New Mexico Geological Society

Downloaded from: https://nmgs.nmt.edu/publications/guidebooks/38



The Triassic System in the Dry Cimarron Valley, New Mexico

Spencer G. Lucas, A. P. Hunt, and Steven N. Hayden
1987, pp. 97-117. https://doi.org/10.56577/FFC-38.97

in:

Northeastern New Mexico, Lucas, S. G.; Hunt, A. P.; [eds.], New Mexico Geological Society 38 th Annual Fall Field Conference Guidebook, 354 p. https://doi.org/10.56577/FFC-38

This is one of many related papers that were included in the 1987 NMGS Fall Field Conference Guidebook.

Annual NMGS Fall Field Conference Guidebooks

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual Fall Field Conference that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

Free Downloads

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs*, *mini-papers*, and other selected content are available only in print for recent guidebooks.

Copyright Information

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.

This page is intentionally left blank to maintain order of facing pages.

THE TRIASSIC SYSTEM IN THE DRY CIMARRON VALLEY, NEW MEXICO, COLORADO AND OKLAHOMA

SPENCER G. LUCAS, ADRIAN P. HUNT and STEVEN N. HAYDEN
Department of Geology, University of New Mexico, Albuquerque, New Mexico 87131

Abstract—Triassic continental sediments exposed in the Dry Cimarron Valley pertain to the Baldy Hill (oldest), Travesser, Sloan Canyon and Sheep Pen formations. The Baldy Hill Formation is at least (its base is nowhere exposed) 37 m of yellowish orange and reddish brown, bioturbated, quartzose sandstone and siltstone capped by as much as 3 m of lithic- and limestone-cobble conglomerate here named the Cobert Canyon Sandstone Bed. The Baldy Hill Formation crops out both in New Mexico and Oklahoma (sec. 18, T5N, R6E) where the Cobert Canyon Sandstone Bed contains fossils of metoposaurid labyrinthodonts and phytosaurs indicative of a Late Triassic age. The Baldy Hill-Travesser contact is a disconformity, not the angular unconformity previously reported. The Travesser Formation is as much as 168 m of reddish brown, laminar and ripple-laminar, quartzose sandstone, siltstone and minor lithic conglomerate. The uppermost Travesser (not the Sloan Canyon as reported previously) produced the phytosaur skull Stovall and Savage (1939) described and contains other Late Triassic vertebrates and unionids. A marked color change to the yellowish green and greenish gray siltstone, sandstone and limestone of the Sloan Canyon Formation (as much as 41 m) marks the Travesser-Sloan Canyon contact. Abundant microvertebrates and reptilian footprints in the Sloan Canyon are of Late Triassic age. The Sloan Canyon-Sheep Pen contact is gradational, and the latter is as much as 33 m of yellowish orange, laminar, quartzose sandstone with a *Scoyenia*-facies ichnofauna. An angular unconformity separates the Triassic strata in the Dry Cimarron Valley from the overlying Middle Jurassic Entrada Sandstone. The Triassic strata in the Dry Cimarron are dominantly of lacustrine origin. They are of Late Triassic age, and probably transgress the Carnian-Norian boundary. Lithologic dissimilarity of the Dry Cimarron Triassic and the Triassic strata to the south in the Tucumcari and Palo Duro basins suggests Late Triassic deposition in a separate Dry Cimarron basin northeast of the Sierra Grande uplift and north of the Bravo dome.

INTRODUCTION

Triassic strata are well exposed in northeastern New Mexico in the Dry Cimarron Valley of Union County, and these exposures extend eastward into Cimarron County, Oklahoma and northward into Las Animas and Baca Counties, Colorado (Fig. 1). Usually these strata are regarded as little more than isolated outcrops of the Dockum Group. However, a local stratigraphic terminology has arisen for Triassic rocks of the Dry Cimarron Valley (Parker, 1933; Baldwin and Muehlberger, 1959), and little attempt has been made to relate these Triassic strata to equivalent rocks elsewhere.

In this paper, we reevaluate the Triassic lithostratigraphy of the Dry Cimarron Valley and present new biostratigraphic data for these rocks. We also discuss, in a preliminary way, the sedimentary petrology, sedimentology and taphonomy of these strata. Finally, a preliminary effort to correlate the Dry Cimarron Triassic with other Triassic strata is included.

PREVIOUS STUDIES

W. T. Lee (1902) first reported the thick sequence of "Red Beds" exposed in the Dry Cimarron Valley, but was uncertain of their age and tentatively regarded them as Triassic. Lee (1902), however, did name the cliff-forming sandstones above these "Red Beds" the Exeter Sandstone (Fig. 2).

Rothrock (1925), who worked only in Cimarron County, Oklahoma, recognized no Triassic strata in the Dry Cimarron Valley, but instead assigned these strata to the Morrison and Purgatoire formations (Fig. 2). Particularly important in Rothrock's decision were "variegated shales" of the Triassic Sloan Canyon Formation of later workers that he mistook for the variegated claystones that are typical of the Morrison Formation.

DeFord (1927, p. 754) pointed out Rothrock's (1925) error, assigning strata below Lee's Exeter Sandstone to "unnamed variegated shales" that are "probably Triassic in age" above "Triassic red beds" (Fig. 2). DeFord referred specifically to the angular unconformity between the Exeter Sandstone and underlying red beds in Union County, New Mexico to justify his assignment of the latter to the Triassic.

Despite this, Darton (1928, pp. 306–307, fig. 144) assigned the

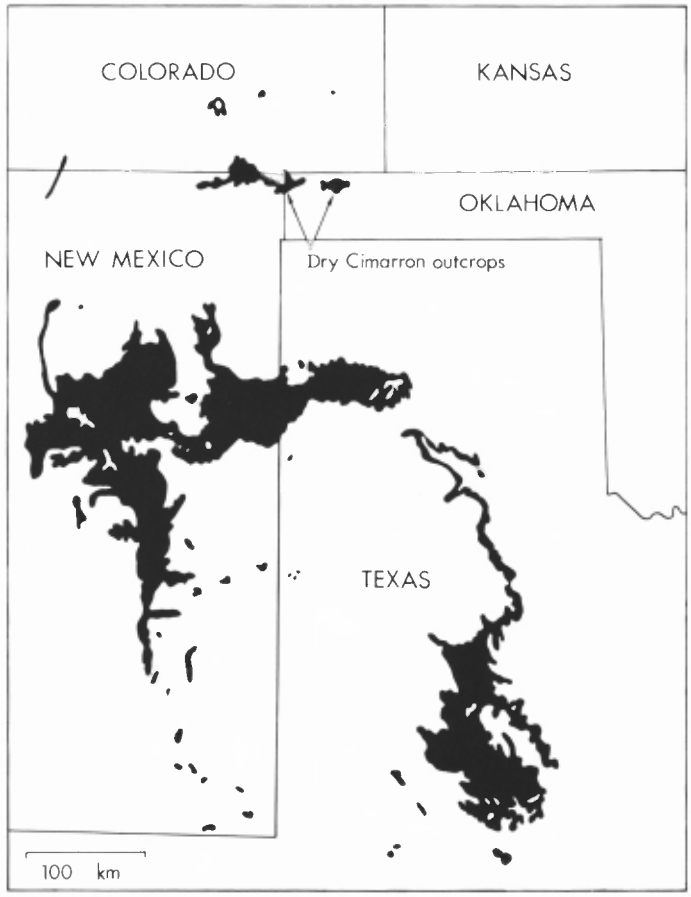


FIGURE 1. Outcrops of Triassic strata on the southern High Plains of the North American Western Interior and the location of the Dry Cimarron outcrops (after King and Beikman, 1974).

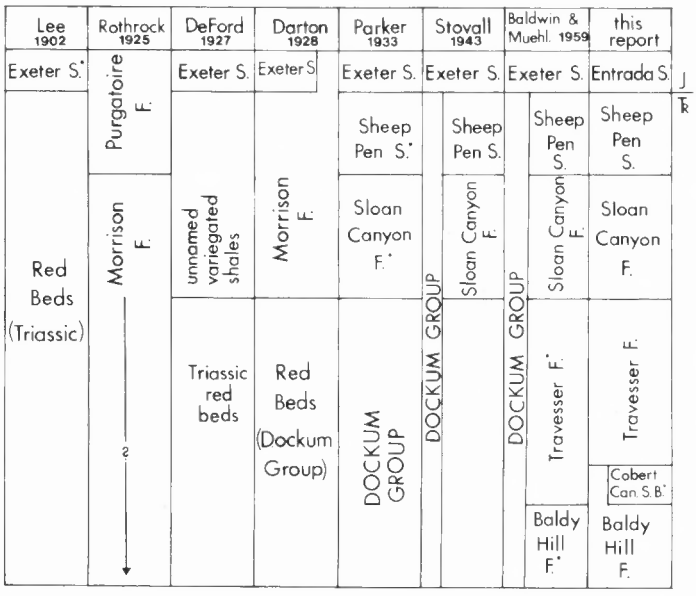


FIGURE 2. Stratigraphic nomenclature of Triassic rocks in the Dry Cimarron Valley used by previous workers compared with the nomenclature advocated in this paper. Asterisks (*) indicate first use of stratigraphic name.

"shales" (= Sloan Canyon Formation) beneath the Exeter to the Morrison Formation. The red beds beneath these "shales" were termed Dockum Group by Darton (Fig. 2).

Parker (1930, 1933) presented the first organized stratigraphy of the Triassic strata in the Dry Cimarron Valley (Fig. 2). Principally discussing the Wedding Cake Butte-Sloan Canyon area in Union County, New Mexico, Parker (1933) divided the Triassic strata into the Sheep Pen Sandstone, Sloan Canyon Formation and underlying red beds he referred to the Dockum Group. Parker (1933) assigned the Sheep Pen and Sloan Canyon to the Triassic because of the angular unconformity that separated them from the overlying Exeter Sandstone.

Stovall and Savage (1939) "confirmed" the Triassic age of Parker's Sloan Canyon Formation when they described a phytosaur skull collected on Sloan Creek, Union County, New Mexico from what they termed the Sloan Canyon (actually uppermost Travesser Formation in this report). Also, Heaton (1939) demonstrated the equivalence of Lee's (1902) Exeter Sandstone with the Jurassic Entrada Sandstone of Gilluly and Reeside (1928), thus resolving the debate about the age and stratigraphic position of the Exeter Sandstone started by Darton (1928), and further supporting the conclusion that the strata below the Exeter in the Dry Cimarron Valley are of Triassic age.

Stovall (1943), in his study of the stratigraphy of Cimarron County, Oklahoma, essentially used the stratigraphy of Parker (1930, 1933) for the Triassic rocks. However, Stovall (1943) did assign all Triassic strata in Cimarron County to the Dockum Group, although he did not recognize strata older than the Sloan Canyon Formation in Oklahoma (Fig. 2).

Baldwin and Muehlberger (1959), working in Union County, New Mexico, established the current nomenclature of Triassic strata in the Dry Cimarron Valley. Beneath the Sloan Canyon Formation, they divided the Triassic rocks, the oldest bedrock exposed along the Dry Cimarron, into the Travesser and Baldy Hill formations (Fig. 2).

The stratigraphic nomenclature we advocate for Triassic and contiguous rocks in the Dry Cimarron (Fig. 2) is only slightly modified from that of Baldwin and Muehlberger (1959). These modifications are: (1) use of the name Entrada Sandstone for the cliff-forming sandstones above the Triassic as justified by Lucas et al. (1985[b]); (2) redefinition of the Sloan Canyon-Travesser contact, a point upon which Baldwin and Muehlberger (1959) were uncertain; (3) recognition of the distinctive conglomeratic sandstone at the Travesser-Baldy Hill contact as the Cobert Canyon Sandstone Bed, and its inclusion in the Baldy Hill Formation, not in the Travesser Formation; and (4) rejection of use of the term Dockum Group in the Dry Cimarron Valley. The justification of these modifications in Baldwin and Muehlberger's (1959) stratigraphic terminology is presented below.

STRATIGRAPHY

We measured five stratigraphic sections of the Triassic strata exposed in the Dry Cimarron Valley and also reexamined 19 stratigraphic sections measured in these rocks by other workers (Figs. 3, 4; Appendix 1). Based on these data, we recognize the five rock-stratigraphic units of Triassic age discussed below.

Baldy Hill Formation

The oldest Triassic strata exposed in the Dry Cimarron Valley pertain to the Baldy Hill Formation of Baldwin and Muehlberger (1959, p. 37). Baldwin and Muehlberger (1959, p. 37) designated the type section of the Baldy Hill Formation in the SE¼ NE¼ NE¼, sec. 36, T32N, R32E "2,000 feet north of Baldy Hill," a prominent conical hill in the SE¼, sec. 36, T32N, R32E, Union County. Here they described the Baldy Hill as 115 ft (35 m) of:

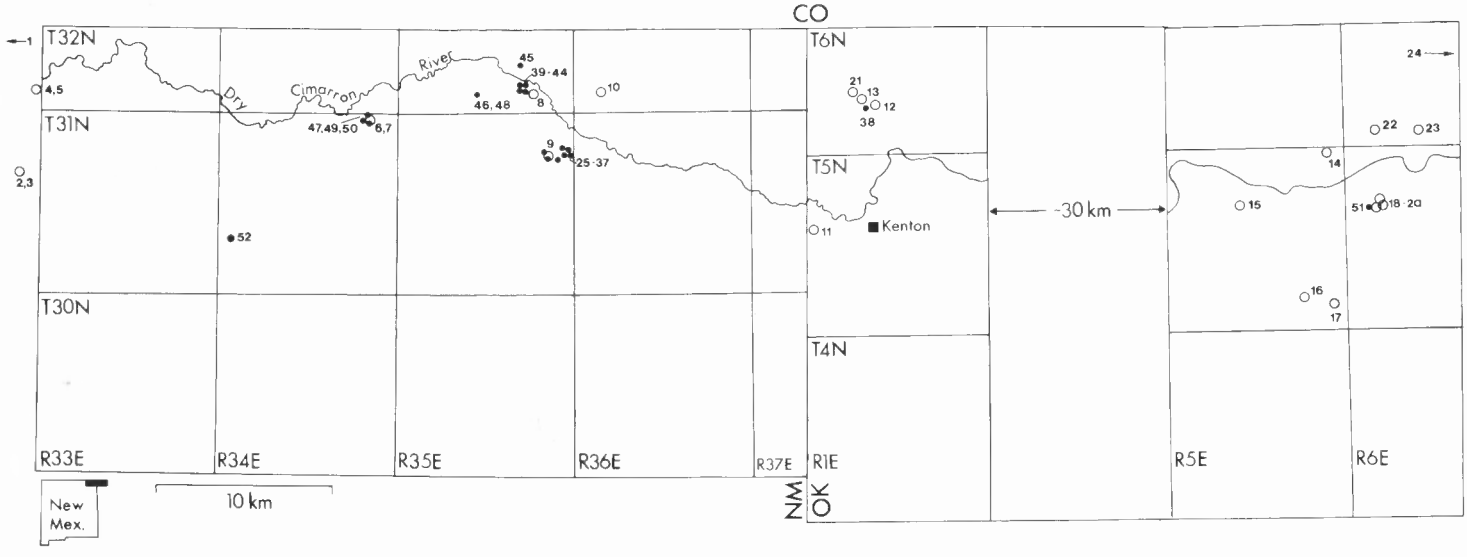


FIGURE 3. Control points (measured stratigraphic sections [open circles] and fossil localities [dots]) in the Triassic strata of the Dry Cimarron Valley (see Appendix 1 for list of and precise locations of numbered points).

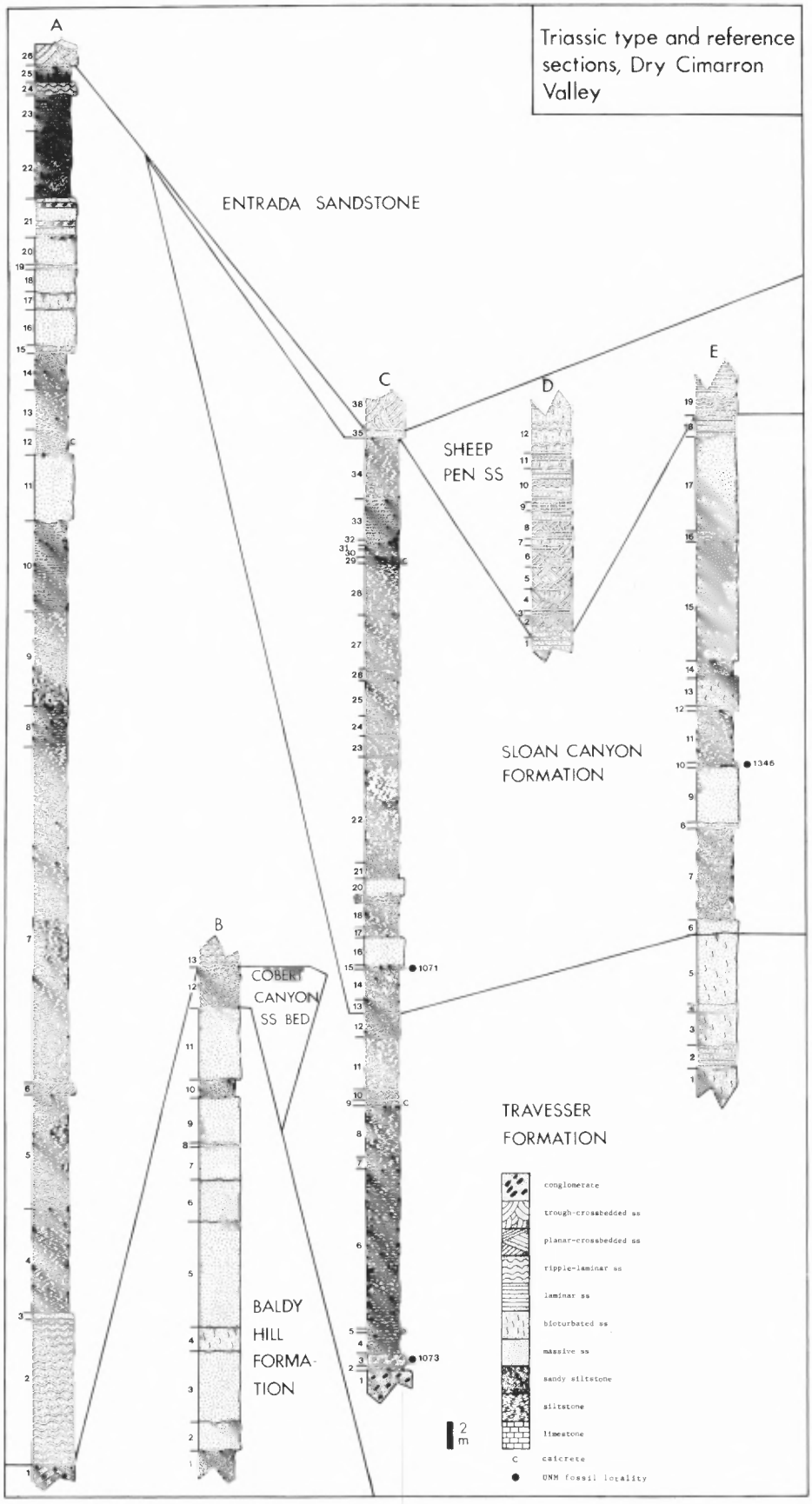


FIGURE 4. Measured stratigraphic sections of type and reference sections of Triassic rocks in the Dry Cimarron Valley (see Fig. 3 and Appendix 2 for locations of sections and lithologic descriptions of numbered units). A, Type section of Travesser Formation. B, Type section of Baldy Hill Formation and Cobert Canyon Sandstone Bed. C, Reference section of Sloan Canyon Formation. D, Type section of Sheep Pen Sandstone. E, Type section of Sloan Canyon Formation.

