mexico is the apparent absence of one important unit—Rock Point Formation at the top of the Chinle Group. The Rock Point Formation is only locally exposed across west-central New Mexico. A particularly thick section

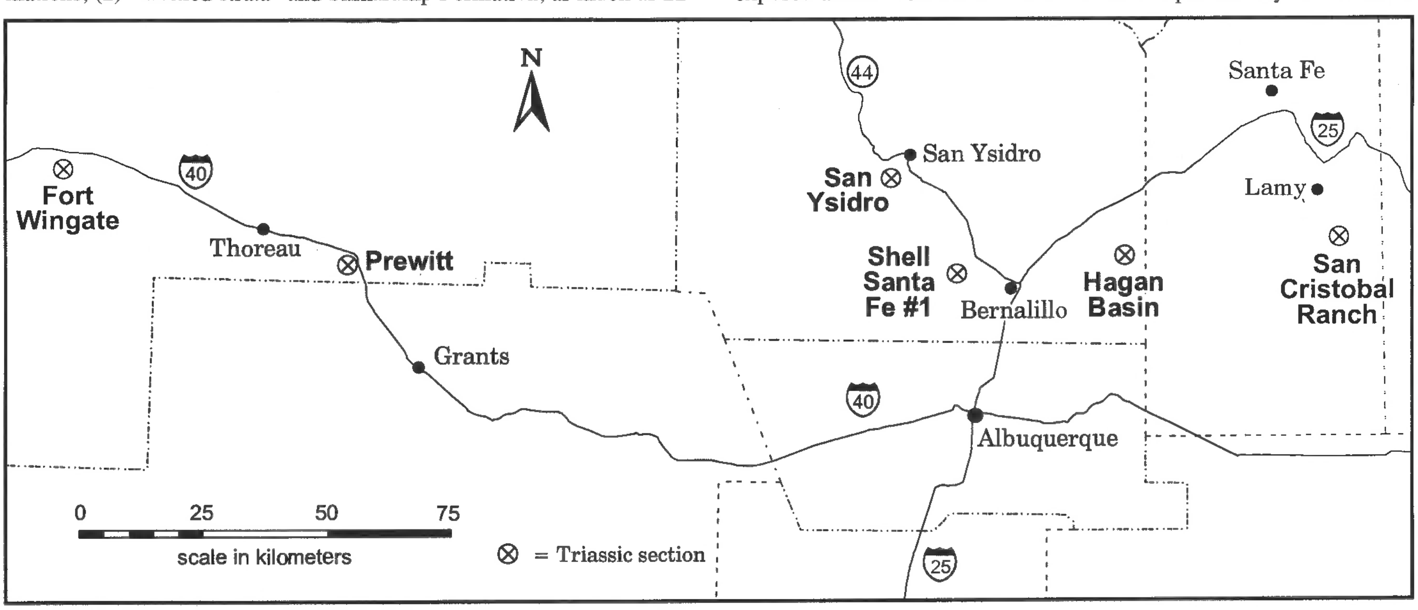

FIGURE 1. Index map of part of New Mexico showing locations of sections discussed in the text.

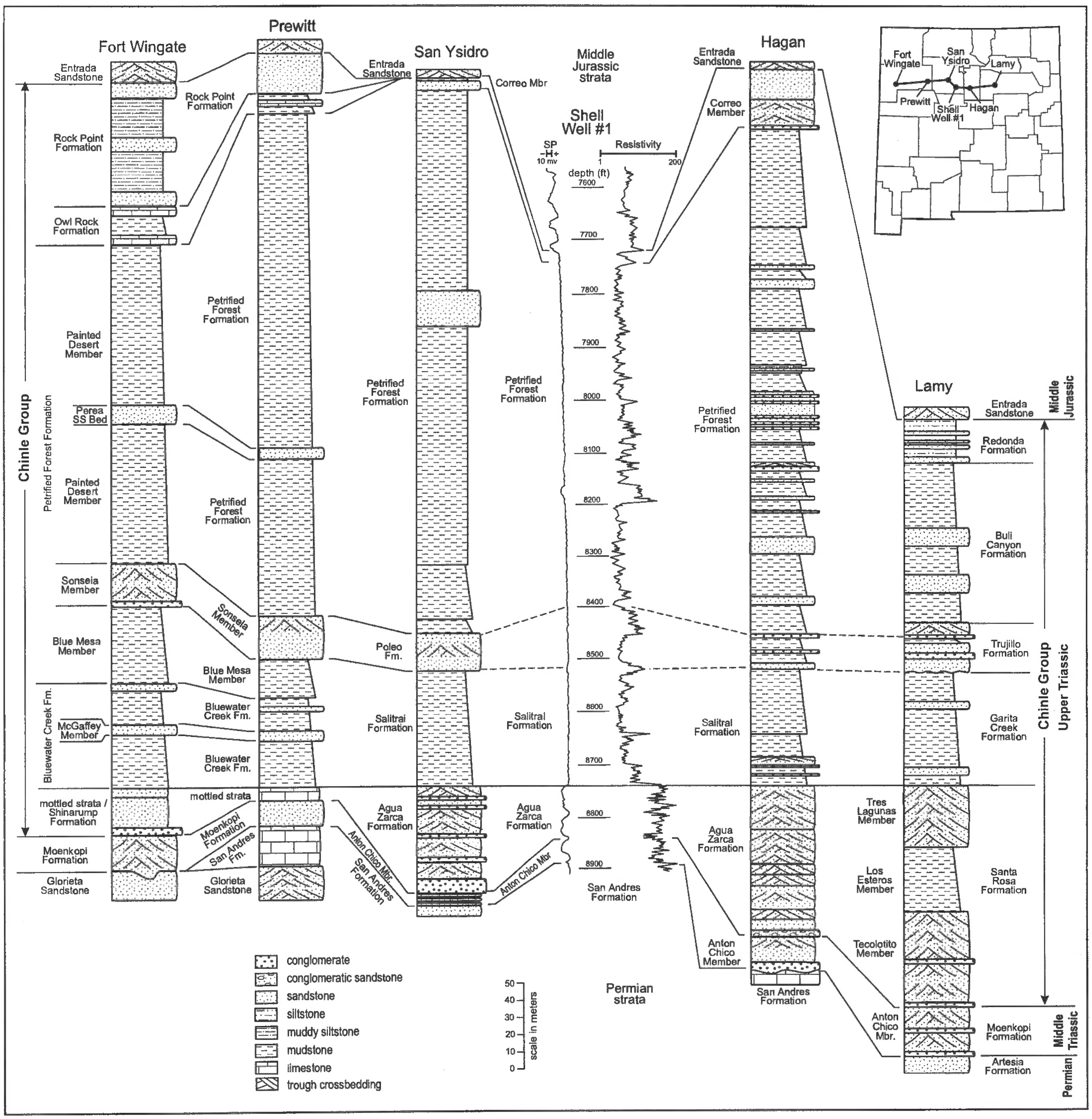

FIGURE 2. Correlation of Triassic sections from Fort Wingate to Lamy.

of the Rock Point Formation is at Petaca Pinta in Cibola County (T6N, R6W), where the unit is 69 m thick and consists of repetitively interbedded, laterally persistent sandy siltstone and silty sandstone (Lucas and Heckert, 1994). For the sake of completeness, we add the Rock Point Formation to the top of the Triassic column from Fort Wingate (Fig. 2), and further discuss this interval in the following section.

PREWITT

Triassic outcrop across the Zuni Mountains is nearly continuous and readily traceable from Fort Wingate eastward to the vicinity of Prewitt. Here, the Triassic System has been most recently described by Stewart et al. (1972), Lucas and Hayden (1989), and Heckert (1997a). The section here is very similar to that at Fort Wingate, with some thickness variation.

A transect from near Bluewater Creek (T13N, R12W) northward crosses the following Triassic units (ascending): (1) Anton Chico Member of the Moenkopi Formation, as much as 15 m of primarily grayish red, trough-crossbedded, ledgy litharenite with minor conglomerate and siltstone; (2) "mottled strata" and Shinarump Formation, as much as 7.6 m of biogenically and pedogenically modified calcareous sandstones and conglomerates (mottled strata) or thin lenses of gray coarse-grained to conglomeratic sandstone and conglomerate (Shinarump Formation); (3) Bluewater Creek Formation, 50–60 m of red-bed mudstone, sandstone, and siltstone; a 5- to 20-m-thick, laterally persistent, bench-forming sandstone in the mid- to upper part of the formation is an eastward extension of the McGaffey Member; (4) Blue Mesa Member of the Petrified Forest Formation, which is as much as 22 m of grayish purple, pale purple, and olive gray bentonitic mudstone with olive-gray sideritic nodules; (5) Sonsela Member of the Petrified Forest Formation, as much as 25 m of yellowish gray to very pale orange quartzarenite and conglomerate with locally abundant petrified wood; (6) Painted Desert Member of the Petrified Forest Formation, as much as 291 m of red-bed mudstone, sandstone, and siltstone with minor conglomerate; (7) Owl Rock Formation, approximately 9–10 m of interbedded pale red-purple siltstone and limestone; (8) Rock Point Formation, nearly 25 m of light brown to reddish orange sandstone interbedded with siltstone and thin stringers of conglomerate.