> . . . silty mudstone, with beds of ledge-forming sandy mudstone and very fine-grained sandstone. A 13-foot interval of claystone is present near the bottom of the section. The formation is characterized by its purple color, which mottles orange, gray red, light to medium gray, and light olive. Under the hand lens, angular white fragments can be seen in much of the purple mudstone. In some places, the interior of chips of purple mudstone is colored red brown. Nodules of red and yellow chalcedony, similar to the "agate bed" of the Morrison formation, and some silicified wood, are present about 15 feet below the top of the unit (Baldwin and Muehlberger, 1959, p. 37).

As Baldwin and Muehlberger (1959, p. 37) noted, the base of the Baldy Hill Formation is nowhere exposed in the Dry Cimarron Valley, and they placed the top of the formation as "the base of a pebbly sandstone that forms the persistent rim of a low bench."

We remeasured the type section of the Baldy Hill Formation in a narrow canyon that drains the northern slope of Baldy Hill (Figs. 4, 5A–D; Appendix 2). Here, we measured 36.8 m of the Baldy Hill, including 3.0 m of conglomeratic sandstone at its top which Baldwin and Muehlberger (1959) included in the overlying Travesser Formation. Contrary to Baldwin and Muehlberger's description, the Baldy Hill Formation at its type section lacks mudstone. Instead, it is dominantly silty sandstone (69%) with minor sandy siltstone (9%), sandstone (13%) and conglomeratic sandstone (8%). Dominant colors are pale red, grayish red and reddish purple. Sandstone is quartzose, very fine to fine grained and bioturbated to massive.

The contact between the Baldy Hill Formation and overlying Travesser Formation is marked by a conglomeratic sandstone as much as 3.0 m thick. This bed is a conglomerate of limestone and lithic cobbles in a matrix of medium- to coarse-grained subarkose (Fig. 5D). It thus contrasts markedly with the generally fine- to very fine-grained quartzarenites of the Baldy Hill and Travesser formations. Because of its lithologic distinctiveness we name this bed (Fig. 4, unit 12 of section B) the Cobert Canyon Sandstone Bed. The name is taken from Cobert Canyon, a northern tributary of the Dry Cimarron River immediately north of Baldy Hill in secs. 23 and 24, T32N, R32E, Union County, New Mexico. The type section of the Cobert Canyon Sandstone Bed is unit 12 of section B (Fig. 4), part of the type section of the Baldy Hill Formation (Fig. 5C, D).

Given the lithologic distinctiveness of the Cobert Canyon Sandstone Bed, the decision to include it in the Baldy Hill may seem somewhat arbitrary. Baldwin and Muehlberger (1959) included it in the Travesser Formation, probably because some thin conglomeratic sandstones also occur in the middle to upper Travesser. We, however, included the Cobert Canyon Sandstone Bed in the Baldy Hill Formation because the marked color change from grayish to reddish brown that occurs at the top of the Cobert Canyon Sandstone Bed provides a good mapping base for the dominantly reddish brown Travesser Formation.

Baldwin and Muehlberger (1959, p. 38) stated that "the Travesser formation may rest on the Baldy Hill formation with angular unconformity" because sandstone beds of the Baldy Hill not present at the type locality apparently crop out beneath the Travesser Formation in secs. 29 and 31, T32N, R32E. However, there appear to be NNE-SSW-trending faults in this area, and the sandstones beneath the Travesser here arguably are equivalent to those at the top of the Baldy Hill type section. Furthermore, at the type sections of the Baldy Hill and Travesser formations there is no evidence of angularity at the Baldy Hill-Travesser contact. Therefore, we believe the Baldy Hill-Travesser contact to be disconformable, not angular.

Baldwin and Muehlberger (1959) stated that the Baldy Hill Formation is only exposed in the eastern part of T32N, R32E and the western part of T32N, R33E in Union County, New Mexico. Our field work confirms the validity of their observations and mapping (Baldwin and Muehlberger, 1959, pl. 1a) in Union County. However, we have located outcrops of the Baldy Hill Formation in Cimarron County, Oklahoma. These outcrops are along Picket House Draw ("Trujillo Creek" of Stovall [1943] and Schoff and Stovall [1943]) in sec. 18, T5N, R6E. Here, the Cobert Canyon Sandstone Bed is well exposed (Fig. 8A, B) and essentially identical in lithology to its type section (see measured stratigraphic sections 27 and 28 of Schoff and Stovall, 1943). It immediately overlies sandstone of typical Baldy Hill lithology that floors Picket House Draw at this location (Fig. 8A). The Late Triassic vertebrate fossils collected from the Cobert Canyon Sandstone Bed along Picket House Draw reported by Stovall (1943) will be discussed later.

As already stated, the base of the Baldy Hill Formation is nowhere exposed. Therefore, it is not possible to determine its total thickness on outcrop. As Foster (1956) and Baldwin and Muehlberger (1959) noted, subsurface data from Union County, New Mexico indicate that 18 to 55 m of "pale-red fine- to coarse-grained and conglomeratic friable quartz sandstone" (Baldwin and Muehlberger, 1959, p. 31) underlie the Baldy Hill Formation. Our preliminary analysis of well-logs from southern Union, Colfax and Mora Counties (also see Bachman, 1953; Wood et al., 1953; Baldwin and Muehlberger, 1959) suggests that this sandstone probably is physically continuous with the Santa Rosa Formation of east-central New Mexico (also see Foster, 1956, p. 137 and Broadhead, 1984). Data from one well log in Union County (the Gruemmer No. 2, Gruemmer in sec. 3, T29N, R24E) suggest a maximum subsurface thickness of the Baldy Hill Formation of 36 m.

Travesser Formation

Baldwin and Muehlberger (1959, p. 38) named the Travesser Formation for Travesser Creek, a southern tributary of the Dry Cimarron River located principally in the NW¼, T31N, R33E, Union County, New Mexico. They placed the Travesser type section in SW¼ NE¼ and NE¼ SW¼ NE¼, sec. 12, T31N, R32E, Union County. Here, Baldwin and Muehlberger (1959, p. 38) measured 245 ft (75 m) of Travesser Formation and described it as follows:

> The Travesser formation consists largely of clayey silt and very fine-grained sandstone. The sandstone beds, which are as thick as 20 feet in the measured section, range from massive to thin bedded, and from parallel bedded to crosslaminated. Conglomeratic lenses that consist of small pebbles of calcareous mudstone and of fine-grained sandstone in a limy matrix are common. Some fissile clay is present in the measured section. Individual sandstone beds can be followed by eye along the valley walls for distances of several miles. The color of the Travesser formation is most commonly medium red brown. . . .

We remeasured the type section of the Travesser Formation (Figs. 4, 5E–H; Appendix 2) and, in contrast to Baldwin and Muehlberger (1959), found it to be 101.6 m thick and dominated by siltstone (60%) with lesser amounts of sandstone (18%), sandy siltstone (11%), silty sandstone (7%) and interbedded conglomerate and sandstone (3%). Color is almost exclusively reddish brown to grayish red.

As argued above, the Baldy Hill-Travesser contact is a disconformity; ripple-laminar, fine-grained sandstone of the basal Travesser rests concordantly on conglomeratic sandstone of the Cobert Canyon Sandstone Bed. The Travesser-Sloan Canyon contact appears to be conformable, although its definition has been something of a problem. This problem arose because Parker (1930, 1933) did not originally define precisely the base of the Sloan Canyon Formation. Thus, Parker included all strata exposed in Sloan Creek in the Sloan Canyon Formation, including the more than 10 m of reddish brown sandstone at the base of the section in the valley of Sloan Creek adjacent to N.M. Highway 325

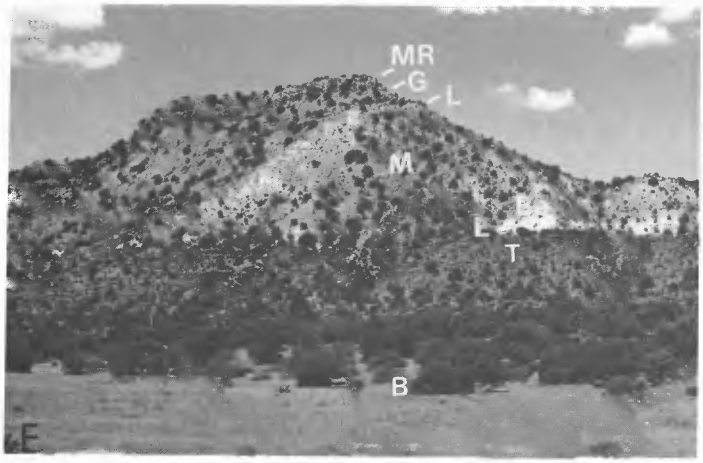
FIGURE 5. Photographs of the type sections of the Baldy Hill and Travesser formations. A, Type section of Baldy Hil Formation from near its base to the Cobert Canyon Sandstone Bed (C). B, Jasper-bearing unit 10 of section B (Fig. 4). C, The Cobert Canyon Sandstone Bed (C) overlain by the Travesser Formation (T) at the Baldy Hill type section. D, Limestone-cobble conglomerate of the Cobert Canyon Sandstone Bed at its type section. E, Overview of the Travesser type section. B = Baldy Hill Formation, T = Travesser Formation, E = Entrada Sandstone, Be = Bell Ranch Formation, M = Morrison Formation, L = Lytle Sandstone, G = Glencairn Formation and MR = Mesa Rica Sandstone. F, Nodular calcrete of the Travesser Formation at its type section (Fig. 4, unit 12 of section A). G, Fluvial-channel complex of the type Travesser (Fig. 4, units 15–20 of section A). H, The Travesser (T) – Entrada (E) disconformity (at head of rock hammer) at the Travesser type section.


C
A



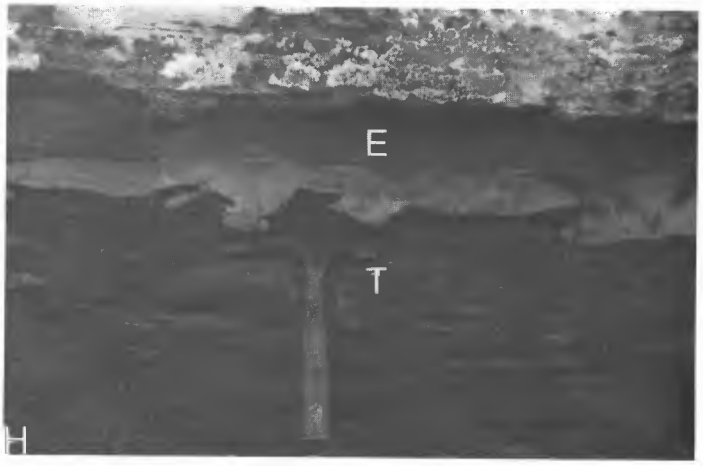

T
C
C


D


MR
G
L
M
L
T
B
E




G


E
T
H

(sec. 12, T31N, R35E). Baldwin and Muehlberger (1959, p. 39) addressed the problem of the Travesser-Sloan Canyon contact as follows:

> In general, the base of the Sloan Canyon formation is considered to be at the lower limit of the light gray-green beds and at the upper limit of the predominantly red-brown beds. Although adequate for mapping purposes, this designation is not entirely satisfactory in the area just east of Wedding Cake Butte, where a massive bed of orange mudstone or fine-grained sandstone about 20 feet thick separates the underlying red-brown mudstone of the Travesser formation from the overlying light gray-green Sloan Canyon formation.

We agree with Baldwin and Muehlberger (1959) in placing the Travesser-Sloan Canyon contact at the color change from reddish brown to yellowish-greenish-grayish, because this provides the most readily mappable contact. This means that the "bed of orange mudstone or fine-grained sandstone" east of Wedding Cake Butte they discussed is placed by us in the Travesser Formation (it is the reddish brown/reddish orange sandy siltstone of unit 11 in section C, Fig. 4). Besides color, the Sloan Canyon Formation is differentiated from the underlying Travesser by the dominance of sandstone in some sections (68% of section E in Fig. 4 is sandstone), generally finer grained sandstones and general lack of ripple-laminar sandstones (Fig. 4). Where the Sloan Canyon Formation does not overlie the Travesser Formation, the Entrada Sandstone rests above it. This contact either is a disconformity (e.g., at the Travesser type section: Figs. 4, 5H) or an angular unconformity (e.g., at and around Steamboat Butte, SE¼, sec. 28, T32N, R35E, Union County).

The Travesser Formation is widely exposed in the Dry Cimarron Valley of Union County, New Mexico. It is the westernmost exposed Triassic bedrock in the Dry Cimarron Valley (near Tollgate Canyon: Baldwin and Muehlberger, 1959, pl. 1b; Hunt and Lucas, 1987). The Travesser is particularly well exposed from Travesser Park-Baldy Hill to Wedding Cake Butte. Its thickness reaches a maximum in the subsurface of 168 m (Foster, 1956).

In Oklahoma, no good outcrops of the Travesser Formation are apparent along the Dry Cimarron Valley. Indeed, Stovall (1943) assigned all Triassic strata in Cimarron County to the Sloan Canyon Formation or the Sheep Pen Sandstone. However, the presence of the Cobert Canyon Sandstone Bed at Picket House Draw, and the presence of the Sloan Canyon Formation further up the western fork of that draw (Fig. 8C, D) suggests that much of the covered bedrock in sec. 19, T5N, R6E and, by inference, along strike to the east and west, is Travesser Formation.

Sloan Canyon Formation

Parker (1930, p. 132) first described the Sloan Canyon Formation as 125–150 ft (38–46 m) of "varicolored, earthy and calcareous shales with thin beds of gray marl and sandstone." He (Parker, 1933, pp. 41–42) later formally defined the formation as follows:

> *Sloan Canyon formation.*—The Sloan Canyon formation is composed of pale, variegated, argillaceous, and calcareous shales with included thin layers of marl and sandstone. It overlies the red beds assigned by Darton to the Dockum Group, and is typically exposed throughout the lower portion of the valley of Sloan Canyon in the east central portion of T. 31 N., R. 35 E., Union County, New Mexico. Because of the poor induration of the shales the basal contact is generally concealed and, consequently, the true character of the lowermost 25–50 feet of the deposit is not known. The thickness is estimated to be between 125 and 150 feet.

Although subsequent workers (especially Stovall and Savage, 1939; Stovall, 1943; Baldwin and Muehlberger, 1959) measured stratigraphic sections in the Sloan Canyon Formation and/or used the term, no formal designation or description of a type section for the Sloan Canyon Formation has been presented. Here, we designate the type section of the Sloan Canyon Formation in outcrops west of N.M. Highway 325 on the north bank of Sloan Creek (Figs. 4, 6A–D; Appendix 2). Here, the Sloan Canyon Formation is 37.4 m of sandstone (68%), sandy siltstone (21%), siltstone (10%) and trace (<1%) amounts of limestone and conglomerate. Greenish gray is the dominant color of these strata, and most sandstones are massive.

In a reference section we designate for the Sloan Canyon Formation (Fig. 4, section C, Fig. 6E–H), it is 41.2 m thick. Greenish gray and yellowish brown are the dominant colors, and sandstones are massive. However, siltstone is the dominant lithology (63%) in this section, followed by sandy siltstone (28%), sandstone (5%), silty sandstone (3%) and a trace (<1%) of conglomerate.

At both the type and the reference sections of the Sloan Canyon Formation, the uppermost bed of the Travesser Formation is dominantly reddish brown fine sandstone or sandy siltstone marking the top of a sequence of reddish brown sandstones and siltstones. Inclusion of the lower red beds at Sloan Creek in the Travesser Formation means that the phytosaur skull described by Stovall and Savage (1939) was collected from the Travesser Formation, not the Sloan Canyon Formation as they reported (see later discussion).

Placement of the Sloan Canyon-Sheep Pen contact also is attended by minor problems. Again, these problems arose because Parker (1930, 1933) did not specifically describe the boundary between these two units. He did state, however, that at its type locality the Sheep Pen "overlies the variegated shales of the Sloan Canyon formation in apparent conformity" (Parker, 1933, p. 41). Baldwin and Muehlberger (1959, p. 40) described the Sloan Canyon-Sheep Pen contact as follows:

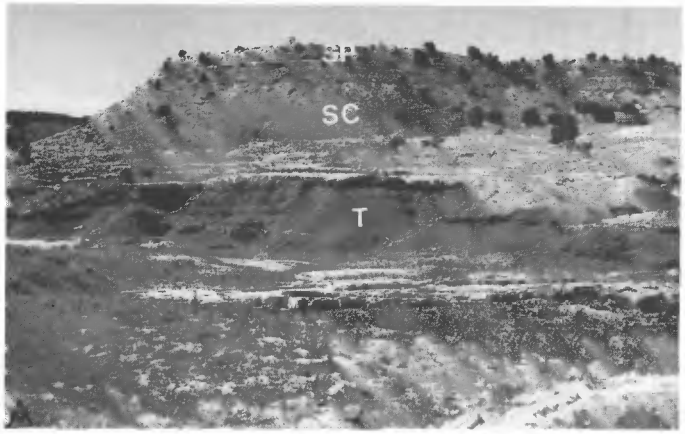
> The Sheep Pen Sandstone rests with a fairly distinct contact on the Sloan Canyon formation. At those outcrops where thin beds of light green or red mudstone are interbedded with the sandstone, the base of the Sheep Pen is taken as the base of the lowest sandstone in a predominantly sandstone sequence; the underlying Sloan Canyon formation has few sandstone beds.

Fay (1983, p. 3) essentially repeated the observations of Baldwin and Muehlberger (1959).

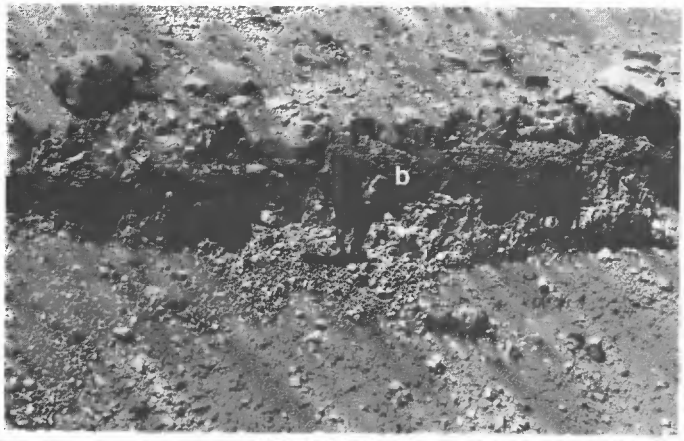
We follow Baldwin and Muehlberger (1959) in placing the base of the Sheep Pen at the base of the sandstone-dominated sequence in sections where sandstones of Sheep Pen lithology are interbedded with upper Sloan Canyon siltstones (cf. section E in Fig. 4). This interbedding of Sheep Pen and Sloan Canyon lithologies and the absence of any scour or rip-up at the base of the Sheep Pen Sandstone support the idea that the Sloan Canyon-Sheep Pen contact is conformable. Furthermore, the local angularity between the Sloan Canyon and Sheep Pen in the SW¼ NE¼ SE¼, sec. 24, T31N, R35E drawn attention to by Baldwin and Muehlberger (1959, p. 40; also see Fay, 1983, p. 3) could not be verified by us.