The most notable aspects of this section relative to that at Fort Wingate are the thinning of the Blue Mesa Member and the much thicker Painted Desert Member. The thinning of the Blue Mesa Member from as much as 44 m near Fort Wingate to 22 m at Prewitt appears to be the result of differential erosion during development of the Tr-4 unconformity (Heckert and Lucas, 1996). The thickening of the Painted Desert Member is more problematic, as the largely covered strike valley between the Sonsela hogback to the south and low badlands to the north prevents accurate measurements. Here, we have relied on the Chavez–Prewitt 1B section of Stewart et al. (1972) to estimate this thickness. However, we note the nearly uniform thickness of the Owl Rock Formation from Fort Wingate (22 m) to Prewitt (25 m) and suggest that this is probably a result of slow deposition and extensive pedogenic modification in a largely stable landscape.

The uppermost Triassic strata from Fort Wingate to Prewitt are, as noted earlier, somewhat problematic. It is widely accepted that the top of the Owl Rock Formation in this area is bounded by an erosional surface, but the reddish orange sandstones and siltstones overlying that surface have variously been called the Wingate Sandstone (Harshbarger et al., 1957; Stewart et al., 1972), the Rock Point Member (= Lukachukai Member of Wingate Sandstone) (Stewart et al., 1972), or even a member of the Entrada, the Iyanbito Member of Green (1974). As noted by Heckert and Lucas (1998), this issue is complex, and here, we restrict our discussion to the following points: (1) the Owl Rock Formation is overlain by strata of Late Triassic age in this area; (2) this interval corresponds to at least parts of the Rock Point-Wingate lithosome; (3) the exact stratigraphic relationships of this (these) unit(s) are difficult to ascertain; and (4) these strata are in turn overlain by the Dewey Bridge (= "medial silty") Member of the Entrada (Lucas and Heckert, 1998).

SAN YSIDRO

Stewart et al. (1972), Woodward (1987), Lucas and Hunt (1992), and Lucas and Heckert (1996) most recently described the Triassic section around San Ysidro on the eastern edge of the Colorado Plateau. The Triassic section (ascending) is: (1) Anton Chico Member of Moenkopi Formation, as much as 39 m of mostly grayish-red sandstone, intraformational conglomerate and mudstone; (2) Agua Zarca Formation of the Chinle Group, as much as 61 m of trough-crossbedded sandstone and siliceous conglomerate; (3) Salitral Formation of the Chinle Group, as much as 102 m of mostly purple, blue and red smectitic mudstone; (4) Poleo Formation, less than 10 m thick near San Ysidro (but as much as 40 m thick northward toward Cuba) and mostly trough-crossbedded sandstone and intraformational conglomerate; and (5) Painted Desert Member of Petrified Forest Formation, as much as 340 m thick and dominated by reddish-brown, smectitic mudstone; it includes the Correo Bed at its top, as much as 15 m of bench-forming litharenite and intraformational conglomerate (Fig. 2). No Owl Rock, Rock Point or Wingate strata are present here, and the presence of the Dewey Bridge Member of the Entrada indicates that substantial erosional relief (>100 m) developed beneath the surface corresponding to the J-2 unconformity.

SHELL OIL, SANTA FE NO. 1 WELL

From the Triassic outcrops on the eastern edge of the Colorado Plateau near San Ysidro to the Triassic outcrops in the Rio Grande rift—in the Hagan basin—there is a distance of more than 50 km covered by younger strata (Fig. 1). To aid in correlation across this gap, we selected a subsurface section about midway between the Colorado Plateau edge and the Hagan basin. This is the geophysical log of the Shell Oil Santa Fe No. 1 well in sec. 18, T13N, R3E (Black and Hiss, 1974). Interpretations of the log of this well by Black and Hiss (1974) and by us (Fig. 2) suggest that the well penetrated a Triassic section similar to that exposed near San Ysidro (also see Lucas, 1991).