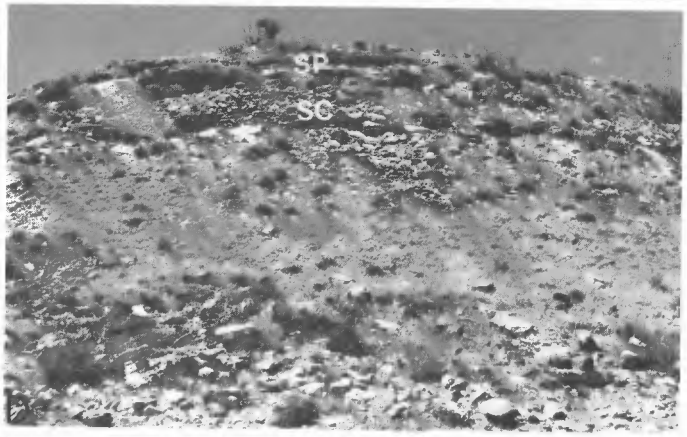
The maximum reported thickness of the Sloan Canyon Formation is the 41.2 m we measured at its reference section (Fig. 4, section C). From its westernmost outcrops at Peacock Canyon, New Mexico (sec. 23, T31N, R33E: Baldwin and Muehlberger, 1959, pl. 1a) to Labrier Butte, Oklahoma, the Sloan Canyon Formation is well exposed at a number of locations (Parker, 1933; Stovall, 1943; Baldwin and Muehlberger, 1959; Finch and Wright, 1983). Its easternmost exposures are those near the head of Picket House Draw (Fig. 8C, D) in the NW¼, sec. 36, T5N, R6E, Cimarron County, Oklahoma (Schoff and Stovall, 1943, p. 258, section 26).

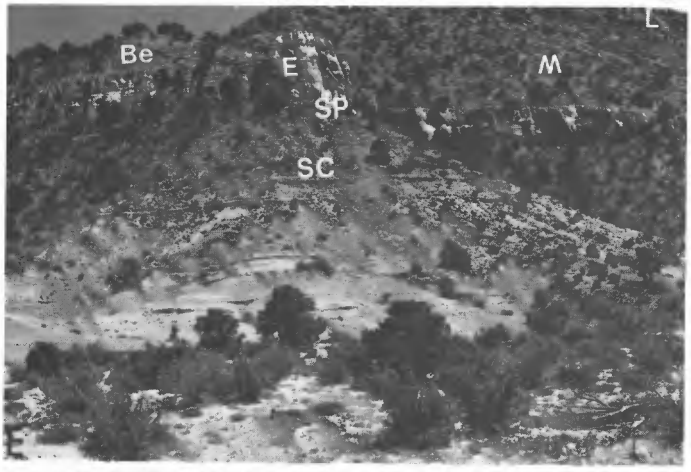
FIGURE 6. Photographs of the type and reference sections of the Sloan Canyon Formation. A, Overview of type section of Sloan Canyon Formation showing Travesser (T) – Sloan Canyon (SC) and Sloan Canyon – Sheep Pen (SP) contacts. B, View from top of Sloan Canyon type section of prominent greenish-gray sandstones of Sloan Canyon Formation (SC) above red beds of the Travesser Formation (T) exposed in the bottom of Sloan Creek. C, Unit 10 of the Sloan Canyon type section (Fig. 4, section E); the bone-bearing conglomerate (b) of UNM locality 1346 is sandwiched between two limestones. D, The Sheep Pen (SP) – Sloan Canyon (SC) contact at the Sloan Canyon type section; note persistent sandstone beds, some of "Sheep Pen lithology," in the uppermost Sloan Canyon. E, Overview of the reference section of the Sloan Canyon Formation; SC = Sloan Canyon Formation, SP = Sheep Pen Sandstone, E = Entrada Sandstone, Be = Bell Ranch Formation, M = Morrison Formation and L = Lytle Sandstone. F, Basal siltstone (Fig. 4, unit 13 of section C) of the Sloan Canyon Formation at its reference section. G, Nodular calcrete of the Sloan Canyon Formation at its reference section (Fig. 4, unit 29 of section C). H, Contacts of the Sloan Canyon (SC), Sheep Pen (SP) and Entrada (E) formations at the Sloan Canyon reference section (Fig. 4, units 34–36 of section C).


SP
SC
T


T
B

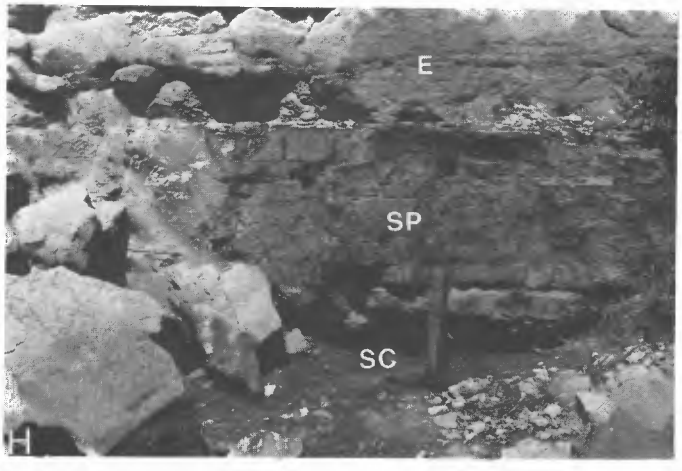

b


SP
SC


L
Be
E
M
SP
SC




G


E
SP
SC
H

Sheep Pen Sandstone

Parker (1930, p. 132) first used the name Sheep Pen Canyon Formation, describing it as "tan to buff, massive and thin bedded sandstone" 0 to 68 ft (0 to 21 m) thick. He (Parker, 1933, p. 41) later defined the Sheep Pen Sandstone as follows:

> *Sheep Pen Sandstone*.—At the type locality, where it caps a small mesa in the E. 1/2 of NW. 1/4 sec. 35, T.32 N., R.35 E., the formation consists of buff to tan sandstone 68 feet in thickness. At this location the formation overlies the variegated shales of the Sloan Canyon formation in apparent conformity. At all localities where it has been observed in contact with the overlying Exeter Sandstone it is considerably reduced in thickness by the pre-Exeter erosion, often being represented by only 1–10 feet of sandstone. The name is derived from Sheep Pen Canyon which joins the Cimarron Valley about 1/2 mile northwest of the type locality.

We measured a type section of the Sheep Pen Sandstone (Fig. 4, section D; Fig. 7A; Appendix 2) and found it to be 16.8 m of dominantly yellowish brown and yellowish orange, very fine-grained quartzarenite. These sandstones are, in places, intensively bioturbated and contain a *Scoyenia*-facies ichnofauna (sensu Frey and Pemberton, 1984) dominated by *Skolithos*.

The Sheep Pen Sandstone is well exposed from Peacock Canyon, New Mexico to Cimarron County, Oklahoma but, as noted by Parker (1933) and Baldwin and Muehlberger (1959), displays remarkable variations in thickness throughout its outcrop belt. The maximum reported thickness of the Sheep Pen is 33 m (Baldwin and Muehlberger, 1959, p. 42) in the SW1/4 NW1/4 NW1/4, sec. 1, T31N, R34E. At this locale, and other locales where the Sheep Pen is relatively thick (>6 m), the Entrada Sandstone is not present above the Sheep Pen. Where the Sheep Pen is relatively thin it is always overlain by the Entrada except at Picket House Draw (Fig. 8D), where the Entrada and Bell Ranch have pinched out, and the Morrison Formation rests directly on the Sheep Pen. This thickness variation of the Sheep Pen is well demonstrated by its type section (Fig. 4, section D; Fig. 7A), where 16.8 m of Sheep Pen are not overlain by the Entrada, and the reference section of the Sloan Canyon Formation (Fig. 4, section C; Fig. 6H), where 0.6 m of Sheep Pen underlie the Entrada. As Baldwin and Muehlberger (1959) concluded, pre-Sheep Pen topography ("residual hills") greatly influenced the deposition of the Sheep Pen Sandstone in the Dry Cimarron area.

Use of the term Dockum in the Dry Cimarron Valley

Part or all of the Triassic strata exposed in the Dry Cimarron Valley have been referred to the Dockum Group since Darton (1928) (Fig. 2). However, we reject use of the name Dockum for Triassic strata in the Dry Cimarron Valley for essentially the same reasons that Lucas et al. (1985[a], p. 176) rejected its use in east-central New Mexico:

1. The term Dockum is not a particularly meaningful stratigraphic term. It has been broadly applied in western Texas, eastern New Mexico, western Oklahoma, southeastern Colorado and western Kansas to strata that encompass very varied lithologies and unequal amounts of Triassic time. Dockum thus lacks specificity and encourages the antiquated concept that all Triassic strata of the southern High Plains are nothing more than "red beds" deposited as a broad sedimentary blanket during a single interval of Triassic time.

2. As argued below, the Triassic of the Dry Cimarron includes strata not equivalent to those of the Dockum Group in western Texas.

Furthermore, there is a problem with application of the term Dockum outside of western Texas not discussed previously. Cummins (1890, p. 189) coined the term Dockum "beds" for Triassic strata in the vicinity of Dockum (now defunct), Dickens County, Texas. The stratigraphic section along Dockum Creek described by Finch and Wright (1983, pp. 48–60) is considered by us to be a "type" section of Cummins' Dockum. Here, the Dockum is 32+ m of quartzose sandstone, pebble conglomerate and claystone. It probably represents little more than the unit Gould (1907) termed the Trujillo Formation. Thus, Cummins' "Dockum" has not only undergone wide and now essentially meaningless extension over a broad geographic area, but has also been widely extended beyond its original definition in and around its type area in western Texas.

SEDIMENTARY PETROLOGY

We made no extensive effort to study the thin-section petrology of Triassic strata in the Dry Cimarron Valley. However, we did prepare 18 thin sections from representative units in the type and reference sections we measured in these strata (Fig. 4; Appendix 2). Terminology used here follows Folk (1980) and Williams et al. (1982), and the numbers of thin sections correspond to the numbered units in our measured sections (Fig. 4; Appendix 2). These thin sections document mineralogical differences between the Baldy Hill, Travesser, Sloan Canyon and Sheep Pen formations when plotted on ternary diagrams with quartz, lithics and calcite at their apices (Fig. 9).

Six thin sections were prepared from the Baldy Hill Formation. BH-1 is a sandy siltstone in which the sand fraction is 95% quartz and 5% lithics; the silt is calcite. BH-6 (Fig. 10A) and 11 are quartzwackes of 90% quartz sand in about 50% fine-grained matrix of calcite and clay that is extensively stained and replaced by hematite and opaques. BH-12(1) is a lithic wacke consisting of limy sand in a quartzose silt and calcite matrix. BH-12(2) (Fig. 10B) is a coarse-grained calcarenite cemented by calcite, silica and hematite. A third thin section of the Cobert Canyon Sandstone Bed, BH-12(3) (Fig. 10C) is of a clast-supported conglomerate with limestone, clay, chert and siltstone pebbles; one clast is a fragment of a crinoid columnal (Fig. 10C). The sand fraction of the Cobert Canyon Sandstone Bed is 60% quartz, 30% calcite and 10% lithics, cemented by calcite.

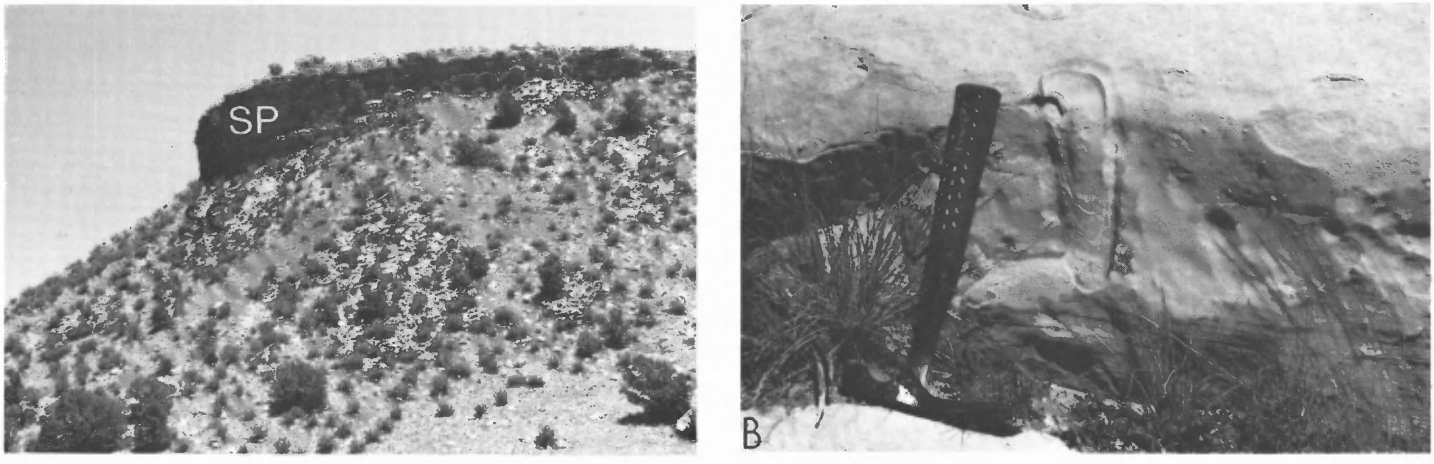


FIGURE 7. Photographs of the type section of the Sheep Pen Sandstone. A, Overview of type section showing resistant, cliff-forming Sheep Pen Sandstone (SP) above colluviated slope of Sloan Canyon Formation (SC). B, Burrow tentatively identified as *Ancorichnus* sp. in unit 11 of the Sheep Pen type section (Fig. 4, section D).

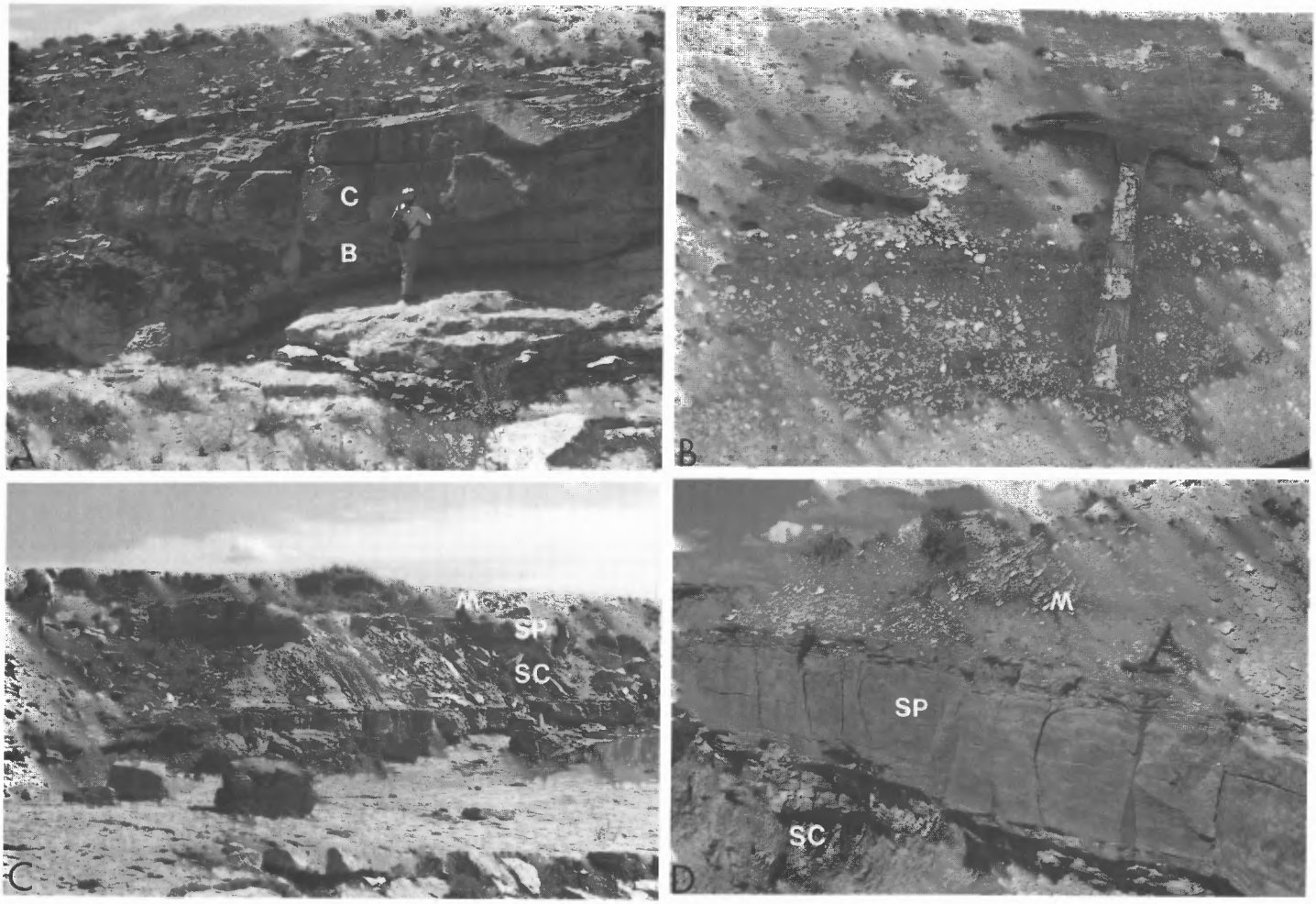


FIGURE 8. Triassic strata exposed in Picket House Draw, Cimarron County, Oklahoma. A, The Cobert Canyon Sandstone Bed (C) overlying the main body of the Baldy Hill Formation (B) at control point 51 (Appendix 1). B, Close-up of Cobert Canyon Sandstone Bed at this locality. C, The Sloan Canyon (SC), Sheep Pen (SP) and Morrison (M) formations at control point 17 (Appendix 1). D, Close-up of the Sloan Canyon (SC), Sheep Pen (SP) and Morrison (M) formations at this locality.

Only two thin sections were prepared from the Travesser Formation. T-20 (Fig. 10D) is a very porous and permeable, calcareous sandy siltstone cemented by calcite and hematite. T-22 is a sandy, calcareous siltstone with sand and silt fractions of 50% quartz and 50% calcite. It is cemented by authigenic hematite clays, calcite and mica.

The Sloan Canyon Formation is represented by eight thin sections. SC-10(T) (Fig. 10E) is a fish-scale, bone-fragment and limestone-pebble conglomerate with a calcitic silt matrix. SC-18(T) is a very fine-grained sandy siltstone. Its sand is almost entirely quartz. SC-14(R) is a sandy limestone with quartz sand and numerous bone fragments. SC-3(R) is a conglomerate; clasts are clay, limestone (including a fragment of a crinoid columnal), siltstone and very fine-grained sandstone. The matrix is clay, calcite, fine quartz sand and silt. SC-4(R) is a ripple-laminar, hematite-stained, calcareous siltstone. SC-15(R) is a clast-supported, clay-pebble conglomerate with a matrix of quartz and calcite sand with a trace of feldspar. It is cemented by calcite and minor clay and silica. SC-21(R) is a calcareous siltstone, whereas SC-26(R) is a calcareous litharenite. It is 45% quartz, 45% calcite and 10% lithics (including fish scales and bone fragments) with calcite vein fillings.

The four thin sections from the Sheep Pen Sandstone are very quartzose. SP-3 is a ripple-laminar, very fine-grained, quartzose sandy siltstone. SP-8a is a ripple-laminar sublitharenite consisting of 90% quartz and 10% lithics (muscovite, calcite, chert and chlorite). SP-8b is a subarkosic, sublitharenite composed of quartz (90%), feldspars (5%) and lithics (5%: chert and calcite) cemented by calcite. A Sheep Pen sample from Picket House Draw (Fig. 8D), SP-P (Fig. 10F) is a sublithic

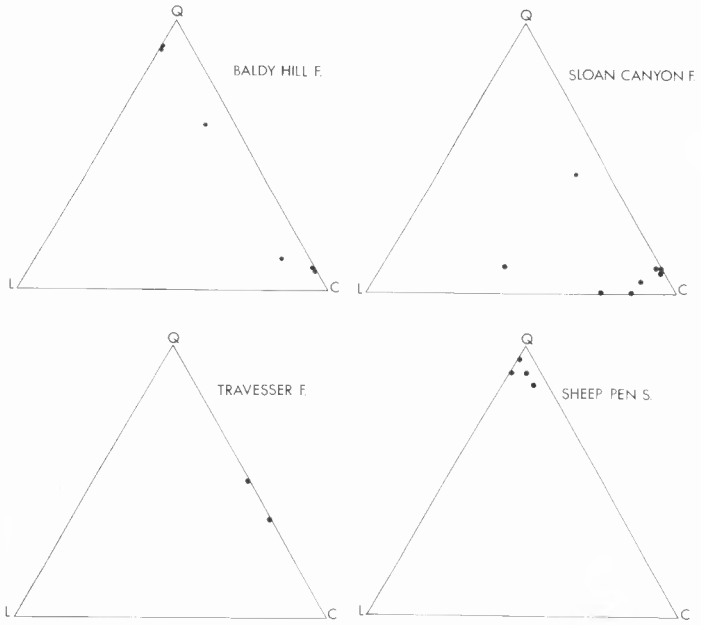


FIGURE 9. Ternary diagrams (Q = quartz, L = lithics, C = calcium carbonate) for thin sections prepared from Triassic strata in the Dry Cimarron Valley.

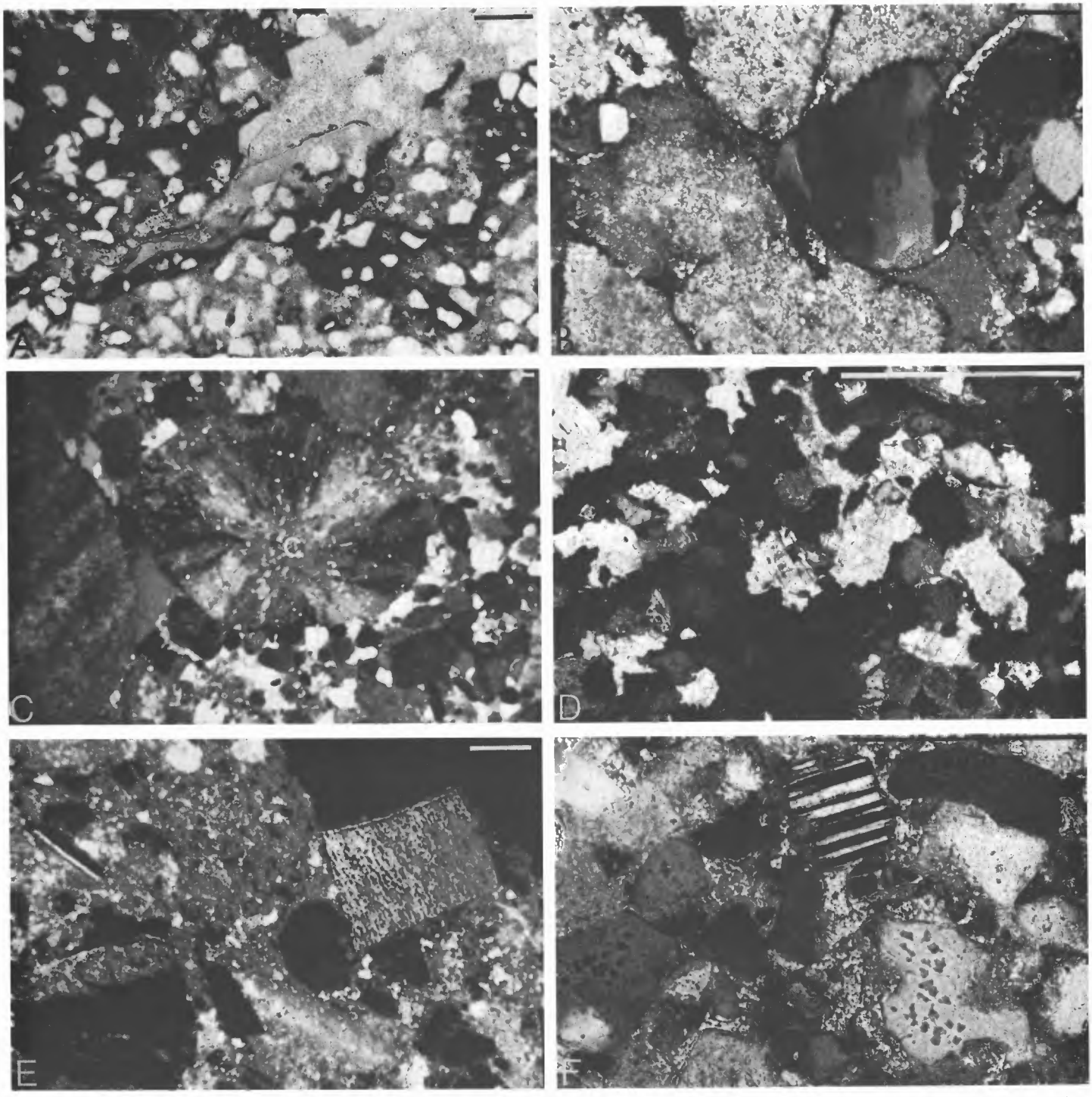


FIGURE 10. Photomicrographs of selected thin sections from Triassic strata in the Dry Cimarron Valley. A, BH-6, quartzwacke. B, BH-12(2), coarse-grained calcarenite. C, BH-12(3) showing cross section of crinoid columnal (C). D, T-20, calcareous siltstone. E, SC-10(T), fish-scale, bone-fragment and limestone-cobble conglomerate. F, SP-P, sublithic wacke. Scale bars are ~100 μ long.

wacke with a sand fraction of 85% quartz, 10% calcite and 5% feldspar in a calcite and clay matrix.

PALEONTOLOGY

Baldy Hill Formation

Prior to this report, petrified wood and "questionable plant fragments" (Baldwin and Muehlberger, 1959, p. 38) were the only fossils reported from the Baldy Hill Formation. However, our identification of the Cobert Canyon Sandstone Bed in Picket House Draw, Cimarron County, Oklahoma (see above) indicates that this unit contains Late Triassic vertebrate fossils. Stovall (1943, p. 50) described these fossils as follows:

> In 1941, Dr. Ed Bloesch collected a few fragmentary bones from an outcrop on the east bank of Trujillo Creek [Picket House Draw of recent maps], about 100 yards south of the stone crossing on the road to the Burnett ranch. Among the collection the writer identified the articular of the right jaw of a phytosaur, and a portion of the interclavicle of the amphibian *Buettneria* [=*Metoposaurus:* Gregory, 1980], both definitely Dockum in age.

Schoff and Stovall's (1943, p. 259) measured stratigraphic section 27 places these bones in the conglomeratic sandstone we identify as the Cobert Canyon Sandstone Bed (Fig. 8A–B). Our attempt to locate these fossils in the Stovall Museum of Science, Norman, Oklahoma, where they should be stored, was unsuccessful. Assuming that Stovall's identifications of them are correct, they indicate a Late Triassic (Carnian-Norian) age for the Cobert Canyon Bed. No age-diagnostic fossils are known from the remainder of the Baldy Hill, and to our knowledge no systematic effort has been made to collect fossils from this part of the Triassic section in the Dry Cimarron Valley. Our assignment of the entire Baldy Hill Formation to the Upper Triassic thus is based on its lithology and stratigraphic position.

Travesser Formation

Prior to this report, no fossils were apparently known from the Travesser Formation (Baldwin and Muehlberger, 1959; Lucas et al., 1985[a]). However, our placement of the Travesser-Sloan Canyon contact indicates that the phytosaur skull described by Stovall and Savage (1939), and said by them to be from the Sloan Canyon Formation, actually is from the upper part of the Travesser Formation.

Stovall and Savage (1939, p. 759) described this locality as "on the north side of Sloan Canyon Creek 200 yards downstream from the crossing of U.S. Highway 64, in Union County, New Mexico." This places the locality in the NE¼ SW¼ NE¼, sec. 12, T31N, R35E (Baldwin and Muehlberger, 1959, p. 36). Stovall and Savage (1939, p. 764) described a stratigraphic section measured at this locality, but it is difficult to relate this section dominated by "marl" and "shale" to the sandstones and siltstones actually present. However, their section indicates the fossiliferous horizon, a "soft, purple-maroon shale, splotched gray or green" is 32.5 ft (10 m) above the base of the creek. Since at least 10 m of Travesser Formation are exposed upstream from this locality (Fig. 4, section E), we are fairly confident that Stovall and Savage's (1939) fossiliferous horizon is in the upper Travesser Formation (a conclusion also reached by Baldwin and Muehlberger, 1959, p. 39). Furthermore, the 15 ft (4.6 m) of "purple-red shale, interbedded with thin, gray to green calcareous sandstones" above the fossiliferous horizon in Stovall and Savage's (1939, p. 764) section is in part equivalent to unit 7 of our section E (Fig. 4), which is 6.7 m of greenish gray and pale reddish brown sandy siltstone.

Stovall and Savage (1939) assigned the phytosaur skull collected on Sloan Creek to *Rutiodon,* noting its similarity to *R. tenuis*. A number of features of this skull support tentative referral to *R. tenuis* sensu Camp (1930): (1) posterior position of the external nares, close to the orbits and between the antorbital fenestrae; (2) relatively large size of the temporal fenestrae; (3) rounded posterior margins of the squamosals that project far posteriad; (4) orbits directed obliquely outward and upward; and (5) heterodont dentition. However, an unusual feature of this skull is the dorsal concealment of the superior temporal fenestrae by overhanging postorbital bars. This may be due, nevertheless, to distortion of the specimen. As Stovall and Savage (1939, p. 759) pointed out, the skull's "posterior part was rolled under toward the left side."

In 1947 J. T. Gregory collected a phytosaur skull from the Redonda Member of the Chinle Formation at Porter Ranch, Quay County, New Mexico (Gregory, 1957; Lucas et al., 1985[a]). Although this skull still has not been fully prepared, Gregory (1957, p. 13) believed it to represent the same phytosaur species as the skull described by Stovall and Savage (1939), a conclusion reiterated by Colbert and Gregory (1957). However, Gregory (1972, p. 122) identified the Travesser phytosaur as *Rutiodon* [*Machaeroprosopus*] *tenuis* and (p. 123) as *Rutiodon validus*. Long and Ballew (1985) considered the Travesser skull to belong to their "*Rutiodon* B" grade of "advanced" phytosaurs.

From the published data and in light of the confused taxonomy of phytosaurs, it is impossible to identify precisely the Travesser skull. This skull, originally catalogued into the collection of the Stovall Museum, has long been in the Royal Ontario Museum, Canada (W. Langston, oral commun., 1986), so we have not had an opportunity to examine it. However, it is clear that the skull represents the "advanced" type of phytosaur found in the upper Petrified Forest Member and younger units of the Chinle Formation on the Colorado Plateau. This suggests a Norian age for the skull and broad correlation with the upper shale/Redonda members of the Chinle Formation in east-central New Mexico (Lucas et al., 1985[a]).

The majority of other fossils now known from the Travesser Formation also come from the upper part of the unit. They include unionid bivalves and fragmentary bones and isolated teeth of phytosaurs and metoposaurid labyrinthodonts.

Three unionid bivalves (UNM MV-2057) from UNM locality 1069 are characteristic specimens in being steinkerns lacking any details of shell and hingeline morphology (Fig. 11A–C). Height/length ratios of about 0.55 and width/length ratios of about 0.35 of these bivalves are close to those of *Unio arizonensis* (Kues, 1985, table 1), and we tentatively refer them to this species.

UNM MV-2054 (Fig. 11D–E) from locality 1068 is a slender, slightly recurved tooth with prominent longitudinal ribs, particularly on the basal half of the crown. The preserved tooth is 16 mm long. Its shape and ornamentation indicate its represents a labyrinthodont (cf. Welles and Estes, 1969); size and stratigraphic position support assignment to the Metoposauridae.

UNM MV-2055 (fig. 11M) is a fragment of the right premaxillary of a phytosaur from locality 1069. The fragment is 18×21 mm in width and height, preserves the medial suture surface and bears five subround alveoli, each with a diameter of 5 mm. We tentatively identify it as *Rutiodon* sp.

UNM MV-2029 is three fragments (one of which is illustrated here: Fig. 11I–J) of the slender rostrum of an archosaur. The largest fragment is 79 mm long and gently tapers from its posterior end, which is delimited by the external narial aperture. Its dorsal surface bears an ornamentation of longitudinal grooves about one mm wide and about two mm apart. The longitudinal suture between the two premaxillaries is evident, but no other sutures are visible. The lateral margins of the ventral aspect bear small, broken teeth that are subround-subrectangular in cross section and as much as three mm in diameter. These teeth are widely spaced; the gaps between them average eight mm in length. The two fragments of UNM MV-2029 not illustrated here are more anterior portions of the rostrum, each less than 15 mm long. The ornamentation of the dorsal aspects of these fragments is not as regular as that of the larger fragment. The three fragments indicate a minimum tooth-row length of 110 mm. The rostrum narrows from 24 mm at the anterior edge of the narial aperture to 18 mm over a distance of 60 mm, but then remains of even width anteriad. The long, slender rostrum, single, medial narial aperture, ornamentation and size suggest UNM MV-2029 represents a phytosaur. However, the narial aperture is not elevated nor does it have a raised rim. Furthermore, the relatively small tooth size and the wide separation of the teeth also are not characteristic of phytosaurs. Little is known of phytosaur ontogeny (Camp, 1930; Colbert, 1947), and it is tempting to argue that these "non-phytosaurian" attributes of UNM MV-2029 reflect its juvenile nature. This argument is reinforced by the similarity of UNM MV-2029 to *Mystriosuchus* from the Stubensandstein of West Germany which has a long, parallel-sided rostrum and small, widely spaced teeth (McGregor, 1936). Identification of UNM MV-2029 as a phytosaur, perhaps the juvenile of a *Mystriosuchus*-like form, thus seems a reasonable, albeit tentative, conclusion.

Other fossils, fragmentary remains of phytosaurs and metoposaurids, have also been collected by us from the uppermost Travesser Formation. However, they are no more complete than those illustrated here, and thus do not merit further discussion.

Sloan Canyon Formation

The Sloan Canyon Formation is the most fossiliferous of the Triassic units in the Dry Cimarron Valley. Indeed, by any standards it is an extremely fossiliferous unit. Numerous bone-bearing conglomerates exist in the Sloan Canyon (cf. UNM localities 1061 and 1075). Most of these conglomerates are a bone "hash" of phytosaur teeth, fish scales and other very small bones and teeth. These strata are well indurated, although soaking heated rock in kerosene results in their disaggregation.

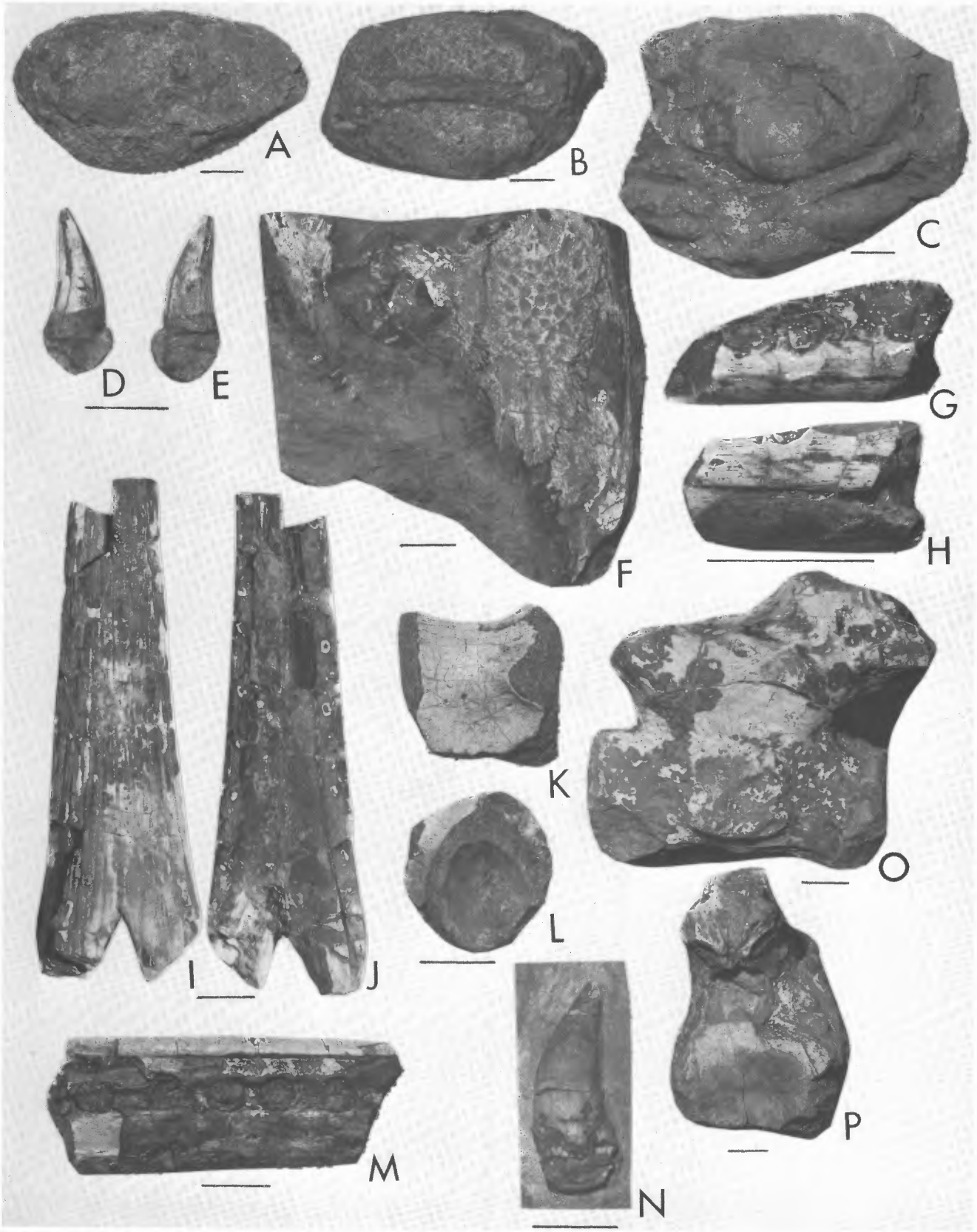


FIGURE 11. Some Triassic fossils from the Dry Cimarron Valley. A–C, cf. *Unio arizonensis*, steinkerns, UNM MV-2057, Travesser Formation (UNM locality 1069). D–E, Metoposauridae, tooth, UNM MV-2054, Travesser Formation (UNM locality 1068). F, Metoposauridae, skull fragment, UNM MV-2058, Sloan Canyon Formation (UNM locality 1070). G–H, Archosauria, jaw fragment, UNM MV-2046, Sloan Canyon Formation (UNM locality 1061). I–J, Parasuchia, rostrum fragment, UNM MV-2029, Sloan Canyon Formation (UNM locality 1050). K–L, Parasuchia, caudal vertebra, UNM MV-2059, Sloan Canyon Formation (UNM locality 1071). M, *Rutiodon* sp., occlusal view of right premaxillary fragment, UNM MV-2055, Travesser Formation (UNM locality 1069). N, Metoposauridae, tooth, UNM MV-2040, Sloan Canyon Formation (UNM locality 1056). O–P, Parasuchia, left lateral (O) and posterior (P) views of dorsal vertebra, UNM MV-2042, Sloan Canyon Formation (UNM locality 1058). The black bars underneath the photos are 1 cm long.