In the well, the Entrada rests directly on the Correo Bed of the Petrified Forest Formation at a depth of about 7727 ft. A thick, mudrock-dominated section from 7727 to 8738 ft (1011 ft = 308 m) is assigned by us to the Petrified Forest Formation. Like Black and Hiss (1974), we pick the base of the Triassic section (contact with the underlying Permian San Andres Formation) at 8875 ft, so that the combined thickness of the sandstone-dominated Agua Zarca and Moenkopi formations is 137 ft (42 m). Probably, the lower 35 ft (11 m) (from 8840 to 8875 ft) of this interval are Moenkopi Formation (Fig. 2; Lucas, 1991). Whether or not a thin Poleo Formation interval is indicated in the log at about 8520 ft depth is not clear. In any case, the log of the Shell Santa Fe No. 1 well indicates a Triassic section very similar to that exposed at San Ysidro.

HAGAN BASIN

Lucas (1991) and Lucas and Heckert (1995) most recently described the Triassic section in the Hagan basin of Sandoval County. This section (ascending) is: (1) Anton Chico Member of Moenkopi Formation, about 20 m of pale-red trough-crossbedded litharenite and siltstone; (2) Agua Zarca Formation, as much as 108 m of mostly gray and yellowish gray, trough-crossbedded sandstone and siliceous conglomerate; (3) Salitral Formation, as much as 92 m of mostly gray and purple mudstone and minor intraformational conglomerate; (4) Petrified Forest Formation, 261 m of mostly grayish red and reddish brown mudstone with numerous thin beds of litharenitic sandstone and intraformational conglomerate; and (5) Correo Member of Petrified Forest Formation, as much as 37 m of crossbedded litharenite and intraformational conglomerate (Fig. 2).

LAMY

To represent the Triassic strata on the southern High Plains, we present a composite section based on strata exposed in Santa Fe, Miguel and Guadalupe counties (Fig. 2). Lucas (1991) presented a composite Triassic section from the Lamy–Clines Corners area of Santa Fe and Torrance counties, but, based on regional thicknesses, we are convinced that parts of this section are depicted as too thin (Garita Creek and Bull Canyon formations), largely because of structural complications. Thus, the Triassic section we present for the western edge of the High Plains is that at Lamy, with the addition of Garita Creek and Bull Canyon Formation thicknesses from San Miguel and Guadalupe counties based on Lucas and Hunt (1989). It is (ascending): (1) Anton Chico Member of Moenkopi Formation, as much as 37 m of grayish red, trough-crossbedded litharenite and conglomerate; (2) Tecolotito Member of Santa Rosa Formation, trough crossbedded sandstones as much as 61 m thick; (3) Los Esteros Member of Santa Rosa Formation, variegated mudstones as much as 47 m thick; (4) Tres Lagunas Member of Santa Rosa Formation, as much as 62 m of trough-crossbedded sandstone; (5) Garita Creek Formation, as much as 71 m of mostly variegated red, green, blue, and gray mudstone with a few thin sandstones; (6) Trujillo Formation, as much as 40 m of trough-crossbedded sandstone and intrabasinal, limestone-pebble conglomerate; (7) Bull Canyon Formation, as much as 95 m of mostly reddish brown, bentonitic mudstone and a few ledge-forming sandstones; and (8) Redonda Formation, as much as 25 m of laterally persistent beds of moderately reddish brown, fine-grained sandstone, siltstone, and non-bentonitic mudstone (Fig. 2).

BIOSTRATIGRAPHY

The correlation of Triassic strata across northern New Mexico advocated here (Fig. 2) is made largely on a lithostratigraphic basis. However, biostratigraphy based on palynomorphs (Litwin et al., 1991), megafossil plants (Ash, 1980) and tetrapod vertebrates (Lucas and Hunt, 1993; Lucas, 1997, 1998) supports this correlation (Fig. 3). Here, we briefly review the paleontology of the sections correlated here and discuss its biostratigraphic significance.

Fort Wingate

Lucas et al. (1997) reviewed Triassic biostratigraphy from the Fort Wingate quadrangle. Here, palynomorphs and megafossil plants from the Bluewater Creek Formation indicate palynomorph zone II and the *Dinophyton* megafloral zone. Adamanian fossil vertebrates are found in the Bluewater Creek Formation at Fort Wingate (Heckert, 1997b).

San Ysidro

Lucas and Heckert (1996) summarized Triassic paleontology in the San Ysidro area. Adamanian fossil vertebrates occur here in the Salitral Formation, and Revueltian vertebrates are found in the Petrified Forest Formation.