We have collected bulk samples of these rocks and have begun the process of disaggregation, concentration and sorting of the microvertebrate material. However, until these studies are complete we only report here on larger vertebrate specimens we have collected from the Sloan Canyon Formation.

These larger specimens are an array of phytosaur and metoposaurid teeth and bones similar to those described from the Travesser Formation. One of the best-preserved metoposaurid specimens is UNM MV-2058 (Fig. 11F), a fragment of the left posterolateral portion of a skull preserving parts of the squamosal, quadratojugal, jugal, supratemporal and tabular. The best preserved bone, the squamosal, is narrow and elongate, measuring 44 mm by 20 mm. The surface pitting of the bones is characteristic of metoposaurids (cf. Branson and Mehl, 1929, pl. 4; Colbert and Imbrie, 1956, pl. 25). However, the specimen cannot be assigned confidently to a genus (cf. Colbert and Imbrie, 1956; Gregory, 1980).

UNM MV-2040 (Fig. 11N) is a 26-mm-long tooth that is strongly recurved and has faint longitudinal ribs on one side of the crown. It represents a metoposaurid amphibian.

UNM MV-2046 (Fig. 11G–H) is a small (18-mm-long) reptilian dentary. Three alveoli are present and bear broken tooth crowns that have ovoid cross sections. The exact identity of this specimen is unclear, although it may represent a juvenile phytosaur. Undoubted adult phytosaurs are represented by a variety of isolated teeth and postcrania, including UNM MV-2059 (Fig. 11K–L) and MV-2042 (Fig. 11O–P), caudal and dorsal vertebrae, respectively.

The vertebrate ichnofauna (reptilian footprints) of the Sloan Canyon Formation was originally discovered by Parker (1933), first described by Baird (1964) and is reported on in detail by Conrad et al. (1987). Conrad et al. (1987) report the following ichnotaxa from the upper part of the Sloan Canyon Formation at Peacock Canyon (Appendix 1, locality 52): *Brachychirotherium* sp., *Chirotherium* sp., *Coelurosaurichnus* sp., *Apatopus* and *Rhynchosauroides* as well as indeterminate footprints of probable therapsids. As Conrad et al. (1987) point out, this footprint assemblage is most similar to that from the lower Passaic Formation of the Newark Supergroup at Milford, New Jersey (Baird, 1957; Olsen and Baird, 1986). This similarity suggests a Norian age. Invertebrate ichnofossils of a *Scoyenia*-facies ichnofauna abound in the Sloan Canyon Formation. Other than some preliminary analysis by Conrad et al. (1987), these ichnofossils have not been studied. Ostracodes and charophytes from the Sloan Canyon Formation are described by Kietzke (1987), but are of no biostratigraphic value at present.

Sheep Pen Sandstone

No body fossils have been discovered in the Sheep Pen Sandstone, but the unit does have a prolific ichnofauna. Conrad et al. (1987) report reptilian footprints from the basal and middle portions of the Sheep Pen at three localities, two in Colorado and one in Oklahoma. These footprints, of *Grallator* and ?*Brachychirotherium*, are consistent with a Late Triassic age assignment.

Trace fossils of invertebrates are abundant in the Sheep Pen with 45% of beds showing some evidence of bioturbation. All the bioturbated beds are fine or very fine-grained sandstone. Most of these beds are so intensively bioturbated that individual trace fossils cannot be distinguished. However, particularly in the upper part of the Sheep Pen, at least two forms of burrow are sufficiently well preserved to allow additional comments.

The first form is ovoid in cross section with average maximum dimensions of 56 cm and 35 cm (n = 4). These are vertical to subvertical, and at least 30 cm long. The only internal structures are series of concentric laminae which are about 3 mm thick and occur adjacent to the outer walls of the structure.

The second form of well-preserved burrow is a meniscate structure which is about 18 cm long and is vertically oriented (Fig. 7B). In lateral view, the burrow tapers downward to a rounded end from a maximum width of 5 cm. Individual meniscate laminae have a vertical height of about 6 cm, connecting with the vertical walls at very acute angles. The meniscate internal structure indicates backfilling by a sediment deposit-feeder (Tevesz and McCall, 1982).

Although these two burrows are well preserved, it is difficult to assign them to any existing ichnogenera. Pemberton and Frey (1982) indicated that many groups of ichnofossils are in taxonomic confusion. For example, Häntzschel (1975) listed ten different ichnogenera of meniscate burrows. In the light of these taxonomic problems we conservatively assign the meniscate burrows to *Ancorichnus* sp. (Frey et al., 1984), and the structureless burrows to *"Skolithos sp."* (Ekdale et al., 1984). These burrows are part of the *Scoyenia*-ichnofacies. Seilacher (1967) originally named this facies for continental red beds, but since that time this concept has been applied to virtually all nonmarine clastic deposits, and now "the term has become synonymous with 'nonmarine trace fossils' and is badly in need of redefinition" (Frey et al., 1984, p. 512).

SEDIMENTARY ENVIRONMENTS AND TAPHONOMY

We made no attempt to study in detail the sedimentology or taphonomy of the Triassic strata in the Dry Cimarron Valley. However, the collection of stratigraphic and paleontological data, the main goal of our field work, provides a basis for some tentative conclusions about the sedimentary environments and vertebrate taphonomy of the Baldy Hill through Sheep Pen sequence.

Baldy Hill Formation

The main body of the Baldy Hill Formation is dominated by laterally continuous, usually bioturbated, poorly sorted siltstone and very fine-grained sandstone. These features, and the lack of channel-form units and bedding, suggest a clastic-lacustrine environment (cf. Picard and High, 1981). In contrast, the Cobert Canyon Sandstone Bed apparently represents a low-sinuosity fluvial deposit (cf. Miall, 1978). The well-rounded, large clasts in the Cobert Canyon suggest vertebrate-fossil occurrences in it will be limited essentially to well rounded fragments.

Travesser Formation

Laterally continuous, bioturbated sandstones and siltstones of the Travesser Formation also suggest a clastic-lacustrine environment. However, crossbedded channel-form sandstones of the Travesser are fluvial in origin and may represent the fluvio-deltaic system landward of the lake facies. Some pebbles in Travesser conglomerates are abraded rhizolith concretions, and there are some in situ calcretes in the formation (Fig. 5F). These strata thus document the formation of some paleosols during Travesser deposition. In addition, laterally continuous, ripple-laminar, laminar and low-angle planar-crossbedded sandstones of the Travesser resemble some Triassic sandbodies on the Colorado Plateau (Moss Back and Church Rock members of the Chinle Formation). Blakey and Gubitosa (1984) interpreted these sandbodies to represent braid sheets formed by reworking sediments on a broad plain by braided streams during low rates of subsidence. Apparently, the Travesser represents a range of depositional environments including lacustrine, lacustrine delta, paleosol and braided stream.

Fossil-vertebrate occurrences in the Travesser Formation are mostly of bone fragments in intraformational conglomerates. Locally abundant fish scales in siltstones are consistent with a lacustrine environment. The nearly complete phytosaur skull collected by Stovall and Savage (1939) suggests that rarely, articulated vertebrate fossils may be recovered.

Sloan Canyon Formation

Laterally continuous, intensively bioturbated siltstone, very fine-grained sandstone and (minor) limestone of the Sloan Canyon Formation also suggest a lacustrine environment. Bone-bearing conglomerates associated with these lithologies are dominated by fish scales and coprolites. Furthermore, these conglomerates grade laterally into siltstone over a distance of 20–30 m, are 10–20 cm thick and lack scour bases. They thus closely resemble the "well sorted breccias" of Triassic lacustrine deposits in Wales interpreted by Tucker (1978) as lacustrine-beach deposits. Local, but minor, calcrete horizons of the Sloan Canyon Formation also suggest some paleosol development.

The majority of the vertebrate fossils in the Sloan Canyon Formation occur in the lacustrine beach deposits as small fragments and isolated teeth and bones. All vertebrate ichnofossils in the Sloan Canyon For-

mation are in fine-grained sandstones and siltstones of lacustrine origin. We see no evidence to support Conrad et al.'s (1987) conclusion that these occurrences are in fluvial deposits.

Sheep Pen Sandstone

Ripple-laminar and crossbedded sandstones of the Sheep Pen suggest the type of braided stream environment documented by Blakey and Gubitosa (1984) and discussed earlier. However, bioturbated, very fine-grained sandstones of the Sheep Pen, particularly in its lower portion, arguably represent higher energy input into the lacustrine basin represented by the Sloan Canyon Formation. A *Scoyenia*-facies (cf. Seilacher, 1967) ichnofauna in these strata supports this conclusion. Sheep Pen reptile footprints are also found in this facies.

As would be expected for a dominantly lacustrine sequence, the Triassic strata of the Dry Cimarron are dominated by amphibious and aquatic animals. The most numerically abundant fossils in these units are ganoid fish scales, although it is virtually impossible to relate isolated scales to a minimum number of individuals (MNI) concept. Phytosaurs and amphibians constitute the remainder of the body fossils. Phytosaurs are common in all North American rocks of Late Triassic age. The relative abundance of amphibian material is much more variable. In the Dry Cimarron, amphibian remains are much more common than in the Chinle of east-central New Mexico (Lucas and Kietzke, 1984), and the abundance is more like portions of the Tecovas Formation in Texas and the Chinle Formation on the Colorado Plateau. Non-aquatic taxa are only represented by ichnofossils (Conrad et al., 1987), in marked contrast to most Upper Triassic red beds in the American Southwest. In the Chinle and Dockum, aetosaurs, dinosaurs, rauisuchid thecodonts and other fully terrestrial animals are an important component of the body-fossil fauna. Thus, faunal as well as sedimentologic evidence suggests that lacustrine development was more pervasive in the Dry Cimarron area than in other parts of the American Southwest during the Late Triassic.

COMPARISON WITH TRIASSIC STRATA IN NEARBY AREAS

Our study of the Triassic strata exposed in the Dry Cimarron Valley provides a more detailed basis than previously available for lithologic and paleontologic comparisons of these strata with other Triassic outcrops. Here, we discuss briefly the lithologic dissimilarity of the Dry Cimarron Triassic and Triassic strata exposed in Texas County, Oklahoma, southeastern Colorado-western Kansas, east-central New Mexico and the Texas Panhandle.

Texas County, Oklahoma

Red-bed inliers of Triassic strata in Texas County, Oklahoma were described by Gould (1905), Gould and Lonsdale (1926) and Schoff (1939, 1953). Principal locales are the drainages of Tepee and Goff Creeks west and northwest of Guymon in the central portion of the county (Schoff, 1939, pl. 1; 1953, fig. 1). Gould (1905) was uncertain of the age of these strata but later tentatively assigned them to the Triassic (Gould, 1925; Gould and Lonsdale, 1926). Bullard (1928) also assigned them to the Triassic.

Schoff (1939, 1953) provided a detailed description of these strata, including a stratigraphic section of 10.2 m of Triassic strata exposed in sections 19 and 30, T3N, R14E (Fig. 12). Our examination of these outcrops confirms Schoff's description, especially the dominance of "shale" (mudstone and claystone), not siltstone, in this area. Clearly, the Triassic strata exposed in Texas County, Oklahoma bear no close lithological resemblance to those exposed in the Dry Cimarron Valley to the west. Instead, they are more similar to Triassic red beds in the Texas Panhandle to the south.

Southeastern Colorado-western Kansas

The Sloan Canyon and Sheep Pen formations are exposed in southeastern Colorado as far north as T34S, R50W, Baca County (McLaughlin, 1954; Fay, 1983). However, north, northwest and northeast of this area, in the remainder of southeastern Colorado and western

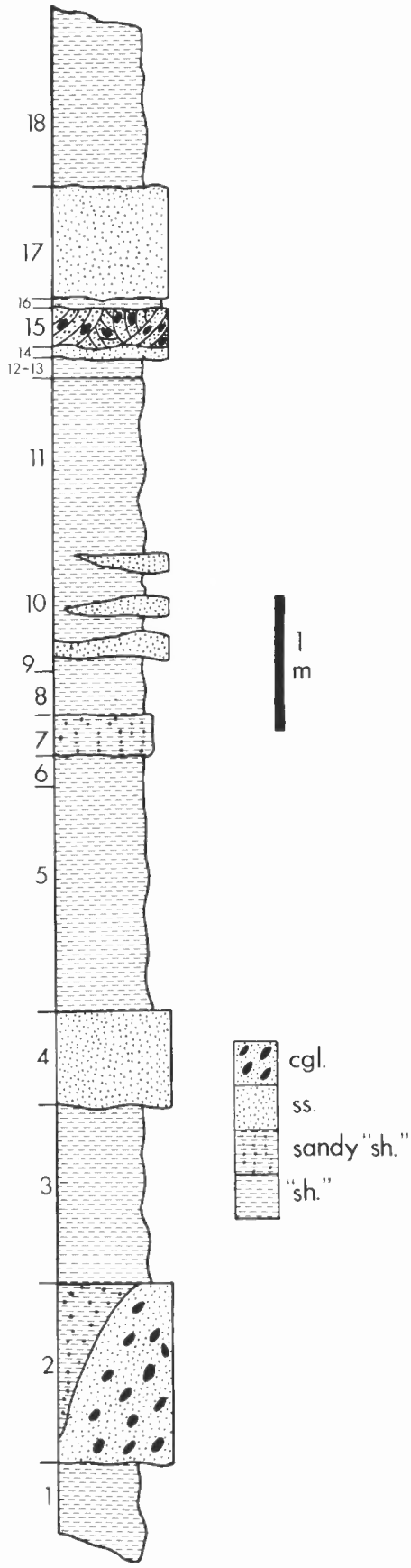


FIGURE 12. Measured section of Triassic strata in SW¼, sec. 19 and NW¼, sec. 30, T3N, R14E, Texas County, Oklahoma (from description in Schoff, 1939, p. 50).

Kansas, the Triassic section differs from that exposed in the Dry Cimarron and is dominated by quartzose sandstone and limestone-pebble conglomerate (e.g., Sanders, 1934a; Buehler, 1947; McLaughlin, 1954; Oriel and Mudge, 1956; Johnson and Baltz, 1960; Merriam, 1963; MacLachlan, 1972). Johnson and Baltz (1960) coined the name Johnson Gap Formation for these strata along Johnson Creek, west of Trinidad (T34S, R69W, Las Animas County). We believe that available stratigraphic data support extension of the term Johnson Gap Formation throughout southeastern Colorado and western Kansas, and thus reject Parker's (1934) critique of Sanders' (1934a, b) interpretation of the section of Two Buttes on the Baca-Prowers County line. Furthermore, these data (e.g., Oriel and Mudge, 1956, pl. 1) suggest that the Johnson Gap Formation as so extended is laterally equivalent to most, if not all, of the finer-grained Triassic strata exposed in the Dry Cimarron Valley. Indeed, thickness trends of the Johnson Gap Formation in southeastern Colorado (MacLachlan, 1972) define a Triassic sedimentary basin here which would include the strata exposed in the Dry Cimarron.

East-central New Mexico

The Triassic strata exposed in east-central New Mexico (San Miguel, Guadalupe, Harding, Quay and DeBaca Counties) were reviewed by Lucas et al. (1985[a]) and Lucas and Hunt (in press). These strata are assigned to the Santa Rosa and Chinle formations and are as much as 634 m dominated by mudstones, fluvial sandstones and conglomerates. There is little close lithologic similarity of these strata to those in the Dry Cimarron Valley with the exception of the Redonda Member of the Chinle Formation in east-central New Mexico. The Redonda is as much as 140 m of mudstone, fine-grained sandstone, limestone and siltstone that is very similar lithologically to the Sloan Canyon Formation.

The entire Triassic section in east-central New Mexico thins northward from Guadalupe-Quay Counties (latitude 35°N) toward Harding County (latitude 36°N) (Foster et al., 1972, fig. 2). This thinning of Triassic strata suggests a highland between east-central New Mexico and the Dry Cimarron Valley that, to some extent, separated these two areas of Triassic deposition. This may account for the lithologic dissimilarity of the mudstone/sandstone-dominated Triassic section in east-central New Mexico and the siltstone/sandstone-dominated section in the Dry Cimarron Valley.

Texas Panhandle

Triassic strata in the Texas Panhandle are those exposed in what was the Palo Duro basin and those present in subcrop in what was the Dalhart basin. These strata of the Palo Duro basin are lithologically similar to, genetically related to and, in part, coeval with the Triassic section in east-central New Mexico (e.g., Finch et al., 1976; McGowen et al., 1979, 1983; Granata, 1981; Lucas et al., 1985[a]; Chatterjee, in press). They are a mudstone and fluvial sandstone-dominated section quite dissimilar to the Dry Cimarron Triassic section.

The subsurface Triassic strata of the Dalhart basin are little studied, but some data are available from Cunningham (1961) and McCasland (1980). Here, the Triassic section is as much as 357 m dominated by mudstone and fluvial sandstone. The Dalhart basin is generally conceived of as a northern re-entrant of the Palo Duro basin (e.g., Totten, 1956; Dixon, 1967), and it is likely that its Triassic strata are closely related genetically to those of the Palo Duro basin to the south. They certainly are lithologically similar to the Triassic strata in the Palo Duro basin, and thus just as dissimilar to the Dry Cimarron Triassic.

CORRELATION

As the above indicates, the Triassic strata exposed in the Dry Cimarron Valley have provided few fossils upon which to base an age assignment more refined than Late Triassic. Furthermore, the lithologic distinctiveness of these Triassic strata makes difficult lithologic correlation of these units with other, more fossiliferous Upper Triassic strata. Nevertheless, a tentative correlation of the Dry Cimarron Triassic with Triassic strata elsewhere (Fig. 13) can be based on the following lines of evidence (listed in order of decreasing confidence):

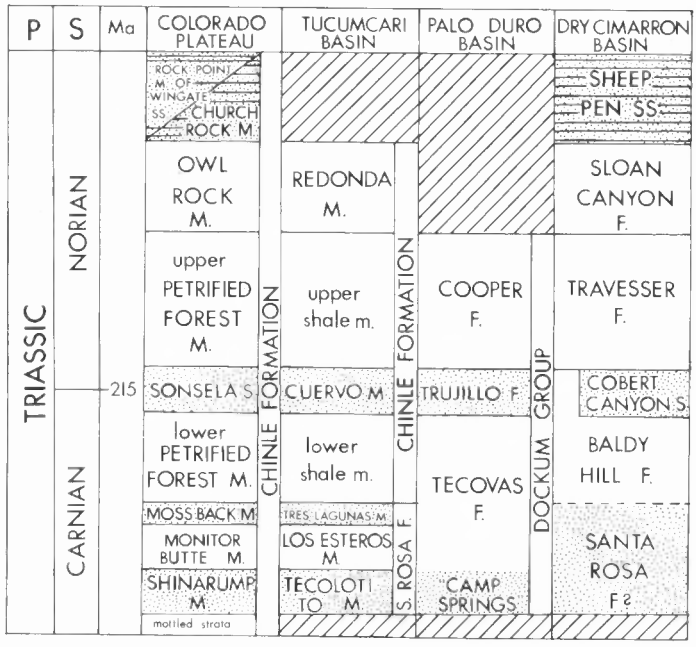


FIGURE 13. Correlation of the Triassic strata in the Dry Cimarron Valley with Triassic strata on the Colorado Plateau (generalized from Stewart et al., 1972), in east-central New Mexico (Tucumcari basin; from Lucas et al., 1985[a]) and in the southern Texas Panhandle (Palo Duro basin; from Lucas et al. 1985[a] and Chatterjee, in press). Stippled units are dominantly fluvial sandstone/conglomerate. Stippled and lined units are dominantly laminar fine sandstones and siltstones.

1. The Baldy Hill (Cobert Canyon Sandstone Bed), Travesser, Sloan Canyon and Sheep Pen formations contain vertebrate body-fossils or ichnofossils of Late Triassic (Carnian-Norian) age.

2. The probable taxonomic identity of the Travesser Formation phytosaur skull and that from the Redonda Member of the Chinle Formation in Quay County, New Mexico suggests that the uppermost Travesser, the Sloan Canyon and the Sheep Pen are post-Carnian (cf. Lucas et al., 1985[a]).

3. The striking homotaxis of upper Triassic strata throughout the Southwest (Lupe, 1977; Blakey and Gubitosa, 1984; Lupe and Silberling, 1985; Lucas et al., 1985[a]; Lucas and Hunt, in press) suggests cycles of fine- and coarse-grained deposition related to climatic and/or tectonic events. The Upper Triassic strata in the Dry Cimarron can be fit to such cycles (Fig. 13). Key to such a fit is accepting homotaxis of the Cobert Canyon Sandstone Bed in the Dry Cimarron and the Cuervo Member of the Chinle Formation to the south (cf. Lucas et al., 1985[a]).

4. The vertebrate ichnofauna of the Sloan Canyon Formation resembles that of the Redonda Member of the Chinle Formation in Quay County, New Mexico (Gregory, 1972; Lucas et al., 1986; Hunt et al., in press) and that of the lower part of the Passaic Formation in New Jersey (Olsen, 1980). This provides tentative support for a Norian age for the Sloan Canyon Formation (Fig. 13).

5. The sandstone below the Baldy Hill Formation in the subsurface probably is the equivalent of the Santa Rosa Formation of east-central New Mexico.

Clearly, the lines of evidence just listed are not a compelling basis for accepting the correlation presented in Figure 13. But, this correlation is consistent with them. Still, the tentative nature of this correlation should be underscored.

CONCLUSION: DRY CIMARRON BASIN

The Triassic section exposed in the Dry Cimarron Valley (Fig. 14) is as much as 282 m dominated by very fine- to fine-grained sandstone and siltstone, dominantly of lacustrine origin. Available fossil verte-

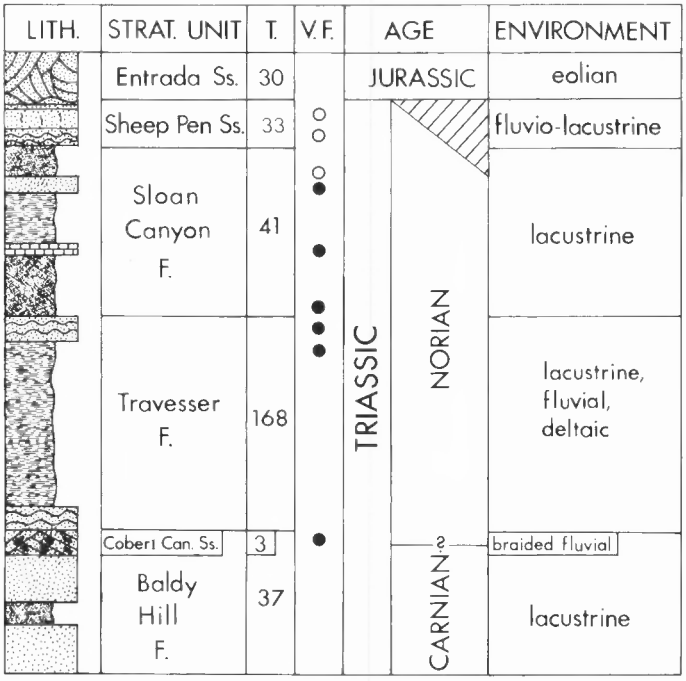


FIGURE 14. Summary of the Upper Triassic stratigraphic units and their maximum thicknesses (T., in m), vertebrate fossil horizons (V.F., open circles are vertebrate trackways, dark circles are body fossils), ages and depositional environments in the Dry Cimarron Valley.

brates indicate that all of these strata are of Late Triassic age; other lines of evidence suggest they may transgress the Carnian-Norian boundary (Fig. 14).

The lithologic dissimilarity of the Dry Cimarron Triassic and other Triassic strata in western Oklahoma, east-central New Mexico, southeastern Colorado, western Kansas and the Texas Panhandle suggests deposition of the Dry Cimarron Triassic in a Late Triassic basin separate from the basins in which most nearby Upper Triassic strata were deposited. Moreover, the probable equivalence of the Johnson Gap Formation of southeastern Colorado-western Kansas and the Dry Cimarron Triassic indicates this separate basin extended well north of the Dry Cimarron into Colorado and Kansas.

These observations, and our preliminary analysis of stratigraphic and sedimentologic data on the Upper Triassic strata of the southern High Plains, suggest a complex basin-and-uplift distribution in this area during the Late Triassic. This distribution corresponds somewhat to the distribution of Permian tectonic elements of the southern High Plains (Totten, 1956). Arguably, these Permian tectonic elements continued to influence sedimentation during the Late Triassic.

ACKNOWLEDGMENTS

We thank numerous landowners in the Dry Cimarron Valley for permission to work on their property. J. W. Froehlich and several UNM students provided assistance in the field for which we are grateful. C. Klein made thin-section photography possible, and B. S. Kues reviewed an earlier version of this paper.

REFERENCES

Bachman, G. O., 1953, Geology of a part of northwestern Mora County, New Mexico: U.S. Geological Survey, Oil and Gas Investigations Map OM-137.

Baird, D., 1957, Triassic reptile footprint faunules from Milford, New Jersey: Museum of Comparative Zoology, Harvard University, Bulletin 117, pp. 447–520.

Baird, D., 1964, Dockum (Late Triassic) reptile footprints from New Mexico: Journal of Paleontology, v. 38, pp. 118–125.

Baldwin, B. and Muehlberger, W. R., 1959, Geologic studies of Union County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 63, 171 pp.

Blakey, R. C. and Gubitosa, R., 1984, Controls of sandstone body geometry and architecture in the Chinle Formation (Upper Triassic), Colorado Plateau: Sedimentary Geology, v. 38, pp. 51–86.

Branson, E. B. and Mehl, M. G., 1929, Triassic amphibians from the Rocky Mountain region: University of Missouri Studies, v. 4, pp. 155–239.

Broadhead, R. F., 1984, Subsurface petroleum geology of Santa Rosa Sandstone (Triassic), northeast New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 193, 22 pp.

Buehler, K. M., 1947, Freezeout Creek fault, Baca County, Colorado: American Association of Petroleum Geologists Bulletin, v. 31, pp. 1863–1868.

Bullard, F. M., 1928, Lower Cretaceous of western Oklahoma: Oklahoma Geological Survey, Bulletin 47, 116 pp.

Camp, C. L., 1930, A study of the phytosaurs with description of new material from western North America: University of California, Memoirs, v. 10, 174 pp.

Chatterjee, S., in press, The Late Triassic Dockum vertebrates: their stratigraphic significance; *in* Padian, K., ed., Faunal changes across the Triassic-Jurassic boundary: Cambridge, Cambridge University Press.

Colbert, E. H., 1947, Studies of the phytosaurs *Machaeroprosopus* and *Rutiodon:* American Museum of Natural History Bulletin, v. 88, pp. 53–96.

Colbert, E. H. and Gregory, J. T., 1957, Correlation of continental Triassic sediments by vertebrate fossils: Geological Society of America Bulletin, v. 68, pp. 1456–1467.

Colbert, E. H. and Imbrie, J., 1956, Triassic metoposaurid amphibians: American Museum of Natural History Bulletin, v. 110, pp. 399–452.

Conrad, K., Lockley, M. G. and Prince, N. K., 1987, Triassic and Jurassic vertebrate-dominated trace fossil assemblages of the Cimarron Valley region: implications for paleoecology and biostratigraphy: New Mexico Geological Society, Guidebook 38.

Cummins, W. F., 1890, The Permian of Texas and its overlying beds: Texas Geological Society, First Annual Report, pp. 183–197.

Cunningham, B. J., 1961, Stratigraphy, Oklahoma-Texas Panhandles; *in* Oil and gas fields of the Texas and Oklahoma Panhandles: Amarillo, Panhandle Geological Society, pp. 45–60.

Darton, N. H., 1928, "Red beds" and associated formations in New Mexico, with an outline of the geology of the state: U.S. Geological Survey, Bulletin 794, 372 pp.

DeFord, R. K., 1927, Areal geology of Cimarron County, Oklahoma: American Association of Petroleum Geologists Bulletin, v. 11, pp. 753–755.

Dixon, G. H., 1967, Paleotectonic investigations of the Permian System in the United States Chapter D. Northeastern New Mexico and Texas-Oklahoma Panhandles: U.S. Geological Survey, Professional Paper 515-D, pp. 61–80.

Ekdale, A. A., Bromley, R. G. and Pemberton, S. G., 1984, Ichnology the use of trace fossils in sedimentology and stratigraphy: Tulsa, Society of Economic Paleontologists and Mineralogists, 317 pp.

Fay, R. O., 1983, Copper deposits in Sheep Pen Sandstone (Triassic) in Cimarron County, Oklahoma, and adjacent parts of Colorado and New Mexico: Oklahoma Geological Survey, Circular 86, 24 pp.

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 pp.

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.

Folk, R. L., 1980, Petrology of sedimentary rocks (2nd ed.): Austin, Hemphill Publishing Co., 127 pp.

Foster, R. W., 1956, Subsurface stratigraphy of northern Union County: Oklahoma City Geological Society, Guidebook 35, pp. 136–141.

Foster, R. W., Frentress, R. M. and Riese, W. C., 1972, Subsurface geology of east-central New Mexico: New Mexico Geological Society, Special Publication 4, 22 pp.

Frey, R. W. and Pemberton, S. G., 1984, Trace fossil facies models; *in* Walker, R. G., ed., Trace fossils facies models: Toronto, Geological Association of Canada Reprint Series 1, pp. 189–208.

Frey, R. W., Pemberton, G. and Fagerstrom, J. A., 1984, Morphological, ethological, and environmental significance of the ichnogenera *Scoyenia* and *Ancorichnus:* Journal of Paleontology, v. 58, pp. 511–528.

Gilluly, J. and Reeside, J. B., Jr., 1928, Sedimentary rocks of the San Rafael Swell and some adjacent areas in eastern Utah: U.S. Geological Survey, Professional Paper 150-D, pp. 61–110.

Goddard, E. N., Trask, P. D., DeFord, R. K., Rove, O. N., Singewald, J. T., Jr. and Overbeck, R. M., 1979, Rock-color chart: Boulder, Geological Society of America.

Gould, C. N., 1905, Geology and water resources of Oklahoma: U.S. Geological Survey, Water-Supply and Irrigation Paper 148, 178 pp.

Gould, C. N., 1907, The geology and water resources of the western portion of the Panhandle of Texas: U.S. Geological Survey, Water-Supply Paper 191, 70 pp.

Gould, C. N., 1925, Index to the stratigraphy of Oklahoma: Oklahoma Geological Survey, Bulletin 35, 115 pp.

Gould, C. N. and Lonsdale, J. T., 1926, Geology of Texas County Oklahoma: Oklahoma Geological Survey, Bulletin 37, 62 pp.

Granata, G. E., 1981, Regional sedimentation of the Late Triassic Dockum Group, west Texas and eastern New Mexico [M.A. thesis]: Austin, University of Texas, 199 pp.

Gregory, J. T., 1957, Significance of fossil vertebrates for correlation of Late Triassic continental deposits of North America: Report of the 20th Session of the International Geological Congress, 1956, section II, pp. 7–25.

Gregory, J. T., 1972, Vertebrate faunas of the Dockum Group, Triassic, eastern New Mexico and west Texas: New Mexico Geological Society, Guidebook 23, pp. 120–123.

Gregory, J. T., 1980, The otic notch of metoposaurid labyrinthodonts; *in* Jacobs, L. L., ed., Aspects of vertebrate history essays in honor of Edwin Harris Colbert: Flagstaff, Museum of Northern Arizona Press, pp. 125–136.

Häntzschell, W., 1975, Trace fossils and Problematica (2nd ed.); *in* Teichert, C., ed., Treatise on invertebrate paleontology, Part W, Miscellanea, Supplement 1: Lawrence, Geological Society of America and University of Kansas, pp. 1–269.

Heaton, R. L., 1939, Contribution to Jurassic stratigraphy of Rocky Mountain region: American Association of Petroleum Geologists Bulletin, v. 23, pp. 1153–1177.

Hunt, A. P. and Lucas, S. G., 1987, Supplemental road-log 5, from Baldy Hill to Folsom: New Mexico Geological Society, Guidebook 38.

Hunt, A. P., Lucas, S. G. and Kietzke, K. K., in press, Dinosaur footprints from the Redonda Member of the Chinle Formation (Upper Triassic), east-central New Mexico; *in* Morales, M., ed., Dinosaur tracks and traces: Flagstaff, Museum of Northern Arizona Press.

Johnson, R. B. and Baltz, E. H., 1960, Probable Triassic rocks along eastern front of Sangre de Cristo Mountains, south-central Colorado: American Association of Petroleum Geologists Bulletin, v. 44, pp. 1895–1902.

Kietzke, K. K., 1987, Calcareous microfossils from the Triassic of northeastern New Mexico: New Mexico Geological Society, Guidebook 38.

King, P. B. and Beikman, H. M., 1974, Geologic map of the United States: U.S. Geological Survey, scale 1:2,500,000.

Kues, B. S., 1985, Nonmarine mollusca from the Chinle Formation, Dockum Group (Upper Triassic), of Bull Canyon, Guadalupe County, New Mexico: New Mexico Geological Society, Guidebook 36, pp. 185–196.

Lee, W. T., 1902, The Morrison shales of southern Colorado and northern New Mexico: Journal of Geology, v. 10, pp. 36–58.

Lockley, M., 1986, A guide to dinosaur tracksites of the Colorado Plateau and American Southwest: University of Colorado at Denver, Geology Department Magazine, Special Issue 1, 56 pp.

Long, R. and Ballew, K., 1985, Aetosaur dermal armor from the Late Triassic of southwestern North America, with special reference to material from the Chinle Formation of Petrified Forest National Park: Museum of Northern Arizona, Bulletin 54, pp. 45–68.

Lucas, S. G. and Kietzke, K. K., 1984, Distribution of Triassic vertebrates, upper shale member of the Chinle Formation, Bull Canyon, east-central New Mexico: New Mexico Journal of Science, v. 24, pp. 23–24.

Lucas, S. G., Hunt, A. P. and Kietzke, K. K., 1986, Late Triassic dinosaur footprints from east-central New Mexico: First International Symposium on Dinosaur Tracks and Traces, Abstracts with Program, p. 19.

Lucas, S. G., Hunt, A. P. and Morales, M., 1985[a], Stratigraphic nomenclature and correlation of Triassic rocks of east-central New Mexico: a preliminary report: New Mexico Geological Society, Guidebook 36, pp. 171–184.

Lucas, S. G., Kietzke, K. K. and Hunt, A. P., 1985[b], The Jurassic System in east-central New Mexico: New Mexico Geological Society, Guidebook 36, pp. 213–242.

Lucas, S. G. and Hunt, A. P., in press, Stratigraphy of the Anton Chico and Santa Rosa formations, Triassic of east-central New Mexico: Journal of the Arizona-Nevada Academy of Science.

Lupe, R., 1977, Depositional environments as a guide to uranium mineralization in the Chinle Formation, San Rafael Swell, Utah: Journal of Research, U.S. Geological Survey, v. 5, pp. 365–372.

Lupe, R. and Silberling, N. J., 1985, Genetic relationship between lower Mesozoic continental strata of the Colorado Plateau and marine strata of the western Great Basin: significance for accretionary history of Cordilleran lithotectonic terranes; *in* Howell, D. G., ed., Tectonostratigraphic terranes of the Circum-Pacific region: Circum-Pacific Council for Energy and Mineral Resources, Earth Science Series, no. 1, pp. 263–271.

MacLachlan, M. E., 1972, Triassic System; *in* Mallory, W. W., ed., Geologic atlas of the Rocky Mountain region, United States of America: Denver, Rocky Mountain Association of Geologists, pp. 166–176.

McCasland, R. D., 1980, Subsurface stratigraphy of the Dalhart basin, Texas Panhandle [M.S. thesis]: Lubbock, Texas Tech University, 85 pp.

McGowen, J. H., Granata, G. E. and Seni, S. J., 1979, Depositional framework of the lower Dockum Group (Triassic) Texas Panhandle: Texas Bureau of Economic Geology, Report of Investigations 97, 60 pp.

McGowen, J. H., Granata, G. E. and Seni, S. J., 1983, Depositional setting of the Triassic Dockum Group, Texas Panhandle and eastern New Mexico; *in* Reynolds, M. W. and Dolly, E., eds., Mesozoic paleogeography of the west-central United States: Denver, Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists, pp. 13–38.