Hagan basin

No fossils are known from the Shell Santa Fe No. 1 well. Triassic paleontology in the Hagan basin was reviewed by Lucas (1991) and Lucas and Heckert (1995). Fragmentary material suggests the *Dinophyton* megafloral zone may be present in the Agua Zarca Formation; probable Adamanian vertebrates are known from the Salitral Formation; and vertebrates from the Correo Member of the Petrified Forest Formation are Revueltian in age.

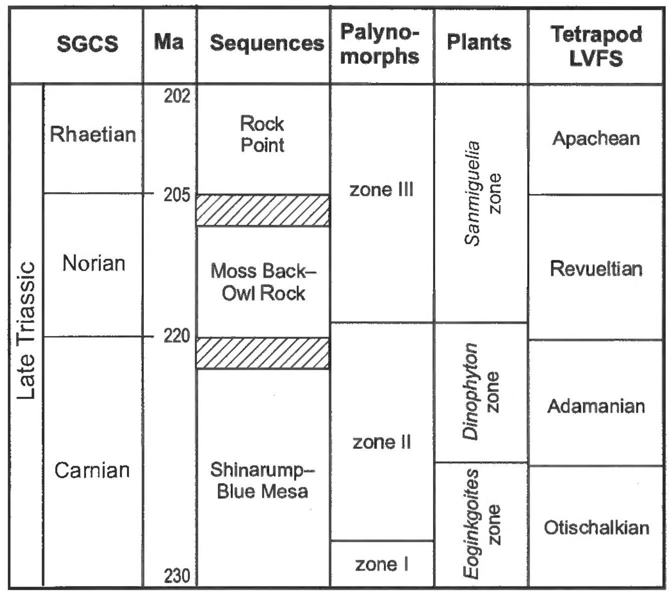

FIGURE 3. Synopsis of the biostratigraphy and biochronology of Chinle Group palynomorphs (Litwin et al., 1991), megafossil plants (Ash, 1980), and tetrapod land-vertebrate faunachrons (LVFs) (Lucas and Hunt, 1993; Lucas, 1998), and its relationship to the standard global chronostratigraphic scale (SGCS) (after Lucas, 1997).

Lamy

Lucas (1991) and Hunt and Lucas (1993, 1995) reviewed Triassic paleontology in the Lamy area. Adamanian vertebrates are known from