McGregor, J. H., 1936, The Phytosauria, with especial reference to *Mystriosuchus* and *Rhytidodon:* American Museum of Natural History, Memoir 9, pp. 27–102.

McLaughlin, T. G., 1954, Geology and ground-water resources of Baca County, Colorado: U.S. Geological Survey, Water-Supply Paper 1256, 232 pp.

Merriam, D. F., 1963, Triassic rocks of Kansas: The Compass of Sigma Gamma Epsilon, v. 40, pp. 122–127.

Miall, A. D., 1978, Lithofacies and vertical profile models in braided river deposits: a summary; *in* Miall, A. D., ed., Fluvial sedimentology: Calgary, Canadian Society of Petroleum Geologists, Memoir 5, pp. 597–604.

Olsen, P. E., 1980, A comparison of the vertebrate assemblages from the Newark and Hartford basins (early Mesozoic, Newark Supergroup) of eastern North America; *in* Jacobs, L. L., ed., Aspects of vertebrate history essays in honor of Edwin Harris Colbert: Flagstaff, Museum of Northern Arizona Press, pp. 35–53.

Olsen, P. E. and Baird, D., 1986, Milford revisited: with notes on a new ichnofaunule from the Norian of New Jersey: First International Symposium on Dinosaur Tracks and Traces, Abstracts with Program, pp. 21–22.

Oriel, S. S. and Mudge, M. R., 1956, Problems of lower Mesozoic stratigraphy in southeastern Colorado: Rocky Mountain Association of Geologists, Guidebook, Raton Basin, Colorado, pp. 19–24.

Parker, B. H., 1930, Notes on occurrence of clastic plugs and dikes in the Cimarron Valley area of Union County, New Mexico: Proceedings of the Fourth Annual Field Conference, Kansas Geological Society, pp. 131–136.

Parker, B. H., 1933, Clastic plugs and dikes of the Cimarron Valley area of Union County, New Mexico: Journal of Geology, v. 41, pp. 38–51.

Parker, B. H., 1934, Geology of Two Buttes Dome in southeastern Colorado [discussion]: American Association of Petroleum Geologists Bulletin, v. 18, pp. 1544–1546.

Pemberton, S. G. and Frey, R. W., 1982, Trace fossil nomenclature and the *Planolites-Palaeophycus* dilemma: Journal of Paleontology, v. 56, pp. 843–881.

Picard, M. D. and High, L. R., 1981, Physical stratigraphy of ancient lacustrine deposits; *in* Ethridge, F. G. and Flores, R. M., eds., Recent and ancient nonmarine depositional environments: models for exploration: Tulsa, Society of Economic Paleontologists and Mineralogists, Special Publication 31, pp. 261–278.

Rothrock, E. P., 1925, Geology of Cimarron County, Oklahoma: Oklahoma Geological Survey, Bulletin 34, 110 pp.

Sanders, C. W., 1934a, Geology of Two Buttes Dome in southeastern Colorado: American Association of Petroleum Geologists Bulletin, v. 18, pp. 860–870.

Sanders, C. W., 1934b, Geology of Two Buttes Dome in southeastern Colorado [discussion]: American Association of Petroleum Geologists Bulletin, v. 18, pp. 1546–1547.

Schoff, S. L., 1939, Geology and ground-water resources of Texas County, Oklahoma: Oklahoma Geological Survey, Bulletin 59, 248 pp.

Schoff, S. L., 1953, Triassic rocks on Goff Creek, Texas County, Oklahoma: Proceedings of the Oklahoma Academy of Science for 1953, v. 34, pp. 149–152.

Schoff, S. L. and Stovall, J. W., 1943, Measured stratigraphic sections in Cimarron County: Oklahoma Geological Survey, Bulletin 64, pp. 247–263.

Seilacher, A., 1967, Bathymetry of trace fossils: Marine Geology, v. 5, pp. 413–428.

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 pp.

Stovall, J. W., 1943, Stratigraphy of the Cimarron Valley (Mesozoic rocks): Oklahoma Geological Survey, Bulletin 64, pp. 43–132.

Stovall, J. W. and Savage, D. E., 1939, A phytosaur in Union County, New Mexico, with notes on the stratigraphy: Journal of Geology, v. 47, pp. 759–766.

Tevesz, M. J. S. and McCall, P. L., 1982, Geological significance of aquatic nonmarine trace fossils; *in* McCall, P. L. and Tevesz, M. J. S., eds., Animal-sediment relations: the biogenic alteration of sediments: New York, Plenum Press, pp. 257–285.

Totten, R. B., 1956, General geology and historical development, Texas and Oklahoma Panhandles: American Association of Petroleum Geologists Bulletin, v. 40, pp. 1945–1967.

Tucker, M. E., 1978, Triassic lacustrine sediments from South Wales: shore-zone clastics, evaporites and carbonates; *in* Matter, A. and Tucker, M. E., eds., Modern and ancient lake sediments: Oxford, Blackwell, pp. 203–222.

Welles, S. and Estes, R., 1969, *Hadrokkosaurus bradyi* from the upper Moenkopi Formation of Arizona: University of California, Publications in Geological Sciences, v. 84, 62 pp.

Williams, H., Turner, F. J. and Gilbert, G. M., 1982, Petrography (2nd ed.): San Francisco, W. H. Freeman & Co., 344 pp.

Wood, G. H., Northrop, S. A. and Griggs, R. L., 1953, Geology and stratigraphy of Koehler and Mount Laughlin Quadrangles, eastern Colfax County, New Mexico: U.S. Geological Survey, Oil and Gas Investigations Map OM-141.

APPENDIX 1—CONTROL POINTS

The locations of the measured stratigraphic sections and the fossil localities in Figure 3 are listed here.

1. Baldwin and Muehlberger (1959, pl. 2), section 5b: SE¼ SE¼, sec. 23, T31N, R29E, Union County, New Mexico.
2. Baldwin and Muehlberger (1959, pl. 2), section 11: SE¼ NE¼, sec. 12, T31N, R32E, Union County, New Mexico (type section of Travesser Formation).
3. This paper, section A (see Fig. 4 and Appendix 2).
4. Baldwin and Muehlberger (1959, pl. 2), section 10b: SE¼ NE¼ NE¼, sec. 36, T32N, R32E, Union County, New Mexico (type section of Baldy Hill Formation).
5. This paper, section B (see Fig. 4 and Appendix 2).
6. Baldwin and Muehlberger (1959, pl. 2), section 13: SW¼ NW¼ NW¼, sec. 1, T31N, R34E, Union County, New Mexico.
7. This paper, section C (see Fig. 4 and Appendix 2).
8. This paper, section D (see Fig. 4 and Appendix 2).
9. This paper, section E (see Fig. 4 and Appendix 2).
10. Baldwin and Muehlberger (1959, pl. 2), section 15: SE¼ NE¼, sec. 31, T32N, R36E, Union County, New Mexico.
11. Schoff and Stovall (1943, p. 255), section 19: sec. 18, T5N, R1E, Cimarron County, Oklahoma (bridge on Carrizo Creek, west of Kenton).
12. Rothrock (1925, fig. 2): NW corner, sec. 28, T6N, R1E, Cimarron County, Oklahoma.
13. Finch and Wright (1983, p. 113), Labrier Butte section: NE¼, sec. 29, T6N, R1E, Cimarron County, Oklahoma.
14. Schoff and Stovall (1943, p. 256), section 21: sec. 1, T5N, R5E, Cimarron County, Oklahoma (0.75 mi N of Cimarron River, edge of valley).
15. Schoff and Stovall (1943, p. 256), section 22: secs. 9 and 16, T5N, R5E (railroad cut N of Boise City; due to modification of the railroad bed, this section is no longer exposed).
16. Schoff and Stovall (1943, p. 258), section 25: sec. 35, T5N, R5E, Cimarron County, Oklahoma.
17. Schoff and Stovall (1943, p. 258), section 26: sec, 36, T5N, R5E, Cimarron County, Oklahoma (cutbank in "Trujillo Canyon" [Picket House Draw], 0.2–0.25 mi W of well 515). Finch and Wright (1983, p. 110) also describe this section as their west fork, South Picket House Draw section.
18. Schoff and Stovall (1943, p. 259), section 27: NE¼, sec. 18, T5N, R6E, Cimarron County, Oklahoma.
19. Schoff and Stovall (1943, p. 259), section 28: NW¼, sec. 18, T5N, R6E, Cimarron County, Oklahoma (0.25 mi SW of rock crossing on "Trujillo Creek" [Picket House Draw]).
20. Schoff and Stovall (1943, p. 259), section 29: NE¼, sec. 18, T5N, R6E, Cimarron County, Oklahoma.
21. Schoff and Stovall (1943, p. 259), section 30: secs. 20 and 29, T6N, R6E, Cimarron County, Oklahoma.
22. Schoff and Stovall (1943, p. 262), section 32: SE¼, sec. 31, T6N, R6E, Cimarron County, Oklahoma.
23. Schoff and Stovall (1943, p. 262), section 33: sec. 33, T6N, R6E, Cimarron County, Oklahoma.
24. Schoff and Stovall (1943, p. 263), section 34: NE¼ NW¼, sec. 30, T6N, R8E, Cimarron County, Oklahoma (N side of tributary to Cimarron River).
25. UNM locality 1063: Sloan Canyon Formation, SE¼ SE¼ NW¼ NE¼, sec. 11, T31N, R35E, Union County, New Mexico.
26. UNM locality 1075: Sloan Canyon Formation, NE¼ NE¼ SW¼ NW¼, sec. 12, T31N, R35E, Union County, New Mexico.
27. UNM locality 1061: Sloan Canyon Formation, NE¼ SW¼ SW¼ NW¼, sec. 12, T31N, R35E, Union County, New Mexico.
28. UNM locality 1345: Sloan Canyon Formation, NE¼ SW¼ SW¼ NW¼, sec. 12, T31N, R35E, Union County, New Mexico.
29. UNM locality 1346: Sloan Canyon Formation, NE¼ SW¼ SW¼ NW¼, sec. 12, T31N, R35E, Union County, New Mexico.
30. UNM locality 1059: Sloan Canyon Formation, NW¼ SE¼ SW¼ NW¼, sec. 12, T31N, R35E, Union County, New Mexico.
31. UNM locality 1053: Travesser Formation, SE¼ SW¼ SW¼ NW¼, sec. 12, T31N, R35E, Union County, New Mexico.
32. UNM locality 1055: Travesser Formation, NW¼ SW¼ NW¼ NE¼, sec. 12, T31N, R35E, Union County, New Mexico.
33. UNM locality 1050: Travesser Formation, NW¼ NE¼ SW¼ NE¼, sec. 12, T31N, R35E, Union County, New Mexico.
34. UNM locality 1052: Travesser Formation, SE¼ NW¼ SE¼ NE¼, sec. 12, T31N, R35E, Union County, New Mexico.
35. UNM locality 1051: Travesser Formation, NE¼ NW¼ SE¼ NE¼, sec. 12, T31N, R35E, Union County, New Mexico.
36. Stovall and Savage (1939) phytosaur-skull locality and UNM locality 1064: Travesser Formation, NE¼ NW¼ SE¼ NE¼, sec. 12, T31N, R35E, Union County, New Mexico.
37. UNM locality 1344: Travesser Formation, NE¼ NW¼ SE¼ NE¼, sec. 12, T31N, R35E, Union County, New Mexico.
38. UNM localities 1070 and 1054: Sloan Canyon Formation, SE¼ SE¼ SE¼ NE¼, sec. 29, T6N, R1E, Cimarron County, Oklahoma.
39. UNM locality 1056: Sloan Canyon Formation, NW¼ NE¼ SE¼ NW¼, sec. 35, T32N, R35E, Union County, New Mexico.
40. UNM locality 1057: Sloan Canyon Formation, SW¼ SE¼ NE¼ NW¼, sec. 35, T32N, R35E, Union County, New Mexico.
41. UNM locality 1058: Sloan Canyon Formation, NE¼ SW¼ NE¼ NW¼, sec. 35, T32N, R35E, Union County, New Mexico.
42. UNM locality 1074: Sloan Canyon Formation, SW¼ NW¼ NE¼ NE¼, sec. 35, T32N, R35E, Union County, New Mexico.
43. UNM locality 1062: Sloan Canyon Formation, NE¼ NE¼ NW¼ NW¼, sec. 35, T32N, R35E, Union County, New Mexico.
44. UNM locality 1072: Travesser Formation, NE¼ NE¼ NW¼ NW¼, sec, 35, T32N, R35E, Union County, New Mexico.
45. UNM locality 1068: Travesser Formation, NW¼ NW¼ SE¼ NW¼, sec. 26, T32N, R35E, Union County, New Mexico.
46. UNM locality 1069: Travesser Formation, NW¼ NW¼ SE¼ NE¼, sec. 33, T32N, R35E, Union County, New Mexico.
47. UNM locality 1071: Sloan Canyon Formation, NW¼ NW¼ NW¼ NW¼, sec. 1, T31N, R34E, Union County, New Mexico.
48. UNM locality 1343: Travesser Formation, NW¼ NW¼ SE¼ NE¼, sec. 33, T32N, R35E, Union County, New Mexico.
49. UNM locality 1073: Travesser Formation, NE¼ NE¼ NE¼ NE¼, sec. 2, T31N, R34E, Union County, New Mexico.
50. UNM locality 1060: Travesser Formation, NE¼ NE¼ NE¼ NE¼, sec. 2, T31N, R34E, Union County, New Mexico.
51. Schoff and Stovall (1943, p. 259) locality for *"Buettneria"* and phytosaur: Baldy Hill Formation (Cobert Canyon Sandstone Bed), SW¼ SW¼ SW¼ SE¼, sec. 7, T5N, R6E, Cimarron County, Oklahoma.
52. Peacock Canyon reptile-footprint locality (Parker, 1933; Baird, 1964; Lockley, 1986; Conrad et al., 1987): Sloan Canyon Formation, SW¼ SE¼ SW¼, sec. 19, T31N, R34E, Union County, New Mexico.

APPENDIX 2—MEASURED STRATIGRAPHIC SECTIONS

The measured stratigraphic sections in Figure 4 are described here. Colors are those of Goddard et al. (1979).

Section A—Type section of Travesser Formation

Measured in the SW¼ SE¼ SW¼, sec. 12, T31N, R32E, Union County, New Mexico.

unit	lithology	thickness (m)
	Entrada Sandstone:	
26	Sandstone; very pale orange (10 YR 8/2) to grayish yellow (5 Y 8/4); quartzose; very fine to fine grained; subangular to round; well sorted; very slightly calcareous; trough cross-bedded.	not measured
	Disconformity (5 to 8 cm of relief)	
	Travesser Formation:	
25	Sandy siltstone; grayish red (5 R 4/2) unweathered; weathers grayish orange (10 YR 7/4); quartzose; subangular; very fine grained; well sorted; slightly micaceous; very slightly calcareous; laminar.	1.4

unit	lithology	thickness (m)
24	Silty sandstone; grayish red (10 R 4/2) to pale reddish brown (10 R 5/4); quartzose; very fine grained; subangular to subrounded; well sorted; slightly micaceous; very calcareous; ripple laminated; forms a prominent bench.	0.9
23	Sandy siltstone; moderate reddish brown (10 R 4/6) to dark reddish brown (10 R 3/4); quartzose; fine grained; angular; well sorted; calcareous; laminar.	2.7
22	Sandy siltstone; mottled grayish red (10 R 4/2) and very pale green (10 G 8/2); sandstone is quartzose, very fine grained; subangular to subrounded and well sorted; very calcareous; multistoried channels of low angle planar crossbeds; forms a bench.	4.6
21	Interbedded conglomerate and sandstone; sandstone is moderate reddish brown (10 R 4/6); conglomerate is dark reddish brown (10 R 3/4) (matrix) and olive gray (5 Y 3/2) (clasts); matrix is very fine grained, quartzose, subrounded, well sorted and calcareous sandstone; clasts are limestone as much as 0.6 cm in diameter; sandstone is quartzose, very fine grained, subrounded and poorly sorted; laminar to massive.	3.0
20	Silty sandstone; moderate reddish brown (10 R 4/6); quartzose; very fine grained; subrounded; very poorly sorted.	1.8
19	Sandstone; moderate reddish brown (10 R 4/6) to grayish red (10 R 4/2); quartzose; very coarse grained; very poorly sorted; subrounded; massive.	0.3
18	Silty sandstone; same lithology as unit 20.	1.8
17	Sandstone; moderate reddish brown (10 R 4/6); quartzose; very fine grained; poorly sorted; rounded to subrounded; calcareous; bioturbated.	1.2
16	Silty sandstone; moderate reddish brown (10 R 4/6) and very pale orange (10 YR 8/2); quartzose; very fine grained; well rounded; poorly sorted; calcareous; massive.	3.2
15	Interbedded conglomerate and sandstone; same lithology as unit 21.	0.5
14	Sandy siltstone; moderate reddish brown (10 R 4/6); quartzose; well sorted; well rounded; calcareous; nodular.	2.4
13	Siltstone; moderate reddish brown (10 R 4/6) to dark reddish brown (10 R 3/4).	2.9
12	Siltstone; moderate reddish brown (10 R 4/6); contains calcrete nodules as much as 4.0 cm in diameter (Fig. 5F).	1.8
11	Sandstone; pale reddish brown (10 R 5/4) and very pale orange (10 YR 8/2); quartzose; very fine grained; subrounded; moderately sorted; moderately calcareous; massive.	4.6
10	Siltstone; moderate reddish brown (10 R 4/6); moderately calcareous; laminar.	6.6
9	Siltstone; mottled moderate reddish brown (10 R 4/6) and moderate orange pink (5 YR 8/4); calcareous.	7.0
8	Siltstone; grayish red (10 R 4/2) to moderate reddish brown (10 R 4/6); calcareous; laminar and ripple laminar.	3.0
7	Siltstone; moderate reddish brown (10 R 4/6) and pinkish gray (5 YR 8/1); calcareous.	24.4
6	Sandstone; pale reddish brown (10 R 5/4); quartzose; very fine grained; well rounded; well sorted; very calcareous; ripple laminae and epsilon crossbeds; first bench above valley floor.	0.9
5	Siltstone; moderate reddish brown (10 R 4/6); calcareous.	8.2
4	Siltstone; moderate reddish brown (10 R 4/6); slightly calcareous.	7.6
3	Sandstone; pale reddish brown (10 R 5/4). unweathered; weathering rind is very pale orange (10 YR 8/2); quartzose; very fine grained; well sorted; well rounded; slightly calcareous.	0.3
2	Sandstone; moderate reddish brown (10 R 4/6); quartzose; very fine grained; well sorted; well rounded; very calcareous; ripple laminar.	10.7
	Baldy Hill Formation:	
	Cobert Canyon Sandstone Bed:	
1	Conglomerate; pale red (5 R 6/2); matrix is quartzose, fine grained, well sorted and subangular to subrounded sandstone; clasts are dominantly limestone with minor lithics (siltstone), as much as 1.2 cm in diameter.	not measured

Section B—Type sections of Baldy Hill Formation and Cobert Canyon Sandstone Bed

Measured in the NW¼ SE¼ NE¼ and SW¼ NE¼ NE¼, sec. 36, T32N, R32E, Union County, New Mexico.

unit	lithology	thickness (m)
	Travesser Formation:	
13	Sandstone; moderate reddish brown (10 R 4/6); quartzose; very fine grained; well rounded; well sorted; very calcareous; laminar and ripple laminar.	not measured
	Baldy Hill Formation:	
	Cobert Canyon Sandstone Bed:	
12	Conglomerate sandstone; olive gray (5 Y 4/1) to pale yellowish brown (10 YR 6/2); sandstone is subarkose, medium to coarse grained, subangular to subrounded and poorly sorted; clasts are lithics (mostly sandstone) and limestone as much as 10 cm in diameter; calcareous; planar crossbeds; forms a prominent bench.	3.0
	Main body:	
11	Silty sandstone; pale red (10 R 6/2) unweathered; weathers to moderate reddish brown (10 R 4/6); quartzose; very fine grained; angular to well rounded; well sorted; very slightly calcareous; massive.	5.2
10	Sandy siltstone; moderate reddish brown (10 R 4/6) unweathered; weathers to dark reddish brown (10 R 3/4); sand is quartzose, fine grained, angular to subangular and moderately well sorted; intensively bioturbated; much jasper near the top of this unit; forms a prominent bench (Fig. 5B).	1.2
9	Silty sandstone; mottled very dusky red purple (5 RP 2/2), dark yellowish orange (10 YR 6/6) and pale reddish brown (10 R 5/4); quartzose; very fine to fine grained; angular to subrounded; poorly sorted; hematitic stains; slightly calcareous; massive.	3.3
8	Silty sandstone; mottled pale red (10 R 6/2), grayish red (10 R 4/2), dark yellowish orange (10 YR 6/6) and very dusky red purple (5 RP 2/2); very fine to medium grained; quartzose; angular; poorly sorted; limonite and hematite stains; non-calcareous; forms a thin ledge; massive.	0.2
7	Silty sandstone; same color and lithology as unit 9.	2.4
6	Sandstone; pinkish gray (5 YR 8/1) unweathered; weathers to very dusky red purple (5 RP 2/2) and dusky red (5 R 3/4); very fine grained; quartzose; angular to subrounded; well sorted; hematite stains; slightly calcareous; massive; forms a bench.	3.0
5	Silty sandstone; grayish red (10 R 4/2) to grayish red purple (5 RP 4/2); quartzose; very fine grained; well sorted; subangular to rounded; very slightly calcareous; forms a partially covered slope.	7.6
4	Silty sandstone; mottled dark yellowish orange (10 YR 6/6), moderate yellowish orange (10 YR 5/4) and grayish orange (10 YR 7/4) unweathered; weathers to moderate brown (5 YR 4/4) and very dusky red purple (5 RP 2/2); very fine to fine grained; quartzose; subangular to rounded; moderately well sorted; some lithic fragments; limonite stains; calcareous; intensively bioturbated; forms a ledge.	1.7
3	Silty sandstone; mottled light olive gray (5 Y 6/1) and very dusky red purple (5 RP 2/2); quartzose; very fine grained; well sorted; angular to subrounded; limonite stains; very slightly calcareous; forms a slope; massive.	5.2
2	Sandstone; very light gray (N 8) to pinkish gray (5 YR 8/1) unweathered; weathers to pale reddish brown (10 R 5/4); quartzose; very fine grained; subangular to subrounded; well sorted; very slightly calcareous; massive; forms a ledge.	2.0

unit	lithology	thickness (m)
1	Sandy siltstone; mottled very dusky red purple (5 RP 2/2), dusky red (5 R 3/4), light olive gray (5 Y 5/2) and dark yellowish orange (10 YR 6/6); quartzose; very fine grained; angular to subrounded; well sorted; some lithic fragments; non-calcareous; forms a slope.	2.0+

Section C—Reference section of Sloan Canyon Formation

Measured in the NE¼ NE¼ NE¼ sec. 2 and the N½ SW¼ NW¼ NW¼, sec. 1, T31N, R34E, Union County, New Mexico.

unit	lithology	thickness (m)
	Entrada Sandstone:	
36	Sandstone; pale yellowish orange (10 YR 8/6) to dark yellowish orange (10 YR 6/6); quartzose; fine to medium grained; subrounded to angular; moderately sorted; non-calcareous; low angle large scale trough crossbeds (Fig. 6H).	not measured
	Disconformity	
	Sheep Pen Sandstone:	
35	Sandstone; light greenish gray (5 GY 5/1) unweathered; weathers to pale yellowish brown (10 YR 6/2); quartzose; fine grained; subangular to subrounded; well sorted; moderately calcareous; massive (Fig. 6H).	0.6
	Sloan Canyon Formation:	
34	Siltstone; mottled pale green (10 G 6/2) and grayish red (10 R 4/2); non-calcareous.	4.3
33	Sandy siltstone; pale red (10 R 6/2) with light greenish gray (5 G 8/1) mottles; sand is quartzose; fine grained, subangular to angular and poorly sorted; moderately calcareous; laminar.	3.0
32	Sandy siltstone; moderate reddish orange (10 R 6/6) to pale red (10 R 6/2) with greenish gray (5 GY 6/1) mottles; sand is quartzose, fine grained, subangular to subrounded and poorly sorted; moderately calcareous; low angle planar crossbeds.	0.3
31	Sandy siltstone; grayish yellow green (5 GY 7/2) with pale reddish brown (10 R 5/4) mottles; sand is quartzose, fine grained, angular to subrounded and poorly sorted; very calcareous; massive; contains water-worn bone fragments and coprolites.	0.2
30	Siltstone; greenish gray (5 G 6/1); non-calcareous.	0.6
29	Same lithology as unit 33 except contains nodular calcrete (Fig. 6G).	0.3
28	Same lithology as unit 24.	3.8
27	Siltstone; light greenish gray (5 G 8/1) and grayish red (10 R 4/2) with some grayish red purple (5 RP 4/2) mottles; non-calcareous; fossiliferous.	4.0
26	Sandy siltstone; light greenish gray (5 G 8/1) with pale red (10 R 6/2) mottles; sand is quartzose, fine grained, subangular to subrounded and well sorted; moderately calcareous; fossiliferous.	0.8
25	Siltstone; pale reddish brown (10 R 5/4); very calcareous; locally contains lenses of fine grained, subangular; moderately sorted quartzose sandstone.	2.6
24	Siltstone; pale yellowish green (10 GY 7/2) to grayish yellow green (5 GY 7/2); non-calcareous.	1.5
23	Siltstone; pale red (10 R 6/2) with grayish yellow green (5 GY 7/2) mottles; non-calcareous; slightly micaceous.	1.5
22	Siltstone and sandy siltstone interbedded; siltstone is grayish yellow green (5 GY 7/2) and non-calcareous; sandy siltstone is pale yellowish brown (10 YR 6/2) and very calcareous; sand is fine grained, angular to subrounded, poorly sorted and quartzose.	7.6
21	Siltstone; grayish yellow green (5 GY 7/2); non-calcareous.	1.1
20	Silty sandstone; pale yellowish brown (10 YR 6/2) to pale red (10 R 6/2) with grayish yellow green (5 GY 7/2) mottles; sand is very fine grained, quartzose; angular to subrounded and poorly sorted; non-calcareous; massive.	1.2
19	Siltstone; pale red (10 R 6/2) to pale brown (5 YR 5/2); slightly calcareous; numerous coprolites; ripple laminar.	0.5
18	Siltstone and sandy siltstone interbedded; siltstone is pale green (5 G 7/2) and slightly calcareous; sandy siltstone is pale red (5 R 6/2) and non-calcareous; its sand is very fine grained, quartzose; subangular to subrounded and poorly sorted.	1.8
17	Siltstone; grayish yellow green (5 GY 7/2) unweathered; weathers to light brown (5 YR 5/6); very slightly calcareous; contains coprolites.	0.7
16	Sandstone; grayish yellow green (5 GY 7/2) with light brown (5 YR 6/4) mottles; quartzose; very fine and fine grained; subrounded and angular; poorly sorted; locally silty; very calcareous; trace feldspar; massive.	2.1
15	Conglomerate; pale reddish brown (10 R 5/4) to pale red (10 R 6/2); moderately calcareous; clasts are as much as 7 mm in diameter and dominantly siltstone; matrix supported; matrix is sandy siltstone; sand is very fine to medium grained, angular to subrounded, very poorly sorted and quartzose; fossiliferous (UNM locality 1071).	0.1
14	Sandy siltstone; variegated light greenish gray (5 GY 8/1) and pale red (10 R 6/2); sand is very fine grained, quartzose, subangular to subrounded, poorly sorted; calcareous; contains coprolites.	2.3
13	Siltstone; yellowish gray (5 Y 7/2) and pale red (10 R 6/2); moderately calcareous; intensively bioturbated.	0.9
	Travesser Formation:	
12	Sandy siltstone; moderate reddish brown (10 R 4/6) to moderate reddish orange (10 R 6/6); very calcareous; sand is fine to coarse grained, quartzose, subangular to subrounded and poorly sorted; forms a prominent bench; lower two-thirds has large sets of low angle planar crossbeds with a gravelly bed at their base.	1.8
11	Siltstone; moderate reddish (10 R 4/6) with sandy pods that are yellowish green (5 GY 7/2); very slightly calcareous; sand is very fine grained, quartzose, subangular to subrounded and well sorted.	3.8
10	Sandy siltstone; moderate reddish brown (10 R 4/6) to pale reddish brown (10 R 5/4); very calcareous; sand is very fine grained, quartzose, poorly sorted and subrounded; forms a bench; low angle planar crossbeds to laminar; thins to 0.1 m locally.	0.8
9	Nodular siltstone; matrix is grayish yellow green (5 GY 7/2) to pale green; nodules are moderate reddish brown (10 R 4/6) with grayish yellow green (5 GY 7/2) mottles; matrix slightly calcareous, nodules very calcareous; some small nodules of fine grained, subangular, quartzose sandstone.	0.3
8	Siltstone; moderate reddish brown (5 R 4/6) and grayish yellow green (5 GY 7/2); slightly calcareous.	3.6
7	Siltstone; moderate reddish brown (10 R 4/6) and light greenish gray (5 G 8/1); very calcareous.	0.9
6	Siltstone; moderate reddish brown (10 R 4/6) to dark reddish brown (10 R 3/4); non-calcareous; laminar and ripple laminar.	11.4
5	Conglomerate; moderate reddish brown (10 R 4/6) to dark reddish brown (10 R 3/4); slightly calcareous; matrix supported; siltstone matrix; clasts are bone, fish scales and siltstone.	0.1
4	Same lithology as unit 6.	1.5
3	Conglomerate; grayish red (10 R 4/2) to pale reddish brown (10 R 5/4); matrix supported; matrix is very calcareous, sandy siltstone; clasts are siltstone, *Unio* and bone (UNM locality 1073); sand in matrix is fine grained, quartzose, poorly sorted and subangular to subrounded.	0.9
2	Siltstone; grayish red (10 R 4/2) to moderate reddish brown (10 R 4/6); very calcareous.	0.3
1	Conglomerate; moderate reddish brown (10 R 4/2) to dark reddish brown (10 R 4/2); very calcareous; matrix supported; matrix is slightly micaceous siltstone; clasts are as much as 8 mm in diameter and are siltstone.	1.4+

Section D—Type section of Sheep Pen Sandstone

Measured in the N1/2 SW1/4 NE1/4, sec. 35, T32N, R35E, Union County, New Mexico.

unit	lithology	thickness (m)
	Erosional unconformity	
	Sheep Pen Sandstone:	
12	Sandstone; pale yellowish orange (10 R 8/6) and grayish orange (10 YR 7/4) unweathered; weathers to moderate reddish orange (10 R 6/6); quartzose; very fine grained; well rounded; moderately sorted; slightly calcareous; intensively bioturbated but in places platey and ripple laminated.	3.7
11	Sandstone; very pale orange (10 YR 8/2) to pale yellowish orange (10 YR 8/6); quartzose; medium grained; well rounded; well sorted; moderately calcareous; bioturbated (Fig. 7B) up to laminar top.	1.1
10	Sandstone; pale reddish brown (10 R 5/4) to moderate reddish brown (10 R 4/6); quartzose; fine grained; well rounded; poorly sorted; very slightly calcareous; laminar and ripple-laminar bedding.	2.4
9	Sandstone; pale yellowish orange (10 YR 8/6) to grayish orange (10 YR 7/4); quartzose; fine grained; subangular; poorly sorted; moderately calcareous; bioturbated and planar bedding.	0.6
8	Sandstone; pale yellowish orange (10 YR 8/6) to grayish orange (10 YR 7/4) unweathered; weathers to pale reddish brown (10 R 5/4); quartzose; very fine grained; subrounded; well sorted; slightly calcareous; laminar and small scale trough crossbeds.	2.0
7	Sandstone; very pale orange (10 YR 8/2) unweathered; weathers to moderate reddish brown (10 R 4/6); quartzose; very fine grained; well rounded; well sorted; non-calcareous; bioturbated with local laminar beds and soft-sediment deformation.	0.5
6	Sandstone; pale reddish brown (10 R 5/4) unweathered; weathers to moderate yellowish brown (10 YR 5/4); quartzose; very fine grained; well rounded; well sorted; non-calcareous; laminar with some trough crossbeds.	1.5
5	Sandstone; pale yellowish orange (10 YR 8/6) to grayish orange (10 YR 7/4); quartzose; very fine grained; well rounded; well sorted; non-calcareous; small scale trough crossbeds at base overlain by planar crossbeds.	1.7
4	Sandstone; very pale orange (10 YR 8/2) to grayish orange (10 YR 7/4); quartzose; very fine grained; well rounded to angular; poorly sorted; moderately calcareous; planar crossbeds except uppermost 0.3 m which are intensively bioturbated.	1.4
3	Silty sandstone; grayish red (10 R 4/2); light greenish gray (5 G 8/1) and grayish orange (10 YR 7/4); sand is quartz, very fine grained, well rounded, well sorted and non-calcareous; laminar with local soft sediment deformation.	0.5
2	Sandstone; grayish orange (10 YR 7/4) to pale yellowish brown (10 YR 6/2); quartzose; very fine grained; well rounded; well sorted; non-calcareous; ripple laminar and laminar with small scale trough crossbeds in uppermost 0.2 m.	1.4
	Sloan Canyon Formation:	
1	Sandstone; grayish red (10 R 4/2) to dark reddish brown (10 R 3/4); quartzose; fine grained; well rounded; poorly sorted; micaceous; non-calcareous; laminar.	not measured

Section E—Type section of Sloan Canyon Formation

Measured in the NW1/4 SW1/4 NW1/4 and SE1/4 SW1/4 NW1/4, sec. 12, T31N, R35E, Union County, New Mexico.

unit	lithology	thickness (m)
	Sheep Pen Sandstone:	
19	Sandstone; light greenish gray (5 G 8/1) to grayish red (10 R 4/2); quartzose; very fine grained; well rounded; poorly sorted; non-calcareous; laminar and ripple laminar.	3.0+
	Sloan Canyon Formation:	
18	Sandstone; pale green (5 G 7/2) to light greenish gray (5 GY 8/1) unweathered; weathers to light brown (5 YR 6/4); quartzose; fine grained; well rounded; moderately well sorted; micaceous; non-calcareous; laminar.	1.5
17	Sandstone; same color and lithology as unit 15.	6.8
16	Sandstone; grayish orange (10 YR 7/4) to grayish yellow (5 Y 8/4); quartzose; fine grained; well rounded; well sorted; ripple laminar.	0.6
15	Sandstone; light greenish gray (5 G 8/1) to grayish red (10 R 4/2); quartzose; very fine grained; well rounded; poorly sorted; non-calcareous; massive.	8.8
14	Sandy siltstone; same color and lithology as unit 7.	1.2
13	Sandstone; light greenish gray (5 G 8/1) and pale brown (5 YR 5/2); quartzose; very fine grained; well rounded; well sorted; slightly calcareous; bioturbated.	2.1
12	Sandstone; light greenish gray (5 G 8/1) with moderate yellowish brown (10 YR 5/4) stains; quartzose; very fine grained; well rounded; well sorted; slightly calcareous; massive.	0.3
11	Siltstone; pale red (10 R 6/2) to moderate reddish brown (10 R 4/6) with light greenish gray (5 G 8/1) mottles; slightly calcareous.	3.8
10	Limestone and conglomerate; limestone is white (N 9) to light greenish gray (5 G 8/1) sparite; conglomerate is grayish red (10 R 4/2) to dark reddish brown (10 R 3/4); matrix is quartzose, medium grained; very poorly sorted; well rounded sandstone; clasts are fish scales and comprise about 50% of the conglomerate (UNM locality 1346: Fig. 6C).	0.4
9	Sandstone; grayish red (10 R 4/2) to pale red (5 R 6/2); quartzose; fine grained; subangular; well sorted; slightly calcareous; massive.	4.0
8	Sandstone; greenish gray (5 GY 6/1) unweathered; weathers to pale brown (5 YR 5/2); quartzose; very fine grained; well rounded; well sorted; non-calcareous; massive.	0.3
7	Sandy siltstone; light greenish gray (5 G 8/1) and pale reddish brown (10 R 5/4); sand is quartzose; very fine grained; well rounded and moderately sorted; non-calcareous.	6.7
6	Sandstone; light greenish gray (5 GY 8/1) and pale red (10 R 6/2); quartzose; very fine grained; well rounded; well sorted; slightly calcareous; forms a ledge; massive.	0.9
	Travesser Formation:	
5	Sandstone; moderate reddish brown (10 R 4/6) with pale green (5 G 7/2) mottles; quartzose; fine grained; subrounded to angular; poorly sorted; bioturbated.	4.9
4	Sandstone; moderate reddish brown (10 R 4/6) with light greenish gray (5 G 8/1) mottles; fine grained; quartzose; well rounded; poorly sorted (some pebbles of coarse sandstone and siltstone); calcareous; massive.	0.5
3	Sandstone; grayish red (10 R 4/2) to dark reddish brown (10 R 3/4) with grayish yellow green (5 GY 7/2) mottles; quartzose; fine grained; well rounded; poorly sorted; moderately calcareous; bioturbated.	2.3
2	Sandstone; pale red (10 R 6/2) to pale reddish brown (10 R 5/4) with light greenish gray (5 G 8/1) mottles; quartzose; very fine to medium grained; well rounded; poorly sorted; moderately calcareous; laminar.	1.7
1	Sandstone; pale red (10 R 6/2) to pale reddish brown (10 R 5/4); quartzose; very fine grained; well rounded; well sorted; non-calcareous; massive with some burrows preserved.	1.2+



Ute Creek Valley and Point of Rocks about 16 km northeast of Abbott. View is N62°E down valley. The broad grassy valley and the narrow shallow channel (dark sinuous line in middle distance) are typical of Ute Creek in the Las Vegas Plateau portion of its course. The mesa is Point of Rocks, a famous landmark on the Santa Fe Trail. The mesa is held up by a phonolite sill. Camera station is in sec. 9, T25N, R26E. Altitude about 1,966 m. W. Lambert photograph No. 86L106. 29 December 1986, 11:30 a.m., MST.