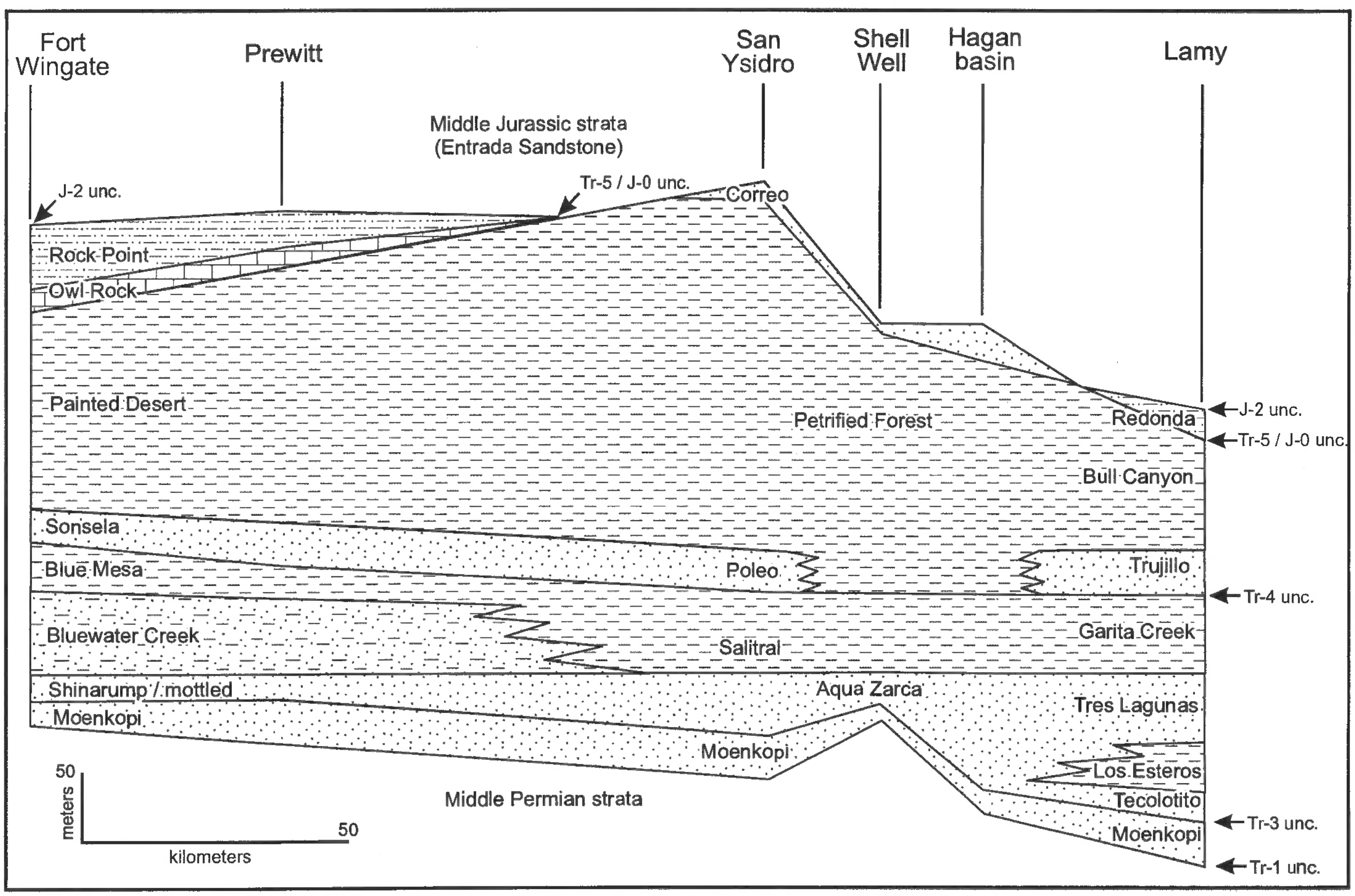

FIGURE 4. Restored cross section of Triassic strata from Fort Wingate to Lamy, New Mexico. See locations on Figure 1.

the Los Esteros and Tres Lagunas members of the Santa Rosa Formation, and from the Garita Creek Formation. Farther east, in Guadalupe and Quay counties, the *Dinophyton* megafloral zone is present in the Los Esteros Member, Revueltian vertebrates are known from the Trujillo and Bull Canyon formations, and Apachean vertebrates are known from the Redonda Formation (also see Lucas, 1993).

CORRELATION

Lithostratigraphic and biostratigraphic data provide the basis for a detailed correlation of Triassic strata from Fort Wingate to Lamy (Figs. 2, 4). This correlation demonstrates the continuity of many Triassic lithofacies from the Colorado Plateau eastward across the Rio Grande rift and onto the southern High Plains (also see Lucas, 1991). Important aspects of this correlation are:

1. Substantial (tens of meters of) stratigraphic relief exists across three pervasive unconformities: Tr-1, Tr-3 and J-2. These are tectonosequence boundaries that correspond to significant tectonic re-organizations of the Triassic–Jurassic depositional basins. Thus, the Tr-1 erosional surface represents the hiatus from Permian to Middle Triassic time (at least 10 million years) and is overlain by Moenkopi fluvial deposits. Tr-3 is the unconformity between early Middle Triassic (Moenkopi) and early Late Triassic (Chinle) rocks (about a 10-million-year hiatus), and this surface is overlain by initial fluvial deposits of the Chinle Group. J-2 is the erosional surface between latest Triassic and Middle Jurassic strata (about a 45-million-year hiatus) overlain by Entrada eolianites (Pipiringos and O'Sullivan, 1978).

2. Much less regional stratigraphic relief exists on the Tr-4 unconformity. This is consistent with the fact that the Tr-4 unconformity is an intrabasinal unconformity that represents a relatively short temporal hiatus close to the Carnian–Norian boundary (Heckert and Lucas, 1996).

3. The nature of the Tr-5 (= J-0) unconformity is difficult to evaluate using these data because in most of the sections the youngest Triassic strata pre-date the Tr-5 unconformity. Nonetheless, the varying thicknesses of the Painted Desert Member of the Petrified Forest Formation and its correlatives may in part be due to erosion beneath the Tr-5 unconformity.

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The collaboration of O. J. Anderson, S. Hayden, P. Huber, A. Hunt and K. Kietzke produced much of the data presented here. Reviews by O. J. Anderson and J. Lorenz improved the article.

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